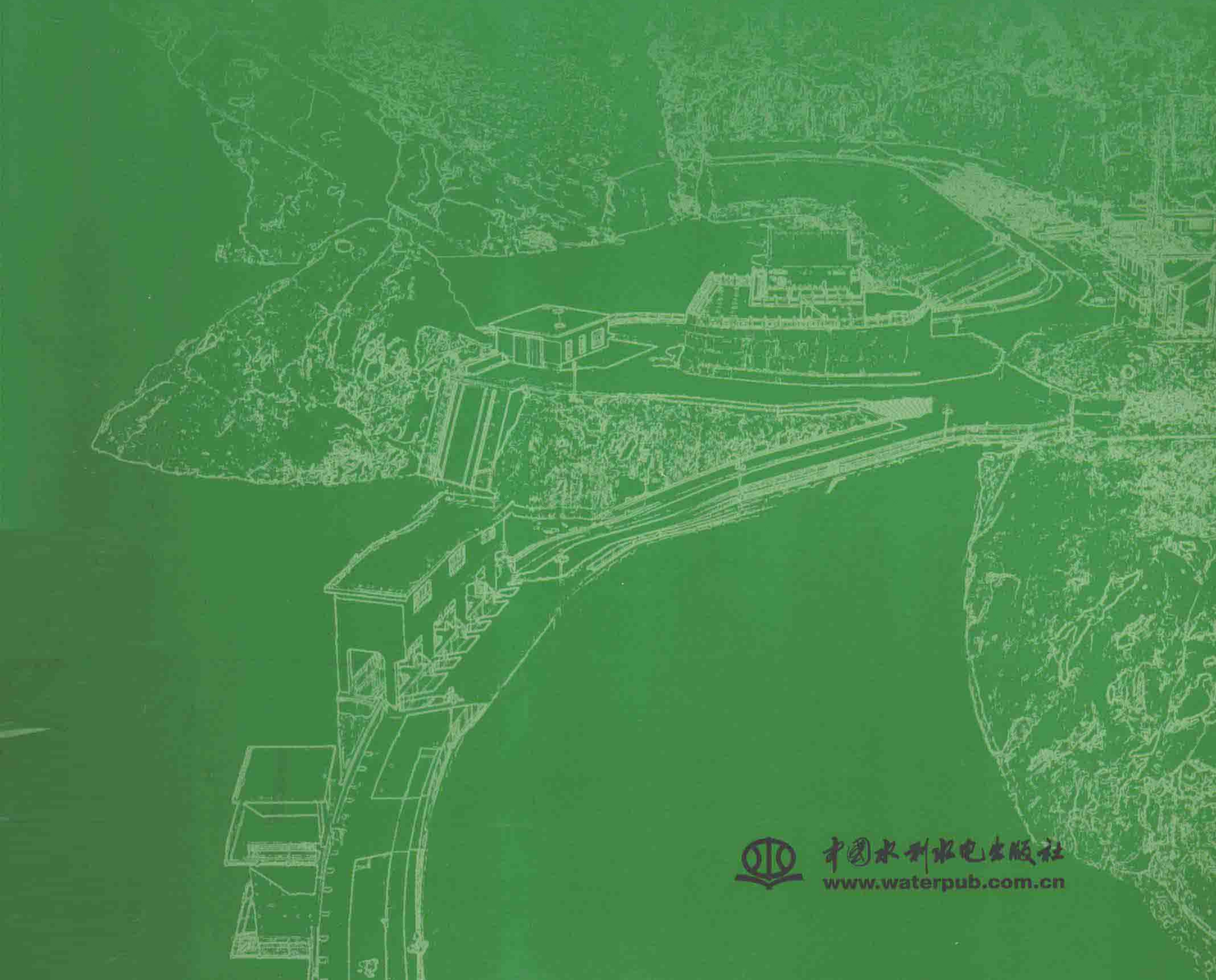
普通高等教育“十二五”规划双语系列教材

Collection of Water Information and Data Processing（英文版）

谢悦波　主编



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内 容 提 要

本教材根据WTO最新颁布的ISO标准编写，主要介绍了传统的水位观测、天然河道的流量测验、泥沙测验（即传统水文测验中的水、流、沙测验），地下水监测和水质信息的采集等方面的内容。

