Spacing of Road Gullies

Hydraulic performance of BS EN 124 gully gratings and kerb inlets

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Report SR 533
September 2000

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Summary

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This is the final report of a study funded by the Highways Agency (HA) to produce guidelines in the form of an Advice Note on the spacing of road gullies for draining surface water from roads. Until now the HA approved document for determining gully spacing has been TRL Contractor Report 2, but this does not cover the range of designs that is now permitted by European product standard BS EN 124:1994.

This report describes the results of a comprehensive test programme that was carried out at HR Wallingford on gully gratings and kerb inlets.

The test programme investigated the effects on the flow collection efficiency of gully gratings of the following geometric factors: plan area; aspect ratio (length parallel to the kerb to width across the flow); percentage waterway area; and number and orientation of the bars. Tests were made on a total of 24 different configurations of grating installed in a test rig with a cross-sectional profile representing a triangular kerb-side channel. The following flow conditions were studied for each grating configuration: flow widths between 0.5m and 1.5m; longitudinal channel slopes between 1/200 and 1/15; and channel cross-falls between 1/50 and 1/30; some additional tests at cross-falls up to 1/15 were carried out to extend the range of the data. Analysis of the results led to the development of a new general design method for predicting the hydraulic performance of gully gratings taking into account the hydraulic properties of the channel and the geometric properties of the grating. The method was validated by comparing its predictions with flow data for a range of manufactured gratings.

Tests were also carried out using two different configurations of kerb inlet: straight and angled. The following flow conditions were studied for the two configurations: flow widths between 0.25m and 1.0m; longitudinal channel slopes between 1/500 and 1/50 and channel cross-falls between 1/50 and 1/30. The data analysis revealed that a single design equation could be developed from the test results for the estimation of the efficiency of kerb inlets, both for straight and angled kerbs. The design equation recommended is based on the opening length of the kerb parallel to the carriageway.

Summary continued

For gully gratings it was decided that the Advice Note (HA 102, DMRB 4.2) would define five grating Types (P to T) covering the practical range of sizes and shapes allowed by BS EN 124:1994. The design method obtained from the experiments was therefore used to produce tables for Advice Note HA 102 giving the maximum areas that can be drained by each grating Type for a range of flow widths, cross-falls and longitudinal gradients. Also, the design equations were modified for use in the Advice Note so as to make them applicable to any configuration of bar pattern. For kerb inlets there was no need to specify different types but tables were also produced for two different opening lengths giving the maximum areas that can be drained for a range of flow widths, cross-falls and longitudinal gradients.

Notation

A	:	cross-sectional area of flow just upstream of gully (m^2)
A_{dr}	:	maximum catchment area that can be drained by a gully (m^2)
A'_{dr}	:	value of A_{dr} for alternative values of I, M , n or L_i (m^2)
A_g	:	area of the smallest rectangle with two sides parallel to kerb that can contain all the slots of a grating (m^2)
B	:	width of flow just upstream of gully (m)
C	:	coefficient for the bar pattern of a grating
C_b	:	design value of C = 1.75 for gratings with transverse bars and = 1.5 for gratings with diagonal, longitudinal or curved bars
E	:	characteristic length of the grating (m)
F_r	:	Froude number of flow ($F_r = \sqrt{\left(BQ^2/gA^3\right)}$)
G	:	dimensional coefficient of best-fit line for capacity of grating (s/m^2)
G_d	:	grating Type parameter (s/m^2); design value of G
g	:	acceleration due to gravity (m/s^2)
H	:	water depth at the kerb (m)
H_1	:	value of water depth measured 0.15 m upstream of the grating at 1/3 of the flow width from the kerb (mm)
H_2	:	value of water depth measured 0.65m upstream of the grating at 1/3 of the flow width from the kerb (mm)
I	:	rainfall intensity (mm/h)
K_A	:	grating parameter (s/m^2), taking account of overall area of grating, A_g, and percentage waterway area, p
K_3	:	empirical grating coefficient (found by Li to be 0.6)
k_{Im}	:	Factor for scaling value of A_{dr} to allow for variation in rainfall intensity, I, and/or maintenance factor, m
k_L	: :	Factor for scaling value of A_{dr} to allow for variation in length of kerb opening L_i
k_n	:	Factor for scaling value of A_{dr} to allow for variation in Manning roughness coefficient, n

Notation continued

L	:	length of grating parallel to the kerb; length of kerb inlet unit (m)
L_i	:	overall length of kerb opening measured along the line of the kerb (L_i = L for non-angled kerb inlets)
L_3	:	length of the grating required to prevent carry-past flow (m)
m	:	maintenance factor
N	:	return period of the design storm (years)
n	:	Manning roughness coefficient of kerb channel
n_d	:	number of diagonal bars
n_l	:	number of longitudinal bars
n_t	:	number of transversal bars
P	:	wetted perimeter of channel (m)
p	:	percentage of the grating area A_g open to the flow
Q	:	total flow rate approaching gully (m^3/s)
Q_m	:	flow rate collected by gully allowing for possible partial blockage by debris (m^3/s)
q_1	:	carry-by flow passing between the kerb line and the first slot of the grating (m^3/s)
q_2	:	carry-over flow passing over the grating by jumping over the bars (m^3/s)
q_3	:	carry-past flow passing round the outside edge of the grating (m^3/s)
q_b	:	flow by-passing kerb inlet
q_c	:	flow collected by kerb inlet
R	:	hydraulic radius (= A/P, in m)
r^2	:	correlation coefficient
S_C	:	cross-fall of kerb channel
S_i	:	longitudinal slope of kerb channel at distance x_i measured from upstream gully
S_L	:	longitudinal slope of kerb channel just upstream of gully

Notation continued

S_p	:	maximum allowable spacing between gullies (m)
T	:	storm duration (minutes)
t_s	:	time of travel of water across width of road (minutes)
t_g	:	time of travel of water along kerb channel (minutes)
W_e	:	effective width of catchment (m)
W_p	:	distance from kerb to outer edge of grating (m)
Z	:	distance between two adjacent gullies (m)
Z_i	:	distance from upstream gully measured in direction of flow (m)
α	:	coefficient of best-fit line for capacity of grating (non-dimensional)
χ	:	parameter in Equation (33)
η	:	collection efficiency of a gully with no blockage by debris (= flow rate collected by grating divided by flow rate approaching gully, expressed as a percentage)
θ	:	angle of orientation of bar in grating, measured between the line of the bar and the line of the kerb viewed in the upstream direction
2 min M5	:	depth of rainfall (mm) occurring at the specified location in a duration of 2 minutes with a return period of 5 years.

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1. INTRODUCTION

1.1 Background

In November 1996 the Highways Agency (HA) commissioned HR Wallingford (HR), in association with the Transport Research Laboratory (TRL), to carry out a study on the hydraulic performance of gully gratings used to collect surface water run-off from roads. The primary output from the study was an HA Advice Note giving design recommendations on the spacings at which gratings should be installed in kerb-and-gully drainage systems, taking into account the local rainfall characteristics and the geometry of the gratings and the road. The Advice Note superseded TRL Contractor Report 2 on gully spacing (Ref 1), and a key requirement for the new document was that the design information should be applicable to any pattern of gully grating that conforms to European Standard BS EN 124 (Ref 2). For this reason it was necessary to carry out a major programme of experimental research on different designs of grating using a test rig that was built at HR specially for the study.

The study consisted of the following five stages:

(1) Review of literature on the hydraulic performance of gully gratings and preparation of draft outline of Advice Note.
(2) Experimental tests on gully gratings at HR.
(3) Aualysis of data from tests.
(4) Preparation of Advice Note and final Project Report.
(5) Technical support during consultation phase of Advice Note.

The results of Stage 1 of the study were described in HR Report SR 505 (Ref 3). Stages 2 and 3 of the work were dealt with in HR Report SR 526 (Ref 4) which covered the following aspects:

- Description of HR test rig for gully gratings
- Details of tests carried out
- Analysis of data and development of general design method
- Examples of how the design method can be presented in the Advice Note.

The present Project Report is mainly based on HR Report SR 526 (Ref 4) with some amendments and a simplification of the design method which arose from consultation with HA and TRL. It describes the work carried out during the whole study, including work leading to the preparation of Advice Note 102 "Spacing of Road Gullies" (Ref 5).

In 1999 the Highways Agency commissioned a study extension to produce a design method for kerb inlets. Kerb inlets are outside the scope of BS EN124 and their hydraulic behaviour is different from that of gully gratings. The results of tests on kerb inlets were used to extend the scope of the draft Advice Note so that it covers kerb inlets as well as gully gratings. This will enable the Advice Note to completely replace the design document TRL Contractor Report 2.

1.2 Objectives

The principal objective of the experimental tests was to develop a consolidated desigu method for determining the spacing of road gullies and kerb inlets. The method needed to take into account the overall geometry of the road and the dimensions of the grating or kerb inlet. For gratings the waterway area, expressed as a percentage of the area of the hole when the grating is removed and the bar pattern of the grating were also important parameters. The new design method needs to cover all types of gully grating that are suitable for use in UK roads, both new and old. The desigu assumptions in the method also need to be compatible with those in other HA documents such as HA37 (dealing with road-edge surface water channels, see Ref 6).

1.3 Available data on gully and kerb inlet performance

The initial report of this study (HR Report SR 505, Ref 3) contains a review of literature on the hydraulic performance of gully gratings. Literature searches were carried out by TRL and HR Wallingford using their own databases, and the library of the Institution of Civil Engineers was also consulted. Sixteen relevant papers or manuals were reviewed and the results can be summarised as follows.

1) Most of the published data on the hydraulic capacity of gully gratings are specific to the particular designs that were tested and have not been generalised. However, some of the information should be of use in this project for checking and extending the range of new measurements that will be obtained in the next phase of work.

2) Many of the gratings used in non-European countries are significantly larger than those available in the UK, and they also differ in having longitudinal bars and being combined with kerb inlets.

3) Only one generalised design method for predicting the flow capacity of gully gratings has been identified in this review. This method was developed by Li (1956) at John Hopkins University in the USA. The method requires knowledge of three non-dimensional coefficients, and only very limited testing has been carried out to determine their values for the types of grating used in the UK.

4) It appears to be fairly generally accepted that hydraulic testing of gratings can be carried out satisfactorily using models of reduced size. This implies that correct application of Froudian scaling should enable results from this phase of the study to be generalised to gratings of different sizes.

5) Information from this review suggests that gratings with longitudinal slots or bars can be made safe for cyclists provided that the length of each slot is not greater than about 100 mm measured parallel to the kerb. The width of the slot does not appear to be a safety issue provided the above limit on its length is not exceeded.

HR Report SR 505 also gives background information about the general requirements for gully gratings as specified by BS EN 124 (Ref 2). Subsequent to completion of the review, contacts were made with Prof. Manuel Gomez of UPC University - Barcelona who had investigated the hydraulic efficiency of nine types of local grating for extreme flow conditions. Some of the data collected in Barcelona (Gómez & González, Ref 7) were analysed in this study to extend the experimental range and check the validity of the new design method.

Kerb inlets can be used as alternatives to gratings installed on the road surface or in combination with them. They are viable options to gully gratings particularly where gratings are considered to be hazardous for pedestrians and/or cyclists, and can be effective in the drainage of highways provided the flow depth at the kerb is sufficiently high. Depressed kerb inlets (where the pavement slope is locally increased near the kerb) are used in some countries, namely in the USA with the aim of increasing the interception capacity (Ref 8). Kerb inlets tend to be less susceptible to clogging and offer little interference to traffic operation.

Design data can be found in TRL Contractor Report 2 (Ref 1) on a particular type of kerb inlet configuration (E14-19) and on a modified alignment where the kerb is angled towards the verge. However, tables with spacings of inlets given in this publication are limited to the type of kerb inlet tested and need therefore to be extended to other sizes.

2. EXPERIMENTS WITH GULLY GRATINGS

2.1 Description of the test rig

2.1.1 Special features of the design

The test rig was designed to allow tests on gully gratings and kerb inlets to be carried out at full size (see Figure 1). The tilting channel is 4.9 m long and 1.5 m wide and can be inclined to a maximum longitudinal gradient of 1:15 and a maximum cross-slope of 1:13. A cut out in the floor of the channel is located near the downstream end so that gratings measuring up to 610mm by 610mm can be installed. Plate 1 shows an overall view of the test rig.

As mentioned previously, results from the test rig can be used for other grating sizes by applying Froudian scaling (the application of this scaling law is discussed later in Section 3.1). This allows the range of grating sizes to be extended to the limits of EN124.

The test rig includes some special features which make it more efficient and easier to operate than other comparable rigs. The tilting channel is supported by a simple system of four jacks and a universal ball-joint. The jacks are interlinked and operated by means of two handles, one for the cross-fall and one for the longitudinal slope, so that any required combination can be set quite easily and quickly. This option was preferred to the more conventional type of system in which a series of geared jacks is mounted along each side of a tilting channel. Plate 2 shows one of the jacks on the HR test rig.

A 1.6m wide siphon conveys the water from a fixed tank at the upstream end of the test rig and distributes it uniformly over the full width of the tilting channel, thereby minimising turbulence in the incoming flow. The siphon also eliminates the need for a complicated flexible connection between the channel and the fixed upstream tank into which the pumps discharge flow. Once all the air has been removed from the siphon, it remains full of water and operates immediately after the pumps are started without any need for further priming.

The length of channel needed to reach uniform flow was considerably reduced by installing three adjustable control gates at the upstream end of the tilting channel. The gates are unusual in that they face into the flow and are lifted about hinges at their downstream ends which are attached to the floor of the channel. This arrangement enables the upstream water level to be raised so that the water can accelerate smoothly into the channel and quickly reach the velocity corresponding to uniform flow. This helps eliminate the problem of cross-waves which tend to form at the upstream ends of steep triangular channels and which can make it difficult to obtain uniform flow conditions. Plate 3 shows the siphon and the three adjustable control gates.

2.1.2 General arrangement of the test rig

Figure 1 shows a plan view of the test rig. Two pumps with flow capacities of 227 l/s and 14 l/s draw water from the main sump and discharge it into a fixed open-topped tank (Tank A). The use of two separate pumps enables flow rates to be controlled accurately over a wide range. The discharge from the 227 l/s pump is measured by an electromagnetic flow meter (EM meter) with an accuracy of the order of 1% or better; the flow rate from the 14 l/s pump is measured by a 62 mm orifice plate whose calibration was determined volumetrically by measuring the rate of filling of Tank A. The same method was also used to check the calibration of the EM meter.

Water from the fixed Tank A flows through the siphon under gravity and into a small tank attached to the upstream end of the tilting channel (Tank B). The main purpose of Tank B is to keep the downstream end of the siphon submerged but it also helps dissipate the excess energy of the flow leaving the siphon. The water then flows down the slope formed by the adjustable control gates into the tilting channel. The water that is collected by the gully grating drops into Channel A and returns to the sump. The flow that by-passes the grating discharges from the downstream end of the rig into Channel B which contains a V-notch weir (see Plate 4). The V-notch weir was calibrated using the EM meter.

2.2 Experimental conditions

2.2.1 Configurations of gratings

Previous studies (reviewed in Ref 3) have shown that the hydraulic performance of a gully grating depends on the geometry of the grating, the geometry of the flow in the channel upstream of the grating, and the Froude number F_r of the approach flow (see Notation for definitions). Therefore, results for different sizes of geometrically-similar grating can be determined from tests carried out according to the Froudian scaling law. In the present study most of the model gratings used were similar in size to typical types of manufactured grating; however, the ability to scale the results to apply to different sizes of grating was an important factor in the development of the general design method described later in this report. Initial tests were carried out on geometrically-similar gratings of different size in order to confirm that Froudian scaling could satisfactorily be applied to the results. However, the major part of the study concentrated on assessing the effects on flow capacity of the following geometric properties of gratings:

- waterway area of grating expressed as a percentage of its overall plan area
- aspect ratio of grating (length/width)
- width of grating relative to width of approach flow
- number of bars
- orientation of the bars (eg, longitudinal, transversal, angled).

Tests with different depths of bar were not carried out because this was not considered to be a significant factor affecting performance. Once the water drops about 10-15mm below the top of a grating, there will be no interaction with the flow at road level. The model gratings used in the HR tests had bars that were 20mm deep; in order to achieve sufficient structural strength, most steel and cast-iron gratings used in roads have similar depths of bar. The gratings tested at HR were either square or rectangular in plan. Circular gratings were not studied because, as far as is known, they are not used for kerb-and-gully systems; their geometry would make them inefficient at collecting flow close to a kerb. Gratings with curvilinear bars (i.e. bars curved in plan) were not tested. We do not have any knowledge of any being manufactured at present. The efficiency of curvilinear bars is considered likely to be similar to that of equivalent angled bars.

The test programme was mainly carried out using model gratings constructed in wood. However, some confirmatory tests on manufactured gratings were also made, and results from earlier studies with other types of proprietary grating were also included in the analysis. The advantages obtained from the use of model gratings were:

- results that were not specific to particular proprietary designs
- ability to study a wide range of geometries covering the full range permitted by BS EN 124 (Ref 2)
- ability to carry out systematic tests in which only one parameter at a time was varied (e.g. bar angle or percentage waterway area)
- ease of construction, installation and modification.

A total of 24 configurations of grating were studied in the HR tests and their geometric properties are summarised in Table 1. The layouts of the model gratings are shown in Figure 2; dotted lines in the drawings indicate an intermediate bar that was added to some of the gratings in order to reduce the slot length to the maximum permitted by BS EN 124 (Ref 2). The hydraulic effects of the geometric factors listed above were investigated as follows:

- **Absolute size**
  Two geometrically similar gratings with linear dimensions differing by a ratio of 1: 1.28 were used to check that Froudian scaling could be applied to the results.

- **Percentage waterway area**
  Gratings with the same overall shape and bar pattern were constructed with percentage waterway areas of 60%, 44% and 26%. The area ratio of 44% is typical of many current UK manufactured gratings; 60% is considered to be close to the maximum that can be achieved taking account of the structural requirements for road gullies; the 26% figure extends the range of the data a little below the minimum value of 30% permitted by BS EN 124.

- **Aspect ratio**
  Tests were carried out with rectangular gratings having aspect ratios (width normal to the kerb / length parallel to the kerb) of 0.5, 1.0 and 2.0.

- **Relative flow width**
  All the gratings were tested with flow widths between 0.5m and 1.5m and a wide range of cross-falls and longitudinal slopes (see Section 2.2.2).

- **Number of bars**
  The number of bars was varied from a maximum of 9 to a minimum of 0 (i.e. an open hole having the same overall size as the grating). For several configurations, an intermediate bar was added in order to comply with the limits on maximum slot length specified by BS EN 124 (Ref 2).

- **Angle of bars**
  The influence of bar angle was investigated using four configurations having bars at $\theta = 0°$, 45°, 90° and 135°, where θ is the angle measured between the line of the bar and the line of the kerb viewed in the upstream direction.

- **Comparison with manufactured gratings**
  Three gratings kindly loaned by Glynwed Brickhouse were also tested in order to check that the results obtained from the model gratings were also applicable to manufactured gratings.

2.2.2 Flow conditions

The specification for the project required that the design information to be provided in the Advice Note should cover the same range of flow conditions as TRL Contractor Report 2 (Ref 1). It was decided to measure the hydraulic performance of each grating under the following conditions:

- three flow widths : 0.5m, 1.0m and 1.5 m.
- five longitudinal slopes : 1/200, 1/100, 1/50, 1/25 and 1/15.
- three cross-falls : 1/50, 1/40 and 1/30.

It was therefore necessary to carry out a total of 45 flow tests for each of the 24 grating configurations described in Section 2.2.1. The tests covered a relatively wide range of experimental conditions: water depths at the kerb varying from 10mm to 50mm, and mean flow velocities varying between 0.23 m/s and 2.7 m/s. Some of the gratings were tested with a wider range of flow conditions including cross-falls up to 1/15, in order to extend the range of data.

2.2.3 Experimental procedure

The first step in the experimental procedure involved setting the longitudinal slope and the cross-fall of the channel to the required values using the system of jacks. The control gates were then adjusted so that the flow was as straight and uniform as possible. The discharge was also adjusted until the required width of flow was reached. Once all the conditions had been set satisfactorily, the input discharge was read from the EM meter or the orifice plate depending on which pump was being used.

Early experiments showed that, at sections upstream of a grating, the water surface normal to the kerb was not horizontal, contrary to normal assumptions. Other researchers (see Ref 3) have also observed this phenomenon which does not appear to be related to the entrance conditions but to be characteristic of shallow flows in triangular channels. After carrying out detailed measurements of the flow profiles, it was decided that the best estimate of the average water depth at a cross-section could be obtained by measuring the level of the water surface at a distance of 1/3 the flow width from the kerb. This transverse measuring position was therefore adopted in the main tests. Values of water depth approaching the grating were measured at two longitudinal positions upstream of the grating: depth H_1 at a distance of 0.15m from the leading edge of the grating and depth H_2 at a distance of 0.65m.

The amount of flow by-passing a grating was normally determined by measuring the water depth upstream of the V-notch weir in Channel B (see Figure 1). However, if the amount of by-passing was very small, the flow rate was measured volumetrically with a graduated bucket.

2.3 Experimental data

Appendix A, which also contains experimental data on kerb inlets, shows the table of the data collected for each of the 24 configurations. Gratings A to C were different designs of manufactured grating (made by Brickhouse Dudley) and gratings D to X were model gratings made at HR for the study. In the Tables, the heading box gives information about the configuration of the grating: the waterway area expressed as a percentage of the open hole; the open hole area; the width and length of the open hole; and the number of longitudinal, transversal or diagonal bars. In the main Tables each row gives the characteristics and results of a particular flow test. The first column contains the test number, and the next two columns give the water depths measured upstream of the grating (H_1 and H_2). The fourth column shows the flow width, while the fifth and sixth columns give the inverse of the longitudinal slope and the cross-fall of the channel. The seventh column lists the flow rate approaching the grating, and the eighth column gives the flow collection efficiency, η, for the grating in that particular test (η = flow rate collected by grating / flow rate approaching grating, expressed as a percentage).

3. ANALYSIS OF THE DATA ON GULLY GRATINGS

3.1 Applicability of Froudian scaling

Tests were carried out to determine whether Froudian scaling would allow the results for particular patterns of grating to be generalised so as to apply to larger or smaller gratings that are geometrically similar (and installed in channels having the same cross-sectional shape). The theory of hydraulic models suggests that a non-dimensional quantity such as the flow collection efficiency, η, should depend only on the geometry of the grating and the Froude number of the approaching flow (or on an equivalent non-dimensional quantity describing the inertial and gravitational characteristics of the flow). Other factors such as the viscosity and the surface tension of the water are likely to have only a minor effect on the performance of different sizes of gully grating. Two configurations of grating were tested corresponding to Model 1 (see Figure 2) with diagonal bars at 45° and 135° with respect to the direction of the flow. The ratio between the linear dimensions of the geometrically similar gratings was 1:1.28.

Figure 3 shows a plot of collection efficiency, η, against discharge for the pair of geometrically similar gratings having their bars at an angle of θ = 45° (configurations F and G in Table 1). The data correspond to an upstream flow width of 1.5 m at the scale of the larger grating (F). The flow rates for the smaller grating (G) were multiplied by the factor $1.28^{2.5} = 1.854$ in accordance with the Froudian scaling relationship for discharge. The graph shows that there is a very good agreement between the discharge/efficiency curves for the three cross-falls tested. Similar results were obtained for other flow widths and also with grating configurations D and E (θ = 135°).

These results provide good proof that Froudian scaling is valid for flow tests on gully gratings and that results can be generalised to apply to different sizes of geometrically similar grating.

3.2 Theoretical approach

3.2.1 Conceptual division of the flow approaching a grating

Figure 4 shows a plan view of the general case of flow approaching a grating. The flow can by-pass a gully grating in the following ways:

(1) between the kerb line and the first slot of the grating: the carry-by flow, q_1
(2) over the grating, by water jumping over the bars: the carry-over flow, q_2
(3) around the grating, by water passing round the outside edge of the grating: the carry-past flow, q_3 .

The division of the by-passing flow into the three different components was first proposed by Li (Ref 9), who used it to develop a semi-theoretical model for predicting the hydraulic performance of gully gratings. The basic assumption of the method is that the cross-fall of a triangular channel provides a lateral component of gravitational acceleration causing water to turn sideways into kerb inlets or towards gratings. Three equations were developed for predicting the components of the by-passing flow (q_1, q_2, and q_3), but each equation contains an empirical coefficient that needs to be evaluated from tests on gratings.

Li's approach was initially adopted for the analysis of the results from this study because the design method has a reasonable physical basis and has been widely used in the USA.

3.2.2 Evaluation of Li's design method

British Standard Code of Practice BS 6367 (Ref 10) covers the design of drainage systems for roofs and paved areas, and recommends Li's method for determining the spacing of gullies draining car parks and access roads. BS 6367 presents the design equations in a different way than Li so as to make them easier to use, but the theoretical basis is the same. The BS 6367 versions of the equations are used in this report.
In order to evaluate the suitability of Li's method, a series of 90 tests was carried out in the HR test rig to measure the amount of flow by-passing a grating with a single open hole measuring 450mmx450mm (i.e. a grating without any bars). The carry-by flow was small and an allowance for it was made in the analysis of the carry past flow using Li's formulae. This was done in order to ensure that any by-passing was due only to carry-past flow (q_3 in Figure 4) so that a direct check could be made of Li's method for predicting this component of the flow. Li's equations for calculating the rate of carry-past flow, q_3, is:

$$q_3 = K_3 Q \left(\frac{B - W_p}{B} \right)^2 \left(1 - \frac{L}{L_3} \right) \tag{1}$$

where L is the actual length of the grating parallel to the kerb and L_3 is the length of grating that would be needed to prevent any flow carrying past. L_3 is given by:

$$L_3 = 2.4\, E \left(\frac{B - W_p}{B} \right)^{1/2} \tag{2}$$

in which E is a characteristic length related to the flow conditions upstream of the grating and defined by:

$$E = \frac{7.9}{1000} \left(\frac{S_C\, S_L^{\,1/2}}{n} \right)^{9/16} \left(\frac{Q}{1000} \right)^{7/16} \tag{3}$$

Other quantities in the equations are: the cross-fall of the channel, S_C; the longitudinal slope of the channel, S_L; the Manning roughness coefficient of the channel, n; the upstream width of flow, B; the distance from the kerb to the outer edge of the grating, W_p. The non-dimensional factor K_3 has to be determined empirically; Li's own tests suggested that it was a constant with a value of $K_3 = 0.6$.

Analysis of the HR data for the simple case of the open hole showed that K_3 was far from being constant but varied significantly with the flow conditions. Attempts were made to explain the variability as a function of factors such as the Froude number of the approaching flow, the ratio between the upstream flow width and the width of the grating, the cross slope and others. Figure 5 shows one of the attempts to calibrate K_3 as a function of the upstream Froude number, F_r. It shows that K_3 can vary by a factor of 2 or more, that the average value is not equal to 0.6, and that there is no significant dependence on the Froude number or the relative flow width. Multiple regression was also attempted but did not prove very satisfactory. It was also realised that the final design method would be complicated to apply if separate formulae were required to predict the "constants" in Li's equations.

3.2.3 Other methods

Since the idea of dividing the approaching flow into three components still seemed to be reasonable, other simpler approaches along the same lines were tested. In one case, the amount of carry-past flow (q_3) was assumed to be dependent on the flow curvature caused by the lateral component of the gravitational acceleration. An alternative approach was to assume that the grating acted as a side weir; this proved a satisfactory model for the carry-by flow, q_1, between the kerb and the grating, but not for the more complicated case of the carry-past flow flow, q_3. Multiple regression based on the parameters that would be likely to affect the grating efficiency (such as the Froude number, the relative flow width, etc) were also attempted but with very little success.

After making detailed measurements of velocity and water level in the channel upstream of the grating, it was realised that the structure of the flow was very complex and that existing theories were too simplistic to describe it satisfactorily. Therefore, even an attempt to develop a method for estimating the proportion of the total flow approaching outside the width of the grating proved to be not at all straightforward.

Since it had proved impossible to find satisfactory methods for predicting the individual components of the by-passing flow, it was decided to adopt a more empirical approach and concentrate on the overall relationships between the total amount of by-passing, the flow conditions and the geometric properties of the gratings.

3.3 Empirical approach

3.3.1 Parameter for flow characteristics

Previous American and Australian studies have indicated that the flow collection efficiency, η, of a gully grating in a triangular channel is primarily dependent on the flow rate approaching it (see Ref 3 for more details). Figure 6 shows a plot of efficiency against discharge obtained in the HR tests for grating configuration L (see Table 1). It shows that straight lines can be drawn for each cross-fall and for each flow width. On each line, the highest efficiency corresponds to a flat longitudinal slope and the lowest efficiency to a steep slope. However, it must be stressed that the flow rates for the flattest gradients are much smaller than those with steep gradients. The same type of result was confirmed by tests with other gratings, and suggested the idea of plotting the efficiency against the discharge, Q, divided by the product of the flow width, B, and the cross slope, S_C. The product of B and S_C is in fact equal to the flow depth, H, at the kerb just upstream of the grating. Figure 7 shows the effect of plotting the data in Figure 6 in this way. All the values for different flow widths and cross-slopes have been collapsed into a single curve which can be approximated as a straight line.

In actual fact, the curve of flow collection efficiency against the quantity Q/H is not exactly a straight line. Gómez & Gonzáles (Ref 7) tested a grating which was 800 mm wide by 900 mm long for a wide range of flow conditions (up to 200 l/s) with collection efficiencies as low as 10%. Figure 8 shows a plot of efficiency against Q/H for the authors' grating. It indicates that the full curve has a reverse S-shape becoming asymptotic to a constant value of efficiency at very high discharges or very small water depths. However, it could be demonstrated that in most UK road drainage schemes, gully gratings would always operate at efficiencies above 50%. Hence, it seems reasonable to focus on the prediction of the performance of gully gratings for flow collection efficiencies between 100% and 50%.

Analysis of the data from the tests on the HR model gratings (see Section 2.3 and Table 1) showed that, except at low values of efficiency, the results for an individual grating could be described satisfactorily by an equation of the form:

$$\eta = \alpha - G\frac{Q}{H} \tag{4}$$

where η is the flow collection efficiency (expressed as a percentage), Q is the flow rate approaching the grating (in m^3/s), H is the water depth at the kerb (in m), and G and α are two constants to be determined for each grating.

3.3.2 Parameter for grating characteristics

Figure 9 shows the best-fit curve calculated by linear regression (least squares method) for grating configuration L. The correlation coefficient of $r^2 = 0.98$ confirms that it is valid to assume a linear relationship between the flow collection efficiency and the flow parameter Q/H. Similarly good results were obtained for nearly all the other grating configurations that were tested.

Table 2 gives the values of the coefficients G and α found by linear regression for the 21 different types of model grating that were tested (i.e. configurations D to X in Table 1). The analysis used all the results from each test above the point at which the data began to deviate from a linear relationship; this typically occurred at values of η between about 40% and 50%. Table 2 also contains data for the three manufactured gratings that were tested at HR (i.e. configurations A to C); these results were not used in the development of the design equations given below but were used later to check their applicability to manufactured gratings.

Both the coefficients G and α are dependent on the geometric characteristics of a grating. However, α varies very little and, as a simplification, it can be assumed that for all the configurations tested, the coefficient is equal to the average value of $\alpha = 102.7$ (based on η being expressed as a percentage). This introduces only a very minor error in the estimation of the best-fit line and simplifies the general relationship to:

$$\eta = 102.7 - G\left(\frac{Q}{H}\right) \quad ; \quad \text{for} \quad \eta \leq 100\% \tag{5}$$

The fact that α is > 100 indicates that a grating will be able to collect 100% of the flow approaching it over a certain limited range of flow conditions (until the quantity Q/H exceeds 2.7/G). Table 2 also shows the new values of coefficient G obtained after adopting a standard value of $\alpha = 102.7$. Having fixed the value of α, the coefficient G becomes the only parameter that is dependent on the grating characteristics since the effect of the flow conditions are fully described by the flow parameter Q/H.

The gratings characteristics which were considered likely to affect the value of G were factors such as the grating width, length, percentage waterway area and bar pattern. Due to the way in which the test programme had been planned, it was possible to identify the effect of each factor separately and in a systematic way. When looking for a method of predicting the value of G, it was also necessary to apply the requirement that the quantity G(Q/H) should be dimensionless in order to satisfy the Froudian scaling law.

The data were split into groups having similar characteristics (e.g. gratings with longitudinal slots or gratings with the same percentage waterway area) in order to establish the effects of the factors mentioned above. Using dimensional analysis and multiple regression techniques, the following general equation was developed for predicting the values of G obtained from the tests on the HR model gratings:

$$G = K_A \, k_{B1} \, k_{B2} \tag{6}$$

Here K_A is the grating parameter defined by:

$$K_A = \frac{69}{A_g^{0.75}\sqrt{p}} \tag{7}$$

where A_g is the area (in m^2) of the smallest rectangle having sides parallel to the kerb that contains all the slots of the grating, and p is the percentage waterway area (i.e. the total area of the slots open to the flow as a percentage of the area A_g). The coefficient k_{B1} takes account of the effects of any transversal and longitudinal bars in the grating and is given by:

$$k_{B1} = (n_t + 1)^{0.19}(n_l + 1)^{0.07} \tag{8}$$

where n_t and n_l are, respectively, the numbers of transversal and/or longitudinal in the grating. Similarly, the coefficient k_{B2} describes the effect of any diagonal bars and is given by:

$$k_{B2} = (n_d + 1)^{0.15} \tag{9}$$

where n_d is the number of diagonal bars in the grating. Some manufactured gratings have more complicated patterns of bars than those tested in the HR study; guidance on how the numbers of transversal, longitudinal and diagonal bars should be determined is given in Appendix B.

It can be seen from Equations (8) and (9) that increasing the number of bars in a grating (while keeping the waterway area constant) will reduce its hydraulic capacity. Transverse bars are slightly less efficient than diagonal bars, while longitudinal bars produce the most efficient arrangement; however, the limitation in BS EN 124 (Ref 2) on maximum slot length normally requires that gratings with longitudinal bars also need to have some transverse or diagonal bars. The HR tests showed that diagonal bars have the same hydraulic capacity whether the bars are set at an angle of 45° or 135° to the upstream line of the kerb.

Table 2 shows the values of G predicted by Equation (6). The ratio between observed and predicted G varies between 0.90 and 1.08, and the value of the correlation coefficient was $r^2 = 0.96$; this demonstrates that the equation provides a good fit to the data for a wide range of grating configurations. The full equation for predicting the flow collection efficiency of a grating is obtained by combining Equations (5) to (9) to give:

$$\eta = 102.7 - \left(\frac{69}{A_g^{0.75}\sqrt{p}}(n_t + 1)^{0.19}(n_l + 1)^{0.07}(n_d + 1)^{0.15}\right)\left(\frac{Q}{H}\right) \tag{10}$$

Figures 10, 11 and 12 show how the formula fits the data in the case of three very different configurations of grating. In each Figure, the dotted line is the best-fit line through the data points and the solid line is the one predicted by Equation (10). As expected from the good correlation achieved with the equation for G, the degree of agreement can be seen to be very satisfactory.

3.4 Validation of the method

3.4.1 Glynwed gratings tested at HR

Equation (10) was obtained from analysis of the HR tests made on the 21 different configurations of model grating (D to X in Table 1). Figures 13, 14 and 15 show the best-fit lines predicted by the equation for the three gratings provided by Glynwed (Configurations A to C). The fit is generally quite good except for configuration C (Glynwed reference M13) where the equation seems to under-predict the efficiency (see Figure 15). This may be explained by the fact that the special edge details allow more efficient collection of flow close to the kerb. The proposed design method has the merit of erring on the conservative side in terms of the predicted performance of the grating.

3.4.2 TRL data

Figures 16 and 17 show the best-fit lines predicted by Equation (10) for tests on BS grating types D10-20 and D11-20 reported by Russam (Ref 11); the test data are also included in TRL Contractor Report 2 (Ref 1). Both Figures indicate a fair degree of scatter in the data which may have been due to the difficulty of setting the flow width (and depth) accurately to the standard values used in the tests. The predicted values of collection efficiency are not far from the best-fit lines through the data, and are generally on the safe side, i.e. lower than observed. Figure 16 also shows that the range of flow conditions used at TRL was much narrower than that studied at HR in tests with a similar grating (see Figure 10, configuration D).

3.4.3 Data from Oxford Brookes University

Figures 18 to 21 show the best-fit lines predicted by Equation (10) for the four types of BS grating tested by Ellett & Stubbs (Ref 12); the test data are also included in TRL Contractor Report 2 (Ref 1). As in the case of the TRL data in Section 3.4.2, it is considered that some of the scatter may be due to the difficulty of setting the required widths of flow upstream of the gratings. All four graphs show that Equation (10) gives a reasonable estimate of the grating efficiency.

3.4.4 Data from UPC University - Barcelona

Figures 22 and 23 show the best-fit lines predicted by Equation (10) for two types of Spanish grating. Both graphs indicate that the predictive method gives a fair estimate of the grating efficiency for values down to about η = 40-50 %; for lower efficiencies, the linear equation is not able to predict the reversed S-shape of the data (see Section 3.3.1).

4. EXPERIMENTS WITH KERB INLETS

4.1 Test facility

The test facility used for the study of gully gratings was also used for testing kerb inlets and only small modifications were needed (see description of test facility in Section 2.1). These involved partly blocking the cut-out in the floor of the flume where the gully gratings were placed. A longitudinal wall was also introduced along the length of the flume to simulate a kerb. Due to the presence of this kerb, the available width in the flume was reduced by 0.5m, as can be seen on Plate 5. This reduction was necessary to allow the construction and testing of an angled kerb inlet configuration, which is described later.

4.2 Experimental conditions

4.2.1 Configurations of kerb inlets

Although different types of kerb inlet are available in the UK, unlike gully gratings, they tend to have fairly similar geometric characteristics. Kerb inlets are often formed in cast-iron and, when installed in the line of a kerb, produce a simple rectangular opening; in some cases the lids of units are stiffened on the underside by shallow transverse ribs. Typical openings are around 0.5m in length. In systems used for drainage of bridge decks, the kerb openings are divided by regularly spaced full-depth ribs. These are necessary for the structural integrity of the units since they are assembled to form continuous drainage channels. This type of system is outside the scope of this study.

In order to improve the interception of the flow, the kerb can be angled upstream of the opening. With this arrangement the road runoff is directed towards the opening much more efficiently because a stronger flow velocity component perpendicular to the opening is created. The optimum angle upstream of the opening is dependent on the ability of the flow to expand laterally. For channel flows with no lateral inflow, it is known that the rate of expansion is about 1 in 4 (i.e. one unit expansion to four longitudinal units). This corresponds to an angle of 14°, which can be considered for the present situation. Tests described in TRL Contractor Report 2 with a modified arrangement of the kerb inlet E14-19 were carried out with an upstream angle close to 14°. For safety reasons, when angled kerb inlets are used, they should be built so that the direction of the traffic is opposite to the direction of the flow.

The experimental programme involved the testing of two types of kerb inlet: straight and angled (see Figure 24). Two lengths L were tested for each configuration, 0.5m and 0.25m, to assess the validity of Froudian scaling. For the angled kerb inlet, the angles were kept constant and only the length of the opening was changed to achieve full similarity.

4.2.2 Flow conditions

The range of flow conditions reproduced in the tests were to some extent dictated by the capacity of the kerb inlets. For example, at the beginning of the test programme it was realised that the efficiency of the 0.25m long straight inlet was very small for flow widths above 0.25m, with practically all the flow by-passing the inlet. For this reason, tests were carried out with a minimum longitudinal slope of 1/500 (compared with 1/200 for the gratings) so as to cover a wider range of conditions for which the kerb inlets would have some intercepting capacity.

In general terms the kerb inlets were tested under the following conditions:

- three flow widths: 0.25m, 0.5m and 1.0m.
- five longitudinal slopes: 1/500, 1/300, 1/200,1/100 and 1/50.
- three cross-falls: 1/50, 1/40 and 1/30.

4.2.3 Experimental procedure

As for the tests with gully gratings (see Section 2.2.3), the experimental procedure involved setting the longitudinal slope and the cross-fall of the channel to the required values using the system of jacks. The control gates and the flow rate were adjusted until the required width of flow was reached.

Measurements of the flow rate were taken using the EM flowmeter or the orifice plate, depending on which pump was being used. Measurements of the flow that by-passed the inlet were either taken with the V-notch weir in Channel B (see Figure 1) or volumetrically with a graduated bucket when the flows were too small to be accurately measured by the V-notch.

The value of the water depth in the cross-section was determined from measurements of the water surface at a distance of 1/3 of the flow width from the kerb. For the tests with straight kerb inlets, the values of water depth approaching the inlet were measured 0.15m upstream of the upstream end of the kerb opening. The location of the measuring point had to be moved further upstream for tests with angled kerb inlets since it was observed that the flow tended to expand outwards at the approach to the receding kerb.

4.3 Experimental data

The data collected for kerb inlets is presented in the last four tables of Appendix A, after the data for gully gratings. In the tables Configurations SA and SB denote straight kerb inlets and configurations AA and AB denote angled kerb inlets. The heading box gives the length of the opening parallel to the carriageway. In the main tables each row gives the characteristics and results of a particular flow test. The first column contains the test number and the next column gives the water depth measured upstream of the inlet. The third column shows the flow width and the fourth and fifth columns show the inverse of the longitudinal slope and cross-fall of the channel, respectively. The flow rate approaching the kerb inlet is given in column six and the efficiency of the inlet in collecting the flow is presented in the last column (the efficiency is defined, as before, as η = flow rate collected by inlet / flow rate approaching the inlet, expressed as a percentage).

5. ANALYSIS OF THE DATA ON KERB INLETS

5.1 Applicability of Froudian scaling

As in the study of gully gratings, tests were carried out to determine whether results of tests with one size of kerb inlet could be generalised to other sizes on the basis of Froudian similarity. A discussion of this scaling law and the factors that can affect the performance of different sizes of grating can be found in Section 3.1. Factors such as the viscosity and surface tension of water, which were considered negligible for gully gratings, can with more reason be neglected in the case of kerb inlets due to the lack of bars in the kerb inlets tested.

Figure 25 illustrates the applicability of Froudian similarity to kerb inlets. The Figure shows a plot of the efficiency against discharge for a pair of geometrically similar straight kerb inlets (0.5m and 0.25m long) at a cross-fall of 1/50. The flow rates for the smaller inlet (which was half the geometric size of the larger inlet) were multiplied by the factor $2^{2.5} = 5.657$ in accordance with the Froudian scaling relationship for discharge. As can be seen in the Figure, data for both inlet sizes fall onto the same curve, thus supporting the assumption that Froudian scaling is also valid for kerb inlets.

5.2 Analysis of test results

The empirical approach adopted for the analysis of test results with gully gratings, which is described in Sections 3.3 and 3.4, provided the basis for the analysis of the kerb inlets. The relationship between discharge and flow collection efficiency (defined as flow rate collected by inlet / flow rate approaching the inlet, expressed as a percentage) is shown in the graph of Figure 26. The figure shows two quite distinct curves, corresponding to straight and angled kerb inlets, respectively. A similar pattern is apparent in Figure 27, where the efficiency is plotted as a function of the discharge divided by the water depth approaching the inlet.

The flow into a kerb inlet can be approximated to a weir-type flow, where the water discharges freely over a straight weir. As well as the head of water over the weir, the length of the kerb opening is an important parameter to take into account. Based on this reasoning, the two types of kerb inlet can be defined by their opening lengths: for straight kerb inlets the opening length L_i is equal to the length of the inlet unit and for angled kerb inlets, L_i is defined as the overall length of the opening in the kerb parallel to the carriageway direction. The assumption of simple weir-type flow implies that the gradual reduction in flow rate along the length of the weir, due to the collection of flow by the inlet (ie, the "side-weir effect"), can be neglected; this helps to simplify the design procedure.

In order to investigate the above assumption, the test data were analysed by plotting the flow collection efficiency, η, against the non-dimensional parameter $Q/(H^{1.5} L_i g^{0.5})$, where the denominator is proportional to the flow over a straight weir of length L_i . As can be seen in Figure 28, this approach enabled the data for both straight and angled kerb inlets to be collapsed onto a single, well-defined curve. Figures 29 and 30 illustrate other attempts to find a good fit for the data, using different powers for L_i and H. However, it was considered that the non-dimensional parameter used in Figure 28 provided the best fit to the data, and had the advantage of being based on established theory for weir-type flow.

It can be seen in Figure 28 that a significant number of data points correspond to flow conditions and/or kerb inlet geometries which had very low efficiencies. For design purposes, these are not important and it was decided to find a best-fit equation for data corresponding to efficiencies equal to or greater than 40%. The linear relationship obtained is presented in Figure 31 as a solid line. Also presented in the Figure is another solid line passing through 100% efficiency when the flow rate is equal to zero. This line provides a safe estimate of the efficiency of kerb inlets since nearly all the data points plot above the line. The design equation proposed for predicting the flow collection efficiency of a kerb inlet is therefore as follows:

$$\eta = 100 - 36.1 \frac{Q}{H^{1.5}\ L_i} \qquad (11)$$

where η is the flow collection efficiency (expressed as a percentage), Q is the flow rate approaching the gully (in m^3/s), H is the water depth (in m) approaching the inlet, and L_i is the length of the opening in the kerb (in m) measured along the line of the kerb. For straight kerb inlets, L_i is equal to the length, L, of the kerb unit; for units set at an angle to the kerb (see Figure 24), L_i is equal to the length over which the flow is able to turn into the inlet and is therefore greater than L.

6. DESIGN PROCEDURE IN ADVICE NOTE FOR GULLY GRATINGS

6.1 Types of grating

Figure 32 shows curves of flow collection efficiency, η, against Q/H predicted by Equation (10) for some of the grating configurations tested in this project and also for some typical gratings that are available commercially. Figure 32 includes upper-band and lower-band curves that correspond to the most efficient and inefficient gratings that are likely to be produced in accordance with BS EN 124 (Ref 2). The upper-band line corresponds to a grating measuring 1m x 1m in plan with a percentage waterway area of 75%, 14 No. longitudinal bars and 4 No. transversal bars. The lower-band line corresponds to a grating measuring 0.3m x 0.3m in plan with a percentage waterway area of 30%, 5 No. longitudinal bars and 1 No. transversal bar. The two extreme cases make it possible to define the practical range of variation of the factor G (between 15 and 110).

The Advice Note was required to be applicable to any design of grating that conforms to BS EN 124 (Ref 2). In order to deal with the very large number of possible designs that could be produced, it was decided to define five categories of grating based on their hydraulic characteristics - Types P, Q, R, S and T. An advantage of defining gratings in terms of their flow capacity is that a drainage designer is able to specify use of a certain grating Type and be sure of achieving the required hydraulic performance whatever make of conforming grating is chosen by the contractor. The category into which a particular grating falls is determined by the value of the parameter G used in Equation (5). This can be calculated from Equation (6) using measurements of the geometry of the grating. However, as will be described in Section 6.2.1, a simpler method of allowing for the number and orientation of the bars was adopted for use in the Advice Note. It is expected that, once the Advice Note is in general use, manufacturers themselves will determine the Type categories of their various designs and provide this information in their brochures. However, an Appendix in the Advice Note explains the method for determining the grating Type so independent checks can be made by a designer or specifier if required. As an alternative to the calculation method, a manufacturer may choose to carry out his own flow tests so as to determine directly the values of G for his gratings.

Gratings corresponding to Type P have a value of G greater than 30, and would typically need to have an overall grating area of at least $A_g = 0.5\ m^2$ and a percentage waterway area p = 50%. Gratings of Type Q have a value of G between 30 and 45 (corresponding to a typical grating area of about $A_g = 0.35\ m^{2)}$ and are likely to be somewhat larger than typical patterns of UK grating. Many current UK road gratings are relatively efficient and measure about 0.45m x 0.45m (e.g. $A_g \approx 0.2m^2$) so are likely to be classified as Type R. Type S covers the smaller or less efficient UK gratings (e.g. $A_g \approx 0.15\ m^2$) having a percentage waterway area of the order of p = 40%. Type T would allow use of small gratings (e.g. $A_g = 0.1\ m^2$) with percentage waterway areas in the range p = 30-40% that, despite their low hydraulic capacity, would still be permitted by BS EN 124 (Ref 2); however, a brief review suggests that UK manufacturers are not currently producing gratings for use in roads that come within this category.

