# SEDIMENT DYNAMICS AND FLOW ANALYSIS OF THE ASSINIBOINE RIVER

by

EDWARD ADAM WOLOWICH

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ABSTRACT

Sediment dynamics at a station and station to station are assessed on the Assiniboine River of Manitoba. Water Survey of Canada sediment and hydraulic data were analyzed yielding sediment parameter relationships. Using these relationships, a comparison of measured data with K-factor and stage-discharge estimated data was carried out. K-factor data proved to be inferior to measured data. The effects of the Portage Diversion works and Shellmouth Dam on the Assiniboine River were also studied. Parameter relationships before and after the construction of the diversion and Shellmouth Dam indicate a change in channel regime downstream.

An intensive on site survey was carried out to identify various physical features that influence the total sediment load, such as landslides, active springs, and channel geology. It was found that much of the Assiniboine's bed is armoured and depleted of sediment. Sediment contribution is chiefly a result of the numerous landslides and ground water springs throughout the river's relic Lake Agassiz delta region. Sediment is not transported in a steady state but rather by pulses in the form of sand waves which approach the flow depth in height.

Total loads at Water Survey of Canada stations are computed using the Ackers-White transport function (1973). These loads were considerably more than those measured by Water Survey. This was also confirmed using the Colby (1964) method of estimating sediment transport, thereby confirming that the stream is armoured along much of its reach and transporting less than an equilibrium sediment load. The existing bed material load is thus supply rather than hydraulics determined.

The MOBED math model was employed to predict a channel profile after 500 real years if the stream were alluvial. The result was degradation of 14 meters at Brandon. This would indicate that degradation is prevented on the present stream by the presence of Currie's Rapids.

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Above all I wish to thank God.

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# Chapter I

# INTRODUCTION

The Assiniboine River has its head waters in eastern Saskatchewan. Its waters flow southeast into Manitoba where the Qu'Appelle River contributes to the flow. The Souris River, winding its way up from the south, meets the Assiniboine east of Brandon, Manitoba. The Assiniboine then continues east to the city of Winnipeg where it empties into the Red River, figure 1 .

The Water Survey of Canada has collected water level and flow data on the Assiniboine River since the late 1800s. Sediment data have been collected since 1956 at one or more stations each year.

Discharges of up to 1500 cms have been recorded on the Assiniboine River (during the 1976 flood) with suspended sediment discharges in excess of 60,000 tonnes per day.

It is desired to study sediment dynamics at a station and station to station. Water Survey of Canada data were used to study sediment dynamics at a station. The reach of river used for this study extends from the Water Survey Station near Russell, Manitoba, located 46 kilometers downstream of the Shellmouth Dam, to the Water Survey station at Headingley, Manitoba, located 30 kilometers upstream of the Assiniboine's mouth. A twenty year period of data from 1956 to 1976 was chosen for this study.

Various hydraulic and sediment parameter relationships were analyzed at each station. It was necessary to examine the physical characteristics at each Water Survey of Canada Stations in this study (figure 2), in order to identify any condition that would induce bias into the flow and sediment data collected. Thus, if a discrepancy between theoretical relationships and relationships derived from analysis of the data occurs, it may be possible to identify the probable cause. It was also important to study the methodology and equipment used in data collection. In some cases Water Survey of Canada uses estimation methods for discharge and sediment discharge if measurements are not obtainable. An evaluation was carried out to study the quality of the estimated data. It was then possible to decide whether or not estimated data could be included in studying hydraulic and sediment relationships.

MOBED, B. G. Krishnappan's (1978) coupled water and sediment routing model, was employed to study station to station sediment dynamics. The reach of the Assiniboine modelled extends from the Water Survey station near Brandon to the Portage Reservoir. This reach has a total length of 307 kilometers. It was thought that this length of river would be the most active in terms of sediment dynamics, because of its steep slope and the availability of a transportable load. The actual profile of the Assiniboine River was compared to a profile generated by the model.

A comparison of measured sediment discharge is made with predicted sediment discharges using the Ackers-White and Colby sediment transport functions. It was then possible to compare the present sediment transport rate with an equilibrium transport rate.

Two major structures were put into operation on the Assiniboine in 1969 for flood protection purposes. These are the Shellmouth Dam and the Portage Diversion.

The Shellmouth Dam was constructed to provide storage for flood waters during high flows on the Assiniboine River. The Shellmouth Dam offers flood protection to the downstream region of the Assiniboine River Valley by reducing flood peaks.

The Portage Diversion (or Assiniboine Diversion) was constructed to supplement the Red River Floodway in offering flood protection to the city of Winnipeg. Flood protection is also offered to the city of Portage la Prairie immediately downstream of the Diversion. Excess flows from the Assiniboine are diverted north to Lake Manitoba. The structure includes a dam with spillway works on the Assiniboine River. A reservoir covering 652 Ha. has been created behind the dam.

Sediment dynamics before and after the construction of the projects were studied to provide information as to their effects on the sediment dynamics of the study reach. Figure 2 shows the locations of the two structures.

Before sediment dynamics can be studied, it is necessary to understand the geomorphology of the region. The geomorphic history of the region was therefore studied along with regional geology. Inspection of the region was carried out by canoeing from Brandon to Holland, flying the reach from Holland to Winnipeg, and by locally visiting each of the Water Survey Stations downstream of the Shellmouth Dam.

# Chapter II

# SEDIMENT TRANSPORT

The Assiniboine frequently transports several thousand tonnes of sediment per day. On occasion, the Assiniboine river has transported as much as 60,000 tonnes per day, during freshet. Sediment transport terms are defined below.

## 2.1 MODES OF SEDIMENT TRANSPORT

Sediment is transported in three modes:

1. Bed Load

Bed load is composed of large sediment particles which are rolled or dragged along, in nearly continuous contact with the stream bed.

2. Suspended Bed Load

Suspended sediment consists of those particles (greater than 0.062 mm.) which are supported in the flow by the turbulent motion of the stream for a considerable length of time.

3. Wash Load

Wash load is composed of very fine particles which remain in suspension until the velocity of the stream is nearly zero.

4. Bed Material Load

Bed material load is the sum of Bed load and Suspended bed load.

## 2.2 EQUILIBRIUM SEDIMENT TRANSPORT

The body of water that a stream flows into is defined as its base level. In the case of the Assiniboine, the base level has changed from Lake Agassiz, to Lake Manitoba, to what is now its present base level, the Red River at Winnipeg. Sediment is transported from the steep uplands and deposited along the lowlands until the river enters the body of water at its base level. This results in a concave up river profile. There are several hydraulic parameters involved in the transport of this sediment.

There exists an equilibrium state between the slope of a river, the discharge of a river, the sediment discharge, and the median grain size. Lane (1955) gives the following relationship:

$$QS \propto QsD_{50}$$

Where:

Q = discharge

S = slope

Qs = sediment discharge

$D_{50}$ = median grain diameter

The maximum amount of sediment that a river can transport at a given slope and discharge is referred to as the capacity of the river. Rivers are very conservative systems. Usually only a fraction of their energy is used to transport sediment. The amount of energy used for sediment transport increases with the size of the stream. External friction against the river bed and internal friction through turbulence absorb all but a small percentage of the stream's energy, Rubey (1933). Therefore, at the equilibrium state, sediment transport is carried out at the capacity of the river. Any change in one of the previously mentioned parameters will offset the equilibrium state of the river.

When the sediment load is increased with all other parameters being constant, the stream, already at capacity, will begin to deposit the excess sediment. The sediment deposited will steepen the slope and will therefore gradually decrease as flow continues. This process will continue until the increase in slope caused by deposition is great enough to increase the capacity of the river to a level capable of transporting the greater sediment load. The stream is now at equilibrium again, with a greater slope and a greater sediment load than before.

If the mean size of sediment particles is decreased, the river is able to move the smaller sediment particles more easily. The river is now under capacity with respect to sediment transport. Since the river desires to operate at capacity, degradation will take place in the upper reach with aggradation along the lower reach. This creates a milder slope which reduces the stream's capacity. The river is now in equilibrium again, however, at a milder slope and smaller mean particle size than before.

When the discharge of a stream is increased, its capacity is also increased. It has the ability to move additional sediment. The stream obtains this sediment by degrading its bed. This degradation continues and decreases the slope until the equilibrium state is again reached.

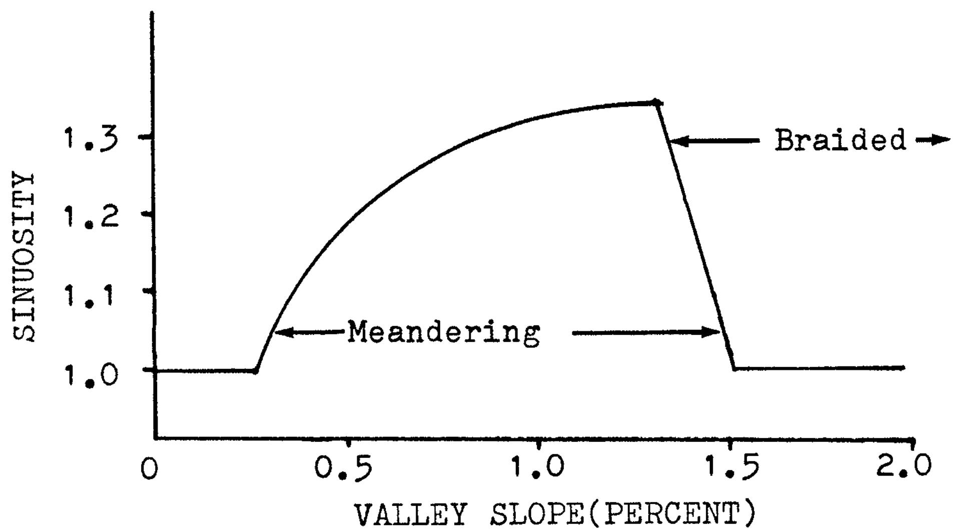
A river can also change its slope by changing its meander pattern. For a given valley slope a straight river would have a much steeper slope than a river that has a meander pattern. This relationshiop between valley slope and river slope is referred to as sinuosity, where:

SINUOSITY = (RIVER DISTANCE) / (VALLEY DISTANCE)

For a given valley slope, a straight river would have a higher sediment capacity than a meandering river due to the steeper slope.

The relationship between valley slope and sinuosity was initially studied by Fisk, H. N. (1944), through an analysis of data collected on the Mississippi River during the early

1900s. Through laboratory studies, Schumm and Khan (1973), devised the following relationship between valley slope and sinuosity:




2.3 <u>PARAMETER DEFINITIONS</u>

The previously discussed parameters are not the only variables involved in the transport of sediment in a stream. There are numerous other variables which may influence sediment transport. Devising relationships between various parameters and their influence on sediment transport has been the motive for much research by notable persons in the field, such as Einstein (1948), Meyer-Peter (1948), Muller (1948), Colby (1964), Ackers (1974), White (1974), along with several others. This report will study only the relationships of the parameters presented in Appendix A.

## Chapter III

## REGIONAL GEOLOGICAL HISTORY

### 3.1 THE PLEISTOCENE PERIOD

During the Pleistocene Ice Age, which ended about 10,000 years ago, glaciers carved out a large shallow basin through central Manitoba. Darling Ford Moraine, otherwise known as the Manitoba escarpment, marks a recessional position of the glaciers. Glacial till was deposited to the west where the glaciers encountered Riding and Porcupine Mountains. Melt water from the receding glaciers filled the basin to form glacial Lake Agassiz. The elevation of Lake Agassiz was 370 meters above sea level and covered an area of about 400,000 square kilometers.

The Assiniboine River, then a mighty stream, drained the land to the West of Lake Agassiz. The Assiniboine formed a huge delta upon entering Lake Agassiz. The delta extended from Brandon east with a radius of about 140 kilometers.

There is evidence of distributaries through the delta. One very pronounced example is Douglas Marsh, figure 3. Douglas Marsh appears to have been a major delta distributary when the Assiniboine flowed into Lake Agassiz. A profile through Douglas Marsh shows that it still retains a reach tangent to the old Lake Agassiz level, figure 4. The flow split between the present channel and Douglas Marsh occurred near what is now the City of Brandon. When Lake Agassiz began to drain, both distributary channels began to degrade. The present channel would have degraded more than the Douglas Marsh channel, thereby pirating the flow from the Douglas Marsh channel.

Over time Lake Agassiz drained until all that remain are Lake Manitoba, Lake Winnipeg, Lake Winnipegosis, and a number of smaller lakes.

## 3.2 PRESENT SETTING

Presently the Assiniboine River flows through three geological regions, the glacial till deposit upstream of Brandon, the alluvial deposit of its ancient delta, and the old lake bottom of Lake Agassiz, figure 5.

The reach of the river upstream of Brandon winds through the glacial till deposited by the Pleistocene glaciers when they encountered the shale summits of Riding and Porcupine Mountains. The glacial till has an average composition of 13% gravel, 33% sand, 31% silt and 23% clay, with occasional deposits of large boulders. Shale bedrock underlies the glacial till in this region. Several tributaries have degraded through the glacial till to the shale bedrock.

Just east of the City of Brandon, it appears that the Assiniboine has penetrated an extension of the Darling Ford Moraine. At Currie's Rapids, downstream of Brandon, boulders of up to three meters in diameter are distributed in a parabola across the Assiniboine's bed. This would imply that the Assiniboine, once a much larger stream, has blasted through the moraine and arranged the material encountered according to its parabolic velocity distribution. The presnt Assiniboine is far too small to move this material, and simply falls over it.

Much of the glacial till has been overlain with coarse alluvial deposits during the formation of the Assiniboine's delta. The delta extends from Brandon to the Portage diversion reservoir. The coarse material near Brandon becomes increasingly finer toward the east. Huge masses of sand have been deposited near what is now Spruce Woods Provincial Park. This wind blown sand has formed the dunes of the unique Carberry Desert. To this day the wind blown dunes have not yet been overtaken by vegetation.

A more recent deposit is found near Portage la Prairie. This deposit is an active alluvial fan being constructed by material in transport on the steeper slope upstream.

The underlying bedrock in the delta region is shale or limestone.

Downstream of Portage la Prairie, the Assiniboine River flows along the ancient lake bottom of Lake Agassiz. Surface deposits consist chiefly of silt laid down by Lake Agassiz. The bedrock here is sedimentary rock, mostly limestone. The bedrock is covered by an average depth of 30 to 50 meters of silt and clay.

# Chapter IV

# GEOMORPHOLOGY

## 4.1 THE ASSINIBOINE'S PROFILE

A longitudinal plot of the Assiniboine River's profile downstream of the Shellmouth Dam is shown in figure 6. The Assiniboine's profile may be broken down into three sections which correspond to the three geological regions discussed in Section 3.2.

Along the upper reach from the Shellmouth Dam to the City of Brandon, a typical concave up river profile is evident. The ancient Lake Agassiz surface level is tangent to the downstream end of this reach at Brandon. From a comparison of valley and upland profiles in figure 5, it is evident that significant degradation has occurred along this reach. This degradation would have begun long before the formation of Lake Agassiz, at a slow rate. Degradation probably kept pace with the uplift of the shale bedrock in this region. The result of this degradation is a valley 100 meters deep at the Shellmouth Dam.

Downstream of Brandon, the Assiniboine flows through its ancient deltaic deposits. Along this reach the slope of the channel is considerably steeper than that upstream of Brandon. When Lake Agassiz drained, the Assiniboine began to degrade through its delta to meet its lowering base level. This material, mainly sand, has formed a great alluvial fan where the Assiniboine reaches the former bed of glacial Lake Agassiz. The extent of this degradation can be seen in figure 5.

Although the material generally exposed in the river valley is unconsolidated sand, glacial till underlies much of the deltaic deposits. It is evident, by the presence of cobbles one third of a meter in diameter, that the Assiniboine has cut down to the glacial till in some locations. Closer examination of the valley profile in figure 5 indicates that there are several inflection points along the steep reach. These are points where the Assiniboine has encountered the glacial till and could not degrade any further. These armoured sections prevent degradation immediately upstream, resulting in a profile with a step-like appearance.

The most pronounced example of armouring is found at Currie's Rapids. Here boulders three meters in diameter prevent head cutting from moving upstream to Brandon. Degradation through the Assiniboine's delta ends at Currie's Rapids. The section upstream of Brandon is being held up by the armour at Currie's Rapids.

Downstream of Portage la Prairie the Assiniboine again reduces its slope as it flows along the bed of glacial Lake Agassiz. The stream appears to be alluvial in this reach, flowing through a channel formed with material from the alluvial fan. Over time the Assiniboine has periodically shifted course in this region. There are a number of abandoned channels that would suggest that the Assiniboine once flowed into Lake Manitoba. The river may have also flowed through a channel which is now occupied by the La Salle River. The present Assiniboine has built up natural levees along its course into Winnipeg. In some areas the channel is quite stable. There are still occasional deposits of rock in the channel. Aggradation occurs along this reach.

## 4.2 SEDIMENT CONDITIONS

Suspended sediment concentrations in the Assiniboine are very low downstream of the Shellmouth Dam. However, there are several tributaries along the upper reach of the Assiniboine. These tributaries flow through the glacial till deposits and have often degraded to the shale bedrock beneath. Since these tributaries are of a much steeper slope than the main channel, they are capable of moving a surprising amount of shale into the Assiniboine.

Shale is being brought into the Assiniboine as far downstream as the Cypress River. Since the specific density of shale is less than that of crystalline material, it is transported more readily. To assess this impact, the junction of the Souris and the Assiniboine was studied.

Bed material samples were taken on the Assiniboine upstream and downstream of the Souris River. It was noted that the Souris was contributing chiefly shale sediment. Upstream of the Souris the median grain size, $D_{50}$, of the bed material was 0.86 mm., while downstream of the Souris the median grain size jumped up to 15.0 mm. Upstream of the Souris, pea-gravel was in motion, while downstream, shale up to 30 mm. long was being transported. Shale, however, is easily fractured. A few kilometers downstream the largest shale particles were reduced to 5 mm. in diameter.

Along the steep reach, where the Assiniboine is actively cutting through its delta, one would anticipate high sediment loads. However, in some reaches extending for several kilometers, the stream appears to be depleted of sediment. This is a result of the channel being armoured. Cobbles with the occasional boulder are strewn along the bed. The present Assiniboine is not capable of transporting this material. No significant lateral sediment inflow occurs in these reaches of sediment depletion.

When the deltaic reach of the river was flown by light aircraft, sand waves were one very obvious mode of sediment transport. Huge masses of sediment were seen propagating downstream in single pulses. Typical amplitudes are equal to the flow depth and wave lengths are on the order of 6 to 10 widths. It was obvious from the air that suspended sediment samples taken at a section would vary tremendously from hour to hour with the passing of one of these waves.

Aside from tributaries there are two prominent contributors of sediment: landslides and ground water springs.

## 4.3 LANDSLIDES

When the Assiniboine River cut through its delta, it left some rather unstable slopes. The amount of degradation can be seen from figure 5. In some areas the degradation is in excess of 60 meters. Since the delta is composed of unconsolidated sand, landslides numbering into the hundreds dot the Assiniboine's valley. One slide, at "Steel's Ferry Overlook", is about 50 meters in height and extends for several hundred meters along the south bank of the river.

During spring freshet the toe of a slide is carried away by the flow. When the discharge decreases into the summer months, the flow is unable to move these deposits and they slowly protrude into the channel to remain until the next spring's freshet.

Thus sediment moves in pulses through this reach. One of these landslide slumps may be carried as a single pulse, forming a sand wave much larger than dunes.

## 4.4 GROUNDWATER SPRINGS

The unconsolidated sand of the deltaic deposit is an excellent aquifer. More than one hundred groundwater springs debouch from the valley slopes along the reach from Brandon to Portage la Prairie. During the summer months inflow from these springs exceeds the inflow provided by tributaries.

During the response to a single rain event, a good-sized spring can wash in many tonnes of the deltaic sand. The alluvial fan formed by one of these springs upon entering the Assiniboine measured 30 meters across. These alluvial fans, just like the landslides, cannot be mobilized by low flow. They too will remain until spring freshet. When they are mobilized, they will also move as pulses in the familiar sand wave form.

## 4.5 CUT-OFFS

Perhaps the most evident indications of the Assiniboine's activity are cut-offs. There have been a number of cut-offs in recent history. Big Island, in Spruce Woods Provincial Park, was formed by a cut-off recently completed. Air photos from the 1950s show what is now Big Island as a large meander loop. In the 1960s a cut-off was formed which was completed in the early 1970s.

Just 6 kilometers to the west of Big Island, another cut-off was formed during the 1976 flood. This cut-off, still in process today, reduces the river length by 2 kilometers. Presently, flow in the old channel is less than 10% of the total flow. This cut-off has been in progress for nine years now and will require a few more years to be completed. The unusually long time period involved in the formation of these cut-offs is a result of the channel being depleted of sediment.

Two other sites were observed where cut-offs began to form during the 1976 flood. Flow has never since reached the discharge of the 1976 flood, therefore the old channels remain occupied while the new channels are dry.

## 4.6 SINUOSITY OF THE ASSINIBOINE

Variation in sinuosity (river distance/valley distance), yields much information about the study reach. For a meandering sand bed channel the sinuosity is usually between 1.5 and 2.0. If the valley slope along a reach is steep, sinuosity will increase to bring the river slope back into an equilibrium state for the sediment available. Likewise, if valley slope is flat, sinuosity will decrease resulting in an increased river slope. When sinuosity decreases to a minimum of 1, the channel becomes straight, with a slope equal to that of the valley.

Sinuosity is also related to sediment concentration. If sediment concentration is low along a reach, sinuosity would increase in order to reach an equilibrium sediment transport state. If a channel is unable to degrade, it could increase its sinuosity in order to reduce its slope. Schumm (1977) gives the following relationship:

$$Q_s \simeq \frac{b, S, \lambda}{d, P}$$

$Q_s$ = sediment discharge

b = channel width

$\lambda$ = meander wavelength

S = slope

d = depth

P = sinuosity

Considering again the three geological regions of the Assiniboine River, it could be seen from figure 5 that sinuosity follows the same three region breakdown.

Along the upper reach from the Shellmouth Dam to Brandon, sinuosity averages 1.98. This is rather high for the shallow valley slope present. The high sinuosity may be explained by the low sediment concentration throughout this reach. Sinuosity is increased in order to decrease the river slope to that of an equilibrium state.

Along the reach where the Assiniboine is cutting through its delta, valley slopes are quite steep. As previously discussed in Section 4.1 periodic armouring of the channel in this reach has resulted in a step-like valley slope profile. Along the deltiac reach the valley slope ranges from 0.00038 to 0.00159. Similarly sinuosity changes to correspond with valley slope. Sinuosity is high where the valley slope is steep and low where the valley slope is flat. The sinuosity along this reach ranges from 1.4 to 2.5 with the occasional section as high as 3.0. The average sinuosity of the reach is 1.96

Downstream of Portage la Prairie, the valley slope becomes steady and shallow, following glacial Lake Agassiz's bed. Sinuosity along this reach is also rather constant, averaging 1.56.

The effect of the varying sinuosity along the entire study reach is evident when comparing Figures 5 and 6. The irregular valley slope is smoothed out by the varying sinuosity to produce the river slope profile in figure 6.

Sinuosity versus valley slope was plotted in figure 7. The relationship was found to be similar to that of Schumm and Khan (1973). The steepest valley slopes of the range present on the Assiniboine fall on the 'near transitional' portion of the classification curve developed by Schumm and Khan (1973). This indicates that the Assiniboine River, along the reach from Currie's Rapids to Portage la Prairie, is near transition from a meandering stream to a braided stream. Aerial inspection of the Assiniboine has confirmed this classification. Flow is split by huge sand bars and shrub covered islands. Three or four channels are evident at some sections during low flow. It would appear that in places the river is on the verge of shifting to a braided channel.

From Lane (1957), if slope exceeds that derived from the following equation the channel will be braided:

$$S = 0.004\ Q^{-\frac{1}{4}}$$

where:

S = slope

Q = mean freshet discharge

The mean freshet discharge on the Assiniboine is 10,200 cfs. Substituting into the above equation yields a slope of 0.0004, which is often exceeded on the Assiniboine from Currie's Rapids to the Portage Reservoir. The results are summarized in Table 1.

The effect of suspended sediment concentration on sinuosity is also evident on figure 7. High concentration reaches have a much lower sinuosity than those reaches where the concentrations are low.

## Chapter V

## DATA COLLECTION

### 5.1 SOURCE AND TYPE OF DATA

The study reach of the Assiniboine River extends from the Shellmouth Dam near Russell, Manitoba to Water Survey's Headingley Station, near Winnipeg.

Flow and/or sediment data were obtained from Water Survey of Canada at seven stations: Russell, Miniota, Brandon, Rossendale, Portage and Headingley, figure 2. A twenty year period from 1956 to 1976 was used for this study. Previous to 1956 sediment and flow data were not available at all the stations. During the twenty year period there is a continuos record of sediment data with sufficient flow data at all of the stations. The period also provides data before and after the implementation of the Shellmouth Dam (1968) and the Portage Diversion (1969). The quantity of data provided by the twenty year study period was sufficient to undergo statistical analysis at a high level of confidence. Table 2 indicates the type of data and the period of available data used at each of the Water Survey of Canada Stations.

## 5.2 REQUIRED FLOW AND SEDIMENT PARAMETERS

It was desired to study the relationship between various sediment and hydraulic parameters at each station. This was accomplished by computer aided analysis of sediment and flow data obtained at the Water Survey Stations. The computer program used for this analysis was written by Western Canada Hydraulics Labs. (1978), for use in a similar study of sediment transport on the Fraser River. The program is listed in Appendix B. Flow and Sediment data were input and various hydraulic parameters were generated by the program.

The following data were required for the program: channel width, cross-sectional area, discharge, water temperature, concentration of suspended sediment, percentage of sediment finer than 0.062 mm. (wash load), water levels, mean grain diameter of suspended sediment ($D_{50}$), and the gradation coefficient of suspended sediment($\Phi$).

Channel width and cross-sectional area were obtained from Water Survey of Canada R-56 forms. Discharge, water temperature, concentration of suspended sediment, and percentage of sediment finer than 0.062 mm. were obtained from Water Survey of Canada flow and sediment year books. Median grain diameter and gradation coefficient were then derived.

## 5.3 DERIVATION OF MISSING DATA

Water Survey of Canada Sediment Reports combine the wash load with the suspended bed material load when listing the particle size distribution. Only the particle size distribution of the suspended bed material was required for computer analysis. Therefore the wash load had to be separated from the suspended bed material load, yielding a particle size distribution only for suspended particles with a diameter greater than 0.062 mm. The follwing proceedure was used to seperate wash load and suspended bed load:

Example of sediment data given by Water Survey:

Particle Size (mm)

| Date | .031 | .062 | .125 | .250 | .500 | 1.00 | |
|---|---|---|---|---|---|---|---|
| April 29 | 82 | 89 | 93 | 97 | 99 | 99 | % Finer |
| April 30 | 73 | 76 | 80 | 88 | 94 | 97 | |

For Suspended bed material only:

$$\% \text{ Finer} = \frac{\%(i) - \%\ (0.062)}{100 - \%\ (0.062)} \times 100$$

For April 30:

$$\frac{97 - 76}{100 - 76} \times 100 = 87.5\% \text{ Finer than } 1.00 \text{ mm}$$

$$\frac{94 - 76}{100 - 76} \times 100 = 75.0\% \text{ Finer than } 0.500 \text{ mm}$$

This procedure was then repeated for all particle sizes greater than 0.062 mm. In the case where data repeats (example: for April 29 there is 99% finer for both 0.500 mm and 1.00 mm), the larger diameter was discarded. These data were then plotted on log-probability paper for each date recorded. A straight line was approximated through the points. The diameter at which 50% of the particles are finer ($D_{50}$) was then read off the plots. The gradation coefficient ($\Phi$) for the suspended bed material is then given by:

$$\Phi = \frac{1}{2}\left\{\frac{D_{84}}{D_{50}} + \frac{D_{50}}{D_{16}}\right\}$$

With the addition of $D_{50}$ and $\Phi$, the complete data set for each date of recorded data, at each of the four stations studied, could then be input to the computer.

## 5.4 GENERATED DATA

Upon input of a complete data set, thirteen hydraulic parameters are generated by the computer in the following manner:

1. Mean Velocity = Discharge/Cross-sectional Area
2. Total Suspended Sediment Load =
(Sediment Discharge) x (Concentration of Suspended Sediment)
3. Suspended Bed Material Load =

(Total Suspended Load) x (percent of sediment larger than 0.062 mm)

4. Hydraulic Depth = (Cross-sectional Area)/(Top Width)

5. Water Surface Slope = (Stage upstream - stage downstream)/distance

6. Wetted Perimeter = Top Width + Hydraulic Depth

7. Hydraulic Radius = (Cross-sectional Area)/(Wetted Perimeter)

8. Manning n = (hydraulic radius) x (slope) / (velocity)

9. Shear Velocity =
((gravity)(hydraulic radius)(slope))$^{\frac{1}{2}}$

10. Chezy C = (Mean Velocity)/Shear Velocity

11. Froude Number =
(velocity)/((depth)(gravity))$^{\frac{1}{2}}$

12. Tractive Shear =
(Hydraulic Radius)x(Water Surface Slope)x(9810.0)

13. Stream Power = (Mean Velocity)x(Tractive Shear)

At the Portage and Russell Stations the data were separated into two groups. These groups were then used to study 'before and after' relationships in order to assess the impacts of the Shellmouth Dam (Russell Station) and the Portage Diversion (Portage Station).

The SAS statistical package was used to run regressions on those relationships involving sediment discharge. These relationships are studied in Chapter 7.

It was desired to model the Assiniboine River using the MOBED (Krishnappin, 1982) Math model. MOBED is a computerized flow and sediment routing model, see Chapter 8. In order to use the MOBED model, bed material data and cross-sectional geometry are required at a number of sections along the modeled reach. Since MOBED uses the Ackers-White (1974) method of sediment transport, $D_{35}$ and $D_{65}$ bed material particles sizes must be input. Due to the unavailability of Water Survey of Canada bed material data, on site bed material sampling was carried out at 24 sections along the study reach. Fourteen cross sections were also surveyed along the reach from Brandon to Holland.

## Chapter VI

# STATION SITE CHARACTERISTICS AND SOURCES OF SAMPLING BIAS

Physical features at a station may induce bias into the flow and sediment data collected at that station. Several assumptions are made when flow and sediment surveys are performed. Any physical feature which creates a condition which deviates from the assumed conditions will cause flow and sediment data to be less accurate (Tamburi, 1985).

## 6.1 THE IDEAL SITE

To obtain good quality data, primary concern should be given to the sampling site. There are a number of criteria which define a good site. Specific standards are set by I.S.O. (748); from Tamburi, 1985 :

1. The velocities at all points are parallel to one another and at right angles to the measuring section.

2. The curves of the distribution of the velocities are regular in the vertical and horizontal planes on which they are measured.

3. The site shall be remote from any bend or natural or artificial obstruction if disturbance of the flow is likely to be caused thereby.

4. Sites at which vortices, backward flow or dead water zones tend to develop shall be avoided.

5. Measurements with converging, and more so with diverging, flow over an oblique measuring-section shall be avoided ... due to systematic errors.

The following restrictions to ensure a good sampling site are imposed by Lambie (1980):

1. The channel should be straight and of uniform cross-section and slope to ensure parallel and non-turbulent flow and to reduce the chance of abnormal velocity distribution. Ideally the length of the reach should be at least three times the channel width with the measuring section mid-way, but where this is not possible, the measuring section should be within the downstream half of the reach. It should, however, be remote from any natural or artificial obstructions on the banks or in the channel likely to cause disturbance, distortion or reversal of flow.

2. The depth and velocity of water at minimum flow and the velocity and turbulence at maximum flow should be within the limits imposed by the type of equipment to be used.

3. The physical characteristics of the channel should ensure a substantially consistent and stable relationship between stage and discharge. The channel itself should be stable and there should be no variable back water such as from tidal influences, downstream tributaries, locks, sluices, off-takes and other structures.

4. The channel and especially the control should be free from weeds in all seasons.

5. Flows at all stages should be confined to a well-defined channel or channels or within an unobstructed floodway having stable boundaries.

6. The site should be accessible at all times and at all stages of flow.

7. The orientation of the reach should be normal to the prevailing wind, particularly where the reach is long and straight and has a flat surface slope.

8. the site should be sensitive, so that a small increase in discharge will produce a relatively large increase in stage.

9. The field of view of the measuring section and the upstream reach should be clear and unobstructed.

10. A local observer should be available to provide routine attendance.

## 6.2 SAMPLING METHODOLOGY

Discharge measurements are made using the velocity-area method. A cross-section is divided into at least twenty panels. One or two velocity measurements are taken on each panel depending on the depth of the panel. If the panel is 2.5 feet deep or less, one velocity measurement is taken because the current meter used would be too close to the channel bed and the water surface to yield dependable results. In very deep channels it is not uncommon for three velocity readings to be taken in one panel. An average velocity is calculated for each panel. This average velocity is then multiplied by the cross-sectional area of the panel to yield a panel discharge. The summation of these panel discharges yields the stream's discharge.

If one velocity measurement is taken per panel, the depth at which it is taken is at 0.6 the depth of the panel. If two velocity measurements are taken per panel, they are taken at depths of 0.20D and 0.80D where D is the total panel depth. The average velocity ($\overline{V}$) is then given by:

$$\overline{V} = \frac{V_{.2D} + V_{.8D}}{2}$$

The use of these depths produce results close to experimental data and the theoretical Keulegan distribution. Keulegan (1938) showed that velocity is greatest at a distance farthest away from the boundaries of a channel. Shear along the boundaries locally reduces the velocity to zero. Since the air above a stream is in effect a boundary, it also exerts drag on the flow. This results in maximum velocities at a depth between 0.05D and 0.25D. It is assumed that the only velocity vector of the flow is one parallel to the banks and surface. figures 8 & 9.

Suspended sediment samples are taken usually by the depth integrated method. A sample bottle is lowered into every fifth velocity panel, opened and moved steadily down to the channel bed then back up to the surface. The concentration is calculated in parts per million for each panel. This concentration is then multiplied by the average velocity of the five panels used to yield a panel suspended sediment discharge. The summation of these panel readings produce the streams suspended sediment discharge.

## 6.3 EQUIPMENT SOURCES OF ERROR

It would seem logical that the primary source of error is induced by the primary equipment used, that being the Price current meter. The Price or Gurley meter used in conjunction with the velocity-area methodology has been used in North America, with little improvement, for the past 100 years. Since the Price meter is a unidirectional current meter, its use results in measurement of speed rather than velocity. Nonparallel velocity vectors cannot be properly accounted for. If flow is turbulent, Price meters tend to over-register by as much as 40% for a horizontal oblique flow of 45 degrees at a flow of 1.5 meters per second, Yarnell and Nagler (1931). Inaccurate velocity readings would result in inaccurate flow and sediment discharges.

Other errors could be attributed to time and human bias as well as equipment. Top width and panel depth measurements are both susceptible to error which would result in a discharge error. Since a considerable time is required to survey a large section, flow conditions may change during the measurement period.

## 6.4 REAL SITE SOURCES OF ERROR

The previously stated methodology would yield good data provided that the standards for a station site in Section 6.1 are met. Often this is not the case.

A Keulegan (1938) velocity distribution is assumed, as are parallel flow lines in any one panel. In a natural channel, several features are often present which distort this distribution. Islands, bar formations, bends, bedrock outcroppings and tributaries will all act to shift flow lines. Tributaries are of particular interest. Since tributaries may have a different concentration of suspended sediment than the main stream, they will have a different density. When this difference is significant, density currents may be present. As a result of these physical features, the direction of flow in a sample vertical is not always the same along the depth of the vertical as it is on the surface. What occurs beneath the surface is usually not known by the surveyor. Since Price current meters, which are unidirectional, are used by Water Survey of Canada, shifts in the flow pattern at depth are generally not detected nor completely accounted for.

Another assumption is that the sediment load being transported through a station is in a state of dynamic equilibrium. The concentration of suspended sediment is assumed to change uniformly between sample verticals. This is rarely the case. Upstream tributaries and unstable bar formations act to interrupt this equilibrium. Tributaries may introduce sediment with a concentration different than that of the main stream. This sediment may require an appreciable distance to fully integrate with the main stream. If measurements are taken before this equilibrium is reached, there may be pockets of relatively high concentrations. In essence, what may be measured in a vertical is the concentration of the tributary and not that of the actual main stream. Bar formations may have material locally suspended by turbulence. Measurements in verticals above unstable bars will then yield a biased panel reading.

It is obvious that collecting accurate data is difficult. There are several areas of bias. A classification of probable sources of bias at each station used in this study may help account for discrepancies between the collected data and theory. The following sections discuss the characteristics of each station.

## 6.5 ASSINIBOINE RIVER NEAR RUSSELL (05ME001)

The Russell station is located 46.1 km. downstream (river distance) of the Shellmouth Dam, figure 2. At low flow the channel is only about 25 meters wide. Measurements are taken from the old Highway #4 traffic bridge during high flow. At low flow measurements are taken by wading 25 meters downstream of the bridge (refer to figure 10).

Two upstream tributaries, Conjuring Creek and Smith Creek, enter the Assiniboine immediately upstream of the station. These creeks flow through the glacial till deposits of the region and have degraded to the shale bedrock in places. At high flows, shale particles mobilized by the tributaries are brought into the Assiniboine. The larger particles drop out upon entering the main stream, forming bars. These bars disrupt the velocity distribution, and obscure the stage discharge relation when flow depth is slightly greater than the bar height. The bars have grown and been stabilized by willow since closure of the Shellmouth Dam, due to the reduction of flood peaks which formerly removed the bars. Although the Assiniboine's channel is rather straight upstream, flow must negotiate an "S" curve around the shale bars just prior to passing under the line of measurement. Even at moderate flow eddies are present where Conjuring Creek flows around its shale deposit into the main channel.

At low flow a very large shale bar extending under the traffic bridge splits the flow into two channels. Supercritical flow occurs at the downstream end of this bar. There are several boulders more than 0.75 meters in diameter in the flow downstream of the bridge. A good deal of brush in the flow even at low discharges adds to roughness at the section. The bridge itself has two piers in the flow.

As a result of the bar formations and various roughness elements, parallel flow lines would not seem likely at this site.

The equilibrium state of sediment transport is locally interrupted by the injection of sediment from the two tributaries. It would be expected that sediment concentrations just one-half kilometer upstream or downstream of this station would be significantly different than that measured at the station.

