DEFINITIONS

Introductory note. The following terms, when used in Volume III of the *Technical Regulations*, have the meanings given below. Some of these terms have already been defined in Volume I or in the *Manual on the Global Observing System* (WMO-No. 544), which constitutes Annex V to the WMO *Technical Regulations*, but it was considered desirable, for the convenience of the reader, to repeat the definitions in this volume. These terms are identified by an asterisk.

Alarm level. Water level (stage) at, or approaching, flood level which is considered to be dangerous and at which warnings should be commenced.

****Altitude.*** The vertical distance of a level, a point, or an object considered as a point, measured from mean sea level.

Aquifer. Porous water-bearing formation capable of yielding exploitable quantities of water.

****Automatic station.*** A station at which instruments make and either transmit or record observations automatically, the conversion to code form, if required, being made either directly or at an editing station.

Catchment area. An area having a common outlet for its surface runoff.

****Climatological station.*** A station from which climatological data are obtained.

Climatological station for hydrological purposes. A climatological station set up in a drainage basin specifically to augment the existing climatological network in order to meet hydrological requirements.

****Climatological station for specific purposes.*** A climatological station established for the observation of a specific element or elements.

Discharge. The volume of water flowing through a cross-section in a unit time.

Drainage basin. (See ***Catchment area***)

Drainage flood. A flood which results from rainwater ponding at or near the point where it falls because it is falling faster than the drainage system (natural or man-made) can carry it away.

****Elevation.*** The vertical distance of a point or level on or affixed to the surface of the Earth, measured from mean sea level.

Estuary. That generally broad portion of a river near its outlet, upstream of which stages are a function of the discharge from upstream, downstream of which they are a function of tides and surges of the water body into which it flows.

Flash flood. Flood of short duration with a relatively high peak discharge in which the time interval between the observable causative event and the flood is less than four to six hours.

Flooded area. Area covered by water when streamflow exceeds the carrying capacity of the channel or as a consequence of damming the channel downstream.

Forecast (warning) lead time. Interval of time between the issuing of a forecast (warning) and the expected occurrence of the forecast element.

Forecast updating. Adjustment of forecasts of events as new information becomes available.

Forecast verification. Determination of the accuracy of the forecasts through the statistical analysis of forecast errors.

Gauge datum. The vertical distance of the zero of a gauge referred to a certain datum level.

Groundwater level. Elevation, at a certain location and time, of the phreatic or the piezometric surface of an aquifer.

Groundwater station. A station at which data on ground-water are obtained on one or more of the following elements: water level, water temperature and other physical and chemical properties of water and rate and volume of abstraction and/or recharge.

Hydrograph. Graph showing the variation with time of water stage, discharge or velocity, or some other hydrological characteristic.

Hydrological advisory. Information on an expected hydrological phenomenon which is considered to be potentially dangerous.

Hydrological drought. A period of abnormally dry weather sufficiently prolonged to give rise to a shortage of water as evidenced by below normal streamflow and lake levels and/or the depletion of soil moisture and a lowering of groundwater levels.

Hydrological forecast. A statement of expected hydrological conditions for a specified period and for a specified locality.

Hydrological observation. The direct measurement or evaluation of one or more hydrological elements, such as stage, discharge, water temperature, etc.

Hydrological observing station. A place where hydrological observations or climatological observations for hydrological purposes are made.

Hydrological station for specific purposes. A hydrological station established for the observation of a specific element or elements, for the investigation of hydrological phenomena.

Hydrological warning. Emergency information on an expected hydrological phenomenon which is considered to be dangerous.

Hydrometric station. A station at which data on water in rivers, lakes or reservoirs are obtained on one or more of the following elements: stage, streamflow, sediment transport and deposition, water temperature and other physical properties of water, characteristics of ice cover and chemical properties of water.

Ice forecast. A statement of expected ice phenomena for a specified period and for a specified locality.

Large river. A river with a mean annual discharge at the mouth exceeding 2 000 m^3/s or with a drainage basin exceeding 500 000 km^2.

Lateral inflow. Inflow of water to a river, lake or reservoir along any reach from the part of the catchment adjacent to the reach.

Long-term hydrological forecast. Forecast of the future value of an element of the regime of a water body for a period extending beyond 10 days from the issue of the forecast.

Major river. A river with a mean annual discharge at the mouth exceeding 100 m^3/s or with a drainage basin exceeding 100 000 km^2.

Medium-term hydrological forecast. Forecast of the future value of an element of the regime of a water body for a period ending between 2 and 10 days from the issue of the forecast.

****Meteorological forecast (Forecast)***. A statement of expected meteorological conditions for a specified time or period, and for a specified area or portion of airspace.

****Meteorological observation (Observation)***. The evaluation or measurement of one or more meteorological elements.

****Ordinary climatological station***. A climatological station at which observations are made at least once daily, including daily readings of extreme temperature and of amount of precipitation.

****Precipitation station***. A station at which observations of precipitation only are made.

Precision of observation or of reading. The smallest unit of division on a scale of measurement to which a reading is possible either directly or by estimation.

****Principal climatological station***. A climatological station at which hourly readings are taken, or at which observations are made at least three times daily in addition to hourly tabulation from autographic records.

Principal hydrometric station. A hydrometric station at which one or a number of elements, taking into account the significance of such elements in relation to the physical environment, are observed for a period of many years. The station is usually equipped with recording instruments.

Rating curve. A curve showing the relation between stage and discharge of a stream at a hydrometric station.

****Reference climatological station***. A climatological station the data of which are intended for the purpose of determining climatic trends. This requires long periods (not less than 30 years) of homogeneous records, where man-made environmental changes have been and/or are expected to remain at a minimum. Ideally the records should be of sufficient length to enable the identification of secular changes of climate.

Seasonal hydrological forecast. Forecast of the future value of an element of the regime of a water body for a season (usually covering a period of several months or more).

Secondary hydrometric station. A hydrometric station which is established only for a limited number of years to supplement the basic network of principal hydrometric stations.

Short-term hydrological forecast. Forecast of the future value of an element of the regime of a water body for a period ending up to two days from the issue of the forecast.

Snow course. A line laid out and permanently marked, along which the snow is sampled, or its depth measured, at appropriate times at stations separated by definite distances.

Snow cover. Snow accumulated on the ground.

Snow depth. The vertical distance between the surface of a snow layer and the ground, the layer being assumed to be evenly spread over the ground which it covers.

Stage. The vertical distance of the water surface of a stream, lake, or reservoir relative to a gauge datum.

Storm surge. The difference between the actual water level under the influence of a meteorological disturbance and the level which would have occurred in the absence of the meteorological disturbance.

Streamflow. The volume of water flowing through an open channel.

Uncertainty. The interval within which the true value of a quantity can be expected to lie with a stated probability.

Water balance. An inventory of water based on the principle that during a certain time interval, the total water gain to a given catchment area or body of water must equal the total water loss plus the net change in storage in the catchment.

Water equivalent of snow cover. Vertical depth of a water layer which would be obtained by melting a snow cover.

Water supply forecast. A statement of the expected volume of available water with associated time distribution and probabilities, whenever feasible for a specified period and for a specified area.

Wind daily run. The distance represented by integration of the wind speed over 24 hours measured at the point of observation.

D.1 — HYDROLOGICAL INFORMATION AND WARNINGS

CHAPTER D.1.1
HYDROLOGICAL OBSERVING NETWORKS AND STATIONS

[D.1.1.] 1

Classification of hydrological observing stations

[D.1.1.] 1.1

Hydrological observing stations should be classified as:

(*a*) Hydrometric stations;

(*b*) Groundwater stations;

(*c*) Climatological stations and precipitation stations for hydrological purposes;

(*d*) Hydrological stations for specific purposes.

NOTE: Any station may fall under more than one of the above categories.

[D.1.1.] 1.2

Climatological stations for hydrological purposes should be classified as:

(*a*) Reference climatological station;

(*b*) Principal climatological station;

(*c*) Ordinary climatological station;

(*d*) Climatological station for specific purposes.

NOTES:

(*a*) The definitions of stations listed above will be found under "Climatological station" in the Appendix of Volume I of the *Manual on the Global Observing System* (WMO-No. 544).

(*b*) Any station may fall under more than one of the above categories.

[D.1.1.] 1.3

Hydrological stations for specific purposes should include those stations the data of which are necessary or used for purposes such as:

(*a*) Determination of the water balance of catchments, lakes, reservoirs or glaciers;

(*b*) Measurement of waves and currents on lakes and reservoirs;

(*c*) Measurement of evaporation and evapotranspiration;

(*d*) Measurement of soil moisture;

(*e*) Determination of the physical and chemical properties of water.

NOTE: A hydrological station for specific purposes may serve more than one of the above purposes.

[D.1.1.] 2

Networks of hydrological observing stations

NOTE: Detailed guidance on design of networks including density is given in the *Guide to Hydrological Practices* (WMO-No. 168).

[D.1.1.] 2.1

Each Member should establish in its territory a network of hydrological observing stations.

NOTE: The design of hydrometric networks may be based on the concept of principal and secondary stations.

[D.1.1.] 2.2

The density of the network of hydrological observing stations should be adequate to permit the assessment, to an accuracy consistent with its purpose, of the elements of the hydrological cycle and other hydrological characteristics of any region.

[D.1.1.] 2.3

In planning networks of hydrological observing stations, account should be taken of the requirements of global or regional studies or programmes. In this regard all rivers with mean annual discharges at the mouth greater than 100 m^3/s or catchment areas greater than 100 000 km^2 should be gauged.

[D.1.1.] 2.4

In planning networks of hydrological observing stations for international drainage basins, account should be taken of the requirements of the various Members concerned.

[D.1.1.] 2.5

Observations of snow depth and water equivalent of snow cover should be made at a selection of climatological stations for hydrological purposes.

[D.1.1.] 3

Location of hydrological observing stations

[D.1.1.] 3.1

Each station should be located at a site which permits correct exposure and functioning of the instruments and satisfactory instrumental and non-instrumental observations.

[D.1.1.] 3.2

Each hydrometric and groundwater station should be located at a place and under an arrangement which will provide for the continued operation of the station for at least 10 years, unless it serves a specific purpose which justifies its functioning for a shorter period.

[D.1.1.] 3.3

Climatological stations for hydrological purposes should be located as recommended in 2.8.5, 2.8.6 and 2.8.7 of Part III of Volume I of the *Manual on the Global Observing System* (WMO-No. 544).

NOTE: For convenience, 2.8.5, 2.8.6 and 2.8.7 of Part III of Volume I of the *Manual on the Global Observing System* are given below.*

[D.1.1.] 3.4

Each hydrological station for a specific purpose should be located at a place and under an arrangement which would provide for its proper operation for the required period of time.

* 2.8 Climatological stations

2.8.5 Each climatological station should be located at a place and under an arrangement that will provide for the continued operation of the station for at least ten years, and for the exposure to remain unchanged over a long period, unless it serves a special purpose that justifies its functioning for a shorter period.