6.2 Modification of the design method for the Advice Note

6.2.1 Simplifying the assessment of bar pattern

During the preparation of the Advice Note, it was realised that Equations (8) and (9) for estimating the effect of the bar pattern could lead to uncertainties when applied to some commercial gratings with complicated patterns containing, for example, staggered bars or short stub bars. In order to provide unambiguous guidelines, it was therefore decided to simplify Equation (6) to the form:

$$G = K_A C \qquad (12)$$

where K_A is the grating parameter defined by Equation (7) and C is an overall coefficient for a particular bar pattern. According to the results of the experimental work, Equations (8) and (9) indicate that C should be related to the number of bars in a grating by:

$$C = (n_t + 1)^{0.19} (n_l + 1)^{0.07} (n_d + 1)^{0.15} \qquad (13)$$

Based on the use of this equation and the guidelines set out in Appendix B, Table 3 gives predicted values of C for a wide range of commercial gratings available in the UK and also for gratings tested by HR or UPC University, Barcelona. It can be seen that, in practice, the value of C does not vary very greatly for a given type of bar pattern.

Figure 33 shows the values of C from Table 3 for gratings with transverse bars plotted as a function of the grating area, A_g ; it can be seen that there is no clear dependency on the size of the grating. Since, in practice, the values of C do not appear to vary greatly, it was decided for the Advice Note to recommend use of a single design value, termed C_b, for all gratings with predominantly transverse bars. The advantage of this simplification is that it eliminated the problem of correctly assessing the numbers of bars in gratings with complex patterns. In order to err on the safe side, the design value of C_b was set equal to the average of the relevant data in Table 3 plus one standard deviation. This resulted in a value of C_b = 1.75 being adopted in the Advice Note for gratings with predominantly transverse bars.

Values of C from Table 3 for gratings with predominantly diagonal bars and longitudinal bars are plotted as functions of the grating area, A_g in Figures 34 and 35 respectively. It can be seen that the differences between the hydraulic efficiencies of the two types of bar pattern are relatively small. On this basis, it was decided to adopt in the Advice Note a common design value of C_b=1.5 for both types of bar pattern (with the value being equal to the average of the data in Table 3 plus one standard deviation).

The lower value of C_b for diagonal and longitudinal bars than for transverse bars reflects the fact that, for the same flow conditions and values of A_g and p, gratings with predominantly transverse bars are somewhat less efficient from the hydraulic point-of-view. The limitation in BS EN 124:1994 of a maximum slot length of 170 mm for gratings with longitudinal bars reduces their performance close to that of equivalent gratings with diagonal bars. If this limitation did not apply, gratings with longitudinal bars only would have the highest collection efficiency because all the slots would be aligned with the flow. Gratings with bars curved in plan are intermediate in character between diagonal and longitudinal bars so in the Advice Note they are also assumed to have a value of C_b = 1.5.

The Table below gives the values of C_b for different bar patterns of gratings.

Grating bar pattern	C_b
Transverse bars	1.75
Longitudinal, diagonal or curved bars	1.5

If a grating contains a mixture of bar orientations, the predominant bar pattern should be determined by counting the numbers of slots in the longitudinal and transverse directions and also any slots at an angle to the line of the kerb. If more than half the total number of slots are transverse, use a value of $C_b = 1.75$; otherwise use a value of $C_b = 1.5$.

6.2.2 Distance between kerb and grating

For most of the tests carried out at HR, the distance between the kerb line and the edge of the first slot of each grating was 35 mm. This distance was considered to be a reasonable approximation of the average distance between kerb and first slot found in many road schemes. However, some sensitivity analysis on the effect of varying this distance was carried out using the side-weir method developed during the initial stages of the data analysis (see Section 3.2.3). It was calculated that if the distance were to be increased to 50 mm, the collection efficiency of a gully grating would decrease by about 1 to 2 %, depending on the flow conditions, due to carry-by flow along the line of the kerb (see Section 3.2.1). To allow for some margin of error in the positioning of gullies on site, it was decided to base the recommendations in the Advice Note on the assumption that the allowable distance between the kerb line and the edge of the first slot of a grating could be a maximum of 50mm. For this reason, it was decided to modify Equation (5), which was obtained as a best fit to the experimental data, to the slightly more conservative form:

$$\eta = 100 - G\left(\frac{Q}{H}\right) \qquad (14)$$

As a result, the Advice Note predicts that, even for very low flows, it is not possible for a grating to collect 100% of the water approaching it. This change provides a small margin of safety in cases where gratings are positioned closer than 50mm to the kerb, but the effect on maximum allowable spacings between gullies will, in practice, be insignificant compared with other uncertainties in the design data. The effect of the modification from Equation (5) to Equation (14) is to reduce all the values of collection efficiency in Figure 32 by 2.7%.

6.2.3 Maintenance factor for effect of debris

All the HR tests and the design methods described up to this point are valid for gully gratings in a clean condition. Leaves and silt on roads can cause gratings to become partially blocked by debris leading to a significant reduction in their efficiency. The amount of blockage can vary considerably depending on the location of the road, the time of year and the frequency of maintenance. For the Advice Note, it was decided to introduce a non-dimensional maintenance factor, m (≤ 1.0), to allow for the effect of a partial blockage. Thus, for design purposes, the flow rate, Q_m , that can be assumed to be collected by a gully is equal to m times the flow rate for a clean gully, ie:

$$Q_m = m\left(\frac{\eta}{100}\right)Q \qquad (15)$$

A value of m = 1.0 is equivalent to a clean grating without debris. Values of m recommended in the Advice Note are given in the following Table:

Situation	Maintenance factor m
Well-maintained roads	1.0
Roads subject to less frequent maintenance	0.9
Roads subject to substantial leaf falls or vehicle spillages (e.g. at sharp roundabouts)	0.8
Sag points on road gradients	0.7

6.3 Steps in design process

The method described in Sections 3.3 and 6.2 for predicting the flow collection efficiency of gully gratings is only part of the design procedure that needs to be followed when determining maximum allowable spacings between gullies. Figure 36 shows the principal steps in the design procedure.

The first step is normally to calculate the rainfall intensity, which is dependent on the location of the road and on the design return period and duration of the storm event for which it is required to cater. If the geometric properties of the kerb-side channel are known (cross-fall, longitudinal slope and surface roughness), and the maximum design width of flow is specified, the maximum flow rate approaching the grating can be calculated using the Manning resistance equation.

Assuming that a particular grating Type has been selected, Equation (14) can then be used to determine the flow collection efficiency of the grating. If information on the grating Type is not available, the grating Type can be assessed from its geometric characteristics (see Section 6.2.1). If the efficiency is less than a certain recommended figure (e.g. 50%), it is necessary either to use a higher category of grating or to reduce the design width of flow. If the choice of grating Type is satisfactory, it is then possible to calculate the maximum allowable spacing based on the effective catchment width of the road and the appropriate design rainfall intensity for the scheme. As an alternative, the design procedure can be used to produce design tables giving values of area that can be drained by particular grating Types depending on the channel geometry, flow width, rainfall intensity and channel roughness (see Section 6.4.6 and Appendix C).

6.4 Description of the design method

Figure 37 shows in more detail the steps that need to be followed by a designer in order to calculate maximum allowable spacings for road gullies.

6.4.1 Determining the rainfall characteristics

The first step is to determine the design rainfall intensity (I, in mm/h) for the drainage system corresponding to the geographical location of the site, the specified return period of the design storm (N, in years) and the critical storm duration (T, in minutes). This can be done using the following formula from HA 37 (Ref 6):

$$I = 32.7\,(N - 0.4)^{0.223}\,\frac{(T - 0.4)^{0.565}}{T}\,(2\min M5) \qquad (16)$$

The quantity 2minM5 is the rainfall depth in mm occurring at the site in a period of 2 minutes with an average return period of 5 years. This quantity is a measure of the rainfall characteristics at the site and can be obtained directly from a Meteorological Office map of the UK that is already contained in HA 37 (Ref 6).

6.4.2 Determining the flow capacity of the channel

It is assumed that the cross-fall (S_C), the longitudinal slope (S_L), and the Manning roughness coefficient (n) of the kerb-side channel are known. It is also necessary for the designer to decide the maximum allowable width of flow (B, in m) in the channel upstream of the grating. The water depth (H, in m) at the kerb is given by:

$$H = B\,S_C \qquad (17)$$

The cross-sectional area of the flow just upstream of the grating (A, in m^2) is calculated as:

$$A = \frac{B\,H}{2} \qquad (18)$$

The hydraulic radius of the channel (R, in m) is given by:

$$R = \frac{A}{H + \sqrt{B^2 + H^2}} \qquad (19)$$

and the flow rate (Q, in m^3/s) approaching the grating is calculated from Manning's equation:

$$Q = \frac{A\,R^{2/3}\,S_L^{\ 1/2}}{n} \qquad (20)$$

In the Advice Note the values of Manning roughness coefficient given for different types and condition of channel surface are consistent with those in Advice Note HA 37 (Ref 6) for the design of road-edge surface water channels. Therefore, the Advice Note contains Tables of drained areas for the five grating Types for a roughness value of n = 0.017, corresponding to a black top surface in average condition.

6.4.3 Determining the grating Type

It is assumed that a drainage designer will normally make an initial choice or assumption about what grating Type (P to T) is likely to be most suitable for a particular scheme. If the calculated gully spacings were found to be unsatisfactory, the design procedure would need to be repeated assuming use of a different grating Type. In most cases, it is envisaged that the work of determining in which category a particular design of grating belongs will be carried out by the manufacturer, who will list this information in the technical brochure for the product. However, the Advice Note includes full details of the assessment method so that independent checks can be made in cases of dispute or where the grating Type is not known.

The first steps in determining the grating Type are to calculate:

- The area A_g of the smallest rectangle that just includes all the slots.
- The total waterway area of the slots as a percentage, p, of the area A_g.
- The grating bar pattern (see Section 6.2.1).

Formulae in the flow chart of Figure 37 can then be used to find the values of the following grating coefficients:

- K_A , relating to the overall area of the grating and the waterway area.
- C_b , relating to the pattern of bars in the grating (see Section 6.2.1).

The value of the overall grating parameter, G, can then be calculated from the equation:

$$G = K_A C_b \tag{21}$$

Comparison of the calculated value of G with the ranges given in the following Table defines the category or Type (P to T) to which the grating belongs (see also Figure 37 and Section 6.1). For purposes of design, all gratings of a particular Type are assumed to have a value of G equal to the design value G_d given in the Table. This design value corresponds to the upper limit of the range so as to ensure that any conforming grating will have a certain minimum flow capacity for given flow conditions in the kerb channel. The values of G and G_d are for clean gratings; in the Advice Note a separate allowance for the effect of debris is made using the maintenance factor, m, described in Sections 6.2.3 and 6.4.5.

Type	P	Q	R	S	T
Range of G	$G \leq 30$	$30 < G \leq 45$	$45 < G \leq 60$	$60 < G \leq 80$	$80 < G \leq 110$
Design value G_d	30	45	60	80	110

Once the grating Type has been selected or is known, the drainage designer can determine the maximum allowable gully spacing by means of design tables such as those in Appendix C (see Section 6.4.6) or by following the calculation steps shown in Figure 37 and described in the following Sections.

6.4.4 Determining the grating efficiency

Knowing the grating Type, the corresponding design value of the grating parameter (G_d), the flow rate (Q) approaching the grating and the water depth (H) at the kerb, it is possible to determine the flow collection efficiency (η, in %) of the grating from:

$$\eta = 100 - G_d (Q/H) \tag{22}$$

If the efficiency of the grating is found to be below $\eta = 50\%$, it is recommended in the Advice Note either to use a more efficient grating Type or to adopt a smaller design width of flow approaching the grating.

6.4.5 Determining the gully spacing

If the maintenance factor for the grating is m (non-dimensional) and the design rainfall intensity is I (in mm/h), the maximum catchment area, A_{dr} (in m^2), that can be drained by each gully in a road of constant longitudinal gradient is given by:

$$A_{dr} = 3.6 \times 10^4 \left(\frac{\eta m Q}{I} \right) \tag{23}$$

Note that the efficiency is expressed as a percentage value.

If the effective width of the catchment is W_e (in m), then the maximum allowable spacing, S_p (in m), between adjacent gullies can be calculated from the equation:

$$S_p = 3.6 \times 10^4 \left(\frac{\eta m Q}{W_e I} \right) \tag{24}$$

If the longitudinal gradient varies significantly along the section of road being considered, it is necessary to take account of the fact that the flow capacity of the kerb channel will vary with distance and that the flow collection efficiencies of two adjacent gullies may not necessarily be equal. The maximum allowable spacing, S_p, between a pair of gullies is reached when the sum of the flow rate bypassing the upstream gully and the rate of run-off from the area of catchment between the gullies is just equal to the downstream flow capacity, Q_2, of the channel, ie:

$$\left(1 - \frac{\eta_1 m}{100}\right) Q_1 + \frac{W_e I S_p}{3.6 \times 10^6} = Q_2 \tag{25}$$

where Q_1 is the flow rate approaching the upstream gully, η_1 is its collection efficiency, and the units are as defined above. Re-arranging the equation gives:

$$S_p = \frac{3.6 \times 10^6}{W_e I} \left[Q_2 - \left(1 - \frac{\eta_1 m}{100}\right) Q_1 \right] \tag{26}$$

If $Q_1 = Q_2$, it can be seen that Equation (26) becomes equivalent to Equation (24). Calculation should proceed from the upstream end of the drainage length being considered; for the first gully, Q_1 should be put equal to zero in Equation (26).

If the longitudinal gradient of the road <u>increases</u> significantly with distance in the direction of flow, it is also necessary to check that the channel has sufficient flow capacity at all points along its length. If the actual distance between two adjacent gullies is Z and the gradient at the downstream gully is S_L, then the local gradient S_i, at any intermediate distance Z_i measured from the upstream gully, should satisfy the following requirement:

$$S_i \geq S_L \left(\frac{Z_i}{Z}\right)^2 \tag{27}$$

This result follows from Manning's equation (20) if it is assumed that the amount of by-passing at the upstream gully is small and that the flow rate in the channel increases linearly with distance. If either of these assumptions is not satisfied, the simplest way to check that the channel has sufficient capacity is to calculate the design rate of flow at a series of intermediate points between adjacent gullies and compare the values with the local flow capacity of the channel, as given by Equation (20). If there is insufficient capacity, an additional gully will need to be installed at an intermediate point.

Having determined the maximum allowable spacing from Equation (24) or (26), it may be necessary to revise the assumed value of storm duration. The most critical case is normally assumed to occur when the duration, T, of the storm event is just equal to the time of concentration of the flow from the most upstream part of the contributing catchment, ie when:

$$T = t_s + t_g \tag{28}$$

where t_s is the travel time of the water across the width of the road and t_g is the time taken by the flow to travel the maximum allowable distance, S_p ,between adjacent gullies. A typical value of t_s is 3 minutes. The value of t_g (in minutes) can be estimated from:

$$t_g = \frac{A S_p}{60 Q} \tag{29}$$

where A (in m^2) is the cross-sectional area of flow in the channel approaching a grating and Q (in m^3/s) is the corresponding flow rate calculated from Equation (20). If the value of storm duration, T, is revised, the design rainfall intensity, I, should be re-calculated using Equation (16) and substituted into Equation (24) or (26) to determine the revised value of gully spacing.

6.4.6 Use of design tables

As an alternative to using the design equations described above, the Advice Note also includes tables that give the maximum catchment areas that can be drained by grating Types P to T for a range of different conditions. The values in the Tables were calculated from the design equations in Sections 6.4.1 to 6.4.5 and the results are reproduced in Appendix C of this report. The following factors are assumed in the tables:

- The longitudinal gradient and the cross-fall of the kerb channel do not vary significantly with distance along the drainage length being considered (so that Equation (23) applies).
- The channel has a Manning roughness coefficient of n = 0.017 (average condition for blacktop surface, see HA37, Ref 6).
- The design rainfall intensity is I = 50 mm/h.
- There is no blockage of the gully by debris, ie the maintenance factor m = 1.0.

Table C1 in Appendix C gives the flow capacities of kerb channels, as calculated from Equation (20), for the following conditions: longitudinal gradients between 1/300 and 1/15; cross-falls between 1/60 and 1/15; and flow widths between 0.5m and 1.5m. Corresponding values of the catchment area, A_{dr}, that can be drained by an individual grating of Type P to T are provided in Tables C2 to C6 respectively; for each combination of conditions the Tables also give (in brackets and italics) the flow collection efficiency of the grating. Situations in which the grating would not be able to collect more than 50% of the approaching flow are labelled in the Tables as "not efficient" (see Section 6.4.4).

Values of drained area for other values of design rainfall intensity (I), maintenance factor (m) and channel roughness coefficient (n) can be found using the following procedure. First, find from Tables C2 to C6 the catchment area, A_{dr}, that could be drained by the grating for the appropriate values of longitudinal gradient, cross-fall and flow width if the design conditions were I = 50 mm/h, m = 1.0 and n = 0.017. For other values of these parameters the maximum area, A'_{dr}, that can actually be drained is given by:

$$A'_{dr} = k_{Im}\, k_n\, A_{dr} \tag{30}$$

From Equation (23) it follows that the factor k_{Im} is given by:

$$k_{Im} = m\left(\frac{50}{I}\right) \tag{31}$$

where m and I (in mm/h) are the appropriate design values.

A variation in the value of n produces two opposing effects: firstly, it reduces the flow capacity (Q) of the kerb channel; and secondly, it reduces the approach velocity of the flow and thereby results in an increase in the flow collection efficiency (η) of the grating. Substituting Equation (20) in Equation (22) shows that the efficiency is given by:

$$\eta = 100 - G_d\left(\frac{A\,R^{2/3}\,S_L^{1/2}}{n\,H}\right) \tag{32}$$

This can be written as:

$$\eta = 100 - \frac{\chi}{n} \qquad (33)$$

where the parameter χ is a constant for a given channel configuration. The flow collection efficiencies of a grating for two different values of channel roughness are therefore related by the equation:

$$\frac{100 - \eta_1}{100 - \eta_2} = \frac{n_2}{n_1} \qquad (34)$$

Similarly, from Equation (20), the flow capacities of the kerb channel corresponding to the two values of roughness are related by:

$$\frac{Q_1}{Q_2} = \frac{n_2}{n_1} \qquad (35)$$

It therefore follows from Equation (23) that the scaling factor, k_n, in Equation (30) that allows for the effect of varying the channel roughness, n, from the value assumed in Tables C2 to C6 is given by:

$$k_n = \frac{\left(\frac{0.017}{n}\right) - \left(1 - \frac{\eta}{100}\right)\left(\frac{0.017}{n}\right)^2}{(\eta / 100)} \qquad (36)$$

where η is the value of collection efficiency (in %) obtained from the Tables for n = 0.017. If η is not greatly less than 100%, Equation (36) can be approximated as:

$$k_n \approx \frac{0.017}{n} \qquad (37)$$

7. DESIGN PROCEDURE IN ADVICE NOTE FOR KERB INLETS

In general terms the design method suggested for gully gratings is also applicable to kerb inlets but it is simplified by the fact that there is no need to define or determine a grating type. Therefore, the first step is to determine the design rainfall characteristics and the flow capacity of the channel as described in Sections 6.4.1 and 6.4.2. The kerb inlet efficiency is then determined using Equation (11). If the efficiency is found to be below η = 50%, it is recommended in the Advice Note to use a kerb inlet with a longer opening length L_i or to adopt a smaller design width of flow approaching the grating. The kerb inlet spacing is determined as described in Section 6.4.5.

In the same way as for gully gratings, the design procedure was used to produce tables for inclusion in the Advice Note giving the maximum areas of road, A_{dr}, that can be drained by different sizes of kerb inlet. Tables C7 to C9 in Appendix C of this report give values of A_{dr} for straight kerb inlets with overall opening lengths of 0.5m and 1.5m and for an angled inlet with L = 0.5m as shown in Figure 24. It is assumed that the inlets are installed in kerb channels of constant longitudinal gradient (so that Equation (23) applies) and that the same conditions apply as for the corresponding Tables C2 to C6 for gratings, ie a rainfall intensity I = 50 mm/h, gully maintenance factor m = 1.0 (no blockage by debris), and a channel roughness of n = 0.017. For other values of these factors the maximum area, A'_{dr}, that can actually be drained is given by:

$$A'_{dr} = k_{Im}\, k_n\, k_L\, A_{dr} \qquad (38)$$

The factors k_{IM} and k_n are given by Equations (31) and (36) respectively. The factor k_L enables the results in Tables C7 to C9 of Appendix C to be scaled for other lengths of kerb opening, L_i. From Equation (11) it follows that the flow collection efficiencies of two kerb inlets having opening lengths L_{i1} and L_{i2} are related by:

$$\frac{100 - \eta_1}{100 - \eta_2} = \frac{L_{i2}}{L_{i1}} \qquad (39)$$

Substituting in Equation (23) it follows that:

$$k_L = \frac{1.0 - \left(1.0 - \frac{\eta_1}{100}\right)\left(\frac{L_{i1}}{L_{i2}}\right)}{(\eta_1 / 100)} \qquad (40)$$

where η_1 is the flow collection efficiency (in %) corresponding to the kerb opening length L_{i1} given in Tables C7 to C9 of Appendix C.

8. CONCLUSIONS

(1) A literature review of technical papers and reports on the hydraulic performance of gully gratings for roads indicated that only one general design method for predicting their flow capacity had been developed (that due to Li, Ref 9); other data and prediction methods were specific to the patterns of grating tested. Experimental data from the present study showed that Li's method could not easily be applied to UK and European gratings because parameters that should have been constant in the design equations were found to vary considerably.

(2) In the experiments carried out by HR Wallingford for this study a total of 23 configurations of gratings were tested by varying the:

- area of the grating
- waterway area as a percentage of the grating area
- ratio between the length and width of the grating
- bar pattern of the grating.

Tests were also carried out on two different configurations of kerb inlet: straight and angled. All the experiments were performed in a specially constructed test rig that simulated flow in triangular channels formed by the cross-fall of a road surface and the kerb.

(3) Each gully grating or kerb inlet was tested for a wide range of flow conditions to investigate the influence of the following parameters:

- width of flow in the channel just upstream of the gully
- velocity of flow in the channel just upstream of the gully
- cross-fall of the channel
- longitudinal gradient of the channel.

(4) Analysis of the data for gully gratings was carried out in terms of the flow collection efficiency, i.e. the ratio between the flow rate collected by a grating and the total flow rate approaching it in the channel

upstream. For the range of practical applications, it was found that the efficiency of an individual grating varied linearly with a quantity equal to the upstream flow rate divided by the depth of water at the kerb.

(5) Dimensional analysis also demonstrated that the efficiency of a grating depended on the overall plan area containing the slots, on the total waterway area of the slots as a percentage of the overall plan area, and on the number and orientation of the bars making up the grating. Analysis of the data enabled the effect of each of these factors to be determined quantitatively.

(6) Combining the results from (4) and (5) enabled a new method to be developed for predicting the flow collection efficiency of any combination of grating and channel type coming within the general limits investigated during the study. The validity of the model was confirmed by checking its predictions with independent data for commercial gratings tested at HR, TRL, Oxford Brookes University and UPC University, Barcelona.

(7) The design method developed in the study forms the basis of an Advice Note on the spacing of road gullies that has been produced for the Highways Agency by HR Wallingford and TRL. In order to give general guidelines on the performance of gratings conforming to BS EN 124:1994, five grating Types (labelled P to T) were defined in terms of their hydraulic capacity. This enables designers to specify the level of performance required for a particular scheme while allowing contractors to choose any make of grating that meets the hydraulic and structural requirements for the particular Type specified. In order to make the Advice Note simple and straightforward to use, some minor modifications were made to the design method developed from the study, in particular concerning the assessment of the bar patterns of gratings.

(8) In the same way as for gully gratings, the data on kerb inlets was analysed in terms of the flow collection efficiency, i.e. the ratio between the flow rate collected by a kerb inlet and the total flow rate approaching it in the channel upstream. For the range of practical applications, it was found that the efficiency of an individual kerb inlet (whether straight or angled) depended only on the upstream flow rate, the depth of water at the kerb and the length of kerb opening parallel to the carriageway.

(9) Guidelines on the spacing of kerb inlets are given in the Advice Note based on the design method developed from the test results. The procedure is similar to that for gully gratings except that the flow capacity of both straight and angled kerb inlets is determined by only one geometric factor, the length of the opening (measured along the line of the kerb) through which water is collected by the inlet.

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Tables

Table 1 Characteristics of the grating configurations tested

	Test code	% open area	Dimensions widthxlength (mmxmm)	Bars with respect to the flow	With intermediate bars	Number of the configuration
Glynwed	5804	62 %	350x500	Mixed		A
	M 13	62 %	400x445	Transversal		B
	5760	56 %	440x440	Diagonal		C
HR Wallingford	SD 135	44 %	440x440	Diagonal 135		D
	LSD 135	44 %	330x330	Diagonal 135		E
	SD 45	44 %	440x440	Diagonal 45		F
	LSD 45	44 %	330x330	Diagonal 45		G
	H21	100 %	440x440	Open hole		H
	TH 60	60 %	440x440	Transversal		I
	SH	44 %	440x440	Transversal		J
	TH	26 %	440x440	Transversal		K
	170 TH 60	54 %	440x440	Transversal	●	L
	170 H	40 %	440x440	Transversal	●	M
	170 TH	23 %	440x440	Transversal	●	N
	TL 60	60 %	440x440	Longitudinal		O
	SL	44 %	440x440	Longitudinal		P
	TL	26 %	440x440	Longitudinal		Q
	170 TL 60	54 %	440x440	Longitudinal	●	R
	170 L	40 %	440x440	Longitudinal	●	S
	170 TL	23 %	440x440	Longitudinal	●	T
	170 RTL	40 %	440x220	Longitudinal	●	U
	170 RLH	40%	220x440	Transversal	●	V
	170 RLL	40 %	220x440	Longitudinal	●	W
	170 RTH	40%	440x220	Transversal	●	X

Table 2 Coefficients for the best fit lines of HR's conceptual gratings

Configuration	Name	Area (cm^2)	p (%)	G	α	G (α = 102.7)	G predicted	n_t	n_l	n_d
D	SD 135	1936	44	52.9	105.37	50.0	49.6	0	0	8
E	LSD 135	968	44	75.5	103.52	74.0	76.3	0	0	8
F	SD 45	1936	44	53.5	107.22	49.9	49.6	0	0	8
G	LSD 45	968	44	73.1	104.19	70.7	76.3	0	0	8
I	TH 60	1936	60	47.1	102.98	46.1	47.3	9	0	0
J	SH	1936	44	54.7	99.83	51.4	52.9	7	0	0
K	TH	1936	26	66.9	98.24	65.5	68.8	7	0	0
L	170 TH 60	1936	54	55.4	105.45	52.9	54.9	9	3	0
M	170 H	1936	39.6	62.1	104.42	58.4	61.5	7	3	0
N	170 TH	1936	23.4	76.5	99.37	86.4	79.9	7	3	0
O	TL 60	1936	60	33.0	105.40	37.1	35.9	0	9	0
P	SL	1936	44	38.6	103.80	42.2	41.2	0	7	0
Q	TL	1936	26	42.7	103.52	48.3	53.6	0	7	0
R	170 TL 60	1936	54	52.5	105.71	48.7	49.2	3	9	0
S	170 L	1936	39.6	58.5	106.01	54.8	56.5	3	7	0
T	170 TL	1936	23.4	67.4	104.69	67.0	73.6	3	7	0
U	170 RTL	968	39.6	61.2	95.88	76.5	83.4	1	7	0
V	170 RLH	968	39.6	101.0	102.73	98.8	98.5	7	1	0
W	170 RLL	968	39.6	90.7	98.30	96.3	90.6	3	3	0
X	170 RTH	968	39.6	95.1	99.69	92.4	90.6	3	3	0

Table 3 Testing of the design method and simplifications

Manufacturers or Laboratory name	Grating name	Model number	Pattern	n_t	n_l	n_d	C	A_g	Average value of C	Standard deviation of C	C_b
Stanton	watershed	HR865		7	3		1.636	0.159			
	watershed	HR880		7	3		1.636	0.152			
	watergate	HY812		7	1		1.558	0.159			
	waterflow			8	1		1.594	0.213			
	pedestrian	HP893L		6	1		1.519	0.101			
	car park gratings	RE50H1FD		9	2		1.673	0.203			
Glynwed	niagara	5760		7	1	1	1.729	0.137			
	aquafall	5804		7	3		1.636	0.175			
	victoria	M13		7	4		1.662	0.178			
	victoria	M13M		7	9		1.744	0.178			
	briflo	6025	**Transverse bars**	6			1.447	0.250	**1.617**	**0.115**	**1.732**
		5790A		6	2		1.563	0.155			
	flowmax	9855		13			1.651	0.340			
Norinco	Runway 300/450			17	4		1.938	0.650			
	Calder			8	8		1.771	0.198			
	Dee			7	3		1.636	0.165			
	Mersey 100			8			1.518	0.124			
	Forth 100			8			1.518	0.198			
	Promenade			8	8		1.771	0.198			
	Severn			9			1.549	0.122			
	Mersey 75			8			1.518	0.123			
	Forth 75			8			1.518	0.198			
	Avon			9			1.549	0.122			
	Tees			8			1.518	0.123			
Gatic	AM			22			1.814	0.343			
Selflock	SKA-G-1-450			9			1.549	0.221			
UPC University, Barcelona	IMPU			17	2		1.870	0.234			
	Ondulada			13			1.651	0.224			
	Talla aigues			7	3		1.636	0.350			
Oxford Brookes University	aquamax straight			6	1		1.519	0.163			
	aquamax trirec			5	1	2	1.740	0.248			
	watergate			6	2		1.563	0.130			
HR conceptual grating	TH 60			9			1.549	0.194			
	SH			7			1.485	0.194			
	TH			7			1.485	0.194			
	170 TH 60			9	3		1.707	0.194			
	170 H			7	3		1.636	0.194			
	170 TH			7	3		1.636	0.194			
	170 RLH			7	1		1.558	0.097			
	170 RTH			3	3		1.434	0.097			

Table 3 Testing of the design method and simplifications (continued)

Firm or Laboratory name	Grating name	Model number	Pattern	n_t	n_l	n_d	C	A_g	Average value of C	Standard deviation of C	C_b
Stanton	waterway	HZ808	**Diagonal bars**			10	1.433	0.188	**1.437**	**0.057**	**1.494**
	waterway 1800	HZ858				12	1.469	0.360			
	waterflow non-rock	HP809				10	1.433	0.190			
	waterflow double	HP844				20	1.579	0.337			
Glynwed	niagara	5762				14	1.501	0.403			
	brimax	5750B				8	1.390	0.178			
	brimax	5981				11	1.452	0.342			
Norinco	Humber 100					8	1.390	0.195			
	Tamar 100					10	1.433	0.370			
	Humber 75					8	1.390	0.195			
Barcelona	E-29				1	12	1.542	0.192			
TRL	D10-20					8	1.390	0.230			
	D11-20					12	1.469	0.230			
Oxford Brookes	waterway					10	1.433	0.203			
HR conceptual grating	SD 135					8	1.390	0.194			
	LSD 135					8	1.390	0.097			
	SD 45					8	1.390	0.194			
	LSD 45					8	1.390	0.097			
Barcelona	R-121		**Longitudinal bars**	1	5		1.293	0.284	**1.431**	**0.102**	**1.533**
HR conceptual grating	170 TL 60			3	9		1.529	0.194			
	170 L			3	7		1.505	0.194			
	170 TL			3	7		1.505	0.194			
	170 RTL			1	7		1.320	0.097			
	170 RLL			3	3		1.434	0.097			

Figures

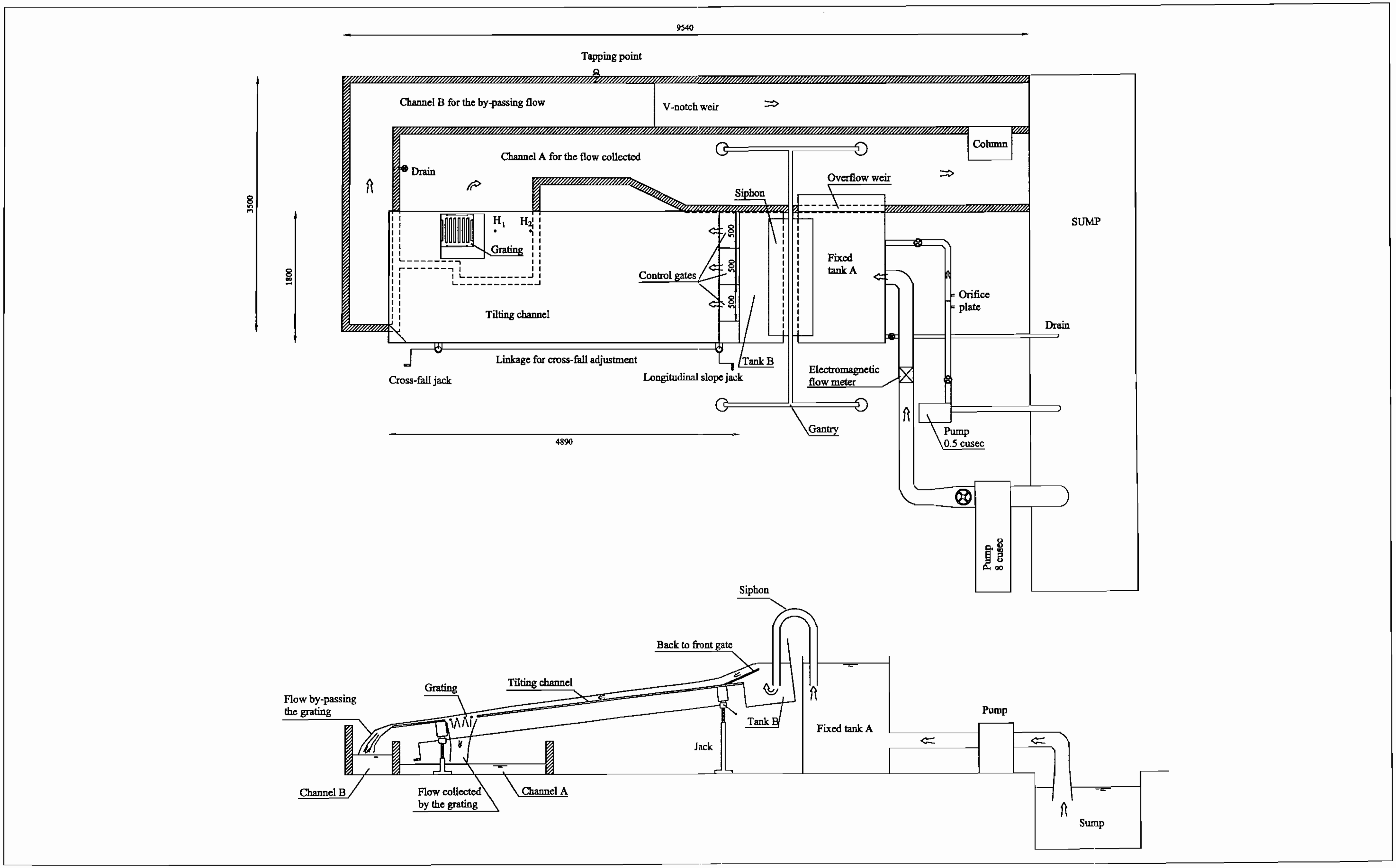


Figure 1 Test rig

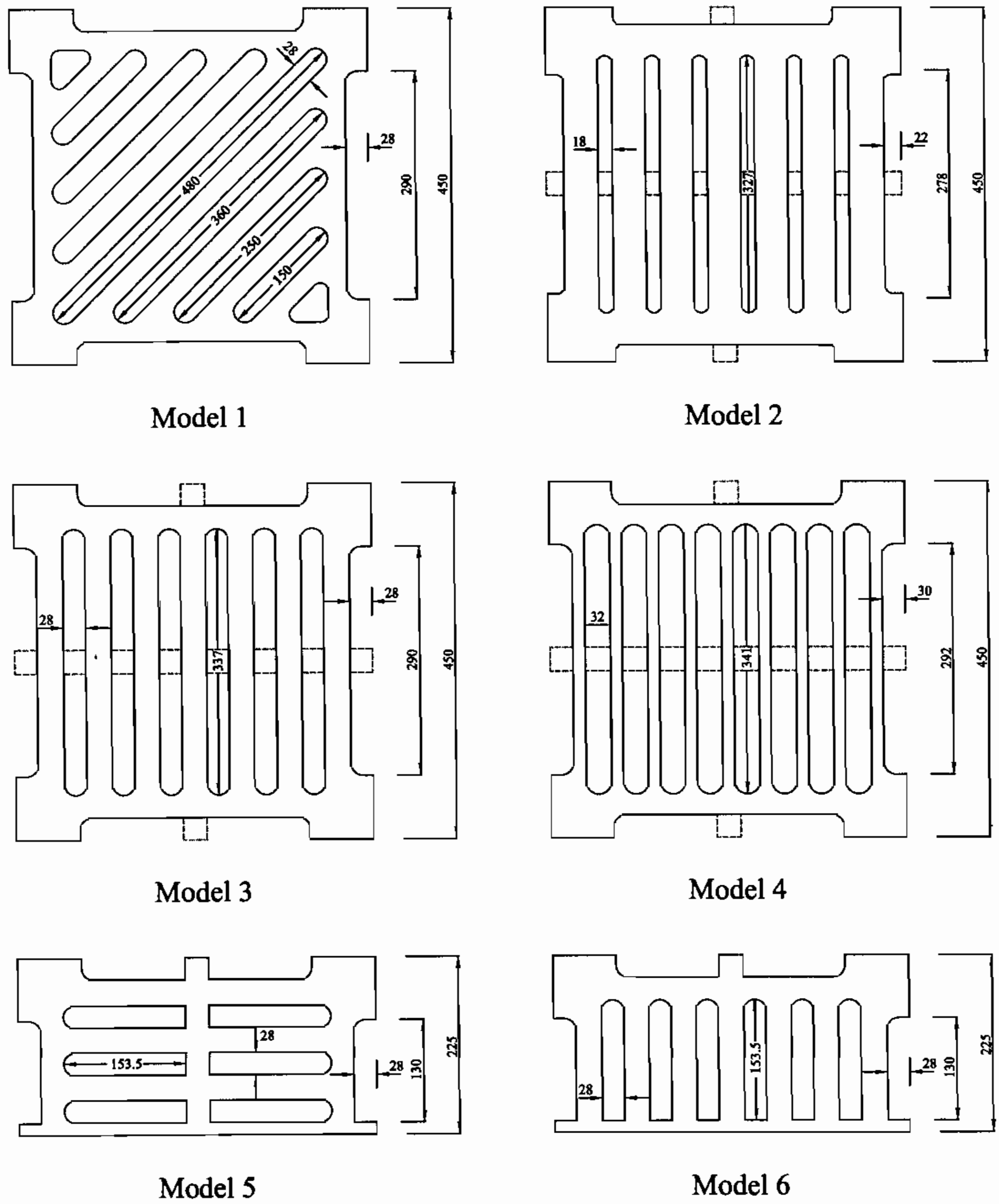


Figure 2 Models of HR's conceptual gratings

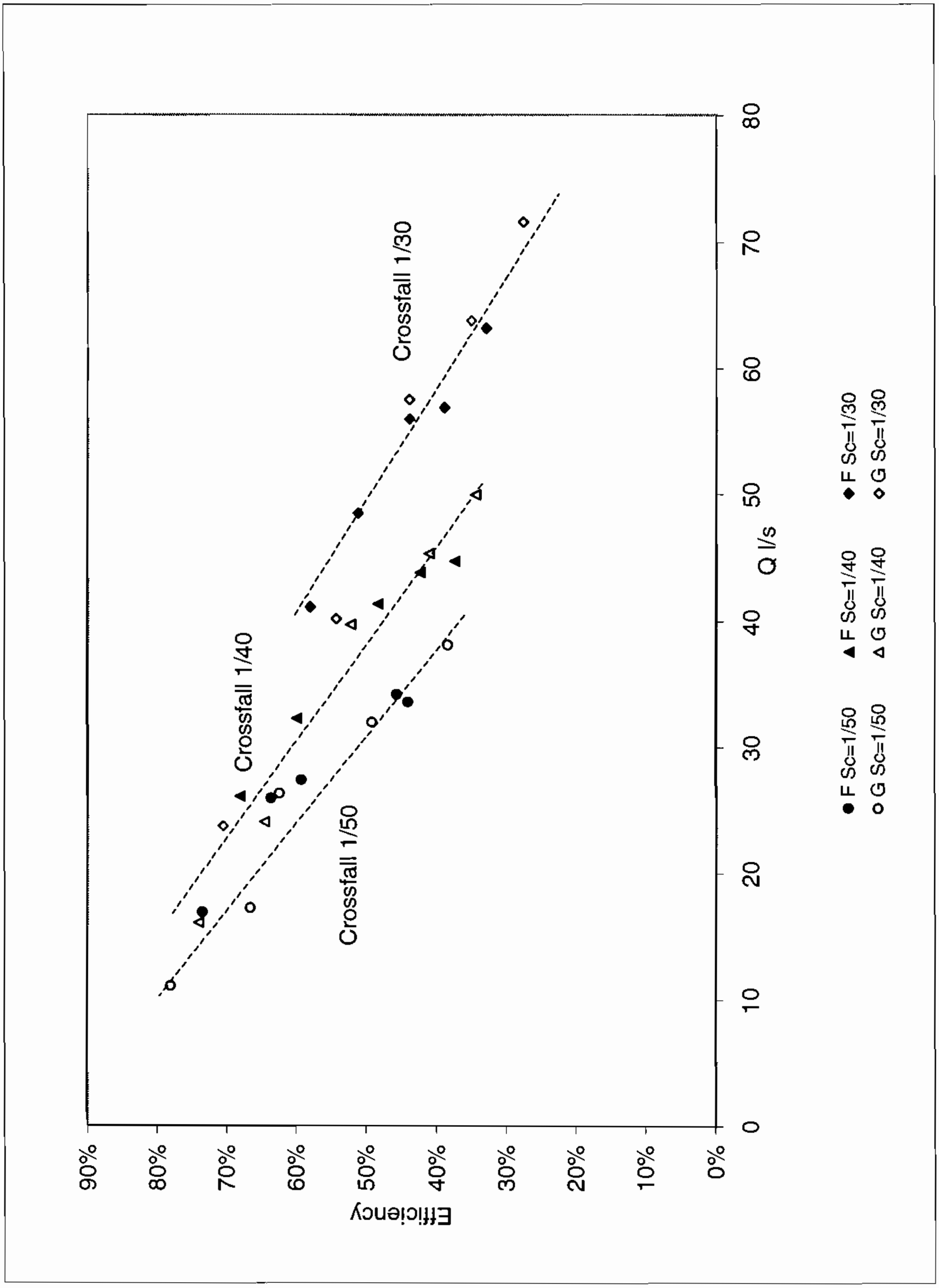


Figure 3 Demonstration of the applicability of Froudian scaling

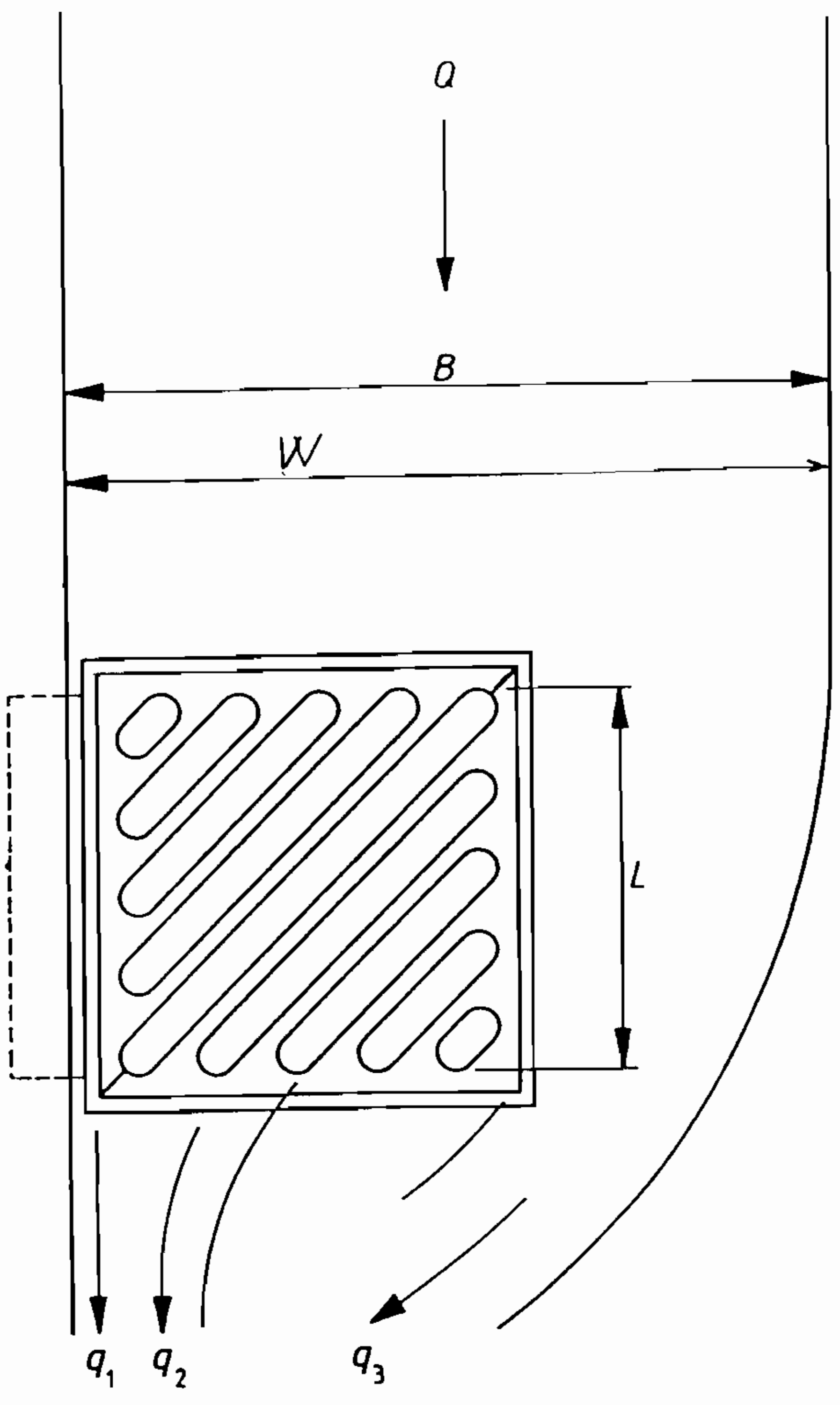


Figure 4 **Schematic layout of flow past a grating**

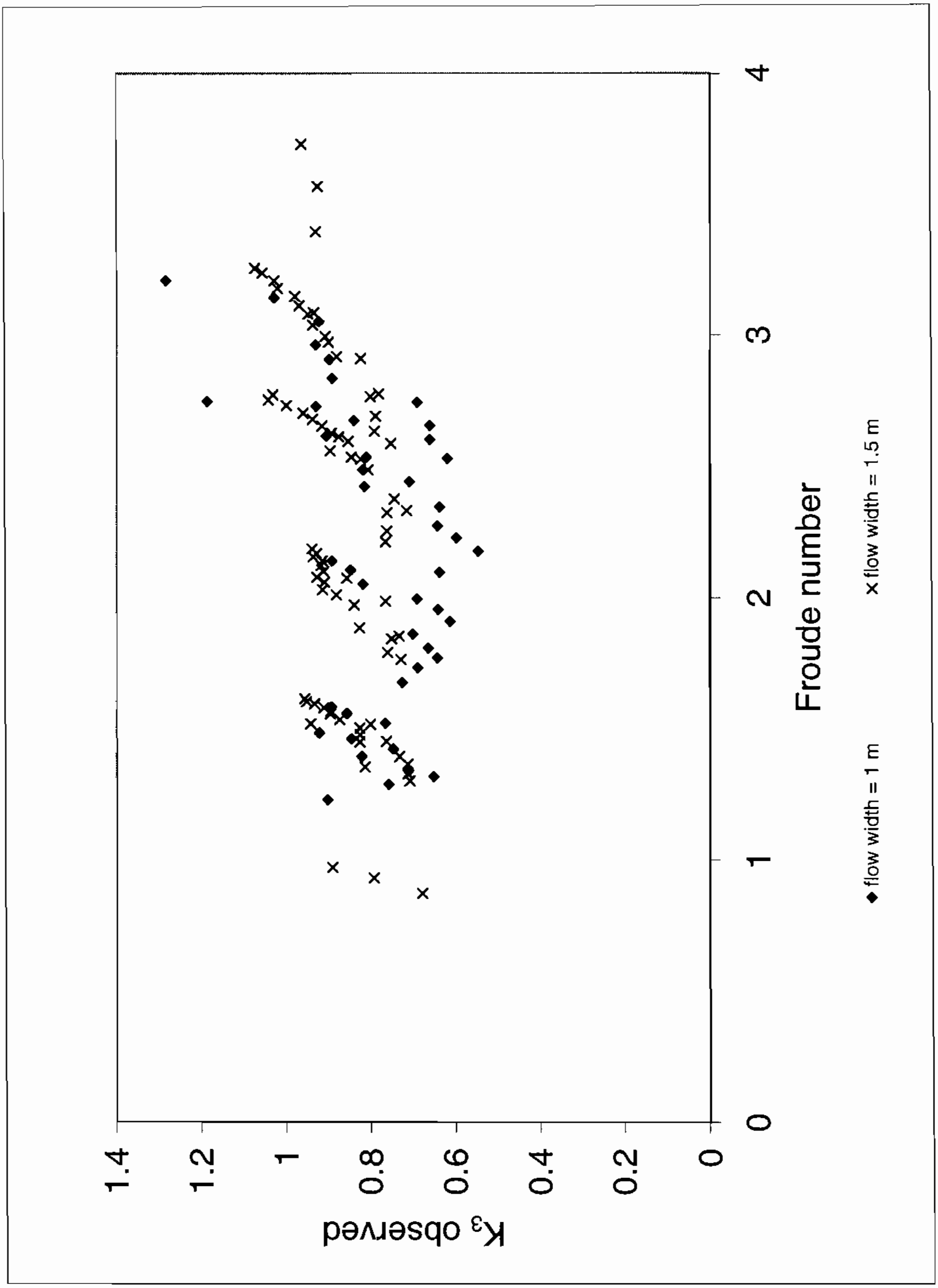


Figure 5 Theoretical approach: behaviour of Li's K_3 coefficient as a function of the Froude number

