A STUDY OF THE TRANSPORT OF GRADED SEDIMENTS

T J Day, BA, MA, PhD, P Eng

Report No. IT 190
April 1980

Hydraulics Research Station
Wallingford
Oxon OX10 8BA
Telephone 0491 35381

PREFACE

This investigation was carried out in Mr A J M Harrison's Fluvial Hydraulics Division while the author was attached to Dr W R White's Section. The author wishes to thank the members of this section plus the numerous members of the Industrial Staff for their assistance. The support of the Terrain Services Division, Geological Survey of Canada, Ottawa, Canada, is most gratefully acknowledged.

The views expressed and the conclusions drawn are those of the author; they do not necessarily reflect the official views of the Station.

ABSTRACT Experimental flume data on the initial motion characteristics of size fractions contained in seven graded bed materials are compared with the behaviour of uniform bed materials of similar size. Expected trends in particle stabilities — higher thresholds for smaller sizes and lower thresholds for larger sizes in a mixture — are found. One size fraction, D_A, in each mixture begins to move under uniform bed material conditions. Whether this size is larger or smaller than D_{50} inversely depends upon grading. Shielding and exposure effects on particles smaller and larger respectively than D_A appear to be common throughout the mixtures analysed.

NOTATION

a	Regression coefficient
A	Value of Fgr at initial motion for uniform sediment
A^1	Value of Fgr at initial motion for a particle in a graded sediment
b	Regression exponent
C	Coefficient in sediment transport function for uniform sediment
C^1	Coefficient in sediment transport function for graded sediment
d (m)	Mean depth of flow
D (m)	Sediment diameter
D_{16}, D_{35}, D_{50}, D_{84} (m)	Sediment diameter for which 16%, 35% 50% and 84% of the sample is finer
D_A (m)	Sediment diameter of a graded bed material which exhibits the same threshold conditions as a uniform sediment of the same diameter
Dgr	Dimensionless grain size
Fgr	Sediment mobility
g (m/s^2)	Acceleration due to gravity
Ggr	Dimensionless observed sediment transport rate
Ggr^1	Dimensionless adjusted sediment transport rate
i	Hydraulic gradient
m	Exponent in sediment transport function for uniform sediment
m^1	Exponent in sediment transport for graded sediment
n	Transition exponent
s	Relative density of sediment
v_* (m/s)	Shear velocity
V (m/s)	Mean velocity
X	Sediment transport, mass flux per unit mass flow rate
ρ (kg/l)	Density of fluid
ν (m^2/s)	Kinematic viscosity of fluid
τ	Tractive shear
α	Coefficient of rough-turbulent equation
Δp_i	Percentage of size fraction in transported load

CONTENTS PAGE

TABLES

FIGURES

INTRODUCTION

Purpose and scope of study

The natural non-uniformity of river bed materials is treated in a simplified manner in both the derivation and application of most sediment transport formulae. Fluid transport processes are sufficiently complex that it is convenient to simplify the problem of sediment movement by considering uniform bed materials. Even with this assumption there is considerable disparity amongst the various formulae (White et al., 1973). However, the necessity to apply these formulae to natural waterway demands an assessment of accuracy, and consequently, a more thorough examination of the effects of non-uniformity of bed material is required.

For beds of coarse uniform sediments such as sands and gravels, the forces resisting motion are caused mainly by the weights of the particles. However, when the bed is composed of a heterogeneous material, the initial movement of any specific size depends not only on its weight, but also upon the variation in stability caused by the relative size of surrounding particles. In a heterogeneous bed material the finer sizes on the surface are shielded by larger ones thereby increasing stability, and the larger sizes being more exposed will exhibit less stability than their uniform counterparts.

Experimental results, for example by Rakoczi (1975) and Fenton and Abbot (1977), field studies by Church (1972), and the theoretical work by Egiazaroff (1965) all offer support for the expected trend in particle stabilities. Rakoczi was able to illustrate larger threshold shears for smaller sizes and smaller threshold shears for larger sizes, and in particular that the D_{50} size of sandy-gravel mixtures have the same threshold as uniform sediments as predicted by the Shields' curve (Yalin, 1972; pp. 80-86, Figure 4.7). This feature was not found for sand or gravel mixtures alone, however. Fenton and Abbot's study of the effect of protrusion heights on threshold conditions illustrated, for example, that coarse sediments with large protrusions exhibited threshold conditions one sixth of the Shields' value. Church's results from field studies of coarse bed material streams indicated that sediments lying on the bed surface (therefore with large exposures) exhibited threshold conditions less than the Shields' value, and similar to Fenton and Abbot's results. Also, from measurements at low bed load transport rates, Church was able to illustrate the possible magnitude change in the Shields' parameter for particles incorporated within the stream bed. Where structural strengthening, such as imbrication occurs, coarse particles (> 3mm) can require threshold conditions one-quarter larger than the expected Shields' parameter. Using a theoretical approach Egiazaroff presented a relationship for threshold conditions for any size in a mixture providing that the size distribution of the transported material is known. Egiazaroff's work led to the conclusion that the D_{50} size of a mixture will move at a higher threshold than the same size as a uniform material.

The purpose of this report is to present the results of a study similar in desiign to Rakoczi's (1975), but where initial and established motion parameters are defined by the Ackers and White (1973) approach to sediment transport. For seven bed materials of varying grading and particle sizes, initial motion characteristics of selected size fractions are determined, and compared with the Ackers-White and Shields' initial motion curves for uniform bed material. Established motion characteristics of these same size fractions in mixtures also are compared to the Ackers-White established motion parameters.

Ackers-White method for computing uniform sediment transport

Ackers and White (1973) described the movement of sediment in terms of three dimensionless groups: (1) particle mobility, Fgr; (2) sediment transport, Ggr; and (3) a dimensionless particle size, Dgr.

The particle mobility number is a ratio of shear forces and immersed weight. For coarse sediments, transport is considered a bed process. The relationship between effective shear stress and the mean stream velocity can be described by the rough turbulent equation:

$$\sqrt{\frac{\tau}{\rho}} = \frac{V}{\sqrt{32}\,\log\left(\alpha \frac{d}{D}\right)} \tag{1}$$

where

τ shear stress

ρ mass density of fluid

V mean velocity of flow

d mean depth of flow

D particle size

α coefficient of rough turbulent equation

A fine sediment is considered to be transported in the main body of the flow, where it is suspended by turbulence. As the intensity of turbulence is dependent upon the total energy degradation, rather than on a net grain resistance, for fine material:

$$\sqrt{\frac{\tau}{\rho}} = v_* = \sqrt{gdi} \tag{2}$$

where

v_* shear velocity

g acceleration due to gravity

i hydraulic gradient

For coarse sediments the equation for particle mobility is

$$Fgr = \frac{V}{\sqrt{g\,D(s-1)}} \cdot \frac{1}{\sqrt{32}\,\log\left(\alpha \frac{d}{D}\right)} \tag{3}$$

and for fine sediments

$$Fgr = \frac{v_*}{\sqrt{g\,D(s-1)}} \tag{4}$$

where s is the relative density of the sediment.

An extensive analysis of flume data led to the definition of Dgr > 60 for coarse sediments, and Dgr = 1.0 for fine sediments. Sizes transitional between these two limits can exhibit both fine and coarse sediment behaviour. Which behaviour is dominant depends upon the size relative to either limit. A general equation for particle mobility is then:

$$Fgr = \frac{v_*^{\,n}}{\sqrt{g\,D(s-1)}} \cdot \left[\frac{V}{\sqrt{32}\,\log\left(\alpha \frac{d}{D}\right)}\right]^{1-n} \tag{5}$$

where n is a transitional exponent ranging from 1.0 for fine sediment to 0 for coarse. The value of n between 0 and 1 depends upon Dgr. For sand the transitional range includes particles approximately between 0.04 and 2.5mm.

The dimensionless particle diameter, Dgr, is defined as the cube root of the ratio of immersed weight to viscous forces or:

$$Dgr = D\left(\frac{g\,(s-1)}{\nu^2}\right)^{1/3} \tag{6}$$

The expression for sediment transport is based on the stream power concept, in the case of coarse sediments using the product of net gain shear and stream velocity as the power per unit area of bed, and for fine sediments using the total stream power. By combining the efficiency of transport with the mobility number a transport parameter is:

$$Ggr = \frac{Xd}{sD} \left(\frac{v_*}{V}\right)^n \quad (7)$$

where X is the sediment transport as mass flux per unit mass flow rate. For coarse sediments (n = 0) Eq. 7 reduces to:

$$Ggr = \frac{Xd}{sD} \quad (8)$$

and for fine sediments (n = 1):

$$Ggr = \frac{Xd}{sD} \cdot \frac{v_*}{V} \quad (9)$$

As functional terms Eq. 7 is

$$Ggr = f\,(Fgr;\ Dgr) \quad (10)$$

and the generalized transport equation is

$$Ggr = C\left(\frac{Fgr}{A} - 1\right)^m \quad (11)$$

where C and m are the coefficient and exponent of the sediment transport function, respectively and A is the initial motion parameter or the value of Fgr below which no significant transport is considered to take place.

On the basis of over 1000 sets of experimental flume data the parameters C, m and A were determined as single value functions of Dgr. These relationships are shown in Figure 1. A was determined as Fgr when Ggr = 10^{-4}.

The following analysis of graded sediment transport focuses upon the observed variations in C, m and A (for graded sediments C^1, m^1, and A^1). As the process of transportation will not alter whether a moving particle is from a uniform or graded bed material, the n-Dgr relationship (cf. Figure 1) is considered valid and is not investigated.

EXPERIMENTAL DATA

A range of transport rates are necessary to determine the form of the Ggr-Fgr functions for each size fraction in motion. For any bed material a series of experimental results are required which range from low transport rates for definition of A^1, to higher transport rates to provide sufficient data for regression analysis to define C^1 and m^1.

Further criteria for data were a range in bed material gradings, a range in mean size parameters of bed materials, and to enable direct comparisons, some overlap of sizes amongst the mixtures.

Size fraction: other sources

Few studies of sediment transport provide the required information on the distribution of size fractions in transport, and even fewer studies provide a sufficient range of transport rates for a bed material. The three sources of data chosen for this study are listed and discussed below. Operational and measurement procedures differ amongst the sources, and these differences have led to several qualifications in the use of their results. Summaries of bed material characteristics, particle size distributions, and ranges in hydraulic conditions and transport rates are included in Tables 1, 2 and 3 respectively. The number of separate experiments that led to a measurement of transport are listed in Table 3, these are referred to as runs. In the experiment of Gibbs and Neill (1972, 1973), and in the HRS experiments to be discussed later, transport measurements are average values based upon several measurements taken during a specific set of flow conditions. Individual sets of measurements are referred to as tests. A listing of individual size fraction rates are presented in the Appendix.

United States Waterways Experimental Station (USWES) (1935)

This report documents an extensive series of experiments into sediment transport rates for nine bed materials (D_{50} ranging from 0.2 to 4.1mm). Of these nine series of experiments, three were chosen: sand nos. 1, 2 and 9, to augment both median size and grading data (cf. Tables 1 and 2 and Figure 2, for distribution parameters, and Table 3 for hydraulic and sediment summaries for all bed materials used in the analysis). Although only one sediment transport measurement was made for each run, the range and detail of runs are considerable.

Gibbs and Neill (1972, 1973)

In their evaluation of the efficiency of basket-type bed-load samplers the authors presented transport measurements from two sets of experiments. A common bed material with a median size similar to that of USWES No. 9 but with a wider grading and range in size fractions was used for all runs.

The experiments were performed with a nearly constant flow depth and a narrow range in mean velocity, with the shear stress being increased by varying the flume slope. Although only six measurements are available, they represent average values of detailed studies into the variation of transport rates. In each run 50 test measurements of bed-load were taken from a slot sampler located in the flume bed. The length of sampling period was variable while the interval between tests in a specific run was kept constant. A summary of these results are presented in Table 4. The authors conclude that sampling errors are not related to transport rates and that at least 15 samples are required to reduce the error range in the mean estimated transport rate to about 10%.

Cecen and Bayazit (1973)

This study differs from more traditional experiments in that they were designed to investigate the removal of an armour bed layer. The authors covered a bed material (two were used) with an armour layer of predetermined size distribution to a thickness of the maximum size found in the bed material (either 20 or 30mm). At the beginning of the experiment the bed was protected by a wire net until uniform flow was established and then quickly removed. After a ten minute period the flow was stopped and the transported sediment collected from the bottom of the flume and then sieved and weighed. The transport rate was determined from a time ratio of the total transport, and therefore is a reasonable estimate of the average transport. Also, as the time period was relatively short, any armouring effect developing from the removal and non-circulation of sediment should have been small.

Several flume slopes were used and for each several runs were made with water discharge extending from very low ones with almost no sediment transport, to those which moved a substantial portion of the armour layer. The combination of coarse size fractions and steep slopes (0.01 to 0.03) resulted in very low flow depth to particle size ratios. Of the very numerous data produced by this study only a series of seven runs over the smaller bed material are chosen. These runs were made over the lowest flume slope and depth-particle size ratios were larger (eg $d/D_{90} \geq 10$). During the analysis it became clear that all the other runs exhibited sediment transport characteristics very different from both this series and from all the remaining data sets as well. These shallow flow data exhibited consistently higher initial motion values and considerably different C^1 and m^1 values. Consequently this report examines only the first data series and an investigation into the remaining data is deferred. The size distribution chosen to represent the bed material source for transported size fractions is the artificial armour layer.

Size fraction data: HRS experiments

Bed materials

Two series of experiments were undertaken to extend the range of available data. Series A, bed material, a natural mixture obtained from a local gravel pit, had the advantages of being both widely graded and bimodal. Although its median size is only 1.4mm it contains size fractions ranging from 0.15 to 14.2mm (Tables 1, 2; Figure 2). This latter particle diameter was near the maximum that could be passed through the sediment return system of the flume.

The second bed material, Series B, was mixed from size fractions abstracted from Series A material. Its composition was designed to produce a sediment of similar mean size but narrower grading. Utilizing the same materials should eliminate any considerations of the effects of particle shape on transport characteristics. This second mixture was also bimodal and its characteristics are listed in Tables 1 and 2.

Flume

The experiments were conducted in a 2.46m wide recirculating tilting flume (Fig 3). A sediment return system had been constructed within the flume channel. Any suspended material was transported through the main pumping system whereas coarser sizes were deposited into hoppers at the downstream end of the sediment bed. This coarser sediment was pumped continuously underneath the flume channel through a separate system of pipes to re-enter the main channel through a set of eight nozzles located downstream of the main discharge pump entrances and just at the beginning of the sediment bed. The sediment bed between the nozzles and the hoppers was 18m in length.

Procedures and measurements

For all runs a 0.2m sediment bed was laid in the flume and smoothed out by template. After each run in Series A the top few centimetres were removed and new sediment added and levelled. In Series B the bed was formed of a 0.1m thick layer of bed material B separated by plywood sheets from an underlying layer of equal thickness of the initial material. After each Series B run the layer of new material was turned over and levelled.

Although there were minor variations in the sampling and measurement procedures, each run consisted of several tests (from 6 to 19), and each test consisted of sediment load, discharge, water surface slope and flow depth measurements. The sediment load was measured as it was returned to the upstream end of the flume. During Series A and low transport tests of Series B small baskets were hand-held under two nozzles, until all eight had been sampled. During higher transport tests a trolley with four collection baskets was pulled up to and under the nozzle outlets and a simultaneous sample was taken across all eight outlets. Sampling times decreased with transport rates, ranging from a three to one minute totals. Again, in Series A and the low transport tests of Series B, sampling would progress from one side across the flume width over a continuous time, ie, the second pair of nozzles would be sampled immediately after the first and so on. Therefore the sampling could be complete within 12 minutes. In an attempt to reduce the variability and number of samples, the sampling of the second series was done over a half hour period with a quarter of the total sample being taken at 10-minute intervals.

Measurement of the transported sediment as it re-entered the flume may have introduced systematic errors, particularly as the rates of size fraction transport must differ between the main flume channel and the return system piping (32mm diameter). This method of sampling was chosen for economic reasons. Suspended material that passed over the collection hopper to be recirculated through the discharge pumping system was sampled via Pitot tubes located in the return pipes. Even at higher transport rates the amount of suspended material was very small and its contribution to the total load has been ignored. All sediment samples used in the subsequent analysis were taken not less than 2 hours after the beginning of the experiment.

Water temperature was kept constant at about 12°C by having a 100mm pipe bringing fresh water into the reservoir tank. Without this input temperatures could increase to 20°C.

Discharge was measured for each test from the flat-V weir located at the downstream end of the flume, two metres beyond the sediment hoppers. For all experiments the discharge was kept constant at about $0.2m^3/s$. The three pump discharge system entered the flume about 2m upstream of the sediment return nozzles. The entrances were proportioned according to the pump discharge (two $0.113m^3/s$ and one $0.028m^3/s$ pump).

Water depth and water surface slope were also measured during each test. Depth was measured at one metre intervals along both sides of the 10m long glass walls of the main channel. Water surface slope was measured from a reservoir system of five point gauges. The inlets for these reservoirs were located at 3.25m intervals along one side of the flume.

Data summary

A total of 20 runs were completed, eleven for Series A and nine for Series B. Summaries of hydraulic and transport measurements are listed in Tables 5 and 6 for Series A and B respectively. Values for discharge, depth, water surface slope and velocity, are means based on the tests made for each run. Each mean hydraulic parameter is presented with the standard deviation given as a measure of the dispersion in the data.

Mean velocities were determined from the continuity equation and represent the mean velocities through the glass walled portion of the main channel. Water surface slope was determined from a regression analysis of the five point-gauge readings.

Sediment concentrations are given as parts per million by weight, with dry weights being used in all calculations. The size distributions of transport sediment are given in Tables 7 and 8. The percentage retained for each size fraction is a mean based upon all the test measurements made during a run. These data are plotted against their respective bed materials in Figure 4. Size fractions dimensions were determined from the variability of sieve sizes. Where the transport of particles are discussed the dimensions given represent an average value between a sieve size (% retained) and the next largest sieve size used. This average size better represents all the particles falling between the two sieve sizes.

Precision and repeatability

The precision of discharge measurements, expressed as a percentage coefficient of variation (standard deviation divided by the sample mean) ranged from 0.3 to 3% over both series. Variations in depth measurements ranged over the same values but this measurement shows progressively less precision during the high transport runs where the sediment bed was deformed. Water surface slopes are the least precise direct hydraulic measurement with coefficients of variation ranging from 3 to 32%, with an average of approximately 10%.

Precision of transport measurements varies from 6.5 to 41% (Tables 5 and 6) with no clear tendency to change with transport rate. On average the second series was slightly more precise (average coefficient of 20% compared to 25% of Series A), and its range is less as well.

A visual indication of the possible repeatability of runs can be seen from comparisons of Runs 1 and 4 of Series A, and Runs 1 and 2 of Series 2 (Tables 5 and 6). Flow conditions are similar for each set of runs, and their average transport rates vary by approximately 40—45%, a not unexpected result as suggested by Gibbs and Neill (1972, 1973). Of individual tests where two or more samples were taken transport rates varied by between 2 and 50% with an average difference (based upon 40 comparisons) of 24%.

ANALYSIS

Transport functions

The required calculations for Dgr, Fgr, and Ggr as outlined are straightforward. These data are presented in the Appendix. The concentration (ppm) of each size fraction in transport, its contributing percentage to the total load, $\triangle p_i$, and the Ackers-White parameters for uniform sediment transport are also included in this Appendix.

Any observed transport rate of a size fraction in a mixture is not directly comparable to a uniform bed of the same size moving under the same flow conditions. The former transport rate will always be smaller than the latter because it is dependent upon the availability of that size fraction in the bed material. As the transport rate of a uniform sediment refers to

100% of the transport, each observed Ggr was adjusted to its new value Ggr^1 by multiplying by $(100/\triangle p_i)$ ie. $Ggr^1 = Ggr \times 100/\triangle p_i$, where Ggr^1 is the adjusted or totalised transport rate for a specific size fraction in a graded sediment. The effect of this totalising procedure can be seen in Figures 5 and 6, where the Ggr-Fgr and the Ggr^1-Fgr^1 functions are plotted for six size fractions.

Initial motion parameter

In all but data sets 4 and 5 the observed Ggr-Fgr data extended through the 10^{-4} Ggr truncation value used to determine A, the threshold for uniform sediment as illustrated in Figure 5. A log-log regression equation was fitted through all data falling below 10^{-4} Ggr and to several data points above as well. These equations were then solved for A^1, the threshold for graded sediments. The observed Ggr-Fgr functions for data sets 1 and 2 are slightly curved towards larger Fgr values, whereas for sets 3, 6 and 7 a straight log-log relationship is maintained across the complete range of Fgr (see Figure 5 where examples are demonstrated for 0.39mm size particles). For data sets 4 and 5 the Ggr-Fgr functions were extrapolated visually to determine A^1. Similar procedures as illustrated in Figure 6 were used to determine initial motion parameters from the Ggr^1-Fgr functions except data sets 4 and 5 were not of sufficient range to extend to lower transport rates.

Established motion parameters

Ackers and White (1973) used an optimizing technique to determine the parameters C and m. The limited data on graded sediments prevented such an approach and the slopes and intercepts of the transport functions are determined by regression analysis of the logarithmically transformed data.

Inclusion of A^1 in transforming the transport functions to Equation 11, as used by Ackers and White, can result in distortions of the modified function. The subtraction of a constant value, such as A^1, from logarithmically distributed data artificially changes the shape of the resulting function. In their original study Ackers and White found that the Ggr - $(\frac{Fgr}{A} - 1)$ functions remained straight on log-log graphs, but with a much reduced slope. Similar results were found for data sets 1 and 2, however, in all the remaining data the inclusion of A^1 resulted in a curvilinear function. An example of this problem is demonstrated in Figure 7, where the original and altered functions are shown.

