钱塘江河口丛书之一

钱塘江河口治理开发

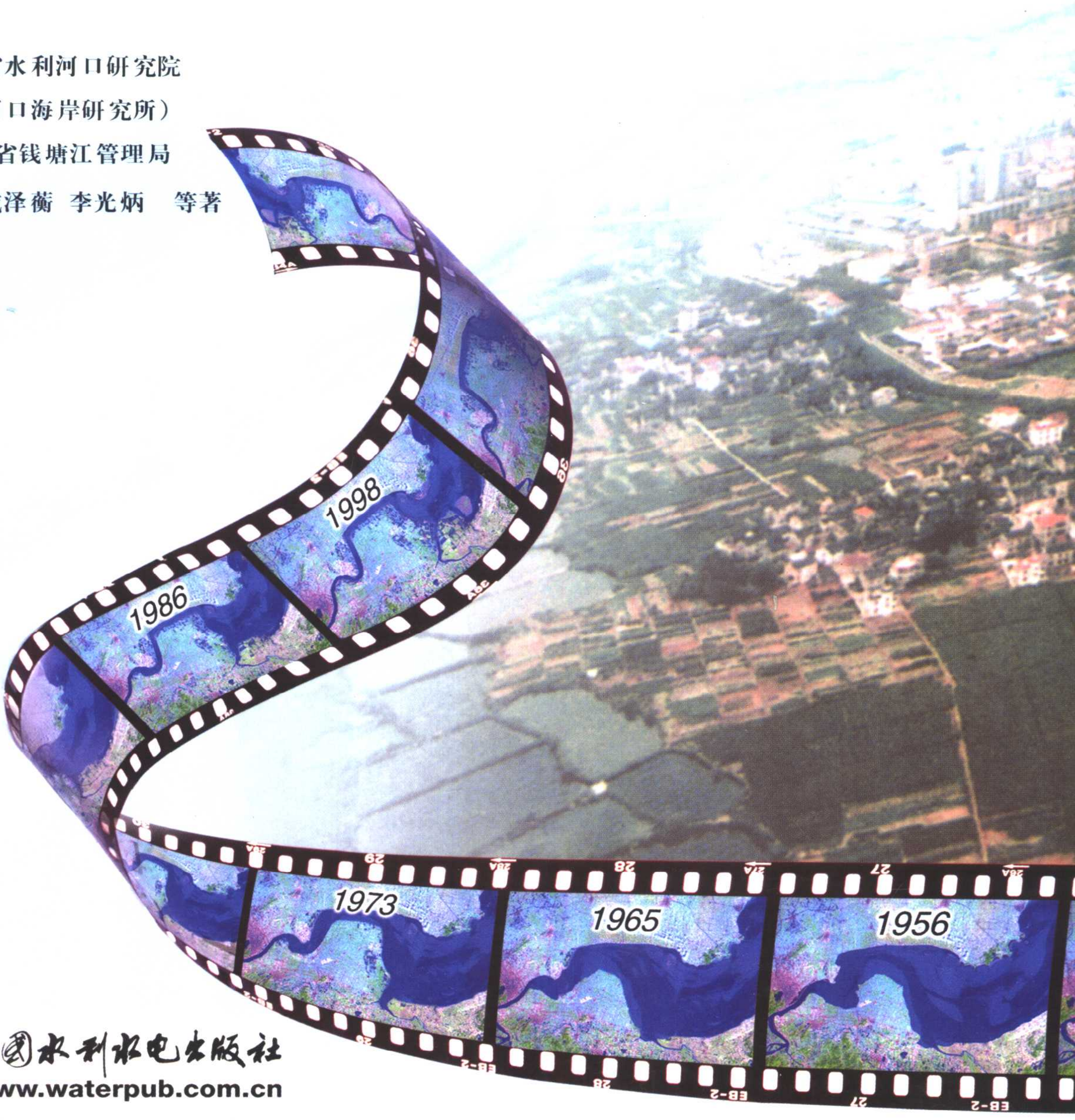
REGULATION AND EXPLOITATION OF QIANTANG ESTUARY

浙江省水利河口研究院

（省河口海岸研究所）

浙江省钱塘江管理局

韩曾萃 戴泽蘅 李光炳 等著



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内 容 提 要

钱塘江河口以其汹涌澎湃的钱江潮闻名古今中外，河口段江道亟度宽浅，动力强劲，冲淤多变。近半个世纪内，通过持续的观测研究、科学规划和工程实践，使杭州以下105km江道缩窄了1/2～3/4，江槽得以稳定，增强了