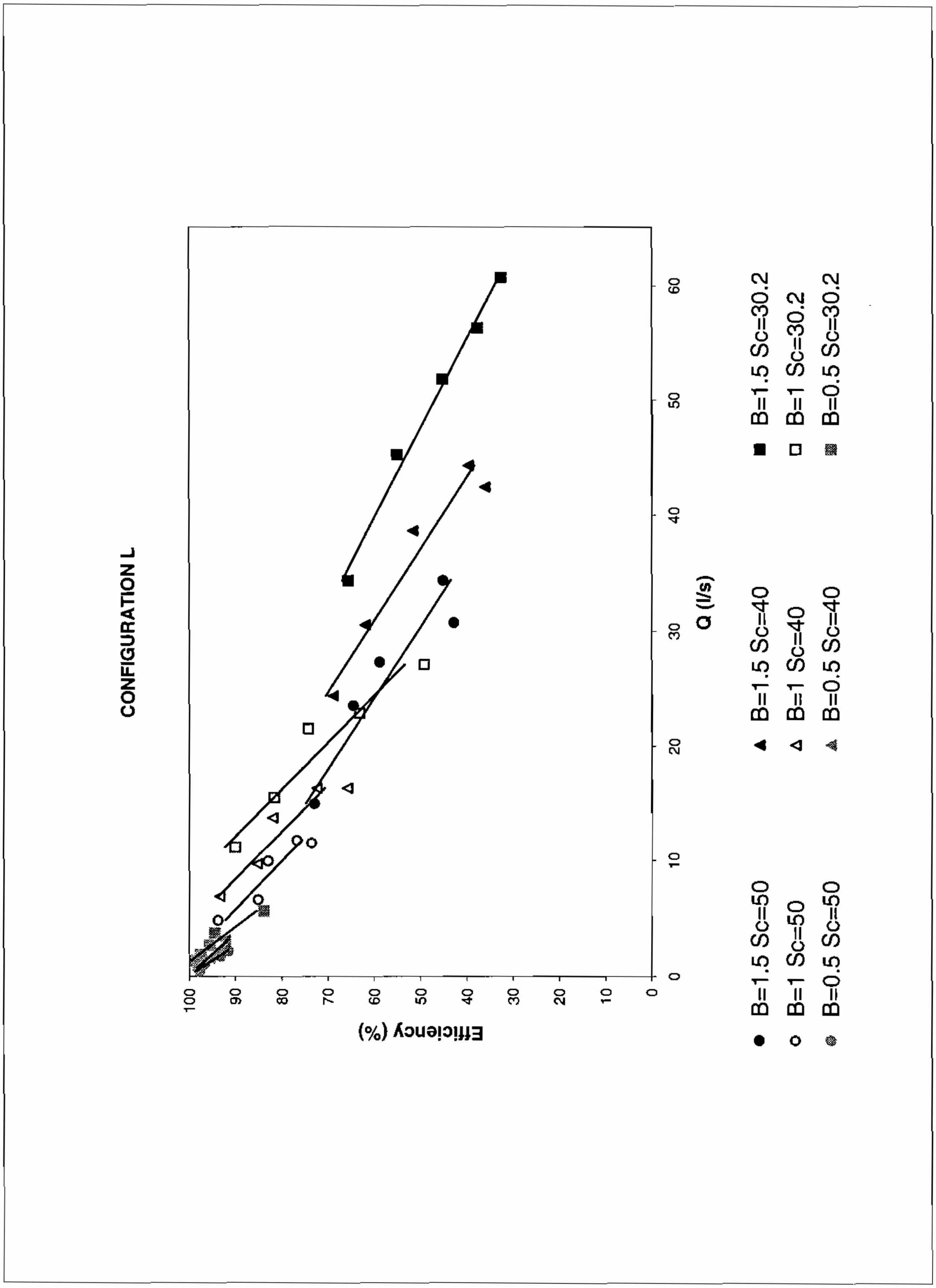


Figure 6 Empirical approach: grating efficiency against discharge

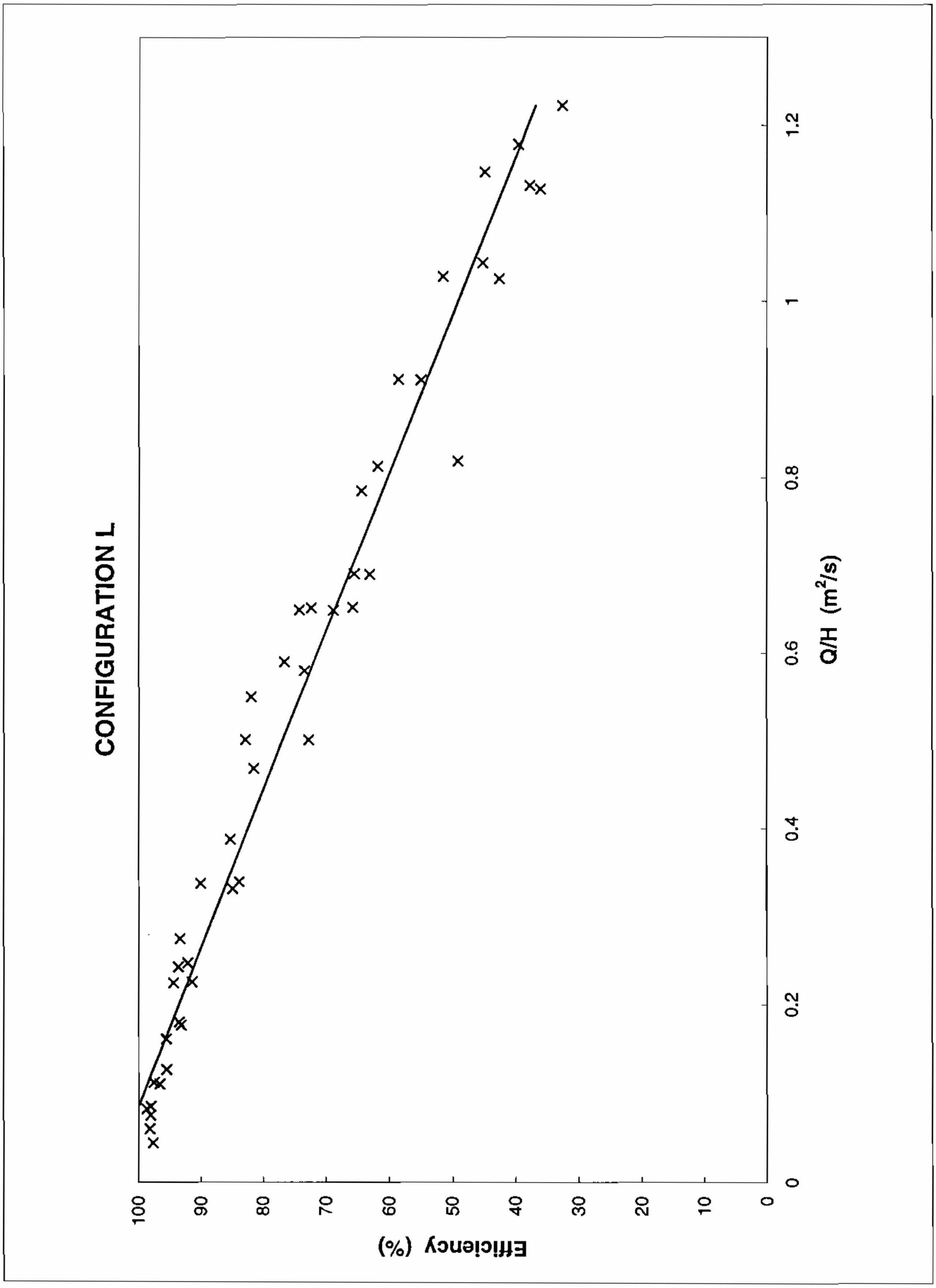


Figure 7 Empirical approach: grating efficiency against discharge divided by water depth at the kerb

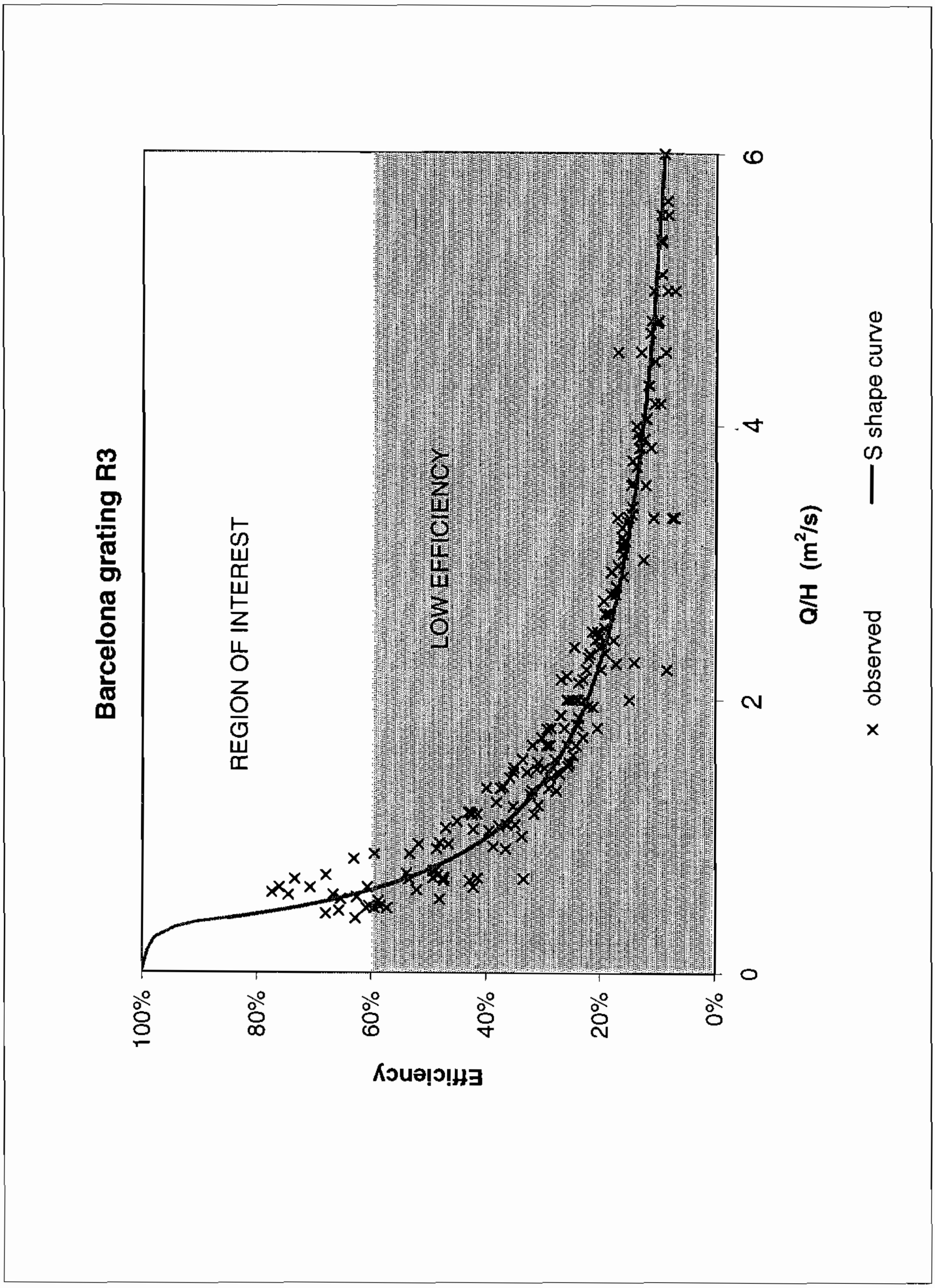


Figure 8 Empirical approach: real shape of the curve of efficiency against discharge/water depth

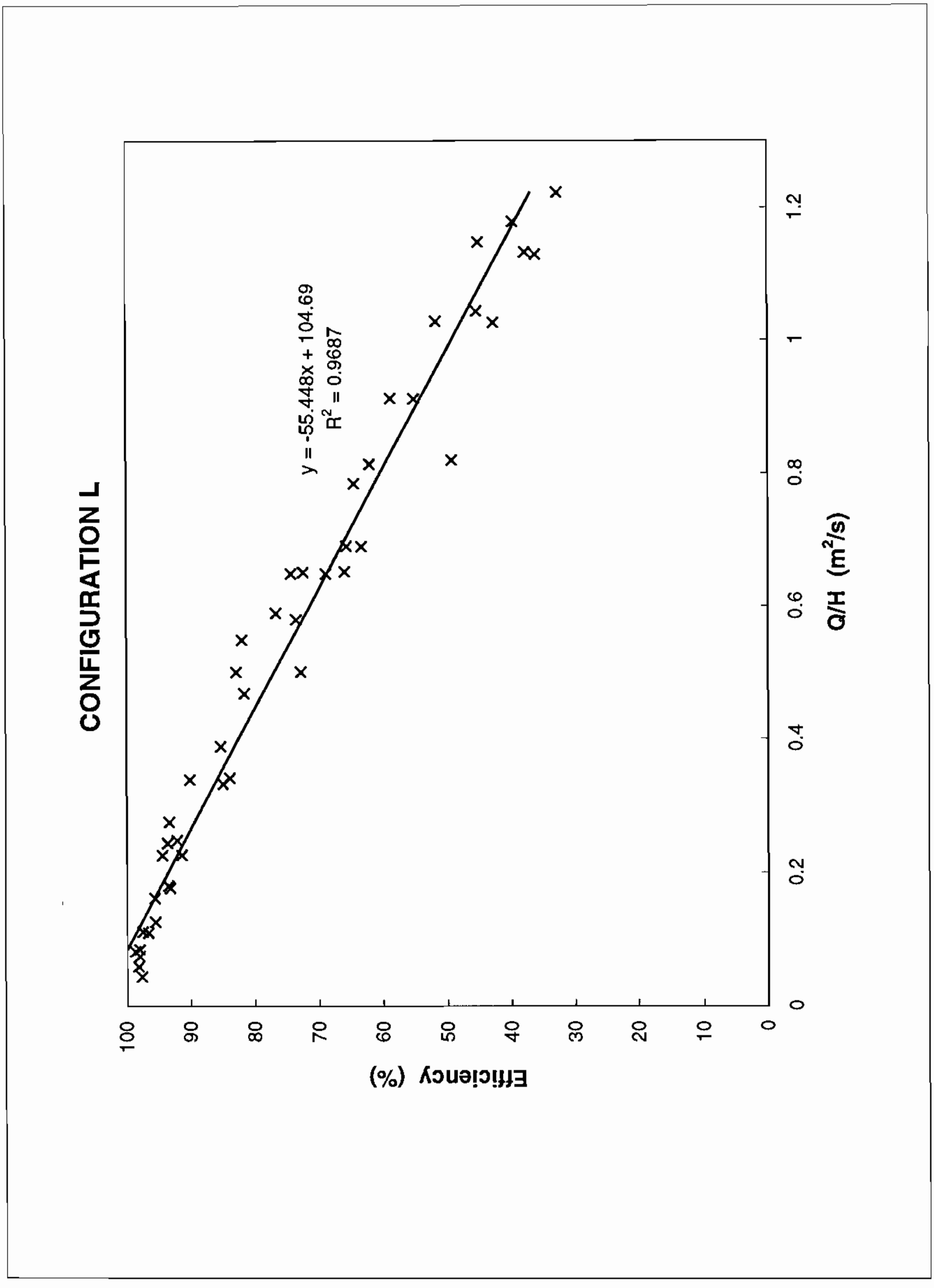
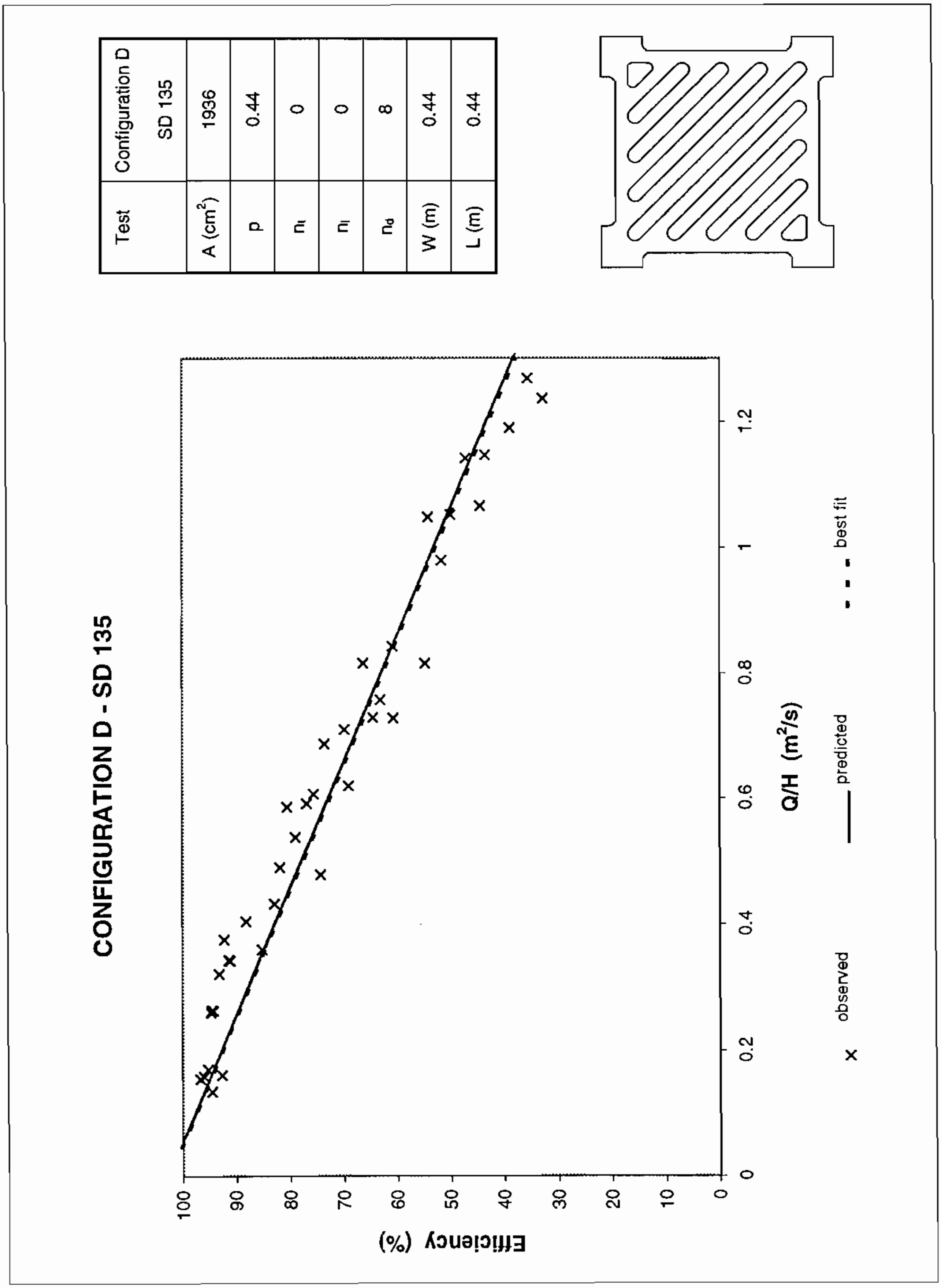
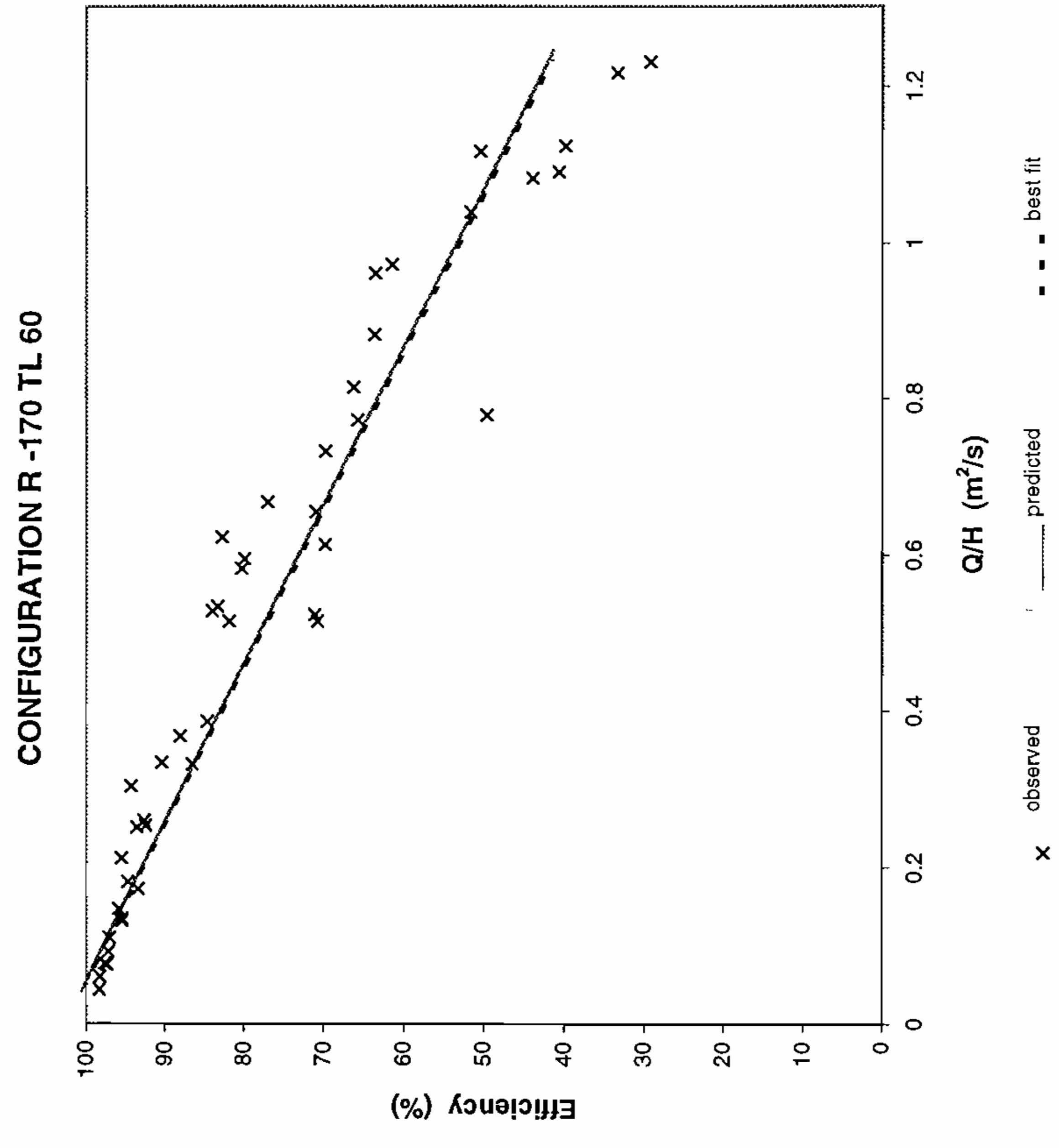


Figure 9 Empirical approach: best-fit line for efficiency against discharge/water depth



Test	Configuration D
	SD 135
A (cm²)	1936
p	0.44
n_t	0
n_l	0
n_d	8
W (m)	0.44
L (m)	0.44

Figure 10 Demonstration of the predictive method for HR conceptual grating (config. D)



Test	Configuration R
	170 TL 60
A (cm^2)	1936
p	0.54
n_t	3
n_l	9
n_d	0
W (m)	0.44
L (m)	0.44

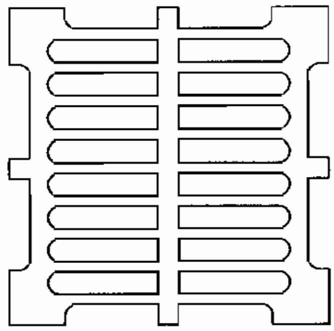
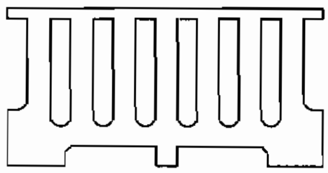


Figure 11 Demonstration of the predictive method for HR conceptual grating (config. R)

Test	Configuration X 170 RLH
A (cm^2)	936
p	0.4
n_t	7
n_l	1
n_d	0
W (m)	0.22
L (m)	0.44



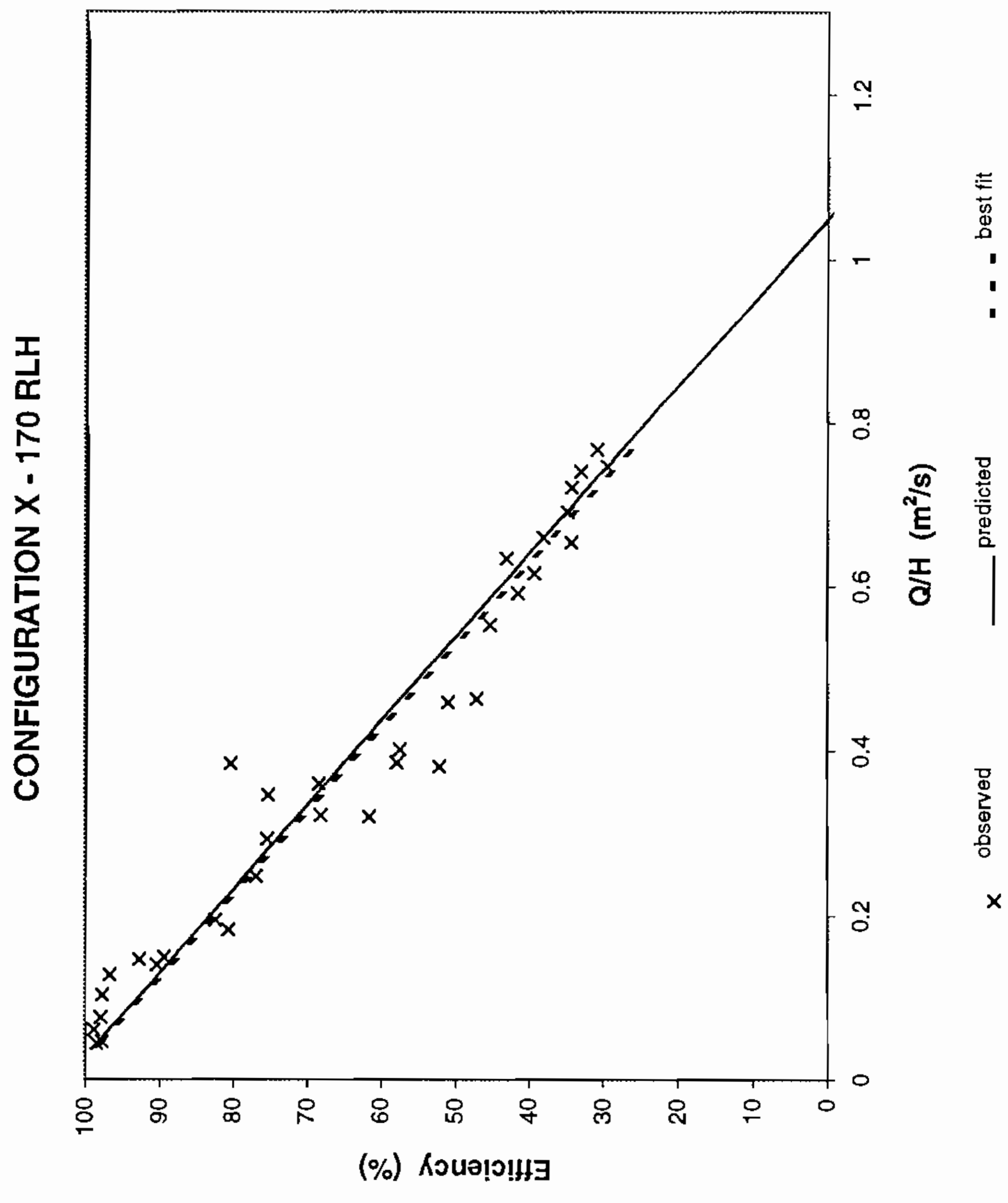
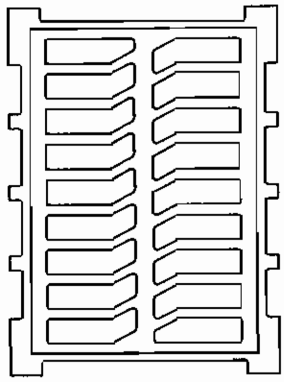


Figure 12 Demonstration of the predictive method for HR conceptual grating (config. X)

Test	Configuration A Glynwed 5804
A (cm²)	1750
p	0.62
n_t	10
n_l	1
n_d	0
W (m)	0.35
L (m)	0.5



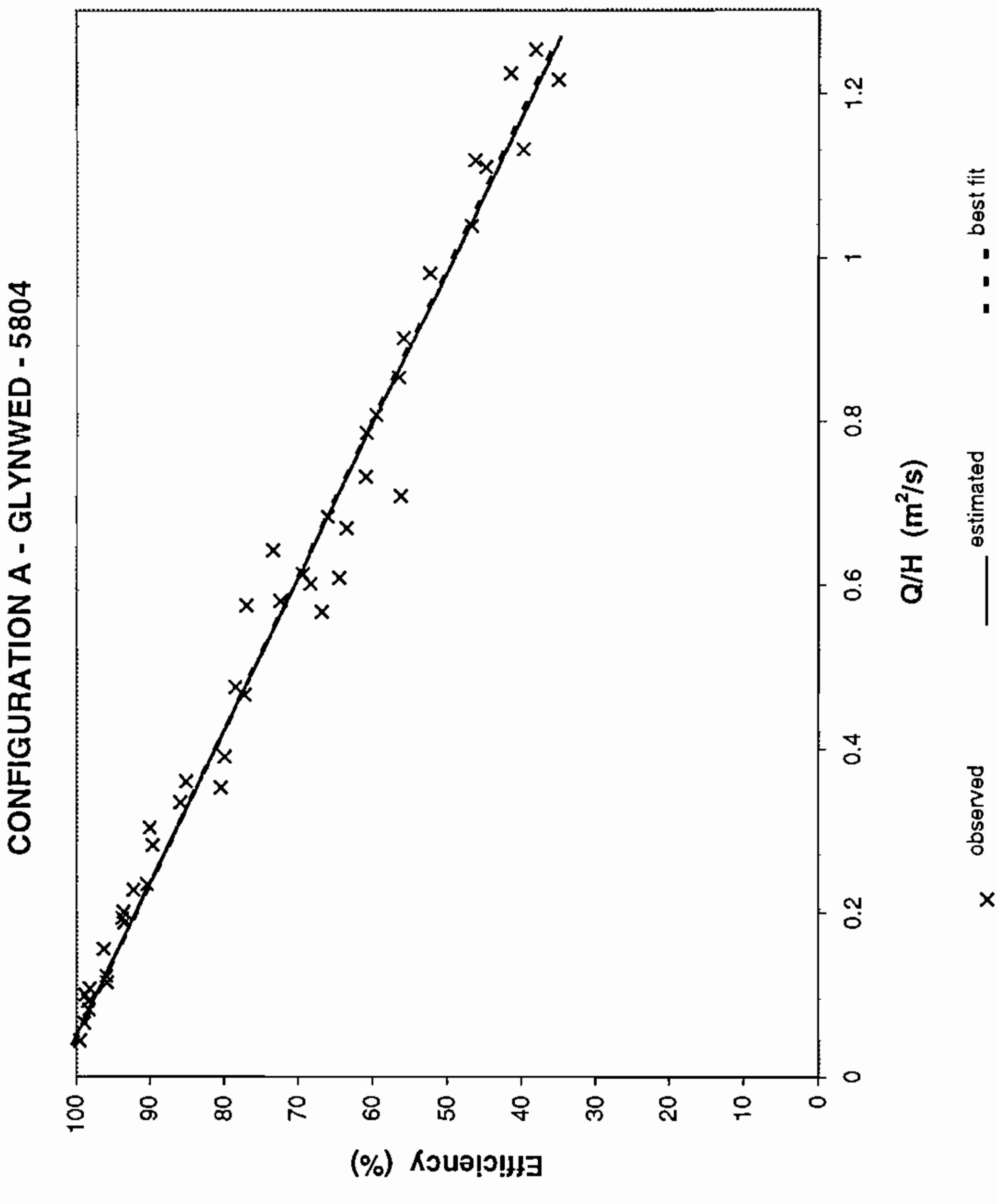
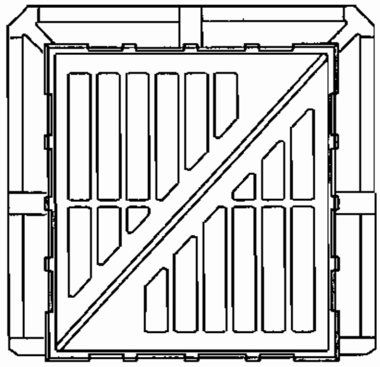


Figure 13 Validation of the predictive method for Glynwed grating (config. A)

Test	Configuration B Glynwed 5760
A (cm^2)	1936
p	0.56
n_t	8
n_l	0
n_d	1
W (m)	0.44
L (m)	0.44



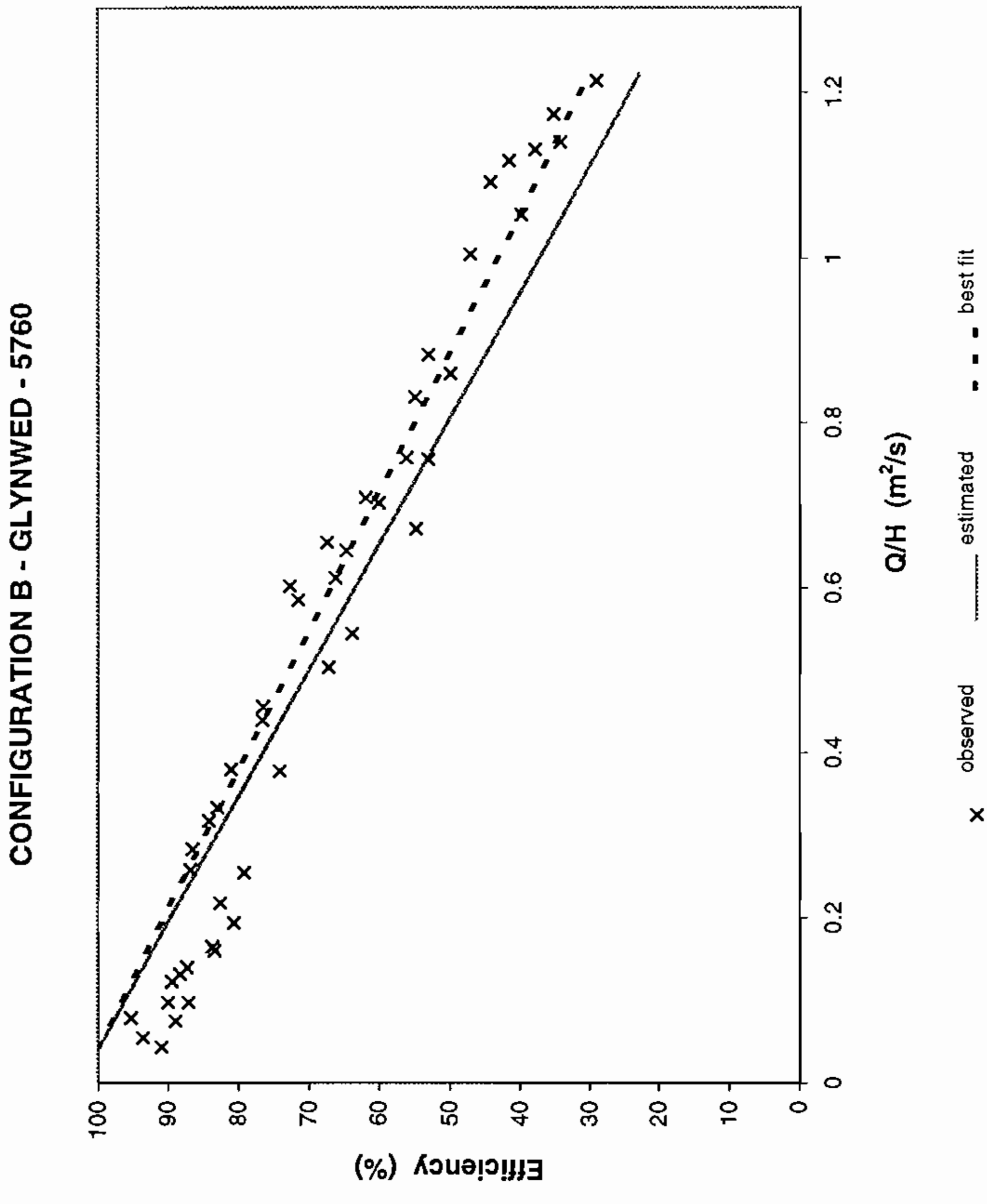
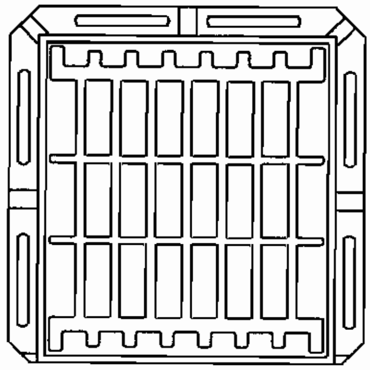


Figure 14 Validation of the predictive method for Glynwed grating (config. B)

Test	Configuration C Glynwed M13
A (cm^2)	1780
p	0.62
n_t	7
n_l	4
n_d	0
W (m)	0.4
L (m)	0.445



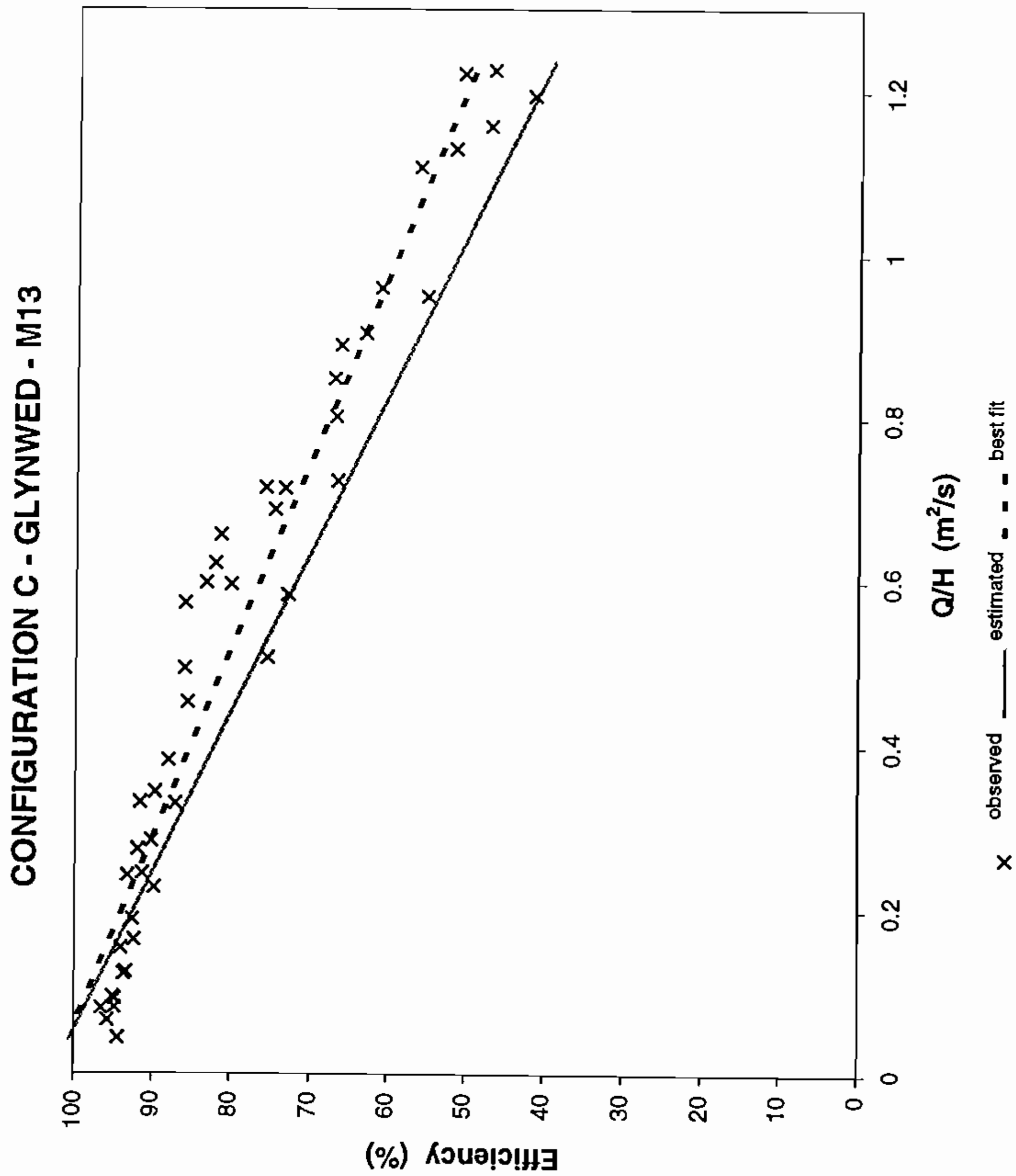


Figure 15 Validation of the predictive method for Glynwed grating (config. C)

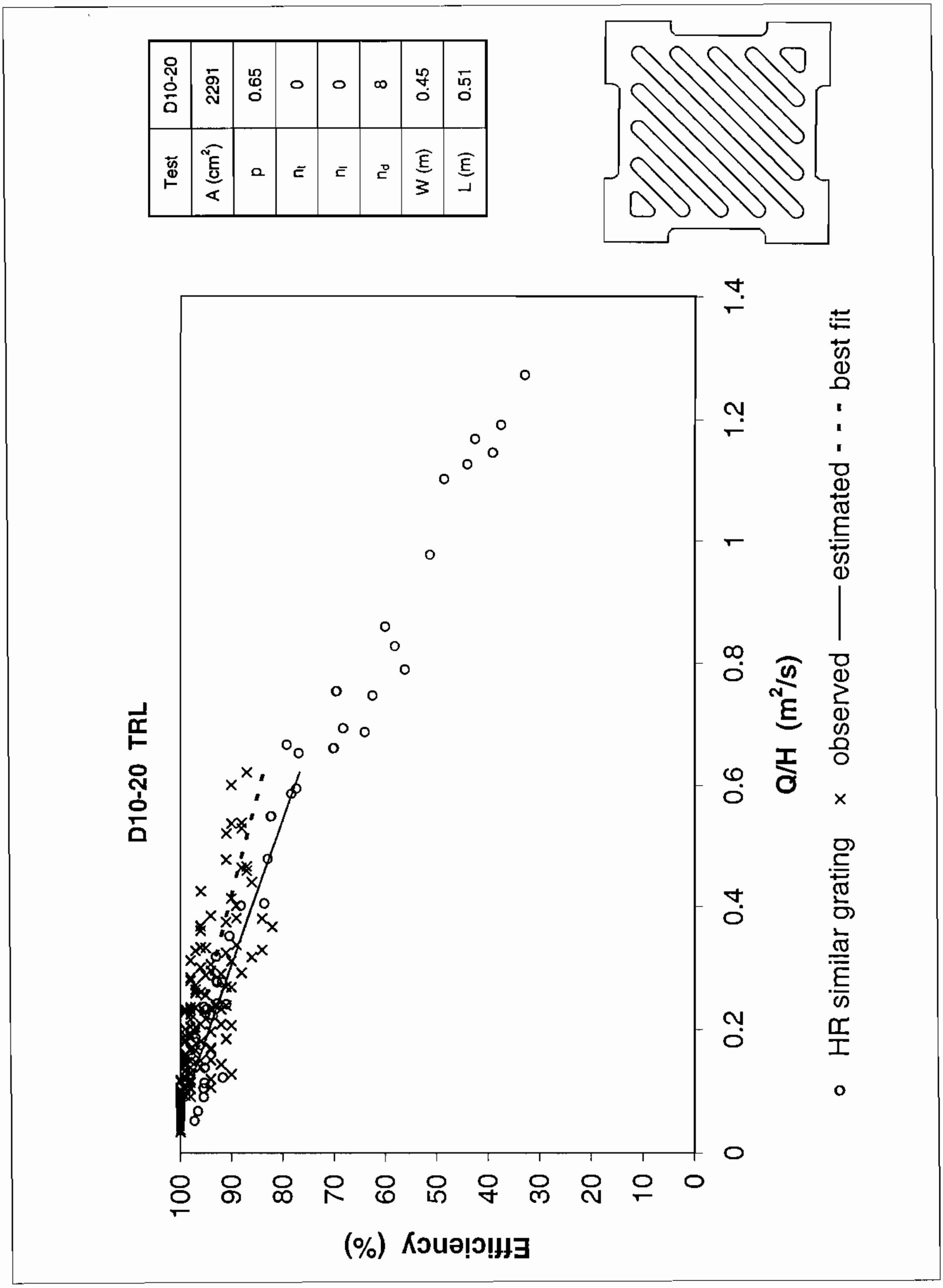
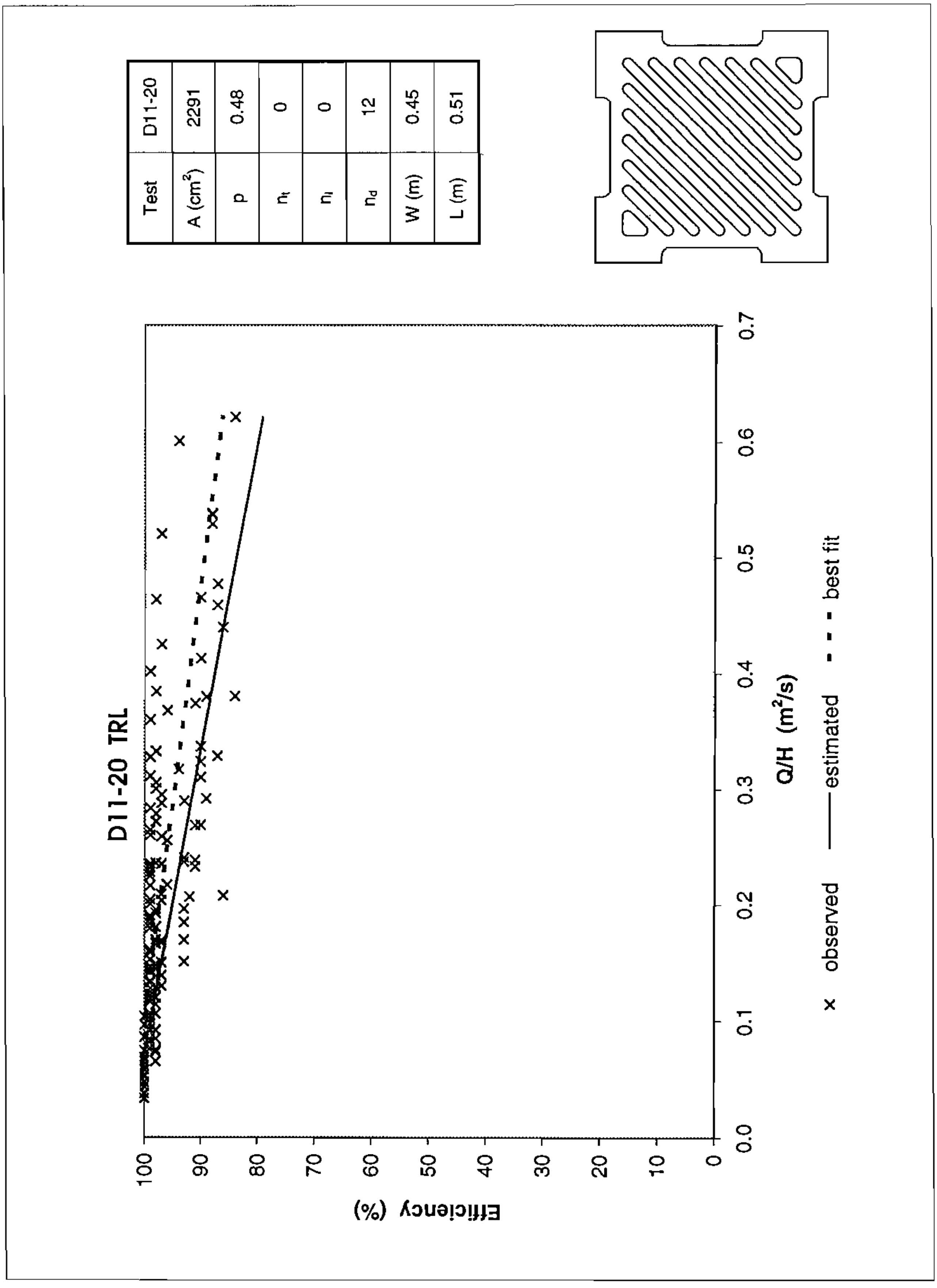
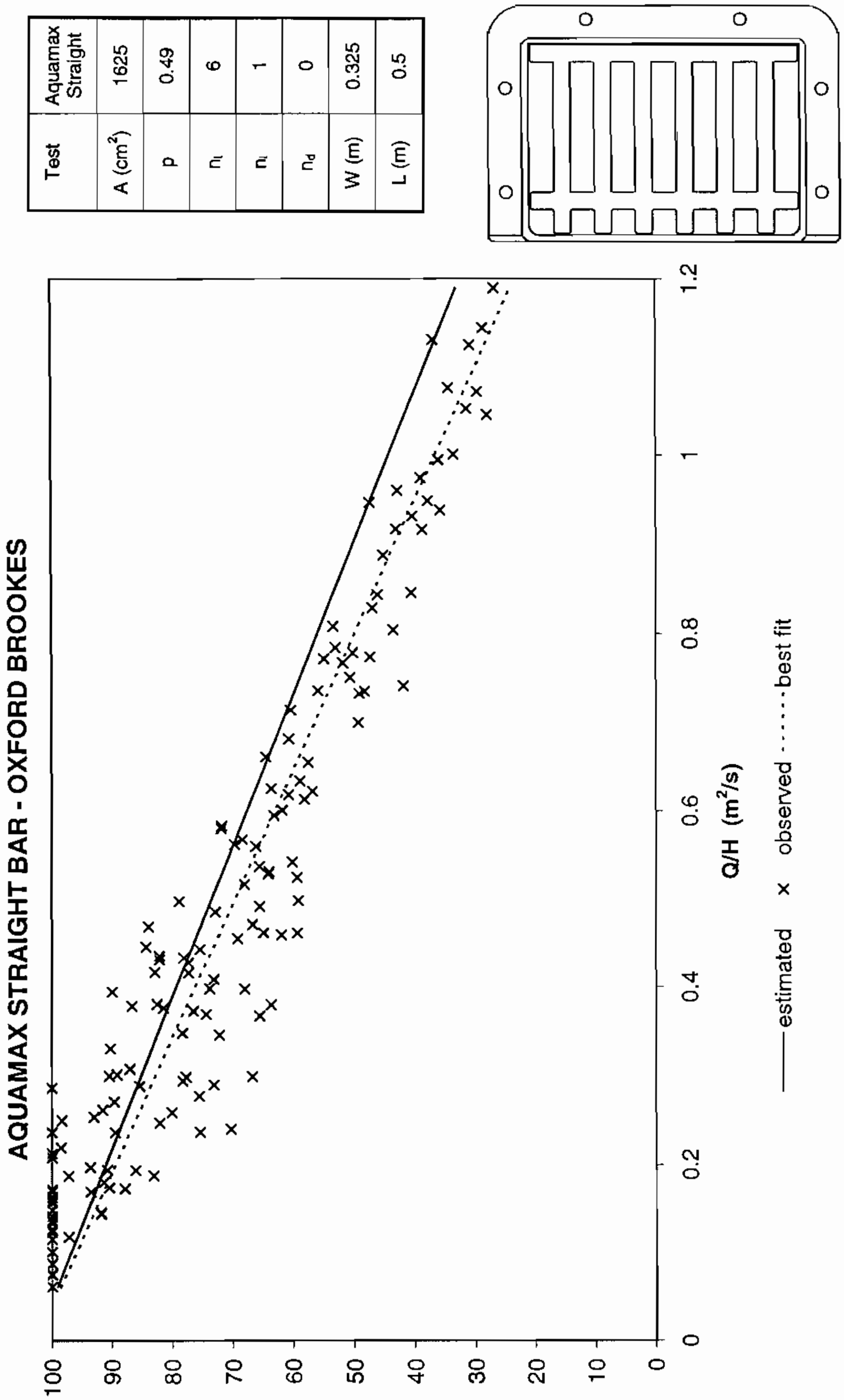