## 6.6 ASSINIBOINE RIVER NEAR MINIOTA (0ME006)

The Miniota station is located 172 kilometers downstream of the Russel station. The station is located at the Highway #83 traffic bridge, figure 11. Channel width at Miniota during low flow is about 30 meters. Although the bridge site is on a straight section of the river, there is a sharp bend approximately 200 meters upstream. Helical flow induced by this bend would most likely progress downstream to the station. The resulting velocity vectors would not be properly measured.

The bed here is coarse sand with the occasional boulder and the banks are covered with thick brush.

## 6.7 ASSINIBOINE RIVER NEAR BRANDON (05MH013)

The Brandon station is located 216.9 kilometers downstream of the Miniota station. Measurements are taken from a cable way just upstream of the Trans-Canada Highway, figure 12.

The station is located just downstream of a significant bend. Helical flow induced by the bend would be anticipated. The Minnedosa River, a relatively major tributary enters the Assiniboine 1.7 kilometers upstream of the station.

Channel width has increased to 40 meters. Occasional boulders are still present in the channel and the banks remain covered with thick brush.

The Brandon station is about 20 kilometers upstream of Currie's Rapids. There is a significant change in river slope along this reach. At the station the slope is about .0002 where as downstream of Currie's Rapids the slope increases to .0006.

All the stations upstream of Currie's Rapids are relatively stable, therefore there is little change in these sections from year to year.

### 6.8 ASSINIBOINE RIVER NEAR HOLLAND (05MH005)

The Holland station is located at the Highway #34 bridge, 198 kilometers downstream of the Brandon station, figure 13. At Holland the channel width has increased to about 80 meters at low flow. The bed is mostly sand, however, there are still several boulders strewn along the bed. A gravel bed is evident downstream.

At low discharges, flow becomes supercritical as it drops over a gravel ledge downstream of the bridge. Water levels taken by a wire-weight gauge on the downstream side of the bridge would be significantly less than those taken by a differential pressure transducer system upstream.

Visual dark bands in the flow are characteristic of Allen cells. Along with the helical flow, eddies are present on the south side of the channel, upstream of the bridge, producing upstream velocities.

The bridge, used for the measurements is at an angle of 67 degrees to the flow, significantly less than the 90 degrees required for a line of measure by ISO 748. The bridge has six piers in the flow around which massive boulders have been placed as scour protection.

The Cypress River enters the Assiniboine 1.9 kilometers upstream of the Holland station. Sediment deposited by the Cypress River has resulted in the formation of several bars and islands in the Assiniboine. A stream of sediment could be seen, in air photos taken during high flow, trailing off the downstream end of Island "A", figure 13. A significant misrepresentation would result in suspended sediment concentrations if depth integrating were carried out in the panel through which this streamer passes. Adjacent panels appear to have a much lower concentration.

The numerous bars at this station location would result in increased turbulence. This increased turbulence would locally suspend additional particles, increasing the measured suspended sediment concentration.

## 6.9 <u>ASSINIBOINE RIVER AT ROSSENDALE</u> (<u>05MJ005</u>)

The Rossendale station is located 42.2 kilometers downstream of the Holland station, figure 14. Measurements are taken from the provincial road #242 traffic bridge. The frequency of bar formations is reduced considerably along the reach from Holland to the Rossendale station. Rossendale is located at the eastern edge of the old Assiniboine's delta. Sand banks, some 15 meters high have proven to be unstable. Sediment from the failing banks considerably biased suspended sediment samples. This resulted in the closure of Rossendale as a sediment station.

Flow upstream must negotiate a slight bend before passing beneath the traffic bridge. Poorly developed helical flow would be expected at the station during high flows.

## 6.10 ASSINIBOINE RIVER AT PORTAGE LA PRAIRIE (05MJ003)

The Portage station is located at the R.C.A.F. roadway bridge, 61.7 kilometers downstream of the Rossendale station. After November 1962 a cableway, 2.1 kilometers downstream of the bridge, was used for measurements. The new station is located 5.6 kilometers downstream of the Portage Reservoir Dam.

The channel maintains its 80 meter width at low flow through the Portage station. The stream has a sand bed with moderately steep sand banks. Rip Rap is present on the south bank. There is extensive island and bar formation along this stretch of river.

At the station located at the bridge prior to November 1962 (figure 15), flow is braided by island group "A". Helical flow would take place around the upstream bend and would be expected to progress downstream to the station. Flow then encounters island "B" immediately upstream of the station. Island "B" bifurcates the flow which converges again at the bridge. Island "C" downstream of the bridge would bifurcate the flow again. This would create a very complicated flow pattern which could not be accurately measured by a unidirectional current meter.

At the cableway station, bar formations are still present, however, the impact on the flow conditions is not as severe as that upstream, figure 16. There are large rocks throughout the cross-section. The south bank is near vertical and slumping is evident. The bank material is typical alluvial silt and clay with embedded sand. There is a dike system constructed along the north bank. A stub dike acts to contain the flow to the measurement cross-section. Brush becomes thicker up the banks, with trees on a terrace at the north side of the channel. A large point bar is evident on the north side, the result of an upstream bend.

Due to the steep south bank, hydraulic radius would increase greatly with discharge. Resistance due to vegetation would also increase rapidly with discharge.

There are two obvious sources of error at this station. The cableway is located at an angle of 75 degrees to the flow. As is the case at Holland this is significantly less than the 90 degrees required by ISO 748. Combined with the helical flow at high discharges the non-perpendicular line of measure would bias velocity measurements to the high side. Bias would also be induced by the slumping south bank. Suspended sediment concentration would be misrepresented due to the heavy concentrations caused by the slump.

### 6.11 ASSINIBOINE RIVER AT HEADINGLEY (05MJ001)

The Headingley station is located 128.2 kilometers downstream of the Portage station and 25.9 kilometers upstream of the Assiniboine's mouth. Measurements are taken from a cableway 100 meters downstream of Provincial Road #241 traffic bridge. Measurements prior to 1961 were taken from the traffic bridge, figure 17.

The channel has a width of 105 meters at low flow. There is much rock in the channel, covered by transient sand. The banks are composed of silt and clay with occasional rock embedded. There is a distinctive terrace at about 7 meters above low flow surface level. Trees cover the terrace while brush occupies the banks below the terrace.

There is a railroad bridge 200 meters upstream of the traffic bridge. Over time an island has formed around the center pier. Streamers of sediment flow off the downstream end of this island as far as the traffic bridge. Again a biased measurement of suspended sediment concentration may result if a sample is taken in this streamer.

Headingley is probably the most stable station on the Assiniboine.

## 6.12 STATION SITE SUMMARY

Site anomalies exist at every station at varying degrees. Table 2 provides a summary of station characteristics. It would be impossible to eliminate the physical influence of the channel on flow and sediment measurements although in some cases, it may be possible to reduce the effects through minor program modifications, (Tamburi, 1985).

While site physical impacts often degrade the quality of the raw data, the quality of the data collection program and organization procedures of the Water Survey of Canada Staff deserves high merit.

# Chapter VII

# ANALYSIS OF STATION DATA

## 7.1 VARIABLES STUDIED

Variable relationships were studied in detail at three sediment stations and one flow station. Headingley, Portage la Prairie, and Holland were all used to analyze flow and sediment data relationships. Since sediment data is not taken at the Russell station, only flow parameters were studied there.

The data set at the Portage station was split into two groups: Before 1969 and after 1969 so that the impacts of the Portage Diversion could be studied. The data set at the Russell station was also split into two groups: Before 1968 and after 1968, so that the impacts of the Shellmouth Dam could be assessed. Finally, the data set from the Holland station were seperated into estimated and non-estimated data, in order to assess the quality of estimated data. A discussion of the preceeding three studies follows as does a discussion of variable relationships at each station.

For the three sediment stations, a large number of hydraulic and sediment variables were plotted.

Velocity, width, area, depth, slope, Chezy's C, Froude number, tractive shear, stream power, shear velocity, suspended sediment discharge, suspended bed material discharge, medium suspended bed material grain size, and gradation coefficient of suspended bed material were all plotted against discharge.

Velocity, depth, slope, Chezy's C, Froude number, tractive shear, stream power, shear velocity, and temperature were all plotted against suspended sediment discharge, suspended bed material discharge, median grain size of suspended bed material and the gradation coefficient of the suspended bed material.

## 7.2 INVERSE SLOPE VS. DISCHARGE RELATIONSHIP

While most relationships were typical and expectable, one rather unorthodox relationship occurred. At the upper three stations, Russell, Holland and Portage, water surface slope was found to decrease as discharge increased, figure 18. Hydraulically this does not seem logical since more energy is required to convey an increasing discharge through a given section. Therefore the water surface or energy slope, should increase with discharge. However this was not the case. Field trips were made to each of the stations where this phenomena occurred. Physical inspection of the stations reveals that there is a greater amount of upper bank brush at the downstream station in each reach. Therefore although the water level rises upstream with an increasing flow, there is a more rapid rise in water levels downstream due to the increased roughness. It can be shown from Manning's equation that if discharge and roughness simultaneously increase, the water surface slope may decrease. This is this most likely cause of the inverse slope-discharge relationship.

Another concern was the length of the reach that was used to obtain the water suface slope at a station. The local slope along the reach between two stations may change several times within the reach. The slope used between two stations is the average slope not the local slope at that station. It would therefore be advantageous to install two water level recorders a few hundred meters apart at each station in order to obtain local slopes, as the local slope supplies the energy to transport sediment through a station and not the average reach slope. Differential pressure transducers lend themselves to automatic data acquisition of local slopes.

## 7.3 VARIABLE RELATIONSHIPS AT RUSSELL (05ME001)

Since slope vs. discharge is an inverse relationship at Russell (figure 19), any relationship with slope as one of the variables will also be inverse to any expected function.

Velocity, width, area, depth, tractive shear, stream power, and shear velocity were all found to be power functions increasing with discharge. figures 20 to 26.

As previously discussed in Section 6.5, there are two very prominent shale and cobble bars at the Russell station. During spring run-off, Conjuring Creek and Smith Creek continue to deposit gravel and shale in the section. Since the closure of the Shellmouth Dam, flows have not been large enough to wash away these deposits of shale. As a result they continue to grow. Flow in the Assiniboine encounters these bars when discharge is about 25 to 30 cms.

The presence of the bars is clear on all the variable plots. Perhaps the most evident is the relationship between Chezy's C and discharge. The relationship is basically a power function with a 'blow out' at 20 to 30 cms. Roughness increases steadily with discharge up to 20 cms. When the shale bars are encountered at 20 cms, the roughness increases rapidly. At 40 cms, when flow over the bars is substantial, roughness then decreases to a constant channel roughness of C=55. (figure 27).

For the relationship between velocity and discharge, velocity also increases rapidly when flow is present over the bars. When the depth increases over the bars, the velocity falls off (figure 20).

The relationship between top width and discharge (figure 21) indicates a width of 33 meters for a variety of discharges. This may be the result of inconsistency between observers in dealing with the bars. This inconsistency is also reflected in the area vs. discharge relationship. (figure 22).

For discharges between 10 and 30 cms. depth appears to remain constant while width increases with discharge. Once flow is established over the shale bars, depth again increases (figure 23).

The relationship between Froude number and discharge shows that flow becomes supercritical over the shale bars between discharges of 20 to 30 cms, the Froude number decreases to a constant of 0.24 (figure 28).

Shear velocity, tractive shear, and stream power all increase when flow depths over the bars are small, then decrease before increasing again with discharge (figures 24 to 26).

## 7.4 VARIABLE RELATIONSHIPS AT HOLLAND (05MH005)

At the Holland station, slope vs. discharge (figure 29) is an inverse relationship, therefore any relationship with slope as one of the variables will also be inverse to the expected function.

Area, depth, tractive shear, stream power, and shear velocity all linearly increase with discharge, figures 30 to 34.

Velocity, width, and median grain size of suspended bed material are all power functions increasing with discharge, figures 35 to 37.

One interesting relationship is that of gradation coefficient vs. discharge. The gradation coefficient decreases exponentially with increasing discharge. This would indicate that as the discharge increases and more sediment is in transport, that sediment becomes more uniform in its size distribution. (figure 38). This may reflect the uniform nature of the deltaic sand deposited throughout the Holland region of Spruce Woods Provincial Park, as it overwhelms small amounts of coarser till derived sediment at higher discharges.

The relationship between Froude number and discharge indicates that the Froude number decreases exponentially with discharge. This would be expected since depth increases with discharge (figure 39).

Roughness is shown to remain almost constant throughout the range of discharges plotted on figure 40, in the relationship Chezy vs. discharge. This is the result of velocity increasing more rapidly than shear velocity as discharge increases, due to the channel geometry.

Table 3 lists the equations derived by regression for those relationships involving suspended sediment discharge (QS) and suspended bed material discharge (QSBM), figures 41 to 58.

For the relationships involving QSBM the estimated data was eliminated from the data set. If estimated data were included only two relationships would result with a confidence of 95%. This will further be discussed in Section 7.10.

For the relationships involving QS, the estimated data were left in the data set since there was a wider range of sediment loads, thus a better defined relationship. Five relationships were significant at the 95% confidence level.

The equations derived are be expected to be unique for the particular station studied. Each station has varying physical characteristic which would result in different equations. Some strong similarities will, however, persist between equations from various stations. This will be discussed in Section 7.8.

## 7.5 VARIABLE RELATIONSHIPS AT PORTAGE BEFORE 1969 (05MJ003)

At Portage, both before and after 1969, slope again is inversely related to discharge, figure 59. Therefore, any relationship with slope as one of the variables will also be inverse to the expected function.

Velocity, area, depth, tractive shear and shear velocity are power functions increasing with discharge, figures 60 to 64. Width and stream power are linearly proportional to discharge, figures 65 & 66.

Chezy's C (figure 67) and Froude number (figure 68) both asymptomically decrease with increasing discharge to constant values of C=34 and Froude number =0.20. These values are also characteristic of this particular section. Median grain size of suspended sediment (figure 69) increases slightly while gradation coefficient (figure 70) decreases slightly with increasing discharge, as is the case at Holland.

Table 4 lists the equations derived by regression for those relationships involing suspended sediment discharge (QS) and suspended bed material discharge (QSBM), figures 71 to 88.

## 7.6 VARIABLE RELATIONSHIPS AT PORTAGE AFTER 1969 (05MJ003)

Those power functions increasing with discharge include velocity, width, area, depth, tractive shear, and shear velocity, (figures 90 to 95). Stream power linearly increases with discharge, figure 96.

After 1969 median grain size of suspended bed material appears to remain constant with discharge (figure 97), while the gradation coefficient increases, figure 98. This is opposite of those relationships before 1969. This would probably be a result of the construction of the Portage Reservoir Dam. The Reservoir would act to filter out any large particles. As discharge increases there are no additional large particles to transport. There is a peak in $D_{50}$ at a discharge of 350 cms. This may be the result of flow mobilizing the coarse sand of upstream bars and islands. Once this material is mobilized an increase in flow no longer furthers an increase in grain size.

Chezy's C (figure 99) and Froude (figure 100) number are again closely related. Both values asymptomically decrease with an increase in discharge to constant values of C=48 and F=0.20. The constant value of Froude number did not change from before 1969, however, the channel roughness appears to have increased.

Table 5 lists the equations derived by regression for those variables involving suspended sediment discharge (QS) and suspended bed material discharge (QSBM), figures 101 to 118.

## 7.7 VARIABLE RELATIONSHIPS AT HEADINGLEY (05MJ001)

The Headingley station is the only station on the Assiniboine where slope increases with discharge, (figure 119). There is considerable scatter to the plot, however, the relationship is identifiable. As a result, slope also increases with suspended bed material discharge and total suspended sediment discharge.

The reach used to define the slope at Headingley is that from the Portage station to the Headingley station. The channel through this reach is the most stable over recent history, flowing along glacial Lake Aggasiz's bed.

Due to the stability of the Headingley station, the relationships studied are all very well defined.

Those power functions increasing with discharge include: velocity, width, area, depth, roughness, Froude number, tractive shear and shear velocity, figures 120 to 127.

Stream power vs. discharge again proved to be a linear relationship, which is the case at all upstream stations with the exception of Russell, figure 128.

Median grain size of suspended bed material increases with discharge (figure 129), while gradation coefficient shows much scatter, figure 130.

Table 6 lists the equations derived by regression for those relationships involving suspended sedidment discharge (QS) and suspended bed material (QSBM), figures 131 to 148.

## 7.8 SUMMARY OF VARIABLE RELATIONSHIPS

Velocity, width, area, depth, tractive shear, and shear velocity all are power functions increasing with discharge. In some cases, such as at Holland, these functions may take on a linear form, depending very much on the geometry of the cross-section at the station.

From Leopold, Wolman & Miller (1964): for a natural channel increasing discharge at a given cross section, the width (w), mean depth (d), and mean velocity (v), all increase as power functions:

$w=aQ^b$ $d=cQ^f$ $v=kQ^m$

where a, c, k, b, f, and m are numerical coefficients.

These coefficients are unique to each station. Since wxd=A and wxdxv=Q, then:

$aQ^b \times cQ^f \times kQ^m = Q$

At the Russell station, the following relationships were derived:

$w = 18.20\ Q^{.209}$

$d = .256\ Q^{.416}$

$v = .213\ Q^{.376}$

where:

$0.209 + 0.416 + 0.376 = 1.001$

$$(18.20)(.256)(.213) = 0.9924$$

At the Holland station, the following relationships were derived:

$$w = 12.02\ Q^{.396}$$

$$d = 0.132\ Q^{.489}$$

$$v = 0.635\ Q^{.115}$$

where:

$$0.396 + 0.489 + 0.115 = 1.000$$

$$(12.02)(0.132)(0.635) = 1.008$$

At the Portage station before 1969, the following relationships were derived:

$$w = 67.51\ Q^{.067}$$

$$d = .058\ Q^{.691}$$

$$v = 0.257\ Q^{.257}$$

where:

$$0.067 + 0.691 + 0.241 = 0.999$$

$$(67.51)(.058)(0.257) = 1.006$$

At the Portage station after 1969 the following relationships were derived:

$$w = 58.88\ Q^{.09}$$

$d = 0.0881\ Q^{.612}$

$v = 0.192\ Q^{.299}$

where:

$0.090 + 0.612 + 0.299 = 1.001$

$(58.88)(0.088)(0.192) = 0.995$

At the Headingley station the following relationships were derived:

$w = 66.30\ Q^{.101}$

$d = 0.156\ Q^{.517}$

$v = 0.099\ Q^{.378}$

where:

$0.101 + 0.517 + 0.378 = 0.996$

$(66.30)(0.156)(0.099) = 1.024$

It is evident from the previous equations that width, depth, velocity, and discharge follow those relationships derived by Leopold and Maddock (1953).

The relationship between suspended load (QS) and discharge (Q) derived by Leopold and Langbein (1962) shows a power function:

$QS = pQ^{j}$

(where p & j are constants) The above relationship is also unique for a given cross-section since roughness and slope play an important role in predicting sediment discharge. At all four sediment stations analyzed, a power function of the above form was found to be the 'best-fit' relationship.

Leopold and Langhein (1962) also state that the most sensitive variable relating to sediment transport is stream power (Po), since it relates slope with velocity and depth as follows:

$$Po = \rho RSV$$

where:

$\rho$ = specific weight of water

R = Hydraulic Radius

V = mean velocity

Those variables which best predict sediment transport are velocity, depth, slope, and roughness. The following relationship was derived by Leopold and Langerbein (1962):

$$C \propto \frac{(vd)^{0.5} s^{1.5}}{n^4}$$

where: C = sediment transport

v = velocity

s = slope

d = depth

n = manning's roughness factor

Stream power consistently yields well defined relationships with total suspended load (QS) and bed material load (QSBM) at all the sediment stations analyzed. Multivariate regression was carried out at the Holland and Portage stations in order to define the best predictive equation for bed material discharge. The result was a one variable model relating power to bed material discharge. The second best equation was a power function relating velocity to discharge.

All the equations involving total load and bed load are of similar form among the stations analyzed. The coefficients and exponents change for each equation at the various stations since each relationship is unique to that station.

## 7.9 ACKERS-WHITE AND COLBY COMPARISON

The Ackers-White (1973) sediment transport function and the Colby (1964) method were used to compare measured sediment transport rates to predicted values. Four sets of data were used from the following Water Survey of Canada stations: Holland, Portage before 1969, Portage after 1969, and Headingley.

The Water Survey of Canada measured values for sediment load do not include bed load but include wash load. Wash load was eliminated from the measured values by multiplying by the percentage of suspended material larger than 0.062 mm. No correction was made for the absence of bed load, hence, the measured values should be increased by some small percentage since the Colby and Ackers-White methods both include bed load.

The comparison was carried out for a range of five discharges at each station. The results are summarized in Table 7. Both Ackers-White and Colby predict higher loads than those recorded by Water Survey of Canada. The average difference for both functions is about one to two times the measured values. Colby generally predicts sediment transport rates slightly higher than Ackers-White.

These results would indicate that the Assiniboine is armoured along much of its reach as previously discussed in Section 4.2. Sediment depletion was evident from inspection of the river. The high values of sediment discharge predicted by both the Ackers-White and Colby methods, confirms the theory that the Assiniboine is not a fully alluvial channel, rather it is controlled very much by the local geology.

## 7.10 ESTIMATED VS. MEASURED DATA

In an attempt to save time, money and effort, a method of estimating suspended sediment concentrations with just one depth integrated sample is sometimes used by Water Survey of Canada and other organizations. This method is known as K-factor sampling. To obtain a K-factor sample, instead of sampling at every fifth vertical, sampling is done at one vertical of a section and adjusted using a pre-determined coefficient to yield a value representative of the average concentration of the stream. The coefficient is determined by collecting single depth integrated sample data for a range of discharges and using regression statistics with the measured data, taken from multiple verticals, held as the dependent variable. The coefficient varies with discharge and with the panel selected. The single panel giving the highest correlation with the average concentration is then used for K-factor sampling. The coefficient is defined as CV/CA for any single panel, where CV is the sample vertical concentration and CA is the average concentration across the section.

In a 1979 report by Inland Waters Directorate titled 'Distribution of Suspended Sediment Concentrations at Two Stream Stations in Manitoba', it is shown that K-factor data at the Headingley station on the Assiniboine, and the St. Agathe station on the Red River does not exceed a 4% difference from measured data under good conditions. These two stations approach more ideal conditions than any of the remaining stations on the Assiniboine River. K-factor sampling is carried out at the Holland station, at which sediment moves in any state but steady. In a situation such as that at Holland, it is virtually impossible to obtain a single representative sample. Upstream landslides create huge sand waves which propagate downstream to Holland in pulses, requiring days to pass. The Cypress River and numerous springs wash in sediment a few hundred meters upstream of the station in discrete events. Sediment then does not move past the station or through any one panel in an equilibrium state. In a case such as this good measured data is difficult enough to obtain. Good K-factor data is impossible.

In a statistical comparison between K-factor data and measured data, regressions were run holding suspended bed material discharge as the dependent variable on Froude number, Manning's n, velocity, discharge, shear velocity, tractive shear, mean depth and stream power. In all cases studied the measured data yield well defined relationships with R-squared values varying from a low of 0.65 to a high of

0.93. K-factor data recorded a highest R-squared value of 0.57, but only 2 K-factor relationships were significant at the 95% confidence level. Interestingly enough, the best defined relationship for the measured data, suspended bed material discharge versus velocity, with an R-squared of 0.93, was not even significant for the K-factor data. The results of the comparison are summarized in Table 8.

Combination of measured data with K-factor data yields relationships which are much worse than those generated by measured data alone. It would be reasonable to exclude any K-factor data from further study. A similar problem was encountered by Tamburi (1978) in studying sediment transport on the lower Fraser River. K-factor data was therefore excluded from use in that study. In a similar study by Mannerstrom and Mclean (1985), the inclusion of estimated data led to poorly defined relationships.

A plot of slope versus discharge at the Holland station (figure 149) indicates two totally different relationships for stage-discharge and measured data. The measured data yields the inverse slope-discharge relationship characteristic of Russell, Holland and Portage. The stage-discharge data indicates a proportional relationship having a regression line with a positive slope. The two regression lines intersect at nearly right angles. This indicates that the estimate for discharge is worse than the estimate for suspended sediment concentration.

The question should then be asked if K-factor data is really worth while obtaining at all. At this point it should be noted that the station previously discussed is far from ideal. At more stable reaches of some streams it has been shown that K-factor data could be within 4% of measured values (Inland Waters 1979). The station should first be studied in some detail before K-factor sampling is permitted. If K-factor sampling is carried out, the coefficients being used should be revised annually.

## 7.11 EFFECTS OF THE PORTAGE DIVERSION

In 1969 construction was completed on the Assiniboine River Diversion works. The diversion is located 5.6 kilometers upstream from the Portage station. The following is a Prairie Farm Rehabilitation (PFRA) description of the works from a public brochure (1968) :

> "A reservoir covering 1,610 acres with a storage capacity of 14,600 acre-feet is being created by the construction of an earthfill dam 1,400 feet long, and rising 35 feet above the bed of the Assiniboine River. A concrete spillway control structure equipped with two Bascule fish-belly type gates, 13 feet by 75 feet in size, is located on the south side of the dam. These gates are the largest of their type in North America.
>
> Also located in this structure is a low-level gate-controlled riparian outlet conduit. North and west of the dam at the upper end of the diversion channel, an inlet control structure regulated the flow to Lake Manitoba. This is accomplished by the use of four vertical lift gates each measuring 14 1/2 feet by 40 feet. The diversion channel is designed to carry a flow of up to 25,000 cubic feet per second.

> As the Portage Diversion is an unlined channel, it was necessary to construct it in such a way as to keep water velocities below those which would cause erosion. When the diversion reservoir is full, there is a drop of 50 feet between the diversion channel inlet and the level of Lake Manitoba, over a relatively short distance of 18 miles. To keep velocities down to about 3 1/2 feet per second, three drop structures along the diversion route are incorporated into the design. The channel has widths varying from 175 feet to 1,200 feet, with an average width of 600 feet. The greater width is through the Delta Marsh area adjacent to the lake. Dykes have been built along the entire length of the channel using much of the 10,000,000 cubic yards of excavated material. The design depth of water above the surrounding terrain will generally be equal to the ground water level when the channel is operating at peak discharge."

Sediment data were recorded before and after the diversion was operational. These data were separated into two groups: Before 1969 and after 1969. Various relationships were studied relating suspended bed material discharge to discharge, velocity, depth, stream power, shear velocity, and tractive shear. The results of the before and after comparison of these relationships are summarized in Table 9. An F-test was carried out at the 99% confidence level to detect any significant change in any relationship after the construction of the diversion works. It was discovered that any relationship involving the parameter 'depth' did change significantly. This would seem reasonable since degradation would be anticipated downstream of the dam.

The two relationships which did not change were those containing the parameters 'velocity' and 'discharge'. This would also seem reasonable if the channel section has changed hydraulic radius and roughness to compensate for a reduction in slope.

## 7.12 EFFECTS OF THE SHELLMOUTH DAM

The Shellmouth Dam, completed in 1969 is a 1280 meter long, 20 meter high, earth fill dam. Closure ofthe dam created a 5.5 kilometer long reservoir with an area of 15,200 acres and a storage capacity of 387,000 acre-feet. The spillway has a capacity of 1500 cms. The dam acts to reduce flood peaks and has increased the minimum flow from 0.2 cms to 8.5 cms.

The Water Survey station near Russell was used to assess the impacts of the Shellmouth Dam.
The Russell station is located 46.1 kilometers downstream (river distance) of the dam.

One obvious result of the closure of the Shellmouth Dam is the growth of the two shale bars at the Russell station, discussed in Section 6.5. Since flood peaks are reduced by the storage action of the reservoir, high discharges are no longer adequate to flush the Assiniboine's channel of the sediment deposited by tributaries. The result is the continual growth of bars in the channel downstream of the dam. Over time these bars become stabilized by vegetation and greatly increase the roughness of the channel, lowering its capacity. The effect of these bars on the various hydraulic parameter relationships are discussed in Section 7.3.

A plot of slope vs. discharge at Russell, figure 150, shows that slope is stratified by year. The year of data taken is coded with a letter from A to I. All the data recorded before 1969 are labelled 'A'. Data taken in 1970 is labelled 'C'. Data taken in 1971 is labelled 'D', etc. up to 1976 which is labelled 'I'. From figure 150, generally the more recent data has a milder slope, at a given discharge, than earlier data. This indicates that degradation has been steadily increasing since closure of the dam. This would be expected since the sediment depleted flow, downstream of the dam, tries to reach equilibrium again by degrading its bed, complying with Lane's theory (1955).

# Chapter VIII

# MOBED STATION TO STATION ANALYSIS

## 8.1 MOBED MODEL

Station to station sediment dynamics were assessed by use of the MOBED model. The MOBED model was written by B. G. Krishnappen (1978) for the Canada Centre for Inland Waters. MOBED is a coupled water and sediment routing model. It is used to predict the unsteady flow characteristics in mobile boundary channel flows.

The model uses a double sweep finite difference method to solve three partial differential equations for sediment continuity, flow continuity, and the momentum equation. Sediment transport is calculated by use of the Ackers-White sediment transport function. The frictional slope, used in the momentum equation is calculated by using the friction factor relations of Kishi and Kuroki.

## 8.2 HYPOTHESIS

From the geomorphic study, it appears that the Assiniboine River is prevented from degrading upstream of Brandon by the armor at Currie's Rapids. In order to test this hypothesis, it was desired to model the river as a totally sand bed stream. If the model predicts degradation at Currie's Rapids, along with degradation at other points of armouring, then it could safely be concluded that the Assiniboine is not in an equilibrium state but rather is 'held up' by Currie's Rapids. It was also desired to estimate the time required to reach equilibrium if armour were not present.

## 8.3 MODELLING PROCEDURE

The reach of river modelled using MOBED was that from the Water Survey Station near Brandon to the Portage Reservoir, a distance of about 300 kilometers. The reach was broken down into 24 sections of equal length, yielding 25 grid points. The bottom elevation and initial flow depth were input for each of the 25 grid points, figures 151 to 164. The cross-sectional geometry at each grid point was obtained by using the nearest of 15 actual cross-sectional surveys. The downstream water surface elevatoin (at the Portage Reservoir) was fixed.

A mean annual flood flow of 300 cms was used as a constant discharge. A time step of two days was used and the model was run for an equivalent period of two years, about 500 years real time. Appendix C lists the input and output from the model.

## 8.4 MOBED RESULTS

The MOBED model predicted substantial degradation at the Brandon station with resulting aggradation at the Portage Reservoir. Degradation of 14 meters was predicted by MOBED at Brandon after a period of two years, figure 165.

Four reference points along the Assiniboine's profile were used to study the change in bed elevation predicted by MOBED. The reference points were located at the upstream boundary, and 100, 200 and 300 kilometers downstream of the upstream boundary, respectively, labelled Range 00.00 to 300.00.

At the upstream boundary (Brandon) the following equation was derived:

$$\text{bed elevation (m)} = 389\ (\text{days})^{-0.01055}$$

with an R-squared of 0.952

At 100,000 modelled days, degradation of 34 meters is predicted. The final bed elevation is at 344 (m). 100,000 modelled days is approximately equal to 10000 years real time.

Degradation is rapid at first then slowly decrease to the equilibrium state over time, figure 166.

At Range 100.00, 100 km. from the upper boundary, bed elevations rise for about 50 days before decreasing. This would appear to be the result of a transient sediment pulse moving through the range. The pulse would be generated by rapid degradation upstream, figures 167 & 168.

At Range 200.00, 200 km. from the upper boundary and 100 km. upstream of the Portage Reservoir aggradation is evident. The aggradation begins gradually after 40 days then levels off to an equilibrium elevation of 315.8 meters, 0.8 meters above the initial elevation, figure 169.

At Range 300.00, at the Portage Reservoir, aggradation is rapid for the first 75 days then drops off steadily to the equilibrium elevation. Aggradation of 0.8 meters is evident after two modelled years, figure 170.

At the downstream boundary (Portage Reservoir), the following equation was derived:

$$\text{bed elevation (m)} = 282.227\ (\text{days})^{0.0004088}$$

with an R-squared of 0.988

At 100,000 modelled days the final bed elevation is at 283.56 meters, nearly the same as that after the modelled two years.

## 8.5 MOBED SUMMARY

The change in bed elevations throughout the modelled reach were those to be expected if the initial hypothesis were correct. It would then be safe to conclude that the Assiniboine River is prevented from upstream degradation by the armour of Currie's Rapids. This would also confirm the sediment depletion of the stream.

# Chapter IX

## CONCLUSIONS

1. The Assiniboine River is not in an equilibrium state of sediment transport. Sediment is being transported under capacity.

2. The stream is armoured along much of its reach resulting in a temporary slope equilibrium.

3. Degradation is prevented from progressing upstream of Brandon by the presence of Currie's Rapids.

4. If the stream were totally alluvial, degradation of 14 meters would have already occured at Brandon.

5. The stream is depleted of sediment resulting in a stable meandering pattern. If the sediment load increased the stream would shift to a braided form.

6. Sediment is contributed by landslides, ground water springs and cut-offs and is transported in pulses or sand waves.

7. Roughness increases as the stream progresses downstream, resulting in an inverse slope-discharge relationship.

8. The theoretical discharge relationships of Leopold, Wolman, & Miller (1964) are verified by the Assiniboine data.

9. The relationship between sinuosity and valley slope follows that of Schumm and Khan (1973).

10. The Assiniboine is close to becoming a braided stream along the reach from Holland to Portage.

11. As the result of the construction of the Assiniboine Diversion and the Shellmouth dam, downstream regime has changed significantly.

12. K-factor estimates for suspended sediment concentrations and stage-discharge estimates are substantially inferior to measured values at the stations investigated.

# Chapter X

## RECOMMENDATIONS

1. The use of K-factor data must be re-evaluated on a station by station basis.

2. Water Survey of Canada station sites should be selected with reduction of non-ideal physical influences on measured data being a priority.

3. Sediment transport on the Assiniboine does not take place in a steady state. Sand waves propagate as pulses. Sediment sampling should be carried out in repetitions during the passing of several of these waves, or at multiple sections over a sequence of waves.

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## Appendix A

## PARAMETER DEFINITIONS

Mean Velocity, V

Mean Velocity is the average flow velocity past a station at that instant of measure. (m/s)

Top Width, W

Top Width is the width across the channel perpendicular to its banks at the level of flow. (m)

Hydraulic Depth, D

Hydraulic depth is the mean depth of flow at a station, at that instant of measure. (m)

Cross-Sectional Area, A

Cross-sectional area is the area of flow at the cross-section of measure. ($m^2$)

Instantaneous Discharge, Q

Instantaneous discharge is the discharge of the channel at that instant of measure, where:

$$Q = VA \quad (m^3/sec)$$

Water Temperature, T

In degrees Celcius, (°C).

Slope, S

Slope is the water surface slope at a station, at that instant of measure.