防潮、排涝和航运的能力，结合围涂110余万亩，形成了新的经济增长点，取得了巨大的综合效益，被国内知名专家誉为强潮河口治理的创举。本书从其潮汐水文、泥沙运动、河床演变、治理规划、工程建筑、人类活动对河口的影响，以及运用数值模拟和实物模型试验的经验等方面，进行了系统总结，是运用现代科学技术总结实践经验的结晶。本书可供从事水利、海洋、地貌等科技工作者参考，也可供有关大专院校师生阅读。

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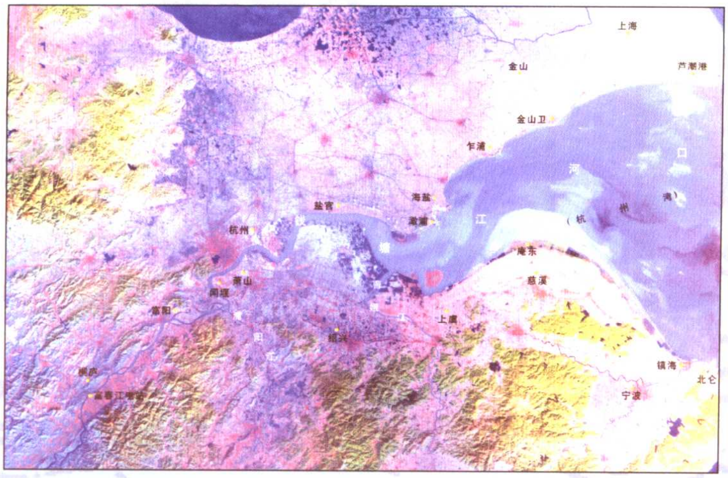
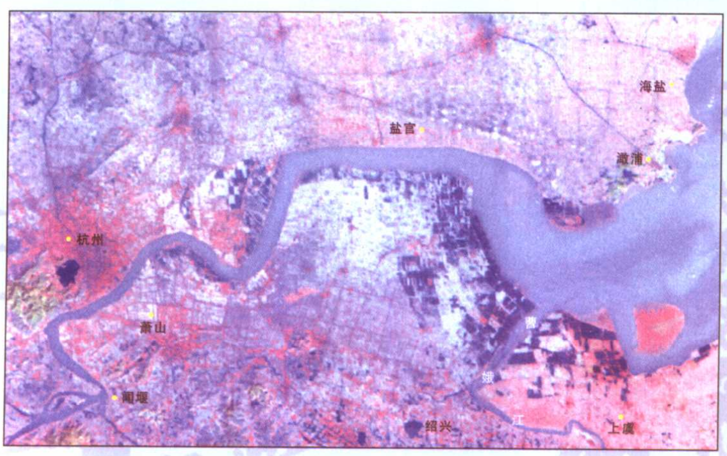