Figure 16 Validation of the predictive method for TRL data (D10-20)



Test	D11-20
A (cm²)	2291
p	0.48
n_t	0
n_l	0
n_d	12
W (m)	0.45
L (m)	0.51

Figure 17 Validation of the predictive method for TRL data (D11-20)



Test	Aquamax Straight
A (cm^2)	1625
p	0.49
n_l	6
n_t	1
n_d	0
W (m)	0.325
L (m)	0.5

Figure 18 Validation of the predictive method for Oxford Brookes University data (Aquamax Straight bar)

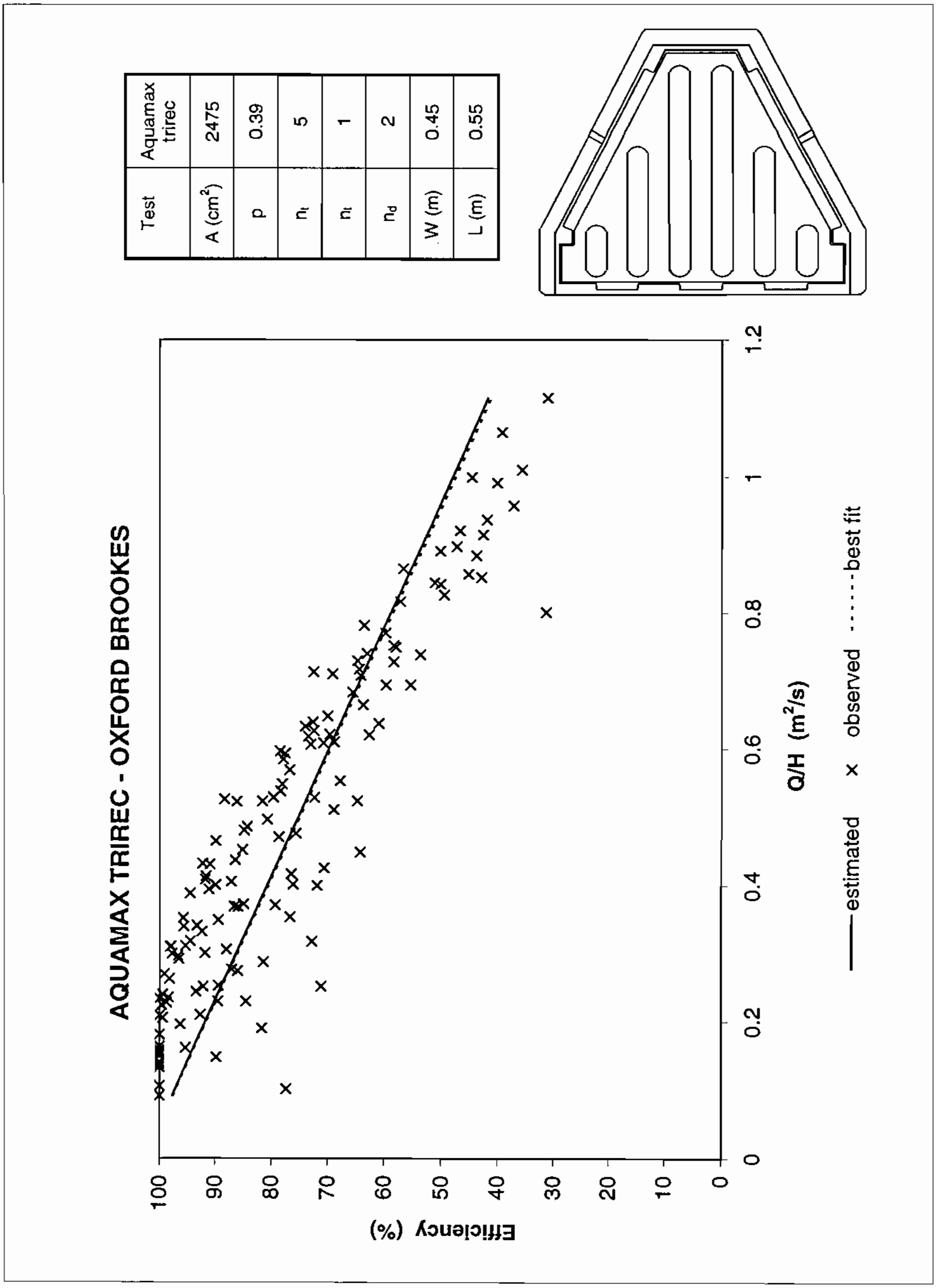


Figure 19 Validation of the predictive method for Oxford Brookes University data (Aquamax Trirec)

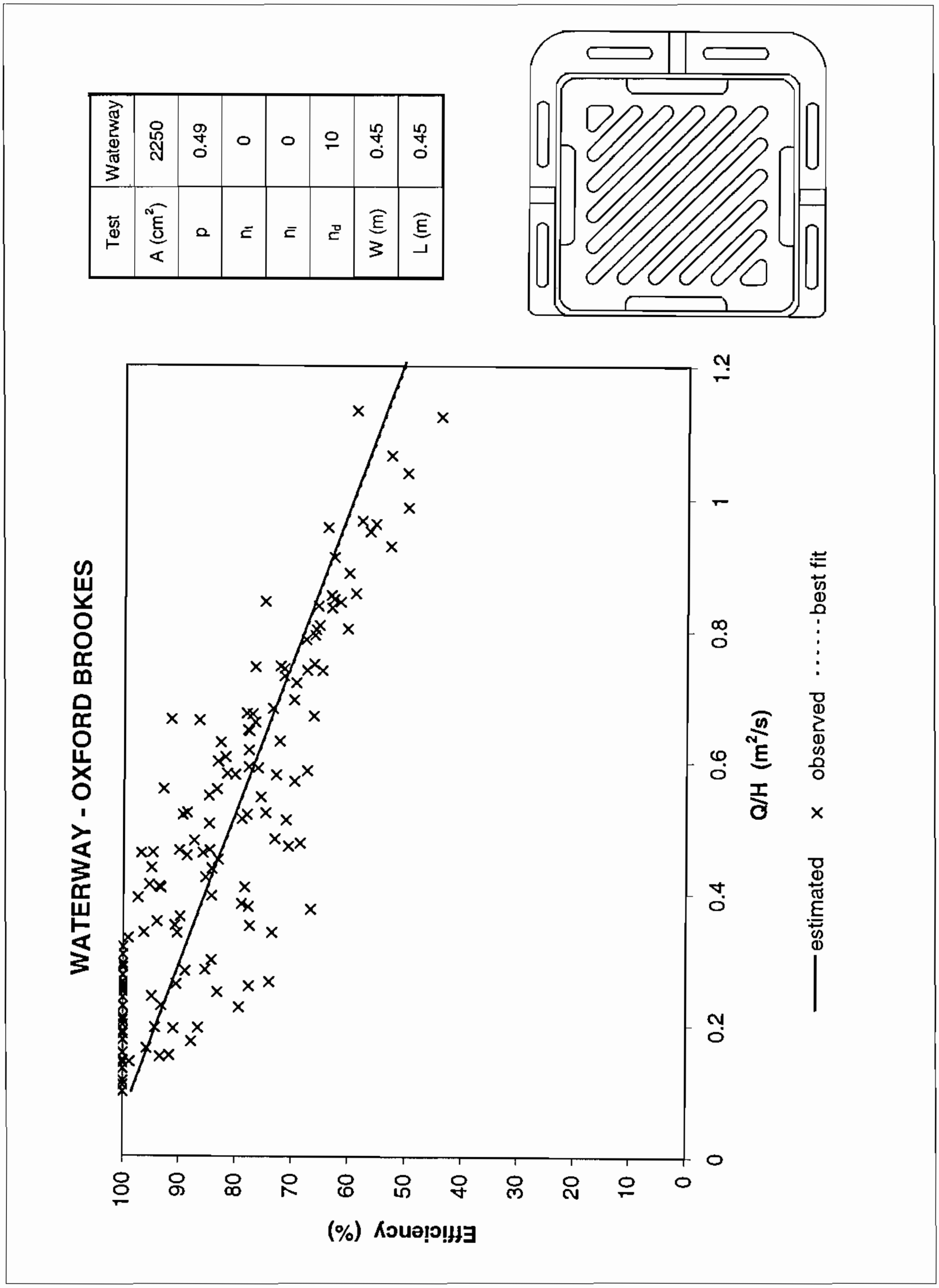


Figure 20 Validation of the predictive method for Oxford Brookes University data (Waterway)

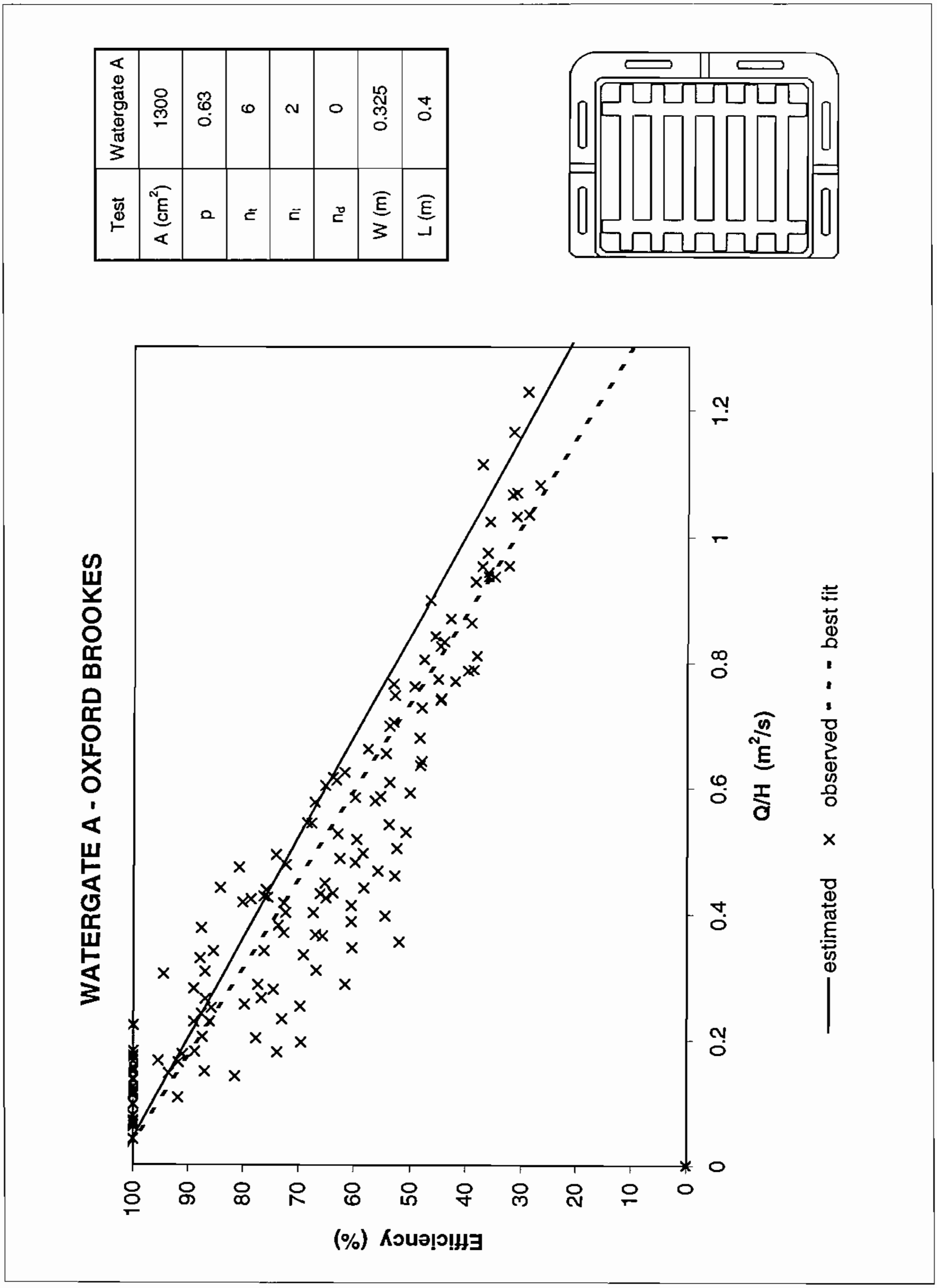


Figure 21 Validation of the predictive method for Oxford Brookes University data (Watergate A)

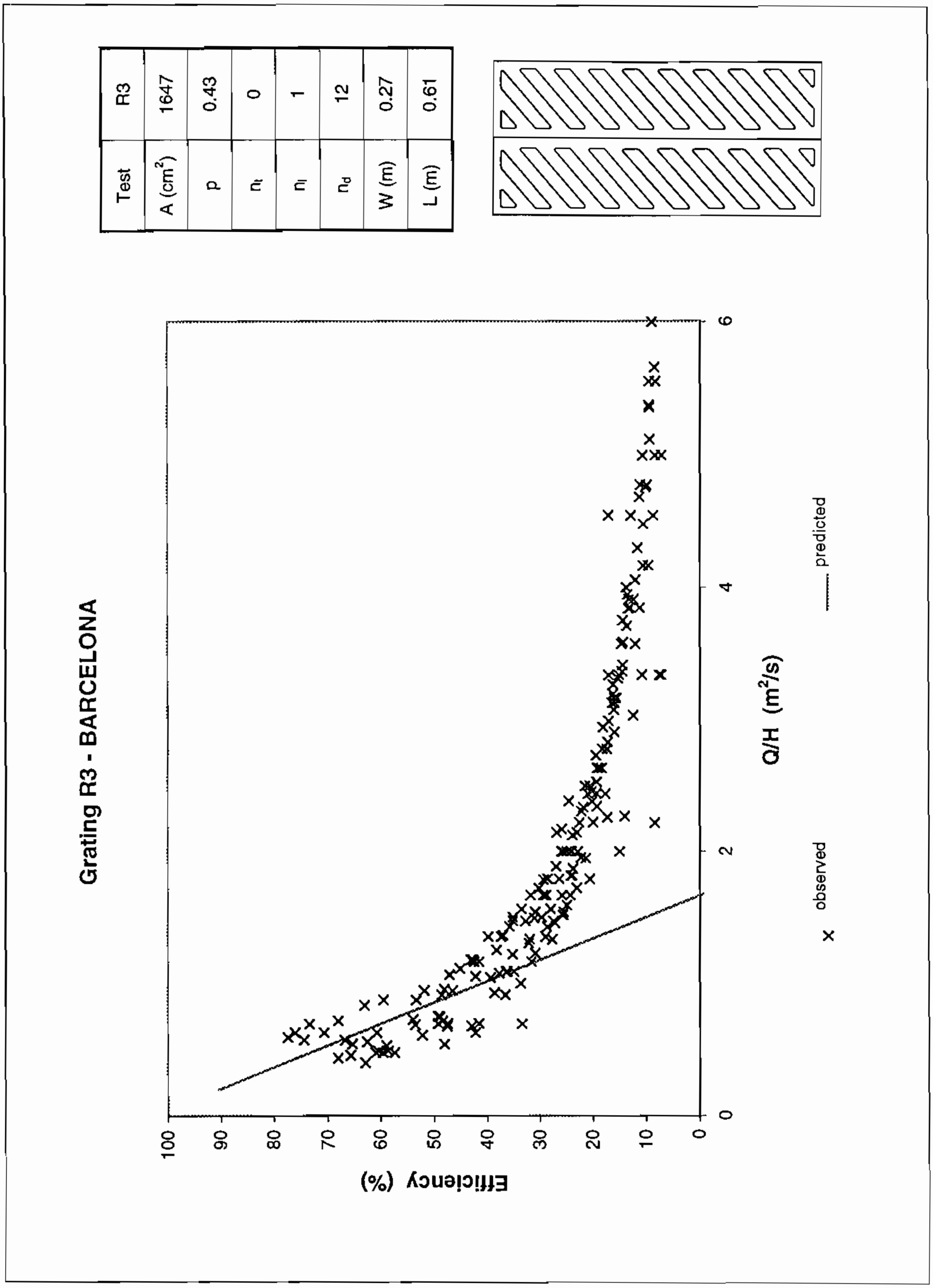


Figure 22 Validation of the predictive method for data from UPC University, Barcelona (Grating R9)

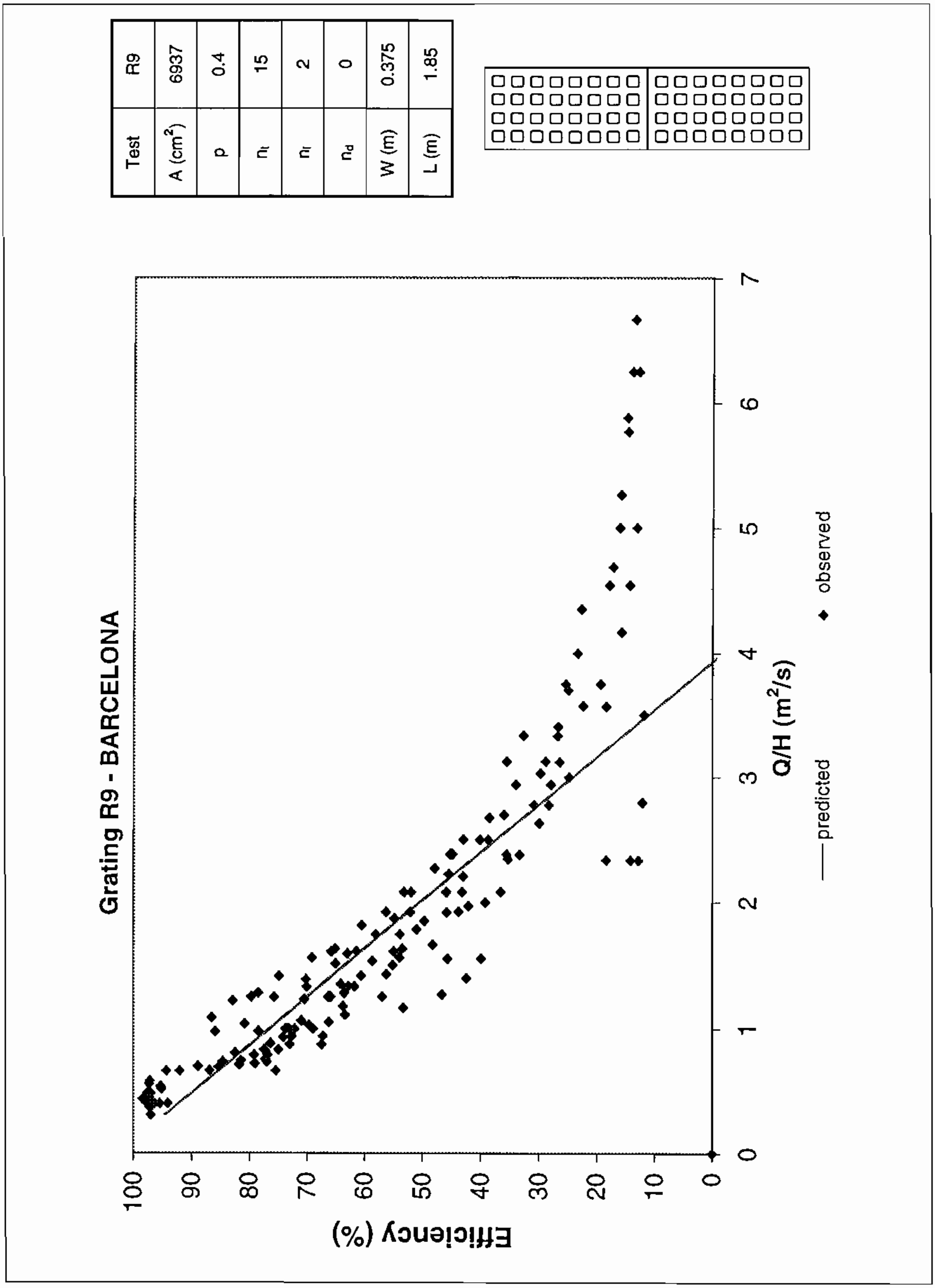


Figure 23 Validation of the predictive method for data from UPC University, Barcelona (Grating R3)

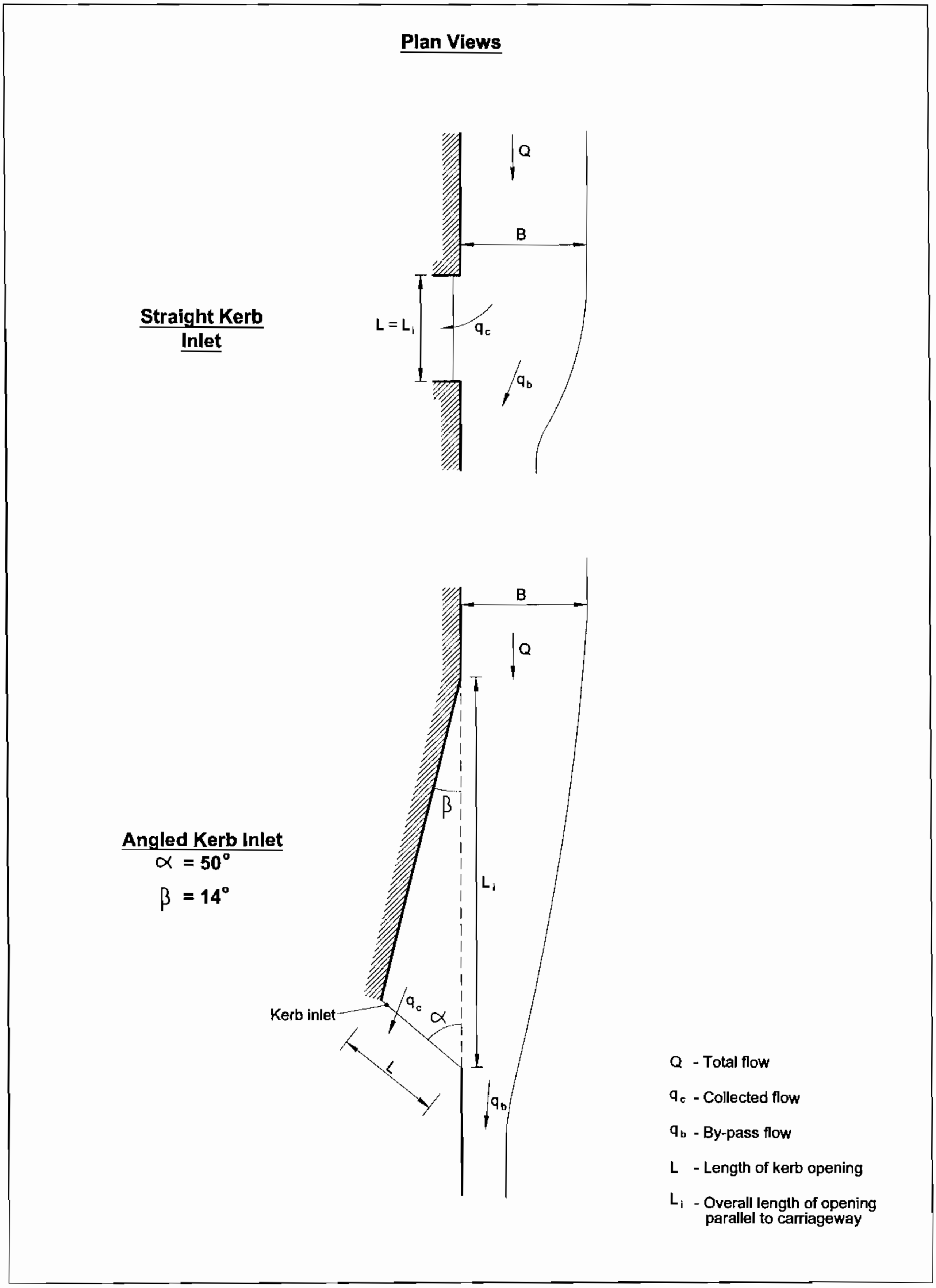


Figure 24 Schematic layout of the kerb inlets tested showing flow past the inlets

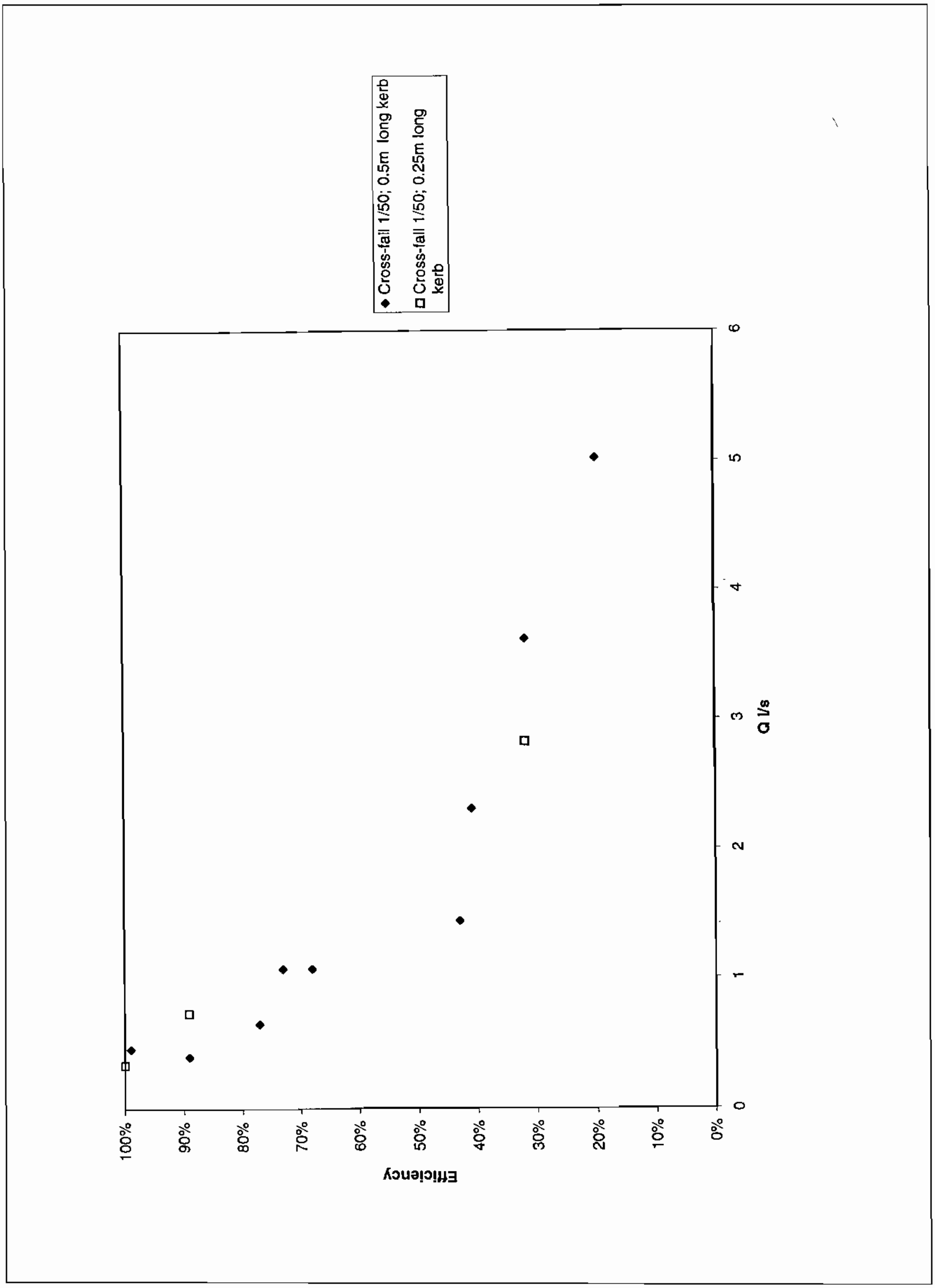


Figure 25 Illustration of the applicability of Froudian similarity to kerb inlets

