INTERNATIONAL ASSOCIATION FOR HYDRAULIC RESEARCH

HYDRAULIC DESIGN CONSIDERATIONS FOR COOLING TOWER COLLECTOR BASINS

(Subject C.c.)

by Prof. Dr. H. Kobus and Dr.-Ing. B. Westrich
Institut für Wasserbau, Universität Stuttgart,
Stuttgart, Germany

SYNOPSIS

Conventional collector basins of natural draft cooling towers have a tendency towards rapid sedimentation. In order to avoid this problem, a shallow type of basin with a system of draining canals is developped. Numerical calculations supplemented by hydraulic model tests yield depths, velocities and energy losses in the system. Prototype measurements are shown to be in good agreement with numerical and experimental predictions for all modes of operation.

RESUME

Les bassins collecteurs conventionels des tours de réfrigération à courant d'air naturel ont la tendance d'une sédimentation rapide des matières en suspension. Pour éviter ce problème, un type de bassin peu profond avec un système de fossés de drainage est développé. La profondeur, la vitesse et la perte d'énergie dans le système sont obtenues par des calculations numériques supplée par des essais hydrauliques. Les mesures en prototype sont en bonne concordance avec les prédictions numériques et expérimentales pour toús des modes d'opération.

1. INTRODUCTION

The installation of power plants in densely populated and industrialized countries requires the use of cooling towers. Apart from such problems as wind loading and the influence of wind upon the performance of natural draft towers, the hydraulic design of the collector basin requires attention.

One problem common to conventional "deep" collector basins is the sedimentation and rapid accumulation of suspended matter not retained by the cleaning screens. This is most undesirable, because it requires interruptions in the operation of the tower for cleaning purposes. The aim of the present study is, therefore, to develop a collector basin in which sedimentation is reduced to a minimum. This can be achieved with "shallow" collector basins.

2. DESIGN CRITERIA FOR SHALLOW BASINS

2.1 Cooling system operation requirements

The collector basin is designed primarily for recirculation or blow down operation; however, it also has to perform satisfactorily at all other possible modes of operation. For instance, provisions for winter operation and deicing have to be made, such as increasing the hot water discharge along the periphery of the tower, or by flushing the collector basin by means of a bypass.Furthermore, sufficient surge volume has to be provided in the basin such as to prevent overtopping in case of sudden pump failure or other disturbances.

2.2 Sedimentation

In order to avoid the accumulation of suspended matter in the collector basin, a certain minimum flow velocity must be achieved everywhere in the basin, and recirculating zones must be avoided. The required critical velocity depends upon the specific characteristics of the suspended matter (fall velocity, cohesive properties) and upon their concentration.

If sedimentation is to be avoided, then it seems reasonable to make use of the energy of the rainfall produced by the distribution system [1]. This can be achieved by locating the basin plateau high enough such that the water depths remain within certain limits - usually between 1o and 3o cm - such as to avoid excessive noise or concrete erosion problems. Raising the basin plateau has several advantages in construction and operation of the tower: the supporting beams of the distribution system become shorter, the stability of the basin against uplift is increased, and construction volume is decreased.

---

[1] Kisisel, I.T., Rao, R.A., Delleur, J.W.,: "Turbulence in Shallow Water Flow under Rainfall", Proc. ASCE, EM 1, 31-53, 1973.

In order to maintain the desired water depths on the basin plateau under all operating conditions, a set of draining canals has to be provided in which the water levels must be low enough so that always free overflow conditions are maintained at the edge of the plateau.

The required maximum plateau area, and hence the spacing of the draining canals, depends upon the intensity of rainfall q^* $[m^3/s \cdot m^2]$. Figure 1 shows two types of canal systems. For small values of q^*, the water depths on the plateau and hence the canal spacing should be small (A), whereas a ring canal arrangement (B) is more suitable for higher rainfall intensities.

The following pages describe a collector basin of the type (A) which was designed for a rainfall intensity of o.oo345 $[m^3/s \cdot m^2]$ This system has been built for the Kernkraftwerk Philippsburg I and was tested under operating conditions. At the same site, the second block will have a cooling tower with increased rainfall intensity (o,oo517 $m^3/s \cdot m^2$) for which arrangement (B) will be constructed [2].