As the curvilinearity is most noticeable at lower values of Ggr and Ggr^1, attempts were made to fit log-log equations to the upper portions of the altered functions. Results produced by this method, and from attempts of fitting exponential equations as well, were erratic and inconclusive.

DISCUSSION

Initial motion

The most significant trends in the A^1 values based upon observed Ggr data are the rapidly changing initial motion characteristics of the smaller shielded particles, and the asymptotic trend shown by the larger sizes in each mixture. A further significant trend is the separation amongst the data sets, with the same sized particle requiring a larger shear force to begin movement in coarser mixtures than in finer ones. This trend continues throughout the range of particles, and is most pronounced with the smaller sizes. These trends are shown in Figure 8 (data are listed in Table 9). The Ackers-White and Shields' curves used for uniform sediment transport are included in Figure 8.

Although these initial motion characteristics are not directly comparable to the two threshold curves for uniform sediments, they indicate that the larger particles in a mixture will move at lower thresholds than uniform sediments of the same size.

The proper comparison between uniform and graded sediment initial motion characteristics is shown in Figure 9 where A^1 values (cf. Table 10) determined from Ggr^1 data are plotted against the two uniform sediment threshold curves. Only five sets are included as sets 4 and 5 could not be extended to 10^{-4} Ggr^1 with sufficient certainty.

The trends illustrated in Figure 8 continue in Figure 9, but the differences in A^1 for any Dgr are much reduced, and the asymptotic trends are continued below the Ackers-White uniform threshold curve. There is a suggestion that this trend continues for $Dgr > 60$. Each data set is separated again by mixture size. In Figure 10 a similar analysis of determining Fgr values for a particular Ggr^1 (in this case $Ggr^1 = 0.005$) is presented to show that the trends in A^1 of data sets 4 and 5 can be expected to be similar to that shown in Figure 9.

An inspection of Figures 8, 9 and 10 suggests that the initial motion parameter of a particle in a mixture not only depends upon its Dgr value as in a uniform sediment, but also upon some particle size below which smaller particles are shielded, and above which larger particles are moving at lower values of Fgr due to increased exposures and instability. Interpretation of Figure 11, where the ratio A^1/A is plotted against Di/D_{50}, indicates that there is a particle size, D_A, in a mixture which begins to move under the same conditions as a uniform bed material (ie $A^1 = A$). Furthermore, the diameter of D_A varies inversely with bed material grading, as $D_A < D_{50}$ for widely graded sediments, and $D_A > D_{50}$ for narrowly graded materials (Figure 12).

The characteristics of stability for particles larger and smaller than D_A are shown in Figure 13, where D_A replaces D_{50} of Figure 11. Clearly stability characteristics are similar amongst the mixtures, and it is only D_A that changes systematically with grading.

The stability relationship of Figure 13 can be described by a modified power equation:

$$\frac{A^1}{A} = 0.4 \left(\frac{D}{D_A}\right)^{-0.5} + 0.6 \qquad (12)$$

The range of data is good, although data for $Di/D_A \gtrsim 4$ is limited, and any extension of Eq. 12 for the larger particles in widely graded sediments must be a qualified one. The initial motion data presented in Figures 8 to 13 inclusive do indicate that narrowly graded mixtures in the order of $\sqrt{D_{84}/D_{16}} \simeq 1.4$, behave as mixtures, not as uniform sediments.

The relationship between D_A and $\sqrt{D_{84}/D_{16}}$ shown in Figure 12 is not as well defined, even though the range is reasonable. The following equation can be fitted to these data:

$$\frac{D_A}{D_{50}} = 1.62 \sqrt{\frac{D_{84}}{D_{16}}}^{\,-0.55} \qquad (13)$$

Interpretation of this relationship must remain provisional. Extension of these data to gradings less than 1.4, and approaching 1.0, has the apparently illogical interpretation that D_A may be one and a half times larger than D_{50}, when the size distribution is approaching one grain size and all D_i, and hence D_A should approach D_{50}. Obviously, more data are required to define the D_A - $\sqrt{D_{84}/D_{16}}$ relationship, and to assist in its physical interpretation.

The incomplete results of previous experimental studies prevent any thorough comparisons. However, data presented here are not in agreement with Egiazaroff's (1965) conclusion that in all mixtures the D_{50} size would move at a higher threshold than the same size as a uniform sediment. The partially available results of Rakoczi's (1975) thorough study agree with the overall trend for the effects of shielding of small particles and the increased exposure and instability of the larger sizes. Fenton and Abbot's (1977) work on protrusion height in general terms is supportive, although it is difficult to transfer results from studies of single grain motion, to the motion of same sized particles contained in a hererogeneous bed material. The series of particle stability curves as shown in Figures 9 and 10 are similar to those suggested by Yalin (1972, pp. 83-86, Fig. 4.12) for the results of a Shields' type analysis.

However, the separation of these curves was based upon the shape of the bed material size distribution curve. The present study indicates that the position of the size fraction within the grading curve is more important than the overall grading of the sediment mixture; ie. A^1/A is more sensitive to D_i/D_{50} than D_{84}/D_{16}.

Established motion Comparisons between the established motion parameters C and m with those observed from the Ggr^1-Fgr functions are inconclusive. The nonlinear Ggr^1-$(\frac{Fgr}{A^1} - 1)$ functions make the results of regression analysis suspect. The limited range of transport conditions for some particle sizes, particularly the coarse ones, make regression equations even less reliable. For example, the m^1 values of HRS A can double if just one low value of Ggr^1 is eliminated from the analysis. Such erratic results lead nowhere.

More consistent results could be found by using the following analysis on the observed Ggr-Fgr functions. The m^1 values shown in Figure 14 (see Table 9) suggest a similar asymptotic relationship with Dgr but with m^1 always less than m. The scatter in m^1 for Dgr values < 10 make any interpretation of the form of this function impossible. The chaotic distribution of C^1 values in Figure 15 (see Table 9) reflects both the availability of particles sizes in the bed material and the sensitivity of regression intercepts for logarithmically distributed data.

In an attempt to compare the established motion characteristics of size fractions in transport amongst the data sets, further power equations were developed

$$Ggr^1 = aFgr^b$$

There is a suggestion of a weak dependence of b, and hence a, upon Dgr with b generally larger for larger particles (Table 10). The b values for bed material 3 are very much different, and this is probably due to the narrow range of the Ggr^1-Fgr functions. The limited data available herein, and the difference in procedures with the uniform sediment transport parameters m and C prevent this approach from proceeding further. These data, however, are offered here as a possible alternative way to approach the application of the Ackers-White method.

CONCLUSIONS

1 The stability of a particle in a graded bed material is determined by its size relative to a critical diameter, D_A. When the ratio of these sizes is smaller than one ($D < D_A$) the particle is shielded from the flow and its initial motion requires a greater tractive force than suggested by its diameter. Conversely, when the ratio is larger than one the particle is more exposed and requires less tractive force to begin movement.

2 The shielding exposure effects on threshold conditions are decidedly similar across a range of particle and mixture characteristics, see Figs 11 and 13.

3 This critical diameter, D_A, appears to vary inversely with grading, see Fig 12. A physical explanation of this relationship has not been found as yet.

4 Results of the established motion analysis were inconclusive.

5 Tentative predictions of transport rates may be made by determining the initial motion parameter for each size fraction from Eqs. 12 and 13, and accepting $C^1 = C$ and $m^1 = m$ (Fig 14 offers some justification for this approach). As the resulting size fraction transport rates are totalised values each rate must be adjusted by the percentage of that size in the bed material. Actually the shape of the transport curve is required but as it cannot be predicted the shape of the bed material curve must be used as an approximation. As transport curves are generally more narrowly graded than the bed material (see Fig 4) some error is introduced by this procedure and that this error will increase with grading of the bed sediment, as well as being more pronounced for lower transport rates.

6 An appendix provides a summary of the transport data for the HRS experiments.

REFERENCES

ACKERS P and WHITE W R. 1973, Sediment transport: new approach and analysis. Proc. ASCE, JHD, 99, HYII, pp. 2041-2060.

CECEN K and BAYAZIT M. 1973, Critical shear stress of armoured beds. International Association for Hydraulic Research, Proc. 15 Congress, pp. 493-500.

CHURCH M. 1972, Baffin Island Sandurs. Geological Survey of Canada, Bulletin 216.

EGIAZAROFF I V. 1965, Calculation of non-uniform sediment concentrations. Proc. ASCE, JHD, 91, HY4, pp. 225-247.

FENTON J D and ABBOT J E. 1977, Initial movement of grains on a stream bed: effect of relative protrusion. Proc. Royal Society of London, A, 352, pp. 523-537.

GIBBS C J and NEILL C R. 1972, Interim report on laboratory study of basket-type bed-load samples. Research Council of Alberta, REH/72/2.

GIBBS C J and NEILL C R. 1973, Laboratory testing of model VUV bed-load samples. Research Council of Alberta, REH/73/2.

RAKOCZI L. 1975, Influence of grain-size composition on the incipient motion and self-pavement of bed materials. International Association for Hydraulic Research, Proc. 16th Congress, pp. 151-157.

USWES. 1935, Studies of river bed materials and their movement with special reference to the lower Mississippi River, USWES Paper 17.

WHITE W R, MILLI H, and CRABBE A D. 1973, Sediment transport: an appraisal of available methods, Hydraulics Research Station, Report No. INT 119, Vols 1 and 2.

YALIN M S. 1972, Mechanics of sediment transport. Pergamon Press.

DDB Dd 650449 4/81

APPENDIX

APPENDIX SUMMARY OF SIZE FRACTION TRANSPORT DATA

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized transport parameter Ggr
				n	A	C	m					
USWES No. 1	0.153	17	4.22	0.650	0.252	0.007	3.632	0.358	0.000000276	0.3	0.056	0.0000920
								0.394	0.000002320	0.3	0.369	0.0007733
								0.447	0.000007224	2.3	0.838	0.0003141
								0.458	0.000101400	4.6	10.472	0.0022043
								0.513	0.000250300	5.7	21.998	0.0043912
								0.326	0.000003100	5.2	1.055	0.0000596
								0.390	0.000015530	1.6	3.768	0.0009706
								0.431	0.000015820	0.9	2.800	0.0017578
								0.458	0.000006810	0.3	1.027	0.0022700
								0.494	0.000206800	5.4	31.538	0.0038296
								0.534	0.000321220	6.5	35.223	0.0049418
								0.617	0.000813600	9.7	60.757	0.0083876
								0.374	0.000002240	0.2	0.752	0.0010182
								0.459	0.000197720	8.8	41.496	0.0022468
								0.506	0.000185600	4.7	28.125	0.0039489
								0.614	0.000725000	8.3	73.189	0.0087349
								0.654	0.000536000	5.4	49.816	0.0099259
	0.215	17	5.92	0.567	0.235	0.012	2.971	0.306	0.000000341	0.4	0.0750	0.0000853
								0.335	0.000042020	6.0	7.423	0.0007003
								0.379	0.000152470	7.9	20.000	0.0019300
								0.386	0.000199400	10.1	22.990	0.0019743
								0.433	0.000433200	11.7	42.279	0.0037026
								0.279	0.000005100	9.7	1.953	0.0000526
								0.333	0.000038400	4.4	10.363	0.0008727

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized transport parameter Ggr
USWES No. 1 (cont'd)	0.215 (Cont'd)							0.364	0.000125670	8.0	24.859	0.0015709
								0.386	0.000067110	3.3	11.324	0.0020336
								0.416	0.000369700	10.8	63.056	0.0034231
								0.449	0.000530000	12.0	65.031	0.0044167
								0.514	0.001104800	14.8	92.704	0.0074649
								0.319	0.000074980	1.7	5.852	0.0044106
								0.389	0.000323200	16.0	75.529	0.0020200
								0.425	0.000341500	9.7	58.108	0.0035206
								0.513	0.001065000	13.7	120.404	0.0077370
								0.547	0.001053000	11.9	109.963	0.0088487
	0.303	17	8.35	0.484	0.220	0.018	2.497	0.263	0.000056770	7.4	1.388	0.0007672
								0.287	0.000117757	18.7	23.126	0.0006297
								0.323	0.000166540	9.6	24.333	0.0017348
								0.327	0.000270000	15.3	34.823	0.0017647
								0.368	0.000548400	18.0	69.468	0.0030467
								0.241	0.000014230	15.5	3.113	0.0000918
								0.286	0.000107950	13.8	32.500	0.0007822
								0.311	0.000294110	21.0	65.266	0.0014005
								0.328	0.000235400	13.0	44.610	0.0018108
								0.353	0.000512700	16.8	98.093	0.0030518
								0.380	0.000610040	15.5	83.999	0.0039357
								0.431	0.001046700	15.8	98.968	0.0066247
								0.275	0.000049050	6.0	20.512	0.0008175
								0.332	0.000366800	20.5	96.772	0.0017990
								0.359	0.000585600	18.8	112.585	0.0031149
								0.431	0.001071000	15.5	139.316	0.0069097
								0.461	0.001331000	16.9	156.089	0.0078751

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized transport parameter Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	0.390	17	10.75	0.423	0.210	0.023	2.239	0.237	0.000007336	10.3	1.933	0.0000712
								0.258	0.000085704	14.7	18.180	0.0005830
								0.288	0.000072240	4.5	11.395	0.0016053
								0.291	0.000175700	10.8	24.585	0.0016269
								0.328	0.000348300	10.6	40.906	0.0032865
								0.218	0.000004520	10.5	2.111	0.0000430
								0.258	0.000054180	7.5	17.663	0.0007224
								0.278	0.000193000	15.0	46.614	0.0012867
								0.293	0.000171100	10.3	35.340	0.0016612
								0.314	0.000336470	12.0	70.067	0.0028039
								0.338	0.00043358	12.0	65.031	0.0036132
								0.381	0.00063110	10.4	65.142	0.0060683
								0.248	0.00005285	7.0	23.930	0.0007550
								0.297	0.00021670	13.0	61.367	0.0016669
								0.319	0.00034221	12.0	71.875	0.0028518
								0.382	0.00063300	10.0	88.169	0.0063300
								0.408	0.00077900	10.8	99.631	0.0072130
	0.463	17	12.76	0.381	0.204	0.026	2.097	0.221	0.000017180	25.5	4.784	0.0000674
								0.240	0.000087400	15.8	19.540	0.0005532
								0.268	0.000228500	15.0	38.041	0.0015232
								0.270	0.000218400	14.2	32.322	0.0015380
								0.304	0.000398600	12.8	49.400	0.0031141
								0.204	0.000006940	17.0	3.430	0.0000408
								0.241	0.000106050	15.5	36.504	0.0006842
								0.258	0.000164220	13.5	41.954	0.0012164
								0.271	0.000141290	9.0	30.883	0.0015699

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	0.463 (Cont'd)							0.291	0.000318100	12.0	70.067	0.0026508
								0.313	0.000444300	13.0	70.451	0.0034177
								0.351	0.000663800	11.6	72.660	0.0057224
								0.232	0.000099620	14.0	47.861	0.0007116
								0.277	0.000144500	9.3	43.901	0.0015538
								0.295	0.000377400	14.8	88.682	0.0026851
								0.352	0.000656000	11.0	96.986	0.0059636
								0.381	0.000764000	12.2	103.690	0.0062623
	0.550	17	15.15	0.339	0.199	0.028	1.978	0.207	0.000063900	27.0	18.762	0.0002367
								0.225	0.000093300	17.8	22.009	0.0005242
								0.250	0.000356300	24.7	62.611	0.0014425
								0.250	0.000213800	14.7	33.462	0.0014544
								0.283	0.000407500	13.8	53.255	0.0029529
								0.192	0.000006920	18.0	3.615	0.0000384
								0.225	0.000135820	15.2	35.800	0.0008936
								0.240	0.000233880	15.5	48.171	0.0015089
								0.252	0.000168970	11.4	39.117	0.0014822
								0.271	0.000380720	15.2	88.751	0.0025047
								0.290	0.000435800	13.5	73.159	0.0032281
								0.324	0.000685100	12.7	79.549	0.0053945
								0.217	0.000117500	17.5	59.826	0.0006714
								0.258	0.000140700	9.7	45.790	0.0014505
								0.274	0.000346400	13.7	82.095	0.0025285
								0.326	0.000774000	13.8	121.682	0.0056087
								0.349	0.000783000	12.5	115.498	0.0062640

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	0.655	17	18.046	0.296	0.194	0.031	1.875	0.194	0.000006806	11.2	2.101	0.0000608
								0.210	0.000050761	10.2	12.613	0.0004977
								0.233	0.000161500	11.8	29.911	0.0013686
								0.233	0.000137600	10.0	22.762	0.0013760
								0.263	0.000215700	7.7	29.717	0.0028013
								0.180	0.000003445	9.5	1.900	0.0000363
								0.212	0.000106270	17.3	40.743	0.0006143
								0.224	0.000108630	10.0	31.076	0.0010863
								0.235	0.000207150	14.8	50.781	0.0013997
								0.252	0.000241450	10.2	59.557	0.0023672
								0.270	0.000295900	9.7	52.567	0.0030505
								0.299	0.000391600	7.7	48.230	0.0050857
								0.204	0.000136500	21.5	73.500	0.0006349
								0.241	0.000129280	7.0	33.044	0.0018469
								0.254	0.000321700	10.3	61.740	0.0031233
								0.301	0.000460000	8.7	76.698	0.0052874
								0.323	0.000605000	10.0	92.251	0.0060500
	0.780	17	21.490	0.254	0.190	0.032	1.790	0.183	0.000005627	9.8	1.839	0.0000574
								0.197	0.000037681	8.0	9.892	0.0004710
								0.218	0.000114100	8.8	22.315	0.0012966
								0.217	0.000097400	7.5	17.070	0.0012987
								0.246	0.000198900	7.5	28.943	0.0026520
								0.170	0.000002840	8.2	1.662	0.0000346
								0.199	0.000088820	15.3	36.033	0.0005805
								0.210	0.000069620	6.8	21.139	0.0010238
								0.219	0.000173990	13.2	45.289	0.0013181
								0.235	0.000162890	7.3	42.626	0.0022314
								0.251	0.000209810	7.3	39.559	0.0028741

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport paramet Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	0.780 (Cont'd)							0.277	0.000334790	7.0	43.845	0.0047830
								0.192	0.000093160	15.5	53.023	0.0006010
								0.226	0.000087400	6.7	31.624	0.0013045
								0.237	0.000156300	7.0	41.892	0.0022329
								0.280	0.000333000	6.7	59.064	0.0050000
								0.301	0.000418000	7.3	67.528	0.0057260
	0.925	17	25.49	0.212	0.186	0.033	1.719	0.173	0.000016460	3.2	5.666	0.0005144
								0.186	0.000013420	3.0	3.712	0.0004473
								0.205	0.000054000	4.4	11.157	0.0012273
								0.203	0.000041600	3.8	7.694	0.0010947
								0.230	0.000100700	4.0	15.438	0.0025175
								0.162	0.000000900	2.8	0.554	0.0000321
								0.188	0.000013230	2.4	5.652	0.0005513
								0.197	0.000023270	2.4	7.461	0.0009696
								0.206	0.000109700	8.8	30.195	0.0012466
								0.221	0.000063350	3.0	17.515	0.0021117
								0.235	0.000146010	3.0	16.255	0.0048670
								0.258	0.000135360	3.0	18.792	0.0045120
								0.182	0.000038000	6.7	22.905	0.0005672
								0.213	0.000030420	2.6	12.273	0.0011700
								0.222	0.000059700	2.4	14.358	0.0024875
								0.261	0.000179000	3.3	29.105	0.0054240
								0.280	0.000205000	3.8	35.055	0.0053947
	1.200	17	33.06	0.149	0.180	0.032	1.633	0.159	0.000001521	3.3	0.563	0.0000461
								0.171	0.000015700	3.8	4.703	0.0004132
								0.187	0.000076800	6.8	17.211	0.0011294
								0.185	0.000053100	4.7	10.700	0.0011298
								0.209	0.000092900	4.0	15.438	0.0023225

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	1.200 (Cont'd)							0.150	0.000000790	2.6	0.528	0.0000304
								0.174	0.000020300	4.0	9.420	0.0005075
								0.181	0.000035550	4.0	12.435	0.0008888
								0.188	0.000111860	9.8	33.625	0.0011414
								0.201	0.000071640	3.7	21.605	0.0019362
								0.213	0.000092210	3.7	20.052	0.0024925
								0.233	0.000165020	4.0	25.056	0.0041255
								0.169	0.000038020	7.3	24.956	0.0005208
								0.195	0.000038020	3.4	16.050	0.0011182
								0.202	0.000057790	3.0	17.990	0.0019213
								0.236	0.000171000	4.0	35.268	0.0042750
								0.254	0.000198000	4.0	36.900	0.0049500
	1.550	17	42.71	0.087	0.175	0.030	1.566	0.148	0.000000152	0.3	0.056	0.0000510
								0.158	0.000002624	0.7	0.856	0.0003750
								0.172	0.000019000	1.8	4.570	0.0010560
								0.169	0.000023900	2.3	5.236	0.0010391
								0.192	0.000030000	1.4	5.405	0.0021429
								0.141	0.000000070	0.3	0.053	0.0000233
								0.162	0.000007490	1.6	3.768	0.0004681
								0.167	0.000013040	1.6	4.974	0.0008150
								0.173	0.000025130	2.4	8.234	0.0010471
								0.185	0.000030190	1.7	9.926	0.0017759
								0.195	0.000038900	1.7	9.217	0.0022882
								0.211	0.000060380	1.6	10.022	0.0037738
								0.158	0.000009510	2.0	6.837	0.0004755
								0.180	0.000015210	1.4	6.609	0.0010864
								0.185	0.000028140	1.6	9.544	0.0017588
								0.215	0.000051000	1.3	11.470	0.0039231
								0.231	0.000072000	1.6	14.760	0.0045000