2.8.6 Each reference climatological station should be sited with an adequate and unchanged exposure where the observations can be made in representative conditions. The surroundings of the station should not alter in time to such an extent as to affect the homogeneity of the series of observations.

2.8.7 The data relating to the elevation of a climatological station should be specified at least to the nearest five metres, except that for a station with a barometer the elevation should be specified to the nearest metre.

[D.1.1.] 4

Identification of hydrological observing stations

A hydrological observing station should be identified by its name and geographical coordinates and, where applicable, by the name of the river and major river basin, lake, reservoir or aquifer on or in which it is situated.

NOTE: The system of station index numbers for hydrological observing stations as used in the WMO international hydrological codes is given in Annex II to the Technical Regulations (*Manual on Codes* (WMO-No. 306), Volume I.1).

[D.1.1.] 5

Information relating to hydrological observing stations

[D.1.1.] 5.1

Each Member should maintain an up-to-date directory of its hydrometric and groundwater stations and hydrological stations for specific purposes. The directory should contain the following information for each station, where applicable:

(*a*) Name of river basin, name of river, lake reservoir or aquifer, name of station and its geographical coordinates;

(*b*) Elevation of reference datum of water-level observations and/or elevation of the station and the geodetic system of reference;

(*c*) Elevation of the surface of the ground at the well used for groundwater measurement;

(*d*) Type of station (stream gauging, lake gauging, groundwater observations, soil moisture, precipitation, snow, evaporation, sediment and chemical quality);

(*e*) Elements observed;

(*f*) Instruments, observing programme, and time of observation;

(*g*) Area of the catchment above the station in km^2;

(*h*) Information on artificial control and regulation of streamflow or water level and on conditions relating to ice;

(*i*) A station history containing dates of beginning, closing or interruption of records, changes in the name of the station, changes in instrumentation or observing programme, changes in the units of recording and information on water abstractions, recharges and returns excluded or included in the observations as the case may be;

(*j*) The name of the operating and supervising organization or institution;

(*k*) Information on characteristics of the catchment or groundwater basin, including elevation, topography, geology, hydrogeology, vegetation, urban development and principal water resources and drainage development, as applicable.

[D.1.1.] 5.2

The information relating to climatological stations for hydrological purposes should be maintained in the manner described in 2.8.4 of Part III of Volume I of the *Manual on the Global Observing System* (WMO-No. 544).

NOTE: For convenience, 2.8.4 of Part III of Volume I of the *Manual on the Global Observing System* is given below.*

[D.1.1.] 6

Supervision of hydrological observing stations

[D.1.1.] 6.1

Each Member should arrange for its hydrometric and groundwater stations to be inspected at least once every six months to ensure the correct functioning of instruments and the maintenance of a high standard of observations. At least once annually, the gauge datum of a hydrometric station and of a groundwater station should be checked.

NOTE: These inspections are independent of routine inspection and maintenance of instruments and stations essential to efficient day-to-day working.

[D.1.1.] 6.2

The inspection of climatological stations for hydrological purposes should be arranged in the manner described in 3.1.9 of Part III of Volume I of the *Manual on the Global Observing System* (WMO-No. 544).

NOTE: For convenience, 3.1.9 of Part III of Volume I of the *Manual on the Global Observing System* is given below.**

[D.1.1.] 6.3

The inspection of hydrological stations for special purposes should be arranged to meet the requirements of specific investigations.

[D.1.1.] 7

Hydrological observing system

[D.1.1.] 7.1

A hydrological observing system should include networks of hydrological observing stations, observers, observing devices, observation methods, procedures and communications links. It should provide hydrological observations according to a given plan.

[D.1.1.] 7.2

The plan of hydrological observations should generally include all major components of the hydrological water balance pertinent to both quantity and quality (including river bed surveys and sediment transport measurement).

[D.1.1.] 7.3

Each Member should establish and operate a hydrological observing system according to the national requirements.

[D.1.1.] 7.4

The hydrological observing system should be reviewed and revised as needed.

[D.1.1.] 8

The functions and responsibilities of National Hydrological Services

[D.1.1.] 8.1

General

Each Member should ensure that there exists a national capacity to acquire, store and disseminate the water-related data and information required for sustainable development and management of its water resources, and for the mitigation of water-related hazards.

NOTE: Detailed guidance on the acquisition of water-related data and hydrological information is provided in the *Guide to Hydrological Practices* (WMO-No.168).

[D.1.1.] 8.2

Organization

Arrangements should be made appropriate to the Member's system of government, socio-economic and geographic characteristics, to ensure efficient and effective coordination and communication amongst the providers and users of water-related data and hydrological information. Where several agencies and/or levels of government have separate responsibility for providing or using information, their responsibilities and relationships should be clearly established and their efforts coordinated using appropriate administrative and legal arrangements.

NOTE: Examples of methods for organizing the acquisition of water-related data and hydrological information are provided in the *Casebook of Examples of Organization and Operation of Hydrological Services* (WMO-No. 461) and in *The Legal Basis and Role of Hydrological Services* (WMO/TD-No. 602).

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* 2.8 Climatological stations

2.8.4 Each Member shall maintain an up-to-date directory of the climatological stations in its territory, giving the following information, often referred to as metadata, for each station:
(*a*) Name and geographical coordinates;
(*b*) Elevation of station;
(*c*) A brief description of the local topography;
(*d*) Category of station and details of observing programmes;
(*e*) Exposure of instruments, including height above ground of thermometers, raingauges and anemometers;
(*f*) A station history (dates of beginning of records, changes of site, closure or interruption of records, changes in the name of the station and important changes in the observing programme);
(*g*) The name of the supervising organization or institution;
(*h*) The datum level to which atmospheric pressure data of the station refer.

** 3.1.9 Principal climatological stations should be inspected at least once every year; ordinary climatological and precipitation stations should be inspected at least once every three years. If possible, relevant inspections should occasionally be carried out during the winter season.

[D.1.1.] 8.3

Functions

In general, the routine functions of National Hydrological Services should include:

(*a*) Coordinating the agencies which have responsibilities for acquiring and/or using water-related data and hydrological information;

(*b*) Establishing the requirements of existing or possible future users of water-related data and hydrological information, including the requirements of other organizations that are collecting environmental and environmental-impact data in relation to land use and climate change;

(*c*) Defining the standards (accuracy, precision, timeliness, accessibility, etc.) of the data which are implied by those requirements;

(*d*) Designing, establishing and operating hydrometric networks to measure the various types of data required. Both "use-specific" and "basic" networks may be needed, which may be complementary or even overlapping, and which should be integrated;

(*e*) Evaluating the adequacy of the existing network to ensure that the data and information collected meet the requirements of the users;

(*f*) Establishing a quality assurance programme including staff qualifications, training and development, documentation of data collection and analysis methods and procedures, procurement and calibration of instrumentation, and review and approval of reports;

(*g*) Developing methods for extrapolating data from sites at which measurements have been made to points or regions for which they are intended to be representative;

(*h*) Collecting data, and maintaining quality control of the data collection process by inspection of both field installations and field practice;

(*i*) Assembling water-related data and hydrological information generated by non-governmental, international and private sector organizations, and ensuring their future accessibility;

(*j*) Transmitting, processing and archiving data, and maintaining control of the quality and security of the archived data;

(*k*) Making the data accessible to users, when, where and in the form they require. For example this may include:
- (i) The dissemination of hydrological forecasts and warnings;
- (ii) The publication of yearbooks of basic data, in paper, microfiche or computer-compatible form;
- (iii) The preparation of reports on water resources, in which data are comprehensively analysed. This may include media such as hydrological atlases or databases in geographical information systems;
- (iv) Informative or educational material for use by the general public, the news media or schools;
- (v) Design information;
- (vi) Supporting global data centres, international programmes and projects;

(*l*) Informing potential users of the information that is available to them, and assisting them to make the best use of it;

(*m*) Adapting or developing new methods and technology, related to:
- (i) Network design;
- (ii) Instrumentation and methods of observation;
- (iii) Data transmission and processing;
- (iv) Hydrological forecasting;
- (v) Data analysis, interpretation and presentation;

(*n*) Carrying out research into hydrological and related processes, in order to assist the user in interpreting and understanding the data;

(*o*) Securing qualified staff and providing staff training and development;

(*p*) Collaborating with agencies which acquire water-related or other relevant information, such as water quantity and quality, sediment, hydrogeological, water use, topographic and land use, or meteorological information;

(*q*) Participating with foreign water-sector agencies in international programmes and projects;

(*r*) Furnishing hydrological information for inclusion in countries' periodic reports on the state of the environment;

(*s*) Undertaking water resources assessment studies for development purposes;

(*t*) Participating in the planning, development and management of water resources projects.

D.2 — METEOROLOGICAL SERVICES FOR HYDROLOGY

[D.2.] 1

General

Each Member should ensure that the dissemination of meteorological information necessary to meet the requirements of hydrology is reliable, regular and adapted to expressed and established requirements.

[D.2.] 2

Meteorological observations for hydrological purposes

[D.2.] 2.1

Each Member should disseminate those meteorological observations from stations which are required for the analysis of the response of a drainage basin to changes in meteorological conditions.

[D.2.] 2.2

Meteorological observations for hydrological purposes from such stations should concern one or several of the meteorological elements listed in [D.1.2.] 1.2, as required.

[D.2.] 2.3

The precision of observation of meteorological elements for hydrological purposes and the reporting interval for hydrological forecasting purposes should be as shown in the table below.

[D.2.] 3

Meteorological forecasts and warnings for hydrological purposes

[D.2.] 3.1

Members should ensure that meteorological forecasts and warnings for hydrological purposes are made available routinely to the hydrological forecaster as required.

[D.2.] 3.2

The programme on forecasts and warnings for hydrology should include:

(*a*) The type of meteorological information listed in section [D.2.] 2.3. The forecasts should be regular and

	Element	*Precision*	*Reporting interval for hydrological forecasting purposes*
(a)	Precipitation – amount and form*	± 2 mm below 40 mm ± 5% above 40 mm	6 hours**
(b)	Snow depth	± 2 cm below 20 cm ± 10% above 20 cm	Daily
(c)	Water equivalent of snow cover	± 2 mm below 20 mm ± 10% above 20 mm	Daily
(d)	Air temperature	± 0.1°C	6 hours
(e)	Wet-bulb temperature	± 0.1°C	6 hours
(f)	Net radiation	±0.4 MJ/m^2d below 8MJ/m^2 ±5% above 8MJ/m^2d	Daily
(g)	Pan evaporation	±0.5 mm	Daily
(h)	Surface temperature – snow	± 1°C	Daily
(i)	Temperature profiles – snow	± 1°C	Daily
(j)	Wind: speed direction	± 10% ± 10°C	6 hours
(k)	Sunshine duration	± 0.1 hour	Daily
(l)	Relative humidity	± 1%	6 hours

* In some locations it will be necessary to distinguish the form of precipitation (liquid or solid).
** The reporting interval in flash flood basins is often required to be two hours or less; in other locations, daily values may suffice.

detailed, specifying to the greatest possible extent local and regional variations;

(*b*) The following forecasts:
  (i) Quantitative precipitation forecasts (QPF) for periods of up to 72 hours;
  (ii) Air temperature, humidity, dew point, wind and sky conditions for up to five days;
  (iii) Wind speed and directions for 24 hours or more;

(*c*) Warnings of hazardous weather conditions, particular-ly
in the following cases:
  (i) Heavy precipitation (amount and intensity);
  (ii) Sudden and persistent changes in temperature to above or below freezing;
  (iii) Strong winds.