2.3 Energy losses

The resulting energy losses within the canal system must be kept to a minimum in order to keep construction heights and pumping requirements as low as possible. The various energy losses in the system due to rainfall, supporting columns, wall friction or canal junctions can only be roughly approximated without actual model tests.

2.4 Concrete erosion

To avoid damage to the basin plateau due to impinging rainfall, a certain minimum water depth (under average conditions roughly 1o cm) on the basin plateau is required. Concerning the erosion of the concrete walls of the draining canals, particular attention must be paid to the outlet conditions. Usually, under recirculating conditions the water level in the cup is controlled by the recirculating system downstream, whereas for blowdown operation there is no backwater effect and hence the basin exit section may exert a flow control. In this case, the flow velocities in the canal system may become excessively high (several m/s) and might therefore be dangerous for unprotected concrete surfaces. This can be avoided by providing the exit section with a submerged sill, which acts as a controlling weir for low downstream water levels but exerts no significant energy loss during recirculation (Figure 4).

---

[2] Kobus, H., Naudascher, E., Richter, A., Westrich, B.: "Strömungsmechanische Probleme bei der Kühlwasserführung in Kernkraftwerken", Wasserwirtschaft, Heft 5, Mai 1979.

3. HYDRAULIC CALCULATIONS AND MODEL TESTS FOR A SPECIFIC PROJECT

According to the criteria given above, a shallow collector basin has been designed for a specific site (Kernkraftwerk Philippsburg I) with the aid of numerical calculations and model tests. The tower is designed for a discharge of 41 m^3/s. The height of the tower is 14o m, the collector basin is 12o m in diameter. The discharge on the basin plateau areas is calculated on the basis of the momentum and energy equations for free surface flow with vertical inflow (rainfall). These lead to a differential equation for the slope of the free surface (dy/dx), as given e.g. by Ven te Chow [3] :

$$\frac{dy}{dx} = \frac{-(J_e - J_o) - 2\,Q\,q^*/g\,A^2}{1 - Q^2/g\,A^2\,r_{hy}} \qquad (1)$$

in which J_e and J_o are the frictional slope and bed slope, Q and q^* are total discharge and rainfall intensity, g is gravitational acceleration, and A and r_{hy} are the cross-sectional area and the hydraulic radius, respectively. For the horizontal basin plateau, the bed slope is zero and the frictional slope can well be neglected. Accordingly, the simplified equation (1) yields the closed solution

$$\left(\frac{x}{L}\right)^2 = \frac{3}{2}\frac{y}{y_o} - \frac{1}{2}\left(\frac{y}{y_o}\right)^3 \qquad (2)$$

for the water depths on the plateau, where y_o is the water depth at the edge and L the distance between the water divide and the draining canal (Figure 2).

The flow in the individual draining canals can be calculated on the basis of eq. (1), with the inflow from the plateau and from direct rainfall being known. The cross section and the slope of the canals is chosen such that the mean velocity in the canal is gradually increasing in the downstream direction. Since frictional effects are of secondary importance in these short canals, the numerical calculation yields acceptable predictions.

The flow in the main canal is more complex due to the presence of numerous supporting columns and due to the canal junctures. These lead to unkown energy losses. Therefore, a hydraulic model of the main canal was built at scale 1:15 (Figure 3). Apart from the discharges of the various side canals, the direct rainfall and the sideways discharge from the basin plateau were also simulated in the model.

---

[3] Ven te Chow: "Open Channel Hydraulics", Mc Graw-Hill Book Company Inc., New York, 1959.

The main canal was designed such that the width increases proportional to the total discharge, so that the mixing energy losses are minimized. Figure 4 shows measured velocity distributions and water levels in the main canal for the final design, which represents the configuration with the minimum energy losses. A comparison of the water levels in the main canal both with and without the streamlined bottom sill at the outlet of the basin shows that for blowdown operation the sill raises the water levels in the main canal and thus reduces the flow velocities substantially. On the other hand, for recirculation conditions the water levels are hardly affected by the presence of the sill.