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	2.030	17	55.93	0.021	0.171	0.026	1.513	0.137	0.000000076	0.2	0.0281	0.0000507
								0.147	0.000001065	0.3	0.369	0.0003550
								0.159	0.000152100	1.6	4.036	0.0095063
								0.155	0.000009200	1.0	2.208	0.0009485
								0.176	0.000031600	1.6	6.174	0.0019750
								0.133	0.000000030	0.1	0.021	0.0000300
								0.152	0.000003880	0.9	2.120	0.0004311
								0.155	0.000007450	1.0	3.103	0.0007450
								0.160	0.000016270	1.7	3.090	0.0009571
								0.170	0.000014640	0.9	5.252	0.0016267
								0.179	0.000019960	0.9	4.876	0.0022178
								0.192	0.000024110	0.7	4.385	0.0034443
								0.149	0.000001330	0.3	1.026	0.0004433
								0.168	0.000003800	0.4	1.889	0.0009500
								0.170	0.000015210	0.9	5.659	0.0016900
								0.196	0.000060000	1.7	14.980	0.0035294
								0.211	0.000072000	1.6	14.760	0.0045000
	2.860	16	78.80	0.0	0.170	0.025	1.5	0.126	0.000000016	0.1	0.009	0.0000320
								0.133	0.000000532	0.2	0.243	0.0002660
								0.143	0.000017500	2.4	6.053	0.0007290
								0.140	0.000001600	0.2	0.521	0.0006960
								0.158	0.000119000	0.8	3.089	0.0148750
								0.137	0.000004819	0.3	0.707	0.0016060
								0.140	0.0000059	0.2	0.617	0.0029500
								0.144	0.000036400	0.9	3.090	0.0040440
								0.153	0.000017400	0.2	1.169	0.0087000
								0.161	0.000020900	0.2	1.084	0.0045000
								0.171	0.000055800	0.3	1.879	0.0186000

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 1 (Cont'd)	2.860 (Cont'd)							0.137	0.000029000	0.2	0.684	0.0014500
								0.154	0.000018000	0.3	1.520	0.0069230
								0.176	0.000118000	0.6	5.308	0.0196670
								0.190	0.000180000	0.7	6.642	0.0257100
USWES No. 2	0.153	10	4.22	0.650	0.252	0.007	3.632	0.348	0.000000865	0.1	0.056	0.0014420
								0.391	0.000005479	0.1	0.102	0.0039140
								0.436	0.000018970	0.8	0.768	0.0024960
								0.475	0.000027180	0.9	0.883	0.0029870
								0.492	0.000046770	1.0	0.992	0.0046310
								0.520	0.000026680	0.8	0.810	0.0032940
								0.547	0.000047620	0.7	0.975	0.0067040
								0.566	0.000077130	1.8	2.429	0.0042850
								0.369	0.000000990	1.4	0.095	0.0000710
								0.712	0.000049300	0.3	1.138	0.0164330
	0.215	15	5.92	0.567	0.235	0.012	2.971	0.294	0.000002526	0.3	0.184	0.0008420
								0.329	0.000005479	0.5	0.320	0.0012180
								0.366	0.00121980	5.6	5.538	0.00219780
								0.397	0.00016421	6.2	5.991	0.0026490
								0.410	0.00022628	8.4	8.261	0.0027000
								0.433	0.00020253	6.9	6.897	0.0029350
								0.456	0.00033360	5.7	7.827	0.0058530
								0.470	0.00024660	6.5	8.771	0.0037940
								0.548	0.00043620	5.5	10.659	0.0079310
								0.586	0.00087390	4.5	16.850	0.0194200
								0.309	0.00000359	5.7	0.394	0.0000630
								0.330	0.00006872	3.3	6.687	0.0020820
								0.379	0.000143100	5.0	11.654	0.0028620
								0.456	0.000274800	5.2	13.553	0.0052850
								0.586	0.000303410	2.1	7.966	0.0144480

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 2 (Cont'd)	0.303	19	8.35	0.484	0.220	0.018	2.497	0.249	0.000015472	1.1	1.266	0.0014070
								0.279	0.000092646	8.6	6.072	0.0010770
								0.309	0.000366960	18.6	18.729	0.0019730
								0.334	0.000536000	22.8	22.031	0.0023510
								0.345	0.000490300	20.5	20.162	0.0023920
								0.364	0.000586760	22.5	22.492	0.0026080
								0.382	0.001094900	21.5	29.525	0.0050930
								0.272	0.000046750	7.2	3.897	0.0006490
								0.295	0.000076540	5.0	7.598	0.0015310
								0.314	0.000096800	4.3	7.064	0.0022510
								0.393	0.000703500	21.0	28.337	0.0033500
								0.452	0.001013000	14.5	17.442	0.0069860
								0.483	0.003066750	18.0	58.039	0.0170380
								0.260	0.000006620	12.0	0.829	0.0000550
								0.279	0.000356370	19.5	39.110	0.0018280
								0.306	0.001099130	6.7	13.735	0.0164050
								0.321	0.000442800	17.5	40.790	0.0025300
								0.456	0.000987870	16.3	42.485	0.0060610
								0.484	0.001773250	14.0	53.109	0.0126660
	0.390	19	10.75	0.423	0.210	0.023	2.239	0.222	0.000014399	5.6	1.289	0.0002570
								0.248	0.000092506	9.3	6.604	0.0009950
								0.274	0.000316730	17.5	17.621	0.0018100
								0.295	0.000376910	17.5	16.909	0.0021540
								0.305	0.000383500	17.5	17.211	0.0021910
								0.321	0.000442760	18.5	18.493	0.0023930
								0.337	0.000758380	16.5	22.658	0.0045960
								0.242	0.000069290	8.5	4.600	0.0008150
								0.263	0.000053210	3.8	5.775	0.0014000

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 2 (Cont'd)	0.390 (Cont'd)							0.282	0.000263490	12.7	20.862	0.0020750
								0.346	0.000565400	18.5	24.964	0.0030560
								0.396	0.000572620	9.0	17.442	0.0063620
								0.421	0.002397900	15.5	58.039	0.0154700
								0.231	0.000007250	7.0	0.483	0.0001040
								0.247	0.000320300	19.3	39.110	0.0016600
								0.273	0.000144750	8.0	16.400	0.0018090
								0.286	0.000346600	15.0	34.963	0.0023110
								0.337	0.000656180	15.5	40.399	0.0042330
								0.423	0.001381160	12.0	45.522	0.0115100
	0.463	19	12.76	0.381	0.204	0.026	2.097	0.206	0.000026208	10.8	2.486	0.0002430
								0.230	0.000128750	13.7	9.729	0.0009400
								0.254	0.000256400	15.0	15.104	0.0017090
								0.272	0.000325130	16.0	15.460	0.0020320
								0.281	0.000434180	21.0	20.653	0.0020680
								0.296	0.000300020	13.3	13.295	0.0022560
								0.310	0.000622400	14.5	19.912	0.0042920
								0.224	0.000020420	4.3	2.327	0.0004750
								0.243	0.000165000	3.8	18.995	0.0043420
								0.263	0.000245700	12.7	20.533	0.0019350
								0.318	0.000488800	17.0	22.940	0.0028750
								0.363	0.001554500	26.0	50.389	0.0059790
								0.385	0.002684000	18.5	69.273	0.0145080
								0.214	0.000003980	7.0	0.587	0.0000570
								0.229	0.000272450	17.5	35.462	0.0015570
								0.253	0.000204430	12.0	24.600	0.0017040
								0.265	0.000489400	22.5	52.444	0.0021750

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 2 (Cont'd)	0.463 (Cont'd)							0.310	0.000676000	17.0	44.309	0.0039760
								0.387	0.001670300	15.5	58.799	0.0107760
	0.550	19	15.15	0.339	0.199	0.028	1.976	0.192	0.000033189	14.5	3.337	0.0002290
								0.214	0.000144650	16.3	11.575	0.0008870
								0.235	0.000242000	15.0	15.104	0.0016130
								0.252	0.000325740	17.0	16.426	0.0019160
								0.260	0.000298300	15.3	15.047	0.0019500
								0.273	0.000327670	15.4	15.395	0.0021280
								0.286	0.000608950	15.2	20.873	0.0040060
								0.208	0.000037990	8.5	4.600	0.0004470
								0.226	0.000180310	12.5	22.034	0.0014420
								0.267	0.000269890	12.5	23.819	0.0021590
								0.293	0.000465080	17.2	23.210	0.0027040
								0.333	0.000982620	17.5	33.916	0.0056150
								0.676	0.002379600	17.5	65.528	0.0135980
								0.198	0.000005050	8.5	0.794	0.0000590
								0.212	0.000010215	7.0	14.185	0.0001460
								0.236	0.000248480	15.5	31.775	0.0016030
								0.246	0.000358150	17.5	40.790	0.0020470
								0.287	0.000709240	19.0	49.522	0.0037330
								0.355	0.002170640	21.5	81.560	0.0100960
	0.655	19	18.05	0.296	0.194	0.031	1.875	0.179	0.000043185	20.0	4.603	0.0002160
								0.199	0.000134080	16.0	11.362	0.0008380
								0.218	0.000121840	8.0	8.055	0.0015230
								0.233	0.000153600	8.5	8.213	0.0018070
								0.240	0.000123200	6.7	6.589	0.0018390
								0.253	0.000166100	8.3	8.297	0.0020010

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
USWES No. 2 (Cont'd)	0.655 (Cont'd)							0.264	0.000329020	8.8	12.085	0.0037380
								0.194	0.000082020	19.5	10.554	0.0004210
								0.211	0.000166370	14.2	21.579	0.0011720
								0.229	0.000229180	13.0	21.355	0.0017630
								0.271	0.000198330	7.8	10.525	0.0025430
								0.307	0.00042434	9.0	17.442	0.0047150
								0.323	0.001401900	11.0	41.189	0.0127450
								0.184	0.000005760	14.0	0.967	0.0000410
								0.197	0.000095760	7.0	14.185	0.0013680
								0.219	0.000218750	14.5	29.725	0.0015090
								0.229	0.000182940	9.5	22.143	0.0019260
								0.265	0.000438050	12.5	32.580	0.0035040
								0.326	0.001227670	13.0	49.315	0.0094590
	0.780	17	21.49	0.254	0.190	0.032	1.790	0.167	0.000035149	17.3	3.982	0.0002030
								0.186	0.000113183	14.3	10.155	0.0007910
								0.203	0.000129050	9.0	9.062	0.0014340
								0.216	0.000127480	7.5	7.247	0.0017000
								0.223	0.000095130	5.5	5.409	0.0017300
								0.244	0.000285450	8.2	11.261	0.0034810
								0.181	0.000075800	19.2	10.391	0.0039480
								0.197	0.000196240	15.3	23.250	0.0012830
								0.251	0.000131210	5.5	7.422	0.0023860
								0.282	0.000370530	7.5	14.535	0.0049400
								0.296	0.000834100	7.0	26.211	0.0119160
								0.172	0.000004220	11.0	0.760	0.0000380
								0.184	0.000076750	6.0	12.158	0.0012790
								0.205	0.000191170	13.5	27.675	0.0014160
								0.214	0.000117480	6.5	15.151	0.0018070
								0.245	0.000262500	8.0	20.851	0.0032810
								0.300	0.000751410	8.5	32.245	0.0088400

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
USWES No. 2 (Cont'd)	0.925	19	25.49	0.212	0.186	0.033	1.719	0.157	0.000018620	9.7	2.233	0.0001920
								0.174	0.000042554	5.7	4.048	0.0007470
								0.190	0.000033890	2.5	2.517	0.0013556
								0.201	0.000008030	0.5	0.483	0.0016060
								0.207	0.000003270	0.2	0.197	0.0016350
								0.218	0.000017840	1.0	1.000	0.0017840
								0.227	0.000032540	1.0	1.373	0.0032540
								0.170	0.000024250	6.6	3.527	0.0003670
								0.184	0.000083120	8.0	12.157	0.0010390
								0.203	0.000086820	5.5	9.030	0.0015790
								0.233	0.000022460	1.0	1.349	0.0022460
								0.261	0.000092750	2.0	3.876	0.0046380
								0.273	0.000134200	1.2	4.493	0.0111830
								0.161	0.000001940	6.0	0.414	0.0000320
								0.172	0.000066060	5.5	11.145	0.0012010
								0.193	0.000073400	5.5	11.275	0.0013350
								0.200	0.000025550	1.5	3.496	0.0017030
								0.229	0.000013840	0.5	1.303	0.0027680
								0.277	0.000248890	3.0	11.380	0.0082960
	1.200	19	33.06	0.149	0.180	0.032	1.633	0.143	0.000021060	12.0	2.762	0.0001760
								0.159	0.000068360	10.0	7.101	0.0006840
								0.172	0.000039701	3.2	3.222	0.0012410
								0.182	0.000017600	1.2	1.160	0.0014670
								0.187	0.000023890	1.6	1.574	0.0014930
								0.196	0.000035890	2.2	2.199	0.0016310
								0.204	0.000082000	2.8	3.845	0.0029290
								0.155	0.000051530	15.2	8.226	0.0007830
								0.168	0.000137470	14.5	22.034	0.0009480
								0.186	0.000167010	11.5	18.891	0.0014520

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
USWES No. 2 (Cont'd)	1.200 (Cont'd)							0.209	0.000030660	1.5	2.024	0.0020440
								0.233	0.000168860	4.0	7.752	0.0042220
								0.242	0.000391800	2.8	10.484	0.0139929
								0.147	0.000004240	13.0	0.898	0.0000330
								0.157	0.000070710	6.5	13.172	0.0010880
								0.176	0.000145910	12.0	24.600	0.0012160
								0.183	0.000074460	4.8	11.188	0.0015510
								0.206	0.000042010	1.5	3.910	0.0028010
								0.247	0.000375420	5.0	18.967	0.0075080
	1.550	19	42.71	0.087	0.175	0.030	1.566	0.132	0.000005625	3.5	0.806	0.0001610
								0.146	0.000030144	4.8	3.409	0.0006280
								0.157	0.000020471	1.8	1.812	0.0011370
								0.151	0.000025680	1.6	1.546	0.0016050
								0.170	0.000019130	1.4	1.377	0.0013660
								0.178	0.000017930	1.2	1.200	0.0014940
								0.185	0.000073930	2.8	3.845	0.0026400
								0.143	0.000023820	7.7	4.167	0.0003090
								0.155	0.000646500	8.8	13.373	0.0073470
								0.173	0.000086940	6.5	10.677	0.0013380
								0.190	0.000018630	1.0	1.349	0.0018630
								0.210	0.000057610	1.5	2.907	0.0038410
								0.217	0.000137800	1.5	5.617	0.0091870
								0.135	0.000002180	6.0	0.511	0.0000360
								0.144	0.000013980	1.4	2.870	0.0009990
								0.162	0.000072120	6.5	13.325	0.0011100
								0.168	0.000045210	3.2	7.459	0.0014130
								0.187	0.000038200	1.5	3.910	0.0025470
								0.222	0.000204200	3.0	11.380	0.0068070

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 2 (Cont'd)	2.030	17	55.93	0.021	0.171	0.026	1.513	0.134	0.000002671	0.7	0.497	0.0003820
								0.144	0.000027030	2.6	2.618	0.0010400
								0.155	0.000009980	0.8	0.787	0.0012480
								0.162	0.000002455	1.8	1.799	0.0013640
								0.168	0.000052160	2.2	3.021	0.0023710
								0.132	0.000006470	2.3	1.245	0.0002810
								0.143	0.000017370	2.2	3.343	0.0007900
								0.161	0.000057740	4.7	7.721	0.0012290
								0.172	0.000013540	0.8	1.080	0.0016930
								0.189	0.000055730	1.6	3.101	0.0034830
								0.193	0.000083050	1.0	3.744	0.0083050
								0.125	0.000000560	2.1	0.145	0.0000267
								0.133	0.000000890	0.1	0.203	0.0000890
								0.150	0.000048400	4.8	9.840	0.0010080
								0.155	0.000034750	2.7	6.293	0.0012870
								0.171	0.000018460	0.8	2.085	0.0023080
								0.199	0.000122990	2.0	7.587	0.0061500
USWES No. 9	0.925	12	22.27	0.246	0.189	0.032	1.774	0.299	0.000000340	0.2	0.002	0.0000170
								0.319	0.000000185	0.2	0.010	0.0000930
								0.325	0.000000804	0.2	0.014	0.0004020
								0.338	0.000000230	0.1	0.010	0.0009650
								0.348	0.000000835	0.4	0.032	0.0002090
								0.374	0.000012810	0.4	0.094	0.0032030
								0.313	0.000000270	0.2	0.017	0.0001350
								0.331	0.000000180	0.2	0.010	0.0000900
								0.348	0.000002380	0.1	0.125	0.0023800
								0.359	0.000003330	0.1	0.159	0.0033300
								0.364	0.000004460	0.1	0.196	0.0044600
								0.388	0.000011620	0.2	0.401	0.0058100

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 9 (Cont'd)	1.200	13	28.89	0.182	0.183	0.033	1.674	0.266	0.000000087	0.6	0.006	0.0000150
								0.283	0.000001050	0.6	0.030	0.0001750
								0.288	0.000002712	2.0	0.142	0.0001360
								0.299	0.000007050	3.4	0.329	0.0002070
								0.307	0.000002067	1.1	0.087	0.0001880
								0.317	0.000021810	0.7	1.163	0.0031160
								0.299	0.000052040	2.0	1.876	0.0026020
								0.277	0.000000360	0.3	0.026	0.0001200
								0.293	0.000001150	0.4	0.073	0.0003290
								0.307	0.000014970	0.7	0.877	0.0021390
								0.321	0.000028000	0.7	1.373	0.0040000
								0.339	0.000030850	0.5	1.374	0.0061700
								0.338	0.000164600	1.3	2.611	0.0126630
	1.550	13	37.32	0.120	0.178	0.031	1.599	0.238	0.000000161	1.2	0.012	0.0000130
								0.254	0.000000901	1.2	0.060	0.0000750
								0.257	0.000003551	2.9	0.207	0.0001220
								0.267	0.000006736	3.6	0.348	0.0001870
								0.273	0.000003220	1.9	0.150	0.0001690
								0.247	0.000001620	1.5	0.128	0.0001080
								0.261	0.000000590	0.2	0.042	0.0002950
								0.274	0.000011550	0.6	0.752	0.0019250
								0.282	0.000016140	0.6	0.957	0.0026900
								0.285	0.000026490	1.1	2.157	0.0024080
								0.273	0.000002870	0.3	0.199	0.0009570
								0.283	0.000007610	0.3	0.471	0.0025370
								0.298	0.000125200	2.7	5.424	0.0046370

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 9 (Cont'd)	2.030	15	48.88	0.054	0.173	0.028	1.538	0.213	0.000000585	4.9	0.048	0.0000120
								0.228	0.000003382	5.0	0.248	0.0000680
								0.230	0.000010791	9.8	0.698	0.0001100
								0.238	0.000011856	10.2	0.987	0.0001160
								0.243	0.000011110	7.3	0.578	0.0001520
								0.221	0.000003400	3.5	0.301	0.0000970
								0.233	0.000002770	1.1	0.219	0.0002520
								0.245	0.000153540	8.9	11.155	0.0017250
								0.251	0.000045800	1.9	3.030	0.0024110
								0.253	0.000225090	7.0	13.726	0.0032160
								0.231	0.000000580	1.0	0.054	0.0000580
								0.243	0.000020510	2.4	1.594	0.0008550
								0.252	0.000101970	4.5	7.068	0.0022660
								0.266	0.000404890	8.2	22.535	0.0050610
								0.262	0.000449350	10.9	21.896	0.0041220
	2.860	13	68.80	0.0	0.170	0.025	1.50	0.190	0.000003763	39.3	0.386	0.0000100
								0.202	0.000019831	36.8	1.826	0.0000540
								0.203	0.000033458	38.3	2.727	0.0000874
								0.209	0.000045910	34.5	3.339	0.0001330
								0.214	0.000042480	35.3	2.794	0.0001200
								0.195	0.000019760	25.7	2.192	0.0000770
								0.206	0.000006770	14.4	0.668	0.0000470
								0.221	0.000507160	26.2	41.780	0.0019360
								0.222	0.000673240	26.1	51.178	0.0025790
								0.205	0.000006890	14.9	0.808	0.0000460
								0.215	0.000180360	26.7	17.729	0.0006760
								0.222	0.000550730	30.9	48.535	0.0017820
								0.233	0.001280370	33.0	90.691	0.0038800