钱塘江河口（含杭州湾）卫星照片（2002年）

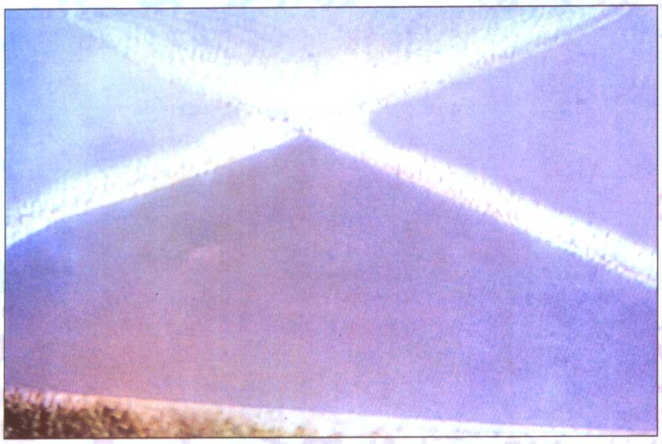
20世纪60年代初，河口段江道形势



21世纪初（大规模整治缩窄后），河口段江道形势

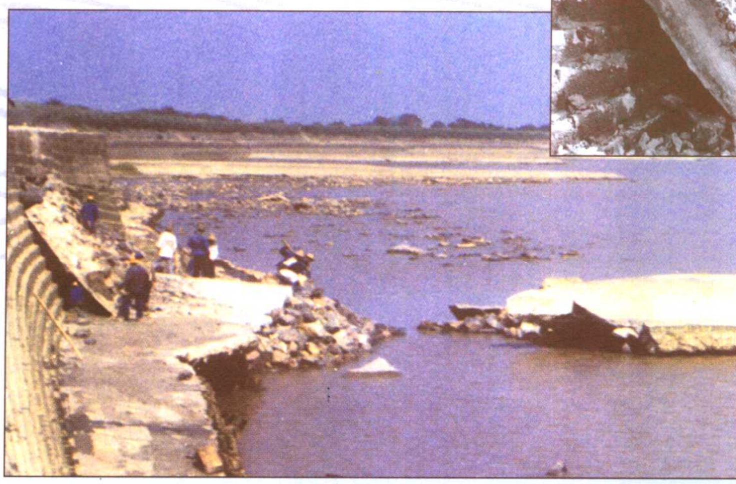
汹涌钱江潮，壮观天下无。这是海宁盐官镇的一线潮

涌潮遇老盐仓高坝反射后产生的回头潮



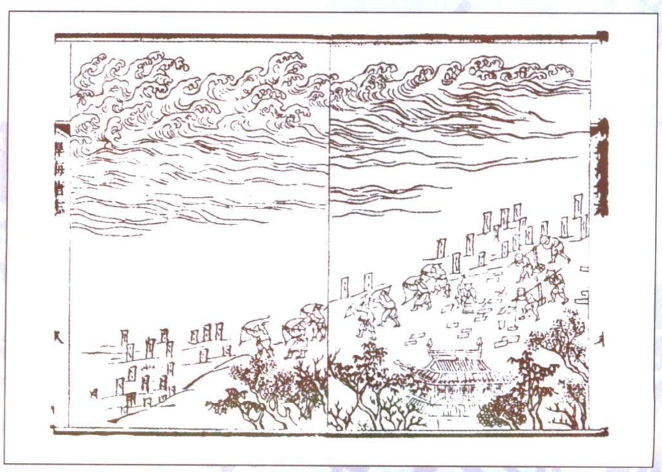
汹涌上溯遇中沙，分成两股，绕过中沙后，形成奇特的交叉潮

海塘前的第二道护坦冲失后，长约4m的头坦排桩出露1.5m左右，海塘岌岌可危

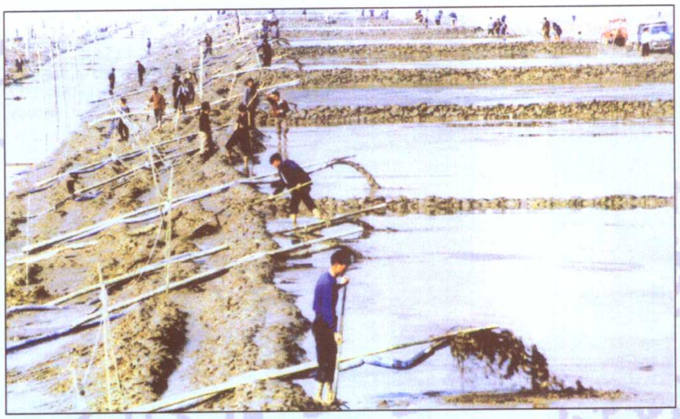


重达30t的坝面混凝土块被涌潮掀起，竖靠在七八米外的海塘边上

涌潮毁塘成灾，史不绝书，古人认为这是魔怪之力，遂有五代吴越王钱镠组织500勇士射潮之举



1949 年以后，大力整治钱塘江河口，上图为围涂治江初期的施工现场情景



20 世纪80 年代开始，大规模采用水力冲填筑堤，提高了质量，节省了劳力

用土工布充泥袋修筑围堰和土堤的临时护坡，显著改善施工条件，提高施工期的安全度

专门设计研制适用于涌潮河段的打桩机，解决了塘基防冲结构不能深筑的老大难问题

明清时代所建直立式鱼鳞石塘，抗洪防潮，历尽沧桑，功不可没

重修老鱼鳞石塘，加固基础，加高加宽塘身，完善护面，提高了抗御洪潮的能力

新建的杭州市城防海塘（内侧为国道公路，下埋杭州市引水涵管）