During the prototype test runs, water levels in the collector basin were measured (Figure 4). It is evident by comparison that the agreement between prototype data, model experiments and numerical calculations is quite satisfactory, which confirms the usefulness of the chosen approach.

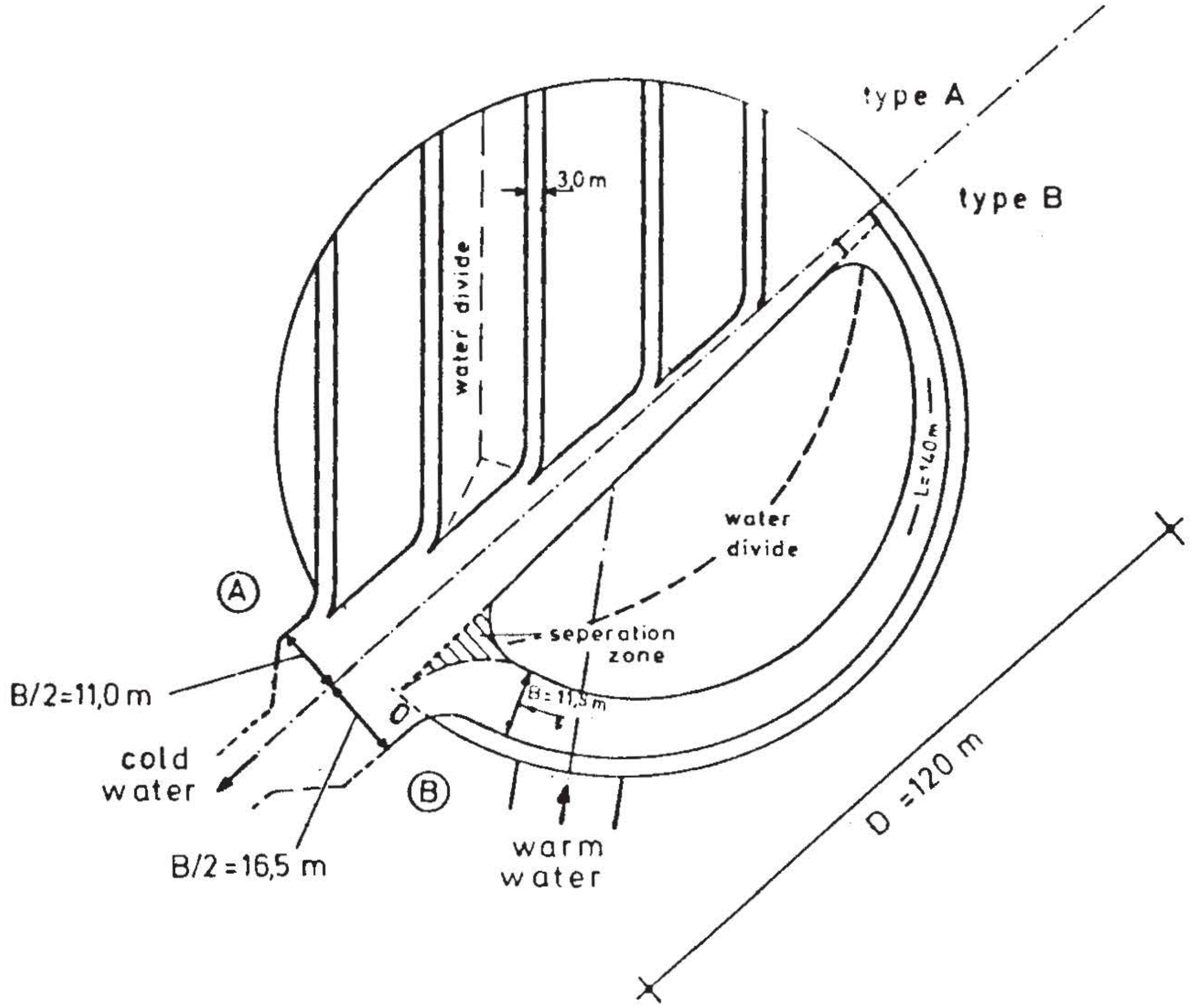

Fig. 1: Collector basin: type A and type B
Bassin de refroidissement: type A et type B