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
USWES No. 9 (Cont'd)	4.060	15	98.65	0.0	0.170	0.025	1.50	0.170	0.000002900	43.0	0.423	0.0000070
								0.181	0.000017236	45.4	2.253	0.0000380
								0.182	0.000008311	13.5	0.961	0.0000620
								0.187	0.000031310	33.4	3.233	0.0000940
								0.190	0.000029920	35.5	2.795	0.0000840
								0.175	0.000029060	53.6	4.578	0.0000540
								0.184	0.000066300	44.5	9.288	0.0001490
								0.193	0.000424670	43.5	54.522	0.0009760
								0.198	0.000595890	43.7	69.687	0.0013640
								0.198	0.000774070	42.6	83.532	0.0018170
								0.184	0.000164200	50.4	2.735	0.0003260
								0.192	0.000745060	51.5	34.197	0.0014470
								0.198	0.000625250	49.8	78.221	0.0012560
								0.208	0.001054990	38.6	106.081	0.0027330
								0.204	0.000803430	35.3	70.911	0.0022760
	5.560	15	135.10	0.0	0.170	0.025	1.500	0.154	0.000000394	8.0	0.079	0.0000050
								0.164	0.000002218	8.0	0.397	0.0000280
								0.165	0.000004770	10.5	0.748	0.0000450
								0.169	0.000007598	11.1	1.074	0.0000680
								0.172	0.000008360	13.5	1.069	0.0000620
								0.159	0.000007490	13.6	1.162	0.0000550
								0.167	0.000038080	35.0	7.305	0.0000110
								0.175	0.000082670	11.6	14.539	0.0007130
								0.179	0.000213080	21.4	34.126	0.0009960
								0.180	0.000246790	18.6	36.472	0.0013270
								0.167	0.000006640	27.9	1.514	0.0000240
								0.175	0.000050380	14.5	9.628	0.0003470
								0.180	0.000099930	10.9	17.121	0.0009170

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
								0.188	0.000287390	14.4	39.574	0.0019960
								0.184	0.000187800	11.3	22.700	0.0016620
GIBBS AND NEILL	1.200	6	31.74	0.159	0.181	0.032	1.644	0.422	0.002949000	11.7	85.739	0.0252100
								0.390	0.002083000	12.3	60.956	0.0169350
								0.344	0.001119000	13.8	32.359	0.0081090
								0.438	0.001239000	3.8	32.821	0.0326050
								0.361	0.000686600	3.8	12.570	0.0180680
								0.446	0.005844000	8.3	123.097	0.0704100
	1.550	6	40.99	0.097	0.176	0.030	1.575	0.377	0.001557000	6.8	49.829	0.0228970
								0.349	0.001080000	7.0	34.692	0.0154290
								0.309	0.000556000	7.5	17.592	0.0074130
								0.403	0.000881000	3.0	25.911	0.0293670
								0.321	0.000630000	4.5	14.886	0.0140000
								0.402	0.002745000	4.8	71.189	0.0571880
	2.030	6	53.69	0.031	0.171	0.027	1.520	0.336	0.002655000	12.8	93.796	0.0207420
								0.312	0.003727000	13.5	66.887	0.0276070
								0.278	0.001011000	15.0	35.176	0.0067400
								0.341	0.001841000	7.0	60.459	0.0263000
								0.284	0.001121500	10.5	34.734	0.0106810
								0.362	0.004502000	9.8	145.343	0.0459390
	2.860	6	75.64	0.0	0.170	0.025	1.50	0.297	0.002505000	15.7	115.050	0.0159550
								0.276	0.001726000	16.0	79.296	0.0107880
								0.246	0.000899000	17.3	40.570	0.0051970
								0.299	0.004473000	22.2	191.741	0.0201490
								0.250	0.001213000	16.0	52.928	0.0075810
								0.321	0.004610000	13.8	204.668	0.0334060

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
GIBBS AND NEILL (Cont'd)	4.060	6	107.4	0.0	0.170	0.025	1.50	0.264	0.001832000	16.3	119.447	0.0112390
								0.245	0.001254000	16.5	81.774	0.0076000
								0.219	0.000612000	16.7	39.163	0.0036650
								0.266	0.001036000	7.3	63.050	0.0141920
								0.222	0.001185600	22.2	73.438	0.0053410
								0.285	0.003930000	16.7	247.678	0.0235330
	5.560	6	147.0	0.0	0.170	0.025	1.50	0.238	0.001083000	13.2	96.726	0.0082050
								0.221	0.000760000	13.7	67.899	0.0055470
								0.198	0.000348000	13.0	30.486	0.0026770
								0.240	0.002125000	20.5	177.059	0.0103660
								0.201	0.000752700	19.3	63.845	0.0039000
								0.257	0.002835000	16.5	244.712	0.0171820
	7.150	6	189.9	0.0	0.170	0.025	1.50	0.219	0.001344600	10.8	79.141	0.0124500
								0.204	0.000475000	11.0	54.516	0.0043180
								0.183	0.000218000	10.5	24.627	0.0020760
								0.221	0.001676000	20.8	179.650	0.0080580
								0.185	0.000531000	17.5	57.890	0.0030340
								0.237	0.002205000	16.5	244.712	0.0133640
	8.730	6	230.9	0.0	0.170	0.025	1.500	0.206	0.000063000	1.2	8.793	0.0052000
								0.192	0.000134000	3.8	18.830	0.0035260
								0.173	0.000034000	2.0	4.690	0.0017000
								0.207	0.000501000	7.7	65.509	0.0065060
								0.173	0.000086900	3.5	11.578	0.0024830
								0.223	0.000689000	6.3	93.435	0.0109370

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
GIBBS AND NEILL (Cont'd)	11.110	6	293.8	0.0	0.170	0.025	1.500	0.191	0.000041000	1.0	7.328	0.0041000
								0.178	0.000022000	0.8	3.962	0.0027500
								0.160	0.000056000	4.2	9.852	0.0013330
								0.193	0.000357900	6.9	59.596	0.0051870
								0.161	0.000047800	2.5	8.105	0.0019120
								0.207	0.000445000	5.2	76.826	0.0085580
	14.200	6	375.5	0.0	0.170	0.025	1.500	0.178	0.000064000	2.0	14.656	0.0032000
								0.166	0.000048000	2.2	10.906	0.0021820
								0.150	0.000008000	0.8	1.873	0.0010000
								0.179	0.000024300	0.6	5.182	0.0040500
								0.150	0.000000800	0.1	0.165	0.0016000
								0.192	0.000006730	0.1	1.483	0.0067300
CECEN AND BAYAZIT	2.860	7	71.9	0.0	0.170	0.0250	1.500	0.264	0.000130000	4.8	13.404	0.0027080
								0.284	0.000381000	4.9	27.213	0.0077760
								0.299	0.000965000	7.5	64.130	0.0128670
								0.301	0.000800000	6.2	48.900	0.0129030
								0.327	0.000962000	4.9	55.243	0.0196330
								0.349	0.001899000	6.4	102.800	0.0296720
								0.348	0.002430000	8.2	131.750	0.0296340
	4.060	7	102.1	0.0	0.170	0.025	1.500	0.235	0.000170000	6.8	18.989	0.0025000
								0.253	0.000278000	5.0	28.191	0.0055600
								0.267	0.000634000	7.0	59.852	0.0090570
								0.268	0.000600000	6.6	52.067	0.0090910
								0.291	0.000692000	5.0	56.371	0.0138400
								0.310	0.001881000	9.0	144.563	0.0209000
								0.310	0.002070000	9.9	159.000	0.0209090

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters n	A	C	m	Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
CECEN AND BAYAZIT (Cont'd)	5.560	7	139.9	0.0	0.170	0.025	1.500	0.213	0.000160000	8.7	24.295	0.0018390
								0.229	0.000292000	7.2	40.596	0.0040560
								0.241	0.000463000	7.0	59.852	0.0066140
								0.243	0.000445000	6.7	52.850	0.0066420
								0.263	0.000471000	6.0	67.643	0.0078500
								0.280	0.001114000	7.3	117.263	0.0152500
								0.280	0.001330000	8.7	139.750	0.0152870
	7.150	7	180.6	0.0	0.170	0.025	1.500	0.198	0.000120000	8.0	22.340	0.0015000
								0.212	0.000199000	6.3	35.532	0.0031590
								0.223	0.000309000	6.0	51.296	0.0051500
								0.225	0.000294000	5.7	44.967	0.0051580
								0.243	0.000456000	5.8	65.386	0.0078620
								0.259	0.000712000	6.0	96.375	0.0118670
								0.258	0.000890000	7.5	120.00	0.0118670
	8.730	7	219.6	0.0	0.170	0.025	1.500	0.187	0.000079000	6.7	18.710	0.0117910
								0.200	0.000143000	5.5	31.021	0.0026000
								0.210	0.000253000	6.0	51.296	0.0042127
								0.211	0.000254000	6.0	47.333	0.0042330
								0.229	0.000273000	5.4	60.886	0.0050560
								0.244	0.000583000	6.0	96.375	0.0097170
								0.243	0.000600000	6.2	99.625	0.0096770
	11.110	7	279.5	0.0	0.170	0.025	1.500	0.174	0.000105000	11.3	31.555	0.0009290
								0.187	0.000268000	13.2	74.426	0.0020300
								0.196	0.000480000	14.5	123.981	0.0033100
								0.197	0.000558000	16.8	132.517	0.0033210
								0.213	0.000672000	13.3	149.943	0.0050530
								0.227	0.001161000	15.2	244.150	0.0076380
								0.226	0.000980000	12.8	205.625	0.0076560

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
CECEN AND BAYAZIT (Cont'd)	14.200	7	357.2	0.0	0.170	0.025	1.500	0.163	0.000113000	15.5	43.284	0.0007290
								0.175	0.000283000	17.8	100.362	0.0015900
								0.183	0.000479000	18.5	158.167	0.0025890
								0.184	0.000520000	20.0	157.767	0.0026000
								0.199	0.000766000	19.5	218.414	0.0039280
								0.211	0.001255000	21.0	337.313	0.0059760
								0.211	0.000930000	15.5	249.000	0.0060000
	18.000	7	453.8	0.0	0.170	0.025	1.500	0.153	0.000207000	36.0	100.530	0.0005750
								0.164	0.000476000	38.0	214.255	0.0012530
								0.172	0.000603000	29.5	252.222	0.0020440
								0.172	0.000574000	28.0	220.867	0.0020500
								0.186	0.001186000	38.0	428.429	0.0031210
								0.198	0.001287000	27.3	438.513	0.0047140
								0.197	0.001300000	27.5	441.750	0.0047270
HRS A	0.153	11	3.24	0.703	0.265	0.005	4.190	0.589	0.000004800	0.6	0.078	0.0008730
								0.613	0.000010000	1.3	0.171	0.0008000
								0.619	0.000011000	0.4	0.233	0.0025580
								0.580	0.000010800	0.9	0.040	0.0012710
								0.641	0.000011200	0.8	0.210	0.0013830
								0.689	0.000011300	0.9	0.243	0.0012560
								0.822	0.000041500	0.6	0.880	0.0069170
								0.774	0.000024400	0.6	0.490	0.0041360
								0.915	0.000043900	0.4	0.930	0.0109750
								0.969	0.000079300	0.5	1.740	0.0158600
								1.047	0.000186080	0.9	4.052	0.0213890

Source	Size D (mm)	Number of observations	Dimensionless Particle Size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS A (Cont'd)	0.215	11	4.55	0.620	0.245	0.009	3.369	0.486	0.000044100	5.6	0.800	0.0007860
								0.507	0.000076600	7.6	1.471	0.0010110
								0.517	0.000068300	8.6	1.543	0.0007910
								0.478	0.000023800	4.7	0.421	0.0005040
								0.531	0.000086700	7.4	1.819	0.0011800
								0.574	0.000090000	7.2	2.154	0.0012530
								0.678	0.000255100	6.3	6.120	0.0040750
								0.637	0.000175000	4.8	3.940	0.0036230
								0.746	0.000294000	4.2	6.560	0.0070330
								0.794	0.000574500	3.3	14.330	0.0174620
								0.853	0.001095270	3.3	27.253	0.0327930
	0.303	11	6.70	0.537	0.229	0.014	2.779	0.403	0.000184600	26.4	3.780	0.0006980
								0.421	0.000261500	29.2	5.654	0.0008970
								0.435	0.000194000	27.4	4.887	0.0007090
								0.396	0.000189600	21.9	1.946	0.0008670
								0.443	0.000252000	24.5	6.058	0.0010290
								0.481	0.000268400	24.0	7.186	0.0011190
								0.562	0.000657700	18.3	17.840	0.0036040
								0.528	0.000466300	14.6	11.870	0.0032000
								0.612	0.000777400	12.7	19.840	0.0061450
								0.655	0.001517500	9.9	43.100	0.0153280
								0.699	0.002988100	10.4	85.260	0.0286770
	0.390	11	8.26	0.476	0.218	0.0190	2.458	0.353	0.000118700	18.5	2.640	0.0006430
								0.369	0.000150300	18.3	3.548	0.0008220
								0.384	0.000095500	14.6	2.606	0.0006540
								0.346	0.000058900	14.4	1.285	0.0004080
								0.389	0.000120400	12.5	3.099	0.0009610
								0.424	0.000121000	11.7	3.520	0.0014070

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS A (Cont'd)								0.493	0.000283200	8.6	8.410	0.0032930
								0.462	0.000238000	8.2	6.640	0.0029200
								0.532	0.000402400	7.2	11.340	0.0055660
								0.571	0.000733700	5.3	22.940	0.0139220
								0.607	0.001337660	5.2	42.223	0.0259220
	0.463	11	9.80	0.434	0.212	0.022	2.282	0.323	0.000088300	14.7	2.100	0.0006020
								0.338	0.000101500	13.1	2.536	0.0007760
								0.354	0.000064600	10.4	1.864	0.0006190
								0.317	0.000046400	12.1	1.073	0.0003850
								0.357	0.000096800	10.7	2.636	0.0009080
								0.391	0.000094600	9.7	2.910	0.0009740
								0.451	0.000232900	7.5	7.450	0.0030970
								0.423	0.000204900	7.5	6.070	0.0027500
								0.484	0.000335800	6.5	10.120	0.0052060
								0.522	0.000657000	5.0	21.900	0.0130620
								0.553	0.001535030	5.3	51.770	0.0288000
	0.550	11	11.64	0.392	0.206	0.025	2.135	0.297	0.000058200	10.2	1.460	0.0005690
								0.311	0.000062400	8.5	1.655	0.0007310
								0.327	0.000042700	7.2	1.292	0.0005910
								0.290	0.000035900	9.9	0.881	0.0003630
								0.328	0.000063700	7.4	1.836	0.0008580
								0.360	0.000062600	6.8	2.029	0.0009260
								0.414	0.000166400	5.7	5.580	0.0029140
								0.388	0.000152400	5.9	4.800	0.0025870
								0.442	0.000280200	5.0	7.900	0.0055560
								0.478	0.000520500	4.3	18.500	0.0122470
								0.504	0.000777500	3.4	28.092	0.0226680

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility Number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS A (Cont'd)	0.655	11	13.87	0.349	0.200	0.028	2.006	0.272	0.000034400	6.5	0.920	0.0005290
								0.286	0.000038600	5.6	1.082	0.0006920
								0.325	0.000030600	5.5	0.985	0.0005540
								0.266	0.000023800	7.0	0.621	0.0003420
								0.302	0.000039800	4.9	1.209	0.0008140
								0.303	0.000037500	4.3	1.293	0.0008700
								0.380	0.000105500	3.9	3.760	0.0027400
								0.356	0.000108000	4.4	3.620	0.0024300
								0.403	0.000182700	4.0	6.290	0.0045560
								0.437	0.000362900	3.2	13.700	0.0114840
								0.460	0.000595460	2.8	22.999	0.0211160
	0.780	11	16.51	0.307	0.195	0.030	1.899	0.251	0.000025400	5.0	0.720	0.0005050
								0.263	0.000027100	4.2	0.808	0.0006500
								0.280	0.000021000	4.0	0.714	0.0005250
								0.263	0.000020000	6.3	0.556	0.0003190
								0.279	0.000032000	4.2	1.033	0.0004800
								0.308	0.000033200	3.8	1.129	0.0008830
								0.350	0.000097600	3.8	3.710	0.0025750
								0.328	0.000098000	4.3	3.500	0.0022840
								0.369	0.000167400	3.9	6.180	0.0042490
								0.402	0.000361900	3.4	14.670	0.0107390
								0.421	0.000587250	3.0	24.344	0.0197060
	0.925	11	19.58	0.266	0.191	0.032	1.811	0.232	0.000015200	3.2	0.460	0.0004720
								0.243	0.000015600	2.5	0.492	0.0006170
								0.260	0.000014600	2.9	0.516	0.0005050
								0.226	0.000014800	4.9	0.438	0.0003010
								0.258	0.000025200	3.5	0.874	0.0007140
								0.286	0.000024800	3.2	0.960	0.0007750

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS A (Cont'd)								0.324	0.000084500	3.5	3.410	0.0024210
								0.303	0.000079900	3.7	3.030	0.0021480
								0.340	0.000136600	3.4	5.390	0.0039710
								0.370	0.000336200	3.3	14.550	0.0100660
								0.387	0.000580600	3.0	25.772	0.0192250
	1.200	11	25.41	0.202	0.185	0.033	1.703	0.206	0.000017200	4.0	0.570	0.0004330
								0.217	0.000018500	3.3	0.649	0.0005540
								0.234	0.000019200	4.2	0.751	0.0004570
								0.201	0.000019200	7.0	0.618	0.0002760
								0.231	0.000063400	5.3	1.302	0.0012050
								0.257	0.000035900	5.0	1.490	0.0007210
								0.289	0.000129400	5.9	5.730	0.0022080
								0.270	0.000132500	6.8	5.510	0.0019600
								0.300	0.000238000	6.6	10.380	0.0035950
								0.329	0.000647600	7.1	30.870	0.0091340
								0.342	0.001002690	6.0	49.255	0.0166280
	1.550	11	32.82	0.140	0.179	0.032	1.621	0.204	0.000006200	1.5	0.210	0.0004190
								0.195	0.000006900	1.3	0.257	0.0005190
								0.212	0.000008100	2.1	0.366	0.0003950
								0.180	0.000007500	3.0	0.265	0.0002510
								0.208	0.000015700	2.7	0.655	0.0005920
								0.232	0.000016900	2.6	0.765	0.0006630
								0.269	0.000064200	3.2	3.120	0.0020190
								0.242	0.000067300	3.8	3.070	0.0017900
								0.267	0.000123200	3.8	5.940	0.0032510
								0.294	0.000367400	4.4	19.290	0.0082930
								0.304	0.000581710	3.9	31.630	0.0150310

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS A (Cont'd)	2.030	11	42.98	0.074	0.174	0.0290	1.555	0.166	0.000006600	1.8	0.260	0.0003630
								0.175	0.000009000	2.0	0.386	0.0004520
								0.192	0.000016200	4.2	0.742	0.0003890
								0.161	0.000009500	4.2	0.370	0.0002290
								0.187	0.000028600	5.1	1.266	0.0005590
								0.210	0.000031800	5.2	1.558	0.0006130
								0.233	0.000117500	6.4	6.290	0.0018270
								0.217	0.000134300	8.3	6.730	0.0016260
								0.238	0.000249900	8.5	13.380	0.0014650
								0.263	0.000735400	9.8	42.700	0.0074960
								0.271	0.001153470	8.5	57.982	0.0135070
	2.860	11	60.55	0.0	0.170	0.025	1.500	0.146	0.000004000	1.2	0.180	
								0.154	0.000007000	1.7	0.327	0.0003250
								0.171	0.000015000	4.5	0.801	0.0004140
								0.142	0.000005200	2.6	0.234	0.0003350
								0.166	0.000028000	5.9	1.458	0.0001980
								0.187	0.000037000	7.0	2.111	0.0004750
								0.206	0.000149000	9.4	9.190	0.0005260
								0.192	0.000150100	10.7	8.720	0.0015850
								0.208	0.000253200	10.1	15.860	0.0014030
								0.232	0.000819000	12.7	55.290	0.0025040
								0.237	0.001377020	11.7	69.230	0.0117490
	4.060	8	89.8	0.0	0.170	0.0250	1.500	0.153	0.000007500	3.1	0.555	0.0002410
								0.149	0.000019000	5.5	1.359	0.0003460
								0.166	0.000019860	5.3	1.603	0.0003720
								0.183	0.000099000	8.9	8.711	0.0011110
								0.171	0.000095000	9.6	7.850	0.0009850

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS A (Cont'd)	4.060 (Cont'd)							0.185	0.000179000	10.2	15.920	0.0017640
								0.206	0.000576000	12.7	55.250	0.0045390
								0.211	0.001049660	12.7	57.772	0.0082780
	5.560	6	117.7	0.0	0.170	0.0250	1.500	0.150	0.000007400	2.7	0.818	0.0002710
								0.166	0.000047000	5.7	5.584	0.0008230
								0.154	0.000035000	4.9	3.990	0.0007140
								0.168	0.000105300	8.2	12.830	0.0012870
								0.187	0.000316000	9.5	41.530	0.0033120
								0.192	0.000688070	11.4	34.593	0.0060460
	7.150	6	152.0	0.0	0.170	0.0250	1.500	0.139	0.000001150	0.6	0.164	0.0002090
								0.153	0.000012000	1.9	1.802	0.0006490
								0.143	0.000009000	1.5	1.250	0.0005840
								0.155	0.000038200	3.8	5.980	0.0010030
								0.173	0.000112000	4.4	18.980	0.0025690
								0.177	0.000301540	6.4	15.160	0.0047040
	8.730	6	184.8	0.0	0.170	0.0250	1.500	0.131	0.000000210	0.1	0.037	0.0001750
								0.144	0.000001800	0.4	0.342	0.0005140
								0.134	0.000001000	0.2	0.180	0.0004545
								0.146	0.000008500	1.0	1.630	0.0008170
								0.163	0.000040700	1.1	8.400	0.0037340
								0.167	0.000073120	1.9	3.676	0.0038480
	11.110	5	235.2	0.0	0.170	0.0250	1.500	0.135	0.000000240	0.1	0.059	0.0004000
								0.125	0.000000100	0.03	0.025	0.0003330
								0.136	0.000001900	0.3	0.470	0.0006330
								0.152	0.000003910	0.2	1.025	0.0016290
								0.156	0.000012650	0.4	0.636	0.0030120