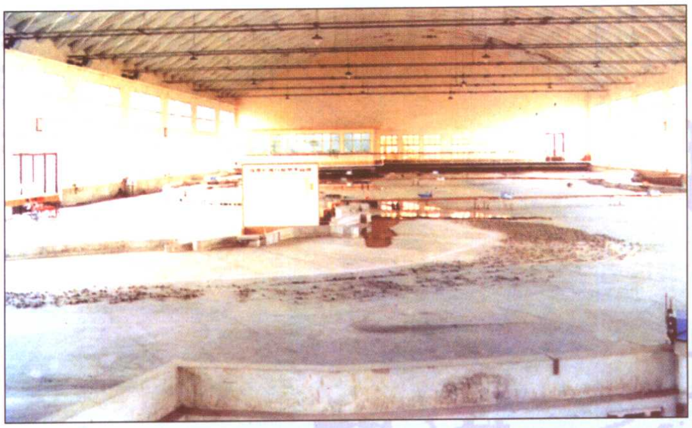
由围堤改建加固后的斜坡式海塘，已是河口段的主要堤塘

高标准的秦山核电站海堤

重要岸段海塘外的保滩护岸丁坝群

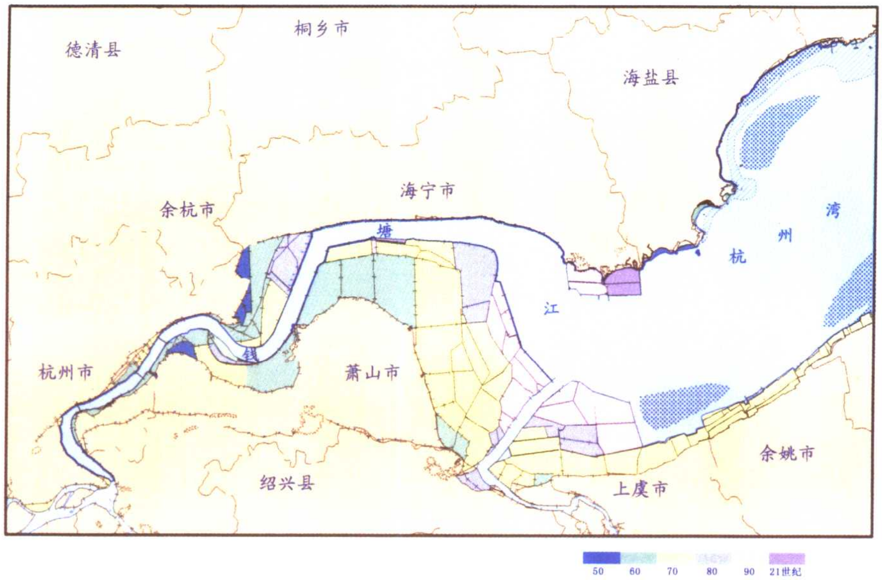
整体深埋的圬工沉井，保护丁坝坝头

河口地形、水文勘测的专用船



研究河口整治方案的动床模型

在涌潮水槽中进行丁坝坝头的冲刷试验



河口段整治缩窄分年代进程图

江道整治缩窄围涂区，生机盎然

江道缩窄主槽稳定后新建的海宁盐官排涝闸

序

钱塘江河口以其气势磅礴、变幻多姿的涌潮，闻名古今中外。河口北岸为太湖平原，南岸为宁（波）绍（兴）平原，地势低平、河网密布、土地肥沃、交通便捷，是江南鱼米之乡、丝绸之府，也是历代王朝财赋主要聚敛之地。为防御洪潮灾害，东汉（25～220年）开始修筑海塘，经历代改进，至明清时期，筑成了构筑精细、高大雄伟的钱塘江海塘，绵延二百余公里，成为我国古代三大水利工程之一，担负着保护两岸千万亩平原安全的重任，迄今仍有约70km屹立在抗洪御潮第一线。

钱塘江河口北邻水沙丰沛的长江河口，东有东海强潮吐纳，形成大喇叭口的平面外形和口内纵向隆起的庞大沙坎，导致潮能聚集，潮波急剧变形，产生破坏力极大的涌潮；江宽水浅，主槽游荡不定，两岸边滩，涨坍无常；潮流大进大出，咸潮入侵。广阔的滩地资源和淡水资源均不能充分利用；水浅潮猛，只能通行数十吨以下的小船。民国时期就几度策划，欲求缩窄江宽，稳定河槽，围涂造地，除害兴利。因对河口特性认识不足，缺乏经验，且财力有限，收效甚微。

