A method for estimating design peak discharge

(Technical Memorandum No. 61)

Planning and Technical Services
Water and Soil Division
Ministry of Works and Development

Wellington 1980

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This publication presents an empirical method for estimating a design flood peak discharge in an ungauged New Zealand catchment.

It is emphasised that this is not a new revision of the method, which is still in its 3rd revised (1964) form, metric version, with only minor modifications.

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TABLES AND FIGURES

1. INTRODUCTION

Technical Memorandum No. 61 (TM61) is an empirical method for estimating a design flood peak discharge in an ungauged New Zealand catchment.

This publication presents a reprint of the metric version of TM61 (October 1975). It is emphasised that this is not a new revision of the method; the method is presented in its 3rd revision form (1964) with only minor modifications. Further clarification of various points and reference to more recent rainfall records are included.

2. FORMULA

The TM61 formula is:

$$Qp = 0.0139\ C\ R\ S\ A^{3/4} \qquad (1)$$

where Qp = estimate of the design peak discharge, in m^3/s
C = a coefficient which depends on the physiography of the catchment
R = a rainfall factor which depends on the design storm
S = a catchment shape factor
and A = catchment area, in km^2.

The derivation of C, R and S is described in sections 3, 4 and 5, respectively.

3. THE COEFFICIENT C

3.1 General Procedure

The coefficient C for the catchment is derived by the following procedure:

(a) Select from Table 1 a value for W_{IC} representative of the catchment.

(b) Determine a value for W_S from Figure 1.

(c) Obtain W, which is the product of the W_{IC} and W_S values.

(d) Convert W to a value for C using Figure 2.

3.2 W_{IC}

The W_{IC} factor is intended to account for the effects of infiltration and ground surface and cover characteristics on runoff. The selection of a value from Table 1 for the factor must take into consideration the moisture condition of the catchment for the design storm. As the return period of the design storm is increased the catchment is more likely to be saturated, and a higher W_{IC} value should be chosen accordingly.

NOTE: Care should be taken when using W_{IC} values of 0.4 and 0.5 for pumice soil. Pumice can be very absorbent when wet. However, high runoff from pumice catchments has been observed after dry conditions and also when the catchment is saturated. Careful judgement based on local knowledge should be made when choosing a value for W_{IC} for these catchments.

TABLE 1

VALUES FOR W_{IC}

Soils	Ground Surface-Cover		W_{IC}
Impervious soils (such as clay soils with poor structure e.g. northern yellow brown earths). Any soil, if saturated, is included in this group.	Urban Catchments	high density development	1.8
		moderate to low density development	1.5
	Mainly bare surfaces		1.2
	Average shortgrazed catchments		1.1
	30% of area in long grass, scrub or bush		1.0
	60% of area in long grass, scrub or bush		0.9
	100% of area in long grass, scrub or bush		0.8
Moderately absorbent soils (such as medium textured soils with good structure e.g. southern yellow brown earths).	Urban Catchments	high density development	1.7
		moderate to low density development	1.3
	Mainly bare surfaces		1.1
	Average shortgrazed catchments		1.0
	30% of area in long grass, scrub or bush		0.9
	60% of area in long grass, scrub or bush		0.8
	100% of area in long grass, scrub or bush		0.7
Absorbent soil (such as deep yellow brown sands and pumice soils).	Urban Catchments	high density development	1.5
		moderate to low density development	1.2
	Mainly bare surfaces		1.0
	Average shortgrazed catchments		0.9
	30% of area in long grass, scrub or bush		0.8
	60% of area in long grass, scrub or bush		0.7
	100% of area in long grass, scrub or bush		0.6
Very absorbent pumice soil.	Mainly bare surfaces Average shortgrazed catchments 30% of area in long grass, scrub or bush		0.5
	60% of area in long grass, scrub or bush 100% of area in long grass, scrub or bush		0.4