Chezy's C

C is Chezy's resistance coefficient. ( $m^{\frac{1}{2}}/sec$ )

Froude Number, F

F is the ratio of internal to gravitational forces, where:

$$F = \frac{V}{(gD)^{\frac{1}{2}}} \qquad \text{(dimensionless)}$$

Tractive Shear,

Tractive Shear is the shear developed on the wetted area of the channel bed, acting in the direction of flow, where:

$\tau = \gamma R S_b \quad (N/m\ )$

and where:

$\gamma$ = specific weight of water

R = hydraulic radius

$S_b$ = bed slope

Shear Velocity, V*

Shear Velocity is defined as:

$V^* = (\tau/\rho)^{\frac{1}{2}}$ where:

$\rho$ = density of fluid

$\tau$ = bed shear stress

Stream Power, Po

Stream power is defined as:

$Po = \tau V \quad (N/ms)$

Suspended Sediment Discharge, QS

QS is the quantity of sediment in the suspended mode that passes a reference point in a given period of time. (tonnes/day)

Suspended Bed Material Discharge, QSBM

QSBM is the quantity of suspended sediment greater than 0.062 mm diameter that passes a reference point in a given period of time. (tonnes/day)

Median Size of Suspended Sediment, $D_{50_S}$

$D_{50_S}$ is the median particle size of the suspended sediment load. (mm)

Median Size of Suspended Bed Material, $D_{50_{BM}}$

$D_{50_{BM}}$ is the median particle size of the suspended bed material. (mm)

Gradation Coefficient of Suspended Sediment, $\phi s$

$\phi s$ is the distribution of particle sizes in the suspended sediment load. (dimensionless)

Gradation Coefficient of Suspended Bed Material, $\phi BM$

$\phi_{BM}$ is the distribution of particle sizes in the suspended bed material load. (dimensionless)

Appendix B

# VARIABLE GENERATION PROGRAM

```
$JOB
C     ASSINIBOINE RIVER SEDIMENT STUDY
C
C     UNIVERSITY OF MANITOBA, WINNIPEG, CANADA
C
C
C     THIS PROGRAM IS ADAPTED FROM WESTERN CANADA HYDRAULICS
C     LABORATORIES LTD, PORT COQUITLAM BC
C
C
C
C
C
C
C
C
C     THE PURPOSE OF THIS PROGRAM IS
C     1) TO READ IN AND STORE HYDRAULIC AND SEDIMENT DATA
C     2) TO CALCULATE OTHER FLOW VARIABLES FROM THIS DATA
C     3) TO CONVERT ALL IMPERIAL QUANTITIES TO METRIC
C
C
C     A 3-DIMENSIONAL ARRAY IS USED TO STORE ALL DATA.
C     THE FASHION OF DATA STORAGE IS AS FOLLOWS
C
C
C     STATION IDENTIFICATION NUMBERS
C
C     DATA(1,J,K)= HEADINGLEY
C     DATA(2,J,K)= PORTAGE 1956-1968
C     DATA(3,J,K)= PORTAGE 1969-1976
C     DATA(4,J,K)= HOLLAND
C
C     DAY SEQUENCE (J) CORRESPONDS TO INPUT SHEETS
C
C
C     INPUT VARIABLES OF (K)
C
C     DATA(I,K,1) =DAY
C              2  =MONTH
C              3  =YEAR
C              4  =UNIT CODE (ENG=0,METRIC=1)
C              5  =TOP WIDTH
C              6  =X-SEC. AREA
C              7  =DISCHARGE Q (CMS)
C              8  =TEMPERATURE (CELSIUS)
C              9  =CONCENTRATION (MG/L)
C             10  =SEDIMENT PERCENT .LT. 0.062 (MM)
C             11  =STAGE AT STATION (FT)
C             12  =STAGE UP OR DOWN STREAM (FT)
C             13  =MEAN GRAIN SIZE D50 (MM)
C             14  =SIZE GRADATION (PHI)
C
C     COMPUTED VARIABLES OF (K)
C
C             15  =MEAN VELOCITY (M/SEC)
C             16  =SUSPENDED LOAD (TNE/DAY)
C             17  =SUSPENDED BED MATERIAL LOAD (TNE/DAY)
C             18  =HYDRAULIC DEPTH (M)
C             19  =WATER SURFACE SLOPE
C             20  =WETTED PERIMETER (M)
C             21  =HYDRAULIC RADIUS (M)
C             22  =MANNING N
C             23  =SHEAR VELOCITY V* (M/SEC)
C             24  =CHEZY C
C             25  =FROUDE NUMBER F
C             26  =TRACTIVE SHEAR TS (N/SQ.M)
```

```
C              27  =STREAM POWER (N/M*S)
C
C
C     PROGRAM IN FORTRAN IV
C
C
C
      DIMENSION DATA(4,200,30)
C
      DO 100 I=1,4
      READ,NDAYS
      DO 200 J=1,NDAYS
C
      READ(5,20) (DATA(I,J,K),K=1,14)
   20 FORMAT(4F2.0,F4.0,F5.0,F4.0,F4.1,F5.0,F3.2,2F5.2,F4.3,F4.2)
C
C     CONVERT WIDTH AND AREA TO  METERS
C
      DATA(I,J,5)=DATA(I,J,5)*0.3048
      DATA(I,J,6)=DATA(I,J,6)*0.3048*0.3048
C
C     CONVERT STAGE TO METERS
C
      DATA(I,J,11)=DATA(I,J,11)*0.3048
      DATA(I,J,12)=DATA(I,J,12)*0.3048
C
C     COMPUTE VELOC,Q(S),Q(SBM),Y
C
      DATA(I,J,15)=DATA(I,J,7)/DATA(I,J,6)
      DATA(I,J,16)=DATA(I,J,7)*DATA(I,J,9)*0.08640
      DATA(I,J,17)=DATA(I,J,16)*(1.0-DATA(I,J,10))
      DATA(I,J,18)=DATA(I,J,6)/DATA(I,J,5)
C
C     SLOPE CALCULATIONS
C
      IF(I.EQ.1) GO TO 301
      IF(I.EQ.2) GO TO 302
      IF(I.EQ.3) GO TO 303
      IF(I.EQ.4) GO TO 304
C
  301 DATA(I,J,11)=DATA(I,J,11)+228.60
      DATA(I,J,12)=DATA(I,J,12)+255.42
      DELTA=DATA(I,J,12)-DATA(I,J,11)
      DATA(I,J,19)=DELTA/128200.0
      GO TO 400
  302 DATA(I,J,11)=DATA(I,J,11)+255.42
      DATA(I,J,12)=DATA(I,J,12)+292.60
      DELTA=DATA(I,J,12)-DATA(I,J,11)
      DATA(I,J,19)=DELTA/109500.0
      GO TO 400
  303 DATA(I,J,11)=DATA(I,J,11)+255.42
      DATA(I,J,12)=DATA(I,J,12)+228.60
      DELTA=DATA(I,J,11)-DATA(I,J,12)
      DATA(I,J,19)=DELTA/128200.0
  304 DATA(I,J,11)=DATA(I,J,11)+292.60
      DATA(I,J,12)=DATA(I,J,12)+353.57
      DELTA=DATA(I,J,12)-DATA(I,J,11)
      DATA(I,J,19)=DELTA/198000.0
C
C     COMPUTE WP,R,N
C
  400 DATA(I,J,20)=DATA(I,J,5)+DATA(I,J,18)
      DATA(I,J,21)=DATA(I,J,6)/DATA(I,J,20)
      DATA(I,J,22)=((DATA(I,J,21)**0.667)*SQRT(DATA(I,J,19)))/DATA(I,J,1
     15)
C
```

```
C      COMPUTE V*,C,F,TS,P
C
       DATA(I,J,23)=SQRT(9.81*DATA(I,J,21)*DATA(I,J,19))
       DATA(I,J,24)=(DATA(I,J,15)*3.123)/DATA(I,J,23)
       DATA(I,J,25)=DATA(I,J,15)/SQRT(DATA(I,J,18)*9.81)
       DATA(I,J,26)=DATA(I,J,21)*DATA(I,J,19)*9810.0
       DATA(I,J,27)=DATA(I,J,15)*DATA(I,J,26)
C
C      END OF CALCULATIONS
C
  200  CONTINUE
C
C
       IF(I.EQ.1) WRITE(6,501)
       IF(I.EQ.2) WRITE(6,502)
       IF(I.EQ.3) WRITE(6,503)
       IF(I.EQ.4) WRITE(6,504)
C
  501  FORMAT('1',////11X,'ASSINIBOINE RIVER AT HEADINGLEY'//)
  502  FORMAT('1',////11X,'ASSINIBOINE RIVER AT PORTAGE BEFORE 1969'//)
  503  FORMAT('1',////11X,'ASSINIBOINE RIVER AT PORTAGE AFTER 1969'//)
  504  FORMAT('1',////11X,'ASSINIBOINE RIVER AT HOLLAND')
C
       WRITE(6,505)
C
  505  FORMAT(10X,'     Q    D50    PHI          Q(S)       Q(SBM)       SLOPE
     5     V*  CHEZY     FROUDE     SHEAR          POWER'/)
C
       DO 206 J=1,NDAYS
C
       WRITE(6,506) DATA(I,J,7),(DATA(I,J,K),K=13,14),(DATA(I,J,K),K=16,1
     67),DATA(I,J,19),(DATA(I,J,K),K=23,27)
C
  506  FORMAT(10X,F5.0,1X,F5.3,1X,F5.2,1X,F11.3,1X,F11.3,1X,F9.7,1X,F8.6,
     61X,F6.2,1X,F8.4,1X,F8.4,1X,F9.4)
C
  206  CONTINUE
C
       WRITE(6,507)
C
  507  FORMAT('1',///11X,'  DATE    CODE   WIDTH     AREA    TEMP    CONC  0.0
     762    STAGE   STAGE   VELOC   DEPTH       WP RADIUS MANNING'/)
C
       DO 208 J=1,NDAYS
C
       WRITE(6,508) (DATA(I,J,K),K=1,3),(DATA(I,J,K),K=4,6),(DATA(I,J,K),
     8K=8,12),DATA(I,J,15),DATA(I,J,18),(DATA(I,J,K),K=20,22)
C
  508  FORMAT(10X,3F3.0,1X,F4.0,1X,F6.1,1X,F7.1,1X,F6.1,1X,F7.0,1X,F5.2,1
     8X,2F7.2,1X,F6.2,1X,F6.2,1X,F6.1,1X,F6.2,1X,F7.5)
  208  CONTINUE
C
       DO 209 J=1,NDAYS
C
       IF(I.EQ.1) WRITE(8,509) (DATA(I,J,K),K=4,27)
       IF(I.EQ.2) WRITE(9,509) (DATA(I,J,K),K=4,27)
       IF(I.EQ.3) WRITE(10,509) (DATA(I,J,K),K=4,27)
       IF(I.EQ.4) WRITE(11,509) (DATA(I,J,K),K=4,27)
C
  509  FORMAT(' ',F4.0,3F7.1,5F8.2,2F7.3,F5.2,2F11.3,F6.2,F10.7,F7.1,F6.2
     9,F8.5,F9.6,F7.2,F7.4,F8.4,F8.4)
C
  209  CONTINUE
  100  CONTINUE
       STOP
       END
```

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 35.1 | 40.5 | 35.5 | 0 | 0 | 0 | 408.13 | 374.55 | 0 | 0 | 0.88 | 0 | 0 | 1.16 | 0.0001918 | 36.2 | 1.12 | 0.01703 | 0.045883 | 59.67 | 0.2604 | 2.1053 | 1.8456 |
| 2 | 0 | 33.5 | 30.1 | 21.4 | 0 | 0 | 0 | 407.85 | 374.27 | 0 | 0 | 0.71 | 0 | 0 | 0.90 | 0.0001919 | 34.4 | 0.87 | 0.01786 | 0.040568 | 54.61 | 0.2390 | 1.6457 | 1.1673 |
| 3 | 0 | 31.7 | 17.3 | 8.2 | 0 | 0 | 0 | 407.43 | 373.67 | 0 | 0 | 0.47 | 0 | 0 | 0.55 | 0.0001929 | 32.2 | 0.54 | 0.01941 | 0.031845 | 46.28 | 0.2041 | 1.0141 | 0.4786 |
| 4 | 0 | 31.7 | 13.6 | 4.6 | 0 | 0 | 0 | 407.30 | 373.25 | 0 | 0 | 0.34 | 0 | 0 | 0.43 | 0.0001946 | 32.1 | 0.42 | 0.02306 | 0.028390 | 37.43 | 0.1661 | 0.8060 | 0.2743 |
| 5 | 0 | 41.8 | 53.7 | 43.7 | 0 | 0 | 0 | 408.34 | 375.36 | 0 | 0 | 0.81 | 0 | 0 | 1.29 | 0.0001885 | 43.0 | 1.25 | 0.01957 | 0.048026 | 52.88 | 0.2289 | 2.3065 | 1.8756 |
| 6 | 0 | 42.1 | 51.2 | 44.7 | 0 | 0 | 0 | 408.40 | 375.46 | 0 | 0 | 0.87 | 0 | 0 | 1.22 | 0.0001883 | 43.3 | 1.18 | 0.01759 | 0.046738 | 58.29 | 0.2525 | 2.1844 | 1.9056 |
| 7 | 0 | 33.5 | 26.7 | 16.1 | 0 | 0 | 0 | 407.74 | 373.82 | 0 | 0 | 0.61 | 0 | 0 | 0.80 | 0.0001938 | 34.3 | 0.78 | 0.01943 | 0.038434 | 49.19 | 0.2167 | 1.4772 | 0.8942 |
| 8 | 0 | 32.6 | 21.5 | 10.7 | 0 | 0 | 0 | 407.51 | 373.54 | 0 | 0 | 0.50 | 0 | 0 | 0.66 | 0.0001941 | 33.3 | 0.65 | 0.02085 | 0.035048 | 44.44 | 0.1963 | 1.2284 | 0.6127 |
| 9 | 0 | 53.0 | 99.4 | 109.6 | 0 | 0 | 0 | 409.47 | 376.65 | 0 | 0 | 1.10 | 0 | 0 | 1.87 | 0.0001875 | 54.9 | 1.81 | 0.01846 | 0.057713 | 59.65 | 0.2571 | 3.3308 | 3.6719 |
| 10 | 0 | 53.3 | 102.2 | 110.2 | 0 | 0 | 0 | 409.53 | 376.71 | 0 | 0 | 1.08 | 0 | 0 | 1.92 | 0.0001876 | 55.3 | 1.85 | 0.01915 | 0.058335 | 57.70 | 0.2486 | 3.4030 | 3.6680 |
| 11 | 0 | 55.2 | 116.1 | 127.4 | 0 | 0 | 0 | 409.79 | 376.92 | 0 | 0 | 1.10 | 0 | 0 | 2.10 | 0.0001878 | 57.3 | 2.03 | 0.02001 | 0.061120 | 56.07 | 0.2415 | 3.7357 | 4.0991 |
| 12 | 0 | 14.0 | 3.6 | 0.8 | 0 | 0 | 0 | 407.14 | 372.82 | 0 | 0 | 0.23 | 0 | 0 | 0.26 | 0.0001961 | 14.3 | 0.25 | 0.02393 | 0.022096 | 33.14 | 0.1473 | 0.4882 | 0.1145 |
| 13 | 0 | 14.0 | 3.0 | 0.4 | 0 | 0 | 0 | 407.10 | 372.73 | 0 | 0 | 0.13 | 0 | 0 | 0.21 | 0.0001964 | 14.2 | 0.21 | 0.03698 | 0.020061 | 20.76 | 0.0925 | 0.4025 | 0.0537 |
| 14 | 0 | 43.9 | 66.3 | 72.2 | 0 | 0 | 0 | 408.90 | 374.87 | 0 | 0 | 1.09 | 0 | 0 | 1.51 | 0.0001945 | 45.4 | 1.46 | 0.01650 | 0.052798 | 64.39 | 0.2827 | 2.7876 | 3.0345 |
| 15 | 0 | 30.5 | 11.8 | 5.0 | 0 | 0 | 0 | 407.27 | 373.12 | 0 | 0 | 0.42 | 0 | 0 | 0.39 | 0.0001952 | 30.9 | 0.38 | 0.01751 | 0.027053 | 48.48 | 0.2155 | 0.7319 | 0.3074 |
| 16 | 0 | 22.6 | 9.1 | 4.7 | 0 | 0 | 0 | 407.31 | 373.38 | 0 | 0 | 0.51 | 0 | 0 | 0.40 | 0.0001939 | 23.0 | 0.40 | 0.01464 | 0.027461 | 58.36 | 0.2579 | 0.7541 | 0.3870 |
| 17 | 0 | 20.1 | 6.4 | 3.8 | 0 | 0 | 0 | 407.29 | 373.29 | 0 | 0 | 0.59 | 0 | 0 | 0.32 | 0.0001943 | 20.4 | 0.31 | 0.01087 | 0.024454 | 75.60 | 0.3348 | 0.5980 | 0.3540 |
| 18 | 0 | 17.4 | 4.2 | 1.2 | 0 | 0 | 0 | 407.17 | 373.00 | 0 | 0 | 0.30 | 0 | 0 | 0.24 | 0.0001953 | 17.6 | 0.24 | 0.01797 | 0.021323 | 43.65 | 0.1940 | 0.4547 | 0.1355 |
| 19 | 0 | 31.7 | 19.5 | 12.9 | 0 | 0 | 0 | 407.65 | 374.15 | 0 | 0 | 0.66 | 0 | 0 | 0.62 | 0.0001914 | 32.3 | 0.60 | 0.01500 | 0.033673 | 61.11 | 0.2682 | 1.1339 | 0.7472 |
| 20 | 0 | 19.5 | 4.9 | 1.8 | 0 | 0 | 0 | 407.18 | 373.01 | 0 | 0 | 0.36 | 0 | 0 | 0.25 | 0.0001953 | 19.8 | 0.25 | 0.01527 | 0.021848 | 51.79 | 0.2302 | 0.4773 | 0.1729 |
| 21 | 0 | 21.3 | 8.1 | 2.0 | 0 | 0 | 0 | 407.21 | 372.91 | 0 | 0 | 0.25 | 0 | 0 | 0.38 | 0.0001960 | 21.7 | 0.37 | 0.02953 | 0.026753 | 28.63 | 0.1272 | 0.7157 | 0.1755 |
| 22 | 0 | 43.9 | 64.5 | 63.1 | 0 | 0 | 0 | 408.70 | 376.08 | 0 | 0 | 0.98 | 0 | 0 | 1.47 | 0.0001864 | 45.4 | 1.42 | 0.01762 | 0.050981 | 60.00 | 0.2580 | 2.5991 | 2.5455 |
| 23 | 0 | 37.5 | 45.9 | 40.5 | 0 | 0 | 0 | 408.32 | 375.11 | 0 | 0 | 0.88 | 0 | 0 | 1.22 | 0.0001898 | 38.7 | 1.19 | 0.01749 | 0.046978 | 58.65 | 0.2546 | 2.2069 | 1.9472 |
| 24 | 0 | 33.2 | 28.1 | 20.1 | 0 | 0 | 0 | 407.79 | 373.94 | 0 | 0 | 0.72 | 0 | 0 | 0.84 | 0.0001934 | 34.1 | 0.82 | 0.01703 | 0.039532 | 56.69 | 0.2493 | 1.5628 | 1.1214 |
| 25 | 0 | 39.9 | 45.9 | 38.2 | 0 | 0 | 0 | 408.26 | 374.43 | 0 | 0 | 0.83 | 0 | 0 | 1.15 | 0.0001933 | 41.1 | 1.12 | 0.01797 | 0.046032 | 56.51 | 0.2481 | 2.1189 | 1.7649 |
| 26 | 0 | 23.5 | 15.3 | 7.3 | 0 | 0 | 0 | 407.40 | 373.32 | 0 | 0 | 0.48 | 0 | 0 | 0.65 | 0.0001948 | 24.1 | 0.64 | 0.02156 | 0.034844 | 42.88 | 0.1890 | 1.2141 | 0.5809 |
| 27 | 0 | 21.3 | 12.0 | 3.3 | 0 | 0 | 0 | 407.23 | 372.98 | 0 | 0 | 0.27 | 0 | 0 | 0.56 | 0.0001958 | 21.9 | 0.55 | 0.03415 | 0.032419 | 26.40 | 0.1168 | 1.0510 | 0.2881 |
| 28 | 0 | 21.9 | 12.8 | 3.7 | 0 | 0 | 0 | 407.26 | 373.15 | 0 | 0 | 0.29 | 0 | 0 | 0.58 | 0.0001949 | 22.5 | 0.57 | 0.03288 | 0.032986 | 27.60 | 0.1218 | 1.0881 | 0.3172 |
| 29 | 0 | 20.4 | 10.8 | 3.4 | 0 | 0 | 0 | 407.25 | 373.07 | 0 | 0 | 0.32 | 0 | 0 | 0.53 | 0.0001953 | 20.9 | 0.51 | 0.02845 | 0.031392 | 31.37 | 0.1386 | 0.9855 | 0.3107 |
| 30 | 0 | 34.4 | 44.2 | 38.8 | 0 | 0 | 0 | 408.27 | 375.01 | 0 | 0 | 0.88 | 0 | 0 | 1.28 | 0.0001901 | 35.7 | 1.24 | 0.01812 | 0.048042 | 57.03 | 0.2472 | 2.3080 | 2.0247 |
| 31 | 0 | 44.8 | 83.0 | 86.9 | 0 | 0 | 0 | 409.08 | 375.74 | 0 | 0 | 1.05 | 0 | 0 | 1.85 | 0.0001905 | 46.7 | 1.78 | 0.01934 | 0.057649 | 56.77 | 0.2459 | 3.3234 | 3.4824 |
| 32 | 0 | 40.8 | 56.5 | 52.7 | 0 | 0 | 0 | 408.55 | 375.25 | 0 | 0 | 0.93 | 0 | 0 | 1.38 | 0.0001902 | 42.2 | 1.34 | 0.01796 | 0.049965 | 58.28 | 0.2532 | 2.4965 | 2.3279 |
| 33 | 0 | 33.5 | 29.7 | 19.7 | 0 | 0 | 0 | 407.80 | 374.01 | 0 | 0 | 0.66 | 0 | 0 | 0.89 | 0.0001931 | 34.4 | 0.86 | 0.01898 | 0.040451 | 51.26 | 0.2251 | 1.6363 | 1.0863 |
| 34 | 0 | 31.4 | 26.8 | 17.6 | 0 | 0 | 0 | 407.77 | 373.98 | 0 | 0 | 0.66 | 0 | 0 | 0.85 | 0.0001931 | 32.2 | 0.83 | 0.01864 | 0.039644 | 51.86 | 0.2277 | 1.5716 | 1.0346 |
| 35 | 0 | 31.7 | 16.0 | 8.5 | 0 | 0 | 0 | 407.39 | 373.24 | 0 | 0 | 0.53 | 0 | 0 | 0.50 | 0.0001951 | 32.2 | 0.50 | 0.01652 | 0.030820 | 53.69 | 0.2383 | 0.9499 | 0.5033 |
| 36 | 0 | 19.8 | 8.1 | 2.1 | 0 | 0 | 0 | 407.18 | 372.84 | 0 | 0 | 0.26 | 0 | 0 | 0.41 | 0.0001962 | 20.2 | 0.40 | 0.02892 | 0.027737 | 29.59 | 0.1313 | 0.7693 | 0.2021 |
| 37 | 0 | 45.1 | 72.7 | 69.7 | 0 | 0 | 0 | 408.84 | 376.16 | 0 | 0 | 0.96 | 0 | 0 | 1.61 | 0.0001868 | 46.7 | 1.55 | 0.01913 | 0.053378 | 56.10 | 0.2412 | 2.8492 | 2.7319 |
| 38 | 0 | 39.0 | 53.1 | 49.3 | 0 | 0 | 0 | 408.42 | 375.49 | 0 | 0 | 0.93 | 0 | 0 | 1.36 | 0.0001882 | 40.4 | 1.32 | 0.01777 | 0.049288 | 58.75 | 0.2536 | 2.4293 | 2.2524 |
| 39 | 0 | 32.6 | 16.8 | 8.8 | 0 | 0 | 0 | 407.39 | 373.32 | 0 | 0 | 0.52 | 0 | 0 | 0.52 | 0.0001947 | 33.1 | 0.51 | 0.01700 | 0.031135 | 52.36 | 0.2321 | 0.9694 | 0.5061 |
| 40 | 0 | 25.0 | 10.4 | 3.4 | 0 | 0 | 0 | 407.24 | 372.96 | 0 | 0 | 0.32 | 0 | 0 | 0.42 | 0.0001959 | 25.4 | 0.41 | 0.02383 | 0.028054 | 36.05 | 0.1603 | 0.7871 | 0.2549 |
| 41 | 0 | 18.6 | 7.4 | 1.7 | 0 | 0 | 0 | 407.16 | 372.85 | 0 | 0 | 0.23 | 0 | 0 | 0.40 | 0.0001961 | 19.0 | 0.39 | 0.03276 | 0.027436 | 26.02 | 0.1154 | 0.7527 | 0.1721 |
| 42 | 0 | 17.7 | 6.0 | 0.8 | 0 | 0 | 0 | 407.09 | 372.75 | 0 | 0 | 0.14 | 0 | 0 | 0.34 | 0.0001962 | 18.0 | 0.34 | 0.04802 | 0.025398 | 17.30 | 0.0768 | 0.6451 | 0.0907 |
| 43 | 0 | 18.9 | 7.1 | 1.6 | 0 | 0 | 0 | 407.10 | 372.86 | 0 | 0 | 0.22 | 0 | 0 | 0.37 | 0.0001957 | 19.3 | 0.37 | 0.03188 | 0.026519 | 26.45 | 0.1173 | 0.7033 | 0.1579 |
| 44 | 0 | 21.9 | 11.9 | 4.4 | 0 | 0 | 0 | 407.32 | 373.19 | 0 | 0 | 0.37 | 0 | 0 | 0.54 | 0.0001950 | 22.5 | 0.53 | 0.02442 | 0.031808 | 36.71 | 0.1622 | 1.0118 | 0.3783 |
| 45 | 0 | 21.9 | 9.8 | 3.7 | 0 | 0 | 0 | 407.25 | 373.01 | 0 | 0 | 0.38 | 0 | 0 | 0.45 | 0.0001957 | 22.4 | 0.44 | 0.02131 | 0.029054 | 40.80 | 0.1809 | 0.8441 | 0.3204 |

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS | QBSM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | 0 | 18.9 | 8.5 | 2.1 | 0 | 0 | 0 | 407.18 | 372.88 | 0 | 0 | 0.25 | 0 | 0 | 0.45 | 0.0001960 | 19.3 | 0.44 | 0.03252 | 0.028989 | 26.70 | 0.1183 | 0.8403 | 0.2083 |
| 47 | 0 | 11.6 | 1.9 | 0.3 | 0 | 0 | 0 | 407.07 | 372.80 | 0 | 0 | 0.17 | 0 | 0 | 0.16 | 0.0001958 | 11.7 | 0.16 | 0.02440 | 0.017434 | 30.03 | 0.1336 | 0.3039 | 0.0510 |
| 48 | 0 | 11.3 | 1.7 | 0.3 | 0 | 0 | 0 | 407.06 | 372.74 | 0 | 0 | 0.15 | 0 | 0 | 0.15 | 0.0001961 | 11.4 | 0.15 | 0.02550 | 0.016779 | 28.36 | 0.1264 | 0.2816 | 0.0429 |
| 49 | 1 | 32.9 | 24.7 | 22.9 | 0 | 0 | 0 | 408.14 | 377.46 | 0 | 0 | 0.93 | 0 | 0 | 0.75 | 0.0001753 | 33.7 | 0.73 | 0.01162 | 0.035528 | 81.49 | 0.3416 | 1.2622 | 1.1701 |
| 50 | 1 | 36.0 | 38.6 | 35.1 | 0 | 0 | 0 | 408.10 | 375.72 | 0 | 0 | 0.91 | 0 | 0 | 1.07 | 0.0001851 | 37.0 | 1.04 | 0.01534 | 0.043473 | 65.42 | 0.2808 | 1.8899 | 1.7212 |
| 51 | 1 | 37.5 | 50.3 | 45.3 | 0 | 0 | 0 | 408.36 | 375.65 | 0 | 0 | 0.90 | 0 | 0 | 1.34 | 0.0001869 | 38.8 | 1.29 | 0.01801 | 0.048713 | 57.79 | 0.2486 | 2.3730 | 2.1391 |
| 52 | 1 | 32.9 | 21.9 | 12.7 | 0 | 0 | 0 | 407.59 | 374.53 | 0 | 0 | 0.58 | 0 | 0 | 0.67 | 0.0001889 | 33.6 | 0.65 | 0.01787 | 0.034782 | 51.95 | 0.2264 | 1.2098 | 0.7000 |
| 53 | 1 | 21.6 | 8.3 | 2.1 | 0 | 0 | 0 | 407.22 | 373.06 | 0 | 0 | 0.25 | 0 | 0 | 0.38 | 0.0001952 | 22.0 | 0.38 | 0.02868 | 0.026810 | 29.52 | 0.1309 | 0.7188 | 0.1822 |
| 54 | 1 | 39.9 | 61.6 | 58.9 | 0 | 0 | 0 | 408.72 | 377.36 | 0 | 0 | 0.96 | 0 | 0 | 1.54 | 0.0001792 | 41.5 | 1.49 | 0.01822 | 0.051091 | 58.45 | 0.2458 | 2.6103 | 2.4960 |
| 55 | 1 | 31.7 | 25.9 | 15.3 | 0 | 0 | 0 | 407.66 | 374.80 | 0 | 0 | 0.59 | 0 | 0 | 0.82 | 0.0001878 | 32.5 | 0.80 | 0.01997 | 0.038324 | 48.07 | 0.2083 | 1.4687 | 0.8665 |
| 56 | 1 | 32.6 | 21.5 | 10.4 | 0 | 0 | 0 | 407.53 | 374.28 | 0 | 0 | 0.48 | 0 | 0 | 0.66 | 0.0001900 | 33.3 | 0.65 | 0.02130 | 0.034674 | 43.50 | 0.1901 | 1.2023 | 0.5806 |
| 57 | 1 | 23.8 | 11.3 | 5.7 | 0 | 0 | 0 | 407.35 | 373.60 | 0 | 0 | 0.50 | 0 | 0 | 0.48 | 0.0001928 | 24.3 | 0.47 | 0.01673 | 0.029735 | 52.48 | 0.2311 | 0.8842 | 0.4418 |
| 58 | 1 | 17.4 | 6.1 | 1.9 | 0 | 0 | 0 | 407.20 | 373.26 | 0 | 0 | 0.31 | 0 | 0 | 0.35 | 0.0001939 | 17.7 | 0.35 | 0.02217 | 0.025653 | 37.67 | 0.1663 | 0.6581 | 0.2036 |
| 59 | 1 | 13.7 | 4.7 | 2.4 | 0 | 0 | 0 | 407.23 | 374.70 | 0 | 0 | 0.50 | 0 | 0 | 0.35 | 0.0001859 | 14.1 | 0.34 | 0.01315 | 0.024787 | 63.25 | 0.2727 | 0.6144 | 0.3084 |
| 60 | 1 | 11.0 | 2.4 | 0.6 | 0 | 0 | 0 | 407.13 | 374.62 | 0 | 0 | 0.26 | 0 | 0 | 0.22 | 0.0001858 | 11.2 | 0.22 | 0.01900 | 0.019831 | 40.61 | 0.1755 | 0.3933 | 0.1014 |
| 61 | 1 | 35.7 | 41.4 | 34.0 | 0 | 0 | 0 | 408.13 | 375.61 | 0 | 0 | 0.82 | 0 | 0 | 1.16 | 0.0001858 | 36.8 | 1.13 | 0.01798 | 0.045292 | 56.55 | 0.2429 | 2.0514 | 1.6823 |
| 62 | 1 | 32.0 | 15.7 | 5.6 | 0 | 0 | 0 | 407.36 | 374.49 | 0 | 0 | 0.36 | 0 | 0 | 0.49 | 0.0001878 | 32.5 | 0.48 | 0.02375 | 0.029839 | 37.19 | 0.1620 | 0.8904 | 0.3163 |
| 63 | 1 | 32.6 | 24.8 | 13.0 | 0 | 0 | 0 | 407.63 | 373.79 | 0 | 0 | 0.53 | 0 | 0 | 0.76 | 0.0001934 | 33.4 | 0.74 | 0.02173 | 0.037548 | 43.68 | 0.1922 | 1.4099 | 0.7404 |
| 64 | 1 | 32.9 | 24.0 | 12.5 | 0 | 0 | 0 | 407.61 | 373.40 | 0 | 0 | 0.52 | 0 | 0 | 0.73 | 0.0001955 | 33.6 | 0.71 | 0.02140 | 0.036960 | 44.02 | 0.1949 | 1.3660 | 0.7117 |
| 65 | 1 | 31.1 | 20.9 | 7.2 | 0 | 0 | 0 | 407.42 | 373.32 | 0 | 0 | 0.34 | 0 | 0 | 0.67 | 0.0001949 | 31.8 | 0.66 | 0.03069 | 0.035469 | 30.30 | 0.1340 | 1.2581 | 0.4329 |
| 66 | 1 | 32.3 | 20.9 | 13.0 | 0 | 0 | 0 | 407.61 | 376.47 | 0 | 0 | 0.62 | 0 | 0 | 0.65 | 0.0001780 | 33.0 | 0.63 | 0.01587 | 0.033277 | 58.23 | 0.2463 | 1.1074 | 0.6870 |
| 67 | 1 | 33.5 | 23.2 | 24.3 | 0 | 0 | 0 | 407.88 | 378.03 | 0 | 0 | 1.05 | 0 | 0 | 0.69 | 0.0001705 | 34.2 | 0.68 | 0.00964 | 0.033697 | 96.95 | 0.4013 | 1.1355 | 1.1878 |
| 68 | 1 | 21.6 | 10.5 | 7.3 | 0 | 0 | 0 | 407.45 | 376.38 | 0 | 0 | 0.69 | 0 | 0 | 0.49 | 0.0001775 | 22.1 | 0.47 | 0.01169 | 0.028743 | 75.32 | 0.3178 | 0.8262 | 0.5727 |
| 69 | 1 | 44.8 | 65.8 | 71.1 | 0 | 0 | 0 | 408.90 | 375.83 | 0 | 0 | 1.08 | 0 | 0 | 1.47 | 0.0001889 | 46.3 | 1.42 | 0.01608 | 0.051329 | 65.75 | 0.2847 | 2.6347 | 2.8470 |
| 70 | 1 | 51.8 | 111.5 | 111.3 | 0 | 0 | 0 | 409.70 | 376.62 | 0 | 0 | 1.00 | 0 | 0 | 2.15 | 0.0001890 | 54.0 | 2.07 | 0.02235 | 0.061892 | 50.37 | 0.2173 | 3.8306 | 3.8238 |
| 71 | 1 | 40.5 | 60.5 | 53.8 | 0 | 0 | 0 | 408.61 | 375.33 | 0 | 0 | 0.89 | 0 | 0 | 1.49 | 0.0001902 | 42.0 | 1.44 | 0.01976 | 0.051813 | 53.62 | 0.2325 | 2.6846 | 2.3882 |
| 72 | 1 | 40.2 | 58.4 | 50.4 | 0 | 0 | 0 | 408.53 | 374.74 | 0 | 0 | 0.86 | 0 | 0 | 1.45 | 0.0001931 | 41.7 | 1.40 | 0.02018 | 0.051525 | 52.28 | 0.2285 | 2.6548 | 2.2899 |
| 73 | 1 | 31.7 | 9.6 | 2.3 | 0 | 0 | 0 | 407.27 | 373.00 | 0 | 0 | 0.24 | 0 | 0 | 0.30 | 0.0001958 | 32.0 | 0.30 | 0.02610 | 0.023967 | 31.23 | 0.1393 | 0.5744 | 0.1377 |
| 74 | 1 | 31.1 | 20.3 | 5.3 | 0 | 0 | 0 | 407.41 | 373.19 | 0 | 0 | 0.26 | 0 | 0 | 0.65 | 0.0001956 | 31.7 | 0.64 | 0.03994 | 0.035069 | 23.18 | 0.1027 | 1.2298 | 0.3201 |
| 75 | 1 | 32.0 | 8.2 | 1.5 | 0 | 0 | 0 | 407.22 | 372.95 | 0 | 0 | 0.18 | 0 | 0 | 0.26 | 0.0001958 | 32.3 | 0.25 | 0.03110 | 0.022065 | 25.49 | 0.1138 | 0.4869 | 0.0877 |
| 76 | 1 | 30.8 | 9.3 | 1.1 | 0 | 0 | 0 | 407.22 | 373.07 | 0 | 0 | 0.12 | 0 | 0 | 0.30 | 0.0001951 | 31.1 | 0.30 | 0.05119 | 0.023917 | 15.92 | 0.0709 | 0.5720 | 0.0697 |
| 77 | 1 | 33.5 | 8.8 | 1.4 | 0 | 0 | 0 | 407.22 | 372.99 | 0 | 0 | 0.16 | 0 | 0 | 0.26 | 0.0001956 | 33.8 | 0.26 | 0.03633 | 0.022386 | 21.93 | 0.0978 | 0.5012 | 0.0788 |
| 78 | 1 | 34.1 | 8.4 | 1.2 | 0 | 0 | 0 | 407.21 | 372.84 | 0 | 0 | 0.15 | 0 | 0 | 0.24 | 0.0001964 | 34.4 | 0.24 | 0.03662 | 0.021645 | 21.50 | 0.0961 | 0.4685 | 0.0698 |
| 79 | 1 | 25.3 | 13.7 | 11.0 | 0 | 0 | 0 | 407.59 | 378.04 | 0 | 0 | 0.81 | 0 | 0 | 0.54 | 0.0001688 | 25.8 | 0.53 | 0.01053 | 0.029586 | 85.14 | 0.3505 | 0.8754 | 0.7060 |
| 80 | 1 | 24.4 | 11.0 | 7.0 | 0 | 0 | 0 | 407.48 | 376.91 | 0 | 0 | 0.64 | 0 | 0 | 0.45 | 0.0001747 | 24.8 | 0.44 | 0.01196 | 0.027505 | 72.74 | 0.3050 | 0.7565 | 0.4846 |
| 81 | 1 | 42.7 | 66.5 | 64.6 | 0 | 0 | 0 | 408.81 | 377.79 | 0 | 0 | 0.97 | 0 | 0 | 1.56 | 0.0001773 | 44.2 | 1.50 | 0.01801 | 0.051138 | 59.27 | 0.2482 | 2.6151 | 2.5381 |
| 82 | 1 | 45.4 | 70.7 | 63.1 | 0 | 0 | 0 | 408.87 | 378.27 | 0 | 0 | 0.89 | 0 | 0 | 1.56 | 0.0001749 | 47.0 | 1.51 | 0.01945 | 0.050813 | 54.89 | 0.2286 | 2.5820 | 2.3062 |
| 83 | 1 | 31.4 | 17.6 | 5.9 | 0 | 0 | 0 | 407.43 | 373.96 | 0 | 0 | 0.34 | 0 | 0 | 0.56 | 0.0001913 | 32.0 | 0.55 | 0.02765 | 0.032109 | 32.63 | 0.1432 | 1.0310 | 0.3458 |
| 84 | 1 | 34.1 | 16.2 | 6.2 | 0 | 0 | 0 | 407.43 | 373.84 | 0 | 0 | 0.38 | 0 | 0 | 0.47 | 0.0001920 | 34.6 | 0.47 | 0.02174 | 0.029657 | 40.40 | 0.1780 | 0.8796 | 0.3374 |
| 85 | 1 | 23.2 | 12.1 | 8.9 | 0 | 0 | 0 | 407.51 | 376.94 | 0 | 0 | 0.74 | 0 | 0 | 0.52 | 0.0001746 | 23.7 | 0.51 | 0.01145 | 0.029556 | 77.79 | 0.3255 | 0.8736 | 0.6431 |
| 86 | 1 | 25.9 | 13.2 | 5.8 | 0 | 0 | 0 | 407.42 | 377.01 | 0 | 0 | 0.44 | 0 | 0 | 0.51 | 0.0001738 | 26.4 | 0.50 | 0.01876 | 0.029178 | 47.33 | 0.1978 | 0.8514 | 0.3765 |
| 87 | 1 | 47.2 | 87.0 | 88.1 | 0 | 0 | 0 | 409.22 | 377.81 | 0 | 0 | 1.01 | 0 | 0 | 1.84 | 0.0001795 | 49.1 | 1.77 | 0.01937 | 0.055848 | 56.63 | 0.2383 | 3.1190 | 3.1587 |
| 88 | 1 | 32.3 | 23.8 | 9.8 | 0 | 0 | 0 | 407.55 | 374.10 | 0 | 0 | 0.41 | 0 | 0 | 0.74 | 0.0001912 | 33.0 | 0.72 | 0.02703 | 0.036737 | 34.92 | 0.1529 | 1.3496 | 0.5544 |
| 89 | 1 | 31.7 | 20.4 | 6.3 | 0 | 0 | 0 | 407.44 | 374.80 | 0 | 0 | 0.31 | 0 | 0 | 0.64 | 0.0001865 | 32.3 | 0.63 | 0.03269 | 0.034001 | 28.25 | 0.1223 | 1.1560 | 0.3556 |
| 90 | 1 | 36.6 | 32.0 | 29.4 | 0 | 0 | 0 | 408.01 | 379.21 | 0 | 0 | 0.92 | 0 | 0 | 0.87 | 0.0001646 | 37.4 | 0.85 | 0.01252 | 0.037118 | 77.53 | 0.3147 | 1.3777 | 1.2696 |