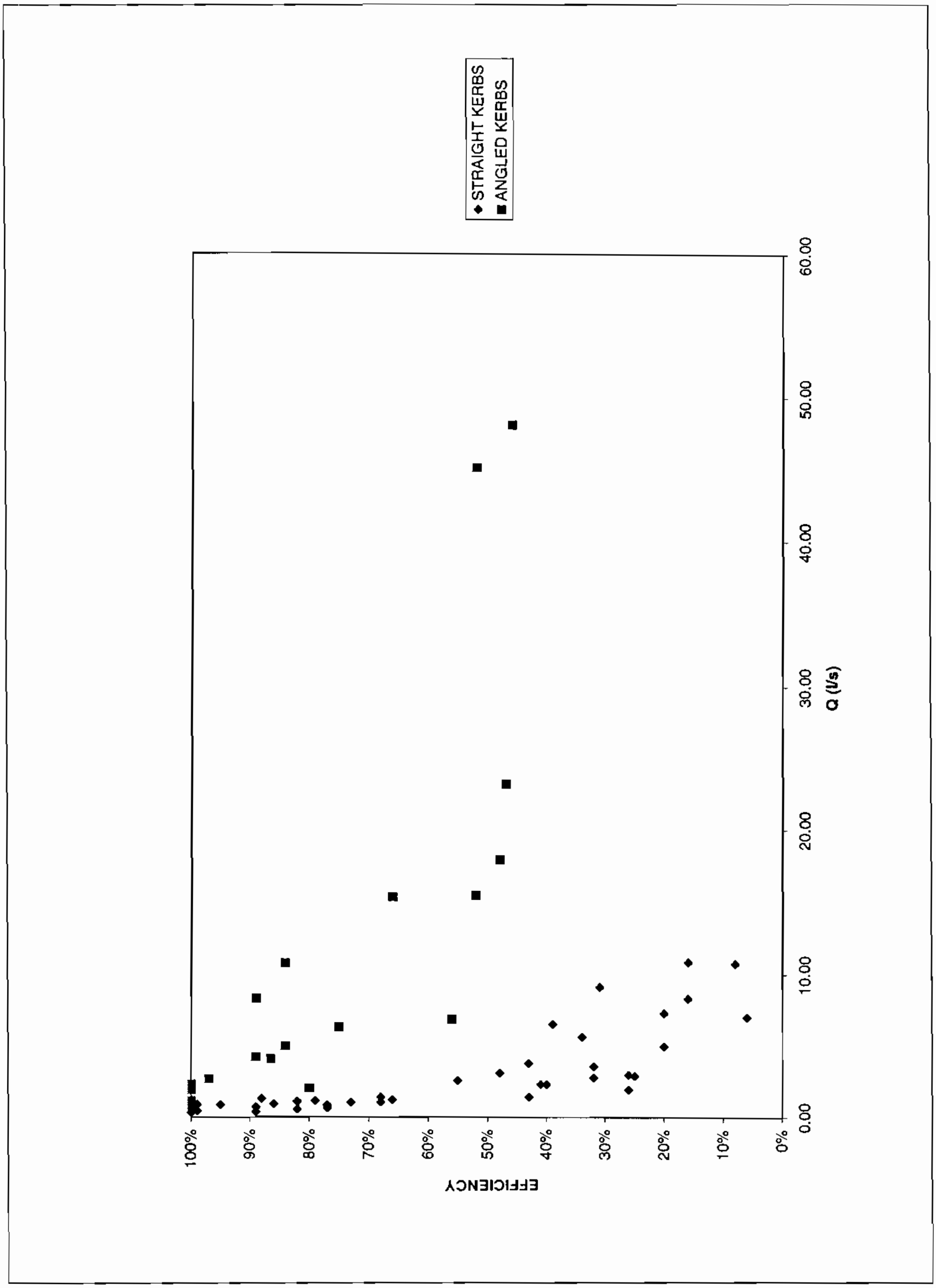


Figure 26 Kerb inlet efficiency against discharge

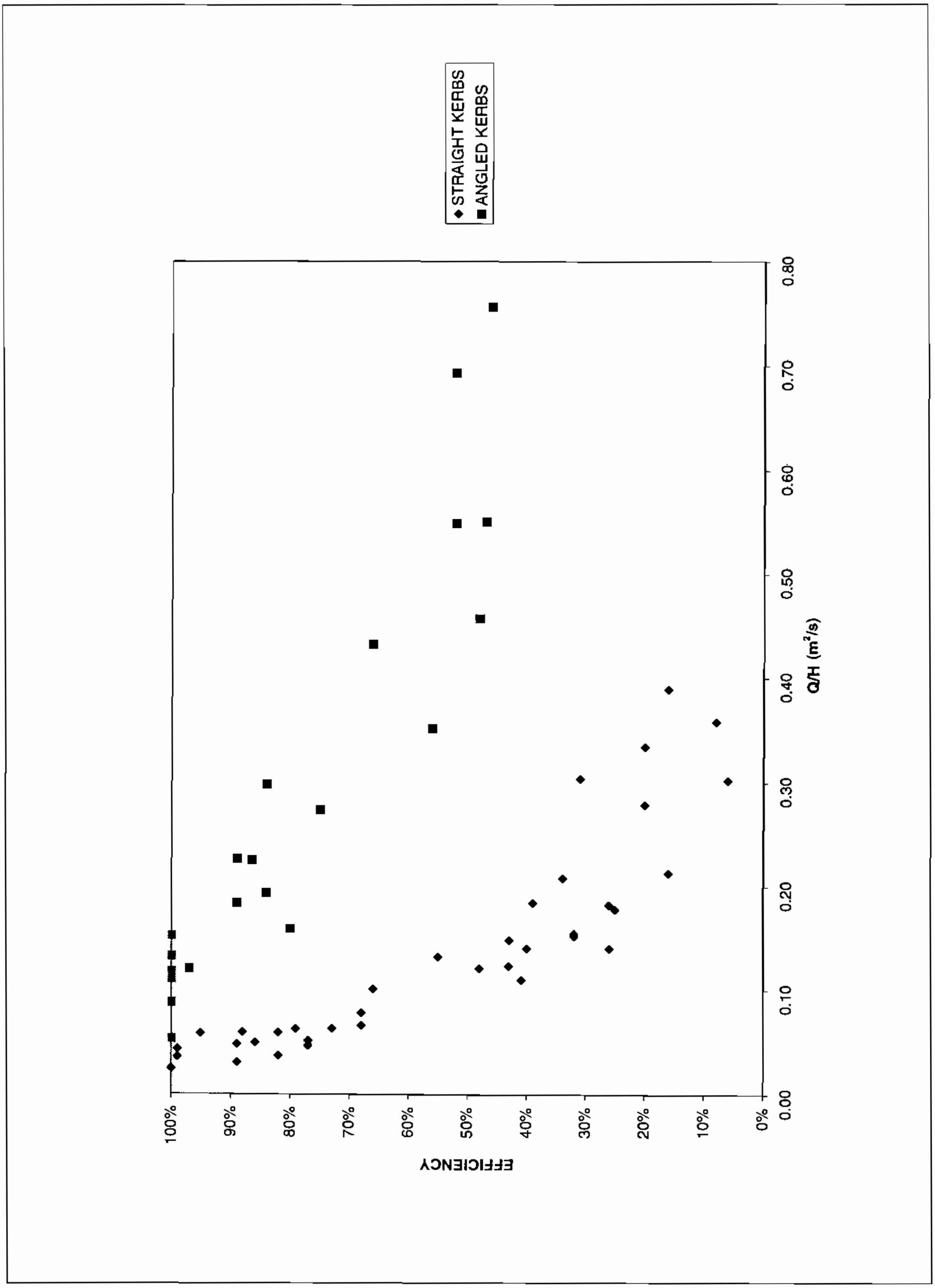


Figure 27 Kerb inlet efficiency against discharge divided by water depth

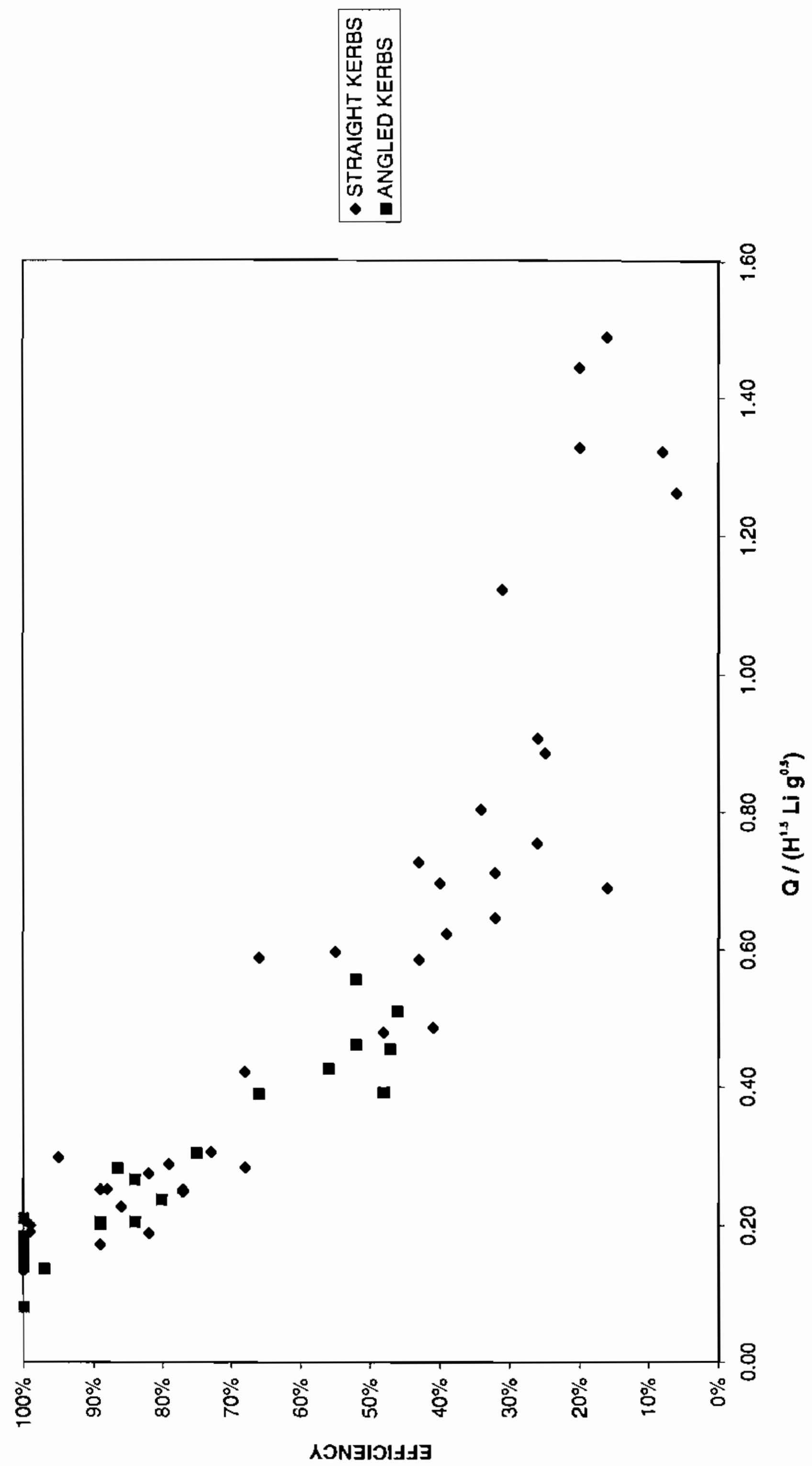


Figure 28 Kerb inlet efficiency against $Q / (H^{1.5} L_l g^{0.5})$

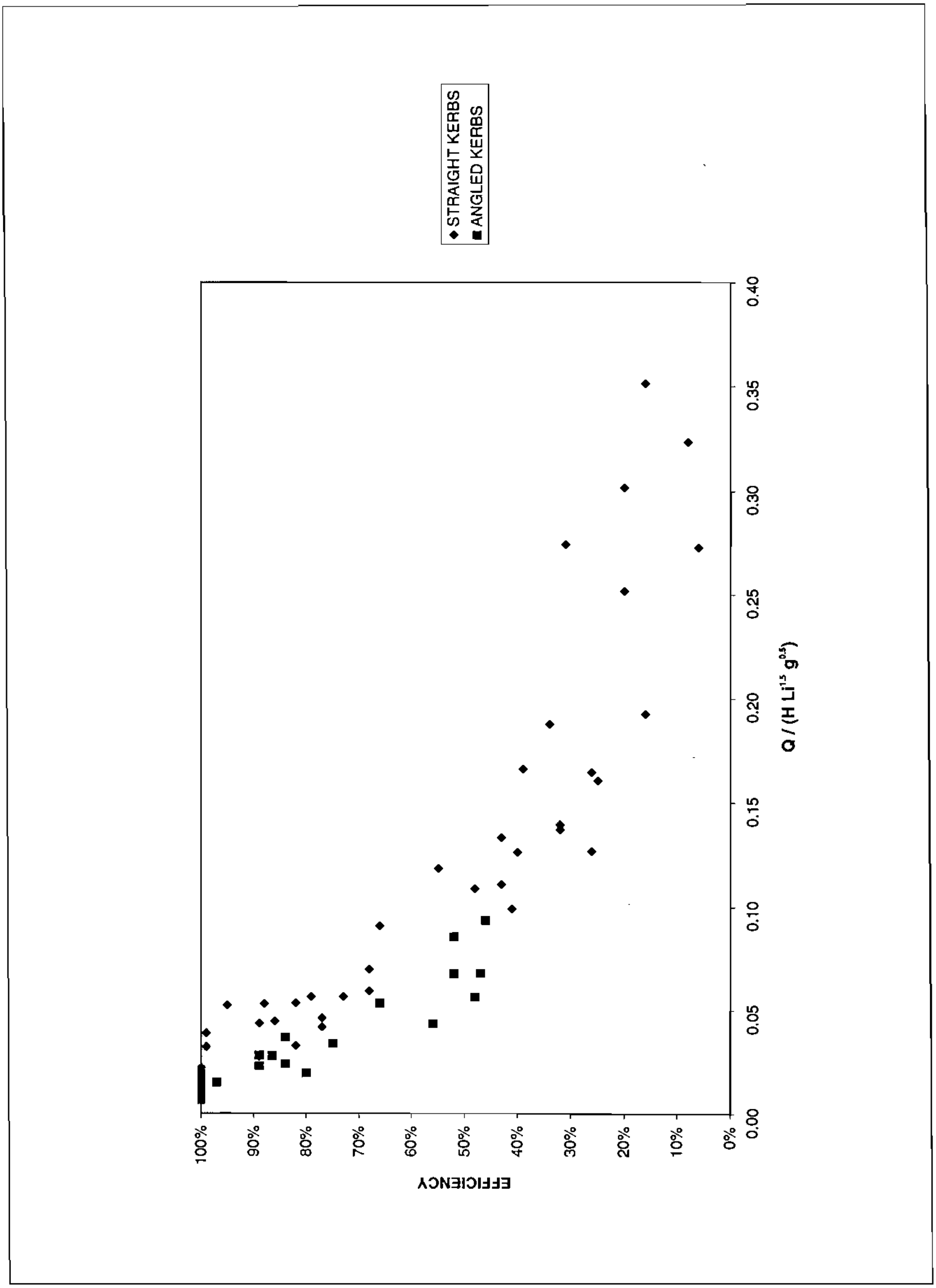


Figure 29 Kerb inlet efficiency against $Q / (H L_i^{1.5} g^{0.5})$

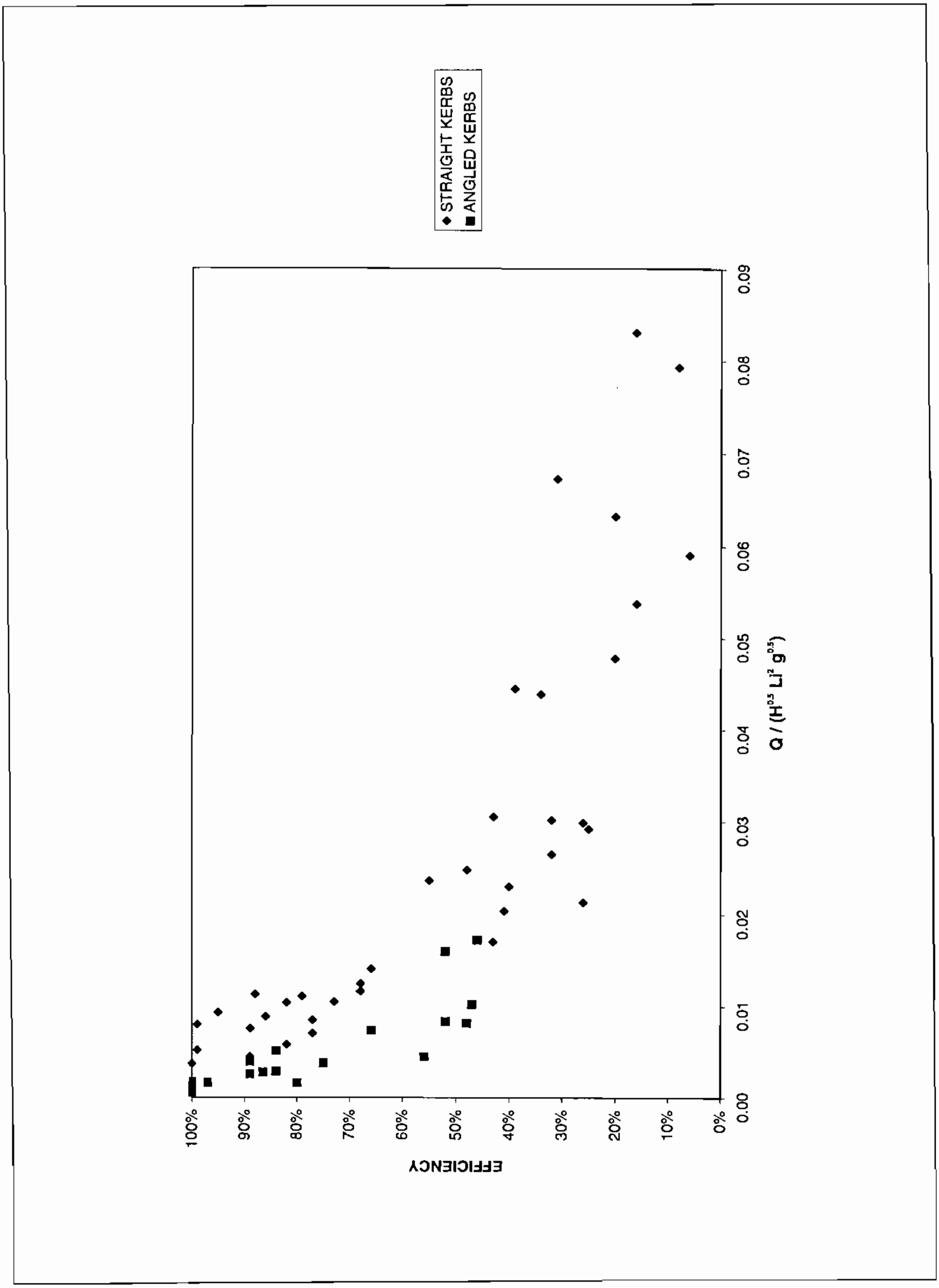


Figure 30 Kerb inlet efficiency against $Q / (H^{0.5} L_i^2 g^{0.5})$

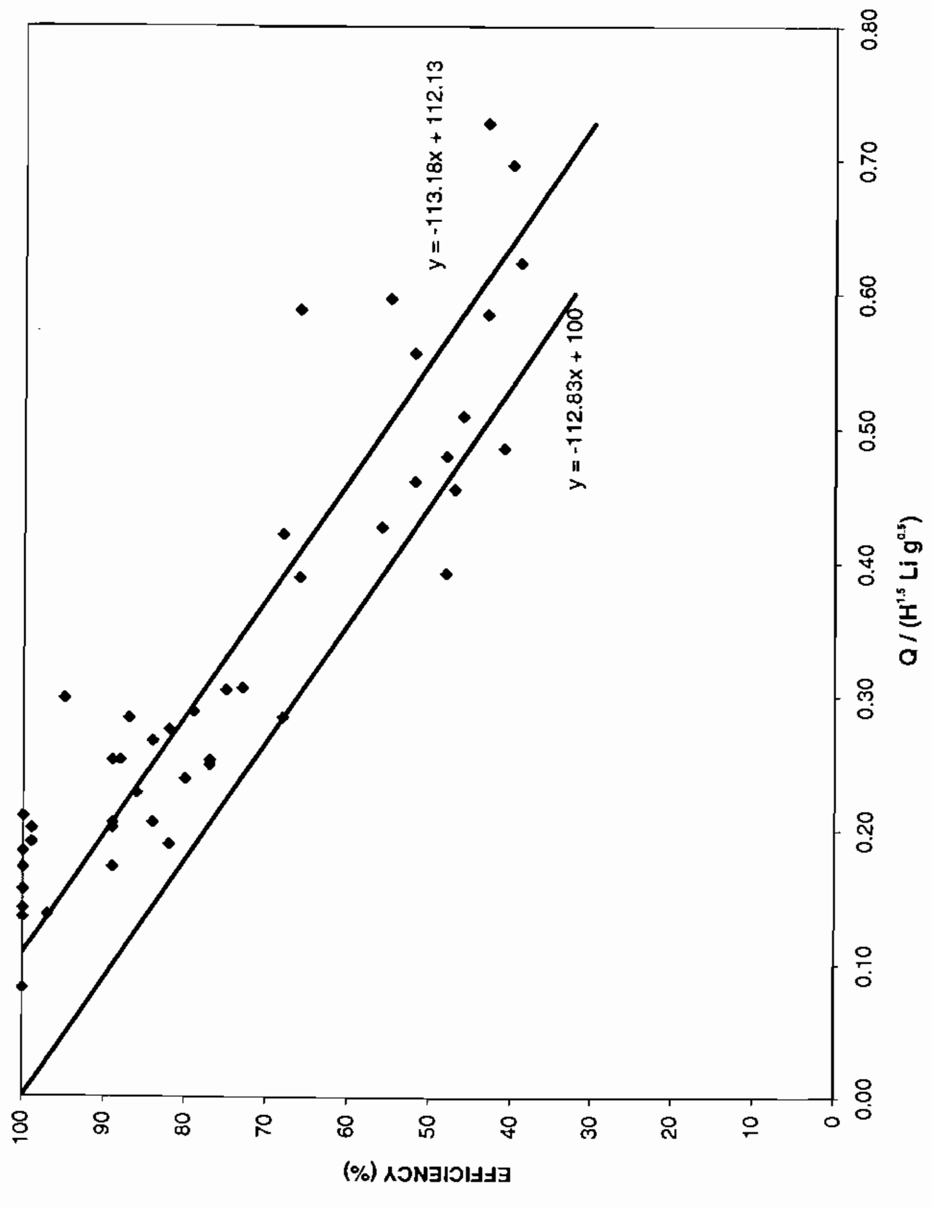


Figure 31 Best fit and design equation for kerb inlets

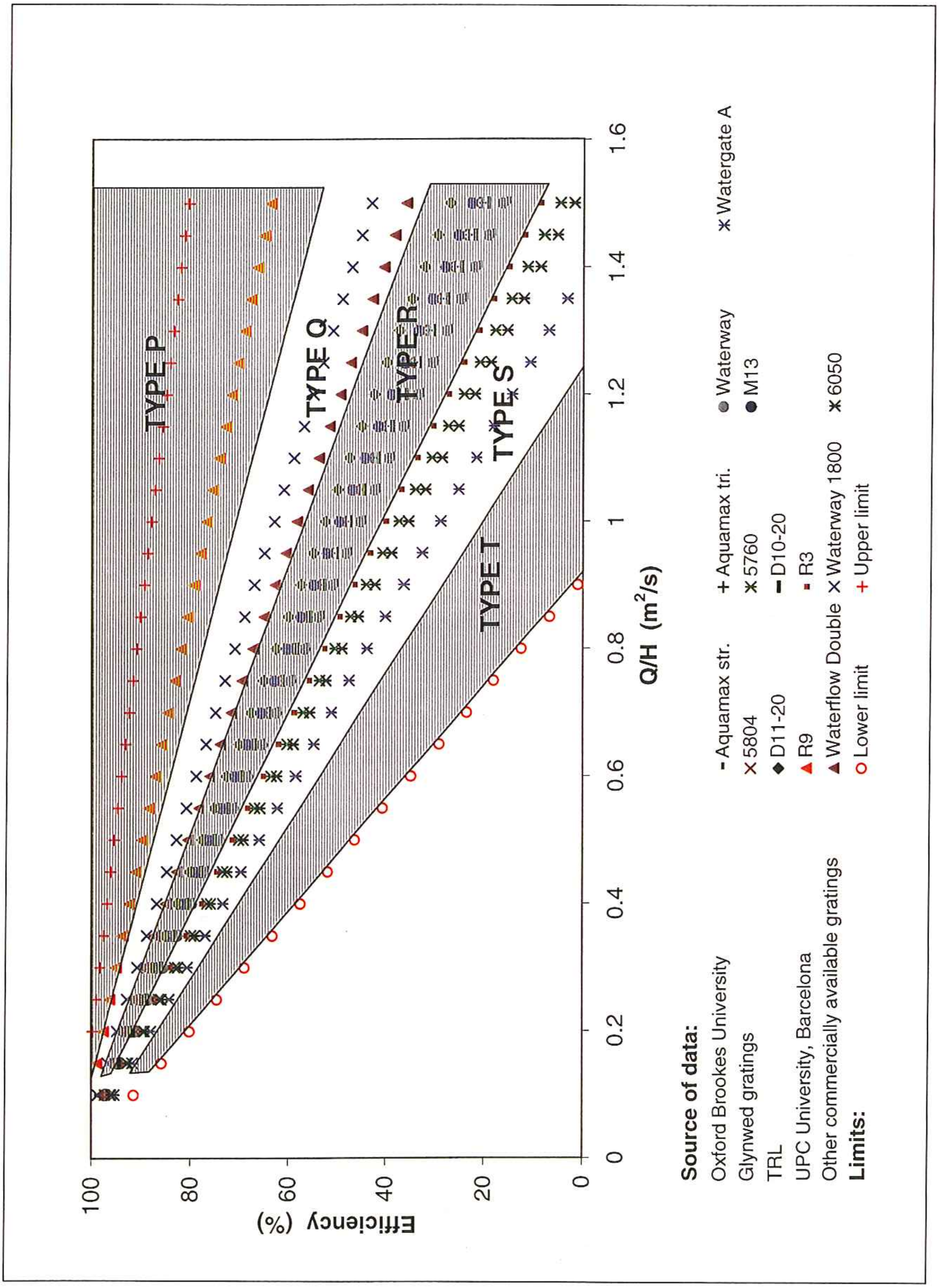


Figure 32 Division of gratings into types depending on their hydraulic capacity

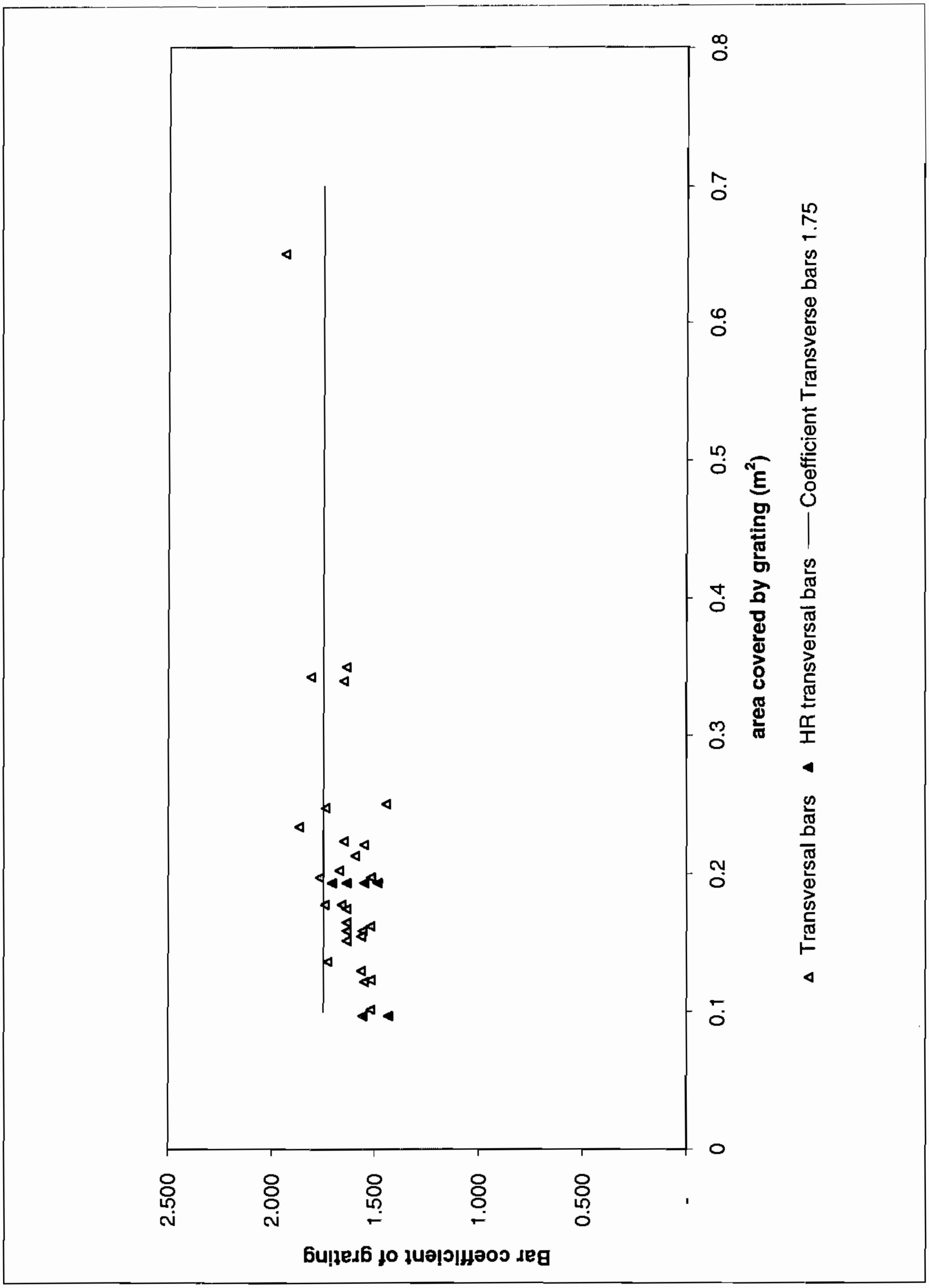


Figure 33 Data on values of bar coefficient for gratings with transverse bars

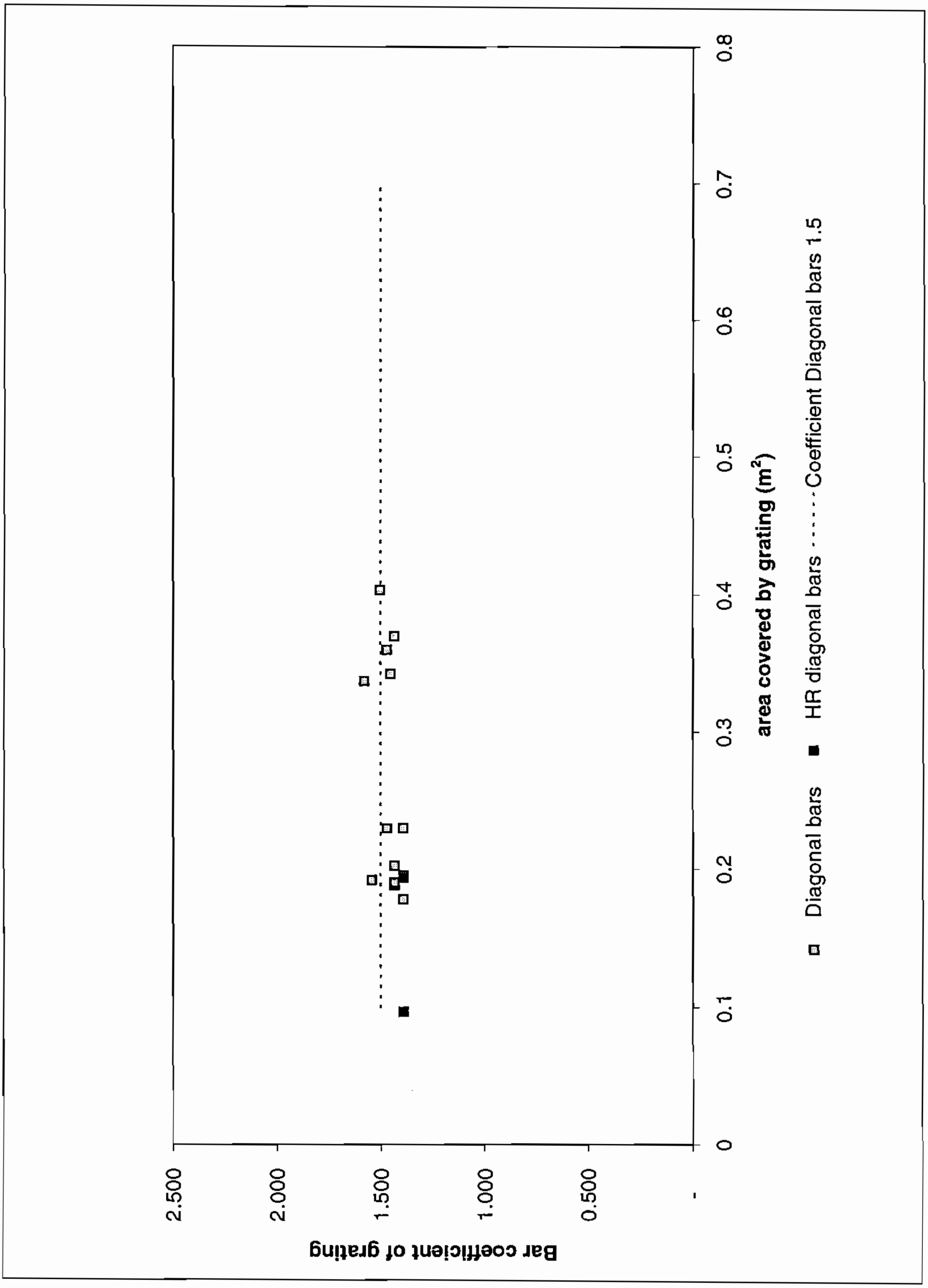


Figure 34 Data on values of bar coefficient for gratings with diagonal bars

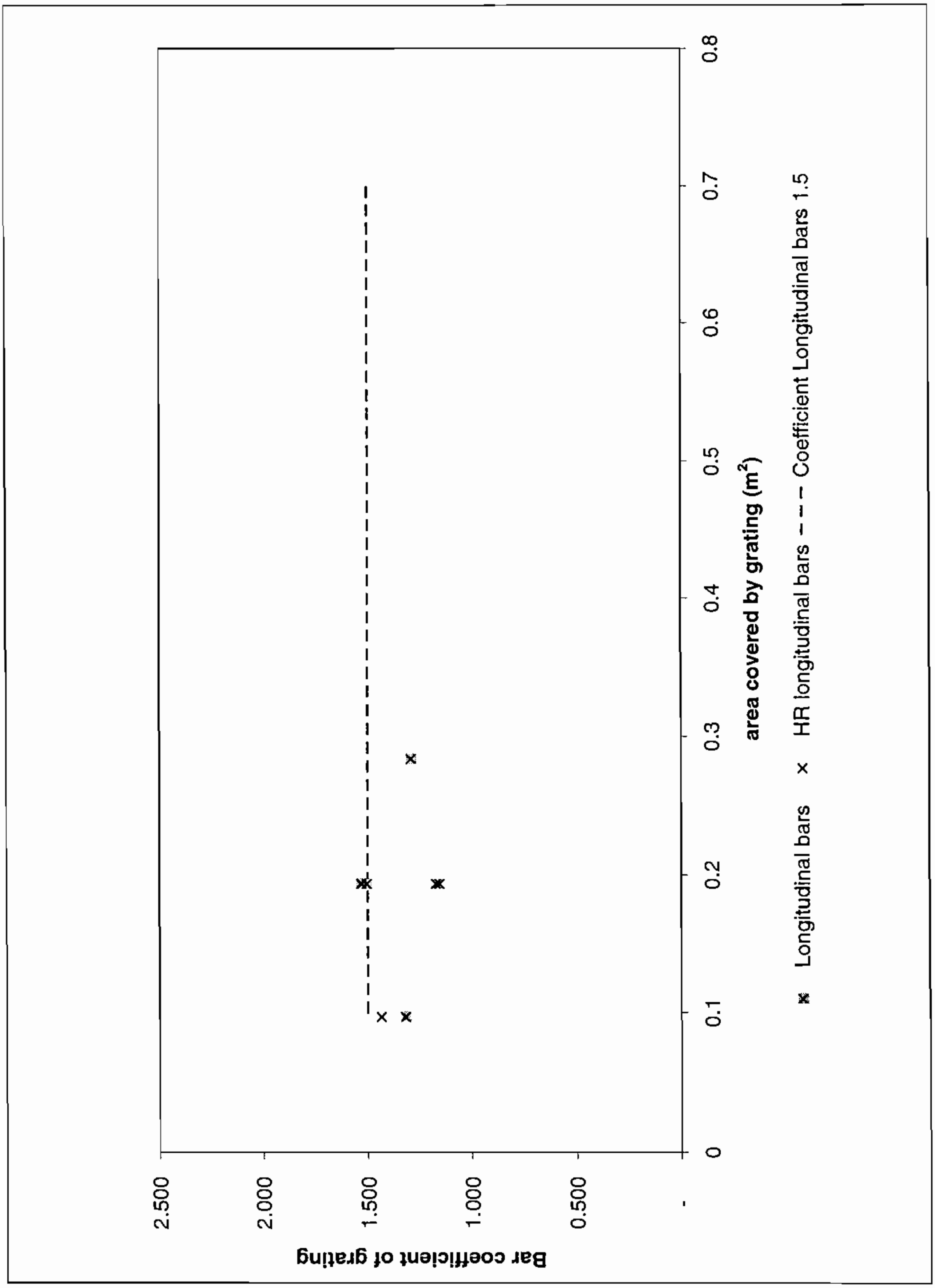


Figure 35 Data on values of bar coefficient for gratings with longitudinal bars

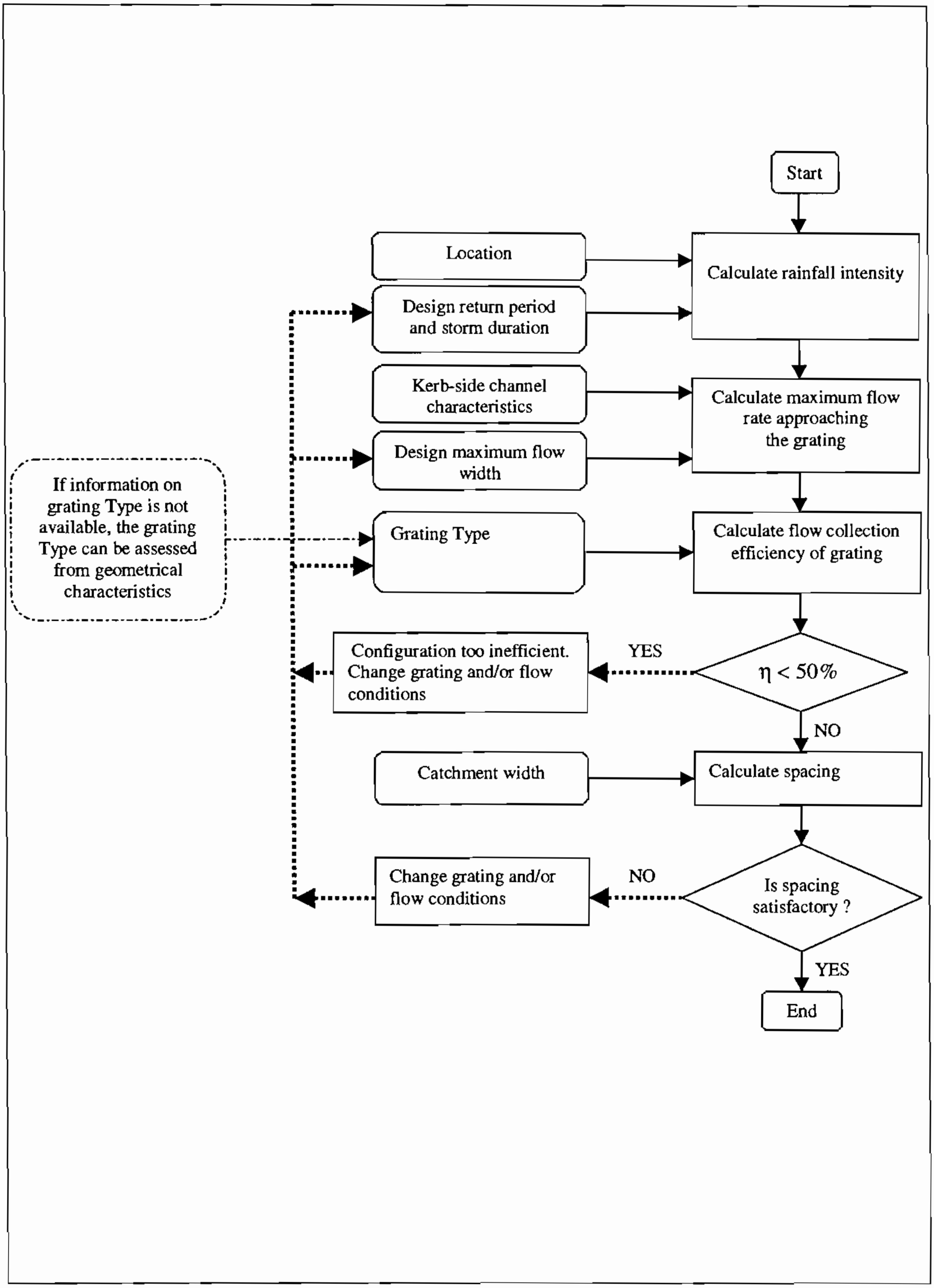


Figure 36 Flow chart showing overall steps for determining the spacing of road gullies

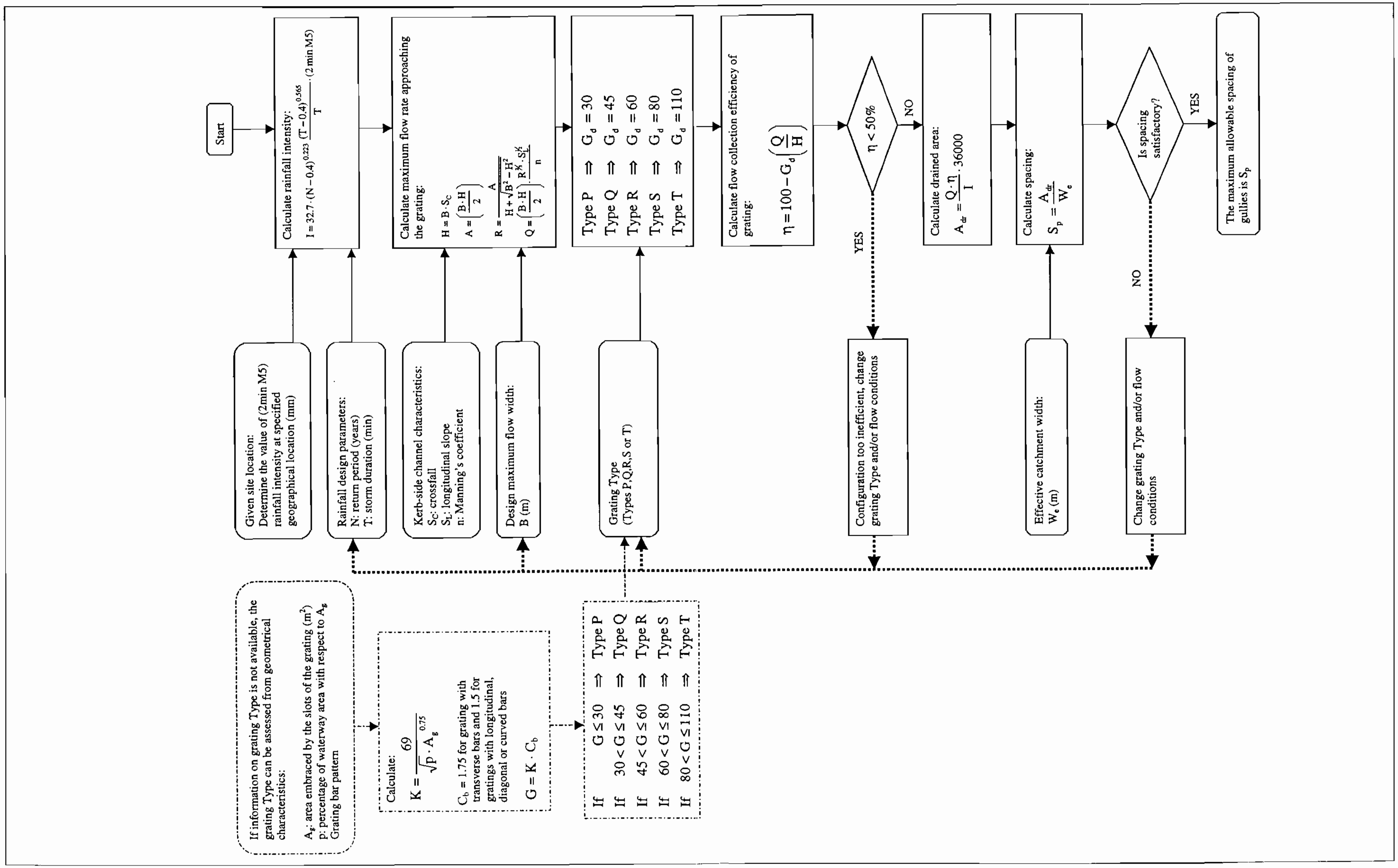


Figure 37 Flow chart showing detailed steps for determining the spacing of road gullies

Plates

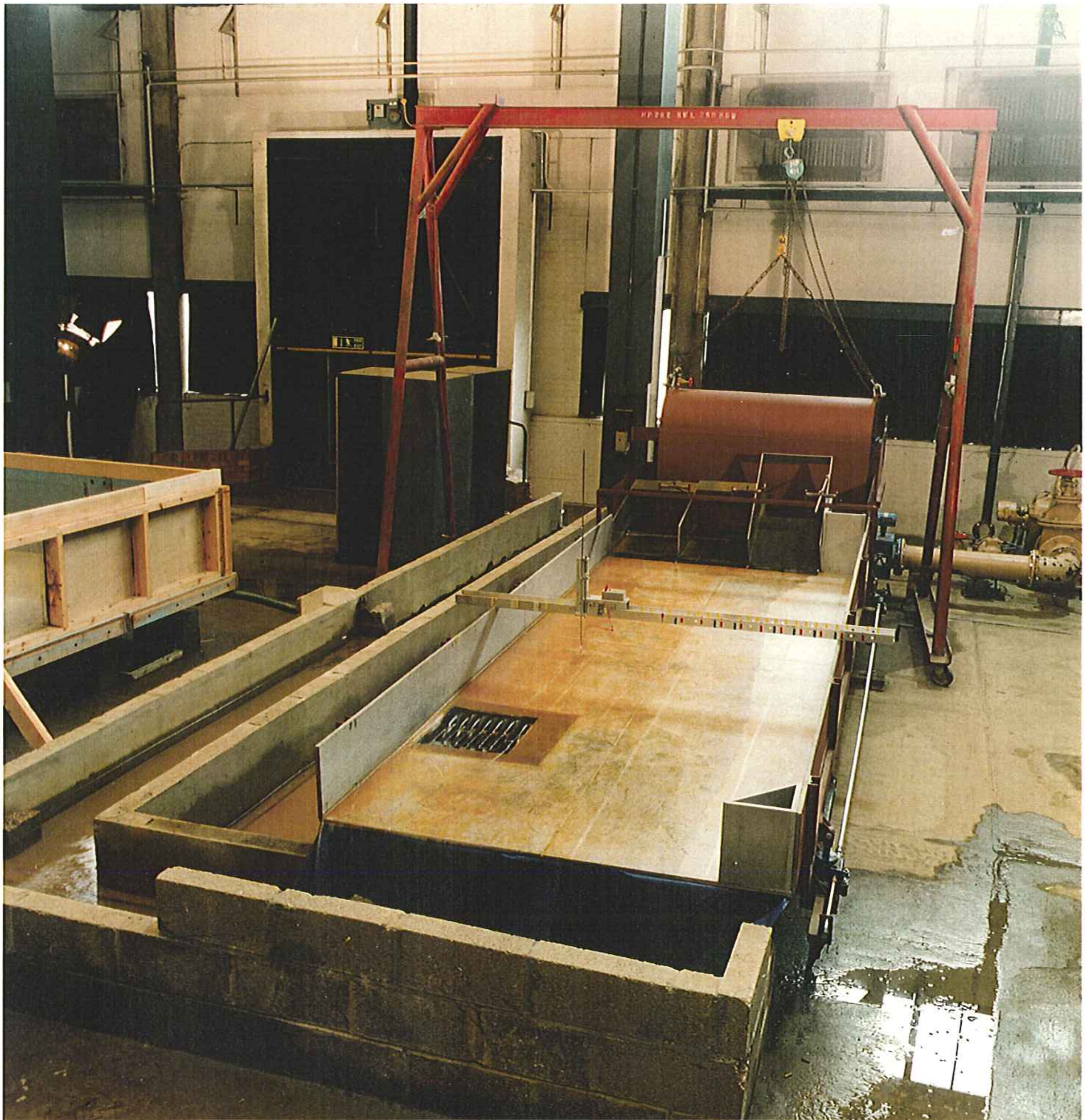


Plate 1 View of the test rig

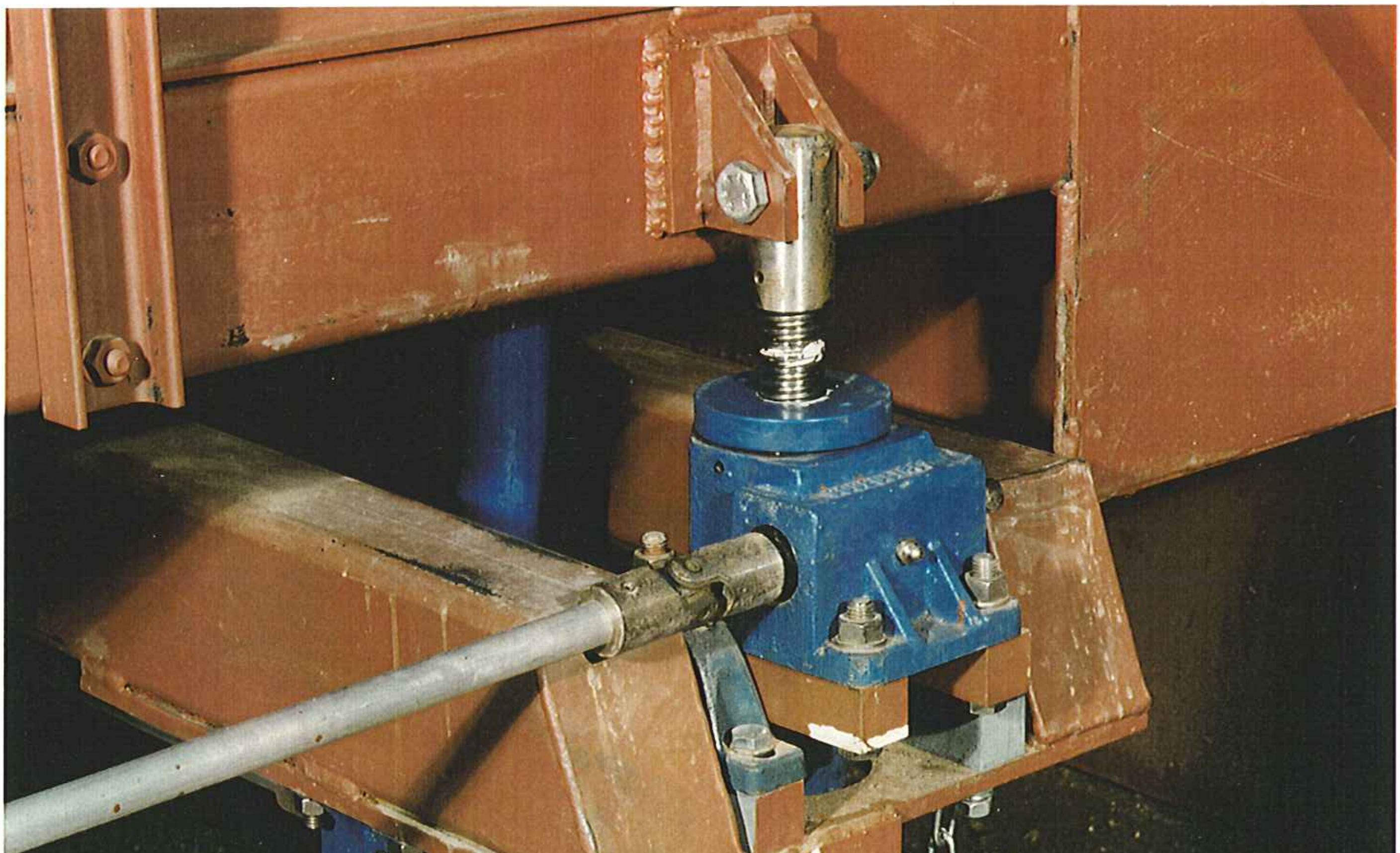


Plate 2 View of the system of jacks (top jack for the cross-fall, bottom jack for the gradient)

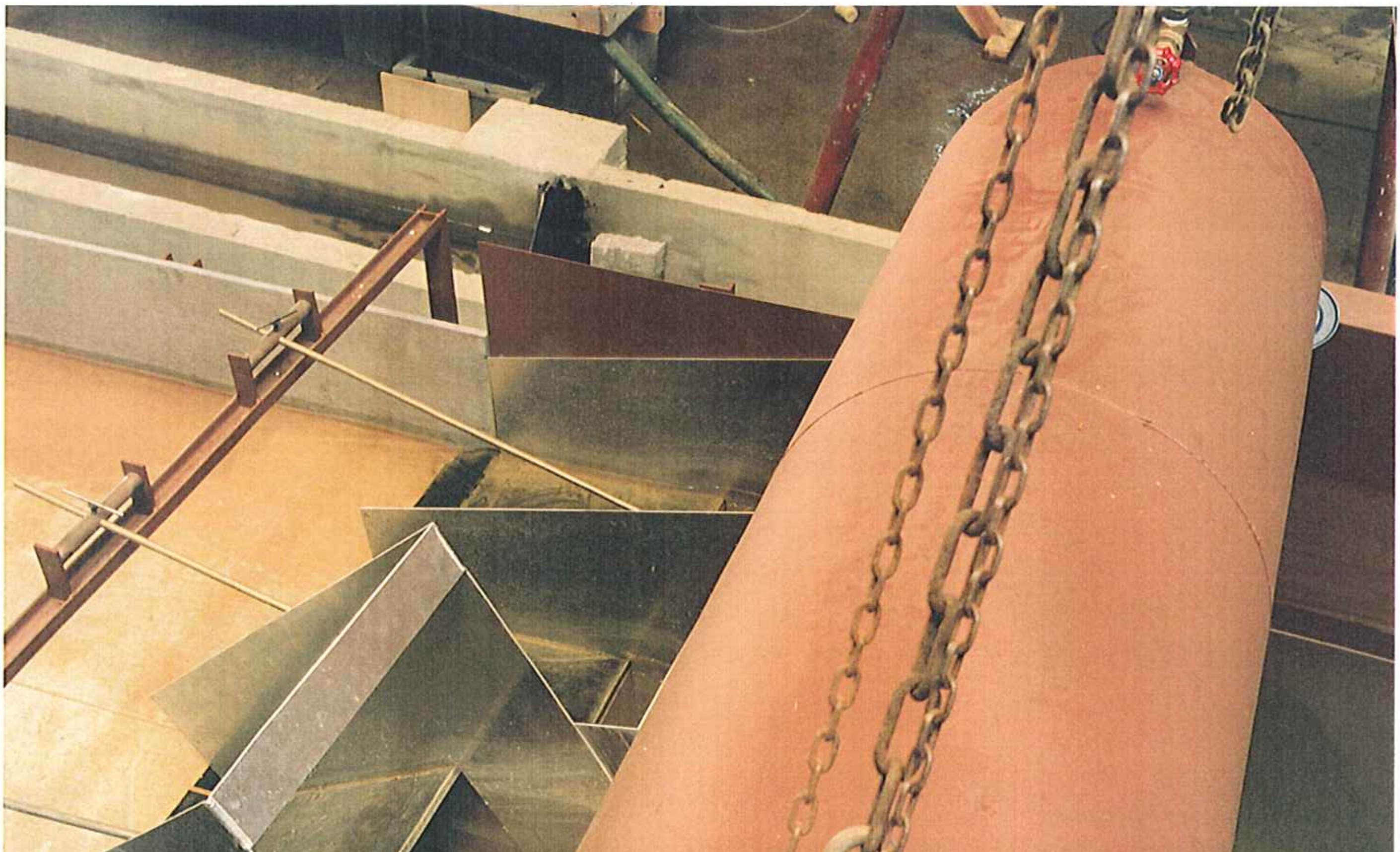


Plate 3 View of the siphon and the control gates

Plate 4 View of the channels for the by-passing flow and the collected flow

Plate 5 View of test rig showing kerb inlet

Plate 6 Straight kerb inlet, 0.5m long

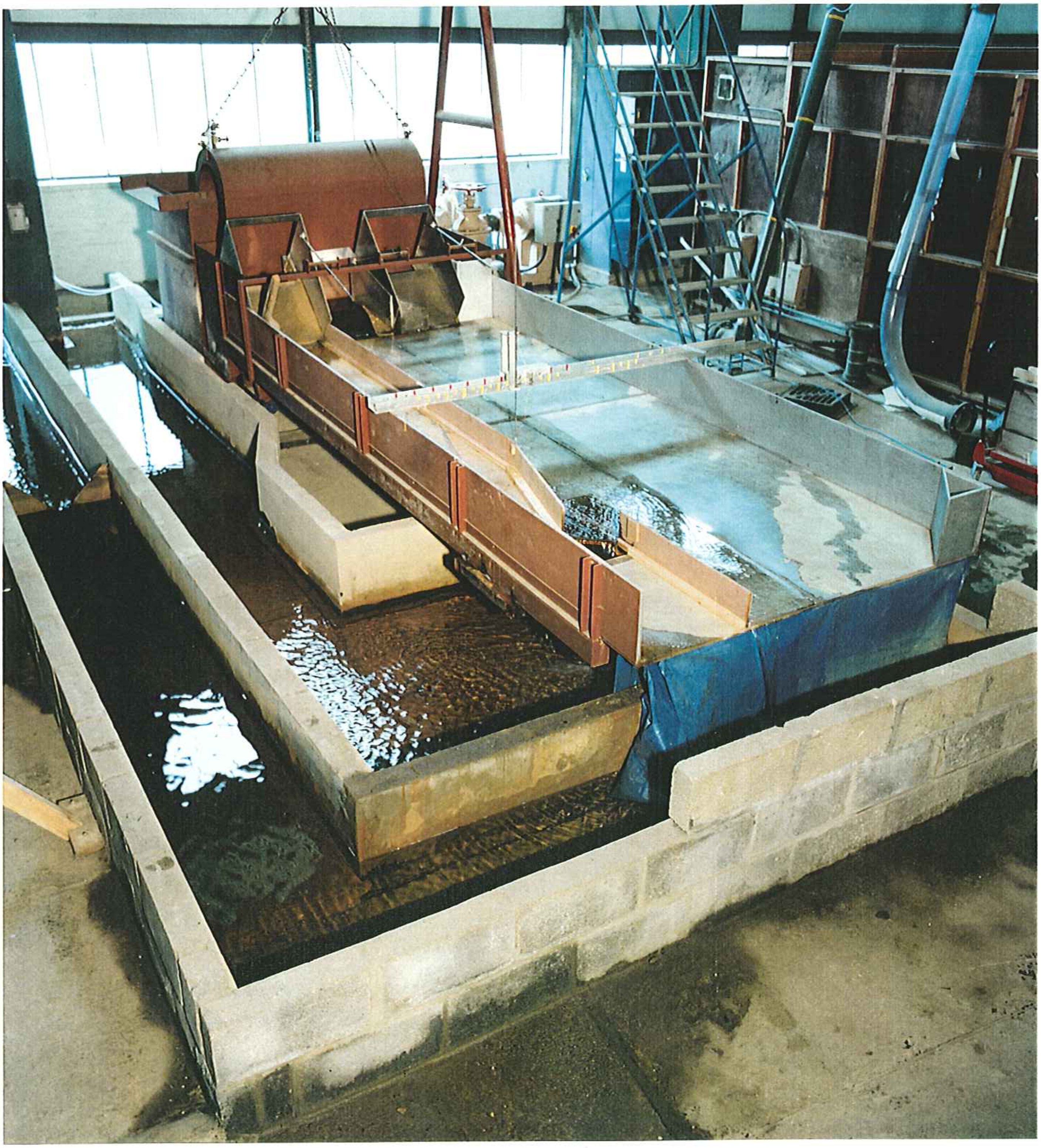


Plate 7 Angled kerb inlet, 0.25m long

Appendices

Appendix A

Data from HR tests

CONFIGURATION A: GRATING 5804

Description: Glynwed rectangular grating with longitudinal and transversal bars

% Opening area	62.0%	Number of transversal bars	10
Area (m^2)	0.175	Number of longitudinal bars	3
Width (mm)	350	Number of diagonal bars	0
Length (mm)	500		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
A.1	22.9	20.1	1.5	197.8	50.0	17.03	66.8
A.2	26.4	24.4	1.5	197.8	40.0	22.89	64.5
A.3	34.8	34.1	1.5	197.8	30.2	36.33	60.9
A.4	14.7	13.4	1	197.8	50.0	4.69	90.4
A.5	17.5	15.6	1	197.8	40.0	7.08	89.7
A.6	23.7	20.4	1	197.8	30.2	11.11	85.9
A.7	6.5	7.5	0.5	197.8	50.0	0.44	99.6
A.8	8.3	8.8	0.5	197.8	40.0	0.81	98.9
A.9	12.3	11.1	0.5	197.8	30.2	1.64	98.8
A.10	23.3	22.9	1.5	101.2	50.0	23.56	60.7
A.11	30.0	27.1	1.5	101.2	40.0	30.33	59.5
A.12	37.9	37.9	1.5	101.2	30.2	42.39	56.3
A.13	14.8	12.8	1	101.2	50.0	7.08	80.4
A.14	18.0	16.1	1	101.2	40.0	9.81	79.9
A.15	23.9	21.4	1	101.2	30.2	15.47	77.2
A.16	6.3	6.4	0.5	101.2	50.0	0.81	98.3
A.17	7.4	7.6	0.5	101.2	40.0	1.15	98.5
A.18	9.8	10.1	0.5	101.2	30.2	1.77	98.2
A.19	21.4	20.8	1.5	49.9	50.0	27.06	55.8
A.20	26.0	27.2	1.5	49.9	40.0	36.86	52.3
A.21	35.9	34.8	1.5	49.9	30.2	51.64	46.7
A.22	14.2	13.4	1	49.9	50.0	9.53	78.5
A.23	19.0	18.8	1	49.9	40.0	14.42	77.0
A.24	23.4	24.1	1	49.9	30.2	21.25	73.4
A.25	6.9	6.5	0.5	49.9	50.0	1.15	95.8
A.26	7.9	7.5	0.5	49.9	40.0	1.52	95.9
A.27	10.1	10.0	0.5	49.9	30.2	2.57	96.3
A.28	20.1	19.6	1.5	24.8	50.0	33.56	46.2
A.29	24.4	22.4	1.5	24.8	40.0	41.72	44.8
A.30	32.4	30.4	1.5	24.8	30.2	58.25	39.7
A.31	15.1	13.2	1	24.8	50.0	11.61	72.4
A.32	17.6	15.9	1	24.8	40.0	15.36	69.4
A.33	22.6	19.6	1	24.8	30.2	22.61	66.1
A.34	7.1	6.3	0.5	24.8	50.0	1.87	93.6
A.35	8.2	7.4	0.5	24.8	40.0	2.42	93.8
A.36	9.7	9.0	0.5	24.8	30.2	3.33	93.6
A.37	19.5	17.1	1.5	14.9	50.0	36.72	41.4
A.38	22.9	20.0	1.5	14.9	40.0	47.03	38.0
A.39	27.6	27.8	1.5	14.9	30.2	60.39	35.0
A.40	12.3	12.0	1	14.9	50.0	12.03	68.4
A.41	16.0	15.4	1	14.9	40.0	16.75	63.5
A.42	20.8	19.1	1	14.9	30.2	23.44	56.1
A.43	6.9	6.4	0.5	14.9	50.0	2.28	92.3
A.44	9.1	8.0	0.5	14.9	40.0	3.81	90.0
A.45	12.5	11.6	0.5	14.9	30.2	5.98	85.1