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS B	0.153	8	3.24	0.703	0.265	0.005	4.19	0.513	0.000001000	0.9	0.015	0.0001120
								0.604	0.000005800	0.5	0.098	0.0011600
								0.806	0.000035900	1.7	0.520	0.0021240
								0.827	0.000081800	1.7	1.259	0.0048980
								0.899	0.00004987	1.5	10.931	0.0341580
								0.892	0.000197570	0.6	4.040	0.0329280
								0.940	0.000228000	0.6	4.686	0.0407140
								0.991	0.000223000	0.4	4.751	0.0518600
	0.215	9	4.55	0.620	0.245	0.009	3.369	0.424	0.000003000	3.1	0.051	0.0000960
								0.431	0.000026700	6.2	0.486	0.0004310
								0.500	0.000035600	3.5	0.680	0.0010260
								0.649	0.000112300	6.1	1.874	0.0018440
								0.668	0.000252500	5.9	4.477	0.0042510
								0.739	0.001430500	4.7	35.487	0.0301790
								0.731	0.000745900	2.6	17.391	0.0184460
								0.766	0.000934000	2.6	21.840	0.0357850
								0.809	0.001000000	1.9	21.333	0.0518130
	0.275	8	5.82	0.571	0.235	0.0118	2.999	0.371	0.000003800	4.3	0.0690	0.0000890
								0.438	0.000059900	6.0	1.2412	0.0009990
								0.557	0.000125800	7.6	2.3278	0.0016640
								0.575	0.000291200	7.6	5.7213	0.0038370
								0.644	0.000155600	5.6	42.225	0.0275890
								0.636	0.000904500	3.4	23.114	0.0263700
								0.666	0.001121000	3.4	28.785	0.0325870
								0.701	0.001244000	3.0	33.269	0.0413290

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS B (Cont'd)	0.328	8	6.94	0.529	0.227	0.0147	2.731	0.338	0.000004300	5.2	0.084	0.0000430
								0.399	0.000074400	8.3	1.636	0.0008920
								0.500	0.000125500	8.1	2.505	0.0015170
								0.518	0.000276200	7.8	5.856	0.0035550
								0.585	0.001556000	5.6	42.225	0.0275890
								0.576	0.000966000	4.1	27.720	0.0234470
								0.603	0.001322000	4.3	36.315	0.0304610
								0.635	0.001568000	4.1	44.990	0.0385260
	0.390	9	8.26	0.476	0.218	0.019	2.458	0.308	0.000004500	5.8	0.094	0.0000780
								0.317	0.000032900	8.9	0.000	0.0003680
								0.365	0.000073900	8.3	1.625	0.0008910
								0.451	0.000104800	7.3	2.244	0.0014380
								0.468	0.000220700	6 [illegible]	5.020	0.0031080
								0.533	0.001279500	5.3	39.455	0.0242790
								0.525	0.000986600	4.3	28.730	0.0231050
								0.550	0.001217000	4.3	35.730	0.0285010
								0.577	0.001531000	4.3	46.975	0.0360240
	0.463	9	9.80	0.434	0.212	0.022	2.282	0.283	0.000004800	6.4	0.104	0.0000750
								0.292	0.000028400	8.2	0.00014	0.0003480
								0.334	0.000067400	8.5	1.665	0.0007940
								0.408	0.000094200	7.0	2.173	0.0013400
								0.424	0.000188400	6.1	4.613	0.0030780
								0.487	0.001119300	5.0	37.209	0.0225210
								0.479	0.001002600	4.6	31.194	0.0216500
								0.501	0.001214000	4.6	38.050	0.0266230
								0.526	0.001494000	4.6	51.289	0.0321980

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS B (Cont'd)	0.550	9	11.64	0.392	0.206	0.025	2.133	0.259	0.000003400	4.9	0.080	0.0000690
								0.268	0.000019200	5.8	0.0001	0.0003300
								0.307	0.000050300	6.7	1.320	0.0007470
								0.370	0.000063100	5.1	1.560	0.0012450
								0.385	0.000124900	4.4	3.286	0.0028650
								0.446	0.000803700	3.8	28.150	0.0213750
								0.438	0.000764700	3.8	25.363	0.0202840
								0.458	0.000945000	3.8	31.630	0.0250000
								0.480	0.001225000	3.9	42.886	0.0315720
	0.655	9	13.87	0.349	0.200	0.028	2.006	0.238	0.0000032000	4.9	0.080	0.0000650
								0.247	0.0000138000	4.4	0.0001	0.0003140
								0.283	0.00004160	5.9	1.157	0.0007050
								0.335	0.000050300	4.4	1.339	0.0011560
								0.350	0.000095900	3.6	2.713	0.0026640
								0.409	0.000678700	3.4	25.305	0.0200800
								0.401	0.000701300	3.7	24.798	0.0190570
								0.419	0.000819000	3.5	29.370	0.0233333
								0.439	0.001070000	3.6	40.014	0.0295580
	0.780	8	16.51	0.307	0.195	0.030	1.899	0.219	0.000003400	5.6	0.089	0.0000610
								0.260	0.000037900	5.7	1.118	0.0006650
								0.305	0.000051400	4.8	1.471	0.0010750
								0.318	0.000097700	4.0	2.977	0.0024730
								0.376	0.000824100	4.4	32.792	0.0188150
								0.368	0.000813600	4.6	30.750	0.0178030
								0.384	0.000955000	4.4	36.650	0.0218040
								0.402	0.001277000	4.6	51.180	0.0275810

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS B (Cont'd)	0.925	8	19.58	0.266	0.191	0.032	1.811	0.203	0.000003200	5.4	0.088	0.0000590
								0.241	0.000032900	5.2	1.026	0.0006290
								0.278	0.000045700	4.6	1.407	0.0010000
								0.291	0.000088800	3.9	2.902	0.0023060
								0.347	0.000693800	3.9	29.348	0.0176990
								0.339	0.000747700	4.5	30.076	0.0167270
								0.354	0.000961000	4.3	39.325	0.0225060
								0.370	0.001112000	4.3	47.532	0.0258600
	1.200	8	25.41	0.202	0.185	0.033	1.703	0.181	0.000006500	12.0	0.195	0.0000540
								0.215	0.000052700	9.0	1.771	0.0005840
								0.243	0.000082500	9.2	2.825	0.0008990
								0.255	0.000174400	8.4	6.361	0.0020660
								0.309	0.001424200	8.9	66.333	0.0160740
								0.277	0.000876300	9.9	66.434	0.0088780
								0.301	0.001496800	9.7	81.150	0.0154310
								0.327	0.002306000	9.9	109.100	0.0233640
	1.550	7	32.82	0.140	0.179	0.032	1.621	0.162	0.000003800	7.7	0.125	0.0000490
								0.193	0.000030100	5.7	1.122	0.0005260
								0.214	0.000047600	5.9	1.816	0.0008070
								0.226	0.000096800	5.7	3.934	0.0018540
								0.269	0.000937000	6.8	45.784	0.0137790
								0.313	0.001868000	6.5	81.150	0.0289160
								0.292	0.001417000	6.7	74.060	0.0211490
	2.030	8	42.98	0.074	0.174	0.029	1.555	0.146	0.000008100	17.9	0.290	0.0000450
								0.174	0.000067400	14.0	2.747	0.0004810
								0.188	0.000099900	13.9	4.275	0.0007190
								0.199	0.000234700	14.2	10.665	0.0016590

Source	Size D (mm)	Number of observations	Dimensionless particle size Dgr	Uniform Ackers-White Parameters				Mobility number Fgr	Transport parameter Ggr	Per cent of load Δp_i	Concentration X (ppm)	Totalized Transport parameter Ggr
				n	A	C	m					
HRS B (Cont'd)	2.030 (Cont'd)							0.248	0.002069600	15.6	116.794	0.0132670
								0.240	0.002159300	17.3	116.595	0.0124670
								0.250	0.002511000	15.6	138.560	0.0151630
								0.260	0.003567000	16.9	186.473	0.0211440
	2.860	8	60.55	0.0	0.170	0.025	1.500	0.128	0.000004300	10.9	0.176	0.0000400
								0.154	0.000040400	9.6	1.888	0.0004200
								0.162	0.000066400	10.6	3.265	0.0006260
								0.172	0.000127300	12.0	9.007	0.0010650
								0.218	0.001811300	15.4	115.371	0.0117540
								0.210	0.001947800	17.7	119.059	0.0110170
								0.219	0.002353000	18.2	152.115	0.0129430
								0.227	0.003089000	18.4	203.607	0.0167700
	4.060	8	89.8	0.0	0.170	0.025	1.500	0.114	0.000001100	4.0	0.065	0.0000270
								0.136	0.000009200	3.1	0.068	0.0002970
								0.144	0.000016700	3.8	1.160	0.0004430
								0.153	0.000084100	8.3	6.233	0.0010170
								0.194	0.000852000	10.3	76.964	0.0082880
								0.187	0.000869100	11.2	75.409	0.0077600
								0.196	0.001079000	12.1	100.910	0.0089470
								0.202	0.001453000	12.3	135.960	0.0118130

TABLES

TABLE 1 DISTRIBUTION PARAMETERS FOR BED MATERIALS

No.	Source	Range of D_i (mm)	D_{16} (mm)	D_{35} (mm)	D_{50} (mm)	D_{84} (mm)	$\sqrt{D_{84}/D_{16}}$
1	USWES No. 1	0.153 – 2.86	0.22	0.32	0.42	0.73	1.82
2	USWES No. 2	0.153 – 2.03	0.32	0.38	0.44	0.73	1.51
3	USWES No. 9	0.925 – 5.56	2.66	3.60	4.10	5.65	1.45
4	Gibbs and Neill	1.20 – 14.2	1.66	3.15	4.75	8.60	2.28
5	Cecen and Bayazit	1.80 – 2.18	6.60	11.20	13.90	18.70	1.68
6	HRS A	0.153 – 11.11	0.33	0.77	1.75	5.45	4.28
7	HRS B	0.153 – 4.06	0.32	0.73	1.55	3.35	3.24

TABLE 2 DISTRIBUTION OF SIZE FRACTIONS IN BED MATERIALS

Intermediate[1] size (mm)	Percentage retained by weight						
	USWES No. 1	USWES No. 2	USWES No. 9	Gibbs and Neill	Cecen and Bayazit	HRS A	HRS B
0.153	8.0	1.6				1.30	2.13
0.215	12.0	7.5				4.46	4.70
0.275	–	–				–	5.67
0.303	16.0	21.5				11.00	–
0.328	–	–				–	6.10
0.390	11.2	12.5				5.68	5.03
0.463	10.3	16.5				5.75	4.27
0.550	11.5	14.0				4.31	2.77
0.655	7.5	8.5				2.69	2.33
0.780	7.7	7.0				2.56	3.07
0.925	2.6	2.7	0.1			2.21	3.07
1.200	2.9	4.5	1.6	10.0		4.98	6.97
1.550	1.8	2.3	1.7	5.8		3.10	4.90
2.030	1.0	0.7	6.3	9.2	0.8	6.96	16.93
2.860	2.5	0.3	18.5	11.3	3.2	10.10	13.47
4.060			38.0	12.0	5.2	9.88	15.00
5.560			28.0	13.7	6.3	10.75	1.47
7.180			5.0	16.0	6.3	6.87	
8.730				9.5	7.0	3.35	
11.110				9.7	12.7	2.27	
14.200				1.8	21.0	0.36	
18.00					37.5		

1 Intermediate particle sized determined as size half way between bracketing sieve sizes.

TABLE 3 RANGE OF HYDRAULIC CONDITIONS AND SEDIMENT TRANSPORT RATES

No.	Source	No. of runs	Mean depth (m)	Mean velocity (m/s)	Shear velocity (m/s)	Transport rates[1] (kg/sec)	Concentration (ppm)
1	USWES No. 1	17	0.019 – 0.067	0.271 – 0.549	0.017 – 0.036	0.00006 – 0.00953	7.14 – 353.74
2	USWES No. 2	19	0.022 – 0.126	0.262 – 0.555	0.021 – 0.043	0.00003 – 0.01925	6.91 – 374.44
3	USWES No. 9	17	0.074 – 0.107	0.558 – 0.732	0.047 – 0.069	0.00003 – 0.01516	0.98 – 274.82
4	Gibbs and Neill	6	0.165 – 0.177	0.810 – 1.088	0.057 – 0.0913	0.0333 – 0.25197	234.51 – 1483.10
5	Cecen and Bayazit	7	0.098 – 0.140	0.816 – 1.143	0.098 – 0.117	0.01117 – 0.12850	279.25 – 1606.25
6	HRS A	11	0.169 – 0.107	0.479 – 0.745	0.033 – 0.062	0.00175 – 0.16100	8.90 – 834.85
7	HRS B	9	0.189 – 0.115	0.189 – 0.722	0.029 – 0.058	0.00033 – 0.22218	1.62 – 1089.95

1 Dry weight used in all calculations

TABLE 4 SUMMARY OF BED-LOAD VARIABILITY, GIBBS AND NEILL(1972, 1973)

Run No.	Duration of transport (s)	Mean transport rate (kg/s)	Standard deviation (kg/s)	Range (kg/s)	Coefficient of variation %
1972 (1)	30	0.1884	0.1297	0.0133 – 0.1893	69
	45	0.1929	0.0856	0.0187 – 0.1642	44
	60	0.1868	0.0856	0.0115 – 0.1119	46
(2)	60	0.0635	0.0502	unavailable	79
	120	0.0571	0.0354	unavailable	62
	180	0.0574	0.0284	unavailable	50
(3)	10	0.2972	0.2437	unavailable	82
	20	0.3522	0.2038	unavailable	58
	30	0.2936	0.1829	unavailable	62
1973 (1)	30	0.1243	0.0992	0.0054 – 0.4514	80
(2)	60	0.0786	0.0523	0.0054 – 0.2180	67
(3)	60	0.0333	0.0242	0.0042 – 0.1031	73

TABLE 5 HYDRAULIC AND SEDIMENT TRANSPORT SUMMARY, HRS SERIES A

Run No.	No. of tests	Discharge, m^3/s mean	Discharge, m^3/s std. dev.	Depth, m mean	Depth, m std. dev.	Water surface slope mean	Water surface slope std. dev.	Mean velocity, m/s mean	Mean velocity, m/s std. dev.	Temperature ^oC	Sediment concentration, ppm mean	Sediment concentration, ppm std. dev.	Sediment concentration, ppm range	Coefficient of variation %
1	6	0.199	0.0006	0.166	0.0009	0.00068	0.00002	0.492	0.0024	12	14.27	9.25	12.65 – 15.15	6.5
2	8	0.199	0.0005	0.159	0.0005	0.00077	0.00011	0.516	0.0016	12	19.35	3.82	14.52 – 25.15	20
3	7	0.199	0.0011	0.145	0.0006	0.00079	0.00005	0.565	0.0040	12	17.79	2.66	14.84 – 21.57	15
4	12	0.197	0.0008	0.169	0.0007	0.00066	0.00001	0.479	0.0029	12	8.88	3.65	3.94 – 16.12	41
5	19 (23)[1]	0.196	0.0010	0.147	0.0011	0.00089	0.00008	0.547	0.0021	12	24.69	8.11	10.79 – 37.06	33
6	19 (29)	0.197	0.0010	0.133	0.0009	0.00109	0.00016	0.608	0.0061	12	30.00	4.97	19.72 – 41.67	17
7	17 (30)	0.197	0.0005	0.123	0.0015	0.00170	0.00042	0.660	0.0092	12	97.56	29.19	61.38 – 153.72	30
8	14 (27)	0.197	0.0011	0.131	0.0016	0.00153	0.00011	0.621	0.0057	12	83.27	26.80	34.27 – 133.90	33
9	13 (25)	0.196	0.0011	0.121	0.0025	0.00249	0.00080	0.666	0.0169	12	156.53	58.42	70.05 – 287.12	37
10	10 (14)	0.198	0.0012	0.112	0.0029	0.00289	0.00021	0.731	0.0200	12	436.06	107.07	259.76 – 627.69	25
11	15	0.193	0.0007	0.107	0.0016	0.003665	0.00009	0.745	0.0100	12	834.85	143.11	656.51 – 1073.69	17

[1] For several tests more than one measurement of sediment bed was made. The bracketed figure refers to the total number of sediment samples.

TABLE 6 HYDRAULIC AND SEDIMENT TRANSPORT SUMMARY, HRS SERIES B

Run	No. of	Discharge, m^3/s		Depth, m		Water surface slope		Mean velocity, m/s		Temperature	Sediment concentration, ppm			Coefficient of
No.	tests	mean	std. dev.	mean	std. dev.	mean	std.dev.	mean	std. dev.	^oC	mean	std. dev.	range	variation %
1	10	0.203	0.006	0.189	0.0005	0.000445	0.000035	0.441	0.001	12	1.62	0.31	1.38 – 2.12	19
2	15	0.210	0.002	0.184	0.0010	0.000446	0.000065	0.469	0.006	12	2.98	0.47	2.35 – 3.75	16
3	9	0.202	0.001	0.162	0.0007	0.000722	0.000060	0.516	0.010	12.5	19.63	3.73	12.7 – 24.3	19
4	10	0.202	0.003	0.154	0.0028	0.001616	0.000105	0.539	0.014	12	30.75	11.60	22.9 – 59.2	38
5	12	0.200	0.004	0.145	0.0016	0.001769	0.000218	0.567	0.008	12	75.40	16.39	48.8 – 99.8	21
6	10	0.202	0.001	0.119	0.0019	0.002262	0.000086	0.697	0.012	12	749.65	113.65	549.8 – 918.8	15
7	6	0.204	0.001	0.124	0.0014	0.002188	0.000127	0.677	0.008	12	673.63	158.33	460.4 – 934.0	24
8	10	0.200	0.002	0.117	0.0021	0.002614	0.000227	0.700	0.016	13	835.85	148.45	472.9 – 1011.5	18
9	9	0.201	0.002	0.115	0.0022	0.002987	0.000115	0.722	0.016	12	1089.95	117.06	877.3 – 1296.8	11

TABLE 7 SIZE DISTRIBUTION OF TRANSPORTED MATERIAL AS PERCENTAGE OF TOTAL, HRS SERIES A

Run No	< 0.125 mm	0.125 mm	0.180 mm	0.250 mm	0.355 mm	0.425 mm	0.500 mm	0.600 mm	0.710 mm	0.850 mm	1.000 mm	1.400 mm	1.700 mm	2.360 mm	3.350 mm	4.760 mm	6.350 mm	7.850 mm	9.520 mm
1	0.12	0.55	5.61	26.44	18.45	14.67	10.22	6.50	5.03	3.22	3.97	1.48	1.82	1.23	0.79				
2	0.12	0.88	7.58	29.15	18.28	13.08	8.54	5.58	4.17	2.53	3.34	1.33	1.99	1.69	1.47				
3	0.08	1.25	8.64	27.36	14.60	10.44	7.23	5.52	4.00	2.89	4.20	2.05	4.16	4.48	3.11				
4	0.18	0.43	4.72	21.86	14.42	12.06	9.90	6.96	6.26	4.92	6.95	2.99	4.15	2.63	1.67				
5	0.14	0.85	7.35	24.49	12.53	10.66	7.42	4.89	4.17	3.53	5.26	2.65	5.12	5.90	5.49				
6	0.12	0.81	7.18	23.95	11.73	9.71	6.76	4.31	3.76	3.20	4.98	2.55	5.19	7.04	5.34	2.73	0.55	0.12	
7	0.12	0.90	6.26	18.25	8.60	7.52	5.71	3.85	3.79	3.49	5.86	3.18	6.43	9.40	8.91	5.71	1.85	0.35	0.06
8	0.12	0.60	4.83	14.57	8.15	7.45	5.89	4.44	4.29	3.72	6.76	3.76	8.26	10.70	9.64	4.90	1.54	0.22	0.03
9	0.06	0.59	4.18	12.65	7.23	6.45	5.04	4.01	3.94	3.44	6.62	3.79	8.53	10.11	10.15	8.18	3.81	1.04	0.30
10	0.07	0.40	3.29	9.90	5.27	5.03	4.25	3.16	3.37	3.34	7.09	4.43	9.81	12.70	12.69	9.54	4.36	1.09	0.24
11	0.06	0.50	3.34	10.42	5.16	5.33	3.43	2.82	2.98	3.02	6.03	3.87	8.54	11.72	12.68	11.38	6.41	1.90	0.42

TABLE 8 SIZE DISTRIBUTION OF TRANSPORTED MATERIAL AS PERCENTAGE OF TOTAL, HRS SERIES B

Run No.	< 0.125 mm	0.125 mm	0.180 mm	0.250 mm	0.300 mm	0.355 mm	0.425 mm	0.50 mm	0.60 mm	0.71 mm	0.85 mm	1.00 mm	1.40 mm	1.70 mm	2.36 mm	3.35 mm	4.76 mm
1	0.12	0.89	3.12	4.25	5.19	5.78	6.41	4.90	4.91	5.55	5.41	12.02	7.74	17.91	10.86	4.03	
2	0.10	1.27	6.20	8.73	9.50	8.93	8.15	5.82	4.40	4.73	4.55	8.55	5.47	11.95	7.50	3.67	
3	0.10	0.50	3.47	6.03	8.34	8.29	8.49	6.73	5.90	5.70	5.23	9.03	5.72	14.01	9.63	3.10	
4	0.08	1.69	6.09	7.56	8.14	7.29	7.03	5.07	4.35	4.78	4.57	9.18	5.90	13.89	10.61	3.77	
5	0.10	1.67	5.94	7.59	7.77	6.66	6.12	4.36	3.60	3.95	3.85	8.44	5.22	14.15	11.95	8.27	0.53
6	0.15	1.46	4.74	5.64	5.64	5.27	4.97	3.76	3.38	4.38	3.92	8.86	5.99	15.60	15.41	10.28	0.86
7	0.10	0.60	2.58	3.43	4.12	4.27	4.63	3.77	3.68	4.57	4.47	9.87	6.80	17.32	17.68	11.20	0.88
8	0.60	0.56	2.61	3.44	4.34	4.27	4.56	3.78	3.51	4.38	4.27	9.70	6.46	16.56	18.18	12.06	1.12
9	0.07	0.43	1.93	3.01	4.07	4.25	4.64	3.88	3.62	4.63	4.30	9.87	6.70	16.87	18.42	12.30	1.01