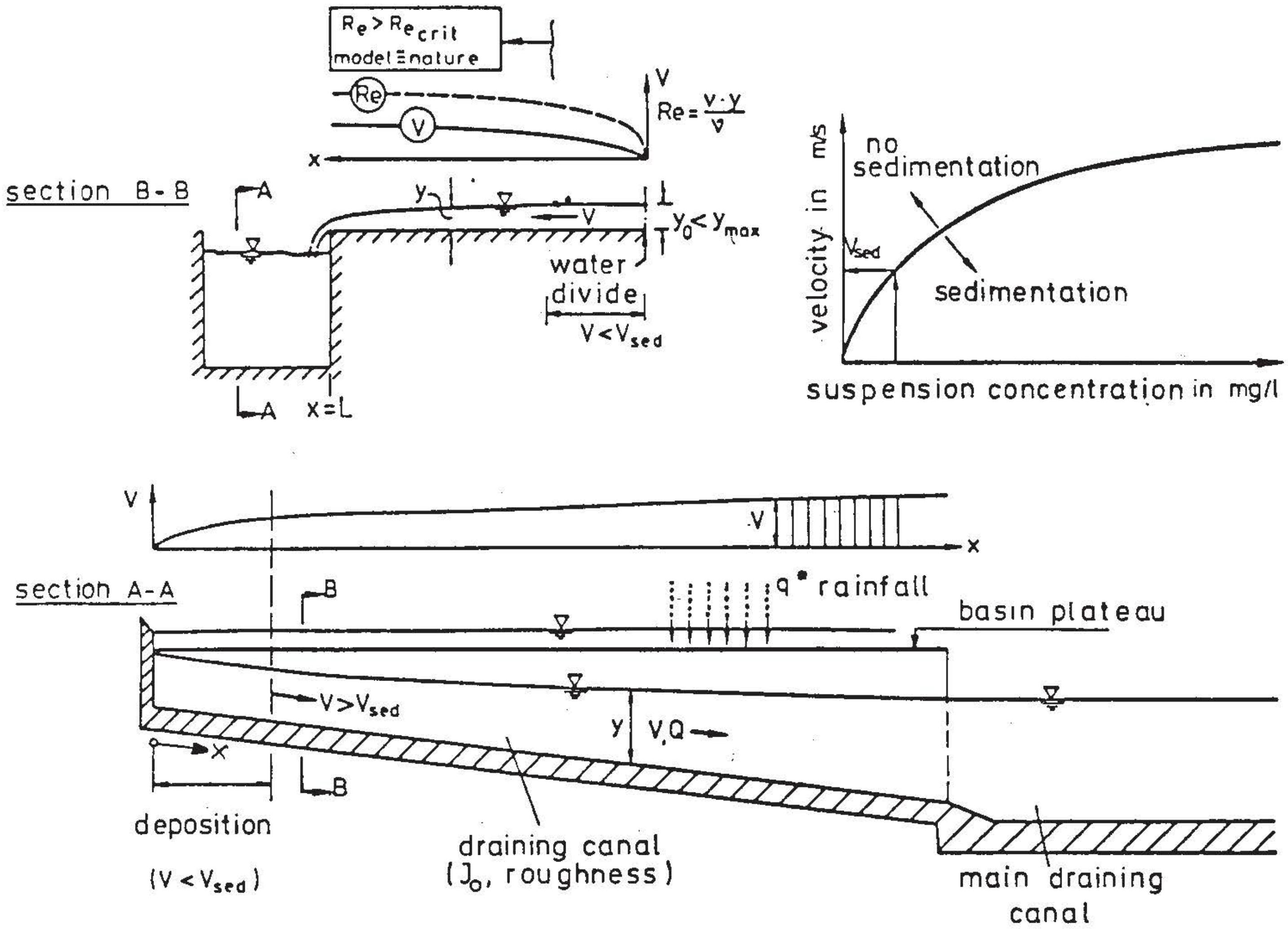

Fig. 2: Flow and Sedimentation Conditions in the Draining Canal
Ecoulement et sedimentation dans un canal