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | 1 | 35.4 | 26.4 | 21.7 | 0 | 0 | 0 | 407.85 | 379.33 | 0 | 0 | 0.82 | 0 | 0 | 0.75 | 0.0001630 | 36.1 | 0.73 | 0.01258 | 0.034182 | 75.21 | 0.3042 | 1.1684 | 0.9618 |
| 92 | 1 | 46.0 | 79.6 | 79.3 | 0 | 0 | 0 | 409.08 | 378.61 | 0 | 0 | 1.00 | 0 | 0 | 1.73 | 0.0001741 | 47.8 | 1.67 | 0.01863 | 0.053365 | 58.28 | 0.2417 | 2.8478 | 2.8360 |
| 93 | 1 | 36.9 | 52.7 | 46.4 | 0 | 0 | 0 | 408.43 | 376.36 | 0 | 0 | 0.88 | 0 | 0 | 1.43 | 0.0001832 | 38.3 | 1.38 | 0.01899 | 0.049715 | 55.38 | 0.2355 | 2.4715 | 2.1789 |
| 94 | 1 | 37.2 | 50.7 | 43.9 | 0 | 0 | 0 | 408.39 | 375.62 | 0 | 0 | 0.87 | 0 | 0 | 1.36 | 0.0001873 | 38.5 | 1.32 | 0.01899 | 0.049164 | 54.96 | 0.2365 | 2.4171 | 2.0914 |

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 181.7 | 516.5 | 637 | 10.0 | 425 | 0.78 | 296.84 | 358.82 | 0.185 | 3.46 | 1.23 | 23390.6 |
| 2 | 0 | 174.0 | 411.6 | 532 | 5.0 | 734 | 0.78 | 296.27 | 358.62 | 0.470 | 5.53 | 1.29 | 33738.1 |
| 3 | 0 | 108.2 | 159.8 | 195 | 2.0 | 1100 | 0.82 | 294.67 | 357.82 | 0.162 | 4.57 | 1.22 | 18532.8 |
| 4 | 0 | 172.5 | 390.2 | 470 | 6.1 | 512 | 0.75 | 296.06 | 358.56 | 0.450 | 9.56 | 1.20 | 20791.3 |
| 5 | 0 | 187.8 | 836.1 | 1250 | 6.0 | 531 | 0.79 | 298.53 | 358.91 | 0.260 | 2.23 | 1.49 | 57348.0 |
| 6 | 0 | 187.5 | 956.9 | 1470 | 6.5 | 482 | 0.81 | 299.22 | 360.07 | 0.720 | 3.19 | 1.54 | 61217.8 |
| 7 | 1 | 88.4 | 236.9 | 314 | 5.0 | 1030 | 0.57 | 295.51 | 356.58 | 0.300 | 1.47 | 1.33 | 27943.5 |
| 8 | 1 | 86.3 | 241.5 | 303 | 11.0 | 632 | 0.67 | 295.44 | 356.34 | 0.290 | 2.24 | 1.25 | 16545.2 |
| 9 | 1 | 89.9 | 105.9 | 101 | 2.0 | 1090 | 0.81 | 294.31 | 355.73 | 0.100 | 4.10 | 0.95 | 9511.8 |
| 10 | 1 | 89.9 | 105.9 | 186 | 3.0 | 1420 | 0.82 | 294.70 | 355.54 | 0.130 | 3.08 | 1.76 | 22819.9 |
| 11 | 1 | 96.3 | 115.2 | 151 | 6.0 | 609 | 0.79 | 294.45 | 355.05 | 0.220 | 2.77 | 1.31 | 7945.3 |
| 12 | 1 | 84.1 | 191.4 | 215 | 4.0 | 1000 | 0.73 | 294.92 | 356.91 | 0.144 | 2.92 | 1.12 | 18576.0 |
| 13 | 1 | 79.9 | 162.6 | 186 | 20.0 | 297 | 0.69 | 294.73 | 355.45 | 0.176 | 1.36 | 1.14 | 4772.9 |
| 14 | 1 | 79.9 | 162.6 | 136 | 21.0 | 326 | 0.66 | 294.37 | 355.21 | 0.190 | 1.42 | 0.84 | 3830.6 |
| 15 | 1 | 181.7 | 516.5 | 818 | 6.5 | 437 | 0.78 | 297.37 | 358.89 | 0.250 | 3.36 | 1.58 | 30885.0 |
| 16 | 1 | 163.4 | 346.5 | 428 | 0.0 | 387 | 0.56 | 295.89 | 357.88 | 0.270 | 3.56 | 1.24 | 14310.9 |
| 17 | 1 | 184.4 | 683.8 | 685 | 3.3 | 1360 | 0.49 | 296.96 | 358.55 | 0.420 | 2.67 | 1.00 | 80490.2 |
| 18 | 1 | 187.1 | 882.6 | 1290 | 0.0 | 314 | 0.81 | 298.83 | 359.49 | 0.840 | 2.86 | 1.46 | 34997.2 |

| OBS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5145.9 | 2.84 | 0.0003130 | 184.5 | 2.80 | 0.02851 | 0.092720 | 41.54 | 0.2335 | 8.5970 | 10.6018 |
| 2 | 7422.4 | 2.36 | 0.0003149 | 176.4 | 2.33 | 0.02416 | 0.084895 | 47.55 | 0.2684 | 7.2072 | 9.3163 |
| 3 | 3335.9 | 1.48 | 0.0003190 | 109.7 | 1.46 | 0.01881 | 0.067520 | 56.44 | 0.3206 | 4.5589 | 5.5634 |
| 4 | 5197.8 | 2.26 | 0.0003157 | 174.8 | 2.23 | 0.02520 | 0.083145 | 45.24 | 0.2557 | 6.9131 | 8.3271 |
| 5 | 12043.1 | 4.45 | 0.0003050 | 192.2 | 4.35 | 0.03114 | 0.114081 | 40.93 | 0.2262 | 13.0145 | 19.4565 |
| 6 | 11631.4 | 5.10 | 0.0003073 | 192.6 | 4.97 | 0.03325 | 0.122399 | 39.20 | 0.2171 | 14.9816 | 23.0148 |
| 7 | 12015.7 | 2.68 | 0.0003084 | 91.1 | 2.60 | 0.02507 | 0.088713 | 46.66 | 0.2585 | 7.8700 | 10.4312 |
| 8 | 5459.9 | 2.80 | 0.0003076 | 89.1 | 2.71 | 0.02720 | 0.090461 | 43.31 | 0.2393 | 8.1832 | 10.2651 |
| 9 | 1807.2 | 1.18 | 0.0003102 | 91.1 | 1.16 | 0.02042 | 0.059482 | 50.07 | 0.2805 | 3.5381 | 3.3741 |
| 10 | 4107.6 | 1.18 | 0.0003072 | 91.1 | 1.16 | 0.01104 | 0.059196 | 92.65 | 0.5166 | 3.5042 | 6.1541 |
| 11 | 1668.5 | 1.20 | 0.0003061 | 97.5 | 1.18 | 0.01492 | 0.059556 | 68.73 | 0.3827 | 3.5469 | 4.6492 |
| 12 | 5015.5 | 2.27 | 0.0003131 | 86.4 | 2.22 | 0.02677 | 0.082480 | 42.54 | 0.2378 | 6.8029 | 7.6425 |
| 13 | 1479.6 | 2.04 | 0.0003067 | 81.9 | 1.99 | 0.02418 | 0.077282 | 46.23 | 0.2560 | 5.9725 | 6.8328 |
| 14 | 1302.4 | 2.04 | 0.0003073 | 81.9 | 1.99 | 0.03311 | 0.077359 | 33.77 | 0.1872 | 5.9844 | 5.0060 |
| 15 | 6794.7 | 2.84 | 0.0003107 | 184.5 | 2.80 | 0.02212 | 0.092375 | 53.54 | 0.2998 | 8.5332 | 13.5132 |
| 16 | 6296.8 | 2.12 | 0.0003131 | 165.5 | 2.09 | 0.02345 | 0.080196 | 48.10 | 0.2708 | 6.4315 | 7.9436 |
| 17 | 41050.0 | 3.71 | 0.0003111 | 188.1 | 3.63 | 0.04164 | 0.105319 | 29.71 | 0.1661 | 11.0922 | 11.1122 |
| 18 | 6649.5 | 4.72 | 0.0003064 | 191.9 | 4.60 | 0.03314 | 0.117579 | 38.82 | 0.2149 | 13.8249 | 20.2068 |

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 99.4 | 243.4 | 217 | 3.3 | 860 | 0.88 | 258.11 | 294.91 | 0.210 | 2.95 | 0.89 | 16124.0 |
| 2 | 0 | 98.1 | 246.2 | 240 | 2.2 | 760 | 0.90 | 258.21 | 294.82 | 0.200 | 7.00 | 0.97 | 15759.3 |
| 3 | 0 | 95.1 | 202.5 | 196 | 3.3 | 560 | 0.90 | 257.89 | 294.51 | 0.150 | 4.40 | 0.97 | 9483.3 |
| 4 | 0 | 92.7 | 141.2 | 112 | 12.2 | 245 | 0.90 | 257.13 | 294.09 | 0.150 | 4.40 | 0.79 | 2370.8 |
| 5 | 0 | 89.3 | 107.8 | 78 | 18.9 | 260 | 0.91 | 256.80 | 293.66 | 0.200 | 3.60 | 0.72 | 1752.2 |
| 6 | 0 | 87.2 | 60.4 | 41 | 20.0 | 300 | 0.95 | 256.28 | 293.26 | 0.094 | 3.40 | 0.68 | 1062.7 |
| 7 | 0 | 96.3 | 189.5 | 148 | 1.1 | 625 | 0.85 | 257.68 | 294.36 | 0.180 | 4.56 | 0.78 | 7992.0 |
| 8 | 0 | 95.1 | 194.2 | 182 | 2.2 | 840 | 0.88 | 257.85 | 294.37 | 0.250 | 2.76 | 0.94 | 13208.8 |
| 9 | 0 | 93.3 | 145.9 | 127 | 4.4 | 440 | 0.91 | 257.35 | 294.07 | 0.210 | 3.52 | 0.87 | 4828.0 |
| 10 | 0 | 95.4 | 170.0 | 150 | 8.9 | 255 | 0.90 | 257.45 | 294.21 | 0.190 | 2.10 | 0.88 | 3304.8 |
| 11 | 0 | 92.7 | 142.1 | 122 | 0.6 | 905 | 0.92 | 257.26 | 294.09 | 0.170 | 2.47 | 0.86 | 9539.4 |
| 12 | 0 | 97.5 | 183.9 | 164 | 2.2 | 395 | 0.90 | 257.63 | 294.36 | 0.170 | 4.00 | 0.89 | 5597.0 |
| 13 | 0 | 96.3 | 183.0 | 161 | 12.2 | 290 | 0.88 | 257.61 | 294.34 | 0.180 | 3.33 | 0.88 | 4034.0 |
| 14 | 0 | 91.4 | 130.1 | 100 | 13.9 | 290 | 0.93 | 257.06 | 293.80 | 0.080 | 5.50 | 0.77 | 2505.6 |
| 15 | 0 | 92.0 | 136.6 | 98 | 0.5 | 976 | 0.92 | 257.11 | 293.86 | 0.094 | 2.23 | 0.72 | 8264.0 |
| 16 | 0 | 87.8 | 96.6 | 74 | 0.5 | 716 | 0.89 | 256.79 | 293.79 | 0.090 | 5.89 | 0.77 | 4577.8 |
| 17 | 0 | 88.7 | 92.5 | 73 | 5.0 | 404 | 0.90 | 256.74 | 293.98 | 0.070 | 4.57 | 0.79 | 2548.1 |
| 18 | 0 | 88.7 | 98.5 | 76 | 5.5 | 419 | 0.91 | 256.75 | 293.83 | 0.170 | 2.35 | 0.77 | 2751.3 |
| 19 | 0 | 89.6 | 108.7 | 83 | 6.5 | 429 | 0.90 | 256.82 | 293.80 | 0.150 | 2.53 | 0.76 | 3076.4 |
| 20 | 0 | 88.4 | 77.8 | 54 | 12.0 | 276 | 0.96 | 256.50 | 293.53 | 0.125 | 2.80 | 0.69 | 1287.7 |
| 21 | 0 | 91.4 | 175.6 | 129 | 0.0 | 825 | 0.86 | 257.49 | 293.99 | 0.125 | 1.92 | 0.73 | 9195.1 |
| 22 | 0 | 93.9 | 117.1 | 101 | 2.2 | 480 | 0.82 | 257.79 | 294.80 | 0.410 | 3.90 | 0.86 | 4188.7 |
| 23 | 0 | 89.9 | 97.5 | 66 | 6.7 | 240 | 0.91 | 256.75 | 293.51 | 0.190 | 8.95 | 0.68 | 1368.6 |
| 24 | 0 | 89.0 | 87.5 | 58 | 10.6 | 300 | 0.96 | 256.65 | 293.39 | 0.125 | 2.72 | 0.66 | 1503.4 |

| OBS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1934.88 | 2.45 | 0.0003361 | 101.8 | 2.39 | 0.03678 | 0.088782 | 31.36 | 0.1819 | 7.8822 | 7.0271 |
| 2 | 1575.93 | 2.51 | 0.0003344 | 100.7 | 2.45 | 0.03406 | 0.089575 | 33.99 | 0.1965 | 8.0237 | 7.8218 |
| 3 | 948.33 | 2.13 | 0.0003345 | 97.2 | 2.08 | 0.03083 | 0.082670 | 36.56 | 0.2117 | 6.8344 | 6.6141 |
| 4 | 237.08 | 1.52 | 0.0003375 | 94.2 | 1.50 | 0.03035 | 0.070461 | 35.15 | 0.2051 | 4.9647 | 3.9377 |
| 5 | 157.70 | 1.21 | 0.0003366 | 90.5 | 1.19 | 0.02848 | 0.062706 | 36.05 | 0.2104 | 3.9321 | 2.8460 |
| 6 | 53.14 | 0.69 | 0.0003377 | 87.9 | 0.69 | 0.02108 | 0.047718 | 44.44 | 0.2605 | 2.2770 | 1.5460 |
| 7 | 1198.80 | 1.97 | 0.0003349 | 98.3 | 1.93 | 0.03631 | 0.079597 | 30.64 | 0.1777 | 6.3357 | 4.9476 |
| 8 | 1585.06 | 2.04 | 0.0003335 | 97.1 | 2.00 | 0.03092 | 0.080871 | 36.20 | 0.2094 | 6.5401 | 6.1303 |
| 9 | 434.52 | 1.56 | 0.0003354 | 94.8 | 1.54 | 0.02803 | 0.071135 | 38.23 | 0.2223 | 5.0601 | 4.4059 |
| 10 | 330.48 | 1.78 | 0.0003357 | 97.2 | 1.75 | 0.03015 | 0.075899 | 36.30 | 0.2110 | 5.7606 | 5.0825 |
| 11 | 763.15 | 1.53 | 0.0003363 | 94.2 | 1.51 | 0.02812 | 0.070563 | 37.99 | 0.2213 | 4.9791 | 4.2736 |
| 12 | 559.70 | 1.89 | 0.0003354 | 99.4 | 1.85 | 0.03096 | 0.078023 | 35.69 | 0.2073 | 6.0875 | 5.4274 |
| 13 | 484.08 | 1.90 | 0.0003355 | 98.2 | 1.86 | 0.03153 | 0.078308 | 35.08 | 0.2038 | 6.1321 | 5.3944 |
| 14 | 175.39 | 1.42 | 0.0003356 | 92.9 | 1.40 | 0.02983 | 0.067902 | 35.36 | 0.2058 | 4.6106 | 3.5449 |
| 15 | 661.12 | 1.48 | 0.0003356 | 93.5 | 1.46 | 0.03286 | 0.069329 | 32.32 | 0.1881 | 4.8065 | 3.4491 |
| 16 | 503.56 | 1.10 | 0.0003380 | 88.9 | 1.09 | 0.02538 | 0.060033 | 39.84 | 0.2331 | 3.6039 | 2.7602 |
| 17 | 254.81 | 1.04 | 0.0003401 | 89.7 | 1.03 | 0.02386 | 0.058655 | 42.00 | 0.2466 | 3.4404 | 2.7142 |
| 18 | 247.62 | 1.11 | 0.0003386 | 89.8 | 1.10 | 0.02536 | 0.060354 | 39.93 | 0.2338 | 3.6426 | 2.8112 |
| 19 | 307.64 | 1.21 | 0.0003377 | 90.8 | 1.20 | 0.02713 | 0.062964 | 37.87 | 0.2214 | 3.9645 | 3.0273 |
| 20 | 51.51 | 0.88 | 0.0003382 | 89.3 | 0.87 | 0.02415 | 0.053761 | 40.34 | 0.2364 | 2.8902 | 2.0071 |
| 21 | 1287.32 | 1.92 | 0.0003333 | 93.4 | 1.88 | 0.03787 | 0.078416 | 29.26 | 0.1693 | 6.1491 | 4.5176 |
| 22 | 753.96 | 1.25 | 0.0003380 | 95.1 | 1.23 | 0.02447 | 0.063881 | 42.18 | 0.2467 | 4.0808 | 3.5210 |
| 23 | 123.17 | 1.08 | 0.0003357 | 91.0 | 1.07 | 0.02837 | 0.059418 | 35.56 | 0.2074 | 3.5305 | 2.3887 |
| 24 | 60.13 | 0.98 | 0.0003356 | 90.0 | 0.97 | 0.02713 | 0.056584 | 36.58 | 0.2134 | 3.2018 | 2.1220 |

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 0 | 88.4 | 79.8 | 50 | 11.1 | 225 | 0.94 | 256.56 | 293.33 | 0.190 | 2.68 | 0.63 | 972.0 |
| 26 | 0 | 93.3 | 107.8 | 74 | 17.8 | 385 | 0.90 | 256.86 | 293.73 | 0.150 | 2.60 | 0.69 | 2461.5 |
| 27 | 0 | 93.3 | 113.3 | 82 | 20.0 | 365 | 0.96 | 256.93 | 293.68 | 0.125 | 2.72 | 0.72 | 2586.0 |
| 28 | 0 | 92.7 | 144.9 | 116 | 1.7 | 1210 | 0.94 | 257.35 | 294.07 | 0.140 | 3.86 | 0.80 | 12127.1 |
| 29 | 0 | 91.4 | 128.2 | 100 | 8.9 | 390 | 0.93 | 257.15 | 293.77 | 0.120 | 4.00 | 0.78 | 3369.6 |
| 30 | 0 | 92.0 | 138.4 | 103 | 11.7 | 320 | 0.93 | 257.01 | 293.95 | 0.120 | 4.00 | 0.74 | 2847.7 |
| 31 | 0 | 90.8 | 108.7 | 71 | 18.9 | 190 | 0.94 | 256.80 | 293.64 | 0.068 | 3.82 | 0.65 | 1165.5 |
| 32 | 0 | 86.9 | 52.8 | 30 | 18.3 | 165 | 0.78 | 256.24 | 293.19 | 0.210 | 12.38 | 0.57 | 427.7 |

| OBS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 58.320 | 0.90 | 0.0003358 | 89.3 | 0.89 | 0.02714 | 0.054260 | 36.06 | 0.2105 | 2.9442 | 1.8446 |
| 26 | 246.154 | 1.16 | 0.0003368 | 94.4 | 1.14 | 0.02919 | 0.061404 | 34.92 | 0.2040 | 3.7705 | 2.5890 |
| 27 | 103.438 | 1.22 | 0.0003356 | 94.5 | 1.20 | 0.02859 | 0.062840 | 35.95 | 0.2095 | 3.9489 | 2.8569 |
| 28 | 727.626 | 1.56 | 0.0003353 | 94.2 | 1.54 | 0.03049 | 0.071134 | 35.14 | 0.2043 | 5.0600 | 4.0500 |
| 29 | 235.872 | 1.40 | 0.0003345 | 92.8 | 1.38 | 0.02908 | 0.067310 | 36.19 | 0.2103 | 4.5307 | 3.5339 |
| 30 | 199.342 | 1.50 | 0.0003373 | 93.6 | 1.48 | 0.03206 | 0.069976 | 33.21 | 0.1937 | 4.8967 | 3.6435 |
| 31 | 69.932 | 1.20 | 0.0003364 | 92.0 | 1.18 | 0.03138 | 0.062435 | 32.67 | 0.1906 | 3.8981 | 2.5462 |
| 32 | 94.090 | 0.61 | 0.0003375 | 87.5 | 0.60 | 0.02306 | 0.044688 | 39.73 | 0.2329 | 1.9970 | 1.1353 |

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 105.8 | 428.3 | 564 | 9.0 | 712 | 0.87 | 552.70 | 588.03 | 0.320 | 2.94 | 1.32 | 34695.5 |
| 2 | 0 | 107.6 | 479.4 | 629 | 10.0 | 616 | 0.93 | 553.03 | 588.27 | 0.230 | 7.83 | 1.31 | 33476.9 |
| 3 | 0 | 102.7 | 332.6 | 348 | 11.0 | 368 | 0.89 | 551.56 | 587.67 | 0.280 | 2.50 | 1.05 | 11064.7 |
| 4 | 0 | 101.2 | 285.2 | 292 | 12.0 | 290 | 0.88 | 551.16 | 586.98 | 0.340 | 11.47 | 1.02 | 7316.3 |
| 5 | 0 | 100.6 | 259.2 | 256 | 11.5 | 252 | 0.91 | 550.85 | 586.68 | 0.260 | 5.77 | 0.99 | 5573.8 |
| 6 | 0 | 95.7 | 210.0 | 189 | 6.0 | 786 | 0.87 | 550.29 | 586.70 | 0.260 | 1.85 | 0.90 | 12835.0 |
| 7 | 0 | 79.2 | 46.6 | 21 | 1.0 | 160 | 0.97 | 548.89 | 584.58 | 0.180 | 2.17 | 0.45 | 290.3 |
| 8 | 0 | 97.5 | 332.6 | 351 | 7.0 | 685 | 0.64 | 551.61 | 587.33 | 0.840 | 2.38 | 1.06 | 20773.6 |
| 9 | 0 | 97.2 | 321.4 | 340 | 9.0 | 499 | 0.78 | 551.44 | 587.16 | 0.680 | 2.94 | 1.06 | 14658.6 |
| 10 | 0 | 87.5 | 126.3 | 102 | 5.0 | 752 | 0.96 | 549.41 | 585.51 | 0.125 | 2.80 | 0.81 | 6627.2 |
| 11 | 0 | 99.4 | 270.3 | 283 | 9.5 | 523 | 0.80 | 550.89 | 586.31 | 0.470 | 4.25 | 1.05 | 12788.0 |
| 12 | 0 | 96.9 | 346.5 | 405 | 0.0 | 1140 | 0.89 | 551.72 | 586.87 | 0.270 | 8.15 | 1.17 | 39890.9 |
| 13 | 0 | 87.8 | 128.2 | 112 | 6.0 | 284 | 0.88 | 549.83 | 585.97 | 0.360 | 3.06 | 0.87 | 2748.2 |

Suspended sediment load

| OBS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4510.41 | 4.05 | 0.0001784 | 109.8 | 3.90 | 0.02514 | 0.082624 | 49.78 | 0.2089 | 6.8267 | 8.9900 |
| 2 | 2343.38 | 4.46 | 0.0001780 | 112.0 | 4.28 | 0.02681 | 0.086433 | 47.41 | 0.1985 | 7.4707 | 9.8023 |
| 3 | 1217.12 | 3.24 | 0.0001823 | 106.0 | 3.14 | 0.02768 | 0.074930 | 43.61 | 0.1857 | 5.6145 | 5.8746 |
| 4 | 877.96 | 2.82 | 0.0001809 | 104.0 | 2.74 | 0.02575 | 0.069766 | 45.83 | 0.1947 | 4.8673 | 4.9832 |
| 5 | 501.64 | 2.58 | 0.0001810 | 103.2 | 2.51 | 0.02518 | 0.066788 | 46.18 | 0.1964 | 4.4607 | 4.4056 |
| 6 | 1668.56 | 2.19 | 0.0001839 | 97.9 | 2.14 | 0.02506 | 0.062196 | 45.20 | 0.1940 | 3.8683 | 3.4821 |
| 7 | 8.71 | 0.59 | 0.0001802 | 79.8 | 0.58 | 0.02083 | 0.032139 | 43.75 | 0.1874 | 1.0329 | 0.4651 |
| 8 | 7478.48 | 3.41 | 0.0001804 | 100.9 | 3.29 | 0.02819 | 0.076360 | 43.16 | 0.1825 | 5.8309 | 6.1536 |
| 9 | 3224.90 | 3.31 | 0.0001804 | 100.5 | 3.20 | 0.02757 | 0.075219 | 43.92 | 0.1857 | 5.6579 | 5.9845 |
| 10 | 265.09 | 1.44 | 0.0001824 | 88.9 | 1.42 | 0.02114 | 0.050417 | 50.01 | 0.2145 | 2.5419 | 2.0520 |
| 11 | 2557.59 | 2.72 | 0.0001789 | 102.1 | 2.65 | 0.02446 | 0.068167 | 47.96 | 0.2026 | 4.6468 | 4.8642 |
| 12 | 4387.99 | 3.58 | 0.0001775 | 100.5 | 3.45 | 0.02603 | 0.077486 | 47.10 | 0.1973 | 6.0041 | 7.0173 |
| 13 | 329.78 | 1.46 | 0.0001826 | 89.2 | 1.44 | 0.01969 | 0.050723 | 53.79 | 0.2308 | 2.5728 | 2.2476 |

suspended bed material

Shear velocity m/s

tractive shear

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

| OBS | CODE | WIDTH | AREA | Q | TEMP | CONC | PERC62 | STAGE1 | STAGE2 | D50 | PHI | VELOC | QS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 120.4 | 381.8 | 345 | 1.7 | 1090 | 0.93 | 233.60 | 258.11 | 0.110 | 2.18 | 0.90 | 32490.7 |
| 2 | 0 | 118.3 | 342.8 | 279 | 1.1 | 990 | 0.94 | 233.57 | 257.85 | 0.125 | 2.04 | 0.81 | 23864.5 |
| 3 | 0 | 126.8 | 505.4 | 527 | 9.0 | 742 | 0.84 | 234.62 | 260.06 | 0.188 | 1.76 | 1.04 | 33785.3 |
| 4 | 0 | 128.6 | 528.6 | 564 | 9.0 | 447 | 0.88 | 234.81 | 260.42 | 0.215 | 2.88 | 1.07 | 21782.1 |
| 5 | 0 | 128.6 | 542.6 | 592 | 9.0 | 343 | 0.85 | 234.90 | 259.84 | 0.260 | 3.31 | 1.09 | 17544.0 |
| 6 | 0 | 118.3 | 354.0 | 306 | 15.0 | 252 | 0.93 | 233.36 | 258.51 | 0.150 | 2.53 | 0.86 | 6662.5 |
| 7 | 0 | 115.8 | 301.0 | 231 | 1.1 | 690 | 0.96 | 232.91 | 257.88 | 0.125 | 2.80 | 0.77 | 13771.3 |
| 8 | 0 | 112.2 | 271.3 | 197 | 1.5 | 728 | 0.91 | 232.74 | 257.65 | 0.116 | 2.76 | 0.73 | 12391.1 |
| 9 | 0 | 114.0 | 289.9 | 226 | 12.0 | 408 | 0.86 | 232.81 | 258.09 | 0.102 | 1.81 | 0.78 | 7966.8 |
| 10 | 0 | 121.9 | 430.1 | 419 | 7.5 | 962 | 0.90 | 233.97 | 258.94 | 0.145 | 1.86 | 0.97 | 34825.9 |
| 11 | 0 | 111.9 | 232.3 | 150 | 14.0 | 584 | 0.90 | 232.49 | 256.57 | 0.160 | 3.94 | 0.65 | 7568.6 |
| 12 | 0 | 115.5 | 320.5 | 271 | 11.0 | 547 | 0.91 | 233.11 | 258.26 | 0.094 | 3.83 | 0.85 | 12807.7 |
| 13 | 0 | 110.3 | 198.8 | 115 | 26.0 | 336 | 0.95 | 232.03 | 256.89 | 0.290 | 1.90 | 0.58 | 3338.5 |
| 14 | 0 | 117.3 | 375.3 | 348 | 7.5 | 1090 | 0.89 | 233.51 | 259.07 | 0.135 | 2.67 | 0.93 | 32773.2 |
| 15 | 0 | 128.3 | 548.1 | 609 | 8.0 | 511 | 0.76 | 234.80 | 260.10 | 0.225 | 3.56 | 1.11 | 26887.6 |

| OBS | QSBM | DEPTH | SLOPE | WP | RADIUS | MANNING | VS | CHEZY | FROUDE | SHEAR | POWER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2274.35 | 3.17 | 0.0001911 | 123.6 | 3.09 | 0.03247 | 0.076113 | 37.07 | 0.1620 | 5.7932 | 5.2344 |
| 2 | 1431.87 | 2.90 | 0.0001894 | 121.2 | 2.83 | 0.03383 | 0.072496 | 35.06 | 0.1526 | 5.2557 | 4.2774 |
| 3 | 5405.65 | 3.99 | 0.0001985 | 130.8 | 3.86 | 0.03329 | 0.086743 | 37.54 | 0.1668 | 7.5243 | 7.8460 |
| 4 | 2613.85 | 4.11 | 0.0001998 | 132.7 | 3.98 | 0.03330 | 0.088354 | 37.71 | 0.1680 | 7.8064 | 8.3289 |
| 5 | 2631.60 | 4.22 | 0.0001945 | 132.8 | 4.08 | 0.03267 | 0.088279 | 38.60 | 0.1696 | 7.7931 | 8.5034 |
| 6 | 466.37 | 2.99 | 0.0001962 | 121.3 | 2.92 | 0.03310 | 0.074947 | 36.02 | 0.1595 | 5.6171 | 4.8560 |
| 7 | 550.85 | 2.60 | 0.0001948 | 118.4 | 2.54 | 0.03388 | 0.069698 | 34.39 | 0.1520 | 4.8578 | 3.7280 |
| 8 | 1115.20 | 2.42 | 0.0001943 | 114.6 | 2.37 | 0.03411 | 0.067179 | 33.76 | 0.1491 | 4.5131 | 3.2774 |
| 9 | 1115.35 | 2.54 | 0.0001972 | 116.5 | 2.49 | 0.03307 | 0.069361 | 35.11 | 0.1561 | 4.8110 | 3.7511 |
| 10 | 3482.59 | 3.53 | 0.0001948 | 125.4 | 3.43 | 0.03259 | 0.080941 | 37.58 | 0.1656 | 6.5515 | 6.3818 |
| 11 | 756.86 | 2.08 | 0.0001879 | 113.9 | 2.04 | 0.03413 | 0.061291 | 32.91 | 0.1431 | 3.7565 | 2.4261 |
| 12 | 1152.69 | 2.77 | 0.0001962 | 118.3 | 2.71 | 0.03221 | 0.072215 | 36.57 | 0.1621 | 5.2150 | 4.4093 |
| 13 | 166.92 | 1.80 | 0.0001939 | 112.1 | 1.77 | 0.03527 | 0.058074 | 31.11 | 0.1376 | 3.3726 | 1.9508 |
| 14 | 3605.06 | 3.20 | 0.0001994 | 120.5 | 3.11 | 0.03248 | 0.078034 | 37.11 | 0.1655 | 6.0892 | 5.6459 |
| 15 | 6453.02 | 4.27 | 0.0001973 | 132.6 | 4.13 | 0.03258 | 0.089459 | 38.79 | 0.1716 | 8.0029 | 8.8916 |