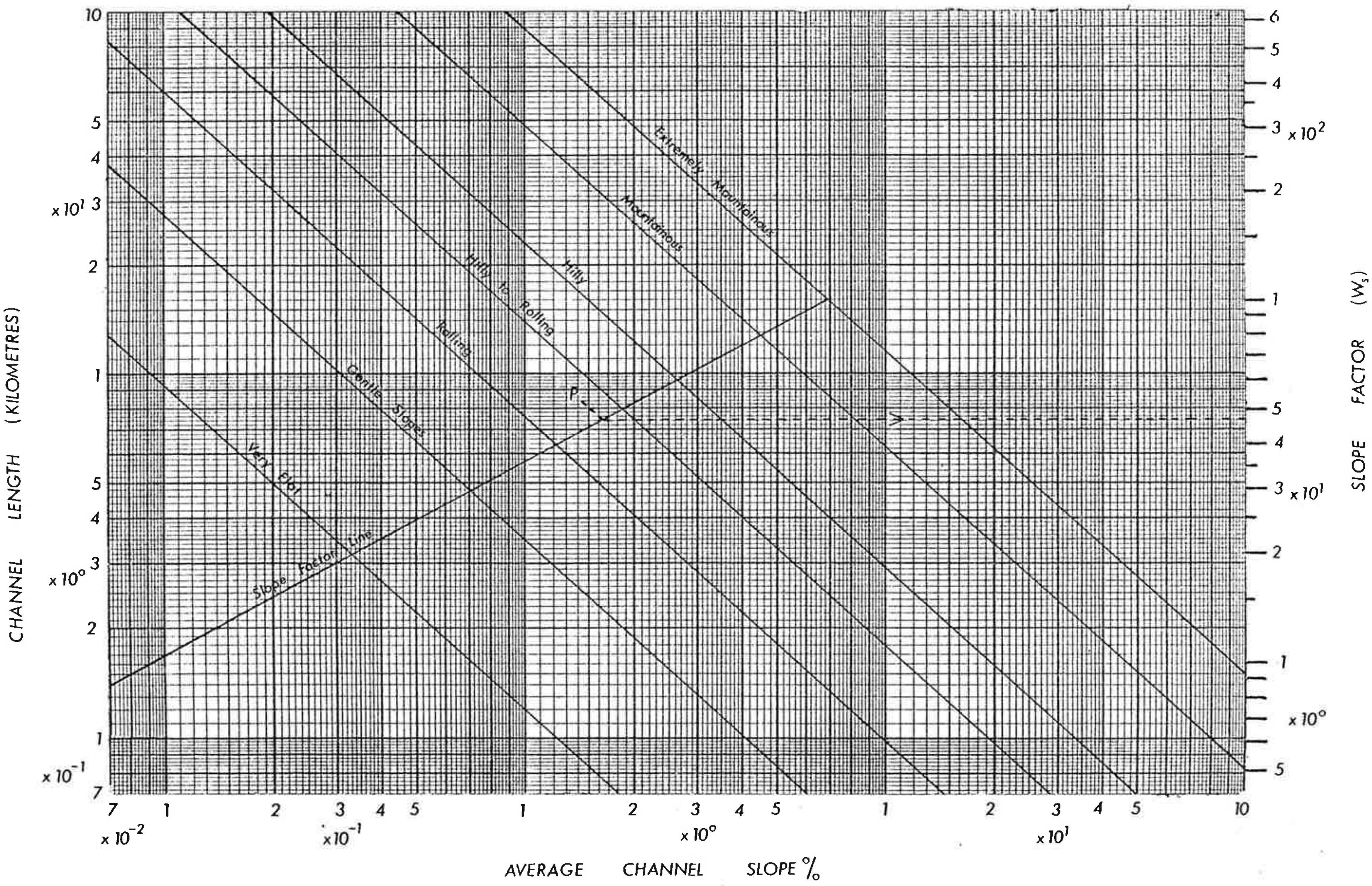

FIG.1 SLOPE FACTOR ESTIMATION

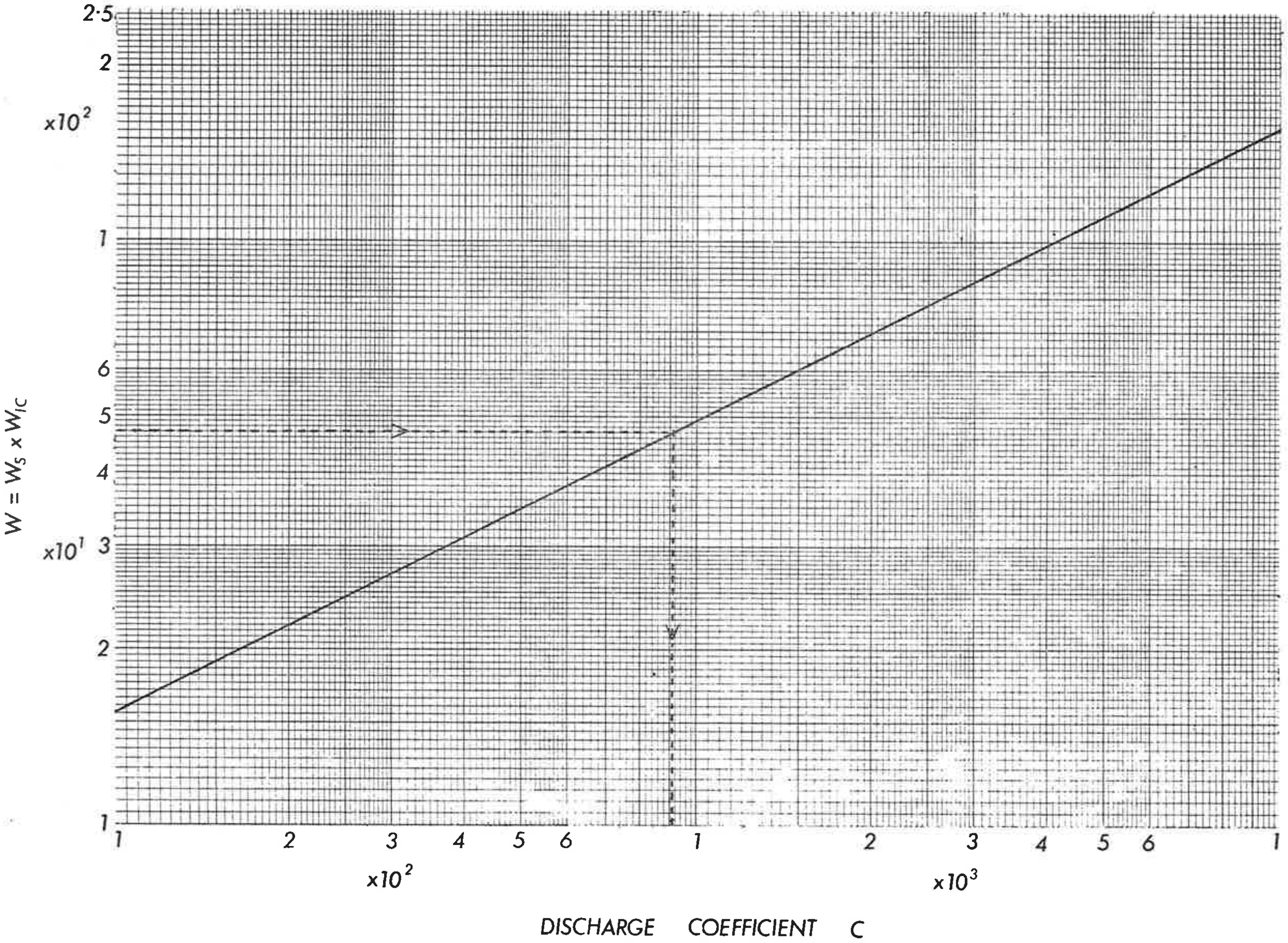

FIG. 2 **CONVERSION CHART W — C**

3.3 W_S

W_S is a slope factor, and its determination requires data on the horizontal length and slope of the main channel extended up to the catchment boundary. Methods of calculating the average channel slope are given in Appendix A.