TABLE 9 OBSERVED VALUES OF A′, C′ AND m′[1]

Particle	USWES No. 1			USWES No. 2			USWES No. 9			Gibbs and Neil			Cecen and Bayazit			HRS Series A			HRS Series B		
size	A′	C′	m′	A′	C′	m′	A′	C′	m′	A′	C′	m′	A′	C′	m′	A′	C′	m′	A′	C′	m′
0.153	0.450	–[2]		0.567	–	–										1.000	–	–	0.845	–	–
0.215	0.370	0.0019	0.772	0.350	–	–										0.590	0.0016	0.954	0.615	0.0052	1.158
0.275																			0.525	0.0063	1.251
0.303	0.282	0.0011	0.618	0.284	0.0024	0.895										0.379	0.0032	2.218			
0.328					0.0019	0.869													0.390	0.0132	2.327
0.390	0.250	0.0013	1.110	0.257	0.0019	0.823										0.370	0.0023	1.786	0.439	0.0076	1.285
0.463	0.230	0.0010	0.886	0.236	0.0020	1.067										0.363	0.0030	1.649	0.402	0.0070	1.233
0.550	0.200	0.0009	0.922	0.210	0.0093	0.907										0.361	0.0015	0.917	0.379	0.0040	0.979
0.655	0.210	0.0008	0.772	0.195	0.0010	1.149										0.363	0.0031	1.296	0.351	0.0078	1.368
0.780	0.195	0.0007	0.857	0.190												0.340	0.0030	1.176	0.319	0.0098	1.454
0.925	0.200	–	–				0.422	–	–	0.430	–	–				0.325	0.0026	0.969	0.294	0.0079	1.380
1.200	0.185	–	–				0.343	–	–	0.300	0.0013	1.507				0.268	0.0034	1.107	0.245	0.0165	1.743
1.550	0.212	–	–				0.307	–	–	0.280	0.0055	1.075				0.267	–	–	0.224	0.0137	1.737
2.030	0.199	–	–				0.255	–	–	0.250	0.0108	1.072				0.221	0.0056	1.210	0.184	0.0135	1.618
2.860	0.196	–	–				0.213	0.0154	1.027	0.230	0.0096	0.893	0.260	0.0069	1.176	0.194	0.0095	1.386	0.168	0.0176	1.774
4.060	0.184	–	–				0.189	0.0053	0.697	0.200	0.0044	0.762	0.230	0.0077	1.444	0.180	0.0039	0.866	0.161	0.0114	1.530
5.560							0.181	–	–	0.190	0.0045	0.759	0.210	0.0031	1.023	0.172	–	–			
7.180										0.185	–	–	0.200	0.0021	0.880	0.169	–	–			
8.730										0.187	–	–	0.190	0.0014	0.778	0.170	–	–			
11.100										0.184	–	–	0.175	0.0031	0.885	0.175	–	–			
14.200										0.183	–	–	0.165	0.0035	0.886						
18.000													0.155	0.0033	0.723						

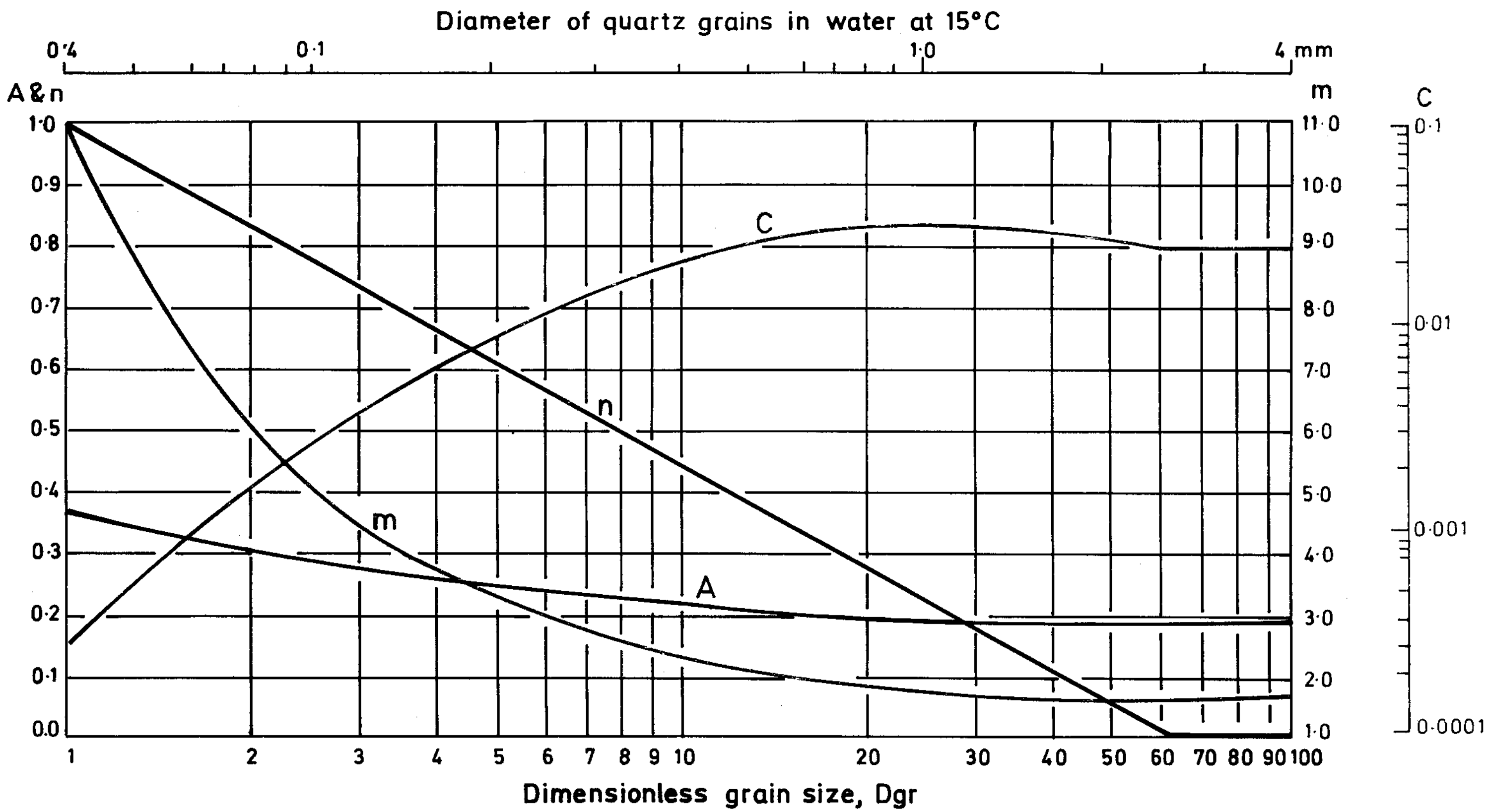
[1] The A subscript signifies that C′ and m′ were determined using Ackers-White method of including the initial motion parameter.

[2] A dash signifies insufficient data above 10^{-4} Ggr to permit regression analysis. Blanks signify no data available.

TABLE 10 OBSERVED VALUES OF A′, a AND b, BASED UPON Ggr′

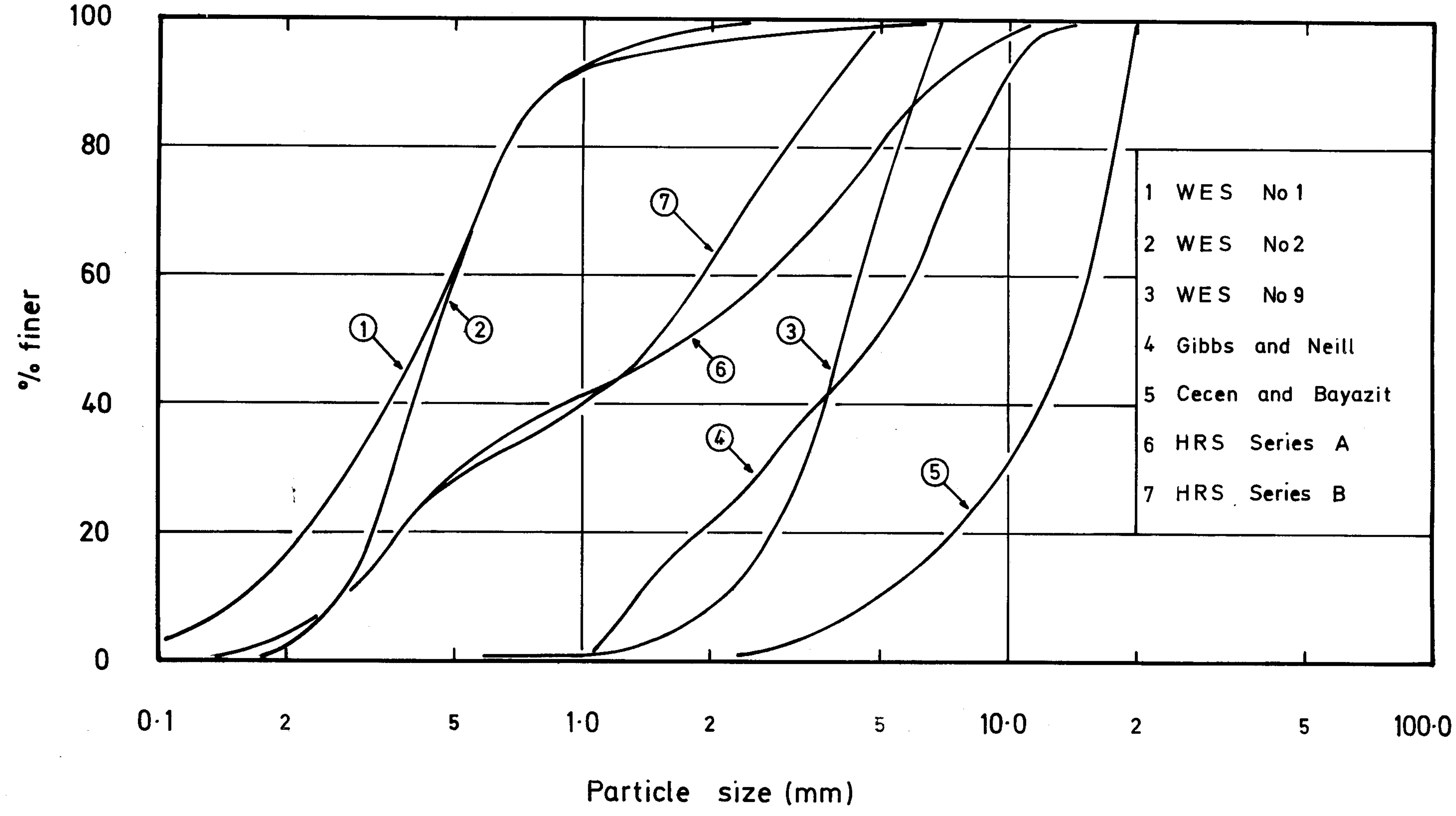
Particle size (mm)	USWES No. 1			USWES No. 2			USWES No. 9			Gibbs and Neil			Cecen and Bayazit			HRS Series A			HRS Series B		
	A′	a	b	A′	a	b	A′	a	b	A′	a	b	A′	a	b	A′	a	b	A′	a	b
0.153	0.380	0.299	6.76	0.320	0.091	4.71										0.400	0.018	5.62	0.500	0.054	9.04
0.215	0.300	0.701	6.35	0.280	0.206	4.70										0.370	0.067	6.52	0.395	0.235	8.42
0.275	–	–	–	–	–	–													0.365	1.262	9.52
0.303	0.245	0.972	5.74	0.260	0.320	4.45										0.305	0.178	6.27			
0.328	–	–	–	–	–	–													0.350	5.363	10.50
0.390	0.230	12.020	7.49	0.230	0.510	4.49										0.280	0.512	6.69	0.300	4.675	8.88
0.463	0.215	22.070	7.57	0.210	2.980	5.68										0.262	1.070	6.93	0.277	11.177	9.03
0.550	0.200	19.749	7.05	0.200	0.262	3.86										0.242	1.746	6.89	0.252	27.117	9.16
0.655	0.192	1.394×10^{2}	8.17	0.180	13.458	6.26										0.225	2.750	6.82	0.237	65.474	9.28
0.780	0.185	2.805×10^{2}	8.33	0.175	10.830	5.76										0.215	7.952	7.39	0.230	3.358×10^{2}	10.15
0.925	0.165	2.027×10^{2}	7.71	0.170	73.660	6.82	0.320	8.165×10^{6}	22.05							0.200	8.962	6.99	0.212	8.678×10^{2}	10.28
1.200	0.160	3.207×10^{3}	9.13	0.140	16.860	5.65	0.280	5.067×10^{9}	24.80		6.468	6.13				0.170	15.061	6.81	0.190	3.582×10^{3}	10.43
1.550	0.150	1.717×10^{4}	9.71	0.140	2.206×10^{2}	6.73	0.255	5.744×10^{11}	26.46		6.814	5.69				0.165	54.437	7.34	0.170	3.380×10^{3}	9.77
2.030	0.143	5.104×10^{4}	9.84	0.130	4.279×10^{5}	10.78	0.230	2.155×10^{14}	28.62		20.383	6.07				0.140	46.023	6.78	0.155	3.345×10^{4}	10.50
2.860	0.135	1.116×10^{9}	14.08				0.205	1.592×10^{17}	30.80		37.162	6.26		1.221×10^{2}	7.70	0.160	1.061×10^{5}	11.25	0.137	1.084×10^{5}	10.47
4.060							0.185	2.354×10^{18}	30.31		55.567	6.27		1.00×10^{2}	7.18	0.135	1.882×10^{4}	9.59	0.125	2.180×10^{5}	10.35
5.560							0.170	2.330×10^{21}	32.92		89.131	6.37		1.173×10^{2}	7.02	0.135	3.273×10^{5}	10.88			
7.180											4.032×10^{2}	7.09		2.380×10^{2}	7.28	0.125	7.882×10^{5}	11.03			
9.730											1.252×10^{2}	6.29		2.443×10^{2}	7.17	0.127	1.075×10^{7}	12.11			
11.100											1.884×10^{2}	6.41		5.703×10^{2}	7.51	0.122	2.547×10^{5}	9.95			
14.200											2.881×10^{2}	6.52		9.367×10^{2}	7.65						
18.000														1.437×10^{3}	7.74						