本教材适用于水文水资源工程专业双语教学外，也可供水利水电类其他专业的师生及相关技术人员参考。

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前 言

河海大学是以水利为特色、国家211工程重点建设的院校。水文学及水资源是国家重点学科，水文与水资源工程是这个重点学科下的本科支撑专业，是江苏省品牌专业。传统的“测”、“报”、“算”是这个学科的看家本领，其中的“测”——《水信息采集与处理》（20世纪90年代以前叫“水文测验学”）是这个专业中唯一同时具备以下两个属性的课程：

（1）水文专业属性——使学生具有一种依靠所学专业在社会上生存的能力。水文上的4个主要业务内容：“测”、“报”、“算”、“编”，其中测（水文测验）和“编”（水文数据处理，也叫资料整编）都是《水信息采集与处理》课程所教授的内容，占了1/2；全国3万多名在职水文职工中，65%是从事这两项工作的。

（2）学科基础属性——为水文预报、水文计算、水资源评价等专业课程提供基本的数据。在这些课程具体应用时，首先要审核数据正确与否、合不合理，这是水文预报精度高，水文计算结果准确，水资源评价合理的基础。

1978年10月至1982年7月，编者在华东水利学院（现河海大学）陆地水文专业（现水文与水资源工程专业）求学期间，于1981年3～7月学习了《水文测验学》课程，任课教师是林传真、林季峰两位教授，当时课内授课96学时（含8个实验），配有一个月的水文测验教学实习（地点在江西宜春地区石上水文站），二周的课程设计（对长江奉节水文站1975年全年水文资料进行整编；1991年编者参加长江三峡工程古洪水研究项目期间到四川奉节时，专门安排去了奉节水文站，仔细查看了1975年全年水文资料整编的成果）；编者1992年在荷兰UNESCO-IHE学习期间，又专门选修了这门课程，当时的授课教师就是Mr. Wubbo Boiten，这门课程学习的结果是：在2007年UNESCO-IHE成立50周年校庆出版的《Water for a Changing World：Enhancing local knowledge and capacity》书中Summaries第8页对编者的介绍，其最后一句“He also colorfully relates how at UNESCO-IHE he earned his reputation of not needing a current gauge to accurately measure discharge，because he could do it just by looking at the water。”2010年2月

1日～4月25日编者在荷兰UNESCO-IHE学术休假（教学交流、学术讲座、野外参观、科研研讨等）期间，又专门查阅这门课程现在的教学设置、教材、参考文献等，发现与18年前编者在那里学习期间的设置一样：仍然分为两门各占2个学分的课程——Hydrometry（水文测验，还是Mr. Wubbo Boiten的教材，2008年出了第三版）和Data Processing（数据处理），其中Hydrometry课程还配有1个学分的实验和二周的野外实习；Data Processing设有二周的课程设计。显然，水文上仅有此门课程“享有”如此全面的教学内容，正是因为其内容的重要性。

由此可见，本门课程内容在本专业中占有极其重要的地位。

近60年来，河海大学的水文学及水资源学科为中国的水文事业培养了7000多名本科学生。在全国各个水文部门，都有河海大学的水文毕业生，他们在不同的岗位为中国的水文事业默默地做着奉献，如中国最大的两个水利流域机构的水文局分管测验工作的局长——长江委的刘东生、黄委的谷源泽就是河海大学水文1978级同宿舍的同学。

2002年以前，河海大学这门课程的英文自编讲义用于给三届国际留学生授课；自2002年教育部要求部分高校对部分课程采用双语教学授课计划实施以来，这门课程是河海水文专业第一门采用双语授课的课程，先后给1999级、2000级、2001级、2002级、2004级、2005级（在全年级153位同学中选择了40位）、2006级和2008级这8级本科学生中开设，并于2002年、2004年和2007年对课程的自编英文讲义进行了3次修改，获得了2009年度国家双语教学示范课程建设项目（项目编码：2017－B0902608）。

为了鼓励河海大学水文与水资源工程专业的学生学好《水信息采集与处理（水文测验学）》这门双语教学示范课程，自2007年，德国KISTERS公司在河海大学设立“KISTERS——河海大学《水信息采集与处理》课程双语教学奖学金”——每年人民币10000元，用于奖励课程考试成绩前5名的学生（并颁发获奖证书）。获得KISTERS奖学金的同学还享有以下机会：

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KISTERS公司CEO Klaus Kisters几乎每年都要亲自来河海大学给水文与水资源工程专业的学生做一次“国际水文数据处理研究新进展”报告。