中华人民共和国成立之后，1950年开始就组织专业队伍，进行潮汐水文观测和江道地形测量，常年不断，积累了大量现场资料；1960年开始以实测资料分析为基础，运用数值模拟技术和实物模型试验相配合，研究各种治理方案，确定首先在杭州—澉浦的河口段内，逐步实施缩窄江道、稳定主槽、围垦边滩的治江围涂方案。半个世纪的实施过程中，在各级政府的组织和大力支持下，科技人员与沿江广大群众密切配合，坚持跟踪观测，不断深入探索，及时调整方案，改进工程措施，在江道冲淤剧变、涌潮动力强劲的恶劣环境中，艰苦拼搏，组织了数十次动员几万人上阵的短期突击战役，配合常年加固维修，取得了很大进展。迄今已完成尖山以上76km河段的整治工程，江道缩窄了1/2～3/4，尖山—澉浦段的工程也完成过半，

共计围涂110余万亩。通过治理，增加了新的防洪御潮屏障；稳定了主槽，改善了排涝和航运条件；缓解了人多地少的矛盾，有力地促进了地区国民经济的发展，取得了巨大的综合效益。这项治江围涂工程，现场资料积累之丰富，分析研究手段之完备，治理成效之显著，在我国河口治理中尚无先例，在世界河口治理中也独具特色。

本书编撰人员，多是从事此项工作三五十年的专业科技骨干。他们系统整理了近50年的连续观测资料和1949年以前的历史资料，对钱塘江河口的历史演变、潮汐水文、泥沙运动、河床冲淤变化等自然规律，治理规划方案的研制修订、实施进程、治理工程措施、环境影响以及数值模拟技术和实物模型试验的运用，分章记述。该书既全面阐述了钱塘江河口河床演变的自然规律，也总结了如何运用先进的科学技术，结合群众经验，应对复杂多变的江道与潮强浪大的险恶环境，制订治理方略和具体措施的经验。尤其可贵的是，运用50年来连续的现场资料，记述和分析了重大人类活动如新安江多年调节大型水库对洪枯流量的调节，以及大规模治江围涂剧烈改变河口边界条件对河口潮汐水文和江道的影响，取得可贵的实践经验，是其他河口难以企及的。

虽然国际泥沙研究培训中心直到1984年才成立，但此前水利水电科学研究院部分人员已开始和浙江省河口海岸研究所合作，不时来浙江参加一些工作，其中包括杰出的钱宁教授。笔者有幸作为合作者的一员也参加了部分研究和考察。合作是有成效和愉快的。

林秉南

2003. 3. 25

序言作者是中国科学院院士、中国水利水电科学研究院名誉院长、国际泥沙研究培训中心顾问委员会名誉主席。

March, 2003

FOREWORD

The magnificent and thunderous bore of the Qiantang Estuary has been famous in China since the ancient time and is among the world's wonders. The estuary is flanked by Taihu Lake Plain on the north and Ningbo-Shaoxing Plain on the south. These plains are flat, fertile and criss-crossed with canals and waterways. Convenient transportation has been possible both on land and by boat. These plains are among the most productive areas of rice, fish and silk in China and used to be the principal regions from which the past dynasties derived their revenues. Being at low ground levels, however, these areas are prone to the attacks of floods and tides. Thus, beginning in Donghan dynasty (25~220AD), seawalls were constructed for their protection. These seawalls, being constantly renovated and upgraded by subsequent dynasties, evolved to be the elaborate and massive masonry structures of the Ming and Qing dynasties, covering a length of over 200 km along the estuary. This project of seawalls has been rated as one of the three outstanding feats of hydraulic engineering in ancient China. It is still shielding vast areas of the plains on both banks from the attacks of bores and tides. A stretch of these seawalls about 70 km long remains still intact today.