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION B: GRATING M13

Description: Glynwed rectangular grating with mainly transversal bars

% Opening area	62.0%	Number of transversal bars	7
Area (m^2)	0.178	Number of longitudinal bars	4
Width (mm)	400	Number of diagonal bars	0
Length (mm)	445		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
B.1	22.8	20.5	1.5	197.8	50.0	15.19	75.4
B.2	27.6	25.0	1.5	197.8	40.0	21.89	72.9
B.3	32.9	33.6	1.5	197.8	30.2	35.89	66.7
B.4	15.0	14.4	1	197.8	50.0	4.92	91.3
B.5	17.9	16.4	1	197.8	40.0	6.89	91.9
B.6	23.4	20.4	1	197.8	30.2	11.00	91.6
B.7	7.2	8.4	0.5	197.8	50.0	0.44	94.4
B.8	8.7	10.0	0.5	197.8	40.0	0.81	95.7
B.9	11.2	10.7	0.5	197.8	30.2	1.33	96.5
B.10	21.8	22.2	1.5	101.2	50.0	21.39	73.4
B.11	28.0	29.4	1.5	101.2	40.0	33.42	66.3
B.12	34.9	34.6	1.5	101.2	30.2	44.92	63.1
B.13	14.7	12.7	1	101.2	50.0	6.61	87.1
B.14	17.2	15.9	1	101.2	40.0	9.58	88.0
B.15	22.7	21.3	1	101.2	30.2	15.00	85.5
B.16	6.5	6.5	0.5	101.2	50.0	0.81	94.8
B.17	8.5	8.5	0.5	101.2	40.0	1.15	94.8
B.18	10.2	10.3	0.5	101.2	30.2	1.55	95.0
B.19	19.5	20.4	1.5	49.9	50.0	25.44	67.1
B.20	23.3	27.6	1.5	49.9	40.0	36.03	61.2
B.21	31.0	31.5	1.5	49.9	30.2	47.14	55.2
B.22	14.5	14.2	1	49.9	50.0	9.86	85.9
B.23	16.2	17.8	1	49.9	40.0	14.36	85.8
B.24	22.0	22.4	1	49.9	30.2	19.78	83.3
B.25	6.6	6.5	0.5	49.9	50.0	1.22	93.6
B.26	7.8	7.9	0.5	49.9	40.0	1.55	93.3
B.27	10.0	10.3	0.5	49.9	30.2	2.55	94.0
B.28	18.8	19.5	1.5	24.8	50.0	33.17	56.4
B.29	22.6	22.6	1.5	24.8	40.0	42.39	51.8
B.30	29.3	29.6	1.5	24.8	30.2	57.42	47.2
B.31	14.2	13.4	1	24.8	50.0	12.42	82.1
B.32	17.8	14.8	1	24.8	40.0	16.44	81.4
B.33	21.8	19.1	1	24.8	30.2	22.75	74.6
B.34	6.3	5.8	0.5	24.8	50.0	1.64	92.3
B.35	7.7	7.3	0.5	24.8	40.0	2.37	92.6
B.36	10.4	9.8	0.5	24.8	30.2	4.02	93.2
B.37	17.8	16.9	1.5	14.9	50.0	36.61	50.7
B.38	21.0	19.0	1.5	14.9	40.0	46.00	46.8
B.39	25.9	25.6	1.5	14.9	30.2	59.31	41.6
B.40	13.4	12.5	1	14.9	50.0	11.92	80.1
B.41	17.0	15.5	1	14.9	40.0	17.89	75.8
B.42	23.1	20.2	1	14.9	30.2	26.56	67.0
B.43	7.0	6.8	0.5	14.9	50.0	2.28	89.7
B.44	9.2	8.8	0.5	14.9	40.0	3.58	90.1
B.45	12.1	11.4	0.5	14.9	30.2	5.71	89.7

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION C: GRATING 5760

Description: Glynwed squared grating with diagonal bars

% Opening area	56.0%	Number of transversal bars	7
Area (m^2)	0.1936	Number of longitudinal bars	1
Width (mm)	440	Number of diagonal bars	1
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
C.1	22.1	20.2	1.5	197.8	50.0	15.08	67.2
C.2	24.5	23.5	1.5	197.8	40.0	20.44	63.8
C.3	30.2	31.4	1.5	197.8	30.2	33.31	54.8
C.4	15.6	14.0	1	197.8	50.0	5.17	86.8
C.5	18.0	16.4	1	197.8	40.0	7.08	86.4
C.6	22.0	20.1	1	197.8	30.2	10.50	84.2
C.7	6.8	8.9	0.5	197.8	50.0	0.44	90.9
C.8	8.0	10.2	0.5	197.8	40.0	0.68	93.5
C.9	11.1	14.1	0.5	197.8	30.2	1.30	95.3
C.10	24.0	22.7	1.5	101.2	50.0	21.25	61.9
C.11	29.8	27.6	1.5	101.2	40.0	31.19	55.0
C.12	36.5	34.8	1.5	101.2	30.2	42.69	50.0
C.13	12.7	12.6	1	101.2	50.0	6.67	82.9
C.14	15.6	15.9	1	101.2	40.0	9.50	81.0
C.15	20.2	20.6	1	101.2	30.2	14.56	76.5
C.16	6.4	6.6	0.5	101.2	50.0	0.75	88.9
C.17	7.7	7.8	0.5	101.2	40.0	1.22	90.0
C.18	10.2	10.1	0.5	101.2	30.2	1.61	87.1
C.19	21.0	20.4	1.5	49.9	50.0	26.47	53.0
C.20	26.9	26.2	1.5	49.9	40.0	37.72	47.1
C.21	33.8	32.8	1.5	49.9	30.2	52.25	39.9
C.22	14.2	12.4	1	49.9	50.0	9.11	76.5
C.23	19.5	19.7	1	49.9	40.0	15.06	72.7
C.24	22.7	20.9	1	49.9	30.2	20.25	66.2
C.25	7.0	6.5	0.5	49.9	50.0	1.22	89.4
C.26	7.9	7.7	0.5	49.9	40.0	1.64	88.3
C.27	10.0	10.3	0.5	49.9	30.2	2.63	83.3
C.28	18.9	20.1	1.5	24.8	50.0	32.72	44.2
C.29	23.2	24.7	1.5	24.8	40.0	42.47	37.9
C.30	28.3	29.6	1.5	24.8	30.2	56.58	34.2
C.31	14.2	13.5	1	24.8	50.0	11.69	71.5
C.32	18.4	16.2	1	24.8	40.0	16.14	64.7
C.33	23.6	21.2	1	24.8	30.2	25.06	56.2
C.34	5.9	5.4	0.5	24.8	50.0	1.39	87.3
C.35	7.2	6.8	0.5	24.8	40.0	2.05	83.7
C.36	9.2	8.8	0.5	24.8	30.2	3.19	80.7
C.37	17.2	15.7	1.5	14.9	50.0	33.47	41.6
C.38	21.2	19.3	1.5	14.9	40.0	44.06	35.2
C.39	27.3	26.4	1.5	14.9	30.2	60.22	29.1
C.40	13.6	12.9	1	14.9	50.0	13.08	67.3
C.41	17.5	15.9	1	14.9	40.0	17.58	60.1
C.42	20.4	20.2	1	14.9	30.2	25.00	53.0
C.43	6.3	6.2	0.5	14.9	50.0	2.17	82.6
C.44	8.2	8.0	0.5	14.9	40.0	3.19	79.2
C.45	13.0	12.1	0.5	14.9	30.2	6.26	74.2

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION D: GRATING SD135

Description: Wooden squared grating with diagonal bars

% Opening area	44.0%	Number of transversal bars	0
Area (m^2)	0.1936	Number of longitudinal bars	0
Width (mm)	440	Number of diagonal bars	8
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
D.1	22.3	21.6	1.5	197.8	50.0	14.31	74.3
D.2	25.3	25.5	1.5	197.8	40.0	23.25	69.1
D.3	34.9	35.8	1.5	197.8	30.2	36.11	60.8
D.4	15.0	14.4	1	197.8	50.0	5.25	94.2
D.5	19.1	18.6	1	197.8	40.0	8.56	91.1
D.6	22.1	21.8	1	197.8	30.2	11.33	91.4
D.7	8.3	8.6	0.5	197.8	50.0	0.75	98.4
D.8	9.0	8.6	0.5	197.8	40.0	0.86	97.9
D.9	12.6	12.5	0.5	197.8	30.2	0.75	93.7
D.10	23.0	24.4	1.5	100.2	50.0	24.44	66.5
D.11	26.8	27.6	1.5	100.2	40.0	31.64	60.9
D.12	34.0	37.3	1.5	100.2	30.2	48.61	51.7
D.13	14.8	13.8	1	100.2	50.0	7.17	85.2
D.14	19.4	17.6	1	100.2	40.0	10.78	82.9
D.15	25.8	24.8	1	100.2	30.2	17.78	79.0
D.16	6.3	7.1	0.5	100.2	50.0	0.81	97.1
D.17	8.0	8.6	0.5	100.2	40.0	1.22	96.4
D.18	12.6	12.7	0.5	100.2	30.2	2.57	96.8
D.19	23.0	23.2	1.5	49.9	50.0	31.39	54.1
D.20	27.2	26.8	1.5	49.9	40.0	39.44	50.0
D.21	33.6	36.2	1.5	49.9	30.2	52.86	44.5
D.22	14.2	14.3	1	49.9	50.0	9.77	81.9
D.23	18.5	18.9	1	49.9	40.0	14.64	80.6
D.24	25.8	25.9	1	49.9	30.2	22.72	73.6
D.25	7.0	6.9	0.5	49.9	50.0	1.58	96.0
D.26	8.0	8.1	0.5	49.9	40.0	1.69	94.6
D.27	10.3	10.8	0.5	49.9	30.2	2.82	95.3
D.28	19.6	19.2	1.5	25.0	50.0	34.20	47.2
D.29	23.2	22.9	1.5	25.0	40.0	43.00	43.5
D.30	29.8	29.6	1.5	25.0	30.2	59.03	38.9
D.31	14.7	13.9	1	25.0	50.0	12.11	75.7
D.32	18.4	16.9	1	25.0	40.0	17.75	69.9
D.33	22.3	20.8	1	25.0	30.2	24.11	64.6
D.34	6.2	6.2	0.5	25.0	50.0	1.61	92.7
D.35	9.6	9.2	0.5	25.0	40.0	3.30	94.5
D.36	11.2	10.6	0.5	25.0	30.2	4.30	94.7
D.37	18.6	19.1	1.5	14.9	50.0	39.39	38.1
D.38	20.8	22.6	1.5	14.9	40.0	47.64	35.6
D.39	26.3	26.5	1.5	14.9	30.2	61.39	32.8
D.40	12.8	12.6	1	14.9	50.0	11.80	76.9
D.41	16.5	17.3	1	14.9	40.0	18.94	63.2
D.42	21.2	20.8	1	14.9	30.2	26.97	54.8
D.43	8.1	8.1	0.5	14.9	50.0	3.21	93.2
D.44	10.4	10.3	0.5	14.9	40.0	4.69	92.3
D.45	13.3	12.4	0.5	14.9	30.2	6.67	88.1

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION E: GRATING LSD135

Description: Wooden squared grating with diagonal bars

% Opening area	44.0%	Number of transversal bars	0
Area (m^2)	0.1089	Number of longitudinal bars	0
Width (mm)	330	Number of diagonal bars	8
Length (mm)	330		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
E.1	15.4	13.0	1.125	197.8	50.0	6.31	76.0
E.2	14.0	9.5	1.125	197.8	40.0	8.64	74.8
E.3	26.0	22.0	1.125	197.8	30.2	14.67	67.2
E.4	10.3	8.6	0.75	197.8	50.0	1.92	95.4
E.5	12.1	11.6	0.75	197.8	40.0	3.11	94.1
E.6	16.0	15.8	0.75	197.8	30.2	5.17	91.9
E.7	4.9	5.1	0.375	197.8	50.0	0.31	100.0
E.8	6.6	6.5	0.375	197.8	40.0	0.44	100.0
E.9	8.2	8.0	0.375	197.8	30.2	0.62	99.0
E.10	15.0	13.2	1.125	101.2	50.0	8.75	67.6
E.11	17.0	17.0	1.125	101.2	40.0	13.81	62.6
E.12	22.4	24.2	1.125	101.2	30.2	22.06	54.1
E.13	9.6	8.3	0.75	101.2	50.0	2.94	88.9
E.14	11.0	9.8	0.75	101.2	40.0	3.94	89.1
E.15	13.9	13.1	0.75	101.2	30.2	6.47	87.0
E.16	5.2	5.1	0.375	101.2	50.0	0.44	98.2
E.17	6.2	6.6	0.375	101.2	40.0	0.53	98.3
E.18	7.4	8.2	0.375	101.2	30.2	0.86	97.0
E.19	16.0	14.8	1.125	49.9	50.0	13.42	61.7
E.20	20.9	19.0	1.125	49.9	40.0	19.53	51.8
E.21	24.2	22.0	1.125	49.9	30.2	26.89	46.5
E.22	11.2	10.9	0.75	49.9	50.0	5.61	78.2
E.23	14.8	14.4	0.75	49.9	40.0	8.25	76.5
E.24	15.2	15.3	0.75	49.9	30.2	9.58	76.1
E.25	4.4	4.5	0.375	49.9	50.0	0.62	96.9
E.26	5.9	6.0	0.375	49.9	40.0	0.81	96.6
E.27	8.0	8.1	0.375	49.9	30.2	1.30	96.0
E.28	14.1	14.0	1.125	24.8	50.0	15.11	49.9
E.29	18.2	18.4	1.125	24.8	40.0	22.11	42.3
E.30	24.2	22.2	1.125	24.8	30.2	32.61	36.7
E.31	10.0	12.7	0.75	24.8	50.0	6.08	79.3
E.32	12.5	12.3	0.75	24.8	40.0	8.61	73.4
E.33	16.7	14.9	0.75	24.8	30.2	12.14	63.9
E.34	4.2	4.3	0.375	24.8	50.0	0.68	93.9
E.35	4.8	5.1	0.375	24.8	40.0	0.75	93.0
E.36	6.3	6.5	0.375	24.8	30.2	1.15	92.6
E.37	14.0	13.2	1.125	14.9	50.0	18.06	41.9
E.38	17.8	17.3	1.125	14.9	40.0	25.53	35.7
E.39	22.2	22.6	1.125	14.9	30.2	37.42	28.6
E.40	9.0	8.9	0.75	14.9	50.0	7.28	77.5
E.41	12.4	11.4	0.75	14.9	40.0	9.28	68.8
E.42	15.7	15.7	0.75	14.9	30.2	14.61	55.2
E.43	3.7	4.1	0.375	14.9	50.0	0.92	93.2
E.44	6.4	6.4	0.375	14.9	40.0	1.69	94.2
E.45	9.8	9.1	0.375	14.9	30.2	3.27	91.9

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION F: GRATING SD 45

Description: Wooden squared grating with diagonal bars

% Opening area	44.0%	Number of transversal bars	0
Area (m^2)	0.1936	Number of longitudinal bars	0
Width (mm)	440	Number of diagonal bars	8
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
F.1	11.2	11.3	0.5	197.8	30.2	1.52	95.4
F.2	9.4	9.5	0.5	197.8	40.0	0.86	96.5
F.3	8.3	8.5	0.5	197.8	50.0	0.53	97.2
F.4	22.6	21.4	1	197.8	30.2	11.66	90.3
F.5	16.8	15.8	1	197.8	40.0	7.02	92.8
F.6	14.0	13.8	1	197.8	50.0	4.85	92.7
F.7	14.0	13.4	1	197.8	50.0	4.68	94.6
F.8	39.0	37.6	1.5	197.8	30.2	41.12	58.1
F.9	28.0	28.6	1.5	197.8	40.0	26.08	68.2
F.10	23.8	24.0	1.5	197.8	50.0	16.97	73.4
F.11	36.8	37.6	1.5	100.2	30.2	48.54	51.3
F.12	27.8	28.2	1.5	100.2	40.0	32.30	60.0
F.13	23.2	25.8	1.5	100.2	50.0	26.00	63.6
F.14	14.8	14.4	1	100.2	50.0	8.10	83.5
F.15	18.8	19.2	1	100.2	40.0	11.98	82.9
F.16	27.0	26.0	1	100.2	30.2	19.42	78.2
F.17	11.0	11.3	0.5	100.2	30.2	2.04	91.6
F.18	8.6	9.3	0.5	100.2	40.0	1.43	95.2
F.19	7.4	7.7	0.5	100.2	50.0	1.06	95.4
F.20	7.0	6.9	0.5	49.9	50.0	1.39	95.2
F.21	8.8	8.7	0.5	49.9	40.0	2.20	96.0
F.22	10.1	10.5	0.5	49.9	30.2	3.10	96.9
F.23	15.8	16.0	1	49.9	50.0	10.98	82.3
F.24	20.2	20.8	1	49.9	40.0	16.70	79.1
F.25	25.2	26.6	1	49.9	30.2	25.00	69.4
F.26	34.2	33.7	1.5	49.9	30.2	55.97	43.9
F.27	26.4	25.8	1.5	49.9	40.0	41.40	48.5
F.28	20.6	21.4	1.5	49.9	50.0	27.44	59.3
F.29	19.6	20.6	1.5	25.0	50.0	43.80	57.5
F.30	23.6	24.4	1.5	25.0	40.0	43.87	42.4
F.31	28.2	29.0	1.5	25.0	30.2	56.90	39.0
F.32	22.2	21.2	1	25.0	30.2	24.75	62.5
F.33	18.8	17.7	1	25.0	40.0	18.89	69.6
F.34	14.6	14.2	1	25.0	50.0	13.06	76.8
F.35	7.8	7.1	0.5	25.0	50.0	2.24	94.1
F.36	8.9	8.5	0.5	25.0	40.0	2.97	95.2
F.37	10.0	9.7	0.5	25.0	30.2	3.85	94.9
F.38	12.1	12.6	1	14.9	50.0	13.23	70.1
F.39	15.6	16.2	1	14.9	40.0	17.23	63.9
F.40	21.9	20.6	1	14.9	30.2	26.17	56.1
F.41	25.6	26.6	1.5	14.9	30.2	63.23	32.9
F.42	21.0	20.2	1.5	14.9	40.0	44.75	37.5
F.43	17.1	16.4	1.5	14.9	50.0	33.67	44.1
F.44	7.2	7.3	0.5	14.9	50.0	2.77	92.7
F.45	8.6	8.3	0.5	14.9	40.0	3.47	91.7
F.46	13.6	12.6	0.5	14.9	30.2	6.65	88.1
F.47	11.8	11.5	0.5	19.3	30.2	5.28	92.9
F.48	8.6	8.3	0.5	19.3	40.0	3.02	90.9
F.49	7.2	6.9	0.5	19.3	50.0	2.23	93.5
F.50	13.4	13.3	1	19.3	50.0	11.9	77.3

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION G: GRATING LSD 45

Description: Wooden squared grating with diagonal bars

% Opening area	44.0%	Number of transversal bars	0
Area (m^2)	0.1089	Number of longitudinal bars	0
Width (mm)	330	Number of diagonal bars	8
Length (mm)	330		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
G.1	15.1	12.2	1.125	197.8	50.0	6.03	78.0
G.2	18.4	15.4	1.125	197.8	40.0	8.69	74.1
G.3	23.8	17.5	1.125	197.8	30.2	12.81	70.5
G.4	11.4	9.9	0.75	197.8	50.0	2.00	97.8
G.5	12.5	11.7	0.75	197.8	40.0	2.75	95.5
G.6	16.6	16.7	0.75	197.8	30.2	5.33	91.1
G.7	5.3	5.3	0.375	197.8	50.0	0.31	100.0
G.8	6.6	6.1	0.375	197.8	40.0	0.44	100.0
G.9	8.4	7.9	0.375	197.8	30.2	0.62	100.0
G.10	13.1	14.3	1.125	101.2	50.0	9.33	66.6
G.11	16.0	18.6	1.125	101.2	40.0	12.97	64.6
G.12	25.2	25.2	1.125	101.2	30.2	21.69	54.4
G.13	9.5	6.5	0.75	101.2	50.0	2.78	90.3
G.14	12.2	10.9	0.75	101.2	40.0	4.47	88.3
G.15	14.4	13.9	0.75	101.2	30.2	6.47	87.5
G.16	5.0	5.1	0.375	101.2	50.0	0.44	100.0
G.17	5.4	5.7	0.375	101.2	40.0	0.62	98.5
G.18	7.8	8.9	0.375	101.2	30.2	0.97	97.0
G.19	16.6	15.6	1.125	49.9	50.0	14.22	62.4
G.20	21.8	19.6	1.125	49.9	40.0	21.44	52.3
G.21	28.2	17.6	1.125	49.9	30.2	31.06	44.0
G.22	10.2	10.1	0.75	49.9	50.0	4.94	80.4
G.23	12.2	11.5	0.75	49.9	40.0	6.97	82.3
G.24	15.7	14.6	0.75	49.9	30.2	10.36	73.8
G.25	5.1	5.3	0.375	49.9	50.0	0.75	97.6
G.26	6.4	6.5	0.375	49.9	40.0	0.92	96.5
G.27	5.4	7.7	0.375	49.9	30.2	1.26	96.6
G.28	15.2	15.7	1.125	24.8	50.0	17.28	49.2
G.29	18.4	19.4	1.125	24.8	40.0	24.47	41.1
G.30	22.9	24.2	1.125	24.8	30.2	34.42	35.0
G.31	11.3	10.5	0.75	24.8	50.0	7.14	77.4
G.32	13.0	12.3	0.75	24.8	40.0	8.64	75.2
G.33	18.0	17.4	0.75	24.8	30.2	14.14	59.7
G.34	4.4	4.7	0.375	24.8	50.0	1.22	97.1
G.35	5.1	5.6	0.375	24.8	40.0	1.10	87.5
G.36	7.2	7.5	0.375	24.8	30.2	1.58	95.1
G.37	15.8	13.2	1.125	14.9	50.0	20.61	38.4
G.38	18.4	16.7	1.125	14.9	40.0	26.94	34.5
G.39	23.2	20.9	1.125	14.9	30.2	38.64	27.6
G.40	8.0	8.9	0.75	14.9	50.0	6.47	79.0
G.41	10.2	12.1	0.75	14.9	40.0	10.00	66.7
G.42	17.1	18.5	0.75	14.9	30.2	17.00	47.7
G.43	5.4	5.4	0.375	14.9	50.0	1.30	94.1
G.44	7.1	6.9	0.375	14.9	40.0	1.92	94.1
G.45	8.5	8.2	0.375	14.9	30.2	2.74	92.7

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION H: GRATING H21

Description: Open hole without grating

% Opening area	100.0%	Number of transversal bars	0
Area (m^2)	0.1936	Number of longitudinal bars	0
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
H.1	22.9	21.4	1.5	197.8	50.0	15.83	75.3
H.2	25.7	27.3	1.5	197.8	40.0	23.67	72.4
H.3	35.9	36.6	1.5	197.8	30.2	36.67	71.0
H.4	15.1	12.8	1	197.8	50.0	5.47	96.7
H.5	17.9	17.4	1	197.8	40.0	8.61	93.7
H.6	25.0	22.0	1	197.8	30.2	13.03	89.8
H.7	24.5	23.4	1.5	101.2	50.0	22.39	69.0
H.8	29.9	29.0	1.5	101.2	40.0	31.50	67.9
H.9	37.8	37.4	1.5	101.2	30.2	48.22	65.5
H.10	15.8	13.8	1	101.2	50.0	8.28	85.7
H.11	20.2	18.4	1	101.2	40.0	11.89	84.5
H.12	25.7	22.9	1	101.2	30.2	16.67	84.0
H.13	20.5	22.6	1.5	49.9	50.0	26.28	68.6
H.14	25.9	28.8	1.5	49.9	40.0	37.89	63.3
H.15	33.5	37.3	1.5	49.9	30.2	53.89	62.6
H.16	14.5	14.2	1	49.9	50.0	10.31	85.1
H.17	17.8	17.4	1	49.9	40.0	13.61	85.7
H.18	23.1	22.4	1	49.9	30.2	20.44	84.4
H.19	19.3	19.4	1.5	25.0	50.0	31.36	62.6
H.20	24.5	23.3	1.5	25.0	40.0	42.22	62.5
H.21	31.3	30.0	1.5	25.0	30.2	58.33	62.8
H.22	14.9	13.0	1	25.0	50.0	12.61	83.9
H.23	17.7	15.9	1	25.0	40.0	17.22	81.7
H.24	21.9	19.2	1	25.0	30.2	24.31	79.8
H.25	19.3	18.8	1.5	14.9	50.0	36.81	60.0
H.26	23.3	23.6	1.5	14.9	40.0	44.72	60.5
H.27	29.5	29.4	1.5	14.9	30.2	63.89	58.5
H.28	12.0	11.4	1	14.9	50.0	12.92	82.1
H.29	13.1	11.8	1	14.9	50.0	12.92	83.5
H.30	14.3	13.9	1	14.9	40.0	17.31	79.6
H.31	20.1	18.4	1	14.9	30.2	25.08	79.1

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION I: GRATING TH 60

Description: Wooden squared grating with transversal bars

% Opening area	60.0%	Number of transversal bars	9
Area (m^2)	0.1936	Number of longitudinal bars	0
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
I.1	23.6	21.7	1.5	197.8	50.0	16.44	70.9
I.2	27.8	26.0	1.5	197.8	40.0	20.00	72.1
I.3	38.6	36.2	1.5	197.8	30.2	37.58	63.1
I.4	14.1	14.0	1	197.8	50.0	4.50	93.6
I.5	17.6	16.2	1	197.8	40.0	6.44	93.6
I.6	22.2	20.4	1	197.8	30.2	10.31	92.3
I.7	7.5	7.2	0.5	197.8	50.0	0.44	98.1
I.8	9.4	8.8	0.5	197.8	40.0	0.92	98.4
I.9	11.6	11.0	0.5	197.8	30.2	1.30	98.0
I.10	24.0	29.7	1.5	101.2	50.0	23.33	66.8
I.11	28.9	38.1	1.5	101.2	40.0	35.42	60.6
I.12	33.7	25.1	1.5	101.2	30.2	48.22	58.1
I.13	14.0	13.1	1	101.2	50.0	6.53	87.7
I.14	18.4	17.4	1	101.2	40.0	10.17	84.2
I.15	25.2	23.0	1	101.2	30.2	16.69	80.9
I.16	7.0	7.5	0.5	101.2	50.0	0.81	97.6
I.17	8.5	8.8	0.5	101.2	40.0	1.18	97.0
I.18	11.0	11.1	0.5	101.2	30.2	1.74	96.2
I.19	23.2	22.4	1.5	49.9	50.0	27.44	60.7
I.20	28.3	26.0	1.5	49.9	40.0	37.64	57.2
I.21	35.9	31.8	1.5	49.9	30.2	52.28	49.9
I.22	15.1	22.2	1	49.9	50.0	10.22	82.5
I.23	18.5	14.1	1	49.9	40.0	14.03	82.1
I.24	24.0	17.6	1	49.9	30.2	21.75	77.9
I.25	7.6	7.5	0.5	49.9	50.0	1.22	94.6
I.26	7.3	6.9	0.5	49.9	40.0	1.36	96.3
I.27	10.5	10.5	0.5	49.9	30.2	2.57	95.7
I.28	20.1	21.6	1.5	24.8	50.0	34.33	50.6
I.29	23.3	24.6	1.5	24.8	40.0	42.81	48.6
I.30	30.1	30.9	1.5	24.8	30.2	61.11	42.0
I.31	15.0	13.7	1	24.8	50.0	11.56	82.8
I.32	17.3	15.5	1	24.8	40.0	14.36	81.8
I.33	22.7	21.5	1	24.8	30.2	22.31	74.8
I.34	6.2	6.5	0.5	24.8	50.0	1.71	93.7
I.35	9.0	8.3	0.5	24.8	40.0	2.71	95.0
I.36	10.4	9.9	0.5	24.8	30.2	3.78	95.3
I.37	19.0	18.0	1.5	14.9	50.0	38.14	47.3
I.38	20.5	20.2	1.5	14.9	40.0	45.17	44.4
I.39	25.0	26.4	1.5	14.9	30.2	65.47	37.3
I.40	11.5	12.1	1	14.9	50.0	10.94	80.5
I.41	14.8	17.2	1	14.9	40.0	15.56	75.8
I.42	21.1	20.9	1	14.9	30.2	24.92	65.4
I.43	6.6	6.7	0.5	14.9	50.0	2.04	92.8
I.44	9.3	9.0	0.5	14.9	40.0	3.51	93.2
I.45	13.0	13.7	0.5	14.9	30.2	6.42	88.9

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION J: GRATING SH

Description: Wooden squared grating with transversal bars

% Opening area	44.0%	Number of transversal bars	7
Area (m^2)	0.1936	Number of longitudinal bars	0
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
J.1	23.7	23.6	1.5	197.8	50.0	18.33	73.8
J.2	25.8	26.5	1.5	197.8	40.0	25.28	67.7
J.3	37.6	37.6	1.5	197.8	30.2	43.33	54.6
J.4	14.4	13.0	1	197.8	50.0	5.30	94.5
J.5	18.2	16.5	1	197.8	40.0	7.69	97.7
J.6	22.0	20.8	1	197.8	30.2	11.28	95.0
J.7	6.3	6.5	0.5	197.8	50.0	0.44	97.5
J.8	8.2	8.0	0.5	197.8	40.0	0.86	97.5
J.9	11.4	11.2	0.5	197.8	30.2	1.33	96.4
J.10	23.1	24.3	1.5	100.2	50.0	25.58	61.3
J.11	27.6	29.3	1.5	100.2	40.0	33.28	57.5
J.12	35.8	40.4	1.5	100.2	30.2	54.56	45.1
J.13	11.8	12.1	1	100.2	50.0	9.33	82.5
J.14	14.2	13.8	1	100.2	40.0	10.83	82.1
J.15	17.0	16.5	1	100.2	30.2	14.39	81.3
J.16	6.4	7.1	0.5	100.2	50.0	0.81	91.2
J.17	7.0	7.7	0.5	100.2	40.0	0.97	95.3
J.18	10.0	10.6	0.5	100.2	30.2	1.80	98.7
J.19	20.5	22.2	1.5	49.9	50.0	25.83	58.5
J.20	24.5	26.6	1.5	49.9	40.0	34.44	52.7
J.21	30.3	34.0	1.5	49.9	30.2	48.33	44.2
J.22	15.2	15.1	1	49.9	50.0	9.83	81.9
J.23	20.6	19.8	1	49.9	40.0	14.86	79.3
J.24	26.0	24.8	1	49.9	30.2	20.67	72.8
J.25	6.9	6.8	0.5	49.9	50.0	1.18	93.6
J.26	8.2	8.7	0.5	49.9	40.0	1.58	97.7
J.27	10.4	10.7	0.5	49.9	30.2	2.69	95.8
J.28	19.6	20.0	1.5	25.0	50.0	33.22	46.4
J.29	23.6	24.6	1.5	25.0	40.0	44.72	39.9
J.30	30.4	30.3	1.5	25.0	30.2	58.42	36.3
J.31	15.2	14.8	1	25.0	50.0	12.97	75.1
J.32	19.2	18.0	1	25.0	40.0	19.56	65.5
J.33	23.3	22.4	1	25.0	30.2	25.83	59.9
J.34	6.6	12.2	0.5	25.0	50.0	1.82	93.6
J.35	8.8	6.7	0.5	25.0	40.0	2.96	94.9
J.36	10.3	6.5	0.5	25.0	30.2	3.88	94.7
J.37	19.5	17.7	1.5	14.9	50.0	39.44	36.9
J.38	21.8	20.2	1.5	14.9	40.0	47.17	34.8
J.39	27.0	27.4	1.5	14.9	30.2	66.94	29.4
J.40	13.6	13.1	1	14.9	50.0	13.00	72.2
J.41	18.0	17.3	1	14.9	40.0	19.44	62.1
J.42	23.6	21.8	1	14.9	30.2	27.44	51.7
J.43	7.5	7.3	0.5	14.9	50.0	2.87	93.6
J.44	10.5	10.3	0.5	14.9	40.0	4.96	92.6
J.45	12.4	11.5	0.5	14.9	30.2	6.06	88.3

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION K: GRATING TH

Description: Wooden squared grating with transversal bars

% Opening area	26.0%	Number of transversal bars	7
Area (m^2)	0.1936	Number of longitudinal bars	0
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
K.1	25.0	23.4	1.5	197.8	50.0	15.78	68.5
K.2	26.8	28.2	1.5	197.8	40.0	24.17	56.3
K.3	36.5	36.8	1.5	197.8	30.2	35.06	49.1
K.4	16.0	14.8	1	197.8	50.0	6.19	90.9
K.5	16.0	16.8	1	197.8	40.0	7.75	90.9
K.6	25.3	23.8	1	197.8	30.2	13.28	80.1
K.7	6.9	6.9	0.5	197.8	50.0	0.44	97.7
K.8	8.2	8.1	0.5	197.8	40.0	0.81	97.9
K.9	12.3	12.0	0.5	197.8	30.2	1.30	95.3
K.10	23.4	21.6	1.5	101.2	50.0	21.22	54.4
K.11	28.3	27.6	1.5	101.2	40.0	28.50	49.7
K.12	38.0	38.3	1.5	101.2	30.2	44.72	40.3
K.13	14.2	13.4	1	101.2	50.0	6.72	84.8
K.14	19.6	18.5	1	101.2	40.0	11.44	76.2
K.15	27.0	24.2	1	101.2	30.2	17.06	66.9
K.16	6.3	6.6	0.5	101.2	50.0	0.75	95.2
K.17	8.4	8.3	0.5	101.2	40.0	1.26	96.7
K.18	10.6	10.9	0.5	101.2	30.2	1.99	94.4
K.19	20.4	21.8	1.5	49.9	50.0	24.86	49.1
K.20	25.3	27.6	1.5	49.9	40.0	35.72	41.4
K.21	34.8	37.6	1.5	49.9	30.2	58.61	31.1
K.22	14.2	14.4	1	49.9	50.0	9.97	74.2
K.23	17.6	18.9	1	49.9	40.0	14.78	65.5
K.24	27.0	18.2	1	49.9	30.2	23.94	53.3
K.25	7.7	7.6	0.5	49.9	50.0	1.64	93.0
K.26	8.4	8.5	0.5	49.9	40.0	1.87	93.4
K.27	10.8	11.2	0.5	49.9	30.2	2.93	93.9
K.28	19.6	18.2	1.5	25.0	50.0	29.31	39.6
K.29	23.5	22.8	1.5	25.0	40.0	38.89	34.3
K.30	30.6	28.6	1.5	25.0	30.2	55.28	29.7
K.31	14.0	13.1	1	25.0	50.0	11.14	64.3
K.32	16.8	15.2	1	25.0	40.0	15.67	57.3
K.33	21.6	20.4	1	25.0	30.2	24.58	47.5
K.34	7.2	6.9	0.5	25.0	50.0	2.10	93.4
K.35	9.5	9.1	0.5	25.0	40.0	3.45	91.2
K.36	10.9	10.3	0.5	25.0	30.2	4.23	87.6
K.37	16.8	16.9	1.5	14.9	50.0	34.44	32.5
K.38	20.9	20.0	1.5	14.9	40.0	44.17	28.8
K.39	39.5	40.9	1.5	14.9	30.2	62.50	21.6
K.40	13.6	13.4	1	14.9	50.0	14.06	55.2
K.41	18.1	17.1	1	14.9	40.0	20.22	46.5
K.42	21.9	20.8	1	14.9	30.2	27.06	40.9
K.43	7.2	7.3	0.5	14.9	50.0	2.72	87.6
K.44	9.3	9.0	0.5	14.9	40.0	3.93	83.5
K.45	13.7	12.8	0.5	14.9	30.2	6.97	74.4

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION L: GRATING 170 TH 60

Description: Wooden squared grating with transversal and longitudinal bars

% Opening area	54.0%	Number of transversal bars	9
Area (m^2)	0.1936	Number of longitudinal bars	3
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
L.1	22.2	22.4	1.5	197.8	50.0	15.00	72.8
L.2	28.8	26.6	1.5	197.8	40.0	24.36	68.9
L.3	36.8	38.0	1.5	197.8	30.2	34.31	65.6
L.4	14.9	14.4	1	197.8	50.0	4.86	93.7
L.5	17.2	16.2	1	197.8	40.0	6.89	93.4
L.6	22.4	21.2	1	197.8	30.2	11.19	90.1
L.7	7.0	6.7	0.5	197.8	50.0	0.44	97.7
L.8	8.5	8.1	0.5	197.8	40.0	0.75	98.2
L.9	11.4	10.5	0.5	197.8	30.2	1.36	98.7
L.10	23.0	22.2	1.5	101.2	50.0	23.53	64.4
L.11	27.8	27.7	1.5	101.2	40.0	30.53	62.0
L.12	35.4	34.4	1.5	101.2	30.2	45.22	55.1
L.13	14.2	13.0	1	101.2	50.0	6.64	84.9
L.14	17.5	16.4	1	101.2	40.0	9.72	85.3
L.15	22.5	21.4	1	101.2	30.2	15.50	81.6
L.16	6.6	6.9	0.5	101.2	50.0	0.75	98.0
L.17	7.7	8.1	0.5	101.2	40.0	1.06	98.0
L.18	10.6	10.4	0.5	101.2	30.2	1.85	97.5
L.19	21.2	21.1	1.5	49.9	50.0	27.33	58.6
L.20	26.4	26.8	1.5	49.9	40.0	38.61	51.7
L.21	33.8	32.8	1.5	49.9	30.2	51.83	45.3
L.22	14.2	14.8	1	49.9	50.0	10.00	82.9
L.23	17.4	17.9	1	49.9	40.0	13.75	81.9
L.24	24.0	24.2	1	49.9	30.2	21.50	74.3
L.25	5.9	8.3	0.5	49.9	50.0	1.10	96.6
L.26	8.0	8.1	0.5	49.9	40.0	1.58	95.6
L.27	10.1	10.5	0.5	49.9	30.2	2.67	95.6
L.28	19.9	20.3	1.5	24.8	50.0	34.42	45.0
L.29	21.9	23.3	1.5	24.8	40.0	44.28	39.6
L.30	29.3	29.6	1.5	24.8	30.2	56.25	37.8
L.31	14.7	13.4	1	24.8	50.0	11.78	76.6
L.32	17.4	15.9	1	24.8	40.0	16.31	72.4
L.33	21.6	19.3	1	24.8	30.2	22.83	63.2
L.34	7.1	6.2	0.5	24.8	50.0	1.77	93.2
L.35	7.5	7.2	0.5	24.8	40.0	2.26	93.5
L.36	9.9	9.5	0.5	24.8	30.2	3.73	94.5
L.37	14.5	13.5	1.5	14.9	50.0	30.75	42.7
L.38	17.4	16.8	1.5	14.9	40.0	42.39	36.1
L.39	22.0	22.8	1.5	14.9	30.2	60.69	32.7
L.40	10.5	11.4	1	14.9	50.0	11.58	73.5
L.41	15.2	15.4	1	14.9	40.0	16.33	65.8
L.42	21.8	21.2	1	14.9	30.2	27.11	49.2
L.43	7.2	6.5	0.5	14.9	50.0	2.26	91.4
L.44	8.3	7.8	0.5	14.9	40.0	3.10	92.1
L.45	11.9	11.1	0.5	14.9	30.2	5.63	83.9

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION M: GRATING 170 H

Description: Wooden squared grating with transversal and longitudinal bars

% Opening area	39.6%	Number of transversal bars	7
Area (m^2)	0.1936	Number of longitudinal bars	3
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
M.1	16.8	18.5	1.5	197.8	50.0	13.69	76.8
M.2	23.5	23.4	1.5	197.8	40.0	21.69	67.7
M.3	27.4	29.8	1.5	197.8	30.2	32.28	57.1
M.4	14.2	13.5	1	197.8	50.0	4.36	94.9
M.5	17.4	15.9	1	197.8	40.0	7.39	92.4
M.6	23.6	21.4	1	197.8	30.2	11.53	90.3
M.7	6.5	6.6	0.5	197.8	50.0	0.44	100.0
M.8	8.2	7.6	0.5	197.8	40.0	0.75	98.5
M.9	11.6	11.1	0.5	197.8	30.2	1.61	98.4
M.10	23.3	21.2	1.5	101.2	50.0	23.11	65.0
M.11	27.4	27.8	1.5	101.2	40.0	32.28	55.1
M.12	36.8	39.0	1.5	101.2	30.2	50.06	43.9
M.13	13.2	13.6	1	101.2	50.0	7.72	85.9
M.14	14.8	16.0	1	101.2	40.0	10.19	85.8
M.15	17.7	22.6	1	101.2	30.2	17.03	77.9
M.16	6.8	7.1	0.5	101.2	50.0	0.92	97.9
M.17	8.5	8.7	0.5	101.2	40.0	1.33	97.2
M.18	11.0	10.6	0.5	101.2	30.2	1.97	97.3
M.19	23.2	23.1	1.5	49.9	50.0	30.47	48.4
M.20	26.6	27.4	1.5	49.9	40.0	39.14	43.3
M.21	32.6	30.3	1.5	49.9	30.2	45.47	36.5
M.22	15.0	14.0	1	49.9	50.0	10.72	78.8
M.23	17.2	16.8	1	49.9	40.0	14.94	74.0
M.24	24.6	21.8	1	49.9	30.2	22.83	63.0
M.25	6.4	6.3	0.5	49.9	50.0	1.15	95.3
M.26	7.6	7.5	0.5	49.9	40.0	1.55	94.9
M.27	9.3	8.3	0.5	49.9	30.2	2.46	95.3
M.28	19.9	19.2	1.5	24.8	50.0	37.78	36.7
M.29	22.2	22.0	1.5	24.8	40.0	45.19	33.5
M.30	24.0	27.0	1.5	24.8	30.2	48.39	34.1
M.31	14.2	14.5	1	24.8	50.0	12.61	74.5
M.32	17.7	17.0	1	24.8	40.0	16.83	63.4
M.33	23.4	22.2	1	24.8	30.2	24.33	52.3
M.34	6.8	6.5	0.5	24.8	50.0	1.81	93.1
M.35	9.8	9.3	0.5	24.8	40.0	3.54	94.3
M.36	8.7	11.3	0.5	24.8	30.2	5.19	90.5
M.37	20.0	15.8	1.5	14.9	50.0	33.56	33.0
M.38	20.8	18.0	1.5	14.9	40.0	46.92	26.3
M.39	28.0	27.6	1.5	14.9	30.2	61.92	26.8
M.40	11.6	13.2	1	14.9	50.0	14.64	60.3
M.41	16.1	17.6	1	14.9	40.0	22.06	48.1
M.42	21.7	22.0	1	14.9	30.2	30.33	40.5
M.43	6.0	1.9	0.5	14.9	50.0	2.01	91.2
M.44	8.6	8.0	0.5	14.9	40.0	3.36	91.8
M.45	12.4	11.2	0.5	14.9	30.2	5.76	76.0

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION N: GRATING 170 TH

Description: Wooden squared grating with transversal and longitudinal bars

% Opening area	23.4%	Number of transversal bars	7
Area (m^2)	0.1936	Number of longitudinal bars	3
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
N.1	20.8	17.9	1.5	197.8	50.0	14.25	61.0
N.2	26.2	25.6	1.5	197.8	40.0	23.53	42.6
N.3	35.3	36.0	1.5	197.8	30.2	33.97	38.3
N.4	14.8	14.1	1	197.8	50.0	4.94	86.9
N.5	18.0	16.4	1	197.8	40.0	6.97	86.4
N.6	21.9	19.7	1	197.8	30.2	9.67	82.8
N.7	6.8	6.9	0.5	197.8	50.0	0.44	97.7
N.8	8.7	8.1	0.5	197.8	40.0	0.68	97.6
N.9	11.1	10.2	0.5	197.8	30.2	1.22	97.7
N.10	22.6	22.1	1.5	101.2	50.0	20.94	44.0
N.11	27.2	26.8	1.5	101.2	40.0	30.42	36.1
N.12	37.8	35.3	1.5	101.2	30.2	45.11	27.8
N.13	14.2	13.1	1	101.2	50.0	6.47	76.4
N.14	19.3	17.6	1	101.2	40.0	10.39	69.8
N.15	23.9	21.6	1	101.2	30.2	14.42	61.4
N.16	6.6	7.0	0.5	101.2	50.0	0.75	96.7
N.17	6.0	8.4	0.5	101.2	40.0	1.15	97.2
N.18	10.1	10.5	0.5	101.2	30.2	1.69	96.1
N.19	19.3	20.8	1.5	49.9	50.0	24.28	34.9
N.20	25.0	26.7	1.5	49.9	40.0	33.33	28.5
N.21	32.5	36.7	1.5	49.9	30.2	48.67	23.3
N.22	14.8	14.2	1	49.9	50.0	9.39	67.1
N.23	19.6	18.2	1	49.9	40.0	13.58	57.9
N.24	22.4	23.1	1	49.9	30.2	19.44	46.6
N.25	6.7	6.7	0.5	49.9	50.0	1.15	94.8
N.26	8.0	8.0	0.5	49.9	40.0	1.52	94.9
N.27	10.5	8.5	0.5	49.9	30.2	2.55	95.2
N.28	19.0	19.3	1.5	24.6	50.0	33.47	21.5
N.29	22.6	23.6	1.5	24.8	40.0	41.67	19.4
N.30	29.2	31.5	1.5	24.8	30.2	55.14	19.0
N.31	13.2	12.5	1	24.8	50.0	10.92	56.3
N.32	17.6	16.2	1	24.8	40.0	15.78	44.6
N.33	22.2	20.6	1	24.8	30.2	23.56	33.6
N.34	6.2	5.8	0.5	24.8	50.0	1.55	93.2
N.35	7.2	7.1	0.5	24.8	40.0	1.97	93.2
N.36	8.7	8.6	0.5	24.8	30.2	3.03	92.1
N.37	17.3	17.2	1.5	14.9	50.0	36.64	15.0
N.38	21.8	20.8	1.5	14.9	40.0	48.97	13.9
N.39	25.8	25.8	1.5	14.9	30.2	64.31	24.3
N.40	11.6	12.4	1	14.9	50.0	11.83	48.1
N.41	14.9	15.3	1	14.9	40.0	15.61	39.0
N.42	21.9	20.7	1	14.9	30.2	26.94	25.5
N.43	7.2	7.1	0.5	14.9	50.0	2.42	91.6
N.44	9.0	8.8	0.5	14.9	40.0	3.78	86.5
N.45	12.6	11.9	0.5	14.9	30.2	6.25	61.6

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION O: GRATING TL 60

Description: Wooden squared grating with longitudinal bars

% Opening area	60.0%	Number of transversal bars	0
Area (m^2)	0.1936	Number of longitudinal bars	9
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
O.1	20.4	18.3	1.5	197.8	50.0	11.28	76.2
O.2	26.0	22.0	1.5	197.8	40.0	18.50	72.5
O.3	30.6	30.8	1.5	197.8	30.2	30.36	68.1
O.4	15.2	13.9	1	197.8	50.0	4.78	93.3
O.5	18.8	16.6	1	197.8	40.0	7.14	92.4
O.6	22.0	22.0	1	197.8	30.2	11.06	90.9
O.7	7.9	7.5	0.5	197.8	50.0	0.53	98.3
O.8	9.3	8.6	0.5	197.8	40.0	0.86	98.4
O.9	11.9	11.2	0.5	197.8	30.2	1.36	98.1
O.10	21.6	22.0	1.5	101.2	50.0	21.00	67.2
O.11	29.0	27.4	1.5	101.2	40.0	30.08	66.3
O.12	37.6	35.0	1.5	101.2	30.2	44.36	65.1
O.13	12.6	12.8	1	101.2	50.0	5.97	88.4
O.14	16.6	16.3	1	101.2	40.0	8.94	86.7
O.15	22.8	21.2	1	101.2	30.2	14.08	85.2
O.16	7.2	7.6	0.5	101.2	50.0	0.81	96.7
O.17	8.4	8.7	0.5	101.2	40.0	1.18	96.1
O.18	11.2	11.3	0.5	101.2	30.2	1.74	96.7
O.19	23.2	22.5	1.5	49.9	50.0	27.42	64.7
O.20	27.2	26.6	1.5	49.9	40.0	36.64	65.0
O.21	36.4	36.6	1.5	49.9	30.2	52.33	63.6
O.22	14.2	13.4	1	49.9	50.0	9.03	82.9
O.23	17.7	16.6	1	49.9	40.0	13.03	82.5
O.24	23.8	24.2	1	49.9	30.2	21.25	81.9
O.25	7.1	7.1	0.5	49.9	50.0	1.06	94.2
O.26	8.2	8.3	0.5	49.9	40.0	1.43	94.5
O.27	10.5	10.9	0.5	49.9	30.2	2.55	95.9
O.28	19.8	21.1	1.5	24.8	50.0	32.61	61.7
O.29	23.7	25.4	1.5	24.8	40.0	41.67	62.6
O.30	30.6	31.6	1.5	24.8	30.2	57.75	62.0
O.31	14.7	14.0	1	24.8	50.0	11.69	80.5
O.32	18.8	17.4	1	24.8	40.0	16.42	80.5
O.33	23.9	21.9	1	24.8	30.2	23.36	81.7
O.34	7.1	6.8	0.5	24.8	50.0	1.55	93.1
O.35	8.1	7.9	0.5	24.8	40.0	2.26	94.5
O.36	9.9	10.0	0.5	24.8	30.2	3.36	95.4
O.37	20.4	19.4	1.5	14.9	50.0	38.31	59.9
O.38	23.0	23.2	1.5	14.9	40.0	49.50	59.2
O.39	29.8	29.1	1.5	14.9	30.2	67.83	55.9
O.40	12.7	13.4	1	14.9	50.0	12.67	83.1
O.41	16.8	17.4	1	14.9	40.0	18.78	81.9
O.42	22.2	22.0	1	14.9	30.2	26.75	82.2
O.43	7.0	7.2	0.5	14.9	50.0	1.97	92.8
O.44	9.0	9.4	0.5	14.9	40.0	3.13	94.0
O.45	13.6	12.1	0.5	14.9	30.2	6.34	94.0