To determine W_S, define the point on Figure 1 corresponding to the channel length in kilometres and the average channel slope in percent. From this point draw a line parallel to the topography lines to intersect the slope factor line. W_S is then the right-hand ordinate that corresponds to the intersection point on the slope factor line.

When there are insufficient data to calculate the average channel slope, W_S can still be determined by assessing the topography of the catchment. W_S corresponds to the point on the slope factor line that represents the average catchment topography. Because of the subjectivity in this approach, it is advisable to make a slightly conservative estimate of the topographical characteristics.

4. THE RAINFALL FACTOR R

4.1 General

The rainfall factor R is given by

$$R = \frac{\text{design rainfall depth}}{\text{standard rainfall depth}} \qquad (2)$$

The design rainfall depth depends on:

(a) the return period of the design storm; and

(b) the duration of the design storm.

Both these points are elaborated upon below.

4.2 Return Period

It is assumed that the design storm has a return period the same as that of the design flood. For practical purposes this assumption is the most reasonable one to make.

The choice of return period must take into account several factors, which include: the expected life of the structure involved; the general economic consequences of the failure of the structure; and the loss of life and livelihood that might result. Information on the return period is available in many hydrological texts, including the "Code of Practice for the Design of Bridge Waterways" (Civil Division, MWD, 1976). Many bridges are designed for the 50, 100 or 200-year peak discharge. Small culverts are often designed for the 10 or 20-year peak discharge and a check made that larger floods can be passed by heading up.

4.3 Duration

If the rainfall in an impervious catchment is temporally and spatially uniform, the peak of the outflow hydrograph is not attained until the whole of the catchment is contributing to the flow at the outlet. Therefore, the duration of the design storm for a catchment is usually taken as being equal to the time for water to travel from the farthest point on the catchment to the outlet. This travel time is known as the time of concentration. The recommended measure of the time of concentration is the fairly constant minimum value for the time of rise of the flood hydrograph that results from short duration rainfall excess.

For an ungauged catchment the formulae and nomogram in Appendix B may be used to estimate the time of concentration. The estimates from these sources will vary because: different interpretations of the time of concentration are involved; not all the sources are suited to the same conditions; and the sources do not account for the tendency of the time of concentration to decrease with increasing rainfall intensity.

The chosen value for the time of concentration should be the one considered the most reasonable for the catchment and for the design storm. It should *not* be arrived at by simply averaging the results from the formulae and nomogram in Appendix B. A useful check on the chosen value is to convert it to an average flow velocity (using the maximum flow length) and then compare this velocity value with those pertaining to nearby, gauged catchments of similar size and topography.

The rainfall factor R may sometimes prove insensitive to different storm durations. In these cases it will not be necessary to estimate the time of concentration.

4.4 Design Rainfall Depth

Robertson (1963) has presented rainfall depth-duration-frequency data in map form for the whole of New Zealand and in detailed tabular form for 46 pluviometer stations. Similar, up-to-date data are available from the Meteorological Office for individual pluviometer stations. From the data the rainfall depth, corresponding to the selected duration and return period of the design storm, can be calculated by the method described by Robertson (1963).

It is preferable to use the more precise pluviometer data when calculating the rainfall depth. The importance of the structure involved may necessitate the processing of data for a pluviometer not covered by Robertson (1963) into depth-duration-frequency form. If no pluviometer is located within reasonable distance of the catchment it will be necessary to use the data given in map form.

NOTE: Data are available in map and tabular form from the Water and Soil Division, MWD (Tomlinson, 1980) and the Meteorological Service (Coulter and Hessell, 1980).

4.5 Standard Rainfall Depth

The value on the standard curve in Figures 3a, 3b corresponding to the design storm duration is the standard rainfall depth. The standard curve is proportional to the rainfall depth-duration relationships existing at Kelburn, but has been set so that 76 mm corresponds to the 1-hour duration.