To the north of the Qiantang estuary is the neighboring estuary of the mighty Yangtze River that carries enormous runoffs and large sediment loads. Both estuaries flow eastward and discharge into the Donghai Sea, which has high tides. Tides of huge volume from the high sea laden with sediment coming mainly from the Yangtze estuary together with favorable topographic and geological conditions eventually help shape the mouth of the Qiantang estuary in the form of a funnel with a gigantic, long dune in its narrower part upstream. This funnel alignment of the mouth and the presence of the gigantic dune together give rise to the formation of a high tidal bore in the Qiantang Estuary. Magnificent to look at, the bore is nonetheless very destructive. In addition, the main channel of the wide and shallow estuary is constantly shifting, so that the tidal flats come and go from time to time. Consequently, it is difficult, if not impossible, to exploit both the extensive but changing tidal flats and the fresh water resources in the riparian areas. Shallow flow and strong tides would limit passage of boats only to those with scores of tons burden. During the years of the former Republic of China, several attempts have been made to set up plans to narrow down the river, as well as to stabilize the channel and reclaim the tidal flats. Because of the lack of adequate experience to deal with an estuary affected by strong bores and shortage in capital, however, little was accomplished.

After founding of the People's Republic of China, a team of experts was gathered together in 1950 to launch year round hydrological observations of tides and to carry out topographical survey of the river. A large amount of field data was thus collected. Beginning with 1960, based on the field data accumulated, numerical simulation coupled with physical modeling was applied to the studies of various plans of regulation. Eventually, the decision was made that regulation of the river should start with the reach between Hangzhou and Ganpu. This reach was to be gradually narrowed down, along with the stabilization of the main channel and reclamation of the tidal flats.

After half century of endeavor, with the benefit of strong administrative support from governments at different levels and close cooperation from the riparian people, engineers have succeeded in carrying out systematic field observations and in-depth investigations that allow timely adjustment and elaboration of the design plans and construction schemes. It was thus able to make great progress under the adverse conditions of constantly shifting channels and attacks of fierce bores. Regular year round maintenance and renovation are combined with scores of short-termed rounds of intensive, large-scaled construction activities carried out by tens of thousands of the local people. Regulation of the reach of 76 km upstream of Jianshan has thus been accomplished with the river narrowed down by one-half to three-quarters. Over half of the regulation work planned for the reach between Jianshan and Ganpu next downstream has also been completed. In total, tidal flats of more than 75000 ha have been reclaimed. Thus by carrying out the regulation as briefed above, great progress has been made. The defense against floods and tides has been strengthened. The main channel has been stabilized. Navigation as well as the drainage of internal floods has been enhanced. The strain of land shortage for the support of a relatively large population has been eased. The regional development in economy is thus greatly promoted.

This book records the technology developed and the experience gained in the course of regulation and development of this unique and extraordinary estuary. Moreover, this book also presents some unusual information about the impacts of human activities on an estuary. For instance, the Xinanjiang hydropower station upstream has a large reservoir. The operation of this station and hence the reservoir would change drastically the yearly distribution of flood-and dry-season runoffs in the estuary. Also, large-scale narrowing of the river reported above presents virtually a new waterway for the passage of tides and bores. Drastic changes in the distribution of runoffs as well as the channel widths are bound to have important impacts on the characteristics of tides and bores and also of the channels in the estuary.

In view of the foregoing, the writer considers this book as precious or even unique source book in the field of regulation of alluvial estuaries affected by bores and strong tidal currents.

Among the authors and editors of this publication are the specialists who have engaged in the work summed up above for 30 to 50 years. This group systematically analyzed the data of continuous field observations carried out in the last 50 years as well as whatever historical information available in earlier years. Individual chapters are devoted to the topics of the historical changes in the Qiantang Estuary, hydrology of tides, transport of sediment, deposition and erosion of the channel, formulation and execution of schemes for regulation, environmental impacts and the application of numerical simulation and physical modeling.

Although IRTCES was not set up until 1984, staff members of IWHR (some of them were later transferred to IRTCES) have started cooperation with Zhejiang Institute of Estuarine and Coastal Engineering Research since 1960's. Among them, was the eminent Professor Ning Qian. The writer was also among this group of people coming to Zhejiang from time to time. He was thankful for being accorded the privilege of joining some of the research and field reconnaissance work. The cooperation was both fruitful and pleasant.

Bingnan Lin

Bingnan LIN (Pin-nam LIN), Ph. D.
Member, Chinese Academy of Sciences
Honorary member, IAHR
Director Emeritus, IWHR
Chairman Emeritus, Advisory Council, IRTCES

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