德国老牌水文仪器OTT公司 Managing Director Anton Felder 在2009年来中国期间特地从上海绕道南京河海大学，与编者座淡1小时后即赶往南京禄口机场；2010年7月11～12日，OTT公司在这次座谈会上承诺的免费赠送河海大学水文与水资源工程专业一套自动降雨测定仪器（含操作软件、含加热装置，可以不受天气条件限制常年自动观测，Precipitation Apparatus：OTT PLUVI02高精度称重法雨量计）安装在河海大学芜湖水文测验学课程教学实习基地宣城水文站，供水文与水资源工程专业的学生在实习时使用。

在本书的编写过程中，佘亮亮参加编写了第6章、吴霞参加编写了第7章并负责对出版社第4～7章打印稿内容进行二校；张君负责对第2～3章打印稿内容进行二校，全书由 Indonesia Parahyangan Catholic University 的 Doddi Yudianto 博士负责统稿、编辑。

限于编者的专业认识深度和英文水平的局限，书中难免会有不当之处，恳请读者不吝指正，以便再版时修改。

同时，借此机会，向所有为本书的出版提供关心、支持和帮助的同仁一并表示诚挚的感谢！

编　者

2011年1月11日

Contents

Chapter I Hydrometric Stations

1. 1 Hydrometric network design

1. 1. 1 Purpose of network design and classification of network

On account of the different geographic regions and natural conditions on the earth, the hydrological phenomena are also diversified everywhere. In order to study the regime of hydrological factors in areas with different hypsographic conditions, various kinds on hydrological stations are required to be set up to collect the hydrological data. The quality of the observed hydrological data closely depends upon the location of the hydrometric stations. Hence it is of great importance to make network design prior to the establishment of hydrometric stations.

The aim of the network design is to set up scientifically various kinds of hydrometric stations in suitable positions so as to make them play greater role than they are individually situated. Hydrometric network may be classified into base network, network for special purposes and experimental network according to their task. The base network must meet the needs of the national economy and is designed according to the scientific principle, that is, to control the area and temporal variation of hydrological elements in an area with a minimum number of hydrometric stations. The hydrometric stations must be able to operate for a long term unless the natural conditions are changed due to human's activity.

The network for special purposes is established for certain special purposes or for a particular project. The observational items, the location of the stations and the requirements of the observation are to be specified by the department concerned. The hydrometric stations can be withdrawn after sufficient data are collected.

The experiment network is set up for the purpose of an all round and deep research of the process of hydrological phenomena or some water body. The number of such stations is generally limited, whereas the measurement is comparatively complicated for carrying out a detailed study of the hydrological phenomena. Therefore, the experimental network not only serves for the special purpose of its own but is also worthy for improving the work of other kinds of network.

According to different observational items, the hydrological networks may be classified as discharge, stage, sediment, rainfall, evaporation and the water quality, etc. network. The experimental stations deal with the following specific subjects, such as: runoff, lake, evaporation, hydrometric method, river bed evolution, and estuary, etc..

Every kind of network must be designed in line with certain criteria. An emphatic introduction of the specifications of base network design will be given below.

1.1.2 Principles for designing a base network

Design of a base hydrometric network rests on the principle that the variation of hydrological factors may be controlled by a minimum and appropriate number of hydrometric stations. However, economic as well as technical considerations are also involved in the design of base network.

Of all the base hydrological network, the stream gauging network is the most important, on which the following introduction will be focused.

Nevertheless a general description will also be given to stage network, sediment load network, rainfall network and the evaporation network.

1.1.2.1 Principles for the design of a streamgauging network

The principles of a stream gauging network design are somewhat different in considering the size of the river basin, the difference between the main stream and tributaries as well as the different reaches of a river.

1. *The linearity principle*

This principle is suitable for large rivers and main streams. It is generally used for rivers with drainage areas larger than 5000km^2.

In establishing stations along large rivers or main streams it is necessary to satisfy the linear interpolation of the runoff characteristics along the river and meanwhile to take account of the requirements of hydrologic forecasting.

Considering the observed error involved in the flow measurement, a reasonable distance must be kept between any two adjacent stations along the river. The increment of the intervening area (or the local inflow) should be larger than 10%-15% of the area (or inflow) controlled by the upstream sites as shown in Figure 1.1.

$$\frac{A_2-(A_1+A_3+A_4)}{A_1+A_3+A_4}>10\%-15\% \tag{1.1}$$

Where A_1, A_2, A_3, A_4—drainage areas controlled by stations 1, 2, 3, 4 respectively.