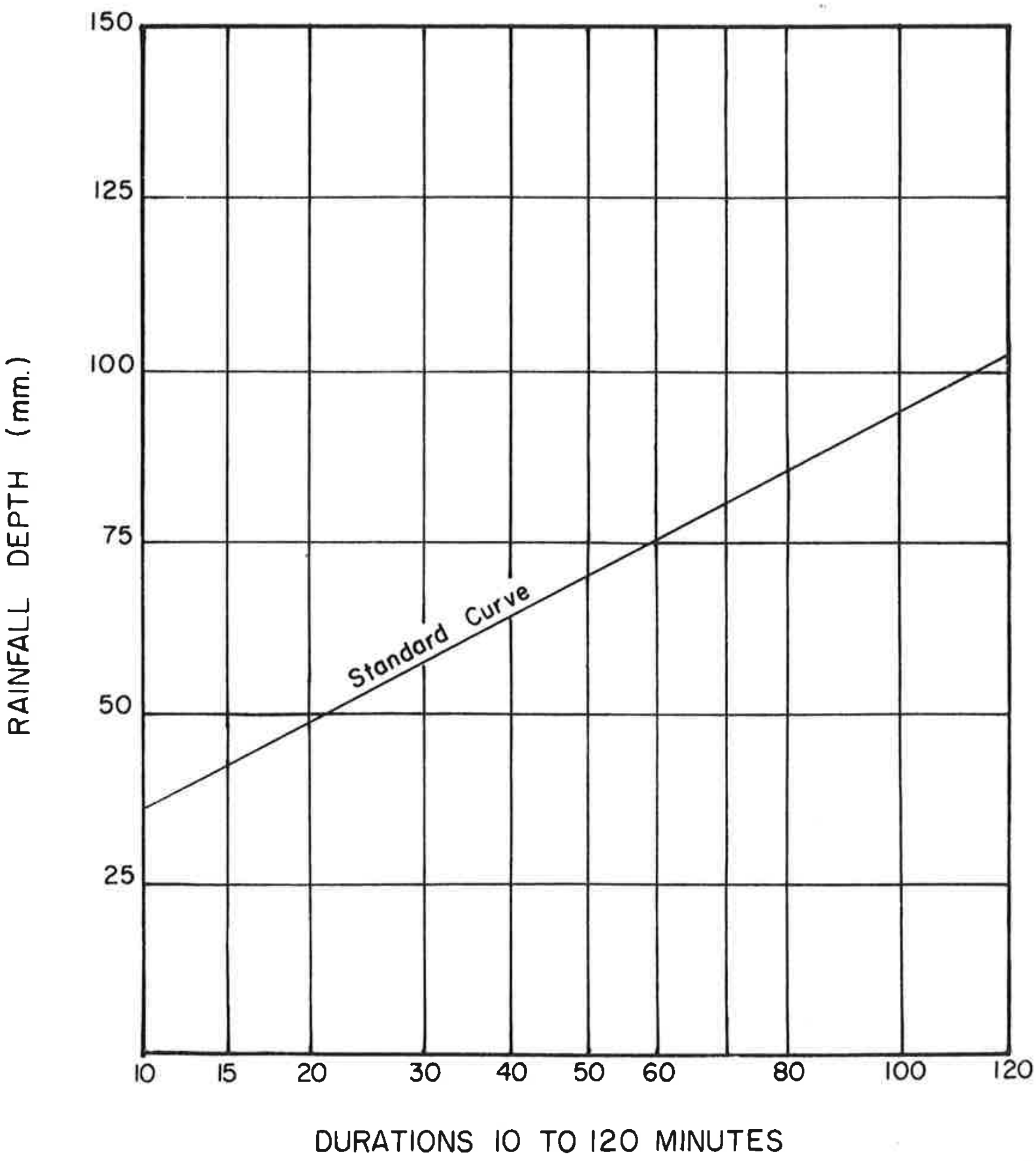

FIG.3A. STANDARD DEPTH — DURATION DIAGRAM