[D.2.] 4

Publication and dissemination of climatological data for hydrological purposes

[D.2.] 4.1

Each Member should publish annually its climatological data for hydrological purposes in addition to those published as climatological data.

[D.2.] 4.2

The publication of climatological data for hydrological purposes should conform with [B.1.] 4.1.1, [B.1.] 5.2.2, [B.1.] 5.2.3 and [B.1.] 5.2.4 of the *Technical Regulations*, concerning the publication of climatological data, except that these data should be grouped according to main drainage basins.

NOTE: For convenience [B.1.] 4.1.1, [B.1.] 5.2.2, [B.1.] 5.2.3 and [B.1.] 5.2.4 are given in the appendix.

[D.2.] 4.3

Climatological data published or disseminated for hydrological purposes should include frequencies, sums or averages, whichever applicable, of the following elements and for time units as indicated in [B.1.] 4.1.1, [B.1.] 4.2.1 and [B.1.] 4.2.2 of the *Technical Regulations*:

(*a*) Air temperature;

(*b*) Relative humidity;

(*c*) Wind speed and direction;

(*d*) Precipitation (amount and intensity);

(*e*) Solar radiation;

(*f*) Snow cover;

(*g*) Pan evaporation;

(*h*) Wet-bulb temperature;

(*i*) Sunshine duration.

NOTE: For convenience [B.1.] 4.1.1, [B.1.] 4.2.1 and [B.1.] 4.2.2 are given in the appendix.

APPENDIX

(*See* [D.3.] 1.2)

UNIVERSAL DECIMAL CLASSIFICATION FOR HYDROLOGY

NOTE: The Universal Decimal Classification (UDC) is internationally sponsored by the International Federation for Documentation (RID), with whose permission the scheme for general hydrology (UDC 556), as well as the major classes and secondary headings applicable to hydrology, are reproduced here. The structure of UDC and explanations for notations used therein are given in the *Universal Decimal Classification*, Standard Edition, 2005.

MAJOR CLASSES AND SECONDARY HEADINGS APPLICABLE TO HYDROLOGY

0	GENERALITIES. SCIENCE AND KNOWLEDGE. ORGANIZATION. INFORMATION. DOCUMENTATION. LIBRARIANSHIP. INSTITUTION. PUBLICATIONS
3	SOCIAL SCIENCES. STATISTICS. POLITICS. ECONOMICS. TRADE. LAW. GOVERNMENT. MILITARY AFFAIRS. WELFARE. INSURANCE. EDUCATION. FOLKLORE
31	**Demography. Sociology. Statistics**
32	**Politics**
33	**Economics. Economic science**
34	**Law. Jurisprudence**
35	**Public administration. Government. Military affairs**
37	**Education**
5	MATHEMATICS AND NATURAL SCIENCES
51	**Mathematics**
519.2	Probability. Mathematical statistics
52	**Astronomy. Astrophysics. Space Research. Geodesy**
520	Astronomical instruments and techniques
528	Geodesy. Surveying. Photogrammetry. Remote sensing. Cartography
53	**Physics**
531	General Mechanics. Mechanics of solid and rigid bodies
532	Fluid mechanics in general. Mechanics of liquids (Hydromechanics)
533	Mechanics of gases. Aeromechanics. Plasma Physics
536	Heat. Thermodynamics
539	Physical nature of matter
54	**Chemistry. Crystallography. Mineralogy**
546	Inorganic chemistry
547	Organic chemistry
548	Crystallography
55	**Earth Sciences. Geological Sciences**
550	Ancillary sciences of geology, etc.
.3	Geophysics
.34	Seismology. Earthquakes in general
.37	Terrestrial electricity. Earth currents
.38	Terrestrial magnetism (geomagnetism)
551	General geology. Meteorology. Climatology. Historical Geology. Stratigraphy. Palaeogeography
.2	Internal geodynamics (endogenous processes)
.3	External geodynamics (exogenous processes)
.32	Glaciology
.33	Glacial geology

.34 Effects of frost on rocks and soils. Cryoturbation
.4 Geomorphology. Study of the Earth's physical forms
.46 Physical oceanography. Submarine topography. Ocean floor
.5 Meteorology*
.7 Historical geology. Stratigraphy
.8 Paleogeography
552 Petrology. Petrography
553 Economic geology. Mineral deposits
556 Hydrosphere. Water in general. Hydrology
.1 Hydrologic cycle. Properties. Conditions. Global water balance
.3 Groundwater hydrology. Geohydrology. Hydrogeology
.5 Surface water hydrology. Land hydrology
56 Paleontology
57 Biological sciences in general
58 Botany
59 Zoology

6 APPLIED SCIENCES. MEDICINE. TECHNOLOGY
61 Medical Sciences
62 Engineering. Technology in general
621 Mechanical engineering in general. Nuclear technology. Electrical engineering. Machinery
.22 Hydraulic energy. Water power. Hydraulic machinery
.3 Electrical engineering
.39 Telecommunication. Telegraphy. Telephony. Radiocommunication. Video technology and equipment. Telecontrol
623 Military engineering
624 Civil and structural engineering in general
625 Civil Engineering of land transport. Railway engineering. Highway engineering
626 Hydraulic engineering in general
627 Natural waterway, port, harbour and shore engineering. Navigational, dredging, salvage and rescue facilities. Dams and hydraulic power plant
628 Public health engineering. Water. Sanitation. Illuminating engineering
629 Transport vehicle engineering
63 Agriculture and related sciences and techniques. Forestry. Farming. Wildlife exploitation
630 Forestry
633 Field crops and their production
634 Horticulture generally
635 Garden plants. Gardening
636 Animal husbandry and breeding in general. Livestock rearing. Breeding of domestic animals
639 Hunting. Fishing. Fish breeding
658 Business management. Administration. Commercial organization
68 Industries, crafts and trades for finished or assembled articles
681.2 Instrument-making in general. Instrumentation. Measuring instruments and their manufacture. Balances. Weighing devices
.5 Automatic control technology. Smart technology
69 Building (Construction) trade. Building materials. Building practice and procedure

7 THE ARTS. RECREATION. ENTERTAINMENT. SPORT
71 Physical planning. Regional, town and country planning. Landscapes, parks, gardens
72 Architecture
77 Photography and similar processes
79 Recreation. Entertainment. Games. Sport

8 LANGUAGES. LINGUISTICS. LITERATURE

9 GEOGRAPHY. BIOGRAPHY. HISTORY
91 Geography. Exploration of the earth and of individual countries. Travel. Regional geography
929 Biography and related studies
93/94 History

* The complete scheme of UDC 551.5 (1985 edition) is reproduced in WMO *Technical Regulations*, Volume I, Appendix C.

SECTION 556 – HYDROSPHERE. WATER IN GENERAL. HYDROLOGY

556 HYDROSPHERE. WATER IN GENERAL. HYDROLOGY
Comprehensive works on surface waters and groundwater
532 Fluid mechanics in general. Mechanics of liquids (hydromechanics)
551.4 Geomorphology. Study of the Earth's physical forms
551.46 Physical oceanography. Submarine topography. Ocean floor
621.6 Fluids handling, storage and distribution plant and techniques
626/627 Hydraulic engineering and construction. Water (Aquatic) structures
628.1 Water supply. Water treatment. Water consumption
628.2 Urban water removal. Town drainage. Sewerage
628.3 Sewage. Treatment, disposal, utilization of sewerage

556.01 Theory. Principles of research and investigation
556.011 Theoretical principles
556.012 Research. Methodology. Requirements, etc.
556.013 Theoretical investigation. Use of models

556.02 Practical work. Organization. Programmes. Projects, etc.
556.023 Laboratories. Laboratory work
556.024 Stations. Field work generally
556.025 Services and networks. Network design
556.028 Representative, experimental, model basins

556.04 Observations. Data. Records
556.042 Observation methods
556.043 Data handling. Collection. Processing. Dissemination
556.044 Observational data on specific hydrological phenomena
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556.047 Hydrological analysis
556.048 Hydrological computation. Coefficients

556.06 Hydrological forecasting and forecasts
556.06 ”32” Seasonal forecasts
556.06 (1/9) Regional forecasts

556.07 Equipment, installations, apparatus for hydrological work
556.08 Measurement: principles, instruments

556.1 Hydrologic cycle. Properties. Conditions. Global water balance
556.11 Water properties
556.113 Physical properties of water. Temperature. Colour
556.114 Chemical properties of water
556.114.2 Dissolved gases in water
556.114.3 Hardness of water
556.114.4 Taste of water. Odour of water
556.114.5 Salinity of water
556.114.6 Water elements. Inorganic content of water
Details by: 546…

556.114.7 Organic chemical content of water
Details by: 547…
556.115 Biological and microbiological properties of water
556.12 Precipitation, rainfall, snow, etc. (as element in the hydrological cycle)
→ *551.577 and 551.578**
556.121 Amount and duration of precipitation

* The symbol "→" means "see also".
** See WMO *Technical Regulations*, Volume I, Appendix C.