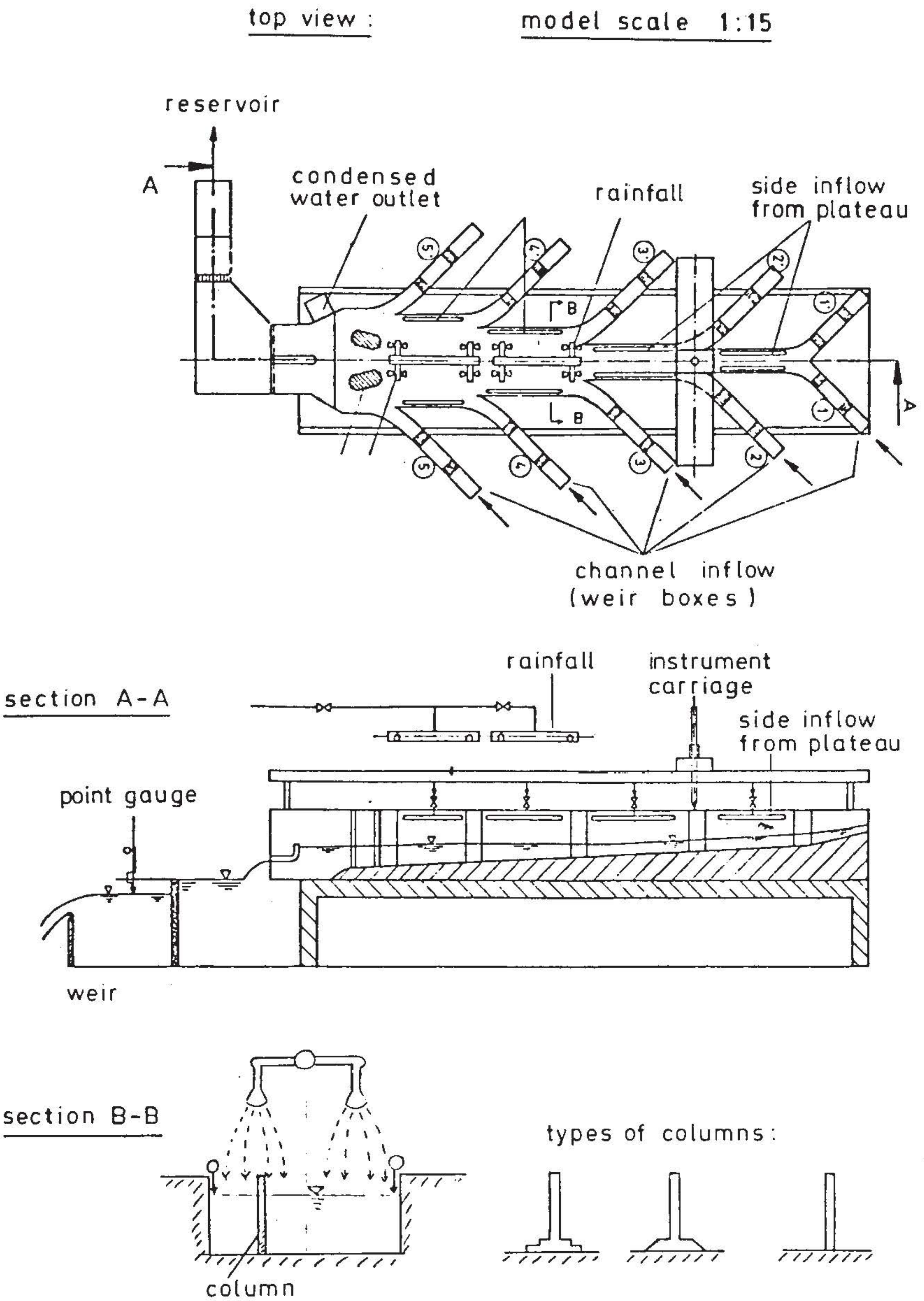

Fig. 3: Hydraulic model (scale 1:15)
Modèle hydraulique

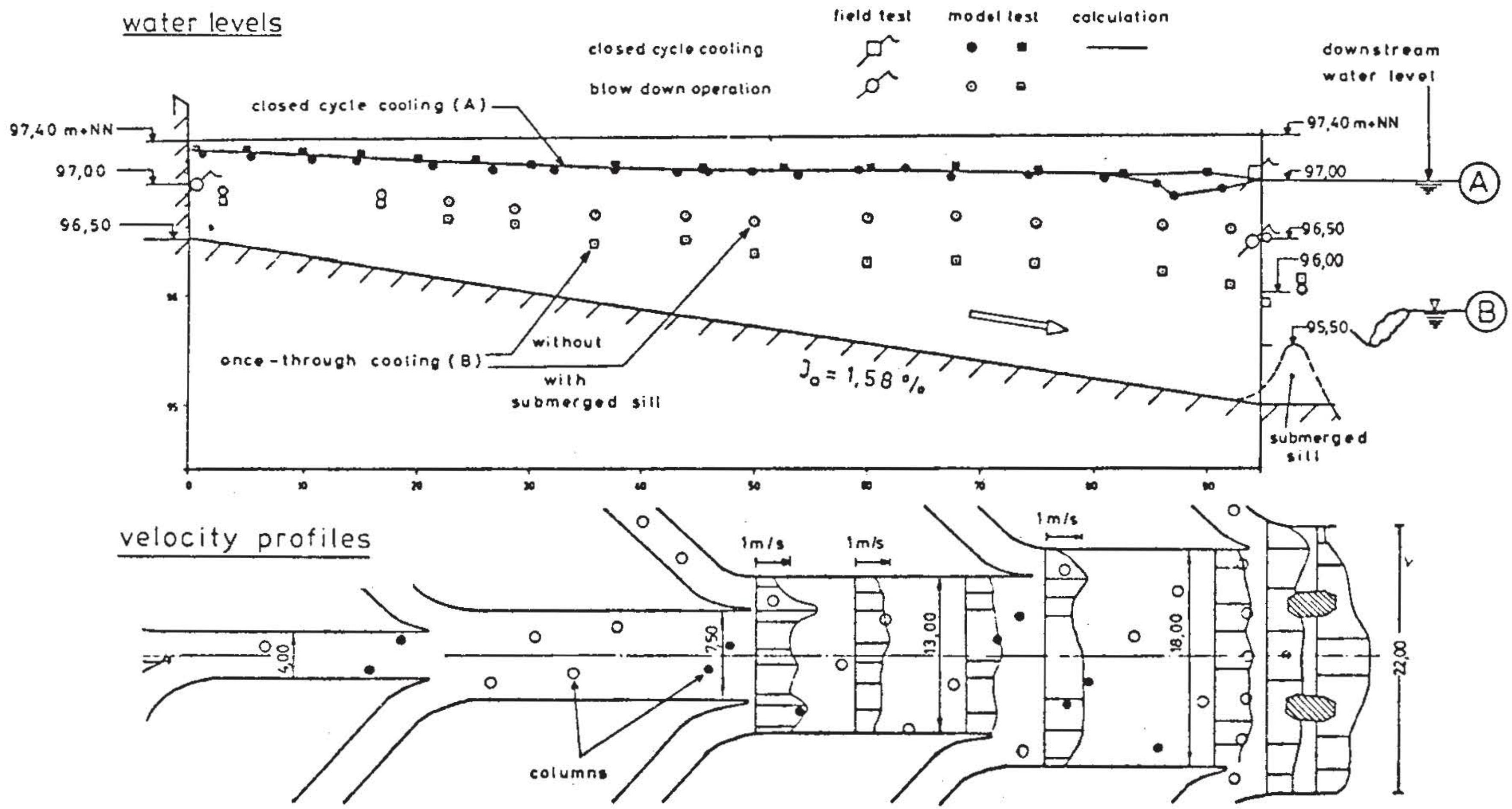

Fig. 4: Results of field measurements, model tests and numerical calculations
Resultats des mesures en nature et modèle et de calcul numérique