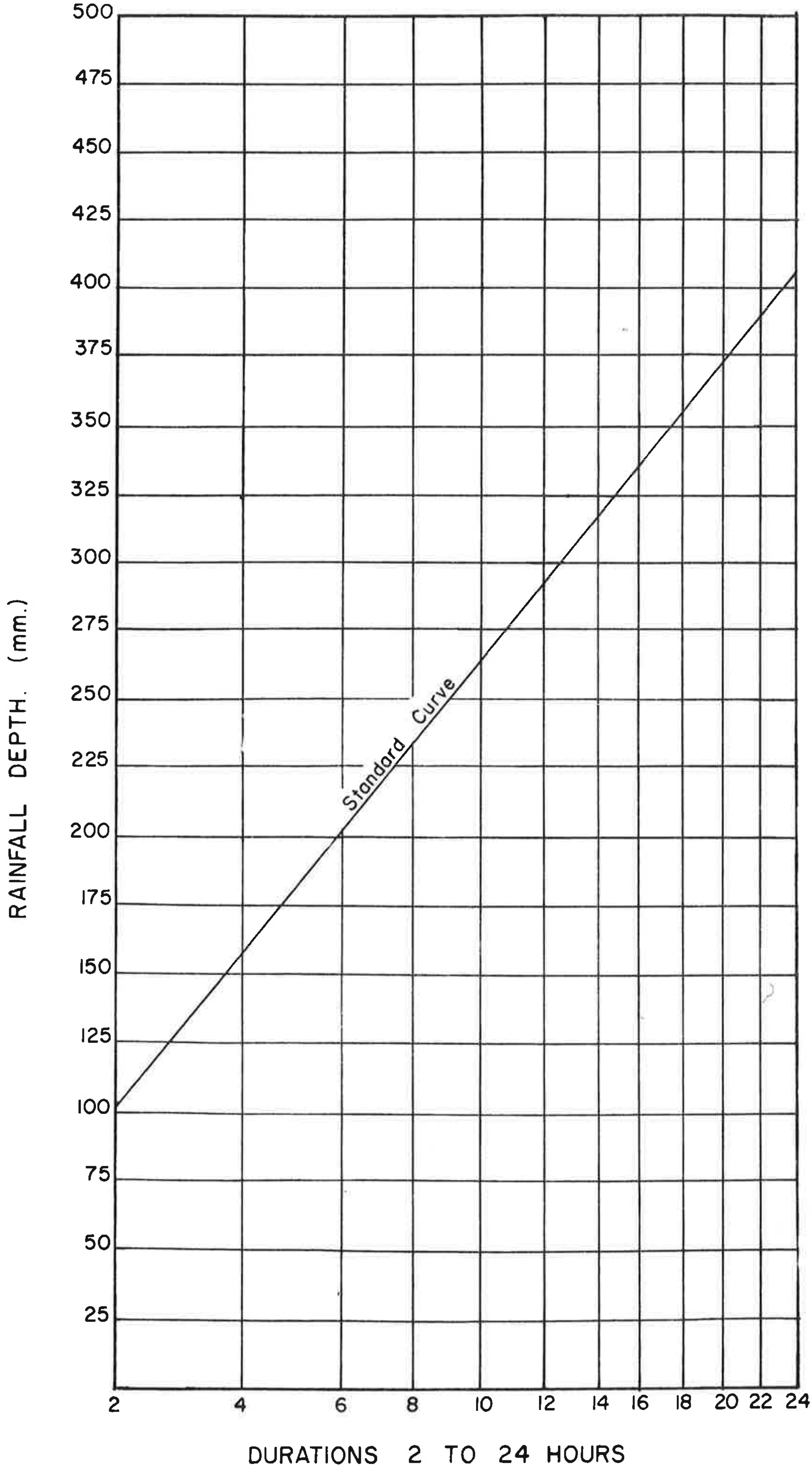

FIG. 3B. STANDARD DEPTH — DURATION DIAGRAM.