Equation (1.1) is applicable to sparse-data regions of comparatively homogeneous hypsographic conditions and uniform rainfall distribution. With adequate data, it is better to use the following condition

$$\frac{Y_2-(Y_1+Y_3+Y_4)}{Y_1+Y_3+Y_4}>10\%-15\% \tag{1.2}$$

Where Y_1, Y_2, Y_3, Y_4—runoff amounts corresponding to stations 1, 2, 3, 4 respectively.

When Equation (1.1) or Equation (1.2) is satisfied, the establishment of the station 2 is permissible. The proportion 10%-15% is the lowest limit. The maximum distance, between adjacent stations will have no definite limit, just as the case may be, as shown in Figure 1.1.

In the adjustment of the network, the established stations should be utilized as far as possible, especially those stations with longer history. The development of the national economy, the natural conditions of the section and the convenience of the daily life should also be taken into consideration.

2. *The rationality principle*

This principle is suitable for establishing stations on rivers with drainage areas ranging from 200 to 5000km². The main idea of the rationality principle is to establish stream gauging stations on the representative rivers. When several similar contiguous basins are under study, the observed data of the representative stations may be utilized and it is unnecessary to establish hydrometric stations on every stream. For instance, if two rivers are similar in area, topography, soil and geological conditions, slope, vegetation cover and other conditions, similar rainfall patterns will result in similar hydrographs. This is the starting point of the rationality principle.

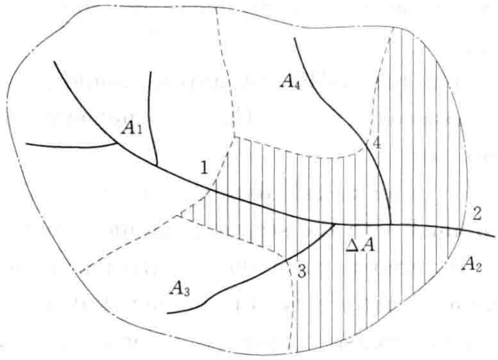

Figure 1.1 Sketch illustrating the locating of stations by the linearity principle

Prior to the choice of a representative river, it is necessary to carry out the investigation of the natural conditions for a number of watersheds, so that the division of hydrological homogeneous areas may be effected.

As to lakes and depressions, marshes, regions of dense drainage net and arid regions, individual division should be made.

3. *Station grouping principle*

Owing to the large number of rivers with drainage areas less than 200km², myriad of representative stations would be required if the rationality principle is followed. Instead, the principle of station grouping will be applied.

The principle of station grouping is one in which a group of stations are established in a region rather than a single one. The data obtained from a group of stations with different hypsographic conditions can be transposed to hydrological similar but engaged small basins.

1.1.2.2 Principle of establishing a base stage network

The change of stage in a river results from the variation of discharge, and also from the influence of river morphology which is affected by scour and silting of the river bed. It is very difficult to make a complete description about the flow regime by means of stage only. On the middle and upper reaches of a river the gauge stations are generally not established individually unless the distance between hydrometric stations are too long, and thus additional gauges are necessary. But for levee confined river reaches, tidal river reaches, regions of dense drainage net and lake basins or reservoir basins, owing to unnecessary or impossible establishment of discharge stations, the base stage network should be well designed so that change in flow regime can be grasped.

1.1.2.3 Principle of establishing a base sediment network

The amount of sediment carried by stream flow is mainly governed by the erosion of ground surface which is closely related with the soil characteristics of the basin. Hence, in establishing the sediment network, careful consideration should be given to the laws of sediment yield in the basin and the accuracy of the measuring device and analysis as well.

The base sediment station should be set up as the mean annual sediment concentration exceeds 0.05 – 0.1kg/m^3, but may still be required for those areas with less sediment load.

In order to calculate the sediment discharge, the base sediment station should be combined with the stream gauging station.

In order to meet the requirement of drawing the isoclines of erosion modulus, the sediment stations need to be distributed uniformly through out the region. However, it should be densely distributed for areas of larger sediment yield and sparely distributed for areas of less erosion.

For the base stream gauging stations located at existing or projected reservoirs, and upstream of the intake of irrigated areas sediment runoff is an indispensable item to be measured.