# Appendix C

## MOBED INPUT AND OUTPUT

```
 1.     25     0     0     0     0     1     1     1.000 41600.000
 2.       .66712812.500043200.0 307500.00    9.810     0.000     0.000     0.00
 3.      3.6576     3.6576     3.6576     3.6576     3.6576     4.8768     4.8768
 4.      4.7244     4.7244     4.8768     3.5052     4.1148     4.1148     3.3528
 5.      3.3528     3.3528     3.3528     3.5814     3.5814     3.5814     3.5814
 6.      3.5814
 7.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
 8.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
 9.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
10.    300.0000
11.    378.0754   374.1034   370.1314   366.1598   362.1884   356.9972   353.0252
12.    345.2336   341.2616   337.1375   334.5372   329.9557   325.9838   322.7742
13.    314.8302   310.8583   306.8865   302.6860   298.7141   294.7422   290.7704
14.    282.8266
15. 1950   30 1
16.   .1000E+04 .1650E+04 .1500E-03 .1250E-03 .1000E-05
17.    .40
18.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
19.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
20.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
21.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
22.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
23.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
24.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
25.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
26.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
27.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
28.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
29.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
30.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
31.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
32.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
33.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
34.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
35.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
36.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
37.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
38.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
39.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
40.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
41.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
42.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
43.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
44.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
45.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
46.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
47.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
48.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
49.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
50.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
51.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
52.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
53.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
54.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
55.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
56.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
57.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
58.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
59.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
60.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
61.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
62.    300.0000   300.0000   300.0000   300.0000   300.0000   300.0000   300.0000
64.    300.0000   300.0000   300.0000   300.0000   300.0000
65.    286.4080   286.4080   286.4080   286.4080   286.4080   286.4080   286.4080
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 66. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 67. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 68. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 69. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 70. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 71. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 72. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 73. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 74. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 75. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 76. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 77. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 78. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 79. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 80. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 81. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 82. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 83. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 84. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 85. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 86. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 87. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 88. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 89. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 90. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 91. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 92. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 93. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 94. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 95. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 96. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 97. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 98. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 99. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 100. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 101. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 102. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 103. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 104. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 105. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 106. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 107. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 108. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 109. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 |
| 110. | 286.4080 | 286.4080 | 286.4080 | 286.4080 | 286.4080 | | |
| 111. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 112. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 113. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 114. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 115. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 116. | 10.00000 | -10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 117. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 118. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 119. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 120. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 121. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 122. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 123. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 124. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 125. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 126. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 127. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 128. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 129. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 130. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 131. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 132. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 133. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 134. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 135. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 136. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 137. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 138. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 139. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 140. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 141. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 142. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 143. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 144. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 145. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 146. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 147. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 148. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 149. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 150. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 151. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 152. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 153. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 154. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 155. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 |