556.13 Evaporation. Evapotranspiration. Transpiration (in the hydrological cycle)
→ 551.573
556.131 Total evaporation. Evapotranspiration
556.132 Evaporation from non-living things
556.136 Transpiration. Evaporation from living things

556.14 Infiltration (as element in the hydrological cycle)
556.142 Soil moisture
→ 551.579
556.143 Groundwater storage
→ 556.3

556.15 Water storage (as element in the hydrological cycle)
556.152 Surface detention
556.153 Channel storage. Bank storage
556.155 Lake storage. Reservoir storage
556.157 Valley storage

556.16 Runoff
556.16.044 Observation data. e.g. runoff depth
556.16.045 Records. e.g. stream-flow records
556.16.047 Analyses. Hydrographs. Unit hydrographs
556.161 Rainfall-runoff relation. Runoff factors
556.162 Distribution. Frequency
556.162 (1/9) Spatial distribution
556.162 "32" Seasonal distribution
556.162 "45" Annual distribution
556.164 Surface runoff. Overland flow
556.165 Normal runoff
556.166 Maximum runoff. Floods. Flood runoff
556.167 Minimum runoff. Base flow. Dry-weather flow
556.168 Underground runoff

556.18 Water management. Applied hydrology. Human control of hydrologic conditions
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556.3 Groundwater hydrology. Geohydrology. Hydrogeology

556.31 Properties of groundwater.
556.31 ≈ 556.11
556.313 Physical properties of groundwater
556.314 Chemical and physicochemical properties of groundwater
556.315 Biological and microbiological properties of groundwater

556.32 Subterranean, underground water. Vertical distribution
556.322 Zone of aeration. Suspended water. Vadose water
556.324 Zone of saturation. Groundwater (in the strict sense)

556.33 Aquifers. Water-bearing strata
556.332 Unconfined aquifers. Phreatic aquifers
556.332.2 Storage capacity. Inflow and outflow
556.332.4 Permeability of rock formations. Aquifuges. Aquicludes
556.332.4.042 Pumping tests
556.332.4.048 Storage coefficient. Specific yield
556.332.5 Water table. Phreatic surface
556.332.6 Recharge of water table. Natural recharge. Juvenile water. Artificial recharge. Injection wells
556.332.7 Seawater intrusion
→ 556.388
556.334 Confined waters. Artesian waters
556.336 Perched aquifers

556.34 Groundwater flow. Well hydraulics
556.342 Flow rate. Velocity. Gradient
556.343 Flow to wells. Drawdown

556.36 Springs
556.362 Depression springs
556.363 Contact springs
556.364 Artesian springs
556.366 Fracture springs
556.367 Intermittent springs
556.368 Volcanic springs

556.38 Groundwater basins. Groundwater management
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556.382 Safe yield
556.383 Overdraft
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556.5 Surface water hydrology. Land hydrology

556.51 Drainage basins. Catchment areas. River basins. Watersheds
556.512 Water balance of drainage basins
556.513 Area of drainage basins
556.514 Shape of drainage basins
556.515 Slope of drainage basins
556.516 Stream density

556.52 Potamology. River systems
556.522 Classification. Order of stream
556.523 Large streams
556.524 Tributaries

556.53 Rivers. Streams. Canals
556.531 Properties of river waters. Fluvial water
556.531 ≈ 556.11
556.532 Water balance of perennial streams
556.535 River regimes. Fluvial regimes. River level. Thermal regime. Ice regime
556.536 Hydrodynamics of rivers. Fluvial hydraulics. Currents. Waves
556.537 Fluvial channel and bank formation
556.538 Intermittent streams. Ephemeral streams

556.54 River mouths. Estuaries. Deltas. Fluvio-marine water
556.541 Properties of water in river mouths and estuaries. Fluvio-marine water
556.541 ≈ 556.11
556.542 Water balance in river mouths and estuaries
556.545 Estuarine regimes. Estuarine pollution. Exchange of fresh and saline water. Formation of brackish water
556.546 Estuarine hydraulics and hydrodynamics

556.55 Limnology. Lakes. Reservoirs. Ponds
556.551 Properties of water in lakes, reservoirs, ponds. Limnic water
556.552 Water balance in lakes, etc.
556.555 Lake regimes. Lake level. Thermal regime. Ice regime
556.556 Hydrodynamics of lakes. Lacustrine hydraulics. Currents. Waves
556.557 Lake shores and their alteration

556.56 Swamps. Marshes. Fens
556.561 Properties of swamp water. Paludal water
556.561 ≈ 556.11
556.562 Water balance of swamps
556.565 Swamp regimes. Pollution of swamps
556.566 Hydraulics and hydrodynamics of swamps.
Paludal hydraulics

DEFINITIONS

NOTE: The following terms, when used in the annex of the *Technical Regulations*, Volume III — Hydrology, have the meaning given below. Those terms which have already been defined at the beginning of the *Technical Regulations*, Volume III — Hydrology, have the meaning given below. Those terms which have already been defined at the beginning of the Technical Regulations are not repeated here.

Acidity. The quantitative capacity of aqueous media to react with hydroxyl ions.

Adsorption. The surface retention of solid, liquid or gas molecules, atoms or ions by a solid or liquid.

Air line correction. Depth correction to a sounding line measurement for that portion of the line which is above the water surface when the flow deflects the sounding line downstream.

Arithmetic mean. Sum of values/variates divided by their number/by the number of occurrences.

Baffle. A wall or blocks placed in the stream to dissipate energy or to cause improved velocity distribution.

Bed profile (of a stream). The shape of the bed in a vertical plane; it may be longitudinal or transversal.

Benchmark. A permanent mark, natural or artificial, at a known elevation in relation to an adopted datum.

Blank. A sample of distilled or deionized water free of analytes of interest.

Bottom sediment. Those sediments which make up the bed of a body of running or still water.

Broad-crested weir. A weir of sufficient breadth (i.e. the crest dimension in the direction of the flow) such that critical flow occurs on the crest of the weir.

Calibration (rating). Experimental determination of the relationship between the quantity to be measured and the indication of the instrument, device or process which measures it.

Calibration (rating) tank. A tank containing still liquid (water) through which the current meter is moved at a constant velocity for calibrating the meter.

Celerity. Speed of propagation of a wave.

Confidence interval. The interval which includes the true value with a prescribed probability and which is a function of the statistics of the sample.

Confidence level. The probability that the confidence interval includes the true value.

Confluence. Joining, or the place of junction, of two or more streams.

Constant-rate injection method. A method of measuring the discharge in which a tracer of known concentration is injected at a constant and known rate at one cross-section and its dilution is measured at another section downstream where complete mixing has taken place.

Contracted weir. A weir having a crest that does not extend across the whole channel width.

Control. The physical properties of a channel, natural and artificial, which determine the relationship between stage and discharge at a location in the channel.

Control section of a weir or flume. The section which induces critical flow.

Cosmic-ray-produced nuclides. Short-lived radioisotopes such as tritium, beryllium-7 and carbon-14 formed by the continuous "rain" of electrons and nuclei of atoms from space interacting with certain atmospheric and terrestrial elements.

Crest. The line or area defining the top of the weir.

Critical depth. The depth of water flowing in an open channel under conditions of critical flow.

Critical flow. Flow in which Froude number equals unity. Under this condition the celerity of small disturbances equals the mean flow velocity.

Critical velocity. (1) Velocity at critical flow in a channel; (2) Velocity at which flow changes from subcritical to supercritical, or vice versa.

Cross-section. Section of a stream at right angles to the main (average) direction of flow.

Current meter. Instrument for measuring the velocity of water at a point.

Current meter, cup type. A current meter whose rotor is composed of a wheel fitted with cups turning on a vertical axis.

Current meter, propeller type. A current meter the rotor of which is a propeller rotating around an axis parallel to the flow.

Dead water. Water in a state of slow or no circulation.

Density current. The phenomenon of gravity flow of a liquid relative to another liquid, or of relative flow within a liquid medium due to difference in density.

Detection limit. The smallest concentration of a substance which can be reported as present with a specified degree of precision and accuracy by a specific analytical method.

Dilution method. A method of determining the discharge of a stream by measuring the degree of dilution by the flowing water of an added tracer solution.

Double float. A body of slightly negative buoyancy which moves with the stream at a known depth and whose position is indicated by a small surface float from which it is suspended.

Drag. Force exerted by a flowing fluid, e.g. water, on an object placed in or adjacent to the fluid, projected in the direction of flow.

Drowned (submerged) weir. A weir in which the upstream water level is affected by the downstream water level.

Duplicate samples. Obtained by dividing one sample into two or more identical subsamples.

Echo sounder. An instrument using the reflection of an acoustic signal from the bed to determine the depth.

Error. The difference between the result of a measurement and the true value of the quantity measured.

NOTE: This term is also used for the difference between the result of a measurement and the best approximation of the true value (rather than of the true value itself). The best approximation may be a mean of several or of many measurements.

Fall. Difference in elevation of water surface between two points of a stream at a given time.

Filtration. The process of passing a liquid through a filtering medium for removal of suspended or colloidal matter.

Float. Any natural or artificial body which is supported and partly or fully immersed in water, its vertical motion indicating the changes in water level or its horizontal movement indicating the velocity of water at the surface or at various depths.

Float gauge. A gauge consisting essentially of a float which rides on the water surface and rises or falls with it, its movement being transmitted to a recording or indicating device.

Flood plain. Adjoining nearly level land at the bottom of the valley of a stream flooded only when the streamflow exceeds the water carrying capacity of the channel.

Flume. An artificial channel with clearly specified shape and dimensions which may be used for measurement of flow.

Froude number. A dimensionless number expressing the ratio of inertia forces to gravity forces:

$$Fr = \frac{v}{\sqrt{g \cdot d}}$$

v = velocity of flow
g = acceleration of gravity
d = average depth of flow

Geochemistry. A science that deals with the chemical composition of and chemical changes in the crust of the earth.

Grab sample. A sample taken at a selected location, depth and time.

Head over (on) the weir. The elevation of the water above the lowest point of the crest, measured at a point upstream. (The point of measurement depends on the type of weir used.)

Height of weir. The height from the upstream-bed to the lowest point of the crest.

Herbicide. A chemical agent that destroys specific vegetation.

Homogeneous. Uniform in composition.

Hysteresis (in stage-discharge relation). The variability of the stage-discharge relation at a gauging station subject to variable slope where, for the same gauge height, the discharge on the rising stage is different from that on the falling stage.

Injection cross-section. The cross-section on a stream at which a tracer solution is injected into the flow of water for the purpose of measuring the discharge.

In situ measurements. Measurements made directly in the water body.

Integration (pulse or gulp injection) method. A method of measuring the discharge in which a known quantity of a tracer is injected over a short time at one cross-section and its dilution is measured at another cross-section downstream where complete mixing has taken place, over a period sufficient to allow all the tracer to pass that cross-section so that the concentration/time relationship of the tracer during the sampling time can be determined.

Invert. Lowest part of the cross-section of a channel.

Kemmerer sampler. A messenger-operated vertical point sampler for water-suspended sediment.

Macrophytes. Large plants.

Measuring (throated, standing-wave) flume. A flume with side contractions and/or bottom contractions within which the flow changes from subcritical to supercritical, the discharge being determined by the cross-sectional area and velocity of flow at critical depth within the throat.

Measuring reach. A reach of open channel selected for measurement of discharge.

Mixing length. The minimum length of travel of a tracer after which good mixing is obtained.

Modular (free) flow. A flow which is not influenced by the level of water downstream of a measuring device.

Moving-boat method. A method of measuring discharge from a boat by traversing the stream along the measuring section whilst continuously measuring velocity, depth and distance travelled.

Multiple sampler. An instrument permitting the collection of several water-suspended sediment samples of equal or different volumes at each site, simultaneously.

Nappe. The sheet of water flowing over the crest of a wall, dam, or weir erected across a stream having an upper and a lower surface.

Normal distribution (Gaussian distribution). A mathematically defined, symmetrical, bell-shaped, continuous distribution, traditionally assumed to represent random errors.

Notch. A thin-plate weir of any defined shape producing side contractions.