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION P: GRATING SL

Description: Wooden squared grating with longitudinal bars

% Opening area	44.0%	Number of transversal bars	0
Area (m^2)	0.1936	Number of longitudinal bars	7
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
P.1	24.7	22.8	1.5	197.8	50.0	16.67	71.2
P.2	25.0	26.0	1.5	197.8	40.0	22.11	69.8
P.3	36.0	36.8	1.5	197.8	30.2	36.61	65.0
P.4	16.1	14.6	1	197.8	50.0	5.83	92.6
P.5	17.6	16.2	1	197.8	40.0	6.94	93.3
P.6	21.2	20.2	1	197.8	30.2	10.61	90.0
P.7	7.6	7.5	0.5	197.8	50.0	0.56	97.6
P.8	9.0	8.5	0.5	197.8	40.0	0.75	97.7
P.9	12.3	11.5	0.5	197.8	30.2	1.48	95.6
P.10	23.0	23.6	1.5	100.2	50.0	23.47	68.7
P.11	28.0	29.6	1.5	100.2	40.0	34.44	64.6
P.12	37.0	34.8	1.5	100.2	30.2	44.94	61.4
P.13	14.9	13.6	1	100.2	50.0	6.86	83.7
P.14	18.0	17.7	1	100.2	40.0	10.56	83.0
P.15	22.0	21.7	1	100.2	30.2	14.06	82.4
P.16	6.7	7.1	0.5	100.2	50.0	0.81	93.3
P.17	9.3	9.5	0.5	100.2	40.0	1.46	94.0
P.18	11.0	11.3	0.5	100.2	30.2	1.92	94.0
P.19	21.4	21.4	1.5	49.9	50.0	27.08	65.3
P.20	25.8	26.6	1.5	49.9	40.0	36.94	59.9
P.21	33.6	34.4	1.5	49.9	30.2	55.83	55.5
P.22	14.6	14.4	1	49.9	50.0	10.00	80.8
P.23	17.8	18.3	1	49.9	40.0	14.17	80.5
P.24	24.3	24.4	1	49.9	30.2	21.94	79.2
P.25	7.1	7.0	0.5	49.9	50.0	1.18	90.1
P.26	8.3	6.7	0.5	49.9	40.0	1.77	91.9
P.27	11.1	11.6	0.5	49.9	30.2	3.19	94.5
P.28	19.9	18.7	1.5	25.0	50.0	30.83	58.5
P.29	24.3	22.8	1.5	25.0	40.0	41.39	56.4
P.30	32.4	29.0	1.5	25.0	30.2	58.33	54.7
P.31	14.7	14.1	1	25.0	50.0	13.00	78.2
P.32	18.0	17.2	1	25.0	40.0	17.64	76.9
P.33	21.6	20.2	1	25.0	30.2	23.33	72.1
P.34	7.2	6.9	0.5	25.0	50.0	1.94	88.0
P.35	8.9	8.7	0.5	25.0	40.0	3.16	89.1
P.36	10.8	10.2	0.5	25.0	30.2	4.30	93.2
P.37	17.0	16.0	1.5	14.9	50.0	33.89	56.5
P.38	20.5	19.4	1.5	14.9	40.0	45.28	54.8
P.39	27.0	27.2	1.5	14.9	30.2	61.67	50.9
P.40	12.3	12.8	1	14.9	50.0	14.50	71.3
P.41	16.3	16.2	1	14.9	40.0	19.17	71.1
P.42	22.6	21.4	1	14.9	30.2	28.61	70.8
P.43	8.2	8.0	0.5	14.9	50.0	3.82	91.8
P.44	9.9	9.8	0.5	14.9	40.0	4.44	90.7
P.45	12.8	12.0	0.5	14.9	30.2	6.29	90.1

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION Q: GRATING TL

Description: Wooden squared grating with longitudinal bars

% Opening area	26.0%	Number of transversal bars	0
Area (m^2)	0.1936	Number of longitudinal bars	7
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
Q.1	24.0	23.2	1.5	197.8	50.0	15.64	71.3
Q.2	29.4	27.4	1.5	197.8	40.0	24.47	66.1
Q.3	35.0	36.4	1.5	197.8	30.2	39.08	58.8
Q.4	15.1	14.6	1	197.8	50.0	5.08	94.3
Q.5	19.0	17.6	1	197.8	40.0	8.06	90.0
Q.6	24.1	22.6	1	197.8	30.2	12.50	86.2
Q.7	7.4	8.1	0.5	197.8	50.0	0.57	98.4
Q.8	8.7	8.0	0.5	197.8	40.0	0.68	96.6
Q.9	11.9	12.0	0.5	197.8	30.2	1.49	92.7
Q.10	23.2	24.1	1.5	101.2	50.0	23.33	65.1
Q.11	28.2	29.7	1.5	101.2	40.0	33.47	61.4
Q.12	35.4	38.6	1.5	101.2	30.2	49.31	54.5
Q.13	14.2	12.8	1	101.2	50.0	6.17	84.4
Q.14	17.6	17.0	1	101.2	40.0	9.89	83.7
Q.15	16.6	17.0	1	101.2	30.2	14.08	81.8
Q.16	7.2	7.6	0.5	101.2	50.0	0.92	90.4
Q.17	9.2	9.1	0.5	101.2	40.0	1.30	90.5
Q.18	12.1	12.1	0.5	101.2	30.2	2.35	93.1
Q.19	22.2	22.6	1.5	49.9	50.0	27.28	61.1
Q.20	26.8	28.6	1.5	49.9	40.0	37.92	56.5
Q.21	33.2	32.9	1.5	49.9	30.2	52.50	50.4
Q.22	14.0	12.8	1	49.9	50.0	9.28	78.3
Q.23	17.7	18.6	1	49.9	40.0	14.06	78.4
Q.24	22.4	24.3	1	49.9	30.2	20.81	75.7
Q.25	7.3	7.4	0.5	49.9	50.0	1.33	89.8
Q.26	8.2	8.5	0.5	49.9	40.0	1.69	90.0
Q.27	10.3	10.6	0.5	49.9	30.2	2.59	91.7
Q.28	18.8	19.6	1.5	25.0	50.0	31.11	56.4
Q.29	23.0	23.8	1.5	25.0	40.0	40.39	53.3
Q.30	30.8	32.0	1.5	25.0	30.2	62.78	43.4
Q.31	14.6	13.7	1	25.0	50.0	11.78	74.1
Q.32	18.0	16.8	1	25.0	40.0	16.28	73.7
Q.33	23.2	23.1	1	25.0	30.2	27.14	68.9
Q.34	7.2	6.6	0.5	25.0	50.0	1.87	86.8
Q.35	9.6	9.0	0.5	25.0	40.0	3.45	87.5
Q.36	10.9	10.3	0.5	25.0	30.2	4.23	87.5
Q.37	17.8	16.4	1.5	14.9	50.0	34.39	49.7
Q.38	20.0	19.4	1.5	14.9	40.0	41.06	49.6
Q.39	32.4	29.6	1.5	14.9	30.2	58.89	42.6
Q.40	13.9	13.4	1	14.9	50.0	13.11	70.4
Q.41	18.1	17.4	1	14.9	40.0	19.78	66.7
Q.42	22.6	21.2	1	14.9	30.2	26.39	62.3
Q.43	7.5	7.4	0.5	14.9	50.0	2.67	83.1
Q.44	9.8	9.3	0.5	14.9	40.0	4.15	82.5
Q.45	12.8	12.2	0.5	14.9	30.2	6.12	80.1

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION R: GRATING 170 TL 60

Description: Wooden squared grating with longitudinal and transversal bars

% Opening area	54.0%	Number of transversal bars	3
Area (m^2)	0.1936	Number of longitudinal bars	9
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
R.1	24.0	21.7	1.5	197.8	50.0	15.44	70.8
R.2	31.9	27.2	1.5	197.8	40.0	19.67	71.1
R.3	31.5	31.0	1.5	197.8	30.2	30.44	69.8
R.4	15.1	14.7	1	197.8	50.0	5.06	92.4
R.5	16.5	15.9	1	197.8	40.0	6.50	92.6
R.6	24.0	20.9	1	197.8	30.2	11.06	90.3
R.7	6.8	6.9	0.5	197.8	50.0	0.44	98.3
R.8	8.7	8.2	0.5	197.8	40.0	0.75	98.2
R.9	11.2	10.5	0.5	197.8	30.2	1.26	97.6
R.10	24.2	25.6	1.5	101.2	50.0	23.14	65.8
R.11	29.6	27.0	1.5	101.2	40.0	30.58	66.3
R.12	37.4	34.6	1.5	101.2	30.2	43.81	63.6
R.13	14.0	12.9	1	101.2	50.0	6.64	86.5
R.14	17.4	16.1	1	101.2	40.0	9.69	84.6
R.15	25.0	23.4	1	101.2	30.2	17.06	81.8
R.16	6.4	6.9	0.5	101.2	50.0	0.75	97.3
R.17	7.9	8.2	0.5	101.2	40.0	1.15	97.1
R.18	10.4	10.5	0.5	101.2	30.2	1.80	97.0
R.19	22.9	22.2	1.5	49.9	50.0	28.81	63.6
R.20	27.2	26.4	1.5	49.9	40.0	36.50	61.5
R.21	33.2	33.6	1.5	49.9	30.2	51.61	51.7
R.22	15.1	15.4	1	49.9	50.0	10.67	83.2
R.23	17.0	16.9	1	49.9	40.0	13.22	84.0
R.24	22.7	23.3	1	49.9	30.2	20.61	82.8
R.25	6.6	6.7	0.5	49.9	50.0	1.30	95.4
R.26	7.6	7.9	0.5	49.9	40.0	1.67	95.4
R.27	9.4	10.0	0.5	49.9	30.2	2.41	95.8
R.28	19.4	19.6	1.5	24.8	50.0	33.47	50.5
R.29	22.0	22.7	1.5	24.8	40.0	40.67	44.0
R.30	29.7	28.2	1.5	24.8	30.2	54.17	40.7
R.31	13.7	13.5	1	24.8	50.0	11.64	80.2
R.32	17.5	16.9	1	24.8	40.0	16.69	77.0
R.33	23.0	20.5	1	24.8	30.2	24.22	69.7
R.34	6.8	6.3	0.5	24.8	50.0	1.71	93.4
R.35	7.5	7.2	0.5	24.8	40.0	2.26	94.6
R.38	9.4	9.3	0.5	24.8	30.2	3.49	95.5
R.37	16.0	15.0	1.5	14.9	50.0	33.69	39.9
R.38	20.0	18.1	1.5	14.9	40.0	45.69	33.2
R.39	23.4	23.8	1.5	14.9	30.2	61.11	29.1
R.40	11.7	12.6	1	14.9	50.0	11.89	79.9
R.41	15.5	15.3	1	14.9	40.0	16.39	71.0
R.42	20.8	21.3	1	14.9	30.2	25.75	49.7
R.43	6.4	7.0	0.5	14.9	50.0	2.51	93.5
R.44	9.5	8.7	0.5	14.9	40.0	3.80	94.3
R.45	12.6	11.7	0.5	14.9	30.2	6.08	88.0

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION S: GRATING 170 L

Description: Wooden squared grating with longitudinal and transversal bars

% Opening area	39.6%	Number of transversal bars	3
Area (m^2)	0.1936	Number of longitudinal bars	7
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
S.1	19.9	19.0	1.5	197.8	50.0	11.17	76.5
S.2	27.2	26.9	1.5	197.8	40.0	18.86	72.6
S.3	39.5	35.0	1.5	197.8	30.2	31.86	67.0
S.4	13.8	13.8	1	197.8	50.0	4.56	94.3
S.5	16.6	16.2	1	197.8	40.0	6.25	93.9
S.6	23.9	21.8	1	197.8	30.2	12.33	90.0
S.7	6.9	7.3	0.5	197.8	50.0	0.53	100.0
S.8	8.6	8.6	0.5	197.8	40.0	0.75	98.3
S.9	11.1	10.6	0.5	197.8	30.2	1.36	98.1
S.10	24.5	22.2	1.5	101.2	50.0	21.64	64.3
S.11	28.8	26.2	1.5	101.2	40.0	28.56	62.9
S.12	38.5	38.9	1.5	101.2	30.2	43.56	60.0
S.13	15.6	13.5	1	101.2	50.0	6.61	83.9
S.14	20.0	18.3	1	101.2	40.0	11.28	80.4
S.15	20.6	19.4	1	101.2	30.2	12.69	86.5
S.16	6.3	6.7	0.5	101.2	50.0	0.81	96.6
S.17	8.3	8.5	0.5	101.2	40.0	1.26	95.8
S.18	10.9	11.6	0.5	101.2	30.2	2.10	96.5
S.19	17.6	19.2	1.5	49.9	50.0	21.00	67.3
S.20	24.4	25.6	1.5	49.9	40.0	31.08	62.9
S.21	34.2	34.5	1.5	49.9	30.2	53.11	48.5
S.22	14.0	13.7	1	49.9	50.0	10.00	80.0
S.23	15.4	17.0	1	49.9	40.0	13.53	80.1
S.24	21.6	24.7	1	49.9	30.2	20.28	78.7
S.25	5.1	4.9	0.5	49.9	50.0	1.26	96.3
S.26	7.5	7.5	0.5	49.9	40.0	1.67	94.0
S.27	9.4	9.6	0.5	49.9	30.2	2.51	94.3
S.28	17.5	18.7	1.5	24.8	50.0	29.44	49.8
S.29	24.1	25.1	1.5	24.8	40.0	43.72	37.2
S.30	30.8	32.4	1.5	24.8	30.2	57.08	35.3
S.31	12.9	12.7	1	24.8	50.0	11.11	75.7
S.32	15.0	14.4	1	24.8	40.0	14.44	74.1
S.33	21.0	20.0	1	24.8	30.2	22.94	61.4
S.34	6.6	5.7	0.5	24.8	50.0	1.77	92.0
S.35	10.3	9.3	0.5	24.8	40.0	4.09	92.4
S.36	13.3	13.0	0.5	24.8	30.2	6.32	90.6
S.37	18.6	16.8	1.5	14.9	50.0	35.47	31.9
S.38	20.1	20.9	1.5	14.9	40.0	43.25	31.3
S.39	23.0	25.2	1.5	14.9	30.2	56.92	30.2
S.40	11.5	11.2	1	14.9	50.0	11.36	73.2
S.41	14.7	14.1	1	14.9	40.0	15.11	67.0
S.42	19.5	18.4	1	14.9	30.2	22.56	50.7
S.43	6.9	6.8	0.5	14.9	50.0	2.88	90.2
S.44	9.6	9.5	0.5	14.9	40.0	4.70	89.5
S.45	12.7	12.5	0.5	14.9	30.2	6.94	78.4

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION T: GRATING 170 TL

Description: Wooden squared grating with longitudinal and transversal bars

% Opening area	23.4%	Number of transversal bars	3
Area (m^2)	0.1936	Number of longitudinal bars	7
Width (mm)	440	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
T.1	21.4	19.0	1.5	197.8	50.0	14.61	71.1
T.2	25.4	23.0	1.5	197.8	40.0	19.06	66.8
T.3	35.8	37.4	1.5	197.8	30.2	34.67	53.2
T.4	15.2	14.2	1	197.8	50.0	5.06	75.1
T.5	21.0	17.6	1	197.8	40.0	9.28	78.8
T.6	26.4	23.4	1	197.8	30.2	14.03	79.5
T.7	7.2	7.1	0.5	197.8	50.0	0.44	98.6
T.8	9.2	8.7	0.5	197.8	50.0	1.26	99.0
T.9	12.0	10.7	0.5	197.8	30.2	1.33	96.5
T.10	25.2	23.8	1.5	101.2	50.0	24.61	55.8
T.11	32.0	30.0	1.5	101.2	40.0	36.72	43.7
T.12	38.8	38.6	1.5	101.2	30.2	52.86	30.9
T.13	14.8	14.8	1	101.2	50.0	8.50	81.8
T.14	17.8	18.8	1	101.2	40.0	11.97	78.9
T.15	21.8	22.6	1	101.2	30.2	16.36	74.9
T.16	6.8	7.1	0.5	101.2	50.0	0.75	91.8
T.17	8.2	8.7	0.5	101.2	40.0	1.18	94.6
T.18	10.6	11.1	0.5	101.2	30.2	1.82	94.5
T.19	23.4	24.6	1.5	49.9	50.0	28.69	45.9
T.20	25.2	27.4	1.5	49.9	40.0	37.83	37.4
T.21	28.4	39.8	1.5	49.9	30.2	55.58	25.9
T.22	15.4	15.2	1	49.9	50.0	11.53	70.5
T.23	22.0	21.2	1	49.9	40.0	18.53	65.9
T.24	25.0	23.8	1	49.9	30.2	22.92	61.3
T.25	7.8	7.3	0.5	49.9	50.0	1.49	92.1
T.26	8.6	8.9	0.5	49.9	40.0	1.87	92.4
T.27	11.6	11.5	0.5	49.9	30.2	3.02	94.3
T.28	18.8	20.8	1.5	24.8	50.0	30.61	34.4
T.29	23.6	25.6	1.5	24.8	40.0	42.81	27.4
T.30	28.2	32.0	1.5	24.8	30.2	55.75	23.3
T.31	15.4	14.2	1	24.8	50.0	11.97	64.2
T.32	16.8	15.8	1	24.8	40.0	13.94	64.3
T.33	24.6	23.0	1	24.8	30.2	25.31	40.0
T.34	7.0	6.5	0.5	24.8	50.0	1.74	92.0
T.35	9.8	9.3	0.5	24.8	40.0	3.33	88.3
T.36	12.8	12.7	0.5	24.8	30.2	5.45	90.6
T.37	17.0	17.2	1.5	14.9	50.0	35.42	20.0
T.38	20.4	21.0	1.5	14.9	40.0	45.69	18.0
T.39	24.8	25.6	1.5	14.9	30.2	61.56	22.4
T.40	11.8	12.2	1	14.9	50.0	11.58	55.1
T.41	16.0	17.0	1	14.9	40.0	17.64	42.5
T.42	25.2	24.2	1	14.9	30.2	30.69	27.7
T.43	9.0	7.7	0.5	14.9	50.0	3.31	85.8
T.44	10.8	10.1	0.5	14.9	40.0	4.50	84.0
T.45	15.4	14.3	0.5	14.9	30.2	6.59	49.6

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION U: GRATING 170 RTL

Description: Wooden rectangular grating with longitudinal bars

% Opening area	39.6%	Number of transversal bars	1
Area (m^2)	0.0968	Number of longitudinal bars	7
Width (mm)	440	Number of diagonal bars	0
Length (mm)	220		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
U.1	22.4	19.7	1.5	197.8	50.0	11.41	52.1
U.2	29.6	30.1	1.5	197.8	40.0	22.19	41.6
U.3	40.3	36.4	1.5	197.8	30.2	42.96	27.9
U.4	14.6	12.7	1	197.8	50.0	4.96	76.9
U.5	18.2	16.9	1	197.8	40.0	8.06	68.1
U.6	22.6	23.1	1	197.8	30.2	12.76	57.8
U.7	8.0	9.4	0.5	197.8	50.0	0.44	98.5
U.8	9.4	8.7	0.5	197.8	40.0	0.75	98.8
U.9	7.0	10.5	0.5	197.8	30.2	0.75	97.8
U.10	22.4	20.2	1.5	101.2	50.0	21.60	34.3
U.11	30.2	27.8	1.5	101.2	40.0	30.51	31.6
U.12	39.4	33.3	1.5	101.2	30.2	44.26	26.5
U.13	12.3	12.6	1	101.2	50.0	6.41	61.6
U.14	16.9	16.8	1	101.2	40.0	10.04	57.5
U.15	23.6	22.3	1	101.2	30.2	15.32	47.2
U.16	6.6	7.1	0.5	101.2	50.0	0.75	97.9
U.17	8.5	8.6	0.5	101.2	40.0	1.30	97.7
U.18	10.8	11.1	0.5	101.2	30.2	2.12	96.7
U.19	19.4	10.4	1.5	49.9	50.0	23.00	30.8
U.20	27.0	27.7	1.5	49.9	40.0	34.47	25.9
U.21	30.8	31.7	1.5	49.9	30.2	42.55	23.5
U.22	13.2	13.0	1	49.9	50.0	9.16	51.0
U.23	17.0	17.5	1	49.9	40.0	13.83	45.3
U.24	22.4	23.6	1	49.9	30.2	20.39	39.3
U.25	7.3	7.2	0.5	49.9	50.0	1.46	89.2
U.26	8.1	8.2	0.5	49.9	40.0	1.74	90.4
U.27	8.9	9.4	0.5	49.9	30.2	2.42	92.8
U.28	19.0	18.3	1.5	24.8	50.0	30.96	24.3
U.29	23.2	23.1	1.5	24.8	40.0	40.41	19.6
U.30	29.9	29.9	1.5	24.8	30.2	53.90	19.8
U.31	13.7	13.6	1	24.8	50.0	12.66	43.1
U.32	17.2	16.4	1	24.8	40.0	16.49	38.1
U.33	21.0	18.6	1	24.8	30.2	21.63	34.3
U.34	7.3	6.7	0.5	24.8	50.0	1.94	82.4
U.35	10.3	9.2	0.5	24.8	40.0	3.66	75.4
U.36	12.7	12.4	0.5	24.8	30.2	5.72	75.3
U.37	16.4	14.8	1.5	14.9	50.0	29.12	22.7
U.38	18.6	18.4	1.5	14.9	40.0	38.57	17.8
U.39	26.0	25.5	1.5	14.9	30.2	54.56	17.4
U.40	12.4	12.8	1	14.9	50.0	13.80	34.8
U.41	8.6	9.0	1	14.9	40.0	18.52	33.0
U.42	12.8	11.2	1	14.9	30.2	24.70	29.4
U.43	6.1	5.8	0.5	14.9	50.0	1.82	80.6
U.44	10.5	10.0	0.5	14.9	40.0	4.81	80.3
U.45	12.3	11.6	0.5	14.9	30.2	5.96	68.3

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION V: GRATING 170 RLH

Description: Wooden rectangular grating with transversal bars

% Opening area	39.6%	Number of transversal bars	7
Area (m^2)	0.0968	Number of longitudinal bars	1
Width (mm)	220	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
V.1	23.6	21.1	1.5	197.8	50.0	16.80	58.4
V.2	28.0	27.7	1.5	197.8	40.0	24.95	53.3
V.3	39.0	36.7	1.5	197.8	30.2	40.48	45.8
V.4	15.7	13.5	1	197.8	50.0	6.46	77.7
V.5	19.4	18.4	1	197.8	40.0	10.04	75.8
V.6	21.1	23.0	1	197.8	30.2	13.97	73.6
V.7	8.2	7.6	0.5	197.8	50.0	0.53	95.2
V.8	9.3	8.1	0.5	197.8	40.0	0.86	94.4
V.9	12.2	11.2	0.5	197.8	30.2	1.49	91.7
V.10	24.6	22.4	1.5	101.2	50.0	22.11	51.6
V.11	28.2	25.3	1.5	101.2	40.0	29.69	45.5
V.12	36.3	32.1	1.5	101.2	30.2	43.02	39.1
V.13	14.1	15.8	1	101.2	50.0	9.16	71.4
V.14	17.9	18.8	1	101.2	40.0	12.13	69.1
V.15	23.8	25.4	1	101.2	30.2	20.49	61.6
V.16	8.1	8.4	0.5	101.2	50.0	1.06	91.9
V.17	9.9	10.6	0.5	101.2	40.0	1.74	89.1
V.18	11.3	11.7	0.5	101.2	30.2	2.33	86.4
V.19	26.5	23.9	1.5	49.9	50.0	34.71	36.9
V.20	30.5	26.7	1.5	49.9	40.0	41.18	33.3
V.21	32.8	34.9	1.5	49.9	30.2	50.39	32.3
V.22	15.2	13.9	1	49.9	50.0	10.48	67.1
V.23	19.0	18.6	1	49.9	40.0	15.77	62.0
V.24	24.2	23.4	1	49.9	30.2	22.29	55.6
V.25	7.1	7.0	0.5	49.9	50.0	1.49	86.8
V.26	8.5	8.8	0.5	49.9	40.0	2.21	78.8
V.27	10.4	10.8	0.5	49.9	30.2	3.58	76.8
V.28	22.3	21.9	1.5	24.8	50.0	35.38	29.2
V.29	25.8	26.6	1.5	24.8	40.0	44.67	26.0
V.30	30.2	27.9	1.5	24.8	30.2	49.91	27.0
V.31	13.7	13.6	1	24.8	50.0	11.27	61.1
V.32	16.1	15.6	1	24.8	40.0	13.79	58.2
V.33	22.4	20.6	1	24.8	30.2	21.41	48.9
V.34	8.1	6.8	0.5	24.8	50.0	2.42	74.5
V.35	10.7	9.8	0.5	24.8	40.0	4.04	76.6
V.36	13.7	12.4	0.5	24.8	30.2	6.17	71.3
V.37	15.2	15.9	1.5	14.9	50.0	30.02	30.6
V.38	18.4	19.1	1.5	14.9	40.0	36.28	26.9
V.39	21.0	21.7	1.5	14.9	30.2	50.31	22.5
V.40	12.4	11.6	1	14.9	50.0	12.12	53.1
V.41	15.8	15.7	1	14.9	40.0	17.56	44.3
V.42	20.5	19.9	1	14.9	30.2	26.07	36.7
V.43	7.1	6.8	0.5	14.9	50.0	2.41	71.3
V.44	10.0	9.9	0.5	14.9	40.0	4.64	66.8
V.45	13.8	13.1	0.5	14.9	30.2	7.22	60.1

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION W: GRATING 170 RLL

Description: Wooden rectangular grating with longitudinal and transversal bars

% Opening area	39.6%	Number of transversal bars	3
Area (m^2)	0.0968	Number of longitudinal bars	3
Width (mm)	220	Number of diagonal bars	0
Length (mm)	440		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
W.1	24.2	23.8	1.5	197.8	50.0	17.61	69.0
W.2	29.1	26.9	1.5	197.8	40.0	25.78	49.7
W.3	40.2	41.1	1.5	197.8	30.2	45.72	32.2
W.4	15.7	14.3	1	197.8	50.0	5.72	80.0
W.5	17.6	15.4	1	197.8	40.0	6.42	60.0
W.6	24.3	21.9	1	197.8	30.2	12.67	57.5
W.7	7.4	8.8	0.5	197.8	50.0	0.62	98.2
W.8	8.9	9.0	0.5	197.8	40.0	0.86	97.8
W.9	11.0	11.2	0.5	197.8	30.2	1.30	97.5
W.10	25.8	25.1	1.5	101.2	50.0	24.64	42.4
W.11	28.9	29.7	1.5	101.2	40.0	31.97	34.8
W.12	37.3	36.7	1.5	101.2	30.2	47.89	32.0
W.13	15.8	14.6	1	101.2	50.0	8.00	69.3
W.14	19.4	18.6	1	101.2	40.0	11.69	63.5
W.15	24.4	23.6	1	101.2	30.2	17.22	53.0
W.16	6.5	7.0	0.5	101.2	50.0	0.92	93.7
W.17	8.3	8.6	0.5	101.2	40.0	1.06	92.5
W.18	11.5	11.5	0.5	101.2	30.2	2.04	96.8
W.19	23.0	21.7	1.5	49.9	50.0	27.58	42.3
W.20	28.1	27.2	1.5	49.9	40.0	34.25	25.5
W.21	36.8	35.3	1.5	49.9	30.2	52.36	37.9
W.22	14.8	15.2	1	49.9	50.0	10.36	56.7
W.23	17.8	18.0	1	49.9	40.0	13.92	52.3
W.24	25.0	24.0	1	49.9	30.2	20.81	49.1
W.25	7.2	7.2	0.5	49.9	50.0	1.30	81.8
W.26	8.5	8.9	0.5	49.9	40.0	1.87	83.8
W.27	10.5	10.6	0.5	49.9	30.2	2.60	87.9
W.28	20.9	19.1	1.5	24.8	50.0	27.67	15.3
W.29	24.7	22.5	1.5	24.8	40.0	34.89	6.9
W.30	31.9	28.9	1.5	24.8	30.2	52.03	16.9
W.31	14.9	13.4	1	24.8	50.0	12.19	51.3
W.32	16.8	16.2	1	24.8	40.0	15.19	48.2
W.33	21.4	21.4	1	24.8	30.2	21.83	38.5
W.34	6.5	6.1	0.5	24.8	50.0	1.49	76.0
W.35	7.5	7.2	0.5	24.8	40.0	2.05	80.2
W.36	11.0	10.2	0.5	24.8	30.2	4.06	76.0
W.37	19.4	17.1	1.5	14.9	50.0	34.33	34.5
W.38	22.6	21.3	1.5	14.9	40.0	41.56	23.7
W.39	29.0	25.0	1.5	14.9	30.2	56.14	19.7
W.40	13.6	12.8	1	14.9	50.0	13.08	43.0
W.41	16.4	14.4	1	14.9	40.0	15.53	36.5
W.42	20.0	20.0	1	14.9	30.2	22.83	28.6
W.43	7.3	7.0	0.5	14.9	50.0	2.42	73.2
W.44	9.4	9.2	0.5	14.9	40.0	3.84	74.2
W.45	13.2	12.3	0.5	14.9	30.2	6.51	65.4

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION X: GRATING 170 RTH

Description: Wooden rectangular grating with longitudinal and transversal bars

% Opening area	39.6%	Number of transversal bars	3
Area (m^2)	0.0968	Number of longitudinal bars	3
Width (mm)	440	Number of diagonal bars	0
Length (mm)	220		

Test nº	Water depth at a third of the width from the kerb		Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm) *	H_2 (mm) *	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
X.1	25.1	22.4	1.5	197.8	50.0	19.17	44.5
X.2	32.0	28.9	1.5	197.8	40.0	27.00	37.4
X.3	41.5	38.9	1.5	197.8	30.2	41.61	31.7
X.4	14.5	13.9	1	197.8	50.0	4.72	86.3
X.5	20.0	18.8	1	197.8	40.0	8.89	73.4
X.6	21.2	19.7	1	197.8	30.2	10.08	71.1
X.7	7.0	7.0	0.5	197.8	50.0	0.44	97.3
X.8	9.9	9.4	0.5	197.8	40.0	0.86	96.7
X.9	12.7	12.2	0.5	197.8	30.2	1.52	95.6
X.10	25.0	23.7	1.5	101.2	50.0	24.50	38.2
X.11	29.4	27.9	1.5	101.2	40.0	30.14	34.7
X.12	38.6	39.9	1.5	101.2	30.2	44.83	27.7
X.13	14.7	13.6	1	101.2	50.0	6.53	72.0
X.14	19.0	17.7	1	101.2	40.0	10.22	61.9
X.15	25.4	24.0	1	101.2	30.2	16.39	50.2
X.16	6.1	6.4	0.5	101.2	50.0	0.62	91.7
X.17	10.3	10.2	0.5	101.2	40.0	1.22	92.4
X.18	12.9	12.4	0.5	101.2	30.2	2.69	95.2
X.19	21.8	22.5	1.5	49.9	50.0	25.22	33.0
X.20	25.8	26.3	1.5	49.9	40.0	33.75	26.4
X.21	34.6	37.6	1.5	49.9	30.2	51.39	21.9
X.22	16.4	15.8	1	49.9	50.0	10.56	56.5
X.23	21.1	20.6	1	49.9	40.0	15.33	46.2
X.24	28.1	27.0	1	49.9	30.2	22.78	38.3
X.25	5.8	5.6	0.5	49.9	50.0	0.81	88.8
X.26	8.3	8.5	0.5	49.9	40.0	1.64	89.8
X.27	11.1	11.4	0.5	49.9	30.2	3.11	85.0
X.28	19.6	20.0	1.5	24.8	50.0	28.75	25.1
X.29	23.7	23.4	1.5	24.8	40.0	38.89	20.0
X.30	31.5	31.1	1.5	24.8	30.2	58.33	17.0
X.31	15.7	14.9	1	24.8	50.0	12.97	41.0
X.32	19.1	17.4	1	24.8	40.0	18.78	32.3
X.33	22.8	21.8	1	24.8	30.2	24.89	28.4
X.34	7.2	7.0	0.5	24.8	50.0	2.04	85.6
X.35	8.4	8.0	0.5	24.8	40.0	2.63	81.0
X.36	9.8	9.8	0.5	24.8	30.2	3.75	75.4
X.37	18.2	16.1	1.5	14.9	50.0	33.19	17.0
X.38	20.6	20.3	1.5	14.9	40.0	42.22	15.4
X.39	27.4	25.9	1.5	14.9	30.2	60.28	18.9
X.40	12.9	12.9	1	14.9	50.0	12.97	36.6
X.41	16.8	16.0	1	14.9	40.0	16.67	30.9
X.42	21.8	20.7	1	14.9	30.2	25.44	25.6
X.43	6.8	6.8	0.5	14.9	50.0	2.14	77.4
X.44	9.7	10.0	0.5	14.9	40.0	4.04	69.1
X.45	12.3	11.8	0.5	14.9	30.2	5.41	57.6

* H_1 and H_2 are measured respectively at 0.15 m and 0.65 m from the grating

CONFIGURATION SA: STRAIGHT KERB 0.5M

Description:

Parallel Opening Length (m)	0.5

Test nº	Water depth at a third of the width from the kerb	Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm)	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
SA.1	7.8	0.5	50	50	1.44	43.0
SA.2	9.4	0.5	50	40	1.98	26.0
SA.3	11.0	0.5	50	30	3.01	26.0
SA.4	11.0	0.5	50	30	2.94	25.0
SA.5	11.0	0.5	100	30	2.31	40.0
SA.6	9.2	0.5	100	50	1.07	68.0
SA.7	8.0	0.5	100	40	1.21	66.0
SA.8	14.6	0.5	200	30	1.44	68.0
SA.9	11.2	0.5	200	40	0.86	77.0
SA.10	9.4	0.5	200	50	0.65	77.0
SA.11	10.4	0.5	300	40	0.91	95.0
SA.12	15.0	0.5	300	30	1.33	88.0
SA.13	8.6	0.5	300	50	0.40	89.0
SA.14	12.6	0.5	300	30	1.12	82.0
SA.15	8.6	0.5	500	50	0.46	99.0
SA.16	10.2	0.5	500	40	0.56	82.0
SA.17	13.0	0.5	500	30	0.97	86.0
SA.18	14.6	1	100	40	7.33	20.0
SA.19	18.6	1	100	30	10.86	16.0
SA.20	12.0	1	100	50	5.02	20.0
SA.21	15.6	1	200	50	3.62	32.0
SA.22	18.2	1	200	40	5.68	34.0
SA.23	20.0	1	200	30	9.12	31.0
SA.24	23.8	1	500	30	6.58	39.0
SA.25	17.4	1	500	40	3.86	43.0
SA.26	14.0	1	500	50	2.31	41.0
SA.27	17.2	0.75	500	30	3.11	48.0
SA.28	11.4	0.75	500	50	1.07	73.0

CONFIGURATION SB: STRAIGHT KERB 0.25M

Description:

Parallel Opening Length (m)	0.25

Test nº	Water depth at a third of the width from the kerb	Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm)	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
SB.1	7.0	0.25	500	30	0.16	99.0
SB.2	4.6	0.25	300	50	0.06	1.0
SB.3	5.0	0.25	200	50	0.13	89.0
SB.4	6.4	0.25	200	30	0.21	79.0
SB.5	6.2	0.25	100	50	0.50	32.0
SB.6	6.6	0.25	100	30	0.46	55.0
SB.7	13.0	0.25	200	30	1.47	16.0
SB.8	10.0	0.25	100	30	1.90	8.0
SB.9	7.8	0.25	100	40	1.25	6.0

CONFIGURATION AA: ANGLED KERB 0.5M

Description:

Parallel Opening Length (m)	1.88

Test nº	Water depth at a third of the width from the kerb	Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm)	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
AA.1	8.2	0.5	300	50	0.65	100.0
AA.2	11.2	0.5	300	30	1.98	100.0
AA.3	11.6	0.5	200	30	2.31	100.0
AA.4	7.4	0.5	200	50	0.97	100.0
AA.5	7.0	0.5	100	50	1.16	100.0
AA.6	10.2	0.5	100	30	2.33	100.0
AA.7	12.2	0.5	50	30	4.13	86.5
AA.8	8.6	0.5	50	50	2.05	80.0
AA.9	17.2	1	300	50	5.01	84.0

CONFIGURATION AB: ANGLED KERB 0.25M

Description:

Parallel Opening Length (m)	0.94

Test nº	Water depth at a third of the width from the kerb	Flow width	Inverse of longitudinal slope	Inverse of cross fall	Discharge	Efficiency
	H_1 (mm)	B (m)	$1/S_L$	$1/S_C$	Q (l/s)	η (%)
AB.1	7.4	0.5	300	50	0.46	97.0
AB.2	12.0	0.5	300	30	1.40	89.0
AB.3	11.8	0.5	200	30	1.81	84.0
AB.4	7.6	0.5	200	50	0.72	89.0
AB.5	7.6	0.5	100	50	1.07	75.0
AB.6	11.6	0.5	100	30	2.58	66.0
AB.7	6.4	0.5	50	50	1.16	56.0
AB.8	9.2	0.5	50	30	2.60	52.0
AB.9	12.8	1	300	50	3.01	48.0
AB.10	21.3	1	300	30	7.6	52
AB.11	20.8	1	200	30	8.1	46
AB.12	13.8	1	200	50	3.91	47

Appendix B

Assessment of the number of bars in a grating

Appendix B Assessment of the number of bars in a grating

A key step in assessing the hydraulic capacity of a grating using Equation (5) (see main text) is the procedure adopted when counting the number of bars. Equations (8) and (9) include the numbers of transversal, longitudinal and diagonal bars (n_t, n_l and n_d respectively) that make up the grating. Obviously the number of bars in a grating is a somewhat simplistic measure of the pattern, and certain proprietary gratings have complex designs (eg, with staggered bars or short stub bars) that may be less easy to categorise than the older types of BS grating. However, the HR tests have shown that there is a good correlation between the hydraulic performance of a grating and the numbers and types of "main" bar that it contains. A "main" bar in this context is defined as: *a structural member that spans from one side to another of the slotted area; a series of short stub bars that are aligned, but have gaps between them and effectively span the slotted area, should be counted as forming one main bar.* In many cases, gratings have a repetitive pattern with a combination of two types of main bar that cross each other (eg, longitudinal and transversal bars, or longitudinal and diagonal bars).

Figure B.1 shows a typical grating with longitudinal and transversal bars. Note that the overall area, A_g, of the grating is defined by the perimeter of the slots, not by the perimeter of the grating itself. In this case, the number of transversal bars is $n_t = 7$, the number of longitudinal bars is $n_l = 3$, and the number of diagonal bars is $n_d = 0$. Figure A1.1b shows a grating with essentially diagonal bars and one longitudinal bar. In this case, the number of transversal bars is $n_t = 0$, the number of longitudinal bars is $n_l = 1$ and the number of diagonal bars is $n_d = 12$.

As mentioned above, some gratings have more complicated patterns with short stub bars or with slots around the sides of the grating. In these cases, it is necessary first to look at the pattern in terms of the slots and then define the main bars that produce this overall pattern (using the definition of "main" bar given above). In case of doubt, it is best to err on the safe side and overestimate the number of bars; increasing the number of transversal bars, from say $n_t = 6$ to $n_t = 7$ would alter the calculated value of G by less than 3%.

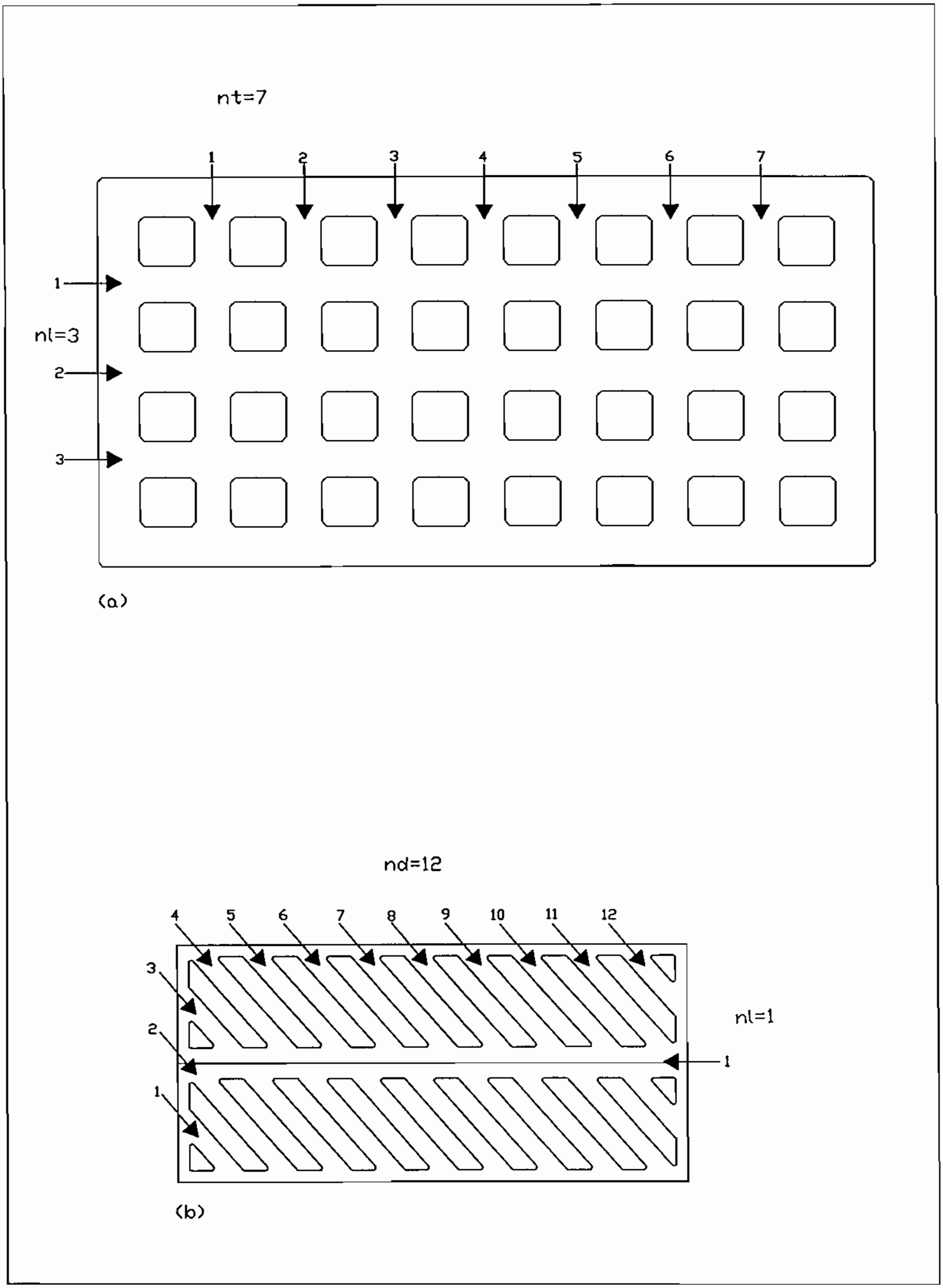


Figure B.1 Flow chart showing detailed steps for determining the spacing of road gullies

Appendix C

Design tables

Table C1: Discharge at the kerb in l/s

Crossfall	Gradient	Flow width (m)			
		0.5	0.75	1	1.5
1/60	1/300	0.18	0.53	1.15	3.39
	1/150	0.26	0.76	1.63	4.80
	1/100	0.31	0.93	1.99	5.87
	1/80	0.35	1.03	2.23	6.57
	1/60	0.41	1.19	2.57	7.58
	1/50	0.44	1.31	2.82	8.31
	1/40	0.50	1.46	3.15	9.29
	1/30	0.57	1.69	3.64	10.73
	1/20	0.70	2.07	4.46	13.14
	1/15	0.81	2.39	5.14	15.17
1/50	1/300	0.24	0.72	1.56	4.59
	1/150	0.35	1.02	2.20	6.49
	1/100	0.42	1.25	2.69	7.94
	1/80	0.47	1.40	3.01	8.88
	1/60	0.55	1.62	3.48	10.25
	1/50	0.60	1.77	3.81	11.23
	1/40	0.67	1.98	4.26	12.56
	1/30	0.77	2.28	4.92	14.50
	1/20	0.95	2.80	6.02	17.76
	1/15	1.10	3.23	6.96	20.51
1/40	1/300	0.35	1.04	2.25	6.63
	1/150	0.50	1.48	3.18	9.38
	1/100	0.61	1.81	3.89	11.48
	1/80	0.69	2.02	4.35	12.84
	1/60	0.79	2.33	5.03	14.83
	1/50	0.87	2.56	5.51	16.24
	1/40	0.97	2.86	6.16	18.16
	1/30	1.12	3.30	7.11	20.97
	1/20	1.37	4.04	8.71	25.68
	1/15	1.58	4.67	10.06	29.65

Manning's coefficient is n = 0.017.
For other values of Manning's n, multiply the discharge by (0.017/n)

Table C1 (cont.): Discharge at the kerb in l/s

Crossfall	Gradient	Flow width (m)			
		0.5	0.75	1	1.5
1/30	1/300	0.57	1.68	3.61	10.65
	1/150	0.80	2.37	5.11	15.06
	1/100	0.99	2.91	6.26	18.45
	1/80	1.10	3.25	6.99	20.62
	1/60	1.27	3.75	8.08	23.81
	1/50	1.39	4.11	8.85	26.09
	1/40	1.56	4.59	9.89	29.17
	1/30	1.80	5.30	11.42	33.68
	1/20	2.20	6.50	13.99	41.25
	1/15	2.54	7.50	16.15	47.63
1/25	1/300	0.77	2.26	4.87	14.37
	1/150	1.09	3.20	6.89	20.32
	1/100	1.33	3.92	8.44	24.88
	1/80	1.49	4.38	9.44	27.82
	1/60	1.72	5.06	10.90	32.13
	1/50	1.88	5.54	11.94	35.19
	1/40	2.10	6.20	13.35	39.35
	1/30	2.43	7.16	15.41	45.43
	1/20	2.97	8.76	18.87	55.64
	1/15	3.43	10.12	21.79	64.25
1/20	1/300	1.11	3.26	7.02	20.70
	1/150	1.56	4.61	9.93	29.28
	1/100	1.92	5.65	12.16	35.86
	1/80	2.14	6.31	13.60	40.09
	1/60	2.47	7.29	15.70	46.29
	1/50	2.71	7.99	17.20	50.71
	1/40	3.03	8.93	19.23	56.69
	1/30	3.50	10.31	22.20	65.46
	1/20	4.28	12.63	27.19	80.18
	1/15	4.95	14.58	31.40	92.58
1/15	1/300	1.77	5.21	11.22	33.07
	1/150	2.50	7.37	15.86	46.77
	1/100	3.06	9.02	19.43	57.28
	1/80	3.42	10.09	21.72	64.04
	1/60	3.95	11.65	25.08	73.94
	1/50	4.33	12.76	27.47	81.00
	1/40	4.84	14.26	30.72	90.56
	1/30	5.59	16.47	35.47	104.57
	1/20	6.84	20.17	43.44	128.07
	1/15	7.90	23.29	50.16	147.89

Manning's coefficient is n = 0.017.
For other values of Manning's n, multiply the discharge by (0.017/n)