| 156. | 10.00000 | 10.00000 | 10.00000 | 10.00000 | 10.00000 | | |
| 157. | 2 1 | 0.010000 | 1.000000 | 0.000000 | 0.010000 | 1.000000 | 0.000000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | X1 | 41.600 | 22.000 | 0.000 | | | | | |
| 2. | GR | 0.000 | 376.300 | 5.000 | 366.300 | 6.400 | 366.080 | 10.400 | 365.88 |
| 3. | GR | 365.740 | 18.400 | 365.700 | 23.400 | 365.650 | 26.400 | 365.390 | 30.40 |
| 4. | GR | 34.400 | 365.220 | 38.400 | 365.240 | 42.400 | 365.180 | 46.400 | 365.24 |
| 5. | GR | 365.350 | 54.400 | 365.400 | 58.400 | 365.470 | 62.400 | 365.420 | 66.40 |
| 6. | GR | 70.400 | 365.580 | 74.400 | 365.720 | 77.400 | 366.300 | 82.400 | 376.30 |
| 7. | X1 | 75.100 | 21.000 | 33.500 | | | | | |
| 8. | GR | 0.000 | 341.500 | 5.000 | 331.500 | 7.700 | 330.570 | 11.200 | 329.55 |
| 9. | GR | 329.360 | 19.200 | 329.600 | 23.200 | 329.810 | 27.200 | 330.290 | 31.20 |
| 10. | GR | 35.200 | 330.730 | 39.200 | 330.760 | 43.200 | 330.580 | 47.200 | 330.54 |
| 11. | GR | 330.260 | 55.200 | 330.560 | 59.200 | 330.730 | 63.200 | 331.000 | 67.20 |
| 12. | GR | 69.200 | 331.320 | 65.900 | 331.500 | 70.900 | 341.500 | | |
| 13. | X1 | 82.600 | 33.000 | 7.500 | | | | | |
| 14. | GR | 0.000 | 339.000 | 5.000 | 329.000 | 6.600 | 328.340 | 8.500 | 327.92 |
| 15. | GR | 327.780 | 12.500 | 327.660 | 14.500 | 327.640 | 16.500 | 327.840 | 18.50 |
| 16. | GR | 20.500 | 327.860 | 22.500 | 327.920 | 24.500 | 327.980 | 26.500 | 327.98 |
| 17. | GR | 328.020 | 30.500 | 328.060 | 32.500 | 328.100 | 34.500 | 328.140 | 36.50 |
| 18. | GR | 38.500 | 328.220 | 40.500 | 328.220 | 42.500 | 328.200 | 44.500 | 328.22 |
| 19. | GR | 328.240 | 48.500 | 328.260 | 50.500 | 328.300 | 52.500 | 328.380 | 54.50 |
| 20. | GR | 56.500 | 328.420 | 58.500 | 328.560 | 60.500 | 328.620 | 62.500 | 328.66 |
| 21. | GR | 329.000 | 70.500 | 339.000 | | | | | |
| 22. | X1 | 83.600 | 19.000 | 1.000 | | | | | |
| 23. | GR | 0.000 | 338.700 | 5.000 | 328.700 | 8.000 | 326.620 | 12.000 | 326.62 |
| 24. | GR | 326.860 | 20.000 | 327.080 | 24.000 | 327.280 | 28.000 | 327.420 | 32.00 |
| 25. | GR | 36.000 | 327.560 | 40.000 | 327.620 | 44.000 | 327.620 | 48.000 | 327.50 |
| 26. | GR | 327.440 | 56.000 | 327.660 | 60.000 | 327.560 | 64.000 | 327.400 | 68.00 |
| 27. | GR | 73.000 | 338.700 | | | | | | |
| 28. | X1 | 84.600 | 22.000 | 1.000 | | | | | |
| 29. | GR | 0.000 | 338.360 | 5.000 | 328.360 | 8.000 | 327.700 | 12.000 | 327.29 |
| 30. | GR | 327.320 | 20.000 | 327.240 | 24.000 | 327.350 | 64.000 | 327.360 | 68.00 |
| 30.5 | GR | 36.000 | 327.440 | 40.000 | 327.500 | 44.000 | 327.540 | 48.000 | 327.62 |
| 30.6 | GR | 327.550 | 56.000 | 327.460 | 60.000 | 327.350 | 64.000 | 327.360 | 68.00 |
| 31. | GR | 72.000 | 327.510 | 76.000 | 327.640 | 79.000 | 328.360 | 84.000 | 338.36 |
| 32. | X1 | 85.800 | 23.000 | 1.200 | | | | | |
| 33. | GR | 0.000 | 337.950 | 5.000 | 327.950 | 8.000 | 327.230 | 12.000 | 326.57 |
| 34. | GR | 325.490 | 18.000 | 325.410 | 20.000 | 325.230 | 22.000 | 325.010 | 24.00 |
| 35. | GR | 26.000 | 324.510 | 28.000 | 324.370 | 30.000 | 324.780 | 32.000 | 325.34 |
| 36. | GR | 325.540 | 36.000 | 325.750 | 38.000 | 326.030 | 40.000 | 326.230 | 42.00 |
| 37. | GR | 44.000 | 326.950 | 48.000 | 327.590 | 52.000 | 327.440 | 56.000 | 327.95 |
| 38. | GR | 337.950 | | | | | | | |
| 39. | X1 | 116.900 | 20.000 | 31.100 | | | | | |
| 40. | GR | 0.000 | 327.380 | 5.000 | 317.380 | 9.000 | 316.760 | 13.000 | 316.16 |
| 41. | GR | 315.520 | 21.000 | 315.500 | 25.000 | 315.130 | 29.000 | 315.430 | 33.00 |
| 42. | GR | 37.000 | 316.600 | 41.000 | 316.700 | 46.000 | 316.720 | 49.000 | 316.63 |
| 43. | GR | 316.830 | 57.000 | 316.820 | 61.000 | 316.970 | 65.000 | 317.020 | 69.00 |
| 44. | GR | 73.000 | 317.380 | 78.000 | 327.380 | | | | |
| 45. | X1 | 130.300 | 15.000 | 13.400 | | | | | |
| 46. | GR | 0.000 | 322.800 | 5.000 | 312.800 | 10.000 | 312.320 | 14.000 | 311.80 |
| 47. | GR | 311.270 | 22.000 | 311.100 | 26.000 | 311.200 | 30.000 | 311.200 | 34.00 |
| 48. | GR | 38.000 | 311.150 | 42.000 | 311.840 | 46.000 | 312.120 | 50.000 | 312.52 |
| 48.5 | GR | 312.800 | 59.000 | 322.800 | | | | | |
| 49. | X1 | 136.700 | 14.000 | 6.400 | | | | | |
| 50. | GR | 0.000 | 320.620 | 5.000 | 310.620 | 9.000 | 309.670 | 13.000 | 309.60 |
| 51. | GR | 309.400 | 21.000 | 309.370 | 25.000 | 309.340 | 29.000 | 309.460 | 33.00 |
| 52. | GR | 37.000 | 309.690 | 41.000 | 310.040 | 45.000 | 310.520 | 45.500 | 310.62 |
| 53. | GR | 320.620 | | | | | | | |
| 54. | X1 | 139.600 | 21.000 | 2.900 | | | | | |
| 55. | GR | 0.000 | 319.600 | 5.000 | 309.600 | 9.000 | 309.410 | 13.000 | 309.37 |
| 56. | GR | 309.390 | 21.000 | 309.410 | 25.000 | 309.340 | 29.000 | 309.180 | 33.00 |
| 57. | GR | 37.000 | 309.090 | 41.000 | 308.930 | 45.000 | 308.890 | 49.000 | 308.82 |
| 58. | GR | 308.680 | 57.000 | 308.650 | 61.000 | 308.540 | 65.000 | 308.680 | 69.00 |
| 59. | GR | 73.000 | 307.710 | 77.000 | 309.600 | 82.000 | 319.600 | | |
| 60. | X1 | 141.100 | 24.000 | 1.500 | | | | | |
| 61. | GR | 0.000 | 319.124 | 5.000 | 309.124 | 9.000 | 308.744 | 13.000 | 308.76 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 62. | GR | 309.034 | 21.000 | 308.804 | 25.000 | 308.764 | 29.000 | 308.844 | 33.00 |
| 63. | GR | 37.000 | 308.864 | 41.000 | 308.844 | 45.000 | 308.674 | 49.000 | 308.55 |
| 64. | GR | 308.434 | 57.000 | 308.324 | 61.000 | 308.344 | 65.000 | 308.274 | 69.00 |
| 65. | GR | 78.000 | 308.244 | 77.000 | 308.314 | 81.000 | 308.304 | 85.000 | 308.30 |
| 66. | GR | 309.124 | 91.000 | 319.124 | | | | | |
| 67. | X1 | 142.600 | 12.000 | 1.500 | | | | | |
| 68. | GR | 0.000 | 318.614 | 5.000 | 308.614 | 9.000 | 307.464 | 13.000 | 307.54 |
| 69. | GR | 307.454 | 21.000 | 307.404 | 25.000 | 307.464 | 29.000 | 307.514 | 33.00 |
| 70. | GR | 37.000 | 308.584 | 38.000 | 308.614 | 43.000 | 318.614 | | |
| 71. | X1 | 144.600 | 18.000 | 2.000 | | | | | |
| 72. | GR | 0.000 | 317.934 | 5.000 | 307.934 | 7.000 | 307.844 | 11.000 | 307.61 |
| 73. | GR | 307.014 | 19.000 | 307.064 | 23.000 | 307.134 | 27.000 | 307.184 | 31.00 |
| 74. | GR | 35.000 | 307.204 | 39.000 | 307.314 | 43.000 | 307.334 | 47.000 | 307.18 |
| 75. | GR | 307.124 | 55.000 | 307.234 | 59.000 | 307.324 | 63.000 | 307.934 | 68.00 |
| 76. | X1 | 198.000 | 7.000 | 53.400 | | | | | |
| 77. | GR | 0.000 | 304.000 | 5.000 | 294.000 | 7.000 | 292.900 | 19.000 | 292.40 |
| 78. | GR | 292.400 | 79.000 | 293.500 | 84.000 | 304.000 | | | |
| 79. | X1 | 281.200 | 7.000 | 83.200 | | | | | |
| 80. | GR | 0.000 | 280.000 | 10.000 | 265.176 | 40.000 | 263.350 | 70.000 | 263.65 |
| 81. | GR | 263.400 | 91.440 | 264.000 | 122.000 | 280.000 | | | |

SOLUTION AT TIME T= 0.0 DAYS 0.0 HOURS 0.0 MINUTES 0.0 SECONDS

| DISTANCE | FLOW RATE | FLOW DEPTH | SEDIMENT RATE | FROUDE N | BOTTOM ELEVATION | TOP WIDTH | FLOW AREA | FRICTION FACTOR | HYDRAULIC RADIUS |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 300.0000 | 3.6576 | 0.003774 | 0.0496 | 378.075439 | 74.9373 | 243.5616 | 12.6534 | 3.1156 |
| 12812.50 | 300.0000 | 3.6576 | 0.206569 | 0.0496 | 374.103516 | 74.9373 | 243.5616 | 12.6534 | 3.1156 |
| 25625.00 | 300.0000 | 3.6576 | 0.206569 | 0.0496 | 370.131348 | 74.9373 | 243.5616 | 12.6534 | 3.1156 |
| 38437.50 | 300.0000 | 3.6576 | 0.206569 | 0.0496 | 366.159912 | 74.9373 | 243.5616 | 12.6534 | 3.1156 |
| 51250.00 | 300.0000 | 3.6576 | 0.206569 | 0.0496 | 362.188477 | 74.9373 | 243.5616 | 12.6534 | 3.1156 |
| 64062.50 | 300.0000 | 4.8768 | 0.188876 | 0.0488 | 356.997314 | 63.6368 | 240.5074 | 12.5491 | 3.2485 |
| 76875.00 | 300.0000 | 4.8768 | 0.188876 | 0.0488 | 353.025146 | 63.6368 | 240.5074 | 12.5491 | 3.2485 |
| 89687.50 | 300.0000 | 5.9436 | 0.273623 | 0.0536 | 347.986328 | 53.3636 | 213.6317 | 13.1509 | 3.7491 |
| 102500.00 | 300.0000 | 4.7244 | 0.218404 | 0.0507 | 345.233643 | 70.4742 | 237.3642 | 12.7817 | 3.2149 |
| 115312.50 | 300.0000 | 4.7244 | 0.218404 | 0.0507 | 341.261719 | 70.4742 | 237.3642 | 12.7817 | 3.2149 |
| 128125.00 | 300.0000 | 4.8768 | 0.271718 | 0.0532 | 337.137451 | 52.1767 | 213.2712 | 13.1050 | 3.7882 |