II-5 Needle gauges

A needle water-level gauge consists of a point and some means of determining its exact vertical position relative to a datum. The two types of needle gauge are:

(*a*) The point gauge, whose tip approaches the free surface from above;

(*b*) The hook gauge, which is hook-shaped, and whose tip is immersed and approaches the free surface from below.

The vertical position may be determined by a graduated scale, a tape with some vernier arrangement, or a digital indicator.

II-5.1 Functional requirements

(*a*) A needle gauge installation should permit measurement of stage to be made at all levels from below the lowest to above the highest level anticipated.

(*b*) There should be good illumination of the place where the tip meets the free liquid surface.

(*c*) The tip should be tapered to a point having an included angle of approximately 60° and the point should be rounded to a radius of approximately 0.25 mm.

II-5.2 Material

A needle gauge and auxiliary parts should be made throughout of durable corrosion-resistant materials.

II-5.3 Graduation

The graduation of a hook or point gauge should be in millimetres and should be clearly and accurately marked.

II-5.4 Installation and use

(*a*) A needle should be mounted over an open water surface at the edge of a stream if conditions permit. If this is not practicable because of turbulence, wind effect or inaccessibility, a stilling bay or stilling well should be installed.

(*b*) The location of the needle gauge should be as close as possible to the measuring section.

(*c*) Where more than one datum plate or bracket is provided at different levels, or where a stepped gauge is used, all should lie on a single cross-section normal to the direction of flow in the stream. If this is not practicable and it is necessary to stagger the points, all should lie within a distance of one metre on either side of the cross-section.

(*d*) Datum plates and brackets should be mounted on a secure foundation which extends below the frost line.

(*e*) The elevation of the datum plates, with reference to which the level of the free surface is determined, should be established with great care. The tolerance on the transfer of level from the station benchmark to each datum plate should not exceed ± 1.0 mm.

II-6 Float gauges

NOTE: The float gauge is used to measure stage usually inside a stilling well. A typical float gauge consists of a float operating in a stilling well, a graduated steel tape, a counterweight, a pulley and a pointer.

II-6.1 Functional requirements

(*a*) A float gauge installation should permit measurement of stage to be made at all levels from the lowest to the highest level anticipated.

(*b*) The float should be made of durable corrosion-resistant and antifouling material. It should be leakproof and function in a truly vertical direction.

(*c*) The float should float properly and the tape or wire should be free of twists or kinks.

(*d*) A means should be provided for readily checking the float gauge readings with the actual stream stage.

II-6.2 Graduation

The graduations of a float gauge should be in millimetres and should be clearly and accurately marked.

II-7 Wire-weight gauges

NOTE: A typical 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 and a counter, all housed within a protective housing. The wire-weight gauge is used as an outside reference gauge where other outside gauges are difficult to maintain. The wire-weight gauge is normally mounted where there is a bridge or other structure over the water.

II-7.1 Functional requirements

A wire-weight gauge should permit measurement of stage throughout the range of levels anticipated.

II-7.2 Material

A wire-weight gauge should be made throughout of durable corrosion-resistant materials.

II-7.3 Graduation

The graduations of a wire-weight gauge should be in millimetres.

II-7.4 Installation and use

(*a*) The gauge should not be installed in a location where the water surface is disturbed by turbulence, wind effects or afflux.

(*b*) The elevation of a wire-weight gauge should be verified frequently to ensure reliability of stage observations.

II-8 Pressure gauges

NOTE: Pressure gauges are frequently used at sites where it would be too expensive to install stilling wells. A widely used method of measuring water level is to measure the height of a column of water with respect to some datum plane. This can be accomplished indirectly by sensing the water pressure at a fixed point below the water surface and then utilizing the hydrostatic principle that the pressure of a liquid is proportional to the depth. The most successful and widely used method of transmitting the pressure is the gas-purge technique.

II-8.1 Gas-purge (bubbler) technique

(*a*) An adequate supply of gas or compressed air should be provided. The supply should have a delivery pressure in excess of the range to be measured.

(*b*) A pressure-reducing valve should be provided so that a pressure safely in excess of that of the maximum ange can be set. A flow control valve and some form of visual flow rate indicator should be installed so that the discharge of gas supplied to the system can be properly adjusted. The pressure should be set to prevent water from entering the tube, even under the most rapid rates of change expected.

(*c*) Incorrect readings due to the friction of the gas moving through the tube should be minimized.

(*d*) The tubing should be installed with a continuous downslope to the orifice.

II-8.2 Water density compensation

Since the density of the water which the sensor is to measure will vary with temperature and also with chemical and silt content, either automatic or manual means of compensating for these changes should be provided.

II-8.3 Changes in gas weight

If the gas technique is used to transmit pressure, provisions should be made for compensating for changes in the density of the gas with temperature and pressure.

II-8.4 Range

The range of the instrument should be adequate to accommodate the anticipated range in water level.

II-8.5 Response

The response of the instrument should be sufficiently rapid to follow any expected rate of change in water level.

II-9 Recording devices

II-9.1 Mechanical recorders

II-9.1.1 Driving torque

NOTE: In the recording devices, the angular movement of the input shaft is transformed by mechanical linkage into movement of the stylus of an analogue recorder or into the coding mechanism of a digital recorder. If the friction is high, i.e. the driving torque required to position the recording element is high, then there is an appreciable time lag following a water-level change.

(*a*) The driving torque should be sufficient to overcome the friction generated by mechanical linkages.

(*b*) The friction should be as low as feasible and should not exceed 7 mNm.

II-9.1.2 *Hysteresis (lost motion)*

Hysteresis should be kept to a minimum and should not exceed 3 mm.

NOTE: If the input shaft is rotated in one direction until the stylus follows and then the direction of rotation reversed, the total hysteresis is the amount of motion required to cause the stylus to follow in the reversed direction.

II-9.1.3 *Timing mechanism*

(*a*) The clock mechanism which rotates the chart plate should be of high quality, sturdy and reliable and should be protected from dirt, corrosion and insects by its housing.

(*b*) The uncertainty in the time measurement or the clockwork should not exceed ± 30 s/d average over a period of at least 30 days.

(*c*) A movement adjustment should be provided to permit regulation within the accuracy requirements set forth in (*b*).

II-9.1.4 *Paper (chart or tape)*

The paper used should remain stable within relatively close tolerance throughout the range of temperature and humidity conditions expected.

II-9.1.5 *Stylus*

If a pen is used, the pen and ink should be such that an easily readable trace is produced without blotting. If a pencil is used, it should be of proper hardness to produce a readable trace.

II-9.1.6 *Errors*

The sources of errors when using a recording device are as follows:

(*a*) Friction in the driving mechanism;

(*b*) Hysteresis in the driving mechanism;

(*c*) Line shift, caused by change in depth of flotation of the float when the stage changes rapidly and with it the weight of the float line changes;

(*d*) Expansion and contraction of paper;

(*e*) Ambiguity, if the stage is between digits (in digital recorders).

In digital recorders, if the stage is between digits, the recorder should be forced to the nearest digit before the tape is punched in order to prevent ambiguity.

VII – DETERMINATION OF THE STAGE-DISCHARGE RELATION

(*See* [D.1.2.] 3.4.1)

VII-1 Scope and field of application

NOTES:

(*a*) The material in this section of the annex is based on ISO 1100-2 (1998 and 2000) entitled "Liquid flow measurement in open channels — Part 2: Determination of the stage-discharge relation".

(*b*) Detailed guidance on the determination of the stage-discharge relation and of the uncertainties involved is given in the *Manual on Stream Gauging* (WMO-No. 519).

This section specifies the methods of determining the stage-discharge relation at a gauging station for stable and unstable channels, including those subject to ice conditions as well as an analysis of the uncertainties involved in the preparation and use of the relation. The specifications are designed to conform to the requirements of Technical Regulation [D.1.2.] 3.1 and to meet the requirements for accuracy as indicated in Technical Regulation [D.1.2.] 3.6.

VII-2 Calibration of a gauging station

VII-2.1 General

An established stage-discharge relation should be continuously reviewed so as to ensure its validity is maintained and to redetermine the relation when it is shown to have been significantly altered by any changes which have occurred.

NOTE: Since a river is continuously in course of development, its characteristics are subject to changes which may affect the calibration These changes may take place gradually as a result of slow processes of erosion or accretion or they may occur suddenly as a consequence of alterations in the channel. In addition, temporary changes may be caused by the growth and decay of aquatic weeds, by the formation and breakup of ice cover or by the deposition of debris.

VII-2.2 Stable stage-discharge relation

NOTES:

(*a*) The simplest expression of the stage-discharge relation is a plot on coordinate graph paper with discharges plotted as abscissae against corresponding stages as ordinates. Since discharge often ranges over several orders of magnitude, it is sometimes more convenient to plot the relation on single or double logarithmically divided paper. The stage used in plotting should be the weighted mean stage during the discharge measurement.

(*b*) Computation of mean stage of a discharge measurement is described in the *Manual on Stream Gauging* (WMO-No. 519), Volume I — Fieldwork, pages 147 to 150.

VII-2.2.1 A smooth curve should be drawn by eye through the array of data points to detect points which may be erroneous.

VII-2.2.2 The rating curve should be defined by a sufficient number of measurements suitably distributed throughout the entire range of water levels.

VII-2.2.3 The rating curve should be examined for hysteresis. Where possible the measurements should have been made at steady stage but, if not, those taken at rising or falling stages should be indicated by distinguishing symbols.

VII-2.2.4 The equation for the rating curve should be obtained, or the curve may be treated as a purely graphic record.

NOTE: If the zero of the gauge corresponds to zero discharge the stage-discharge relation at a station may often be expressed by an equation of the form $Q = Ch^{\beta}$ (where Q is the discharge, h is the gauge height and C and β are coefficients) over the entire range of water levels, or more often by two or more similar equations, each relating to a portion of the range. If the zero of the gauge does not correspond to zero discharge a correction "*a*" should be applied to h resulting in the equation:

$$Q = C\,(h + a)^{\beta}$$

The quantity a may be determined from the level on the control section in relation to zero flow. Alternatively, the constant a may be determined by trial and error while plotting Q (either on ordinary or on logarithmic scale), versus $h + a$ (on logarithmic scale). The value of a which gives the best straight alignment of the data points may be considered as the best value of a.

VII-2.3 Unstable stage-discharge relation

VII-2.3.1 *General*

Smooth rating curves should be drawn for those periods when little or no shift is apparent.

NOTE: In unstable channels the channel geometry and friction properties — and hence the control characteristics — vary as a function of time and so does the stage-discharge relation at any given point in the channel. Such variations in control are evident particularly during and after flood periods, under ice conditions and during periods of weed growth and decay. In such cases, all discharges measured are plotted against their corresponding stages and each point labelled by date order.