1.1.2.4 A brief introduction to the design of basic precipitation and evaporation networks

The base rainfall stations are chiefly established to meet the requirements of hydro logical computations and forecasting. However, the network density required to control the storms is still akey problem in China.

Basicaly, the distribution of base evaporation stations will depend on the desired accuracy of observation and calculation. Because the mild area is relatively small, one evaporation station usually installed per 5000km^2 is acceptable for the average conditions. This desity of network might be still smaller for the remotel locations.

1.1.3 Hydrometric networks in some countries

The network design is a matter of great significance for the hydrological work. At present, considerable attention has been paid to it and different extents of development have also been achieved. A list of the network in some countries is given in Table 1.1.

Table 1.1 Hydrometric networks in some countries

No.	Country	Area (km^2)	Number	
			Rain gauges	Stream gauging stations
1	Argentina	2776763	3445	700
2	Australia	7000000	6660	1359
3	Austria	83849	771	249
4	Brazil	8850000	5000	1300
5	Canada	9950000	1940	1327
6	China	9600000	12817	2917

Continued

No.	Country	Area (km^2)	Number	
			Rain gauges	Stream gauging stations
7	Costa Rica	50900	142	31
8	ech Repubhc	128000	1242	519
9	Egypt	1002000	91	66
10	Ethiopia	90720	360	55
11	Finland	337000	570	190
12	France	550000	4295	760
13	Germany	248000	2950	1757
14	Ghana	238000	449	35
15	Guinea	255000	43	—
16	Honduras	115205	75	49
17	Italy	301000	2080	520
18	Japan	370000	6000	2000
19	Kenya	583000	1435	425
20	Mauritania	1085000	33	4
21	Mauritius	2090	259	18
22	Morocco	500000	602	57
23	Norway	324000	700	600
24	Peru	1285215	926	210
25	Rwanda	26338	9	8
26	Senegal	201000	65	4
27	Sweden	450000	1000	388
28	Tanzania	833000	942	133
29	Tunisia	67000	510	95
30	Turkey	776980	1317	909
31	Uganda	236037	424	78
32	U. S. A.	9300000	10500	7601
33	U. S. S. R.	22402000	18489	11000
34	Zaire	2344116	445	2

Note: Should be taken out since the union of soviet socialist Republics was dissolved in late 1991.

1. 2 Selection and reconnaissance of river reaches for hydrometric stations

The selection of river reaches for measurement is related to the convenience of the measurement and the desired accuracy of the observed data. Hence it is also very important to select and survey the concrete river reaches after the network design. The gauging stations are established chiefly for knowing the flow regime of the river interested. It is quite simple, however, to obtain a record of river stage. If a stable (single valued) relation between stage and rate of discharge can be developed, then the work of discharge measurement and data compilation is expected to be greatly reduced by using this relationship.

1.2.1 Control of hydrometric stations

By control reach (or section if shorter) is meant the river reach situated downstream of the hydrometric site having a stable and single valued stage discharge relationship.

The relationship between discharge and stages (also called the rating curve of the $Z—Q$ relation) is generally set up for a pre-selected cross section of a river or an artificial channel.

Controls are classified as follows.

1. *Section control*

The effect of the stable section is called the section control, which says natural or artificial local narrowing of the cross section (waterfall, rock bar, gravel bar) creating a zone of acceleration. Disturbance downstream the control will not be able to pass the control in upstream direction. The section control is located usually at places with rock sills, rapids and contracted opening etc. The pre-selected cross section is also referred to as a control. A control is governed by the geometry of the cross section and usually by the physical features of the river downstream of the section.

2. *Channel control*

The effect of the control reach is called the channel control, which means a cross section in which no acceleration of flow occurs or where the acceleration is not sufficient to prevent passage of disturbances in upstream direction. The rating curve depends on the geometry and the roughness of the river downstream of the control. The length of the downstream river-affecting the rating curve depends on the discharge and on the energy slope $L : \frac{Q}{S}$. Channel control is generally formed in the case of straight channel reach with uniform section, stable bed and relatively steep longitudinal profile.

Both the channel control and the section control are known as the station control. Obviously, it is disable to select the hydrometric stations with a good control located downstream from the site under consideration.

In many situations the cross section is a complex control: during low discharges the section is a section control or a structure control, during peak flow the section becomes a channel control.

3. *Structure control*

This control is artificial local narrowing of the cross section like weirs and flumes discharging under free flow conditions.

The characteristics of the control determine the behavior of the stage-discharge rela-