| 140937.50 | 300.0000 | 3.5052 | 0.176534 | 0.0480 | 334.537109 | 83.6052 | 257.4304 | 12.4384 | 2.8871 |
| 153750.00 | 300.0000 | 4.1148 | 0.236991 | 0.0508 | 329.955811 | 61.1944 | 227.5895 | 12.7983 | 3.4879 |
| 166562.50 | 300.0000 | 4.1148 | 0.236991 | 0.0508 | 325.983887 | 61.1944 | 227.5895 | 12.7983 | 3.4879 |
| 179375.00 | 300.0000 | 3.3528 | 0.209779 | 0.0509 | 322.774170 | 75.9490 | 242.2321 | 12.8140 | 3.0714 |
| 192187.50 | 300.0000 | 3.3528 | 0.209779 | 0.0509 | 318.802002 | 75.9490 | 242.2321 | 12.8140 | 3.0714 |
| 205000.00 | 300.0000 | 3.3528 | 0.209779 | 0.0509 | 314.830078 | 75.9490 | 242.2321 | 12.8140 | 3.0714 |
| 217812.50 | 300.0000 | 3.3528 | 0.209779 | 0.0509 | 310.858398 | 75.9490 | 242.2321 | 12.8140 | 3.0714 |
| 230625.00 | 300.0000 | 3.3528 | 0.209779 | 0.0509 | 306.886475 | 75.9490 | 242.2321 | 12.8140 | 3.0714 |
| 243437.50 | 300.0000 | 3.5814 | 0.178767 | 0.0459 | 302.686035 | 88.2231 | 262.0393 | 12.1632 | 2.9130 |
| 256250.00 | 300.0000 | 3.5814 | 0.178767 | 0.0459 | 298.714111 | 88.2231 | 262.0393 | 12.1632 | 2.9130 |
| 269062.50 | 300.0000 | 3.5814 | 0.178767 | 0.0459 | 294.742187 | 88.2231 | 262.0393 | 12.1632 | 2.9130 |
| 281875.00 | 300.0000 | 3.5814 | 0.178767 | 0.0459 | 290.770508 | 88.2231 | 262.0393 | 12.1632 | 2.9130 |
| 294687.50 | 300.0000 | 3.5814 | 0.178767 | 0.0459 | 286.798584 | 88.2231 | 262.0393 | 12.1632 | 2.9130 |
| 307500.00 | 300.0000 | 3.5814 | 0.178767 | 0.0459 | 282.826660 | 88.2231 | 262.0393 | 12.1632 | 2.9130 |

AVERAGE ENERGY SLOPE OF THE REACH= 0.00031

AVERAGE SLOPE OF BED= 0.00031 .

THE BED IS IN A TRANSITION STATE FROM DUNE 1 TO FLAT BED

THE FRICTION PARAMETERS AREA CONSTANT= 0.0287 M= -0.4290 N= 0.1430

SURFACE ELEVATION 381.733
377.761
373.789
369.817
365.846
361.874
357.902
353.930
349.958
345.986
342.014
338.042
334.071
330.099
326.127
322.155
318.183
314.211
310.239
306.267
302.295
298.323
294.352
290.380
286.408

SOLUTION AT TIME T: 726.00DAYS 0.0 HOURS 0.0 MINUTES 0.0 SECONDS

| DISTANCE | FLOW RATE | FLOW DEPTH | SEDIMENT RATE | FROUDE N | BOTTOM ELEVATION | TOP WIDTH | FLOW AREA | FRICTION FACTOR | HYDRAULIC RADIUS |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 300.0000 | 5.4434 | 0.003774 | 0.0138 | 364.112793 | 76.7231 | 378.9844 | 7.0939 | 4.6123 |
| 12812.50 | 300.0925 | 6.4348 | 0.045992 | 0.0082 | 361.092773 | 77.7145 | 455.5381 | 5.4569 | 5.3983 |
| 25625.00 | 300.1799 | 4.7903 | 0.093252 | 0.0208 | 360.579346 | 76.0700 | 329.0925 | 8.6937 | 4.0775 |
| 38437.50 | 300.2603 | 4.2416 | 0.124907 | 0.0307 | 358.528076 | 75.5212 | 287.4883 | 10.5892 | 3.6171 |
| 51250.00 | 300.3330 | 3.7979 | 0.162992 | 0.0440 | 356.065918 | 75.0775 | 254.0890 | 12.6436 | 3.2372 |
| 64062.50 | 300.3926 | 4.6399 | 0.187703 | 0.0590 | 352.124268 | 63.3998 | 225.4613 | 14.6414 | 3.0872 |
| 76875.00 | 300.4397 | 4.4534 | 0.210761 | 0.0690 | 348.978027 | 63.2133 | 213.6571 | 15.8288 | 2.9232 |
| 89687.50 | 300.4780 | 6.0063 | 0.229729 | 0.0515 | 344.388184 | 53.4264 | 216.9816 | 13.6748 | 3.7986 |
| 102500.00 | 300.5122 | 4.3536 | 0.242836 | 0.0712 | 342.843750 | 70.1033 | 211.2939 | 16.0896 | 2.8943 |
| 115312.50 | 300.5457 | 4.2327 | 0.265182 | 0.0803 | 339.501221 | 69.9825 | 202.8257 | 17.0779 | 2.7886 |
| 128125.00 | 300.5708 | 4.6182 | 0.272359 | 0.0643 | 335.927246 | 51.9180 | 199.8103 | 15.2886 | 3.5860 |
| 140937.50 | 300.5935 | 2.7195 | 0.284792 | 0.1137 | 334.140381 | 82.8195 | 192.0429 | 20.3236 | 2.1971 |
| 153750.00 | 300.6111 | 3.5444 | 0.294225 | 0.0822 | 329.607422 | 60.6241 | 192.8532 | 17.2788 | 3.0145 |
| 166562.50 | 300.6211 | 3.5237 | 0.298426 | 0.0837 | 326.262939 | 60.8034 | 191.5984 | 17.4433 | 2.9970 |
| 179375.00 | 300.6294 | 2.6653 | 0.304630 | 0.1035 | 323.484600 | 75.2778 | 190.2510 | 19.3899 | 2.4600 |
| 192187.50 | 300.6353 | 2.6575 | 0.306686 | 0.1044 | 319.635742 | 75.2702 | 189.6632 | 19.4783 | 2.4530 |
| 205000.00 | 300.6370 | 2.6484 | 0.309027 | 0.1055 | 315.798096 | 75.2614 | 188.9836 | 19.5810 | 2.4448 |
| 217812.50 | 300.6365 | 2.6511 | 0.308322 | 0.1052 | 311.946045 | 75.2640 | 189.1858 | 19.5504 | 2.4472 |
| 230625.00 | 300.6338 | 2.6514 | 0.308250 | 0.1052 | 308.101318 | 75.2643 | 189.2040 | 19.5474 | 2.4475 |
| 243437.50 | 300.6289 | 2.7539 | 0.305676 | 0.1173 | 304.035400 | 86.0845 | 189.9087 | 20.6420 | 2.1785 |
| 256250.00 | 300.6230 | 2.7610 | 0.303587 | 0.1162 | 299.927490 | 86.1028 | 190.5185 | 20.5450 | 2.1849 |
| 269062.50 | 300.6167 | 2.7705 | 0.300817 | 0.1147 | 295.829834 | 86.1274 | 191.3414 | 20.4159 | 2.1936 |
| 281875.00 | 300.6108 | 2.7788 | 0.298429 | 0.1135 | 291.746582 | 86.1489 | 192.0587 | 20.3045 | 2.2011 |
| 294687.50 | 300.6064 | 2.7874 | 0.298004 | 0.1122 | 287.675293 | 86.1709 | 192.7971 | 20.1910 | 2.2088 |
| 307500.00 | 300.6047 | 2.7905 | 0.295112 | 0.1117 | 283.617432 | 86.1791 | 193.0714 | 20.1491 | 2.2117 |

AVERAGE ENERGY SLOPE OF THE REACH: 0.00028

AVERAGE SLOPE OF BED: 0.00027

THE BED IS IN A TRANSITION STATE FROM DUNE 1 TO FLAT BED

THE FRICTION PARAMETERS AREA CONSTANT: 0.0287 M: -0.4290 N: 0.1430

SURFACE ELEVATION 369.556
367.528
365.370
362.770
359.864
356.764
353.431
350.395
347.197
343.734
340.545
336.880
333.152
329.787
326.130
322.293
318.447
314.597
310.753
306.789
302.688
298.600
294.525
290.463
286.408

TABLE 1

VALLEY SLOPE - SINUOSITY RELATIONSHIP

| REACH | VALLEY SLOPE | SINUOSITY |
|---|---|---|
| MOUTH TO PORTAGE LA PRAIRIE | .00033 | 1.54 |
| PORTAGE LA PRAIRIE TO ROSSENDALE | .00042 | 1.58 |
| ROSSENDALE TO HOLLAND | .00104 | 2.14 |
| HOLLAND TO HWY. 258 | .00038 | 1.40 |
| HWY. 258 TO R.M. OF SOUTH CYPRESS BOUNDARY | .00159 | 2.50 |
| R.M. OF SOUTH CYPRESS BOUNDARY TO BRANDON | .00060 | 1.87 |
| BRANDON TO MINIOTA | .00022 | 2.06 |
| MINIOTA TO RUSSELL | .00038 | 2.00 |
| RUSSELL TO SHELLMOUTH DAM | .000304 | 1.92 |

TABLE 2

SUMMARY OF STATION CHARACTERISTICS

| STATION | UPSTREAM BEND | OBSTACLES IN FLOW | UNSTABLE BARS | NON $\perp$ PLANE | UPSTREAM TRIBUTARIES |
|---|---|---|---|---|---|
| HEADINGLY | | X | | | |
| PORTAGE BEFORE 1962 | X | X | X | | |
| PORTAGE AFTER 1962 | X | | X | | |
| ROSSENDALE | X | | | | |
| HOLLAND | | X | X | X | X |
| BRANDON | X | | | | X |
| MINIOTA | X | X | X | | X |

TABLE 3

RELATIONSHIPS AT HOLLAND

| VARIABLE | RELATIONSHIP | R-SQUARED |
| --- | --- | --- |
| QSBM (tonnes/day) vs. | | |
| Discharge (cms) | $102.214(Q)^{0.6508}$ | 0.89 |
| Velocity (m/s) | $-1497.3+74003.8LOG_{10}(V)$ | 0.93 |
| Depth (m) | $-126.2+16830.3LOG_{10}(D)$ | 0.89 |
| Froude number | $130.6(F)^{-2.853}$ | 0.65 |
| Manning's n | $719.72x10^{36}(n)$ | 0.74 |
| Tractive Shear | $-882.6+17580.6LOG_{10}(\tau)$ | 0.85 |
| Stream Power (N/ms) | $777.09(Po)^{0.89}$ | 0.89 |
| QS (tonnes/day) vs. | | |
| Discharge (cms) | $171.5(Q)^{0.8}$ | 0.65 |
| Tractive Shear ($N/m^2$) | $1733(\tau)^{1.25}$ | 0.46 |
| Stream Power (N/ms) | $1446.12(Po)^{1.20}$ | 0.58 |
| Shear Velocity (m/s) | $9.7x10^6(V_*)^{2.5}$ | 0.46 |
| Depth (m) | $7008.1(D)^{1.21}$ | 0.44 |

TABLE 4

RELATIONSHIPS AT PORTAGE BEFORE 1969

| VARIABLE | RELATIONSHIP | R-SQUARED |
|---|---|---|
| QSBM (tonnes/day) vs. | | |
| Discharge (cms) | $0.0547(Q)^{1.89}$ | 0.72 |
| Velocity (m/s) | $1677.9(V)^{6.54}$ | 0.62 |
| Depth (m) | $19.429 \times 10^{0.83(D)}$ | 0.71 |
| Shear Velocity (m/s) | $1.132 \times 10^{36(V_*)}$ | 0.71 |
| Tractive Shear ($N/m^2$) | $18.08 \times 10^{0.26(\tau)}$ | 0.71 |
| Stream Power (N/ms) | $24.34(Po)^{2.06}$ | 0.72 |
| QS (tonnes/day) vs. | | |
| Discharge (cms) | $1.962(Q)^{1.636}$ | 0.78 |
| Velocity (m/s) | $14920.7(V)^{5.62}$ | 0.66 |
| Depth (m) | $1690.06\ (D)^{2.31}$ | 0.76 |
| Shear Velocity | $1.26 \times 10^{9}(V_*)^{4.73}$ | 0.76 |
| Tractive Shear ($N/m^2$) | $102.5(\tau)^{2.37}$ | 0.76 |
| Stream Power (N/ms) | $384.85(Po)^{1.79}$ | 0.79 |

TABLE 5

RELATIONSHIPS AT PORTAGE AFTER 1969

| VARIABLE | RELATIONSHIPS | R-SQUARED |
|---|---|---|
| QSBM (tonnes/day) vs. | | |
| Discharge (cms) | $0.064(Q)^{1.76}$ | 0.88 |
| Velocity (m/s) | $1076.40(V)^{5.81}$ | 0.89 |
| Depth (m) | $71.02(D)^{2.89}$ | 0.88 |
| Shear Velocity (m/s) | $1.05x10^{10}(V_*)^{5.9}$ | 0.88 |
| Tractive Shear ($N/m^2$) | $13.16(\tau)^{2.97}$ | 0.88 |
| Stream Power (N/ms) | $56.60(Po)^{1.99}$ | 0.90 |
| QS (tonnes/day) vs. | | |
| Discharge (cms) | $5.67(Q)^{1.36}$ | 0.88 |
| Velocity (m/s) | $10592.5(V)^{4.51}$ | 0.89 |
| Depth (m) | $1275(D)^{2.22}$ | 0.88 |
| Shear Velocity (m/s) | $2.33x10^{9}(V_*)^{4.55}$ | 0.88 |
| Tractive Shear ($N/m^2$) | $351.7(\tau)^{2.28}$ | 0.88 |