VII-2.3.2 *Shifting controls*

NOTE: The term "shifting control" refers to that condition where the stage-discharge relations do not remain permanent but vary from time to time, either gradually or abruptly, because of changes in the physical features forming the control for the station. If discharge measurements indicate that the stage-discharge relation has changed from a previous direction, one may use shifting-control corrections (addition or subtraction from the gauge height) in order that the effective gauge height corresponds to the measured discharge and rating curve.

VII-2.3.3 *Shifting control due to ice conditions*

VII-2.3.3.1 *Discharge measurements and ice thickness*

(*a*) Discharge measurements should be made before and after the formation of the ice cover to determine the initial decrease in discharge, at appropriate intervals to define the flow recession under the ice cover, and before and after the ice breakup to determine when the open-water stage-discharge relation becomes again applicable.

(*b*) Ice thickness should be measured every time a discharge measurement is made.

VII-2.3.3.2 *Computation of daily discharge*

Daily mean discharges should be computed by means of a standard method.

NOTE: The most common standard methods are:

(*a*) Using effective gauge heights and the open-water stage-discharge relation;

(*b*) Direct interpolation between measured values of discharge;

(*c*) Using the recession equation, particularly in larger streams having significant lake storage;

(*d*) Using a winter rating curve, in particular if the ice regime appears to be consistent from winter to winter.

VII-2.3.4 *Evaluation involving surface slope (fall)*

NOTE: For gauge sites affected by variable backwater and subject to hysteresis due to changing discharge when the hydraulic slope is very mild, the evaluation of discharge requires the use of the fall between two reference gauges located within the reach as an additional parameter. The plotting of the stage-discharge observations with the value of fall marked at each observation will reveal whether the relationship is affected by variable slope at all stages or only when the fall is smaller than a particular value.

VII-2.3.4.1 If the discharge is affected by the fall at all stages, the constant-fall method should be applied when evaluating the stage-discharge relation.

VII-2.3.4.2 If the discharge is affected by the fall only when the fall is smaller than a particular value, the normal-fall method should be applied when evaluating the stage-discharge relation.

NOTE: Methods for evaluating stage-discharge relations, using slope as a parameter, are described in the *Manual on Stream Gauging* (WMO-No. 519), Volume II — Computation of discharge, Chapter 2 and ISO 1100-2, Annex C.

VII-2.4 **Extrapolation of the rating curve**

VII-2.4.1 A rating curve preferably should not be applied outside the range of observations upon which it is based.

VII-2.4.2 When extrapolation is necessary, the results obtained should be checked by more than one method.

VII-2.5 **Rating table**

A rating table can be prepared from the rating curve(s) or from the equation(s) of the curve(s), showing the discharges corresponding to stages in ascending order and at intervals suited to the desired degree of interpolation.

VII-3 **Methods of testing stage-discharge curves**

The rating curves should be tested for bias and goodness of fit.

NOTE: Methods of testing are given in the *Manual on Stream Gauging* (WMO-No. 519), Volume II — Computation of discharge, Chapter 1 and ISO 1100-2, Annex A.

VII-4 **Uncertainty in the stage-discharge relation and in mean discharges**

VII-4.1 **Statistical analysis of the stage-discharge relation**

VII-4.1.1 The stage-discharge relation should be more accurate than any of the individual gaugings.

VII-4.1.2 The uncertainty in the stage-discharge relation should be expressed as E_{mr}, which is the confidence interval, at the 95 per cent level, as a percentage of the discharge calculated from the stage-discharge relation at each stage.

VII-4.1.3 If the stage-discharge relation contains one or more break points, E_{mr} should be calculated for each range.

VII-4.1.4 At least 20 observations should be available in each range before a statistically acceptable estimate can be made of E_{mr}.

NOTE: The procedure to evaluate the uncertainty in the stage-discharge relation $Q = C\,(h + a)^{\beta}$ is as follows:*

* An example calculation for uncertainty in the stage-discharge relation is given in the *Manual on Stream Gauging* (WMO-No. 519), Volume II, Chapter 1, pages 28 to 33.

(*a*) The standard error of estimate is calculated for the logarithmic relation according to:

$$S_e(In\ Q) = \pm\left[\left[\frac{N-1}{N-2}\right]\left[S^2\ (In\ Q) - \beta^2\ S^2\ \left(In\ (h+a)\right)\right]\right]^{1/2}$$

in which:

S_e (In Q) is the standard error of estimate of In Q, expressed in absolute terms;
N is the number of discharge measurements;
$S_{(x)}$ is the standard deviation of x;
β is the exponent of the stage-discharge relation;
$(h + a)$ is the stage.

(*b*) The uncertainty E_{mr} is obtained by the formula:

$$E_{mr} = \pm\ tS_e(In\ Q)\left[1/N + \frac{\left[In\ (h+a) - \overline{In\ (h+a)}\right]^2}{\sum\left[In\ (h+a) - In\ (h+a)\right]^2}\right]^{1/2}$$

in which:

t should be taken as Student's t at the 95 per cent confidence level;
E_{mr} is expressed as percentage of discharge.

(*c*) The uncertainty in stage is computed as:

$$E_{(h+a)} = \pm\frac{100}{(h+a)}\left(E_g'^2 + E_z'^2\right)^{1/2}$$

where:

$E_{(h+a)}$ is the uncertainty in stage (or head);
$(h + a)$ is the stage (or head) (metres);
E'_g is the random uncertainty in the recorded value of stage (or head) (metres) (recommended value for punched tape recorder = ± 3 mm; for chart recorder = ± 5 mm);
E'_z is the random uncertainty in the gauge zero (metres) (recommended value = ± 3 mm).

VII-4.2 Uncertainty In the mean discharges

VII-4 2.1 The daily mean discharge should be calculated by taking the average of the observations of discharge during the 24-hour period.

NOTE: The procedure to evaluate the uncertainty in the daily mean discharge is as follows:

(*a*) For a velocity-area station:

$$E_{dm} = \pm\frac{\sum\left(E_{mr}^2 + \beta^2\ E_{h+a}^2\right)^{1/2} Q_h}{\sum Q_h}$$

in which:

E_{dm} is the uncertainty in the daily mean discharge;
E_{mr} is the uncertainty in the stage-discharge relation;
E_{h+a} is the uncertainty in the measurement stage-;
Q_h are the values of discharges used to calculate the daily discharge;
β is the exponent of the stage-discharge relation.

(*b*) For a measuring structure:

$$E_{dm} = \pm\frac{\sum\left(E_c^2 + \beta^2\ E_{h+a}^2\right)^{1/2} Q_h}{\sum Q_h}$$

in which E_c is the uncertainty in the coefficient of discharge.

VII-4.2.2 For monthly mean discharge:

$$E_{mm} = \pm\frac{\sum E_{dm} Q_{dm}}{\sum Q_{dm}}$$

in which:

E_{mm} is the uncertainty in the monthly mean discharge;
Q_{dm} is the daily mean discharge.

VII-4.2.3 For annual discharge:

$$E_a = \pm\frac{\sum E_{mm}\ Q_{mm}}{\sum Q_{mm}}$$

in which:

E_a is the uncertainty in the annual discharge;
Q_{mm} is the monthly mean discharge.

VIII – ESTIMATION OF UNCERTAINTY OF DISCHARGE MEASUREMENTS

(*See* [D.1.2.] 3.7)

VIII-1 Scope and field of application

NOTES:

(*a*) The material in this section of the annex is based on ISO 5168 (2005) entitled "Measurement of fluid flow — Procedures for the evaluation of uncertainties."

(*b*) Detailed guidance on the estimation of uncertainty of discharge measurements is given in the *Manual on Stream Gauging* (WMO-No. 519), Volumes I and II.

This section describes the calculations which should be performed in order to arrive at a statistical estimate of the interval within which the true discharge may be expected to lie, given a single discharge measurement, in order to support Technical Regulation [D.1.2.] 3.6.

VIII-2 General principles

NOTE: It is physically impossible to effect a measurement without error. However, it is usually possible to assign an interval around the measurement, called the confidence interval, within which the true value can be expected to lie with a prescribed probability, called the confidence level. There is a close relationship between the confidence level and the confidence interval such that the higher the level, the wider the interval. In this section, the 95 per cent confidence level is used.

VIII-3 Nature of errors

VIII-3.1 Classification of errors

Errors should be classified into the following three groups (see the figure below):

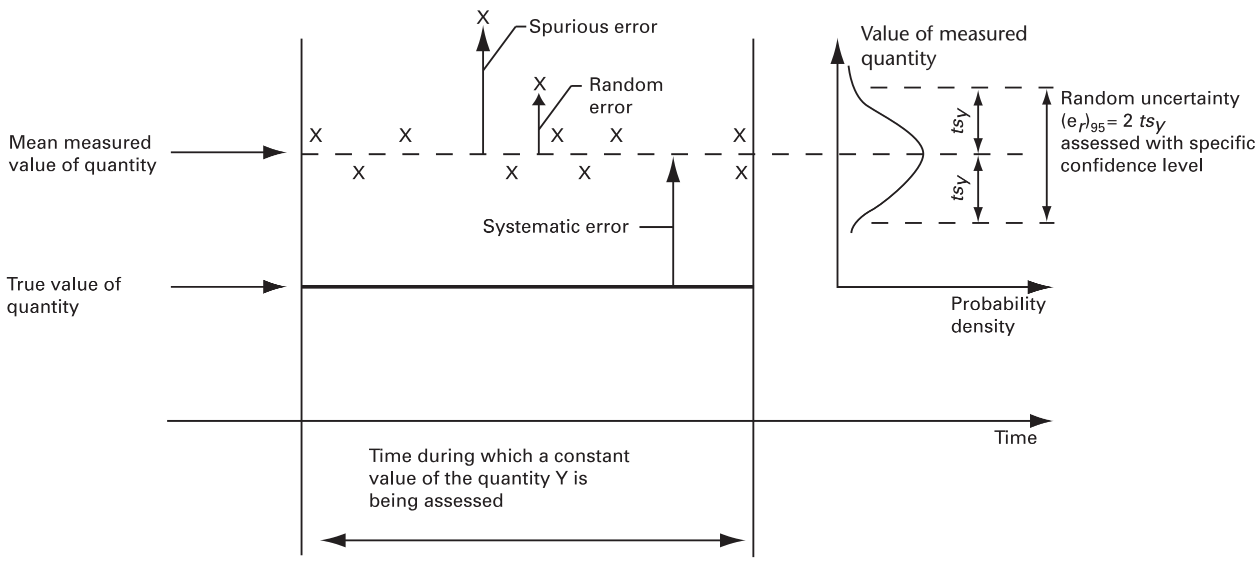
(*a*) Spurious errors;

(*b*) Random errors;

(*c*) Systematic errors.

VIII-3.1.1 *Spurious errors*

Spurious errors should be eliminated by discarding the measurement.



NOTE: In order to identify spurious errors, a statistical "outlier" test, such as the one described in Annex A of ISO 5168, may be applied as a rejection criterion.