Table C2: TYPE P
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(99)*	38	*(99)*	81	*(98)*	234	*(96)*
	1/150	18	*(99)*	53	*(98)*	114	*(97)*	325	*(94)*
	1/100	22	*(99)*	65	*(98)*	138	*(96)*	393	*(93)*
	1/80	25	*(99)*	73	*(98)*	154	*(96)*	436	*(92)*
	1/60	29	*(99)*	84	*(97)*	177	*(95)*	496	*(91)*
	1/50	31	*(98)*	91	*(97)*	193	*(95)*	539	*(90)*
	1/40	35	*(98)*	102	*(96)*	214	*(94)*	594	*(94)*
	1/30	40	*(98)*	117	*(96)*	245	*(93)*	673	*(87)*
	1/20	49	*(97)*	142	*(95)*	295	*(92)*	797	*(84)*
	1/15	57	*(97)*	162	*(94)*	336	*(91)*	893	*(82)*
1/50	1/300	18	*(99)*	51	*(99)*	109	*(98)*	315	*(95)*
	1/150	25	*(99)*	72	*(98)*	153	*(97)*	437	*(94)*
	1/100	30	*(99)*	88	*(97)*	186	*(96)*	526	*(92)*
	1/80	34	*(99)*	98	*(97)*	207	*(95)*	583	*(91)*
	1/60	39	*(98)*	113	*(97)*	237	*(95)*	663	*(90)*
	1/50	42	*(98)*	123	*(96)*	259	*(94)*	718	*(89)*
	1/40	47	*(98)*	137	*(96)*	287	*(94)*	791	*(87)*
	1/30	54	*(98)*	157	*(95)*	328	*(93)*	893	*(85)*
	1/20	66	*(97)*	190	*(94)*	395	*(91)*	1052	*(82)*
	1/15	76	*(97)*	218	*(94)*	449	*(90)*	1174	*(79)*
1/40	1/300	25	*(99)*	74	*(98)*	158	*(97)*	452	*(95)*
	1/150	36	*(99)*	104	*(98)*	220	*(96)*	624	*(92)*
	1/100	44	*(99)*	126	*(97)*	267	*(95)*	751	*(91)*
	1/80	49	*(98)*	141	*(97)*	297	*(95)*	829	*(90)*
	1/60	56	*(98)*	162	*(96)*	340	*(94)*	941	*(88)*
	1/50	61	*(98)*	177	*(96)*	370	*(93)*	1017	*(87)*
	1/40	68	*(98)*	196	*(95)*	411	*(93)*	1117	*(85)*
	1/30	78	*(97)*	225	*(95)*	468	*(91)*	1256	*(83)*
	1/20	96	*(97)*	272	*(94)*	562	*(90)*	1469	*(79)*
	1/15	110	*(96)*	311	*(93)*	637	*(88)*	1628	*(76)*

Manning's coefficient is n = 0.017
For others values of rainfall intensity I, multiply the area by (50/I)

Table C2: TYPE P
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	41	*(99)*	118	*(98)*	252	*(97)*	718	*(94)*
	1/150	57	*(99)*	166	*(97)*	351	*(95)*	986	*(91)*
	1/100	70	*(98)*	202	*(97)*	425	*(94)*	1181	*(89)*
	1/80	78	*(98)*	225	*(96)*	472	*(94)*	1301	*(88)*
	1/60	89	*(98)*	258	*(95)*	539	*(93)*	1470	*(86)*
	1/50	98	*(97)*	281	*(95)*	586	*(92)*	1584	*(84)*
	1/40	109	*(97)*	312	*(94)*	649	*(91)*	1732	*(83)*
	1/30	125	*(97)*	358	*(94)*	738	*(90)*	1935	*(80)*
	1/20	152	*(96)*	431	*(92)*	880	*(87)*	2235	*(75)*
	1/15	175	*(95)*	491	*(91)*	994	*(85)*	2449	*(71)*
1/25	1/300	55	*(99)*	159	*(98)*	338	*(96)*	960	*(93)*
	1/150	77	*(98)*	223	*(97)*	471	*(95)*	1314	*(90)*
	1/100	94	*(98)*	271	*(96)*	569	*(94)*	1569	*(88)*
	1/80	105	*(98)*	302	*(96)*	631	*(93)*	1725	*(86)*
	1/60	120	*(97)*	346	*(95)*	720	*(92)*	1942	*(84)*
	1/50	132	*(97)*	377	*(94)*	782	*(91)*	2088	*(82)*
	1/40	147	*(97)*	419	*(94)*	865	*(90)*	2276	*(80)*
	1/30	168	*(96)*	478	*(93)*	981	*(88)*	2528	*(77)*
	1/20	204	*(96)*	576	*(91)*	1167	*(86)*	2892	*(72)*
	1/15	234	*(95)*	655	*(90)*	1313	*(84)*	3140	*(68)*
1/20	1/300	79	*(99)*	229	*(97)*	484	*(96)*	1367	*(92)*
	1/150	110	*(98)*	320	*(96)*	672	*(94)*	1861	*(88)*
	1/100	135	*(98)*	388	*(95)*	812	*(93)*	2211	*(86)*
	1/80	150	*(97)*	432	*(95)*	899	*(92)*	2423	*(84)*
	1/60	173	*(97)*	494	*(94)*	1024	*(91)*	2716	*(81)*
	1/50	189	*(97)*	538	*(94)*	1111	*(90)*	2910	*(80)*
	1/40	210	*(96)*	597	*(93)*	1225	*(88)*	3156	*(77)*
	1/30	241	*(96)*	681	*(92)*	1386	*(87)*	3479	*(74)*
	1/20	293	*(95)*	817	*(90)*	1638	*(84)*	3921	*(68)*
	1/15	335	*(94)*	927	*(88)*	1835	*(81)*	4197	*(63)*
1/15	1/300	125	*(98)*	363	*(97)*	767	*(95)*	2145	*(90)*
	1/150	176	*(98)*	507	*(96)*	1061	*(93)*	2895	*(86)*
	1/100	214	*(97)*	614	*(95)*	1276	*(91)*	3415	*(83)*
	1/80	239	*(97)*	682	*(94)*	1411	*(90)*	3725	*(81)*
	1/60	274	*(96)*	780	*(93)*	1602	*(89)*	4143	*(78)*
	1/50	299	*(96)*	848	*(92)*	1734	*(88)*	4415	*(76)*
	1/40	333	*(96)*	939	*(91)*	1906	*(86)*	4749	*(73)*
	1/30	382	*(95)*	1069	*(90)*	2146	*(84)*	5167	*(69)*
	1/20	462	*(94)*	1276	*(88)*	2516	*(80)*	5678	*(62)*
	1/15	528	*(93)*	1443	*(86)*	2796	*(77)*	5924	*(56))*

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C3: TYPE Q
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(99)*	38	*(98)*	80	*(97)*	229	*(94)*
	1/150	18	*(99)*	53	*(97)*	112	*(96)*	316	*(91)*
	1/100	22	*(98)*	64	*(97)*	136	*(95)*	378	*(89)*
	1/80	25	*(98)*	72	*(96)*	151	*(94)*	417	*(88)*
	1/60	29	*(98)*	82	*(96)*	172	*(93)*	472	*(86)*
	1/50	31	*(98)*	90	*(95)*	187	*(92)*	509	*(85)*
	1/40	35	*(97)*	100	*(95)*	208	*(91)*	557	*(83)*
	1/30	40	*(97)*	114	*(94)*	236	*(90)*	623	*(81)*
	1/20	49	*(96)*	138	*(93)*	282	*(88)*	722	*(76)*
	1/15	56	*(96)*	157	*(91)*	319	*(86)*	794	*(73)*
1/50	1/300	17	*(99)*	51	*(98)*	108	*(97)*	307	*(93)*
	1/150	25	*(98)*	71	*(97)*	151	*(95)*	422	*(90)*
	1/100	30	*(98)*	87	*(96)*	182	*(94)*	504	*(88)*
	1/80	33	*(98)*	96	*(96)*	202	*(93)*	554	*(87)*
	1/60	38	*(98)*	111	*(95)*	231	*(92)*	625	*(85)*
	1/50	42	*(97)*	121	*(95)*	251	*(91)*	673	*(83)*
	1/40	47	*(97)*	134	*(94)*	277	*(90)*	734	*(81)*
	1/30	54	*(97)*	153	*(93)*	315	*(89)*	817	*(78)*
	1/20	65	*(96)*	185	*(92)*	375	*(86)*	938	*(73)*
	1/15	75	*(95)*	210	*(90)*	422	*(84)*	1022	*(69)*
1/40	1/300	25	*(99)*	73	*(97)*	155	*(96)*	439	*(92)*
	1/150	35	*(98)*	103	*(96)*	216	*(94)*	599	*(89)*
	1/100	43	*(98)*	125	*(96)*	261	*(93)*	713	*(86)*
	1/80	48	*(98)*	139	*(95)*	289	*(92)*	782	*(85)*
	1/60	55	*(97)*	159	*(94)*	329	*(91)*	878	*(82)*
	1/50	61	*(97)*	173	*(94)*	357	*(90)*	941	*(81)*
	1/40	67	*(97)*	192	*(93)*	394	*(89)*	1022	*(78)*
	1/30	77	*(96)*	219	*(92)*	446	*(87)*	1130	*(75)*
	1/20	94	*(95)*	263	*(90)*	529	*(84)*	1279	*(69)*
	1/15	108	*(94)*	299	*(89)*	593	*(82)*	1375	*(64)*

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C3 (cont.): TYPE Q
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	40	*(98)*	117	*(97)*	247	*(95)*	693	*(90)*
	1/150	57	*(98)*	163	*(96)*	342	*(93)*	937	*(86)*
	1/100	69	*(97)*	198	*(95)*	412	*(92)*	1108	*(83)*
	1/80	77	*(97)*	220	*(94)*	456	*(91)*	1209	*(81)*
	1/60	88	*(97)*	252	*(93)*	518	*(89)*	1347	*(79)*
	1/50	97	*(96)*	274	*(93)*	561	*(88)*	1437	*(77)*
	1/40	107	*(96)*	303	*(92)*	617	*(87)*	1549	*(74)*
	1/30	123	*(95)*	345	*(90)*	696	*(85)*	1690	*(70)*
	1/20	149	*(94)*	413	*(88)*	817	*(81)*	1867	*(63)*
	1/15	171	*(93)*	467	*(86)*	909	*(78)*	1959	*(57)*
1/25	1/300	54	*(98)*	157	*(97)*	332	*(95)*	923	*(89)*
	1/150	76	*(98)*	219	*(95)*	458	*(92)*	1240	*(85)*
	1/100	93	*(97)*	266	*(94)*	550	*(91)*	1457	*(81)*
	1/80	103	*(97)*	295	*(93)*	607	*(89)*	1585	*(79)*
	1/60	119	*(96)*	337	*(92)*	688	*(88)*	1756	*(76)*
	1/50	130	*(96)*	366	*(92)*	744	*(87)*	1865	*(74)*
	1/40	144	*(95)*	405	*(91)*	817	*(85)*	1997	*(70)*
	1/30	165	*(95)*	460	*(89)*	917	*(83)*	2157	*(66)*
	1/20	200	*(93)*	548	*(87)*	1070	*(79)*	2334	*(58)*
	1/15	228	*(92)*	618	*(85)*	1184	*(75)*	2397	*(52)*
1/20	1/300	78	*(98)*	226	*(96)*	474	*(94)*	1305	*(88)*
	1/150	109	*(97)*	314	*(94)*	651	*(91)*	1738	*(82)*
	1/100	133	*(97)*	379	*(93)*	780	*(89)*	2026	*(78)*
	1/80	148	*(96)*	420	*(92)*	859	*(88)*	2192	*(76)*
	1/60	170	*(96)*	479	*(91)*	971	*(86)*	2407	*(72)*
	1/50	186	*(95)*	520	*(90)*	1047	*(85)*	2540	*(70)*
	1/40	206	*(95)*	574	*(89)*	1145	*(83)*	2693	*(66)*
	1/30	236	*(94)*	650	*(88)*	1279	*(80)*	2862	*(61)*
	1/20	285	*(92)*	771	*(85)*	1479	*(76)*	2996	*(52)*
	1/15	324	*(91)*	866	*(83)*	1622	*(72)*	Not eff. *(44)*	
1/15	1/300	124	*(98)*	357	*(95)*	746	*(92)*	2027	*(85)*
	1/150	174	*(97)*	496	*(93)*	1020	*(89)*	2659	*(79)*
	1/100	211	*(96)*	597	*(92)*	1215	*(87)*	3061	*(74)*
	1/80	235	*(95)*	660	*(91)*	1335	*(85)*	3282	*(71)*
	1/60	269	*(95)*	751	*(90)*	1500	*(83)*	3552	*(67)*
	1/50	293	*(94)*	813	*(89)*	1611	*(81)*	3706	*(64)*
	1/40	326	*(93)*	895	*(87)*	1753	*(79)*	3863	*(59)*
	1/30	372	*(92)*	1010	*(85)*	1942	*(76)*	3986	*(53)*
	1/20	447	*(91)*	1189	*(82)*	2211	*(71)*	Not eff. *(42)*	
	1/15	508	*(89)*	1325	*(79)*	2389	*(66)*	Not eff. *(33)*	

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C4: TYPE R
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(99)*	37	*(97)*	79	*(96)*	224	*(92)*
	1/150	18	*(98)*	52	*(96)*	110	*(94)*	306	*(88)*
	1/100	22	*(98)*	64	*(96)*	133	*(93)*	363	*(86)*
	1/80	25	*(97)*	71	*(95)*	148	*(92)*	398	*(84)*
	1/60	28	*(97)*	81	*(94)*	168	*(91)*	447	*(82)*
	1/50	31	*(97)*	88	*(94)*	182	*(90)*	479	*(80)*
	1/40	34	*(96)*	98	*(93)*	201	*(89)*	520	*(78)*
	1/30	40	*(96)*	112	*(92)*	228	*(87)*	573	*(74)*
	1/20	48	*(95)*	134	*(90)*	269	*(84)*	648	*(68)*
	1/15	55	*(94)*	152	*(89)*	302	*(81)*	695	*(64)*
1/50	1/300	17	*(99)*	51	*(97)*	107	*(95)*	300	*(91)*
	1/150	24	*(98)*	71	*(96)*	148	*(93)*	406	*(87)*
	1/100	30	*(97)*	86	*(95)*	178	*(92)*	481	*(84)*
	1/80	33	*(97)*	95	*(94)*	197	*(91)*	526	*(82)*
	1/60	38	*(97)*	109	*(94)*	224	*(90)*	587	*(79)*
	1/50	42	*(96)*	118	*(93)*	243	*(89)*	627	*(78)*
	1/40	46	*(96)*	131	*(92)*	268	*(87)*	677	*(75)*
	1/30	53	*(95)*	149	*(91)*	302	*(85)*	741	*(71)*
	1/20	64	*(94)*	179	*(89)*	355	*(82)*	825	*(64)*
	1/15	74	*(93)*	203	*(87)*	396	*(79)*	871	*(59)*
1/40	1/300	25	*(98)*	73	*(97)*	153	*(95)*	427	*(89)*
	1/150	35	*(98)*	101	*(95)*	211	*(92)*	574	*(85)*
	1/100	43	*(97)*	123	*(94)*	254	*(91)*	675	*(82)*
	1/80	48	*(97)*	136	*(94)*	281	*(90)*	735	*(79)*
	1/60	55	*(96)*	156	*(93)*	318	*(88)*	814	*(76)*
	1/50	60	*(96)*	169	*(92)*	344	*(87)*	865	*(74)*
	1/40	67	*(95)*	187	*(91)*	378	*(85)*	928	*(71)*
	1/30	76	*(95)*	213	*(89)*	425	*(83)*	1003	*(66)*
	1/20	92	*(93)*	253	*(87)*	496	*(79)*	1089	*(59)*
	1/15	105	*(92)*	286	*(85)*	549	*(76)*	1122	*(53)*

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C4 (cont.): TYPE R
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	40	*(98)*	116	*(96)*	243	*(93)*	669	*(87)*
	1/150	56	*(97)*	161	*(94)*	334	*(91)*	888	*(82)*
	1/100	68	*(96)*	195	*(93)*	400	*(89)*	1034	*(78)*
	1/80	76	*(96)*	216	*(92)*	440	*(87)*	1117	*(75)*
	1/60	87	*(95)*	246	*(91)*	497	*(85)*	1225	*(71)*
	1/50	95	*(95)*	267	*(90)*	536	*(84)*	1290	*(69)*
	1/40	106	*(94)*	294	*(89)*	585	*(82)*	1365	*(65)*
	1/30	121	*(94)*	333	*(87)*	653	*(79)*	1445	*(60)*
	1/20	146	*(92)*	395	*(84)*	754	*(75)*	1500	*(51)*
	1/15	166	*(91)*	443	*(82)*	825	*(71)*	Not eff. *(43)*	
1/25	1/300	54	*(98)*	156	*(95)*	325	*(93)*	886	*(86)*
	1/150	76	*(97)*	216	*(94)*	445	*(90)*	1166	*(80)*
	1/100	92	*(96)*	260	*(92)*	531	*(87)*	1346	*(75)*
	1/80	102	*(96)*	288	*(91)*	583	*(86)*	1446	*(72)*
	1/60	117	*(95)*	327	*(90)*	656	*(84)*	1570	*(68)*
	1/50	128	*(94)*	355	*(89)*	706	*(82)*	1642	*(65)*
	1/40	142	*(94)*	391	*(88)*	769	*(80)*	1718	*(61)*
	1/30	162	*(93)*	441	*(86)*	853	*(77)*	1785	*(55)*
	1/20	195	*(91)*	520	*(82)*	974	*(72)*	Not eff. *(44)*	
	1/15	222	*(90)*	581	*(80)*	1056	*(67)*	Not eff. *(36)*	
1/20	1/300	78	*(97)*	222	*(95)*	463	*(92)*	1244	*(83)*
	1/150	108	*(96)*	307	*(93)*	630	*(88)*	1614	*(77)*
	1/100	132	*(95)*	370	*(91)*	748	*(85)*	1841	*(71)*
	1/80	146	*(95)*	409	*(90)*	819	*(84)*	1961	*(68)*
	1/60	167	*(94)*	464	*(88)*	917	*(81)*	2099	*(63)*
	1/50	182	*(93)*	502	*(87)*	983	*(79)*	2170	*(59)*
	1/40	202	*(93)*	551	*(86)*	1065	*(77)*	2231	*(55)*
	1/30	231	*(92)*	620	*(84)*	1173	*(73)*	Not eff. *(48)*	
	1/20	277	*(90)*	725	*(80)*	1319	*(67)*	Not eff. *(36)*	
	1/15	314	*(88)*	805	*(77)*	1409	*(62)*	Not eff. *(26)*	
1/15	1/300	123	*(97*	352	*(94)*	726	*(90)*	1909	*(80)*
	1/150	172	*(96)*	483	*(91)*	979	*(86)*	2422	*(72)*
	1/100	208	*(94)*	579	*(89)*	1154	*(83)*	2707	*(66)*
	1/80	231	*(94)*	638	*(88)*	1258	*(80)*	2839	*(62)*
	1/60	264	*(93)*	721	*(86)*	1398	*(77)*	2962	*(56)*
	1/50	287	*(92)*	778	*(85)*	1489	*(75)*	2998	*(51)*
	1/40	318	*(91)*	851	*(83)*	1600	*(72)*	Not eff. *(46)*	
	1/30	362	*(90)*	951	*(80)*	1739	*(68)*	Not eff. *(37)*	
	1/20	432	*(88)*	1101	*(76)*	1905	*(61)*	Not eff. *(23)*	
	1/15	488	*(86)*	1208	*(72)*	1981	*(55)*	Not eff. *(11)*	

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C5: TYPE S
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(98)*	37	*(97)*	78	*(94)*	218	*(89)*
	1/150	18	*(98)*	52	*(95)*	108	*(92)*	292	*(85)*
	1/100	22	*(97)*	63	*(94)*	130	*(90)*	343	*(81)*
	1/80	24	*(97)*	70	*(93)*	143	*(89)*	374	*(79)*
	1/60	28	*(96)*	79	*(92)*	162	*(88)*	414	*(76)*
	1/50	31	*(96)*	86	*(92)*	175	*(86)*	439	*(73)*
	1/40	34	*(95)*	95	*(91)*	193	*(85)*	470	*(70)*
	1/30	39	*(94)*	108	*(89)*	216	*(83)*	507	*(66)*
	1/20	47	*(93)*	129	*(87)*	252	*(79)*	548	*(58)*
	1/15	54	*(92)*	146	*(85)*	279	*(75)*	562	*(51)*
1/50	1/300	17	*(98)*	50	*(96)*	105	*(94)*	290	*(88)*
	1/150	24	*(97)*	70	*(95)*	144	*(91)*	386	*(83)*
	1/100	30	*(97)*	84	*(93)*	173	*(89)*	451	*(79)*
	1/80	33	*(96)*	93	*(93)*	191	*(88)*	488	*(76)*
	1/60	38	*(96)*	106	*(91)*	216	*(86)*	536	*(73)*
	1/50	41	*(95)*	115	*(91)*	233	*(85)*	567	*(70)*
	1/40	46	*(95)*	127	*(89)*	254	*(83)*	601	*(67)*
	1/30	52	*(94)*	144	*(88)*	284	*(80)*	640	*(61)*
	1/20	63	*(92)*	171	*(85)*	329	*(76)*	673	*(53)*
	1/15	72	*(91)*	193	*(83)*	361	*(72)*	Not eff. *(45)*	
1/40	1/300	25	*(98)*	72	*(96)*	150	*(93)*	410	*(86)*
	1/150	35	*(97)*	100	*(94)*	206	*(90)*	540	*(80)*
	1/100	42	*(96)*	120	*(92)*	245	*(88)*	624	*(76)*
	1/80	47	*(96)*	133	*(91)*	270	*(86)*	671	*(73)*
	1/60	54	*(95)*	151	*(90)*	304	*(84)*	730	*(68)*
	1/50	59	*(94)*	164	*(89)*	327	*(82)*	764	*(65)*
	1/40	65	*(94)*	181	*(88)*	356	*(80)*	801	*(61)*
	1/30	75	*(93)*	204	*(86)*	395	*(77)*	834	*(55)*
	1/20	90	*(91)*	241	*(83)*	452	*(72)*	Not eff. *(45)*	
	1/15	102	*(90)*	269	*(80)*	491	*(68)*	Not eff. *(37)*	

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C5 (cont.): TYPE S
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	40	*(97)*	114	*(95)*	238	*(91)*	636	*(83)*
	1/150	56	*(96)*	158	*(92)*	323	*(88)*	823	*(76)*
	1/100	68	*(95)*	190	*(91)*	383	*(85)*	936	*(70)*
	1/80	75	*(95)*	210	*(90)*	419	*(83)*	995	*(67)*
	1/60	86	*(94)*	238	*(88)*	469	*(81)*	1061	*(62)*
	1/50	94	*(93)*	257	*(87)*	502	*(79)*	1094	*(58)*
	1/40	104	*(93)*	282	*(85)*	543	*(76)*	1120	*(53)*
	1/30	118	*(91)*	317	*(83)*	597	*(73)*	Not eff. *(46)*	
	1/20	142	*(89)*	370	*(79)*	669	*(66)*	Not eff. *(34)*	
	1/15	161	*(88)*	410	*(76)*	712	*(61)*	Not eff. *(24)*	
1/25	1/300	54	*(97)*	153	*(94)*	317	*(90)*	836	*(81)*
	1/150	75	*(96)*	211	*(91)*	428	*(86)*	1067	*(73)*
	1/100	91	*(95)*	253	*(90)*	505	*(83)*	1197	*(67)*
	1/80	101	*(94)*	279	*(88)*	551	*(81)*	1260	*(63)*
	1/60	115	*(93)*	315	*(87)*	614	*(78)*	1322	*(57)*
	1/50	125	*(92)*	340	*(85)*	654	*(76)*	1345	*(53)*
	1/40	139	*(92)*	372	*(83)*	704	*(73)*	Not eff. *(48)*	
	1/30	158	*(90)*	417	*(81)*	768	*(69)*	Not eff. *(39)*	
	1/20	189	*(88)*	484	*(77)*	846	*(62)*	Not eff. *(26)*	
	1/15	213	*(86)*	532	*(73)*	885	*(56)*	Not eff. *(14)*	
1/20	1/300	77	*(96)*	218	*(93)*	449	*(89)*	1161	*(78)*
	1/150	107	*(95)*	299	*(90)*	601	*(84)*	1450	*(69)*
	1/100	129	*(94)*	358	*(88)*	705	*(81)*	1594	*(62)*
	1/80	144	*(93)*	393	*(87)*	766	*(78)*	1652	*(57)*
	1/60	164	*(92)*	443	*(84)*	846	*(75)*	1687	*(51)*
	1/50	178	*(91)*	477	*(83)*	898	*(72)*	Not eff. *(46)*	
	1/40	197	*(90)*	520	*(81)*	959	*(69)*	Not eff. *(40)*	
	1/30	224	*(89)*	579	*(78)*	1031	*(64)*	Not eff. *(30)*	
	1/20	266	*(86)*	664	*(73)*	1106	*(56)*	Not eff. *(14)*	
	1/15	300	*(84)*	723	*(69)*	Not eff. *(50)*		Not eff. *(1)*	
1/15	1/300	122	*(96)*	344	*(92)*	699	*(87)*	1751	*(74)*
	1/150	169	*(94)*	468	*(88)*	925	*(81)*	2107	*(63)*
	1/100	204	*(93)*	556	*(86)*	1073	*(77)*	2234	*(54)*
	1/80	226	*(92)*	609	*(84)*	1156	*(74)*	Not eff. *(49)*	
	1/60	257	*(91)*	682	*(81)*	1262	*(70)*	Not eff. *(41)*	
	1/50	279	*(90)*	731	*(80)*	1326	*(67)*	Not eff. *(35)*	
	1/40	308	*(88)*	793	*(77)*	1396	*(63)*	Not eff. *(28)*	
	1/30	348	*(87)*	873	*(74)*	1467	*(57)*	Not eff. *(16)*	
	1/20	412	*(84)*	984	*(68)*	Not eff. *(48)*		Not eff. *(0)*	
	1/15	461	*(81)*	1052	*(63)*	Not eff. *(40)*		Not eff. *(0)*	

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C6: TYPE T
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(98)*	37	*(95)*	77	*(92)*	208	*(85)*
	1/150	18	*(97)*	51	*(93)*	105	*(89)*	272	*(79)*
	1/100	22	*(96)*	61	*(92)*	125	*(87)*	314	*(74)*
	1/80	24	*(95)*	68	*(91)*	137	*(85)*	336	*(71)*
	1/60	28	*(95)*	77	*(89)*	154	*(83)*	364	*(67)*
	1/50	30	*(94)*	83	*(88)*	165	*(81)*	380	*(63)*
	1/40	33	*(93)*	92	*(87)*	180	*(79)*	395	*(59)*
	1/30	38	*(92)*	104	*(85)*	199	*(76)*	408	*(53)*
	1/20	46	*(91)*	122	*(82)*	226	*(71)*	Not eff. *(42)*	
	1/15	52	*(89)*	136	*(79)*	245	*(66)*	Not eff. *(33)*	
1/50	1/300	17	*(97)*	49	*(95)*	102	*(91)*	275	*(83)*
	1/150	24	*(96)*	68	*(93)*	139	*(88)*	356	*(76)*
	1/100	29	*(95)*	82	*(91)*	165	*(85)*	405	*(71)*
	1/80	32	*(95)*	90	*(90)*	181	*(83)*	431	*(67)*
	1/60	37	*(94)*	103	*(88)*	203	*(81)*	461	*(62)*
	1/50	40	*(93)*	111	*(87)*	217	*(79)*	476	*(59)*
	1/40	45	*(93)*	122	*(85)*	235	*(77)*	488	*(54)*
	1/30	51	*(91)*	137	*(83)*	258	*(73)*	Not eff. *(47)*	
	1/20	61	*(90)*	160	*(79)*	290	*(67)*	Not eff. *(35)*	
	1/15	69	*(88)*	177	*(76)*	309	*(62)*	Not eff. *(25)*	
1/40	1/300	25	*(97)*	71	*(94)*	146	*(90)*	385	*(81)*
	1/150	34	*(96)*	97	*(91)*	197	*(86)*	489	*(72)*
	1/100	42	*(95)*	116	*(89)*	232	*(83)*	548	*(66)*
	1/80	46	*(94)*	128	*(88)*	253	*(81)*	576	*(62)*
	1/60	53	*(93)*	145	*(86)*	282	*(78)*	603	*(57)*
	1/50	58	*(92)*	157	*(85)*	300	*(76)*	612	*(52)*
	1/40	64	*(91)*	171	*(83)*	323	*(73)*	Not eff. *(47)*	
	1/30	73	*(90)*	192	*(81)*	352	*(69)*	Not eff. *(39)*	
	1/20	87	*(88)*	222	*(76)*	387	*(62)*	Not eff. *(25)*	
	1/15	98	*(86)*	244	*(73)*	404	*(56)*	Not eff. *(13)*	

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C6 (cont.): TYPE T
Drained area of road under a rainfall intensity of 50mm/h in m^2
and collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	39	*(96)*	112	*(93)*	229	*(88)*	587	*(77)*
	1/150	55	*(95)*	153	*(90)*	306	*(83)*	725	*(67)*
	1/100	66	*(93)*	182	*(87)*	357	*(79)*	789	*(59)*
	1/80	74	*(93)*	200	*(86)*	387	*(77)*	811	*(55)*
	1/60	84	*(92)*	225	*(83)*	427	*(73)*	Not eff. *(48)*	
	1/50	91	*(91)*	242	*(82)*	451	*(71)*	Not eff. *(43)*	
	1/40	101	*(90)*	264	*(80)*	480	*(67)*	Not eff. *(36)*	
	1/30	114	*(88)*	293	*(77)*	512	*(62)*	Not eff. *(26)*	
	1/20	136	*(85)*	334	*(71)*	542	*(54)*	Not eff. *(9)*	
	1/15	152	*(83)*	362	*(67)*	Not eff. *(47)*		Not eff. *(0)*	
1/25	1/300	53	*(96)*	149	*(92)*	304	*(87)*	762	*(74)*
	1/150	73	*(94)*	203	*(88)*	402	*(81)*	918	*(63)*
	1/100	89	*(93)*	242	*(86)*	467	*(77)*	974	*(54)*
	1/80	98	*(92)*	265	*(84)*	503	*(74)*	Not eff. *(49)*	
	1/60	112	*(91)*	297	*(81)*	549	*(70)*	Not eff. *(41)*	
	1/50	121	*(90)*	318	*(80)*	577	*(67)*	Not eff. *(35)*	
	1/40	134	*(88)*	345	*(77)*	608	*(63)*	Not eff. *(28)*	
	1/30	151	*(87)*	380	*(74)*	639	*(58)*	Not eff. *(17)*	
	1/20	179	*(84)*	428	*(68)*	Not eff. *(48)*		Not eff. *(0)*	
	1/15	200	*(81)*	458	*(63)*	Not eff. *(40)*		Not eff. *(0)*	
1/20	1/300	76	*(95)*	212	*(90)*	427	*(85)*	1038	*(70)*
	1/150	105	*(93)*	287	*(86)*	559	*(78)*	1203	*(57)*
	1/100	126	*(92)*	339	*(83)*	641	*(73)*	Not eff. *(47)*	
	1/80	140	*(91)*	370	*(81)*	686	*(70)*	Not eff. *(41)*	
	1/60	159	*(89)*	413	*(79)*	740	*(65)*	Not eff. *(32)*	
	1/50	172	*(88)*	440	*(77)*	770	*(62)*	Not eff. *(26)*	
	1/40	189	*(87)*	474	*(74)*	799	*(58)*	Not eff. *(17)*	
	1/30	213	*(85)*	518	*(70)*	818	*(51)*	Not eff. *(4)*	
	1/20	250	*(81)*	572	*(63)*	Not eff. *(40)*		Not eff. *(0)*	
	1/15	279	*(78)*	601	*(57)*	Not eff. *(31)*		Not eff. *(0)*	
1/15	1/300	120	*(94)*	332	*(89)*	658	*(81)*	1515	*(64)*
	1/150	165	*(92)*	444	*(84)*	843	*(74)*	Not eff. *(49)*	
	1/100	198	*(90)*	521	*(80)*	950	*(68)*	Not eff. *(37)*	
	1/80	218	*(89)*	565	*(78)*	1003	*(64)*	Not eff. *(30)*	
	1/60	247	*(87)*	624	*(74)*	1058	*(59)*	Not eff. *(19)*	
	1/50	267	*(86)*	661	*(72)*	1081	*(55)*	Not eff. *(11)*	
	1/40	293	*(84)*	705	*(69)*	Not eff. *(49)*		Not eff. *(0)*	
	1/30	328	*(82)*	756	*(64)*	Not eff. *(41)*		Not eff. *(0)*	
	1/20	381	*(77)*	808	*(56)*	Not eff. *(28)*		Not eff. *(0)*	
	1/15	420	*(74)*	Not eff. *(49)*		Not eff. *(17)*		Not eff. *(0)*	

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C7: KERB INLET WITH OPENING LENGTH EQUAL TO 0.5m
Drained area of the road under a rainfall of 50mm/h in m^2
and the collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)					
		0.5		0.75		1	
1/60	1/300	11	*(83)*	28	*(72)*	51	*(61)*
	1/150	14	*(76)*	33	*(61)*	Not eff. *(45)*	
	1/100	16	*(70)*	35	*(52)*		
	1/80	17	*(67)*	Not eff. *(46)*			
	1/60	18	*(62)*				
	1/50	18	*(58)*				
	1/40	19	*(53)*				
	1/30	Not eff. *(46)*					
	1/20						
	1/15						
1/50	1/300	15	*(82)*	38	*(72)*	68	*(60)*
	1/150	19	*(75)*	44	*(60)*	Not eff. *(44)*	
	1/100	21	*(69)*	46	*(51)*		
	1/80	22	*(66)*	Not eff. *(45)*			
	1/60	24	*(60)*				
	1/50	24	*(57)*				
	1/40	25	*(52)*				
	1/30	Not eff. *(44)*					
	1/20						
	1/15						
1/40	1/300	21	*(82)*	53	*(71)*	95	*(59)*
	1/150	27	*(74)*	62	*(58)*	Not eff. *(42)*	
	1/100	30	*(68)*	Not eff. *(49)*			
	1/80	32	*(64)*				
	1/60	34	*(59)*				
	1/50	34	*(55)*				
	1/40	35	*(50)*				
	1/30	Not eff. *(42)*					
	1/20						
	1/15						

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C7 (cont.): KERB INLET WITH OPENING LENGTH EQUAL TO 0.5m
Drained area of the road under a rainfall of 50mm/h in m^2
and the collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)					
		0.5		0.75		1	
1/30	1/300	33	*(81)*	84	*(69)*	149	*(57)*
	1/150	42	*(73)*	97	*(57)*	Not eff. *(39)*	
	1/100	47	*(67)*	Not eff. *(47)*			
	1/80	50	*(63)*				
	1/60	52	*(57)*				
	1/50	54	*(52)*				
	1/40	Not eff. *(47)*					
	1/30						
	1/20						
	1/15						
1/25	1/300	44	*(80)*	112	*(68)*	196	*(56)*
	1/150	56	*(72)*	128	*(56)*	Not eff. *(38)*	
	1/100	63	*(66)*	Not eff. *(46)*			
	1/80	66	*(62)*				
	1/60	69	*(56)*				
	1/50	70	*(52)*				
	1/40	Not eff. *(46)*					
	1/30						
	1/20						
	1/15						
1/20	1/300	64	*(80)*	159	*(68)*	276	*(55)*
	1/150	80	*(71)*	180	*(54)*	Not eff. *(36)*	
	1/100	90	*(65)*	Not eff. *(44)*			
	1/80	94	*(61)*				
	1/60	98	*(55)*				
	1/50	98	*(50)*				
	1/40	Not eff. *(45)*					
	1/30						
	1/20						
	1/15						
1/15	1/300	100	*(79)*	249	*(66)*	427	*(53)*
	1/150	126	*(70)*	278	*(52)*	Not eff. *(33)*	
	1/100	140	*(64)*	Not eff. *(42)*			
	1/80	146	*(59)*				
	1/60	151	*(53)*				
	1/50	Not eff. *(49)*					
	1/40						
	1/30						
	1/20						
	1/15						

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C8: KERB INLET WITH OPENING LENGTH EQUAL TO 1.5m
Drained area of the road under a rainfall of 50mm/h in m^2
and the collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	12	*(94)*	35	*(91)*	72	*(87)*	194	*(79)*
	1/150	17	*(92)*	47	*(87)*	96	*(82)*	244	*(71)*
	1/100	20	*(90)*	56	*(84)*	111	*(78)*	272	*(64)*
	1/80	22	*(89)*	61	*(82)*	121	*(75)*	284	*(60)*
	1/60	25	*(87)*	68	*(79)*	132	*(71)*	294	*(54)*
	1/50	27	*(86)*	73	*(77)*	139	*(68)*	Not eff. *(49)*	
	1/40	30	*(84)*	79	*(75)*	147	*(65)*		
	1/30	34	*(82)*	86	*(71)*	155	*(59)*		
	1/20	39	*(78)*	96	*(64)*	161	*(50)*		
	1/15	43	*(74)*	101	*(59)*	Not eff. *(42)*			
1/50	1/300	17	*(94)*	47	*(90)*	97	*(87)*	260	*(79)*
	1/150	23	*(92)*	64	*(87)*	129	*(81)*	326	*(70)*
	1/100	27	*(90)*	75	*(84)*	149	*(77)*	361	*(63)*
	1/80	30	*(89)*	82	*(82)*	161	*(74)*	376	*(58)*
	1/60	34	*(87)*	92	*(79)*	176	*(70)*	387	*(52)*
	1/50	37	*(86)*	98	*(77)*	185	*(68)*	Not eff. *(48)*	
	1/40	40	*(84)*	105	*(74)*	195	*(64)*		
	1/30	45	*(81)*	115	*(70)*	206	*(58)*		
	1/20	53	*(77)*	128	*(63)*	Not eff. *(49)*			
	1/15	58	*(74)*	134	*(58)*				
1/40	1/300	24	*(94)*	68	*(90)*	140	*(86)*	372	*(78)*
	1/150	33	*(91)*	92	*(86)*	185	*(81)*	465	*(69)*
	1/100	40	*(89)*	108	*(83)*	214	*(76)*	512	*(62)*
	1/80	44	*(88)*	118	*(81)*	230	*(73)*	531	*(57)*
	1/60	49	*(86)*	131	*(78)*	251	*(69)*	540	*(51)*
	1/50	53	*(85)*	140	*(76)*	263	*(66)*	Not eff. *(46)*	
	1/40	58	*(83)*	150	*(73)*	277	*(62)*		
	1/30	66	*(81)*	164	*(69)*	291	*(57)*		
	1/20	75	*(76)*	181	*(62)*	Not eff. *(47)*			
	1/15	83	*(73)*	189	*(56)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C8 (cont.): KERB INLET WITH OPENING LENGTH EQUAL TO 1.5m
Drained area of the road under a rainfall of 50mm/h in m^2
and the collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	38	*(93)*	108	*(89)*	223	*(86)*	591	*(77)*
	1/150	53	*(91)*	146	*(86)*	293	*(80)*	732	*(68)*
	1/100	63	*(89)*	172	*(82)*	339	*(79)*	800	*(60)*
	1/80	70	*(88)*	187	*(80)*	364	*(72)*	825	*(56)*
	1/60	78	*(86)*	208	*(77)*	396	*(68)*	Not eff. *(49)*	
	1/50	85	*(84)*	222	*(75)*	414	*(65)*		
	1/40	93	*(82)*	238	*(72)*	433	*(61)*		
	1/30	103	*(80)*	258	*(68)*	450	*(55)*		
	1/20	120	*(75)*	283	*(60)*	Not eff. *(45)*			
	1/15	131	*(72)*	293	*(54)*				
1/25	1/300	51	*(93)*	146	*(90)*	300	*(85)*	791	*(76)*
	1/150	71	*(91)*	196	*(85)*	393	*(79)*	976	*(67)*
	1/100	85	*(89)*	231	*(82)*	453	*(74)*	1061	*(59)*
	1/80	93	*(87)*	251	*(80)*	486	*(72)*	1090	*(54)*
	1/60	106	*(85)*	279	*(76)*	529	*(67)*	Not eff. *(47)*	
	1/50	114	*(84)*	296	*(74)*	550	*(64)*		
	1/40	124	*(82)*	318	*(70)*	575	*(60)*		
	1/30	138	*(79)*	344	*(67)*	595	*(54)*		
	1/20	158	*(74)*	375	*(59)*	Not eff. *(43)*			
	1/15	175	*(71)*	387	*(53)*				
1/20	1/300	74	*(93)*	209	*(89)*	429	*(85)*	1129	*(76)*
	1/150	102	*(90)*	281	*(85)*	562	*(79)*	1384	*(66)*
	1/100	122	*(88)*	330	*(81)*	646	*(74)*	1496	*(58)*
	1/80	134	*(87)*	359	*(79)*	692	*(71)*	1529	*(53)*
	1/60	151	*(85)*	398	*(76)*	748	*(66)*	Not eff. *(46)*	
	1/50	163	*(83)*	422	*(74)*	779	*(63)*		
	1/40	178	*(82)*	452	*(70)*	811	*(59)*		
	1/30	198	*(79)*	488	*(66)*	834	*(52)*		
	1/20	228	*(74)*	528	*(58)*	Not eff. *(41)*			
	1/15	249	*(70)*	542	*(52)*				
1/15	1/300	118	*(93)*	333	*(89)*	681	*(84)*	1781	*(75)*
	1/150	162	*(90)*	446	*(84)*	888	*(77)*	2168	*(64)*
	1/100	194	*(88)*	523	*(81)*	1018	*(72)*	2324	*(56)*
	1/80	213	*(86)*	568	*(78)*	1088	*(68)*	2361	*(51)*
	1/60	240	*(84)*	628	*(75)*	1171	*(63)*	Not eff. *(44)*	
	1/50	240	*(83)*	666	*(72)*	1261	*(55)*		
	1/40	282	*(81)*	711	*(69)*	1286	*(50)*		
	1/30	313	*(78)*	765	*(64)*	Not eff. *(39)*			
	1/20	359	*(73)*	821	*(56)*				
	1/15	391	*(69)*	Not eff. *(49)*					

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C9: KERB INLET WITH OPENING LENGTH EQUAL TO 1.85m
Drained area of the road under a rainfall of 50mm/h in m^2
and the collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/60	1/300	12	*(95)*	36	*(92)*	74	*(90)*	203	*(83)*
	1/150	17	*(93)*	49	*(89)*	100	*(85)*	264	*(76)*
	1/100	21	*(92)*	58	*(87)*	118	*(82)*	300	*(71)*
	1/80	23	*(91)*	64	*(86)*	128	*(80)*	319	*(68)*
	1/60	26	*(90)*	72	*(83)*	142	*(77)*	341	*(62)*
	1/50	28	*(89)*	77	*(82)*	151	*(74)*	353	*(59)*
	1/40	32	*(87)*	84	*(80)*	162	*(71)*	362	*(54)*
	1/30	35	*(85)*	93	*(76)*	175	*(67)*	Not eff. *(47)*	
	1/20	41	*(82)*	106	*(71)*	191	*(60)*		
	1/15	46	*(79)*	115	*(67)*	197	*(53)*		
1/50	1/300	17	*(95)*	48	*(92)*	100	*(89)*	273	*(83)*
	1/150	23	*(93)*	66	*(89)*	134	*(85)*	353	*(76)*
	1/100	28	*(92)*	78	*(87)*	158	*(81)*	402	*(70)*
	1/80	31	*(91)*	85	*(86)*	172	*(79)*	426	*(67)*
	1/60	35	*(89)*	96	*(83)*	190	*(76)*	454	*(61)*
	1/50	38	*(88)*	103	*(81)*	202	*(74)*	467	*(58)*
	1/40	42	*(87)*	112	*(79)*	216	*(70)*	477	*(53)*
	1/30	47	*(85)*	124	*(76)*	234	*(66)*	Not eff. *(45)*	
	1/20	56	*(81)*	142	*(70)*	253	*(58)*		
	1/15	62	*(79)*	153	*(66)*	260	*(52)*		
1/40	1/300	24	*(95)*	69	*(92)*	144	*(89)*	392	*(82)*
	1/150	34	*(93)*	94	*(89)*	193	*(84)*	505	*(75)*
	1/100	40	*(91)*	112	*(86)*	226	*(81)*	571	*(69)*
	1/80	45	*(90)*	123	*(85)*	246	*(78)*	605	*(65)*
	1/60	51	*(89)*	138	*(82)*	272	*(75)*	642	*(60)*
	1/50	55	*(88)*	148	*(80)*	289	*(73)*	658	*(56)*
	1/40	60	*(86)*	161	*(78)*	308	*(70)*	668	*(51)*
	1/30	68	*(84)*	178	*(75)*	332	*(65)*	Not eff. *(44)*	
	1/20	80	*(81)*	202	*(69)*	357	*(60)*		
	1/15	89	*(78)*	217	*(64)*	364	*(50)*		

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C9 (cont.): KERB INLET WITH OPENING LENGTH EQUAL TO 1.85m
Drained area of the road under a rainfall of 50mm/h in m^2
and the collection efficiency in % (in brackets)

Crossfall	Gradient	Flow width (m)							
		0.5		0.75		1		1.5	
1/30	1/300	39	*(95)*	111	*(91)*	230	*(88)*	624	*(81)*
	1/150	54	*(93)*	151	*(88)*	308	*(84)*	799	*(74)*
	1/100	65	*(91)*	179	*(86)*	360	*(80)*	900	*(68)*
	1/80	71	*(90)*	196	*(84)*	390	*(76)*	950	*(64)*
	1/60	81	*(88)*	220	*(81)*	431	*(74)*	1001	*(58)*
	1/50	88	*(87)*	236	*(80)*	456	*(72)*	1022	*(54)*
	1/40	96	*(86)*	256	*(77)*	486	*(68)*	Not eff. *(49)*	
	1/30	108	*(84)*	282	*(74)*	521	*(63)*		
	1/20	127	*(80)*	318	*(68)*	555	*(55)*		
	1/15	141	*(77)*	340	*(63)*	Not eff. *(48)*			
1/25	1/300	52	*(95)*	149	*(92)*	309	*(88)*	837	*(81)*
	1/150	72	*(92)*	203	*(88)*	413	*(83)*	1068	*(73)*
	1/100	87	*(90)*	241	*(85)*	482	*(79)*	1199	*(67)*
	1/80	96	*(90)*	264	*(84)*	523	*(77)*	1263	*(63)*
	1/60	109	*(88)*	295	*(81)*	576	*(73)*	1326	*(57)*
	1/50	118	*(87)*	316	*(79)*	609	*(71)*	1349	(53)
	1/40	129	*(85)*	342	*(77)*	648	*(67)*	Not eff *(48)*	
	1/30	145	*(83)*	377	*(73)*	692	*(62)*		
	1/20	170	*(79)*	423	*(67)*	732	*(54)*		
	1/15	188	*(76)*	451	*(62)*	Not eff *(47)*			
1/20	1/300	75	*(95)*	215	*(91)*	444	*(88)*	1197	*(80)*
	1/150	104	*(92)*	291	*(88)*	591	*(83)*	1521	*(72)*
	1/100	125	*(90)*	345	*(85)*	690	*(79)*	1701	*(66)*
	1/80	138	*(89)*	377	*(83)*	746	*(76)*	1786	*(62)*
	1/60	156	*(88)*	422	*(80)*	820	*(72)*	1866	*(56)*
	1/50	169	*(87)*	452	*(78)*	866	*(70)*	1890	*(52)*
	1/40	185	*(85)*	488	*(76)*	919	*(66)*	Not eff *(46)*	
	1/30	208	*(83)*	536	*(72)*	979	*(61)*		
	1/20	243	*(79)*	600	*(66)*	1028	*(52)*		
	1/15	269	*(76)*	638	*(61)*	Not eff *(45)*			
1/15	1/300	120	*(94)*	341	*(91)*	705	*(87)*	1895	*(80)*
	1/150	165	*(92)*	462	*(87)*	936	*(82)*	2395	*(71)*
	1/100	199	*(90)*	547	*(84)*	1090	*(78)*	2665	*(65)*
	1/80	219	*(89)*	598	*(82)*	1178	*(75)*	2787	*(60)*
	1/60	248	*(87)*	668	*(80)*	1292	*(72)*	2893	*(54)*
	1/50	268	*(86)*	714	*(78)*	1441	*(65)*	Not eff *(44)*	
	1/40	294	*(84)*	771	*(75)*	1526	*(60)*		
	1/30	330	*(82)*	845	*(71)*	1586	*(51)*		
	1/20	384	*(78)*	941	*(65)*	Not eff *(43)*			
	1/15	424	*(75)*	995	*(59)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)