FIGURES



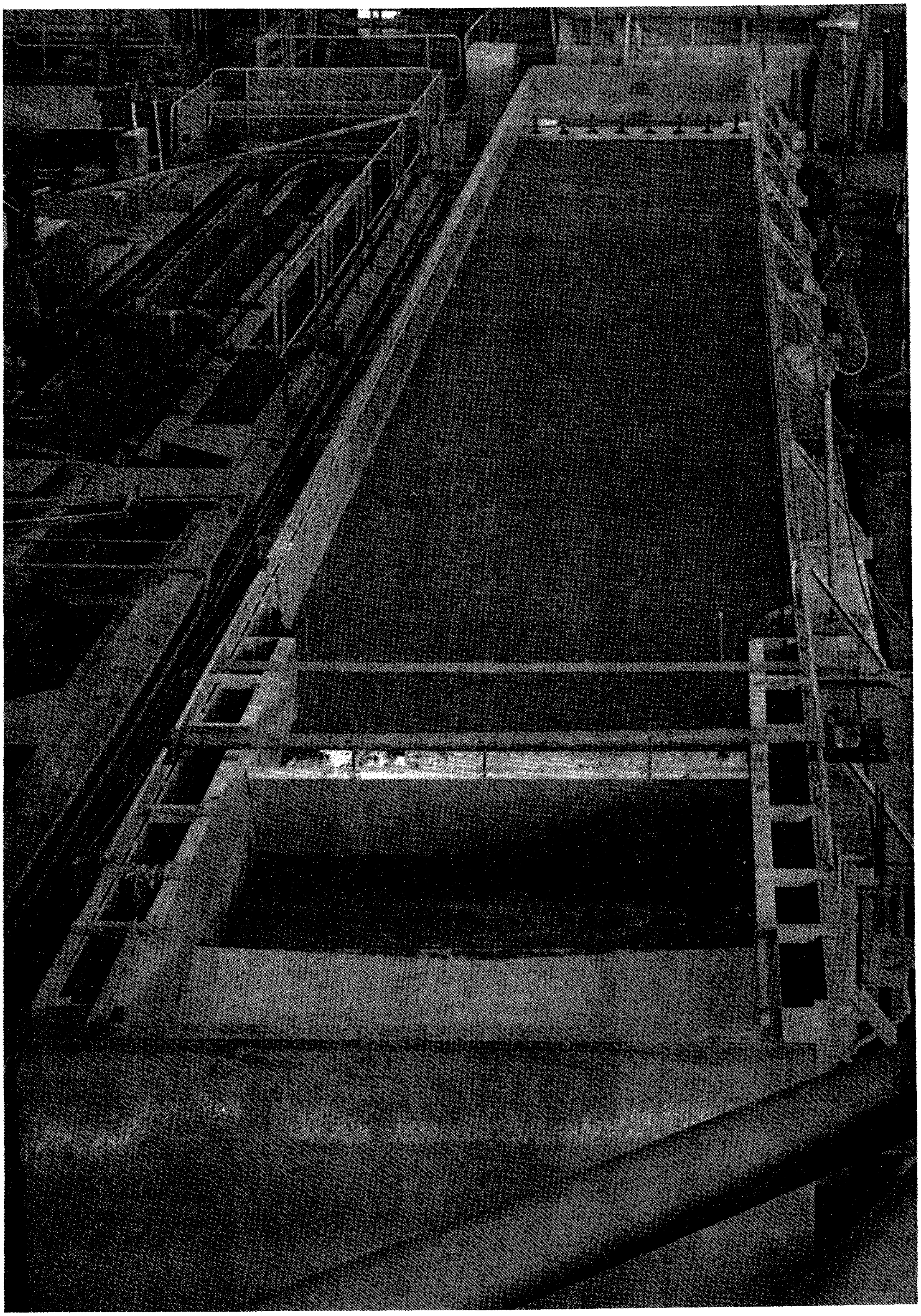
Variation of A,C,m and n with Dgr

Fig.1

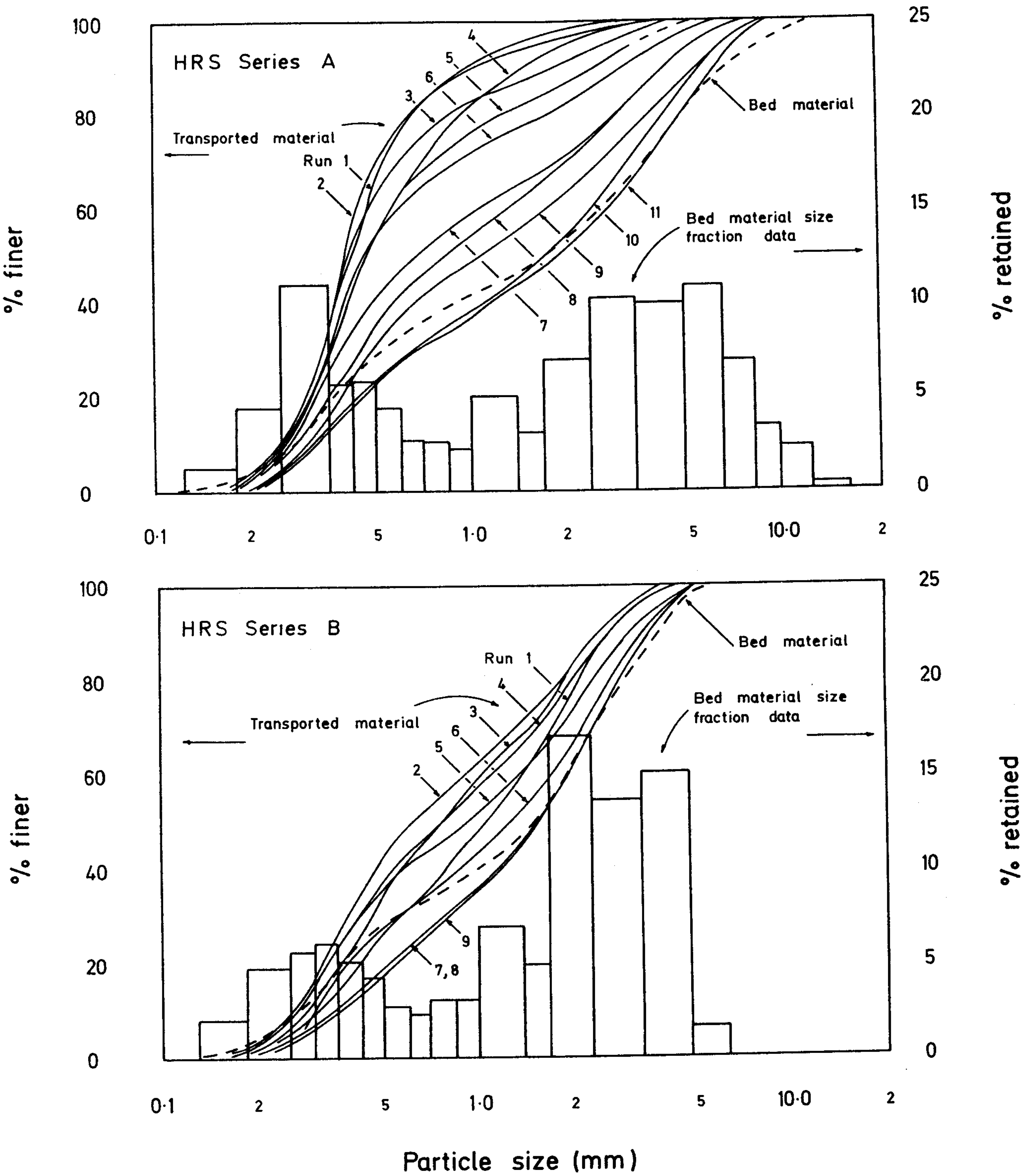


BED MATERIAL - PARTICLE SIZE DISTRIBUTIONS

FIG 2

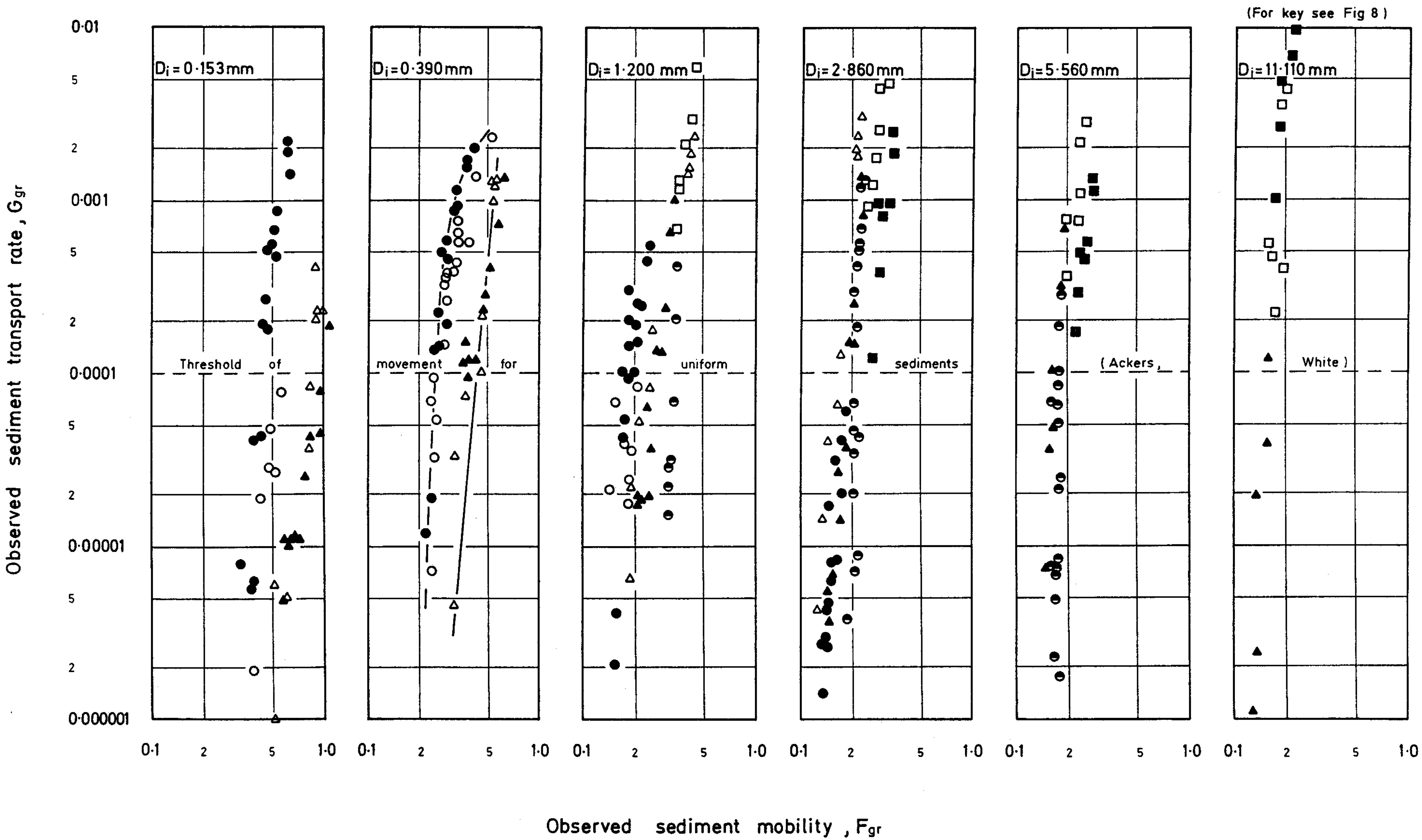


HRS Tilting flume Fig 3



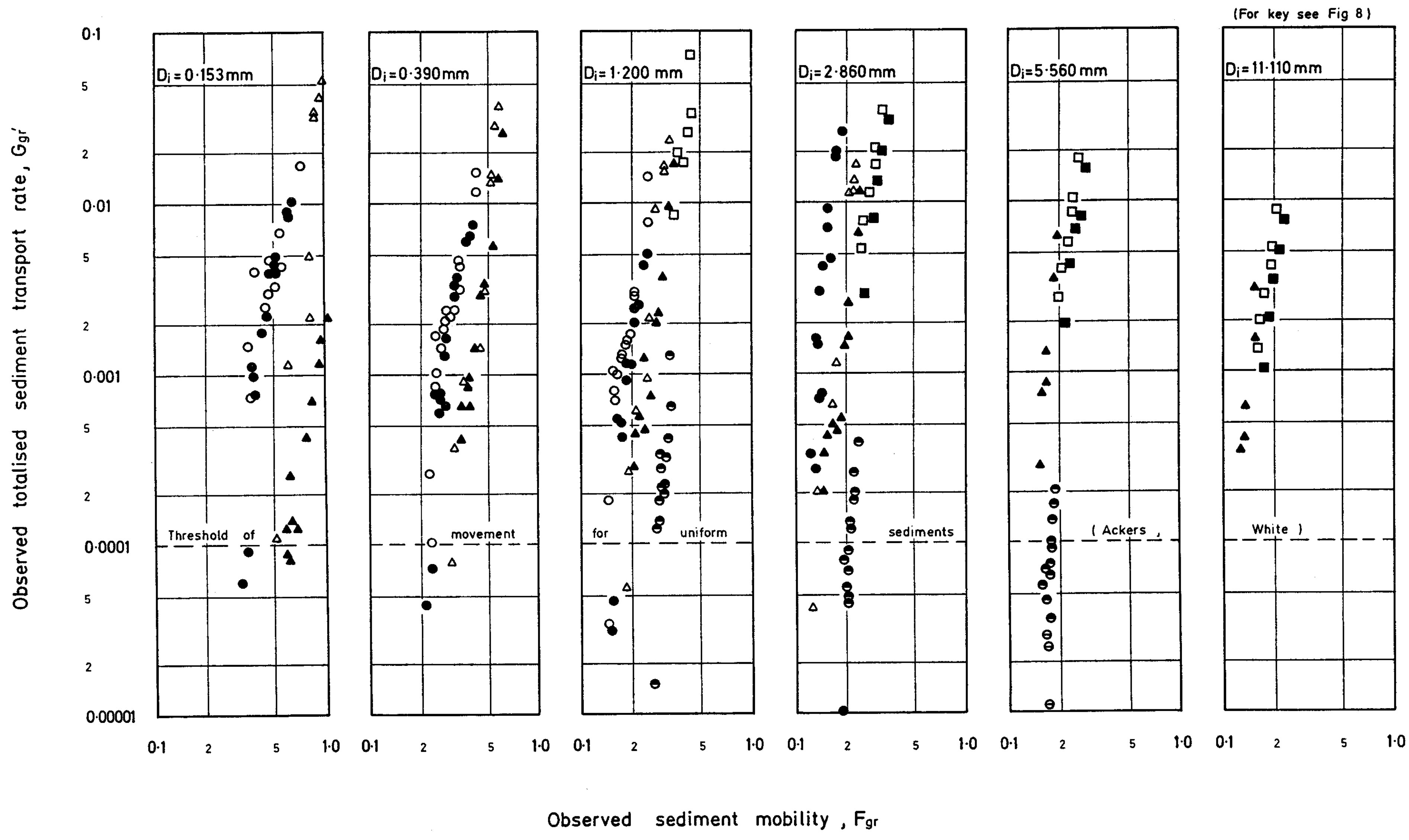
PARTICLE SIZE DISTRIBUTION - HRS INVESTIGATION

FIG. 4



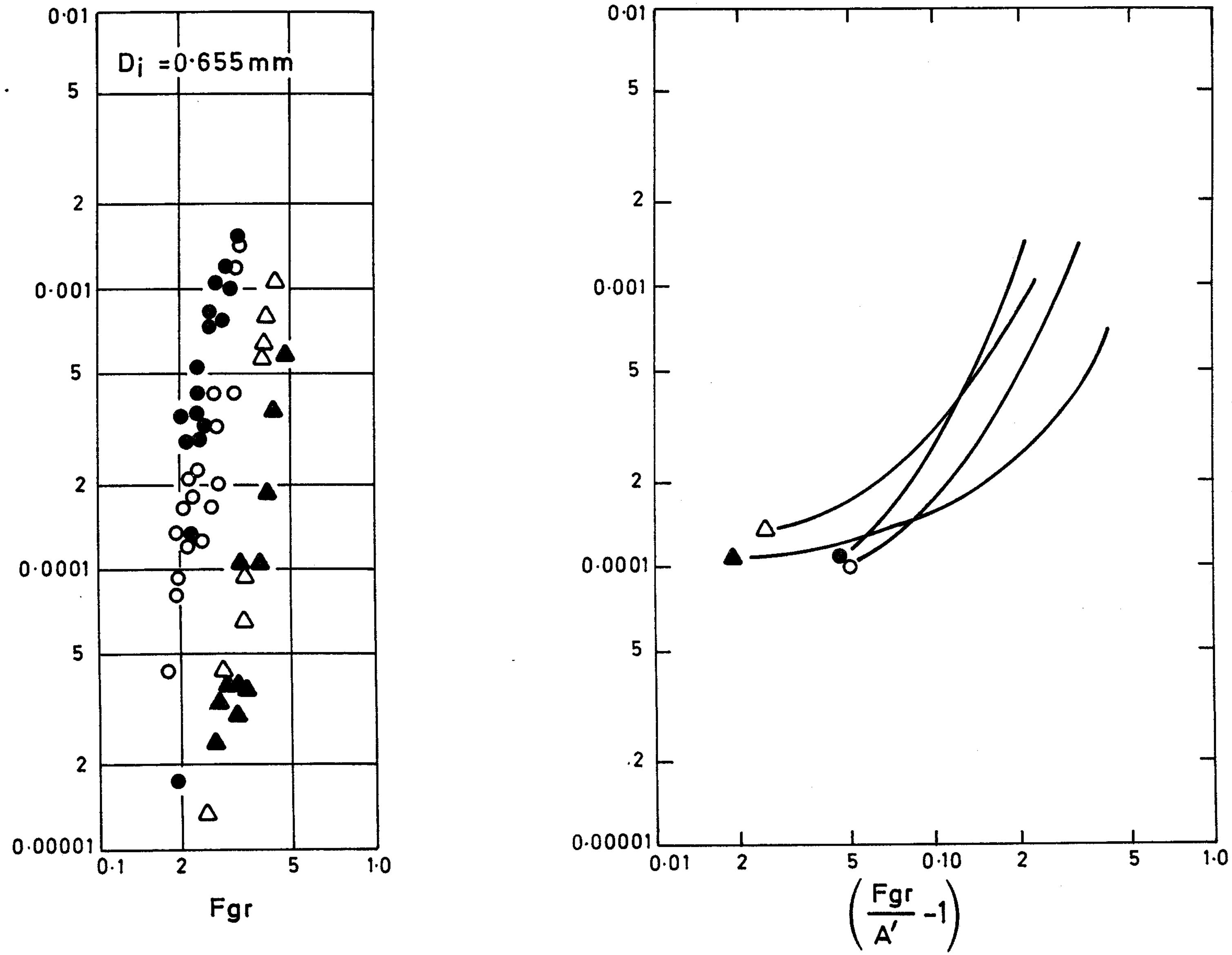
OBSERVED TRANSPORT - MOBILITY RELATIONSHIPS

FIG 5



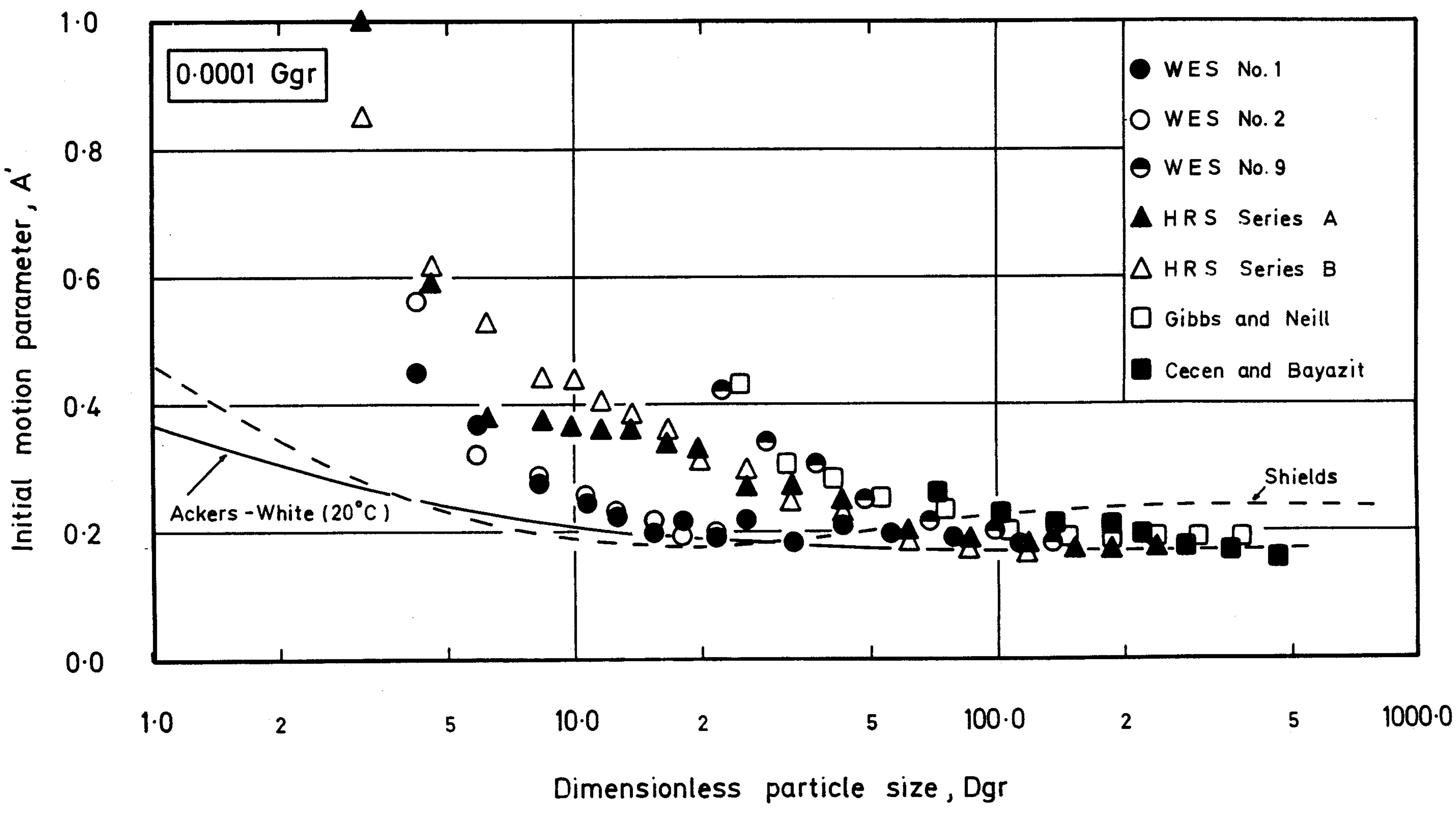
OBSERVED TOTALISED TRANSPORT - MOBILITY RELATIONSHIPS

FIG 6



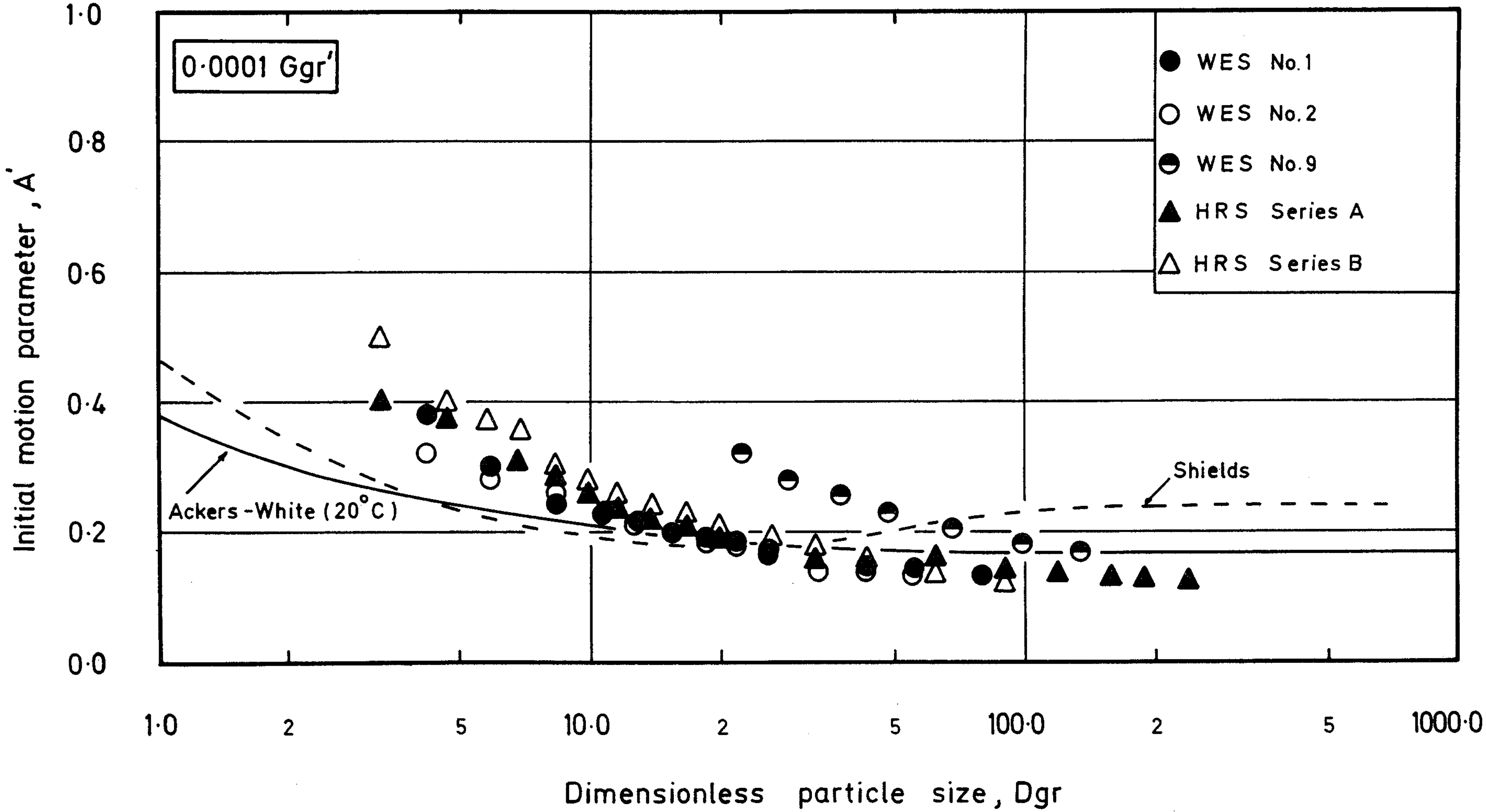
Effect of initial motion parameter on the Ggr - Fgr functions