VIII-3.1.2 *Random errors*

The uncertainty associated with random errors at the 95 per cent confidence level should be calculated as:

(*a*) 1.960σ*Y* in case of a large number of measurements;

(*b*) *t*σ*Y* in case of a small number of measurements;

σ*Y* is the true standard deviation, estimated by the standard deviation s_y of the measurements of the variable *Y*; *t* being a value of Student's *t* distribution.

NOTES:

(*a*) Random errors are caused by numerous, small, independent influences. When measuring a certain quantity repeatedly, under equal conditions, the data points deviate from the mean in accordance with the law of chance, such that their distribution can be assumed to be normal. For a small sample of data points, the normal distribution should be replaced by the Student's *t* distribution. Tables of the *t* distribution can be found in most handbooks on statistics.

(*b*) The random error in the result of a measurement can be reduced by making repeated measurements of the variable and using the arithmetic mean value, since the standard deviation of *n* independent measurements is √*n* times smaller than the standard deviation of the individual measurement.

VIII-3.1.3 *Systematic errors*

VIII-3.1.3.1 *Minimizing uncertainties in systematic errors*

The uncertainty associated with systematic errors should be minimized by one of the following methods:

(*a*) By changing equipment or conditions of measurement;

(*b*) By subjective judgement.

NOTE: Systematic errors are those errors which cannot be reduced by increasing the number of measurements if the equipment and conditions of measurement remain unchanged.

VIII-3.1.3.2 *Correction for systematic errors*

If the systematic error has a unique, known value, this value should be added to (or subtracted from) the result of the measurement and the uncertainty in the measurement due to this source should be taken as zero.

VIII-3.2 **Numerical values of uncertainties**

NOTE: Recommended values of component uncertainties for use in the computation of overall uncertainty in discharge measurement may be found in the *Manual on Stream Gauging* (WMO-No. 519), Volume I, sections 5.8 and 7.9.

VIII-4 **Combination of errors**

If a quantity *Q* is a function of several measured quantities *x, y, z,* the error e_Q in *Q* due to errors e_x, e_y, e_z, in *x, y, z,* respectively, should be evaluated by the equation:

$$(e_Q)^2 = \left(\frac{\partial Q}{\partial x} e_x\right)^2 + \left(\frac{\partial Q}{\partial y} e_y\right)^2 + \left(\frac{\partial Q}{\partial z} e_z\right)^2$$
$$+ \frac{\partial Q}{\partial x} \cdot \frac{\partial Q}{\partial y} e_x \cdot e_y + \frac{\partial Q}{\partial x} \cdot \frac{\partial Q}{\partial z} e_x \cdot e_y + \ldots$$

However, the terms $\frac{\partial Q}{\partial x} \cdot \frac{\partial Q}{\partial y} e_x \cdot e_y$ etc. are covariance terms and their sum is considered negligible when compared with the squared terms since they contain quantities which are as equally likely to be positive or negative. Therefore, the error e_Q may be approximated by a simplified equation:

$$(e_Q)^2 = \left(\frac{\partial Q}{\partial x} e_x\right)^2 + \left(\frac{\partial Q}{\partial y} e_y\right)^2 + \left(\frac{\partial Q}{\partial z} e_z\right)^2$$

EXAMPLE:* Uncertainty in velocity-area method

The channel cross-section under consideration is divided into segments by *m* verticals. The width, depth and mean velocity associated with the i^{th} vertical are denoted by b_i, d_i and $\bar{v}_i$ respectively. Then the computed discharge is:

$$Q = F_m \sum_{i=1}^{m} (b_i \, d_i \, \bar{v}_i)$$

in which the factor F_m approaches 1 when the number of verticals *m* increases. In actual calculations it is assumed that *m* is sufficiently large to make $F_m \approx 1$.

Random uncertainty

Introducing the notation $E_{Fm} = (e_{Fm})/F_m$ for the relative uncertainty due to the limited number of verticals $(E_{b_i})_r = (e_{b_i})_{r/b_i}$ for the relative random uncertainty in b_i, etc., then the total relative random uncertainty in the discharge measurement can be expressed by:

$$(E_Q)_r^2 \approx (e_{Fm})^2 + \frac{1}{m}\left[(E_b)_r^2 + (E_d)_r^2 + (E_{\bar{v}})_r^2\right]$$

In the derivation, the following simplifying assumptions have been made: the segment discharges b_i, d_i, $\bar{v}_i$ are nearly equal and the uncertainties $(E_{b_i})_r$, $(E_{d_i})_r$ and $(E_{\bar{v}_i})_r$, are nearly equal for all *i*'s and have the values $(E_b)_r$, $(E_d)_r$ and $(E_{\bar{v}})_r$ respectively. $(E_{\bar{v}})_r$ can be broken down further into:

$$(E_{\bar{v}})_r^2 = (E_p)_r^2 + (E_c)_r^2 + (E_e)_r^2$$

in which:

$(E_p)_r$ is the percentage uncertainty due to the limited number of points in the vertical;

$(E_c)_r$ is the percentage uncertainty of the current meter rating

*A numerical example is given in ISO 5168, Section two, pages 21 and 22.

$(E_e)_r$ is the percentage uncertainty due to pulsations of flow.

Systematic uncertainty

The equation for calculating the overall percentage systematic uncertainty is:

$$\left(E_Q\right)_s^2 = \left(E_b\right)_s^2 + \left(E_d\right)_s^2 + \left(E_c\right)_s^2$$

in which:

$(E_b)_s$ is the percentage systematic uncertainty in the instrument measuring width;

$(E_d)_s$ is the percentage systematic uncertainty in the instrument measuring depth;

$(E_c)_s$ is the percentage systematic uncertainty in the current meter rating tank.

The overall uncertainty in a single discharge measurement (random and systematic uncertainties together) is then:

$$E_Q = \left[\left(E_Q\right)_r^2 + \left(E_Q\right)_s^2\right]^{1/2}$$

VIII-5 Reporting of discharge measurements

A discharge measurement should be reported in one of the following forms:

(*a*) Uncertainties expressed in absolute terms

(i)	Discharge	Q	= . . . .
	Random uncertainty	$(e_r)_{95}$	= . . . .
	Systematic uncertainty	e_s	= . . . .
(ii)	Discharge	Q	= . . . .
	(Overall) uncertainty	$\sqrt{\left(e_r\right)_{95}^{2} + e_s^{2}}$	= . . . .
	Random uncertainty	$(e_r)_{95}$	= . . . .

(*b*) Uncertainties expressed in percentage terms

(i)	Discharge	Q	= . . . .
	Random uncertainty	$(E_r)_{95}$	= . . . .%
	Systematic uncertainty	E_s	= . . . .%
(ii)	Discharge	Q	= . . . .
	(Overall) uncertainty	$\sqrt{\left(E_r\right)_{95}^{2} + E_s^{2}}$	= . . . .%
	Random uncertainty	$(E_r)_{95}$	= . . . .%

XIII — WATER QUALITY MONITORING

(*See* [D.1.5.] 1)

XIII-1 Monitoring objectives

XIII-1.1 A water quality monitoring programme should clearly define the objectives of the programme.

XIII-1.2 The objectives should be based on existing legislation and/or policy directives; on national, regional and organizational priorities; and on a reasonable assessment of available resources (human, financial and material).

XIII-1.3 The objectives should be, as far as possible, product oriented, i.e. should have an identifiable output, such as interpretative report, water quality standards or pollution control measures.

XIII-1.4 The objectives should specify time limits. They can be long or short term. Long-term objectives are usually achieved by establishing a network in which samples are collected at regular intervals, e.g. monthly, bimonthly or seasonally, over a long period of time, i.e. of at least 10 years. Short-term objectives are usually achieved by conducting special intensive studies characterized by frequent sampling over short periods of time.

XIII-1.5 Possible long-term objectives are to:

(*a*) Increase knowledge of existing water quality conditions and understanding of the aquatic environment;

(*b*) Determine the availability of water quantity and quality, i.e. a quantity-quality inventory of water resources;

(*c*) Provide information on the past, present and future effects of significant natural and anthropogenic activities on the aquatic environment, including water projects such as dams, diversions, stream enlargement, massive irrigation projects and aquifer flooding, and agricultural, industrial and urban developments;

(*d*) Monitor pollution systems, such as industrial complexes, urban areas, mineralized water and sea water, to safeguard water supplies;

(*e*) Assess the effectiveness of pollution control measures;

(*f*) Detect trends in water quality to provide an early warning system.

XIII-1.6 Possible short-term objectives are:

(*a*) Identification of problem areas;

(*b*) Identification of sources of pollutants and their loads;

(*c*) Determination of compliance with regulations and standards;

(*d*) Monitoring of interjurisdictional water quality;

(*e*) Research on processes and pathways.

XIII-2 Network design

XIII-2.1 The network design should be based on the monitoring objectives. It consists of:

(*a*) Selection of sampling sites;

(*b*) Selection of physical, chemical and biological parameters to be measured in situ, in the field and in the laboratory;

(*c*) Selection of media (i.e. water, sediment, biota) and type of samples (e.g. grab, integrated, composite) to be collected for analysis;

(*d*) Determination of sampling frequency;

(*e*) Determination of sampling collection, preservation, transport, analytical and data heading methodologies;

(*f*) Determination of quality assurance protocols for field, laboratory, and data storage and retrieval activities;

(*g*) Determination of analysis requirements and selection of methods;

(*h*) Determination of requirements and selection of interpretation products, e.g. reports, fact sheets, models.

XIII-2.2 Selection of sampling sites

XIII-2.2.1 The selection of sampling sites should follow from the objectives established for the monitoring programme.

NOTES:

(*a*) If the purpose of the monitoring programme is to monitor the quality of drinking water supplies, then the sampling will concentrate on the proximity of the intake for the water treatment plants. If the purpose is to establish the effects of long-range transport of airborne pollutants (LRTAP), the sites will be located in areas remote from anthropogenic activities. If the objective is to enforce or monitor compliance with certain regulations or laws, then the protocols specified in the legislation should be followed.

(*b*) For selection of sampling sites for monitoring long-range transport of airborne pollutants see XIII-4.4 below.

XIII-2.2.2 Other factors which should be considered in establishing a water quality sampling site are:

(*a*) Accessibility and safety of the site;

(*b*) Availability of other measurements at the site, e.g. river discharge or precipitation quantity and quality (especially when studying LRTAP effects);

(*c*) Degree of cooperation from other agencies if this cooperation is significant for the programme, e.g. will provide samples or measurements impossible to obtain otherwise, or will reduce the overall costs;

(*d*) Costs of sampling, and costs and time for sample transport to the laboratory;

(*e*) Availability of prior water-quality data;

(*f*) Land use;

(*g*) Location of inputs (point and non-point sources) in relation to the water bodies being studied.