FIG 7



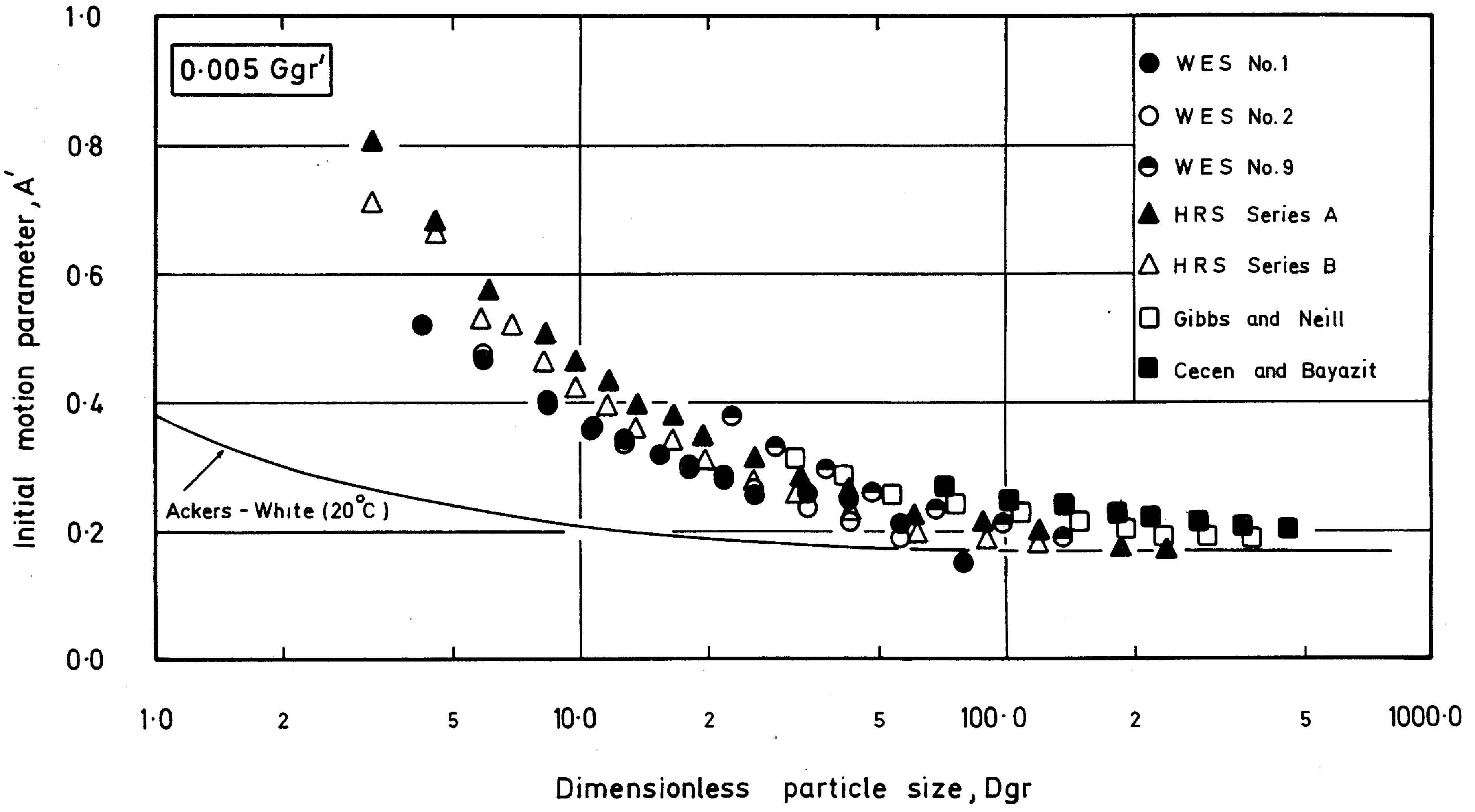
INITIAL MOTION CHARACTERISTICS BASED ON Ggr VALUE OF 10^{-4}

FIG 8



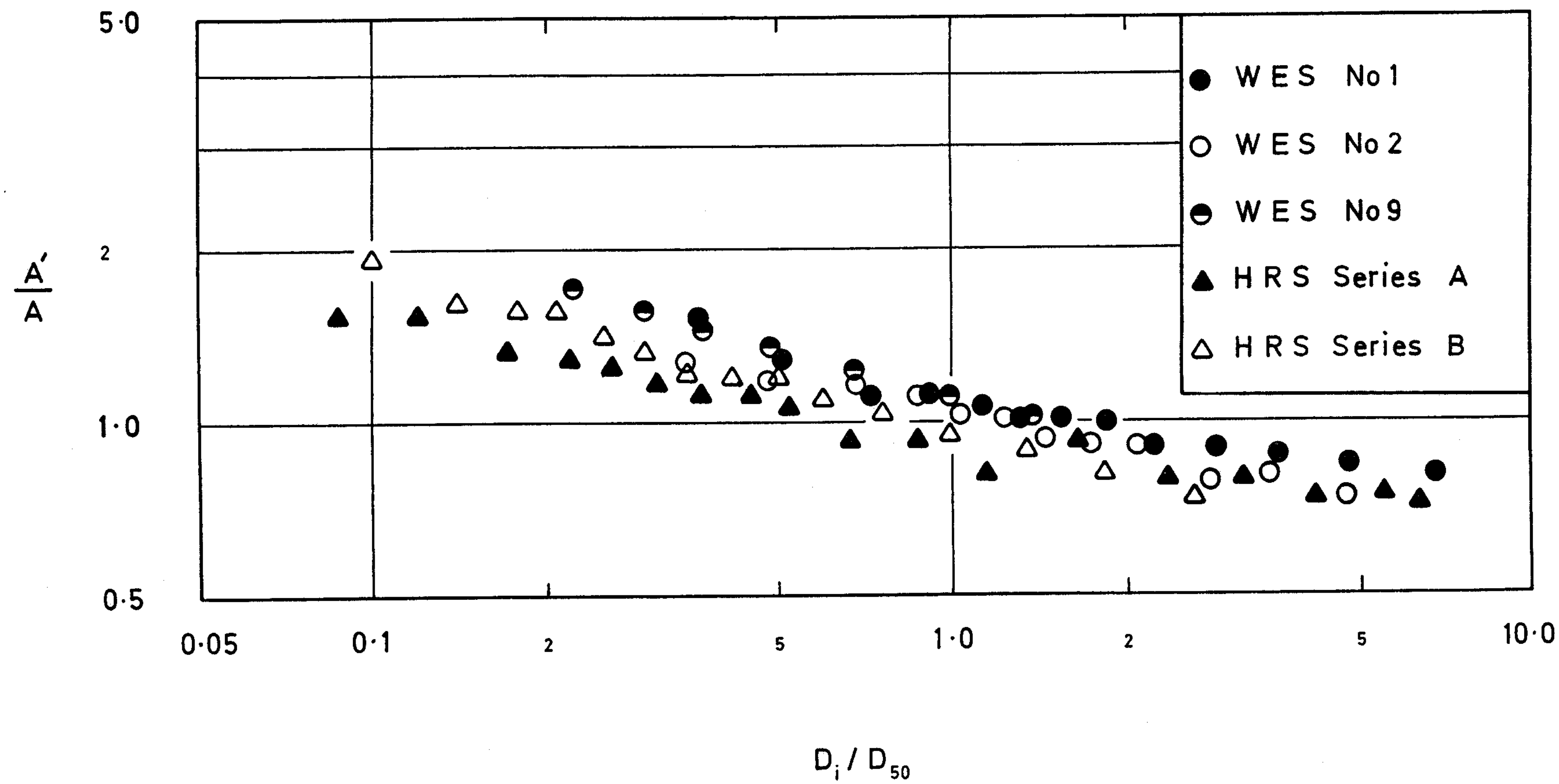
INITIAL MOTION CHARACTERISTICS BASED ON Ggr' VALUE OF 10^{-4}

FIG 9



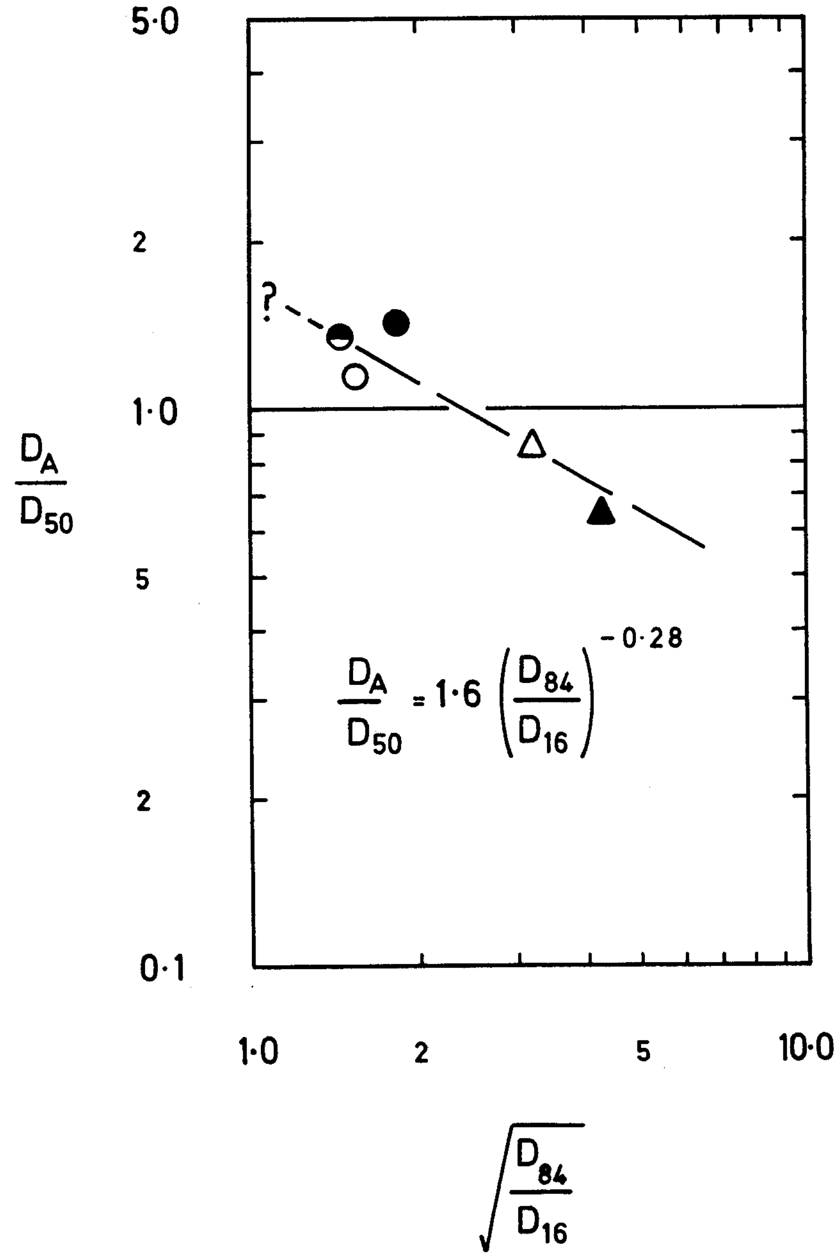
INITIAL MOTION CHARACTERISTICS BASED ON Ggr′ VALUE OF 5×10^{-3}

FIG 10



A′/A versus D_i/D_{50}

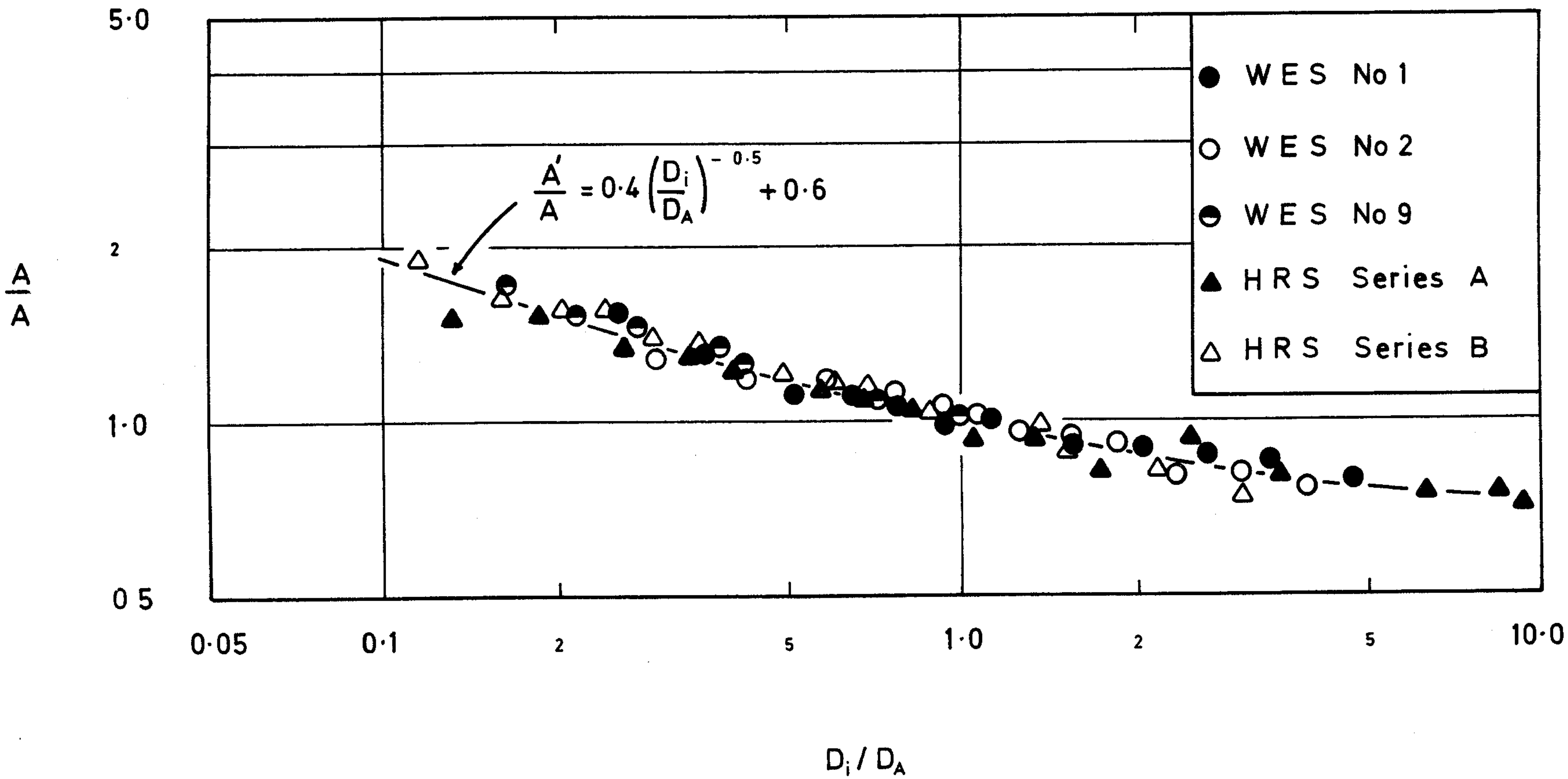
FIG 11



BED MATERIAL	SYMBOL	$\sqrt{\frac{D_{84}}{D_{16}}}$	D_A (mm)	$\frac{D_A}{D_{50}}$	D_A (%)
WES No 1	●	1·82	0·59	1·4	73
WES No 2	○	1·51	0·51	1·16	63
WES No 9	⊖	1·45	5·54	1·35	82
HRS A	▲	4·28	1·14	0·65	43
HRS B	△	3·24	1·32	0·85	46

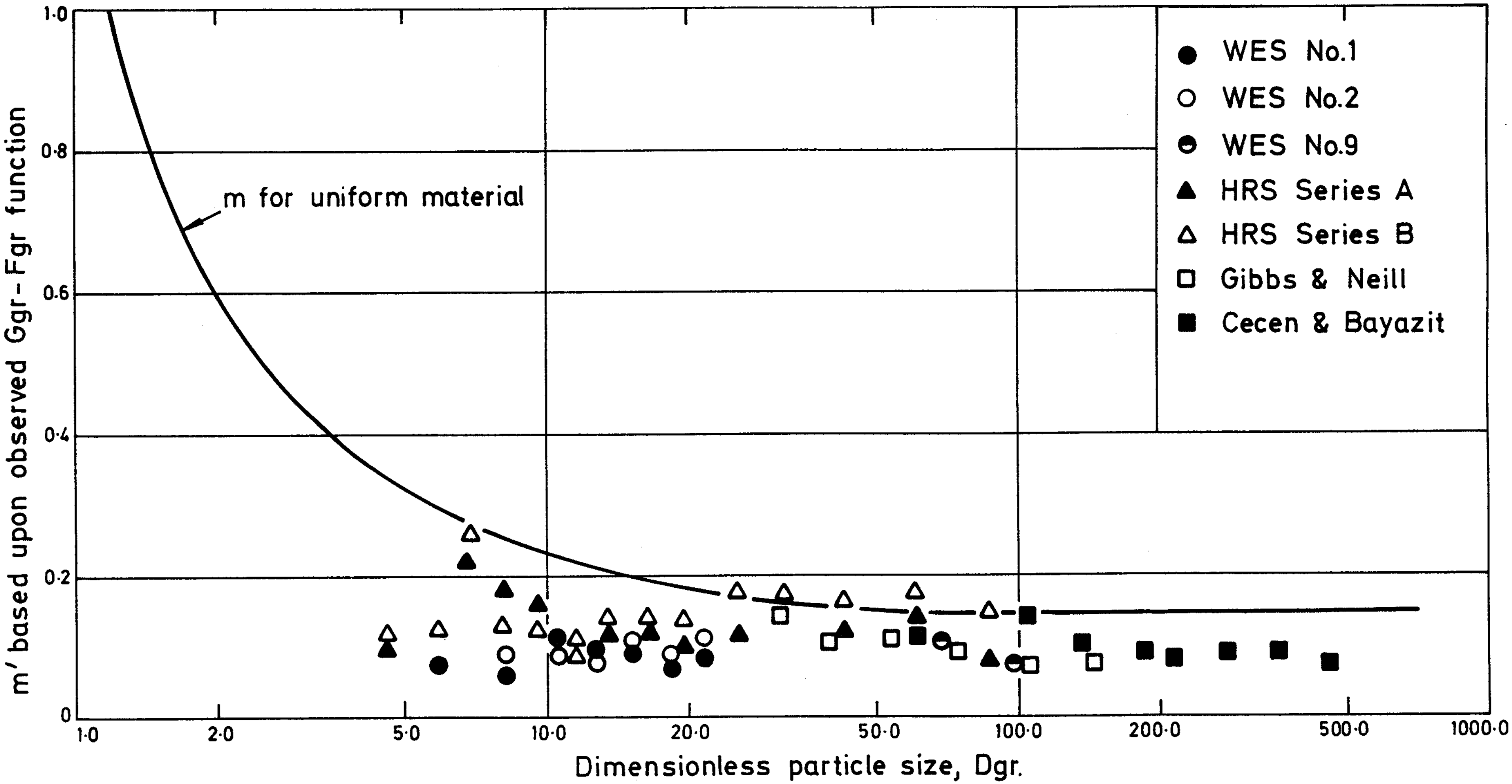
D_A / D_{50} versus $\sqrt{D_{84} / D_{16}}$

FIG 12



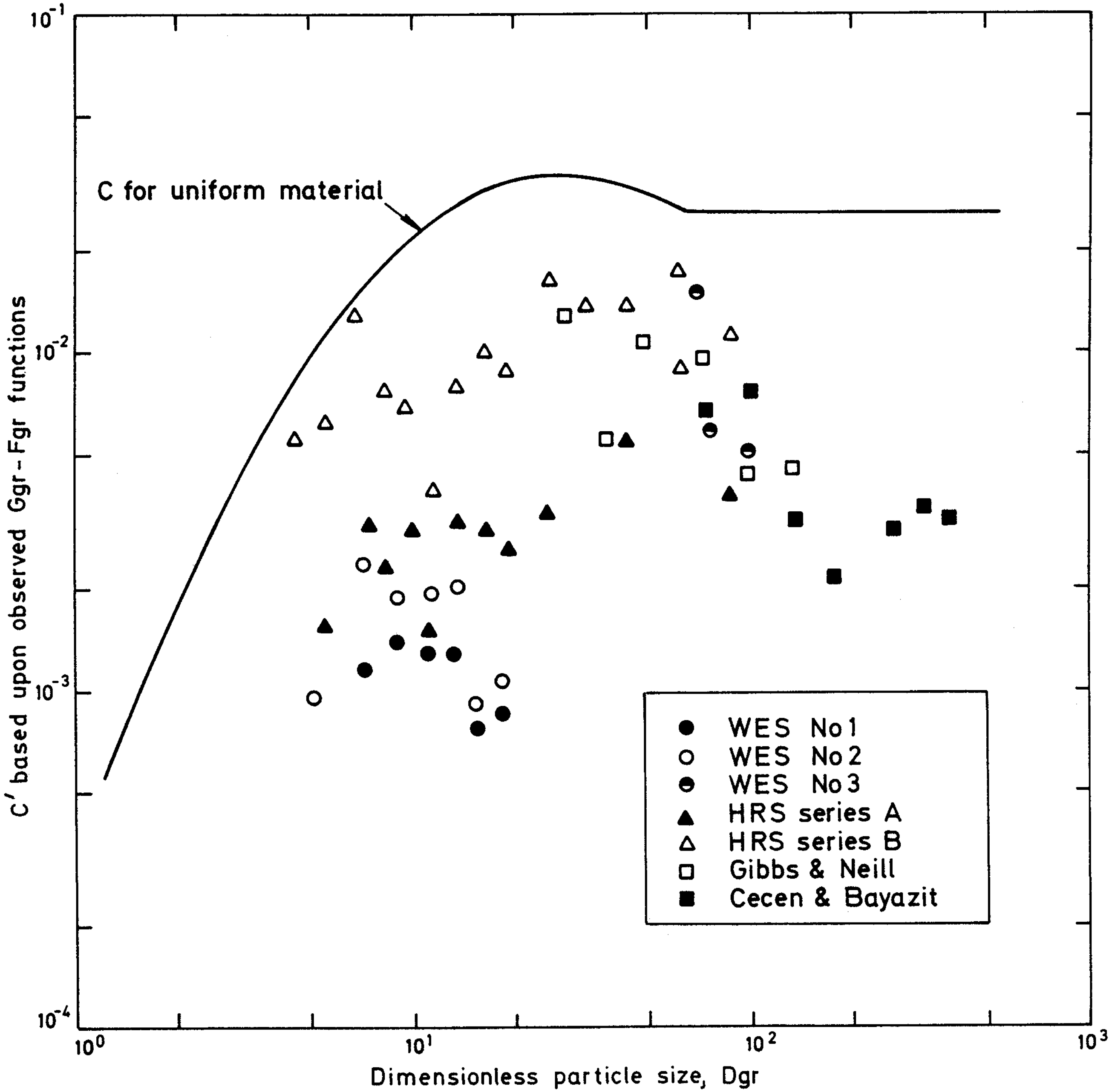
A'/A versus D_i/D_A

FIG 13



m' and m in terms of Dgr.

FIG 14



C' and C in terms of Dgr

FIG 15