XIII-2.3 **Selection of water quality parameters**

XIII-2.3.1 Water quality parameters can be classified by their nature as:

(*a*) Physical properties, e.g. temperature, colour, turbidity, electrical conductivity;

(*b*) Inorganic chemical components, e.g.:
– gases — O_2, NH_3;
– major ions — Cl^-, SO_4^{2-}, HCO_{3-}, CO_3^{2-}, Na^+,Mg^{2+}, Ca^{2+};
– nutrients — N and P compounds;
– trace metals — e.g. Cd^{2+}, Pb^{2+}, Zn^{2+};
– general measurements, e.g. alkalinity, pH, total dissolved solids;

(*c*) Organic substances, e.g.:
– pesticides, herbicides;
– polyaromatic hydrocarbons (PAHs);
– polychlorinated biphenyls (PCBs);
– phenols, chlorinated phenols;
– volatile organic compounds (VOCs);

(*d*) Biological components, e.g.:
– microbiological — coliforms;
– plankton, chlorophyll, biomass;
– fish.

XIII-2.3.2 The basic water quality parameters which should be monitored are listed in the table below. Water quality parameters to be measured in a monitoring programme should be based on:

(*a*) Objectives of the programme;

(*b*) Costs of sample collection and analysis;

(*c*) Resources available (e.g. money, personnel, field equipment and instrumentation, laboratory facilities);

(*d*) Methods available for sample collection, preservation, quality assurance and analysis;

(*e*) Existing knowledge of water quality of the water bodies under study, such as their chemical composition or any relationships between variables;

(*f*) Geochemistry of the region under study;

(*g*) Land use;

(*h*) Production or use of chemicals in the region;

(*i*) Physical, chemical and biological nature of inputs to the water bodies.

XIII-2.4 **Media selection**

XIII-2.4.1 The objectives of the programme are the main factors in deciding what materials, e.g. water, suspended sediment, bottom sediment or biota, should be collected for physical, chemical and biological analysis.

NOTE: If the objective of the programme is to monitor the quality of drinking water supplies, then the water column should be sampled. If the objective is to find out what chemicals are present in a given aquatic system, then all media, i.e. water, suspended and bottom sediments and biota, should be sampled, as some substances can be detected only in some media.

XIII-2.4.2 Other factors which should be considered in deciding which media to sample are the availability of:

(*a*) Sampling methods and equipment;

(*b*) Analytical methods for particular media compatible with the objectives of the programme.

XIII-2.5 **Determination of sampling frequency**

XIII-2.5.1 Sampling frequency depends on:

(*a*) The purpose of the network (e.g. the type and magnitude of change to be detected);

(*b*) The range of the measured variables;

(*c*) The time variability of the parameters of interest;

(*d*) The availability of resources for sample collection, preservation, transport to the laboratory, sample analysis, data storage and retrieval, quality assurance and data interpretation.

NOTE: If the purpose of the network is to determine the average (yearly, monthly, weekly, ...) value of a parameter with standard deviation S and an error E at a degree of certainty, statistical considerations require the number of (yearly, monthly, weekly, ...) samples to be:

$$n \geq \frac{t_{\alpha/2} \cdot S^2}{E}$$

where $t_{\alpha/2}$ is the Student's *t* constant (see also the *Manual on Water Quality Monitoring* (WMO-No. 680), section 2.4).

XIII-2.5.2 The time variability of water quality parameters can be determined by:

(*a*) Using existing water-quality data; or

(*b*) Carrying out a preliminary (pilot) sampling programme.

(*e*) The local name of the well, and its owner's name;

(*f*) The use of the well.

XIII-4.6.2 The water level should be measured, using either a weighted steel measuring tape rubbed at the lower end with blue carpenter's chalk to show the water level, or a tape detecting the water level by its electrical conductivity, or a bubbling air line converting the pressure required for bubbling into the depth of submersion to be subtracted from the total length of the line. Recording devices employing floats, electrical devices and pressure gauges can be used to monitor changes in water levels.

XIII-4.6.3 Samples should be taken from pumping wells or from capped artesian wells. In open wells and where samples from specific depths are required grab samplers, of small external diameter for narrow well casings, should be used.

XIII-4.6.4 Soil water samples from above the water table should be taken by driving tubes with a porous region near the bottom into the soil, or by embedding porous ceramic cups in the ground supplied with vacuum lines.

XIII-4.7 Samples for radioactivity measurement

XIII-4.7.1 Precautions should be taken to avoid adsorption on the walls of the container or on suspended matter.

NOTE: Acceptable container materials include polypropylene, polyethylene or Teflon.

XIII-4.7.2 To keep metals in solution and minimize their adsorption, hydrochloric or nitric acid, 2 ml/l of sample, should be added.

XIII-4.8 Shipping of samples

When shipping samples to the laboratory for analysis, each sample should be labelled with full information on the station, date, time, parameters to be analysed, methods of preservation if any, and the identity of the collector, together with an optional narrative description to identify any special circumstances affecting the interpretation of the data.

NOTE: Depending on local rules of evidence, any sample which may form part of the evidence in legal proceedings may require the maintenance of a verifiable chain of custody through all persons having custody of the sample from the collector to the analyst.

XIII-5 Quality assurance

XIII-5.1 Generalities

NOTES:

(*a*) Quality assurance consists of quality control, the overall system of guidelines and procedures designed to control the quality of the product, and quality assessment, the overall system of activities which ensure that quality control is being effectively performed.

(*b*) Analytical methods can be classified as:
  (i) Primary methods, suitable for establishing the analytical data for standard reference material; exacting, time-consuming and requiring a high degree of skill;
  (ii) Routine methods, suitable for day-to-day use with numerous samples, for good precision and accuracy.

(*c*) Accuracy of routine methods can be checked by the use of samples of known concentration, such as standard reference materials, and by the addition of known amounts of "spikes" to the sample being analysed.

XIII-5.1.1 The quality assurance programme shall include documentation of field and laboratory protocols.

NOTES:

(*a*) Quality of analytical results is defined by their precision, a measure of the closeness of agreement between data generated by replicate measurements, and accuracy, the degree of agreement of the data with the "true value".

(*b*) The precision measures the variability of the method resulting from random errors, and is generally reported as the standard deviation or the relative standard deviation of a series of replicate analyses.

(*c*) Accuracy is usually expressed in the form of % error, i.e. 100 times the difference between the mean value obtained and the true value, divided by the true value.

(*d*) The accuracy of a method can be determined by analysing standard reference materials or by the addition of known amounts of "spikes", analysing them, and determining the % recovery. This measures the capability of the method to recover known amounts of material added to a sample.

XIII-5.1.2 For each method and for each instrument in a laboratory the following values should be determined:

(*a*) Instrument detection limit — the lowest concentration of analyte that an instrument can detect which is statistically different from the instrumental background noise;

(*b*) Method detection limit — the lowest concentration that a method can reliably detect which is statistically different from the value obtained from a blank, e.g. distilled water, carried through the same method;

(*c*) Practical detection limit — the lowest concentration that a method can reliably detect in a real sample-matrix which is statistically different from a blank carried through the method on the same sample-matrix;

(*d*) Limit of quantitation — a value of a sufficient number of standard deviations, usually above the average value of the blank, that not only indicates the presence of the analyte detected, but is also a useful value for the concentration determined.

NOTE: The quality monitoring process includes the following types of samples:

(*a*) Sampler blanks — samples consisting of ultra-pure distilled water poured into or permitted to pass through the sampler and run through the rest of the field and analytical process, including field preservation and transportation to the laboratory.

(*b*) Bottle blanks — samples prepared from ultra-pure water or a solvent placed in randomly selected sample containers and run through the analytical process to ensure that no contamination is introduced through the bottle-washing process.

(*c*) Field blanks — samples prepared as the bottle blanks, but also adding the chemicals required to preserve the sample until it is analysed. These samples detect any contamination due to the chemical preservation of samples.

(*d*) Filter blanks — samples prepared from ultra-pure water which was passed through the field filtering apparatus. These samples are used to detect contamination occurring during field filtration.

(*e*) Duplicate samples (splits) — subsamples obtained by dividing a sample in two or more parts.

(*f*) Replicate samples (temporal) — samples taken at the same location at specified, usually short, time intervals.

(*g*) Spiked samples (standard additions) — split samples spiked with several different levels of the parameters of interest, to detect the introduction of systematic errors or bias into the analytical method.

XIII-5.2 Quality assessment reports

XIII-5.2.1 Quality assessment reports should be required from each level of laboratory supervision, from bench analyst to section head.

XIII-5.2.2 The bench analyst should report:

(*a*) The variability of data for blanks and standards;

(*b*) The precision and accuracy of groups of tests;

(*c*) The number and type of quality control analyses whose results deviated by more than a preset amount, e.g. two standard deviations, from the true values;

(*d*) Other information relevant to quality control, such as: variation in standard solutions, reagents found to be substandard, methods used in housecleaning, samples with incorrect or inadequate information, frequency of instrument calibration.

XIII-5.2.3 Laboratory supervisors should report, appropriate to the supervisory level:

(*a*) Frequency of user/client complaints;

(*b*) Training sessions attended by staff;

(*c*) Analytical audits and checks of data against historical values;

(*d*) Interlaboratory quality control studies in which the laboratory participated;

(*e*) New analytical procedures introduced or modified;

(*f*) Overall precision and accuracy of group results;

(*g*) Other information relevant to quality control, such as incidence of instrumental breakdown, frequency of data verification.

XIII-5.3 Data recording

XIII-5.3.1 In no case should a value of zero be recorded for an analytical result.

NOTE: If the value obtained is below the method detection limit, it should be recorded as such, e.g. "less than [state the method detection limit]".

XIII-5.3.2 Values below the practical detection limit or the limit of quantitation should be so identified, in the latter case normally by enclosing the data in parentheses.

XIII-5.3.3 Quantitative data should be accompanied by measures of precision and accuracy where available, and by expected reliability such as the confidence interval.

NOTE: A confidence interval is a statistically-derived estimate that the true value lies in a given percentage of determinations between the stated upper and lower limits about the sample mean value as determined.

XIII-6 Field safety

XIII-6.1 Training

XIII-6.1.1 Field personnel should receive the necessary training to become knowledgeable of the hazards they may encounter, to recognize potential hazardous situations, and to take measures to minimize hazards.

XIII-6.1.2 Training should include water safety, field first aid, wilderness survival and basic methods for repairing transportation vehicles.

XIII-6.1.3 Field offices should maintain a current list of relevant safety courses available from government or private agencies, together with a record of courses taken by their personnel.

XIII-6.1.4 Periodic refresher courses should be organized.

XIII-6.2 General practices

XIII-6.2.1 All employees should be aware of, and adhere to, safety procedures promulgated by their governments.

XIII-6.2.2 Field staff should be provided with available information on the characteristics of water bodies to be studied and weather forecasts for the area.

XIII-6.2.3 Sampling should not be carried out if abnormal weather or water conditions prevail which are considered to be hazardous to the safety or the health of staff members or likely to damage equipment.

XIII-6.2.4 Field parties should leave accurate sampling schedules and expected itineraries in the field office.