| Stream Power (N/ms) | $1071.5(Po)^{1.53}$ | 0.89 |

TABLE 6

RELATIONSHIPS AT HEADINGLEY

| VARIABLE | RELATIONSHIP | R-SQUARED |
|---|---|---|
| QSBM (tonnes/day) vs. | | |
| Discharge (cms) | $0.0943(Q)^{7.39}$ | 0.73 |
| Velocity (m/s) | $2914.7(V)^{4.50}$ | 0.74 |
| Depth (m) | $40.45(D)^{3.28}$ | 0.73 |
| Shear Velocity (m/s) | $2.356\text{x}10^{10}(V_*)^{6.40}$ | 0.72 |
| Tractive Shear ($N/m^2$) | $5.99(\tau)^{3.20}$ | 0.72 |
| Stream Power (N/ms) | $79.15(Po)^{1.86}$ | 0.73 |
| Froude Number | $3.48\text{x}10^{13}(F)^{12.97}$ | 0.72 |
| QS (tonnes/day) vs. | | |
| Discharge (cms) | $31.38(Q)^{1.08}$ | 0.59 |
| Velocity (m/s) | $23911.4(V)^{2.88}$ | 0.60 |
| Depth (m/s) | $1519.03(D)^{2.11}$ | 0.60 |
| Shear Velocity (m/s) | $6.18\text{x}10^{5}(V_*)^{4.09}$ | 0.58 |
| Tractive Shear ($N/m^2$) | $458.48(\tau)^{2.05}$ | 0.58 |
| Stream Power (N/ms) | $2376.84(Po)^{1.19}$ | 0.59 |
| Froude Number | $6.09\text{x}10^{10}(F)^{8.25}$ | 0.57 |

TABLE 7

SEDIMENT TRANSPORT COMPARISON

PORTAGE STATION

| Date | Discharge (cms) | Sediment discharge (Tonnes/day) W.S.C. | Ackers-White | Colby |
|---|---|---|---|---|
| 17/04/68 | 76 | 248 | 1345 | 1888 |
| 13/04/66 | 182 | 1585 | 3000 | 4813 |
| 19/04/65 | 217 | 1981 | 6197 | 3963 |
| 29/04/74 | 351 | 7478 | 3788 | 7081 |
| 18/04/69 | 564 | 4729 | 17178 | 21285 |
| AVERAGE | 278 | 3204 | 6302 | 7806 |

HOLLAND STATION

| Date | Discharge (cms) | W.S.C. | Ackers-White | Colby |
|---|---|---|---|---|
| 31/05/72 | 136 | 1302 | 5798 | 3450 |
| 22/04/72 | 314 | 12016 | 19468 | 19329 |
| 01/05/75 | 532 | 7422 | 31103 | 27476 |
| 25/04/76 | 1290 | 6650 | 23867 | 40488 |
| 19/04/76 | 1470 | 11631 | 33721 | 48200 |
| AVERAGE | 748.4 | 7804 | 22791 | 27789 |

HEADINGLEY STATION

| Date | Discharge (cms) | W.S.C. | Ackers-White | Colby |
|---|---|---|---|---|
| 26/04/67 | 231 | 566 | 2763 | 3621 |
| 13/04/66 | 279 | 1372 | 2317 | 3339 |
| 14/05/69 | 306 | 455 | 3203 | 3579 |
| 19/04/65 | 345 | 2388 | 4703 | 6714 |
| 29/04/69 | 592 | 2790 | 12458 | 15837 |
| AVERAGE | 350.6 | 1514 | 5089 | 6618 |

Table 8 K-Factor vs. measured data comparison at Holland

| Relationship $Q_{SBM}$ vs | K-Factor Relation | $R^2$ | Measured Relation | $R^2$ | F-Test for Significant different ($\alpha$ = .01) |
|---|---|---|---|---|---|
| Froude Number | NONE | | $130.6\ (F)^{-2.8533}$ | 0.65 | DIFFERENT |
| Mannings n | NONE | | $719.724 \times 10^{36.1(n)}$ | 0.74 | DIFFERENT |
| Velocity | NONE | | $-1497.32 + 74003.84\ LOG_{10}(V)$ | 0.93 | DIFFERENT |
| Discharge | $77.309\ (Q)^{0.6924}$ | 0.51 | $102.214\ (Q)^{0.6508}$ | 0.89 | SAME |
| Shear Velocity | NONE | | $-8018.312 + 164471\ (V_*)$ | 0.87 | DIFFERENT |
| Tractive Shear | NONE | | $-8882.561 + 17580\ .60\ LOG_{10}(\tau)$ | 0.85 | DIFFERENT |
| Mean Depth | NONE | | $-\ 126.24 + 16830.36\ LOG_{10}\ (D)$ | 0.86 | DIFFERENT |
| Power | $382.204\ (Po)^{1.119}$ | 0.57 | $777.0888\ (Po)^{0.890}$ | 0.89 | SAME |

| | COMBINED DATA | $R^2$ |
|---|---|---|
| Discharge | $80.6362\ (Q)^{0.68596}$ | 0.64 |
| Power | $423.753\ (Po)^{1.097}$ | 0.67 |

Table 9 Statistics at the Portage station
comparison of before and after construction of reservoir (1969)

| Relationship $Q_{SBM}$ vs. | Before 1969 | $R^2$ | After 1969 | $R^2$ | F-test for significant change ($\alpha$ = .01) |
|---|---|---|---|---|---|
| Discharge | $0.0547\ (Q)^{1.8868}$ | 0.72 | $0.06397\ (Q)^{1.7632}$ | 0.88 | SAME |
| Depth | $19.429\ 10^{0.8318(D)}$ | .71 | $71.0194(D)^{2.8873}$ | .88 | DIFFERENT |
| Velocity | $1677.87\ (V)^{6.5386}$ | .62 | $1076.40\ (V)^{5.810}$ | .89 | SAME |
| Power | $24.336\ (Power)^{2.059}$ | .72 | $56.600\ (Power)^{1.9867}$ | .90 | DIFFERENT |
| Shear Velocity | $1.13167 * 10^{36.055(V_*)}$ | .71 | $1.0487 \times 10^{10}\ (V_*)^{5.9342}$ | .88 | DIFFERENT |
| Tractive Shear | $18.0844 * 10^{0.2632\ (\tau)}$ | .71 | $13.1649\ (\tau)^{2.9671}$ | .88 | DIFFERENT |

| Relationship $Q_{SMB}$ vs. | Combined Date | $R^2$ |
|---|---|---|
| Q | $0.1332\ (Q)^{1.673}$ | 0.80 |
| V | $1279\ (V)^{5.743}$ | 0.77 |

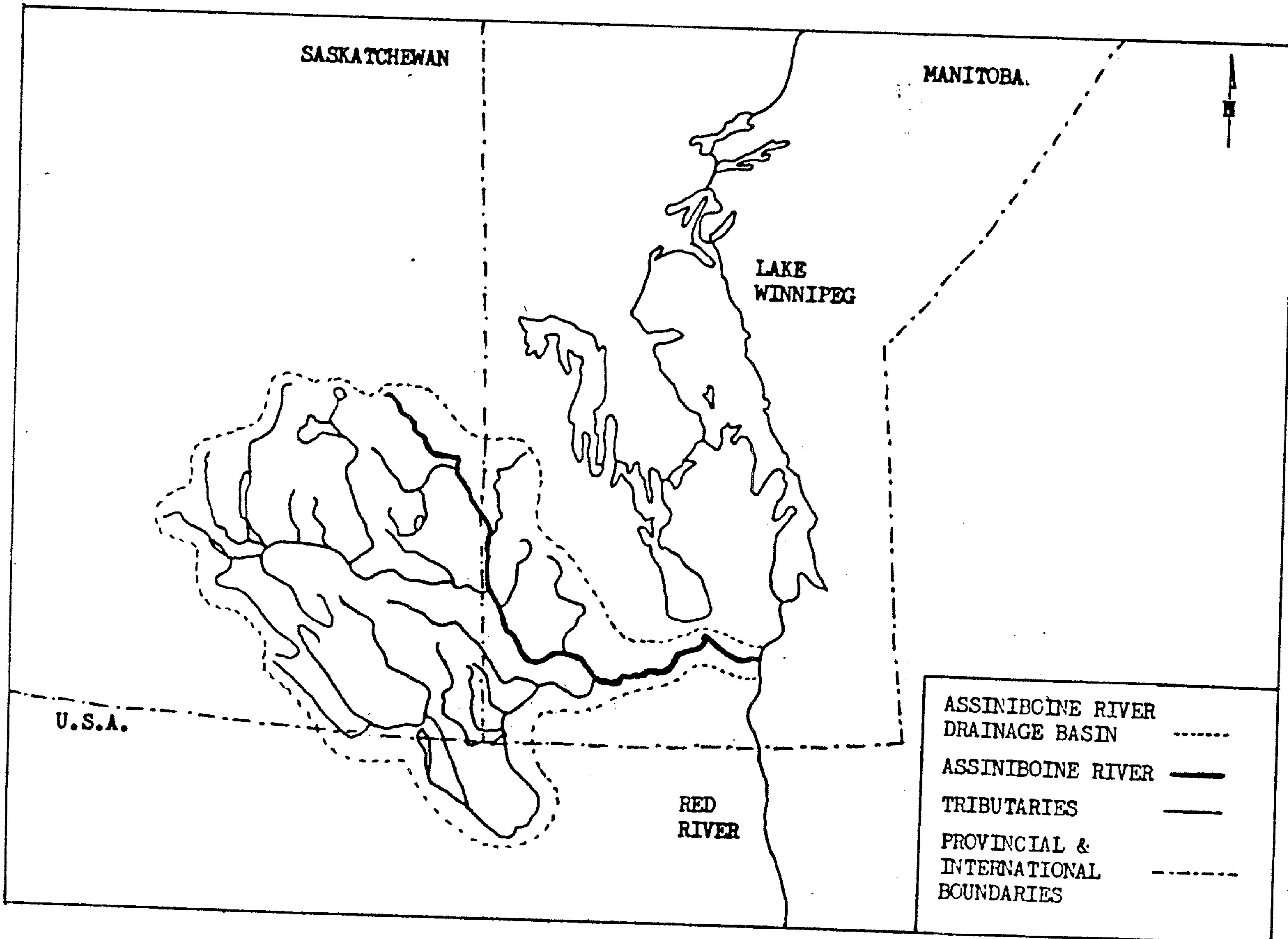



Fig. 1 ASSINIBOINE RIVER DRAINAGE BASIN

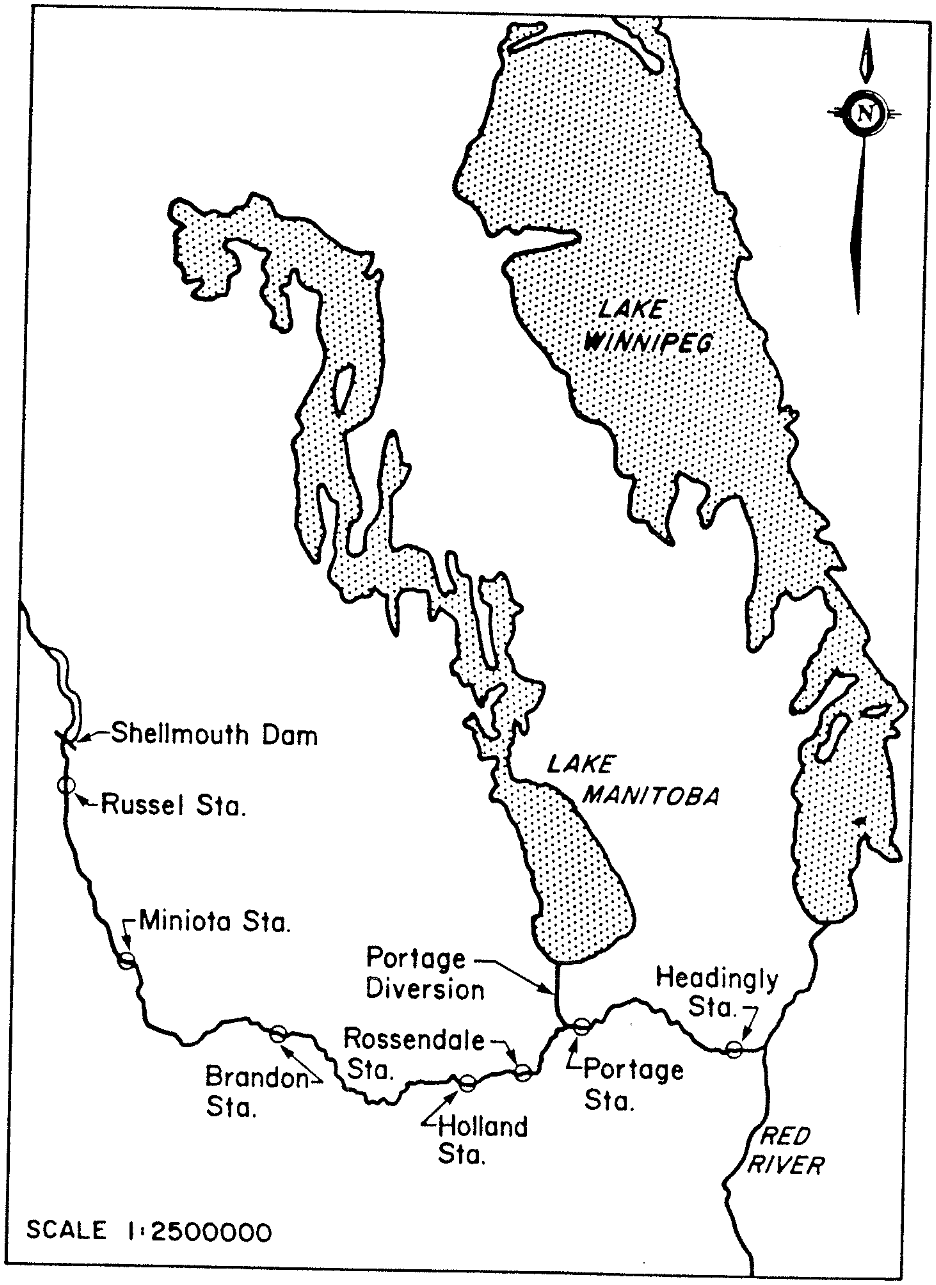



Fig. 2 Water Survey of Canada Station Locations on the Assiniboine River.

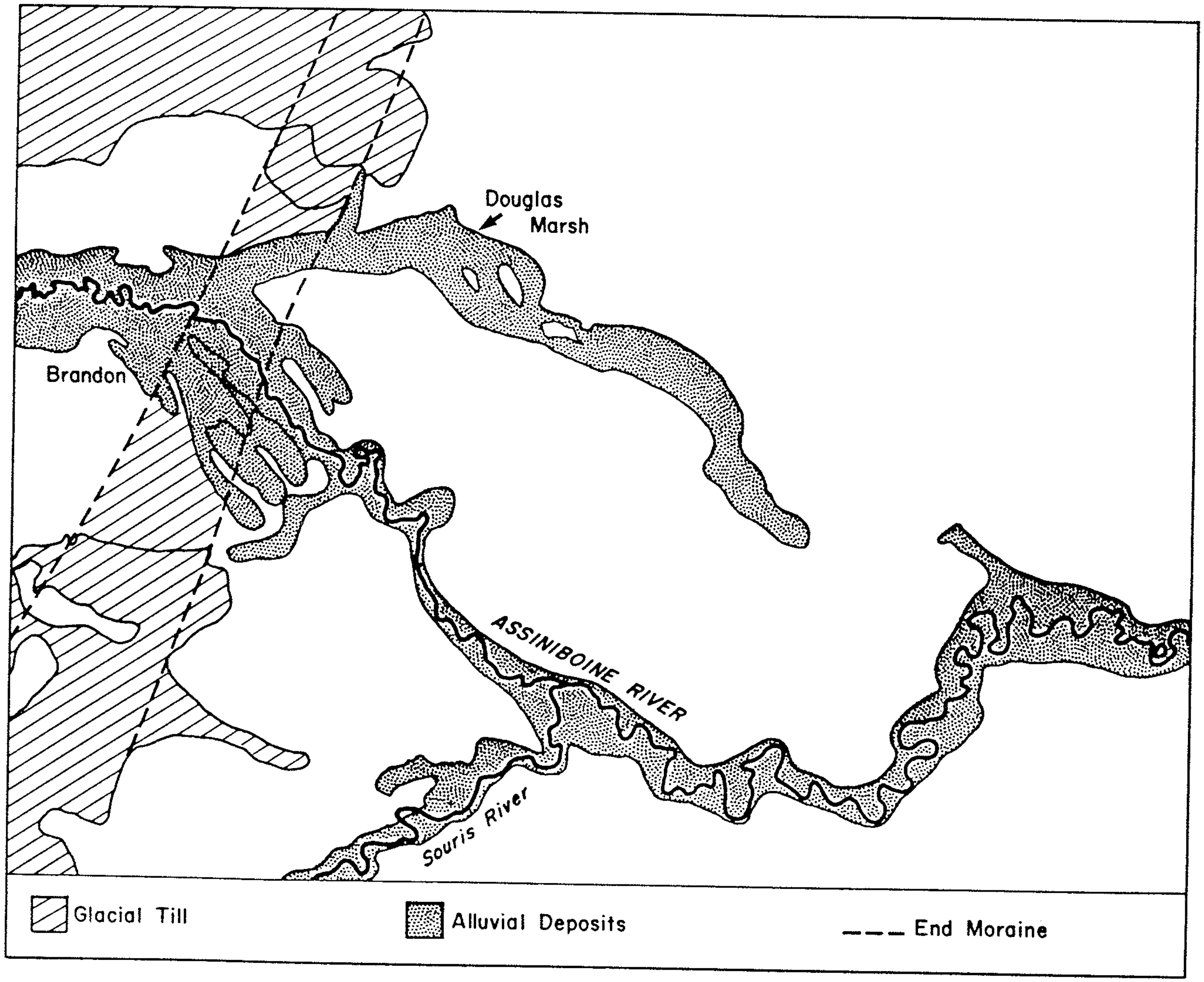



Fig. 3 Local geology near Brandon showing probable extension of the end moraine.

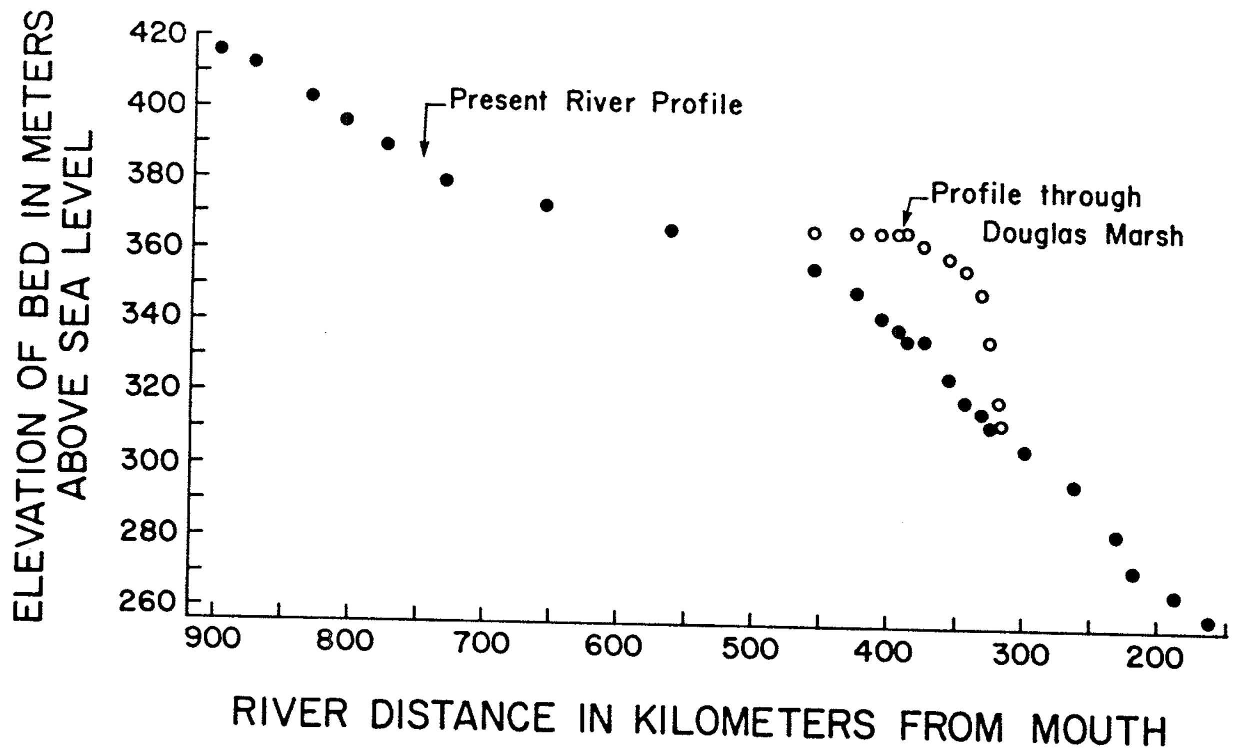



Fig. 4 Profiles of present Assiniboine River and abandoned channel.

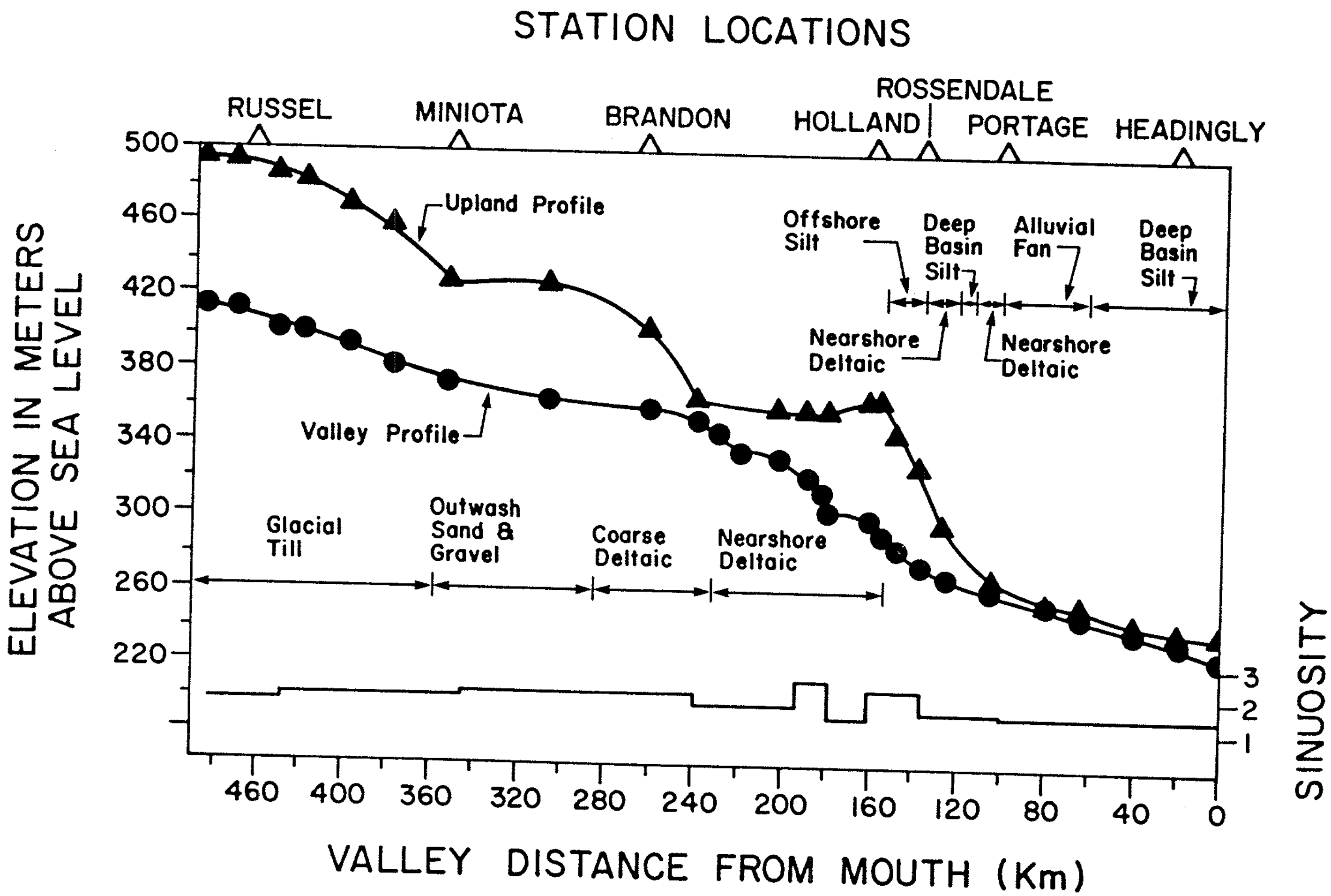



Fig. 5 Longitudinal profile showing geology and river sinuosity.

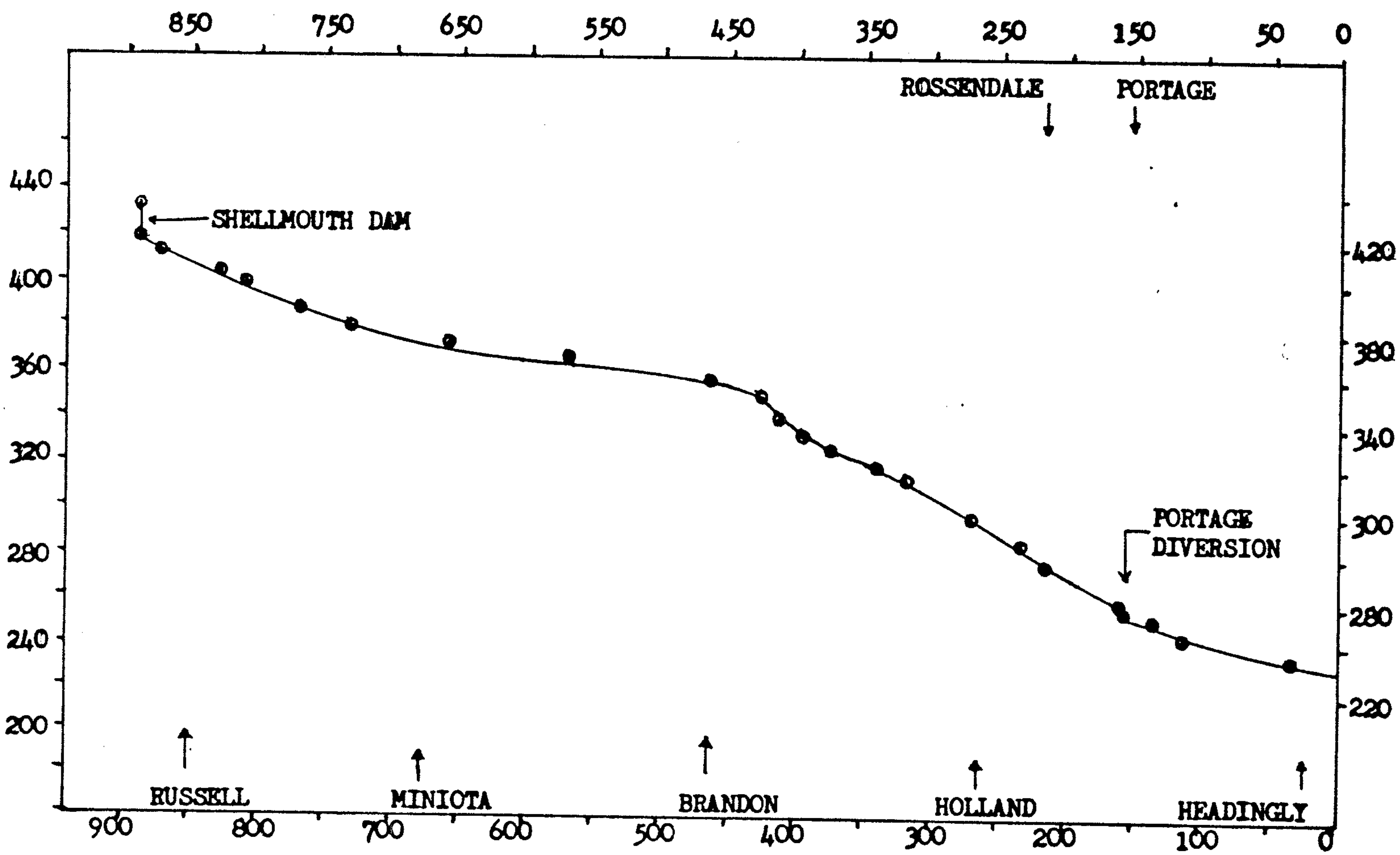



Fig. 6 LONGITUDINAL PROFILE OF THE ASSINIBOINE RIVER

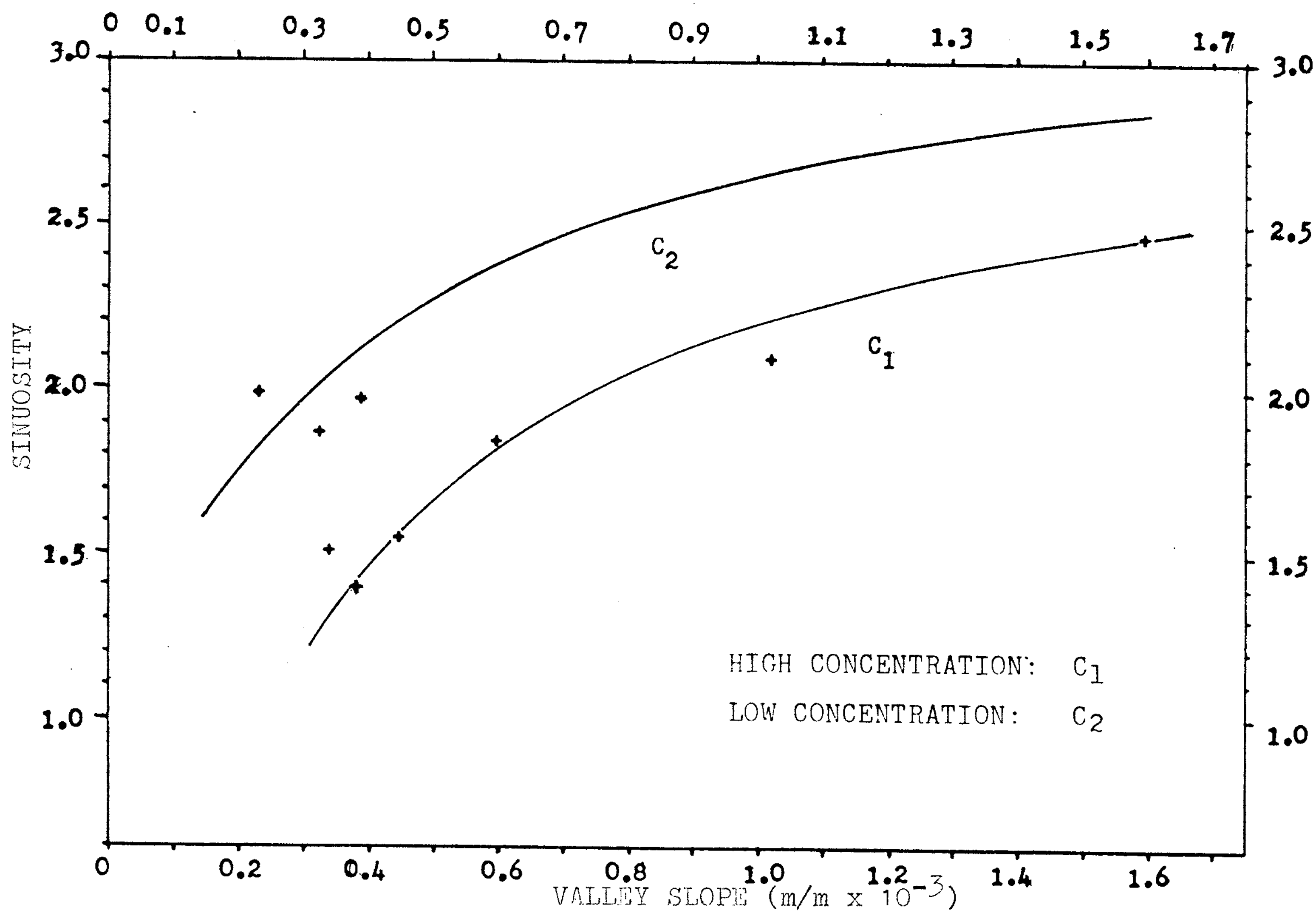
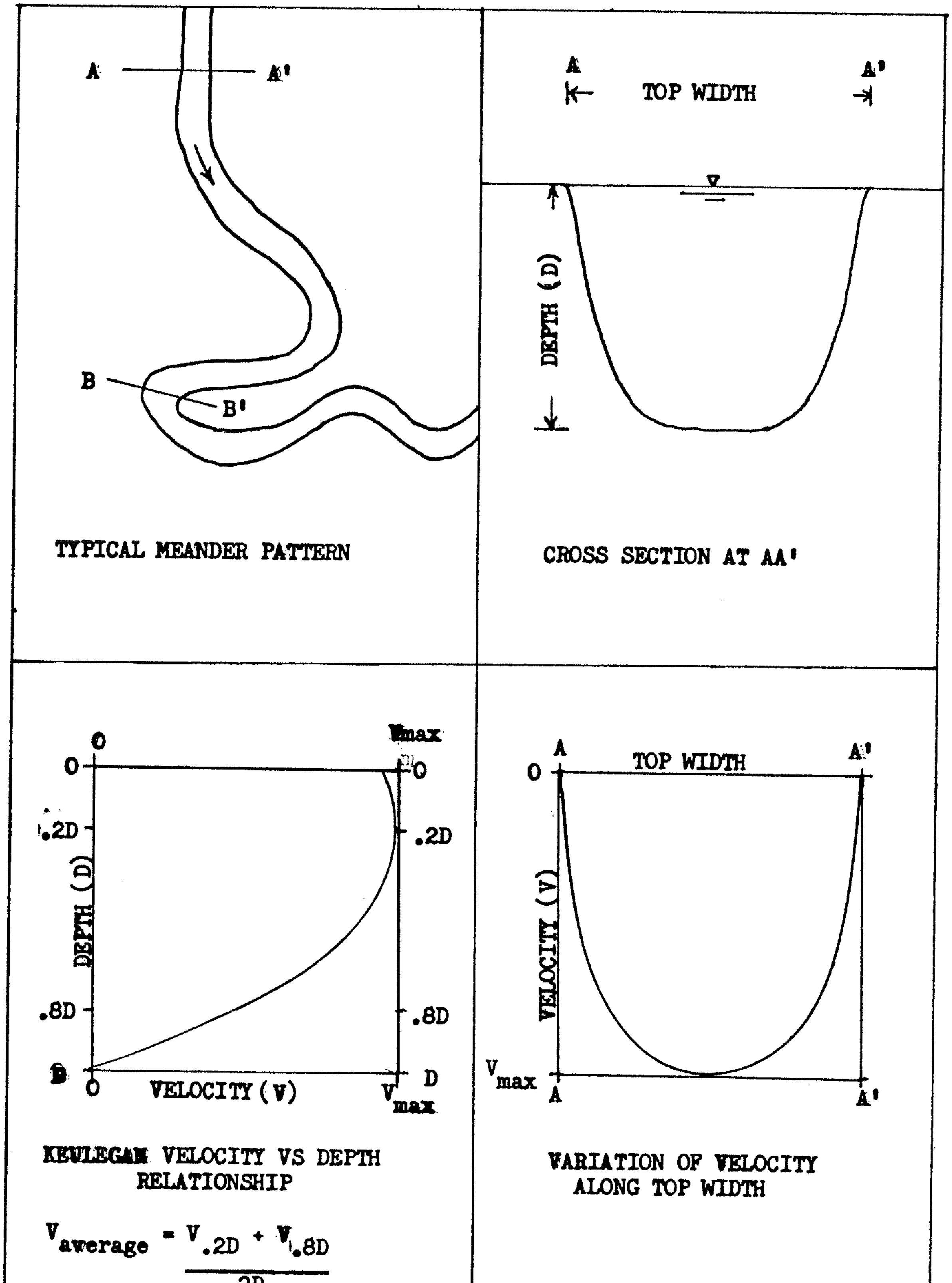



Fig. 7 VALLEY SLOPE VS. SINUOSITY




$$V_{average} = \frac{V_{.2D} + V_{.8D}}{2D}$$

Fig. 8 ASSUMED IDEAL FLOW CHARACTERISTICS

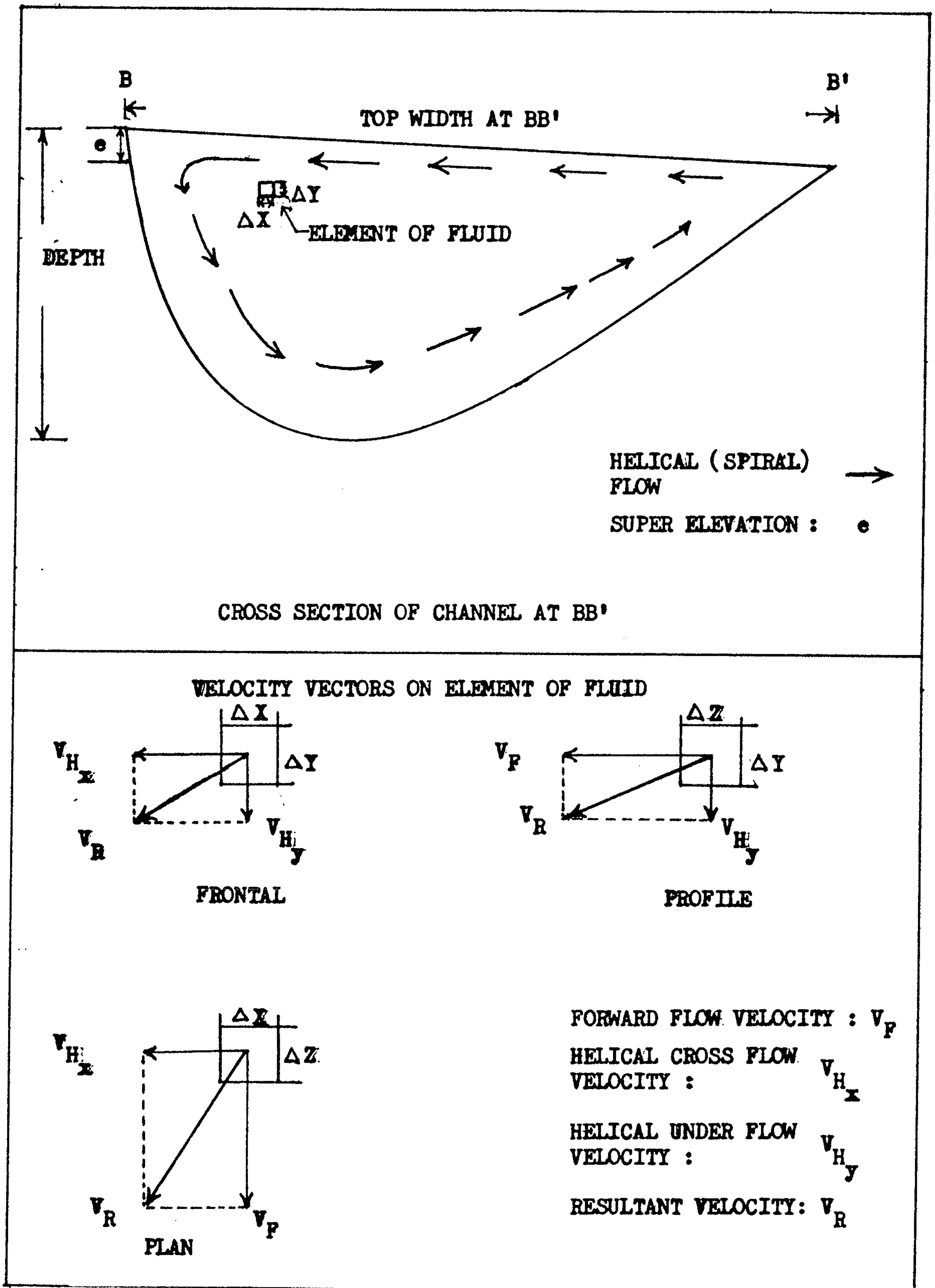



FIG. 9 HELICAL FLOW CHARACTERISTICS

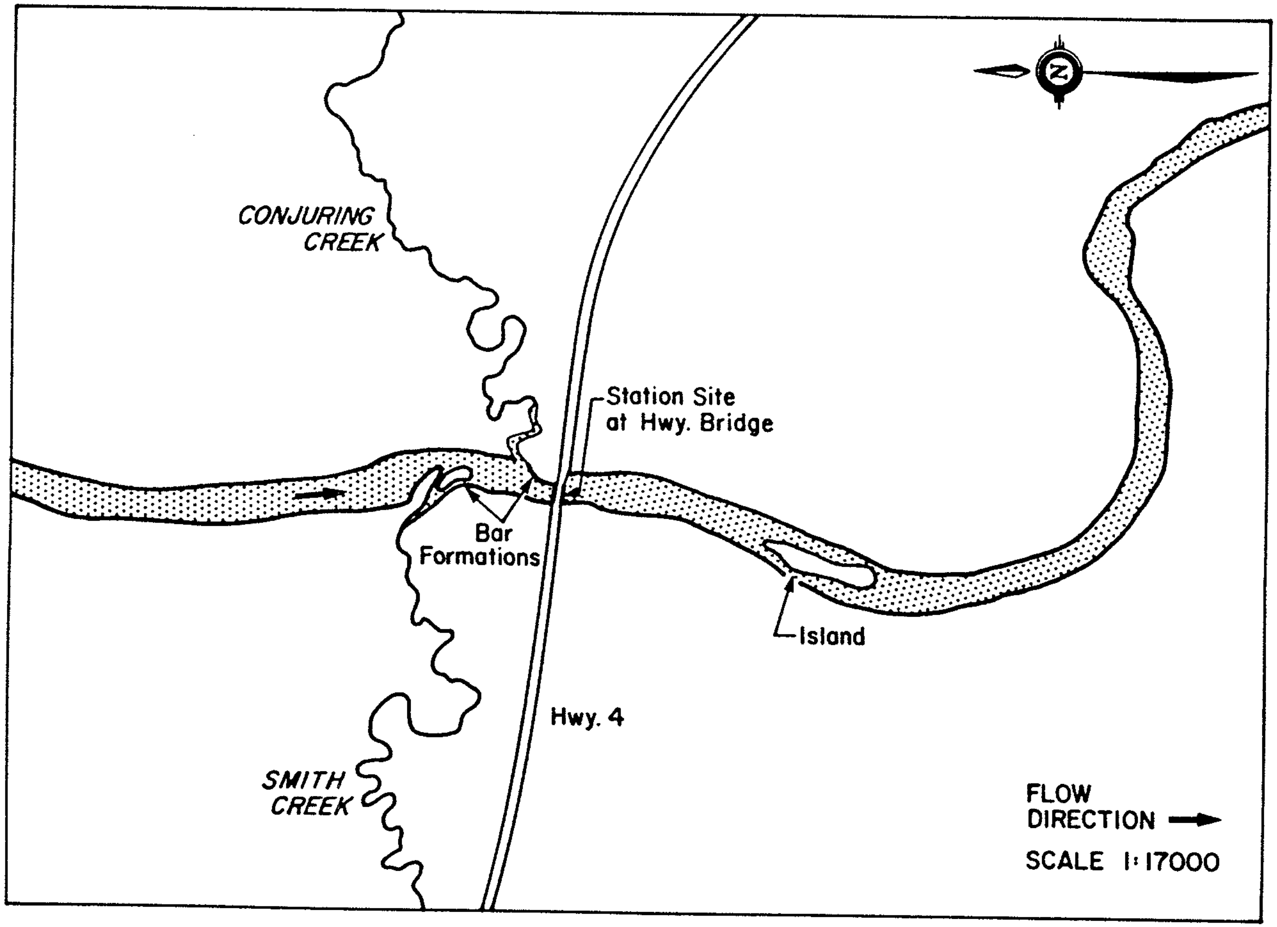



FIG. 10 Water Survey of Canada station on the Assiniboine near Russell.

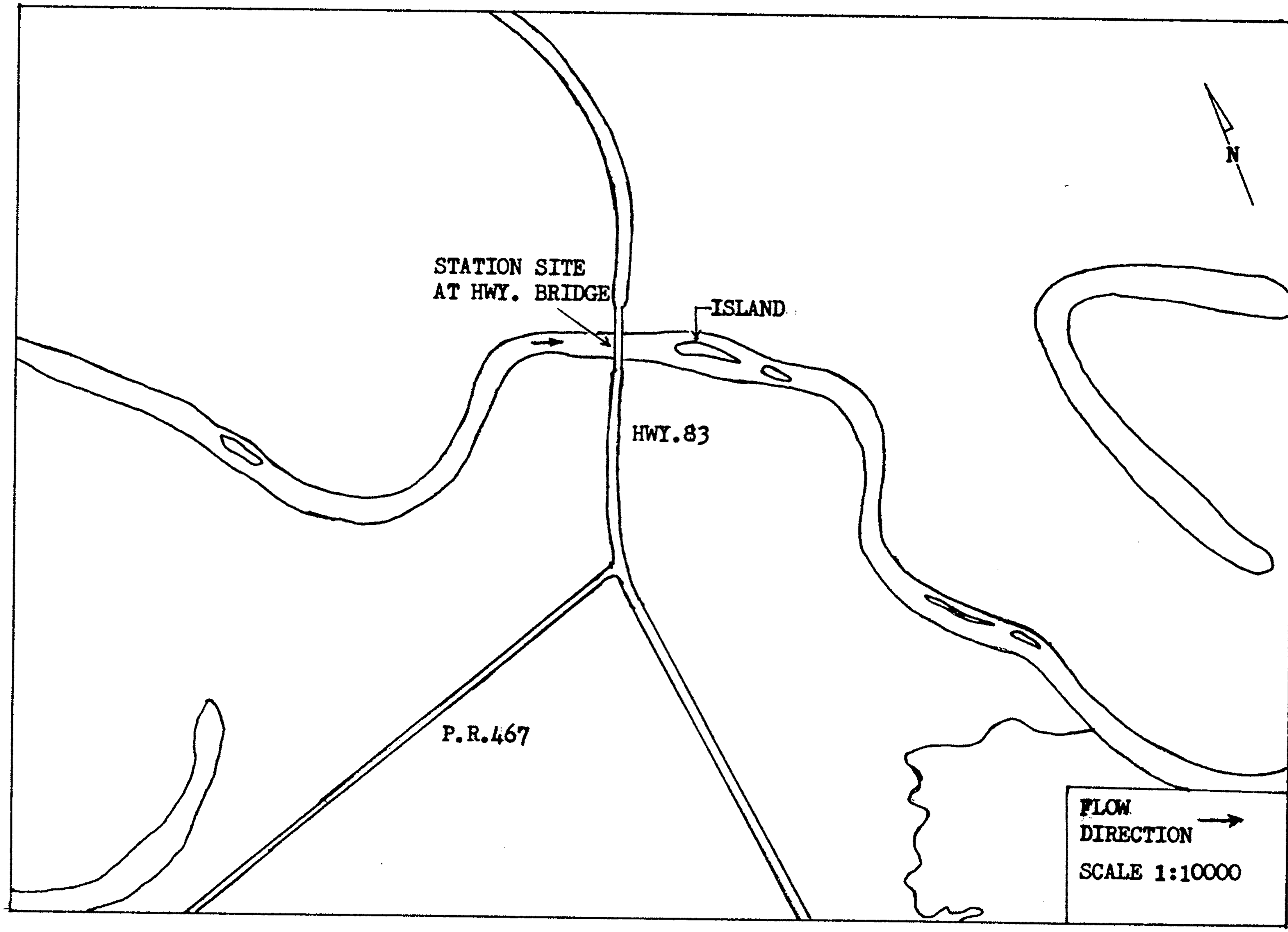



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FIG. 11 ASSINIBOINE RIVER AT MINIOTA

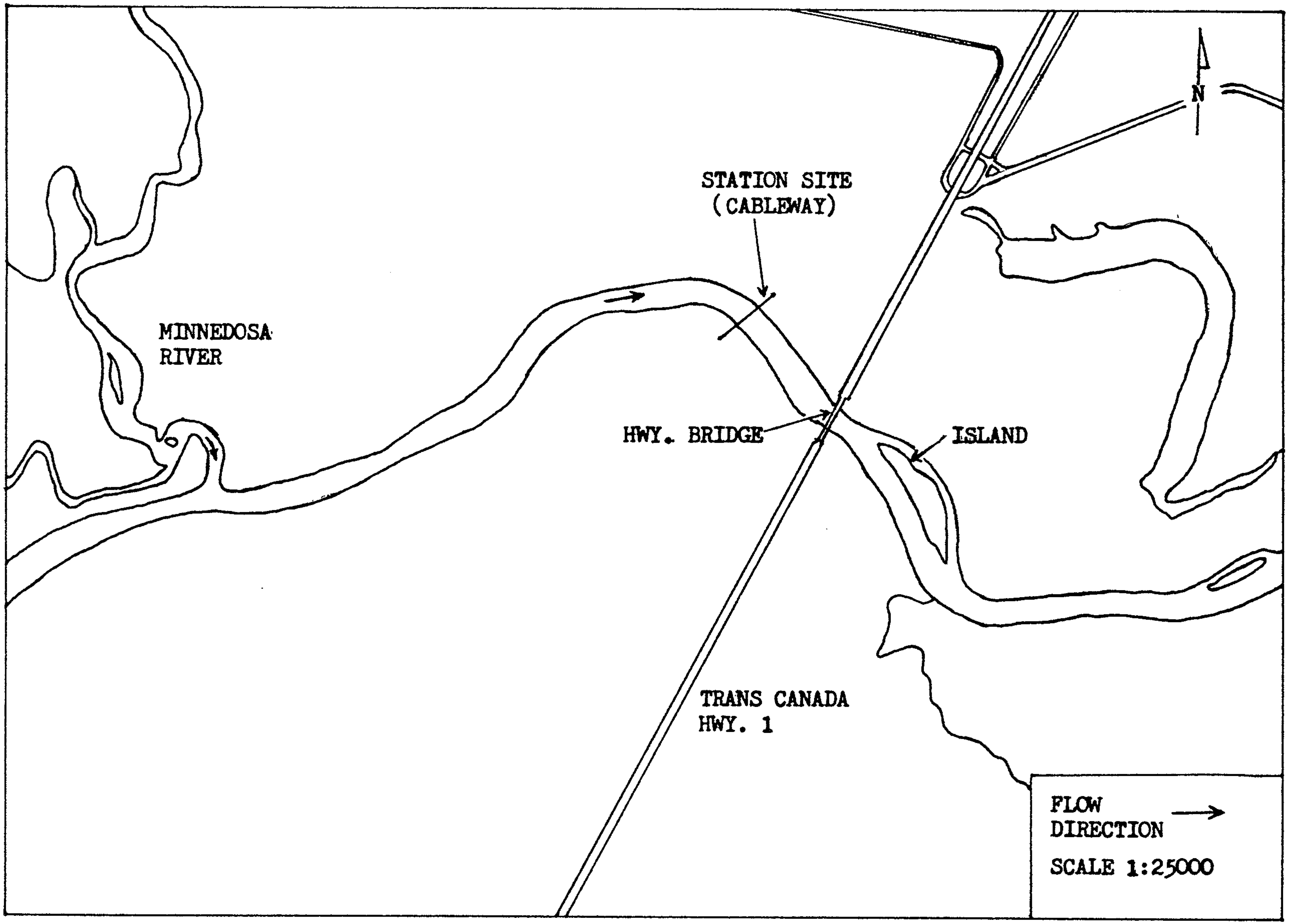


FIG. 12 ASSINIBOINE RIVER NEAR BRANDON

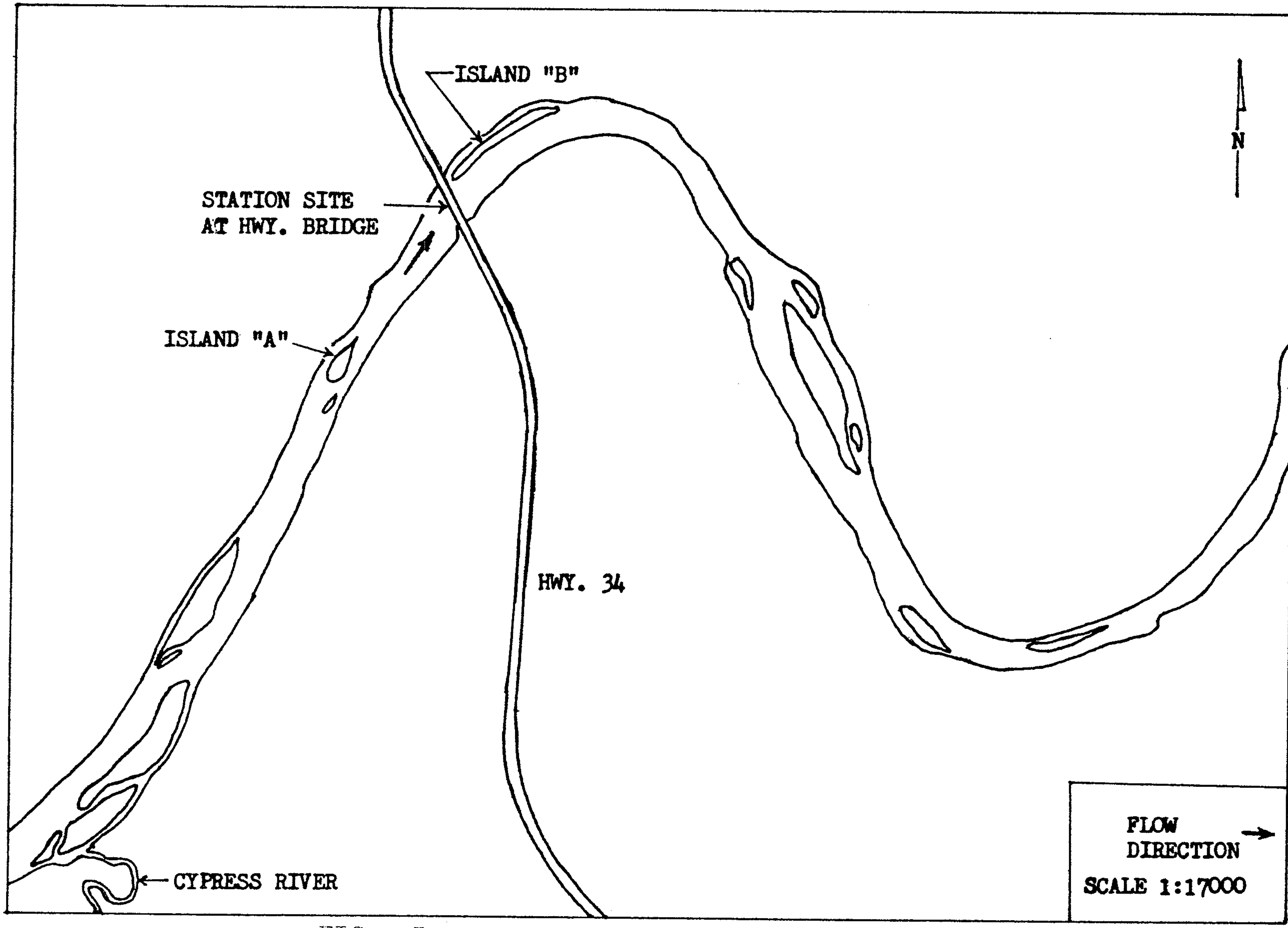


FIG. 13 ASSINIBOINE RIVER NEAR HOLLAND

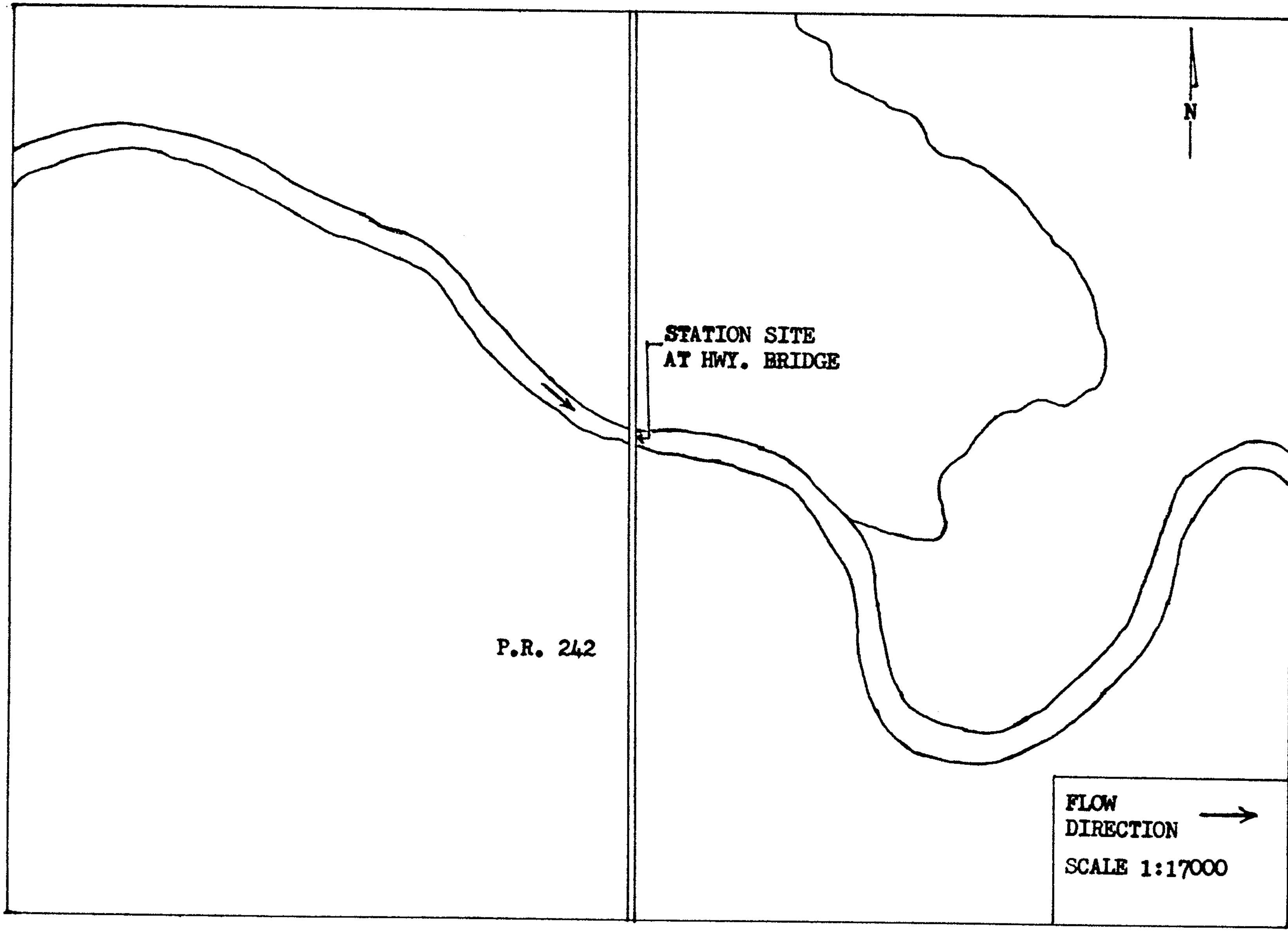


Fig. 14 ASSINIBOINE RIVER AT ROSSENDALE

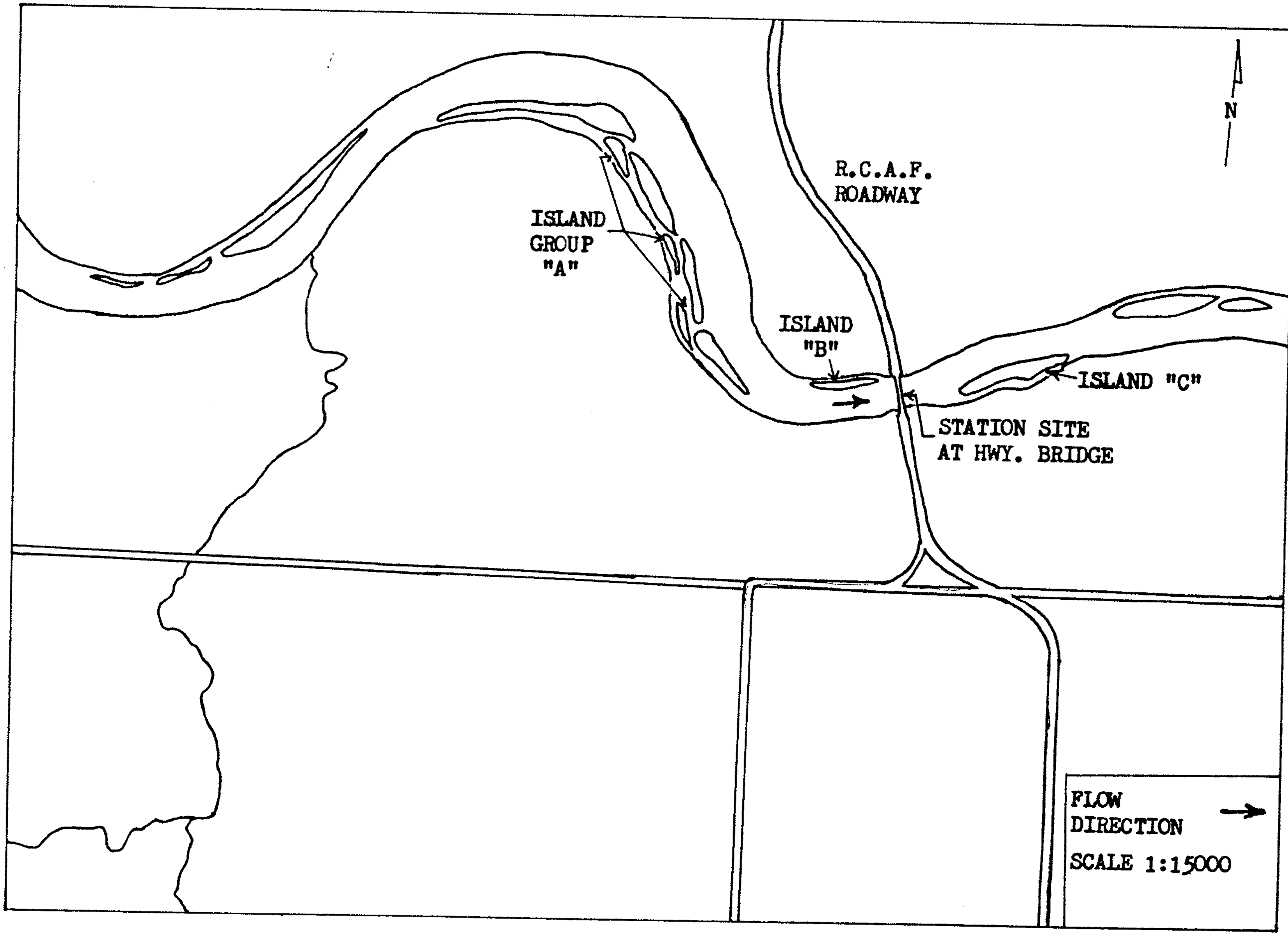


Fig. 15 ASSINIBOINE RIVER AT PORTAGE (Before 1962)

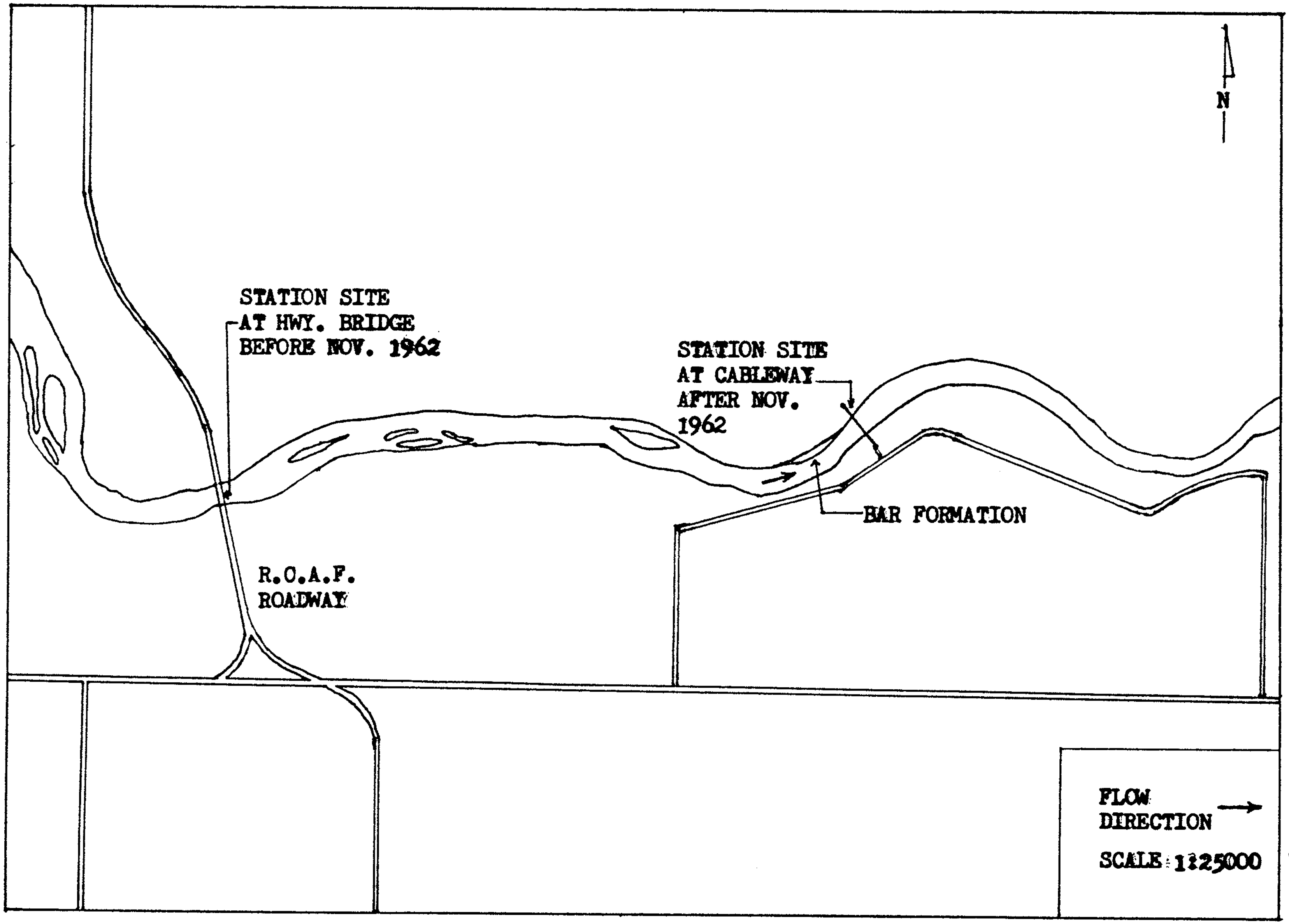


Fig. 16 ASSINIBOINE RIVER AT PORTAGE (After 1962)

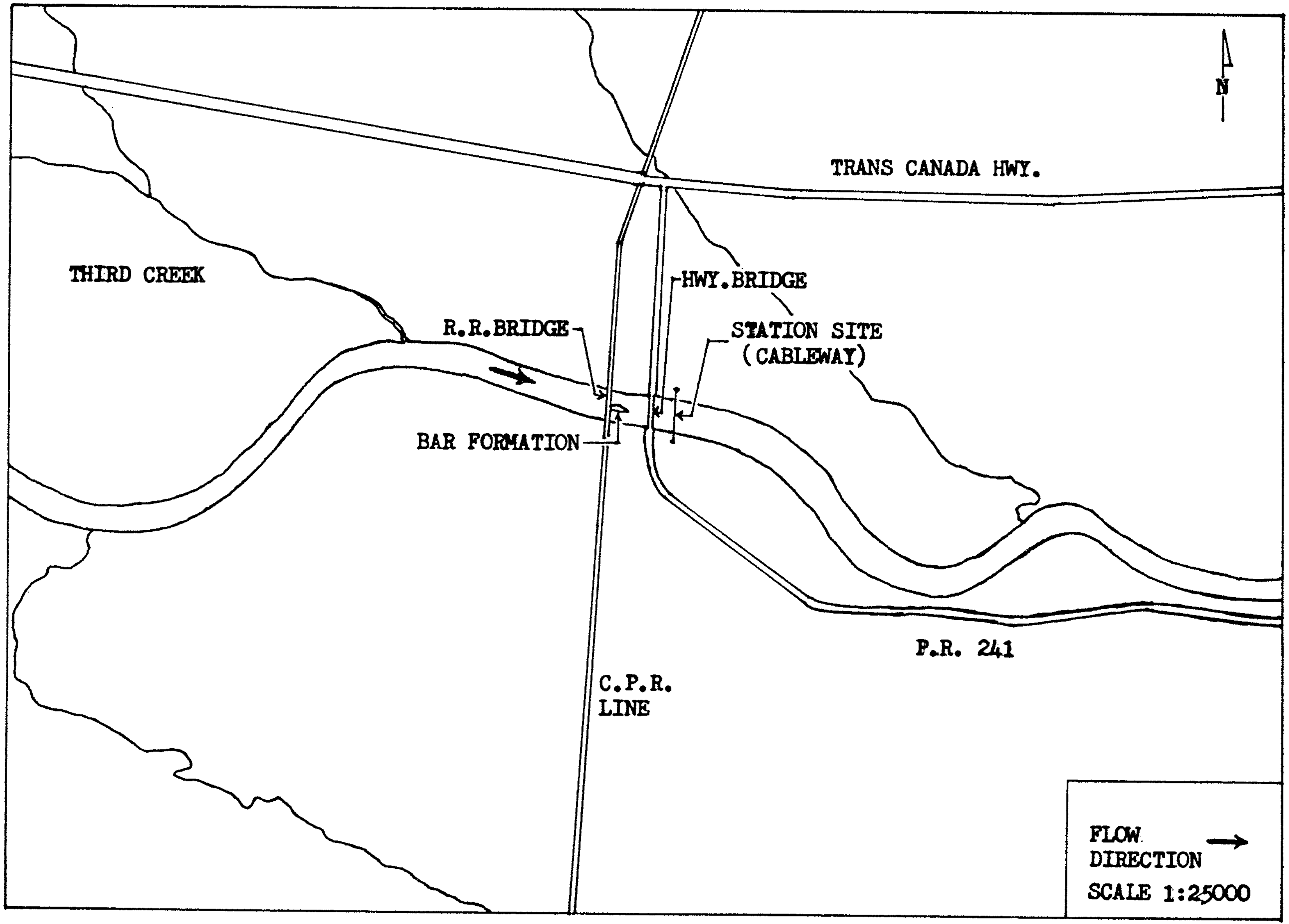


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Fig. 17 ASSINIBOINE RIVER AT HEADINGLEY STATION

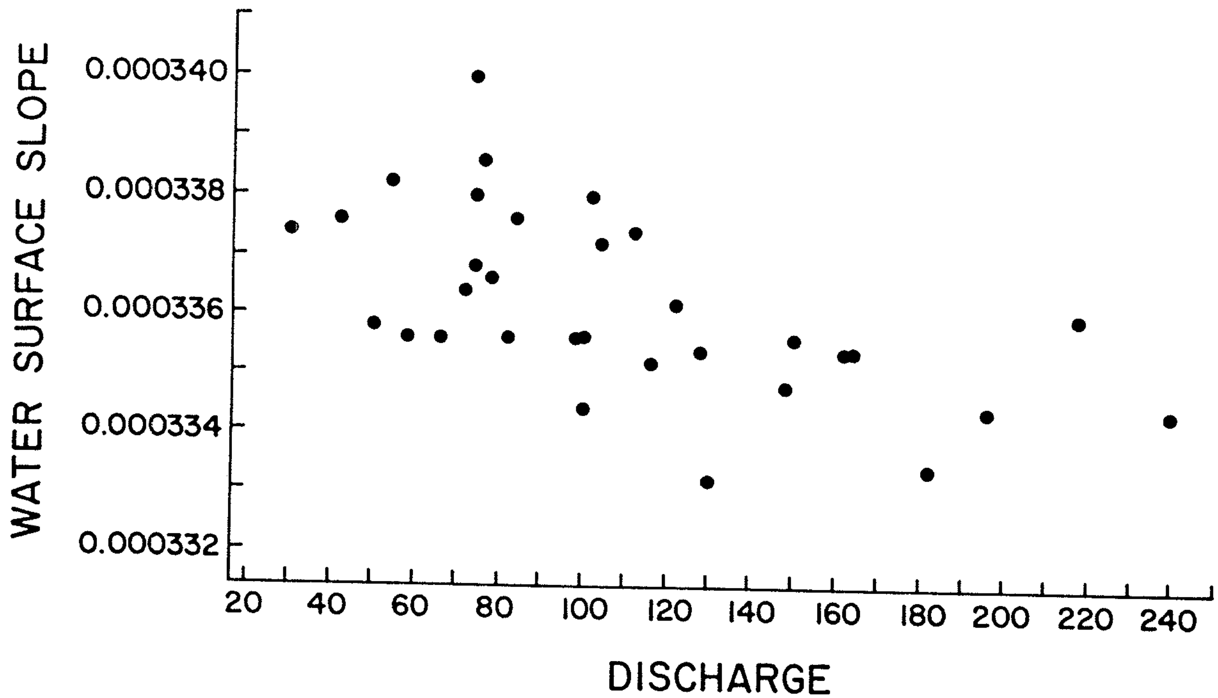
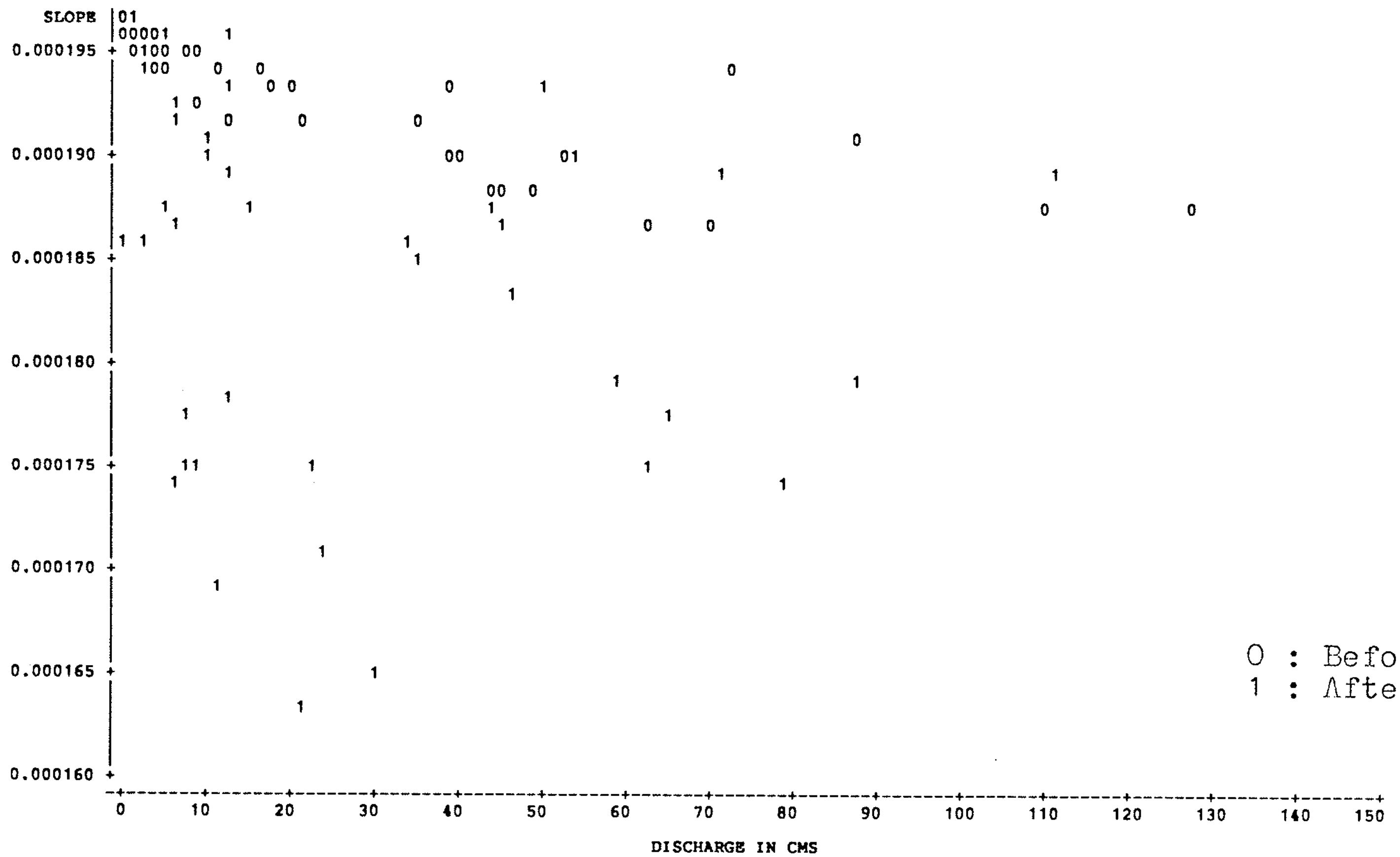



Fig. 18 Inverse slope-discharge relationship at Portage.

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF SLOPE*Q SYMBOL IS VALUE OF CODE




0 : Before 1968
1 : After 1968

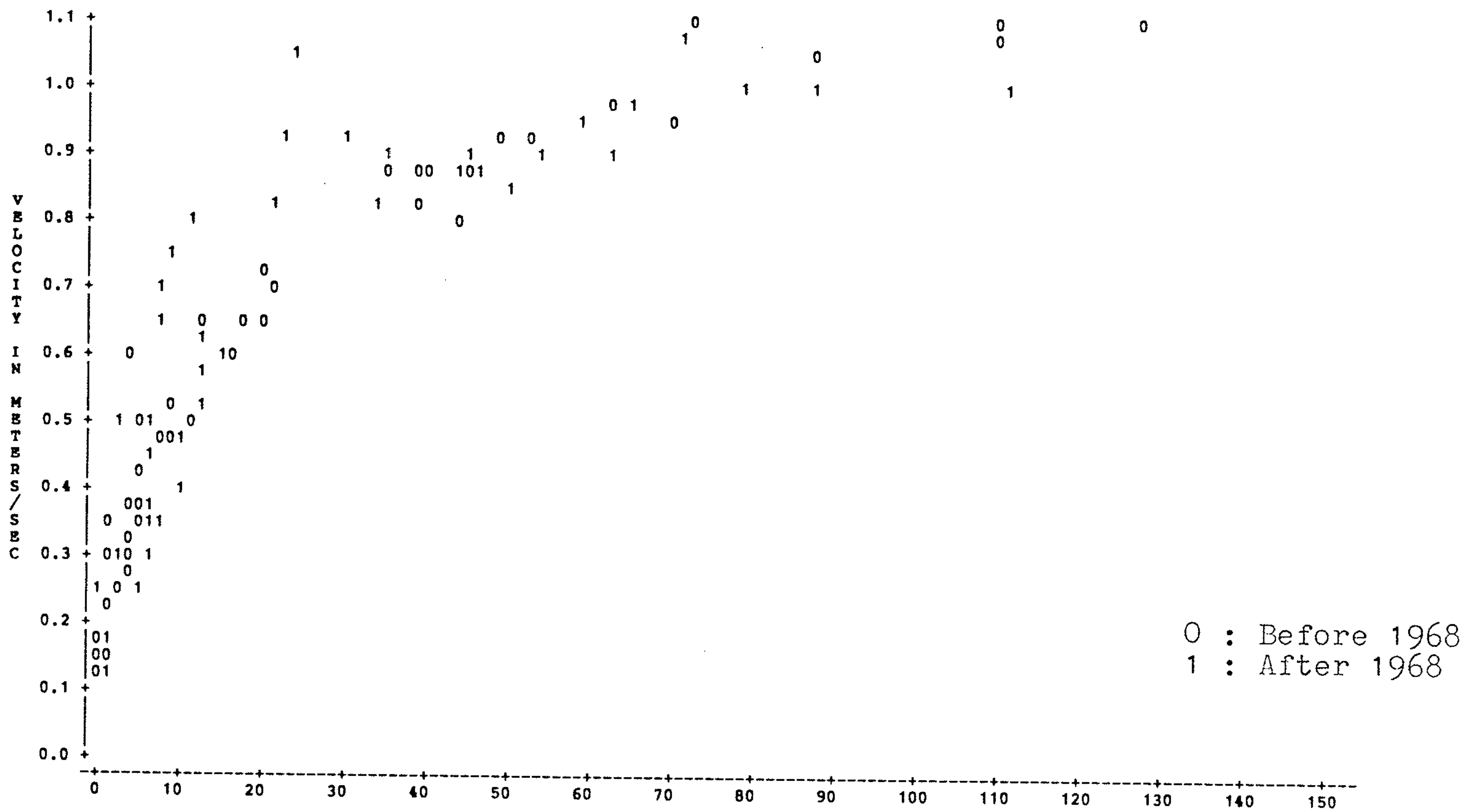
NOTE: 21 OBS HIDDEN

Fig. 19 SLOPE VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF VELOC*Q SYMBOL IS VALUE OF CODE



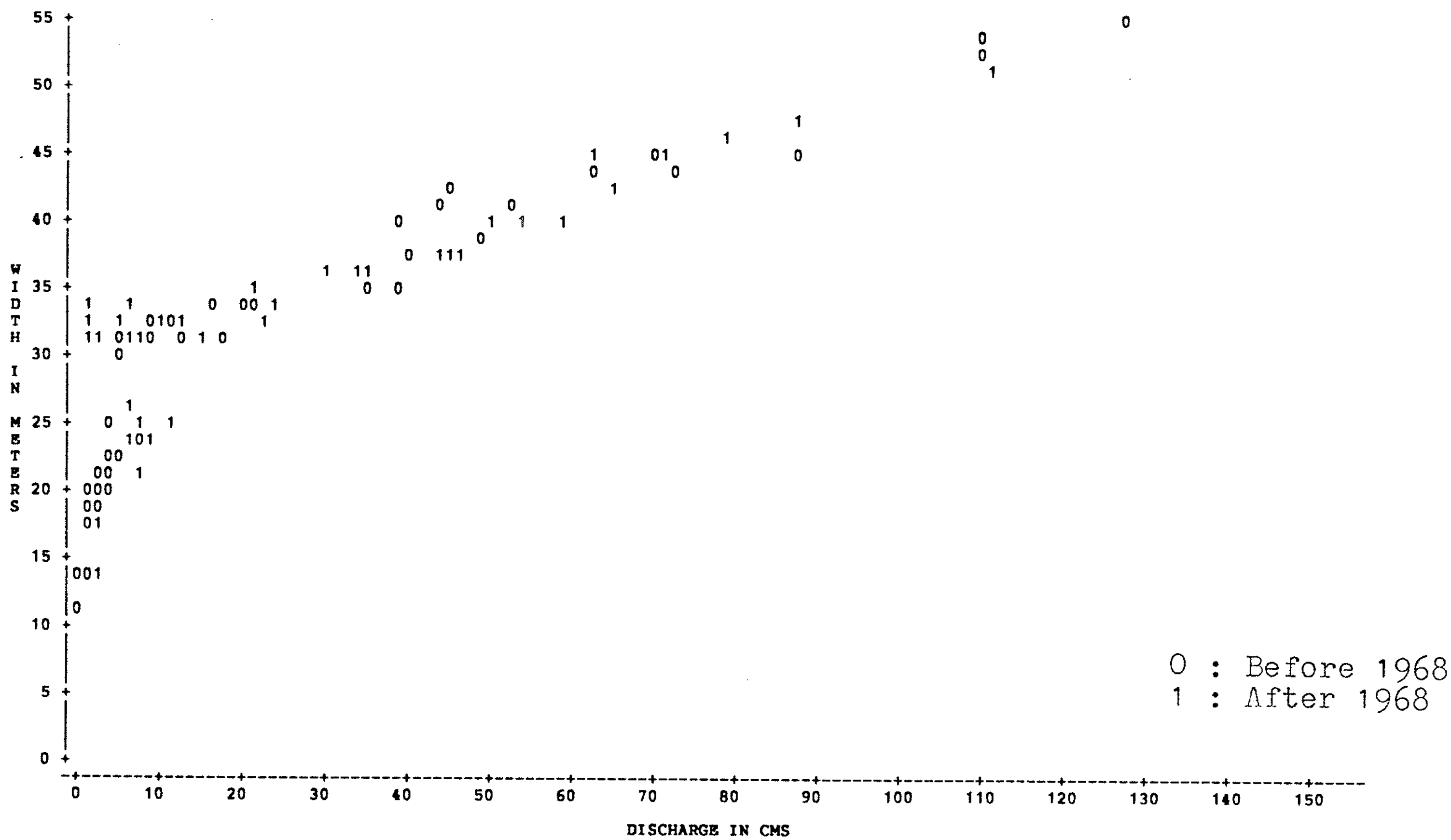

NOTE: 12 OBS HIDDEN

Fig. 20 VELOCITY VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF WIDTH*Q SYMBOL IS VALUE OF CODE



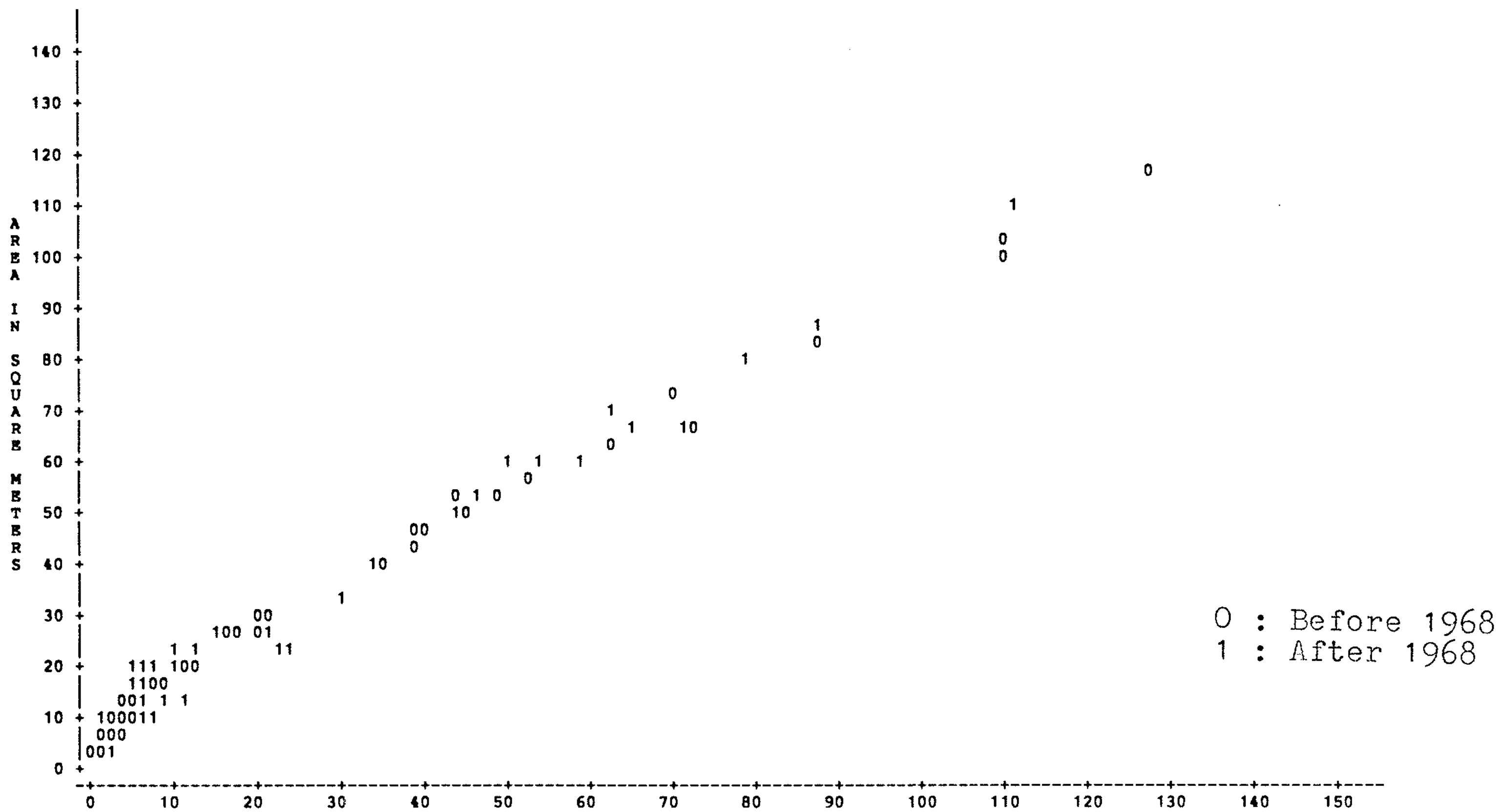

NOTE: 17 OBS HIDDEN

Fig. 21 WIDTH VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF AREA*Q SYMBOL IS VALUE OF CODE



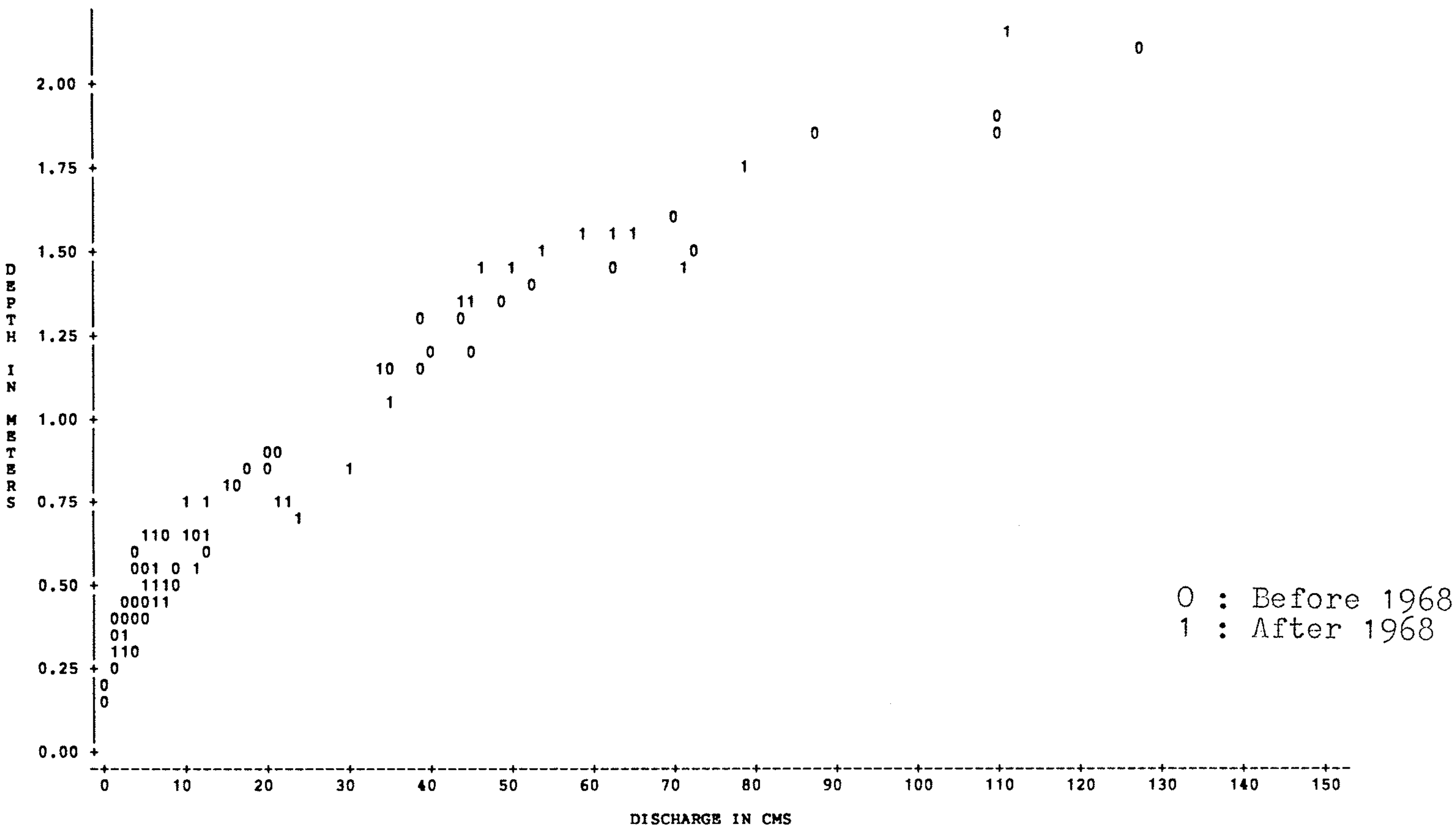

NOTE: 28 OBS HIDDEN

Fig. 22 AREA VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF DEPTH*Q SYMBOL IS VALUE OF CODE



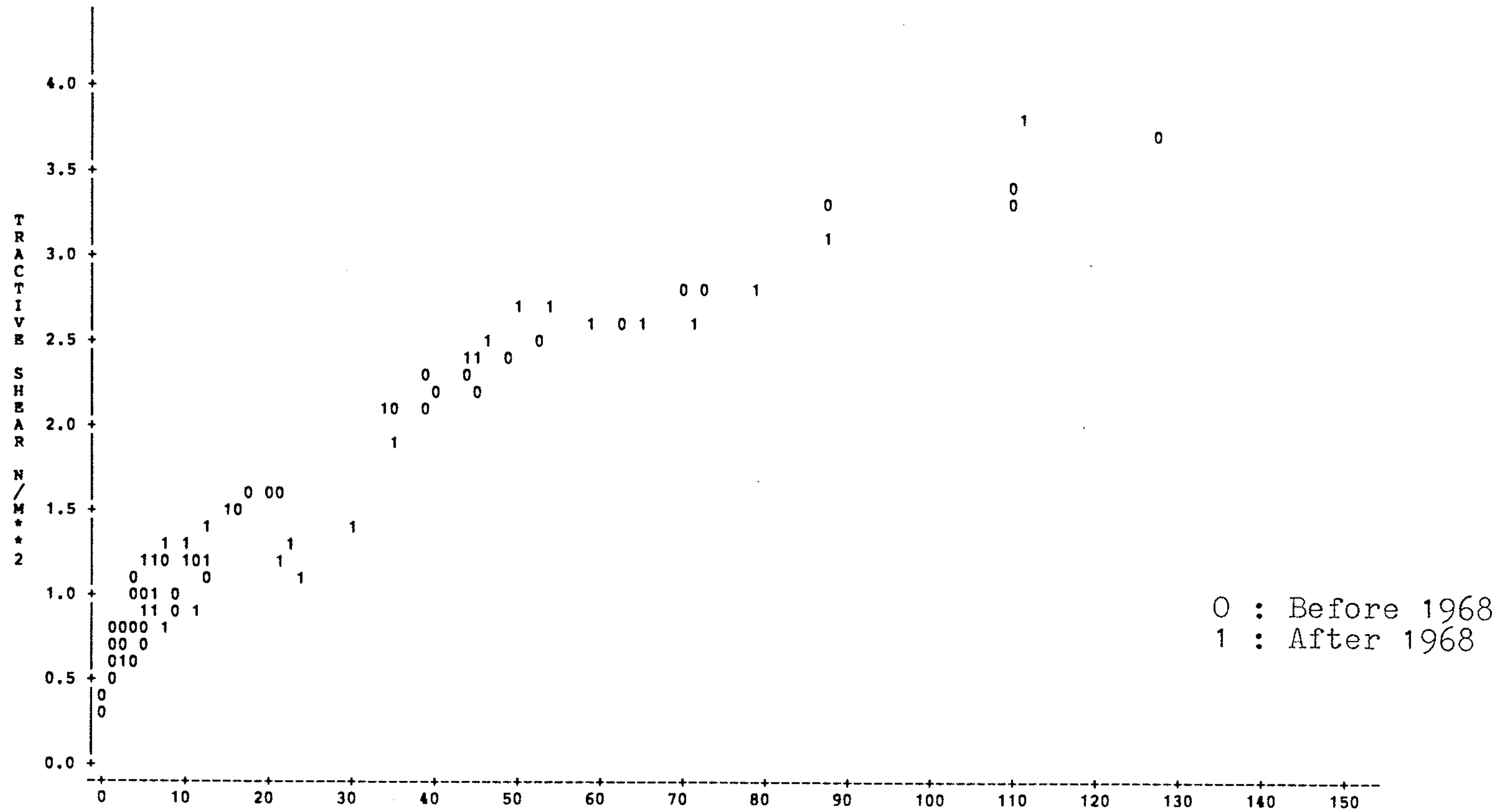

NOTE: 20 OBS HIDDEN

Fig. 23 DEPTH VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF SHEAR*Q SYMBOL IS VALUE OF CODE



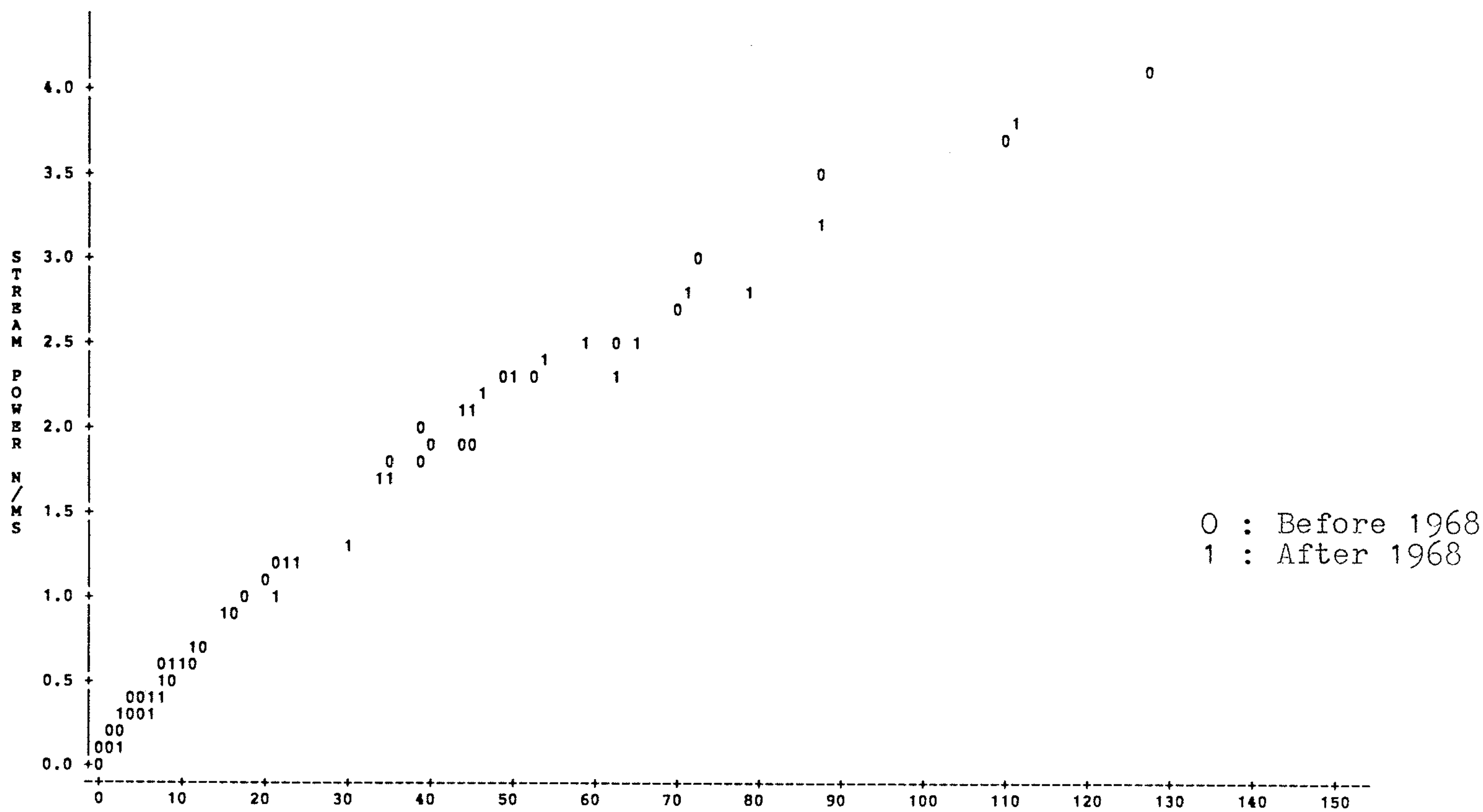

NOTE: 24 OBS HIDDEN

Fig. 24 TRACTIVE SHEAR VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF POWER*Q SYMBOL IS VALUE OF CODE



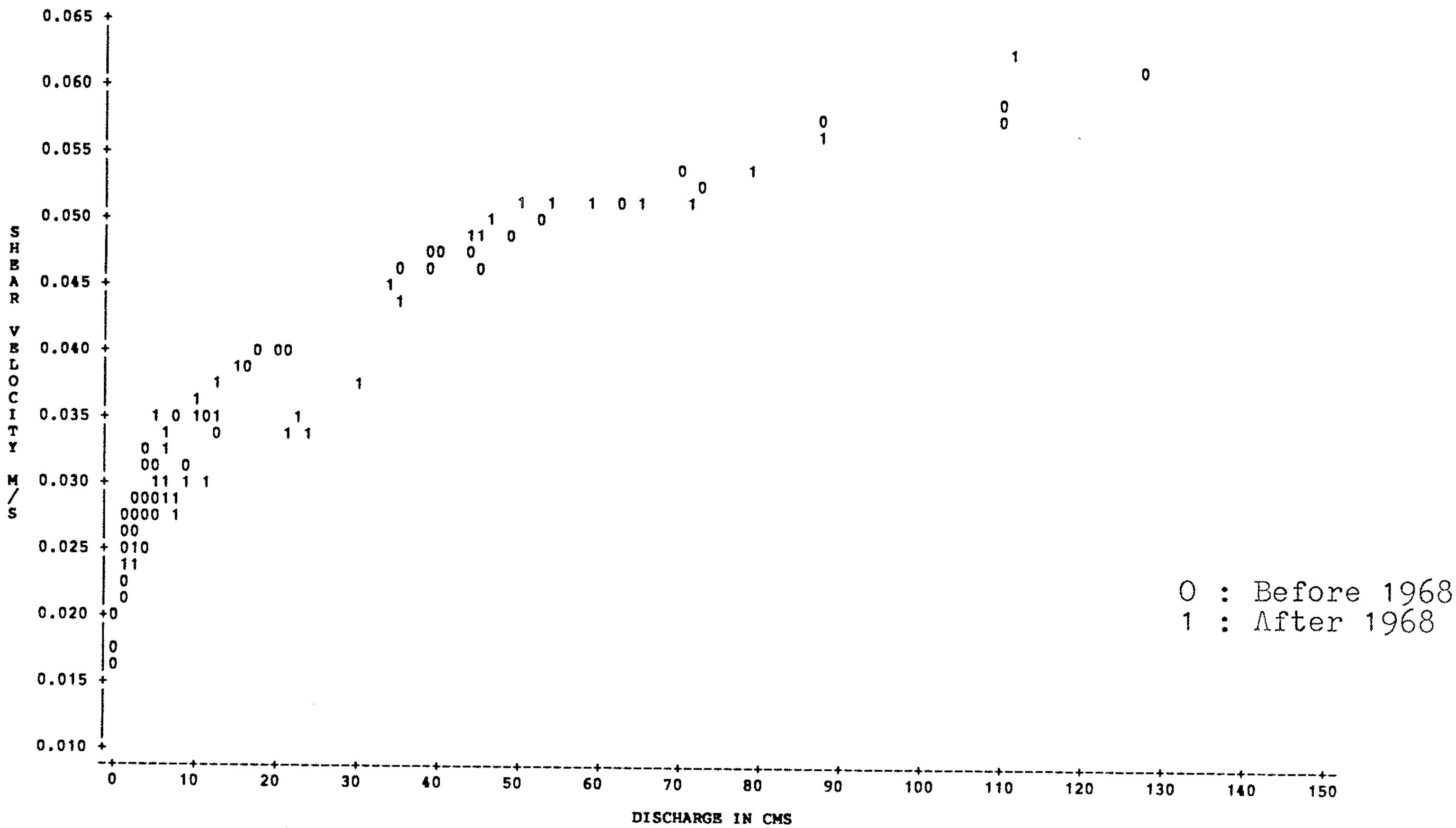

NOTE: 35 OBS HIDDEN

Fig. 25 STREAM POWER VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF VS*Q SYMBOL IS VALUE OF CODE



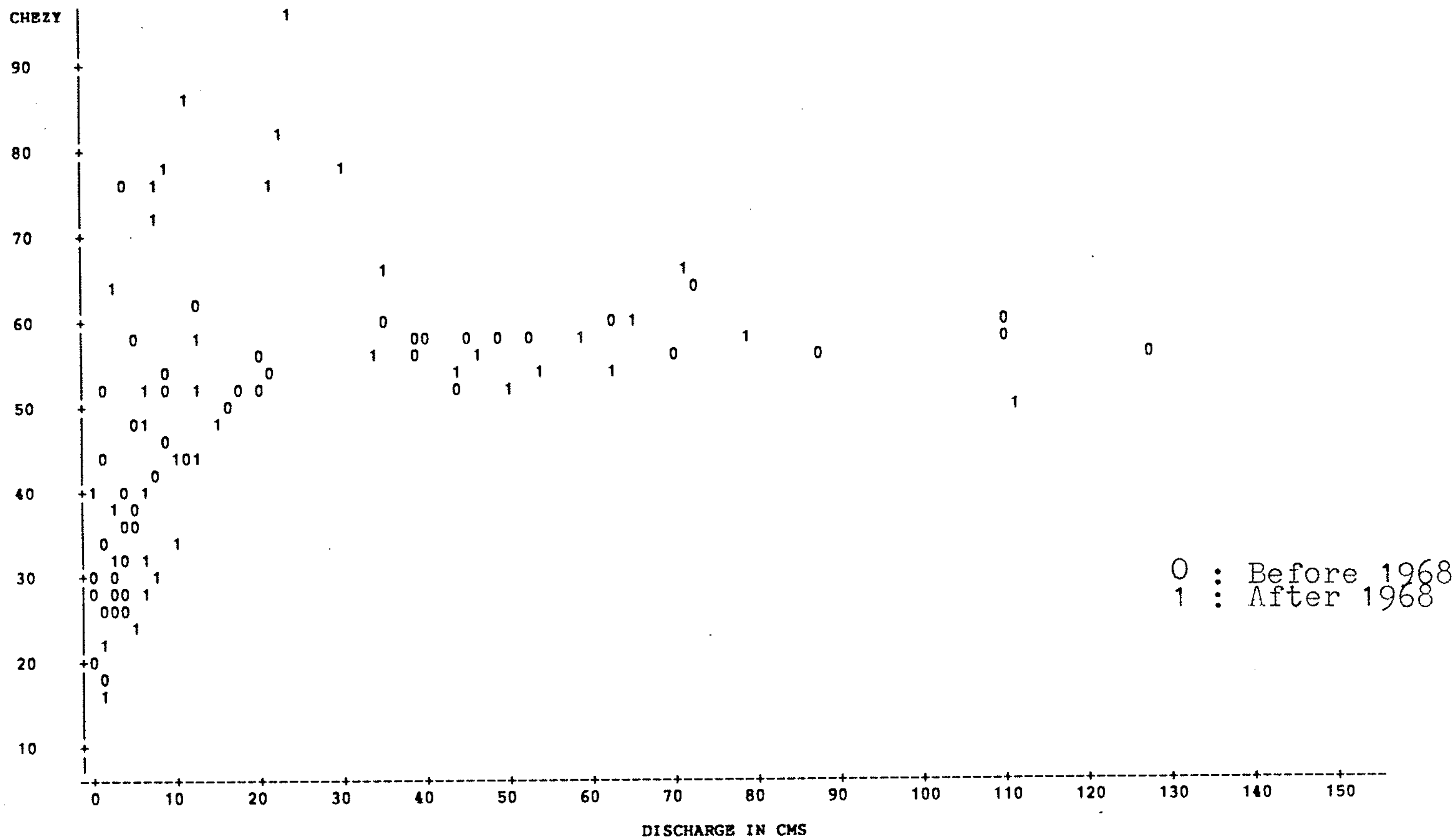

NOTE: 17 OBS HIDDEN

Fig. 26 SHEAR VELOCITY VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF CHEZY*Q SYMBOL IS VALUE OF CODE



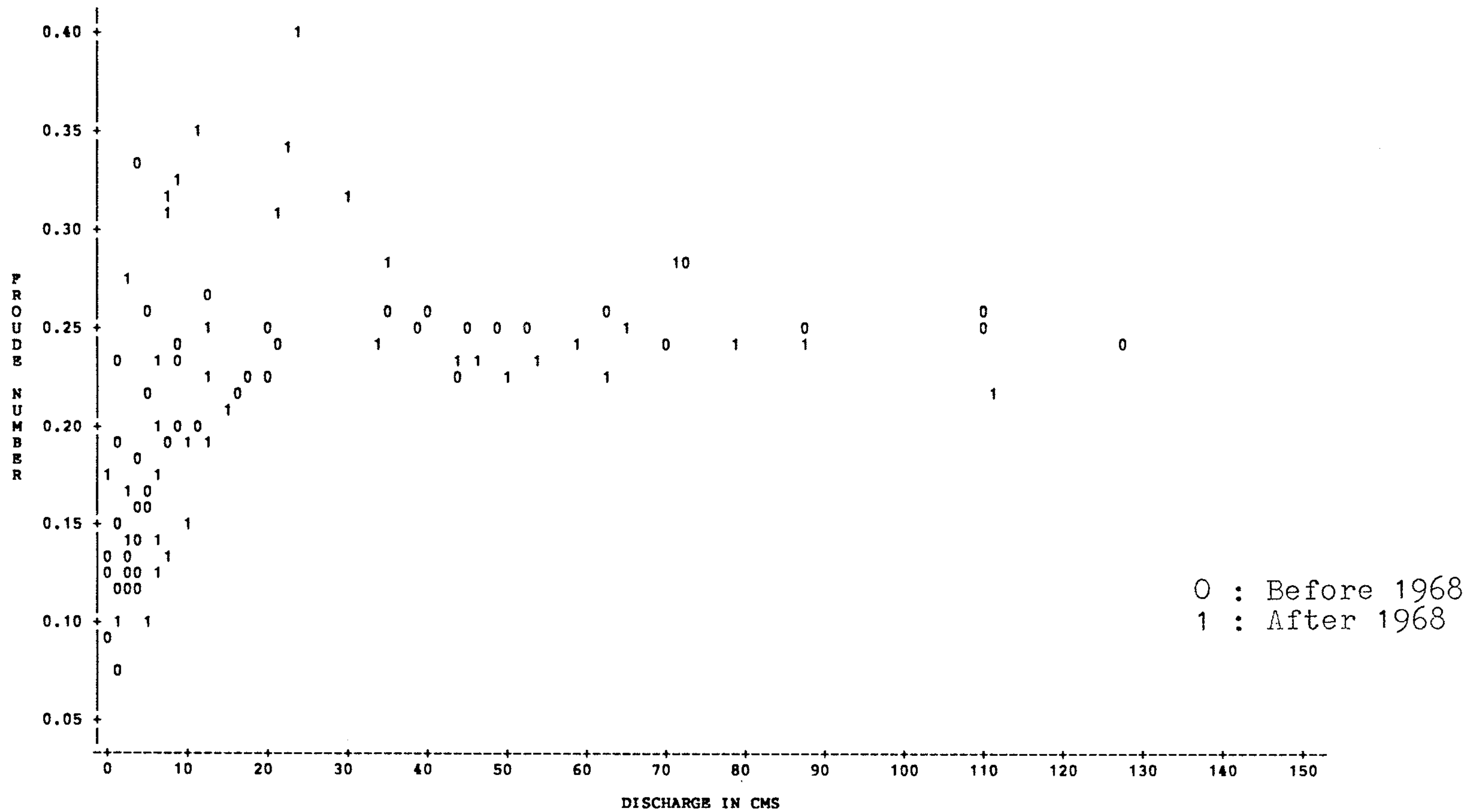

NOTE: 8 OBS HIDDEN

Fig. 27 CHEZY VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER DATA

RUSSELL STATION

PLOT OF FROUDE*Q SYMBOL IS VALUE OF CODE




NOTE: 9 OBS HIDDEN

Fig. 28 FROUDE NUMBER VS. DISCHARGE AT RUSSELL

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF SLOPE*Q SYMBOL IS VALUE OF CODE

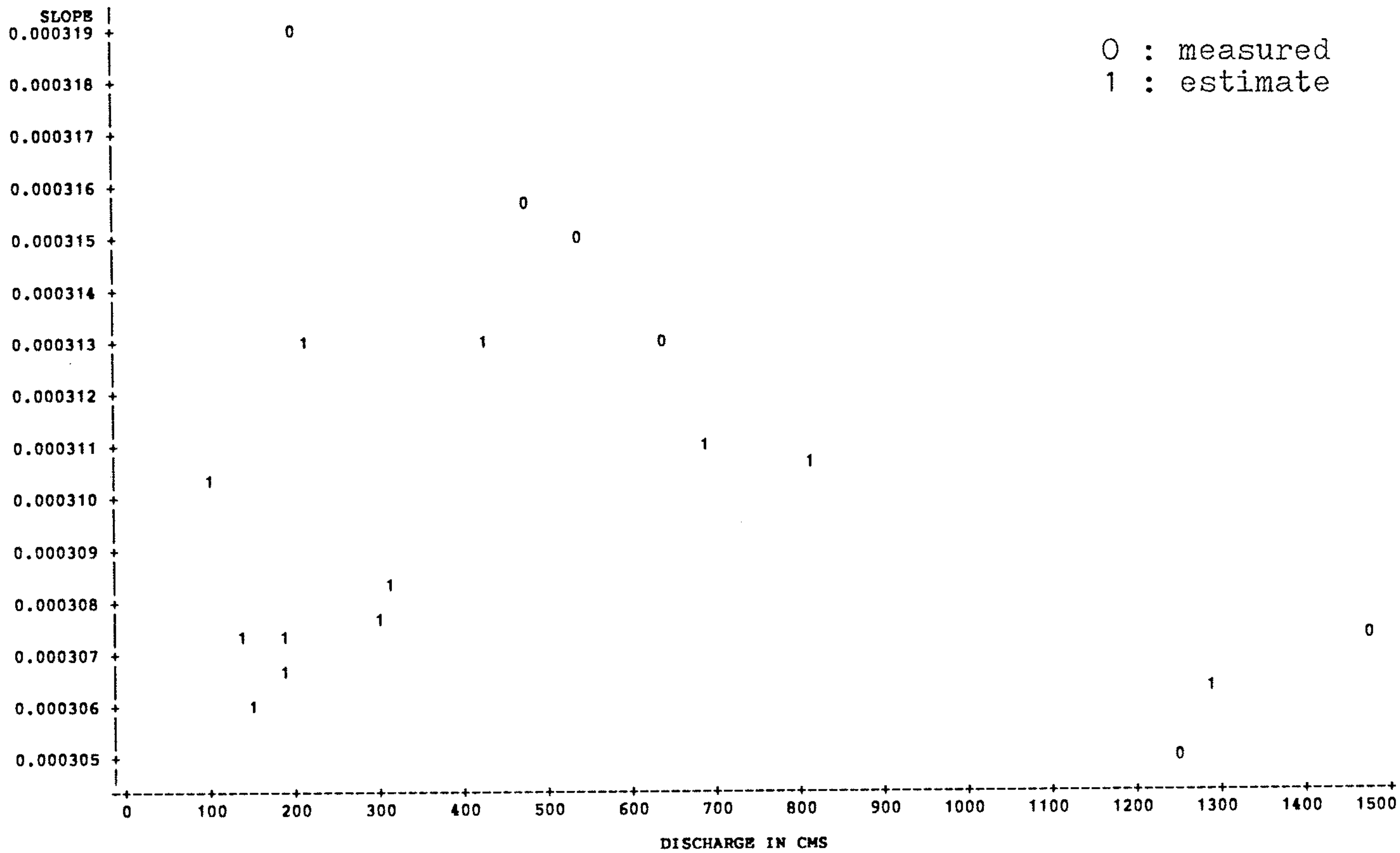



FIG. 29 SLOPE VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF AREA*Q SYMBOL IS VALUE OF CODE

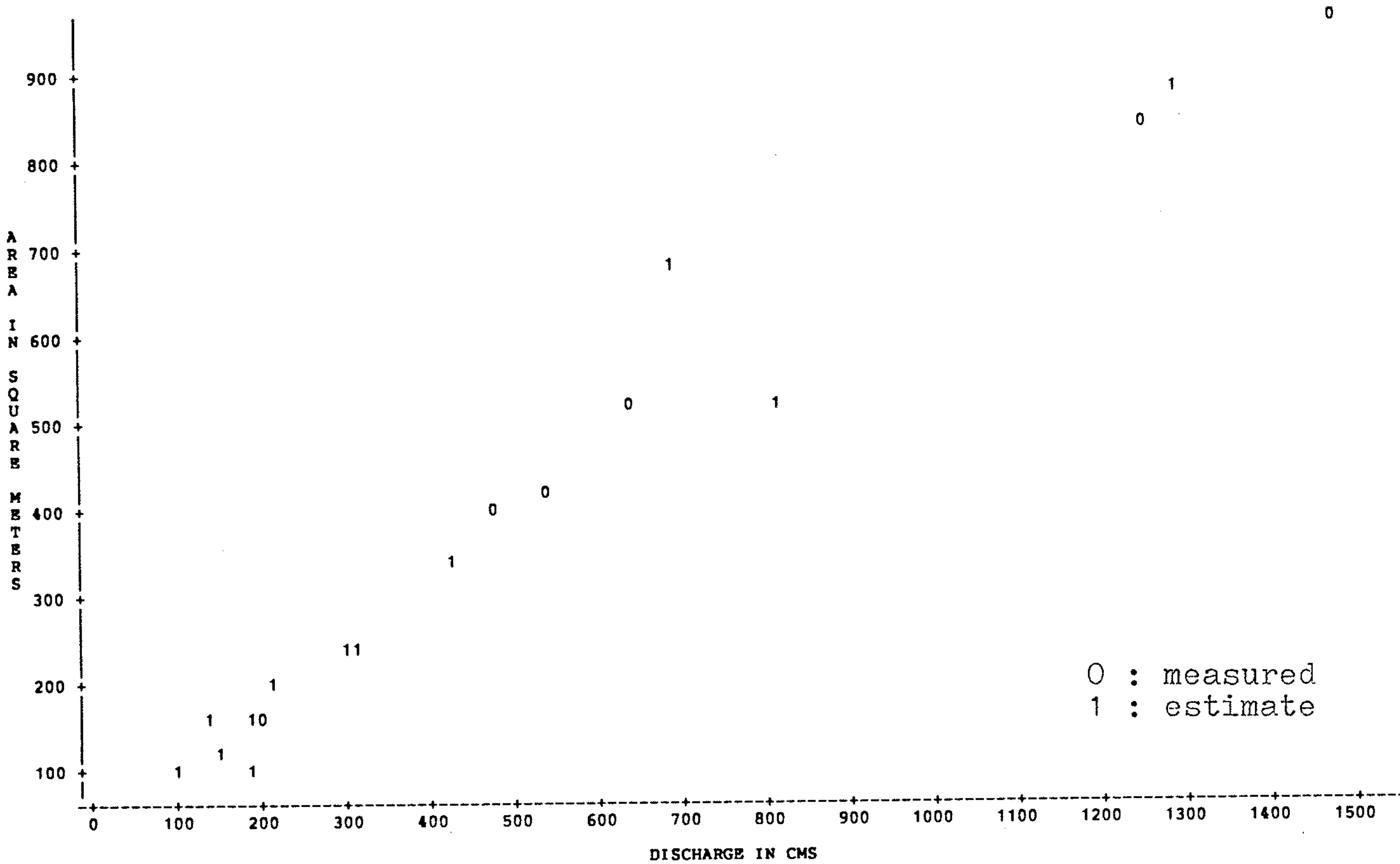



Fig. 30 AREA VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF DEPTH*Q SYMBOL IS VALUE OF CODE

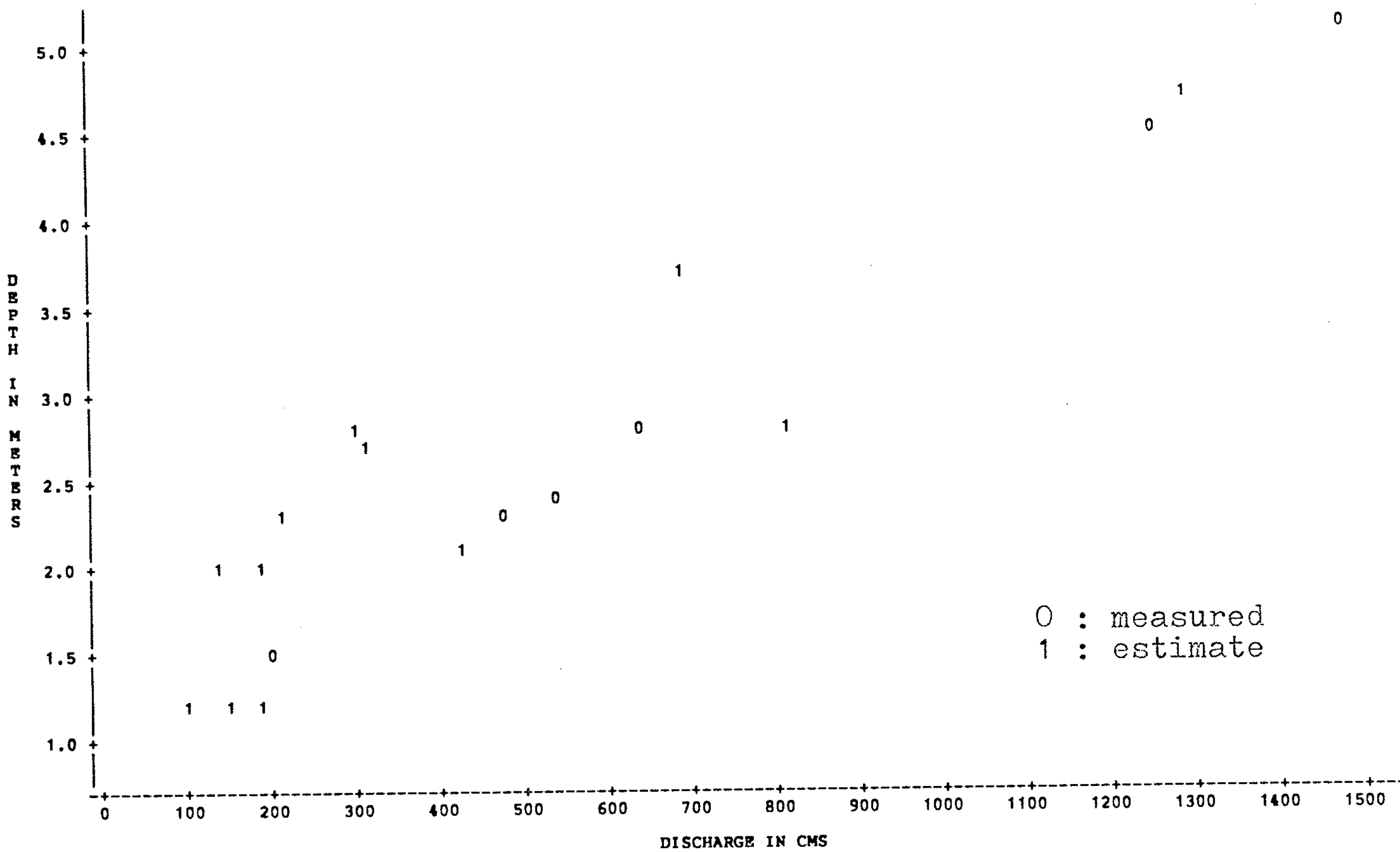



Fig. 31 DEPTH VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF SHEAR*Q    SYMBOL IS VALUE OF CODE

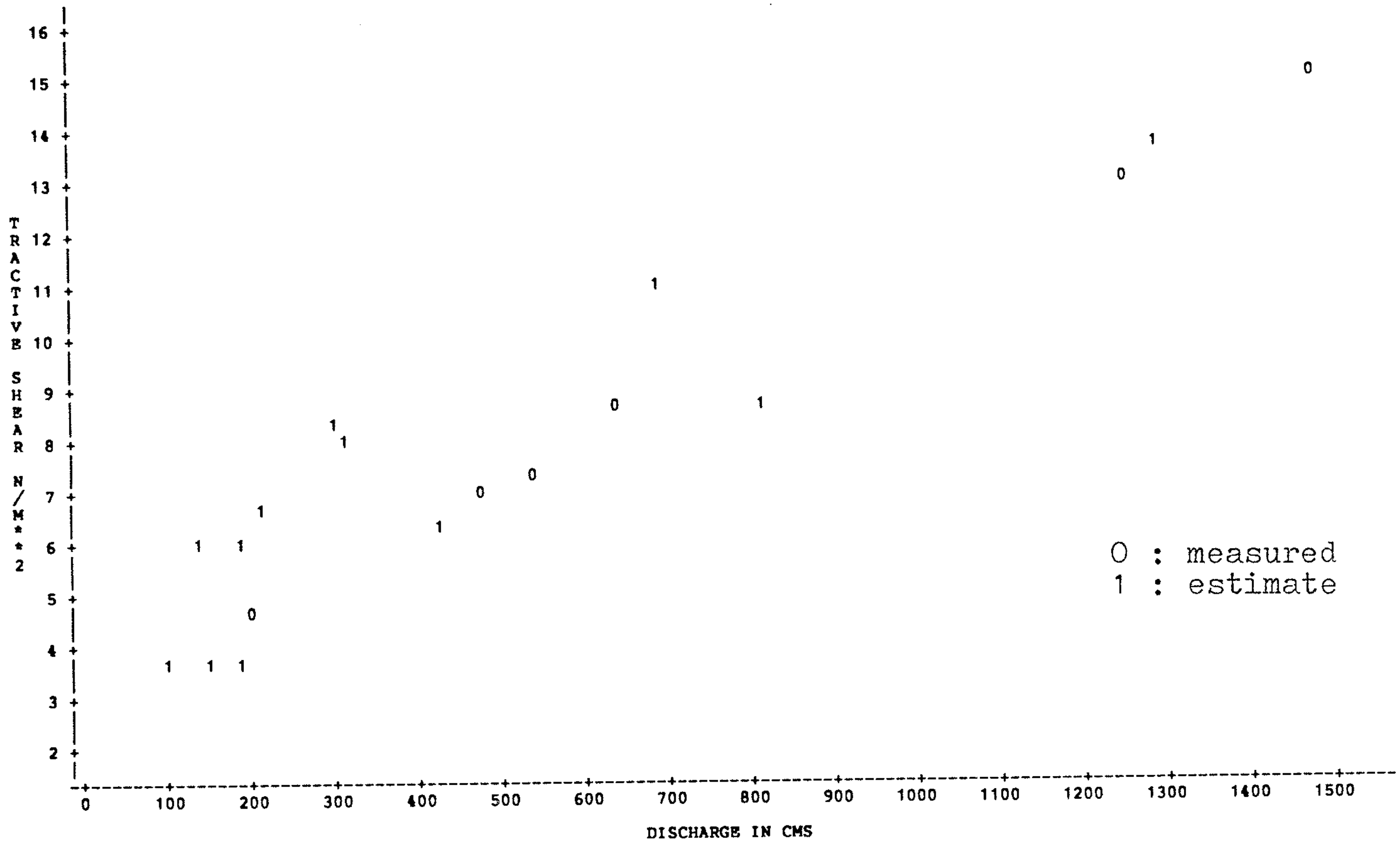



Fig. 32 TRACTIVE SHEAR VS. DISCHARGE AT HOLLAND

11:56 WEDNESDAY, MAY 1, 1985 164

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF POWER*Q    SYMBOL IS VALUE OF CODE

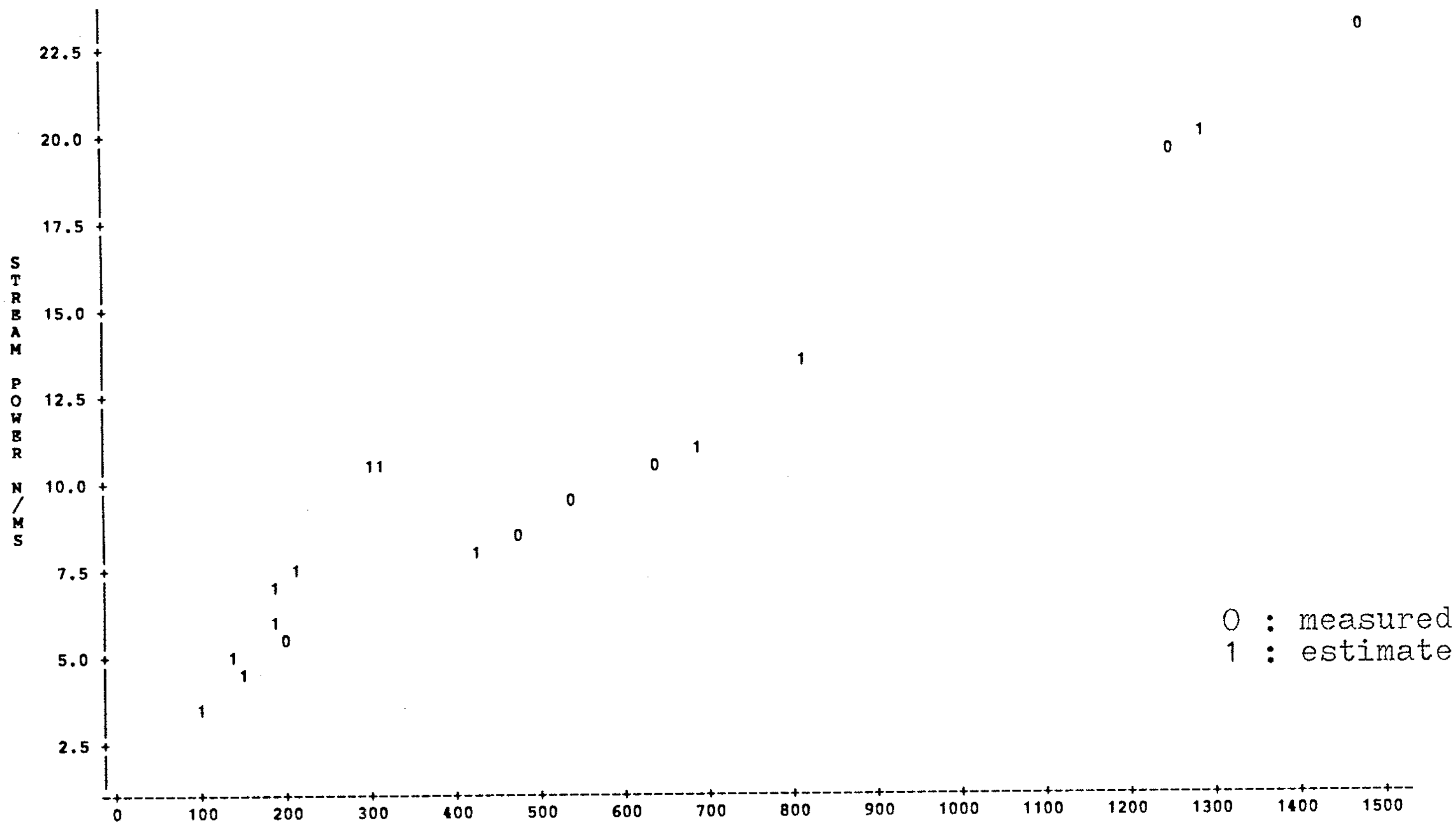



Fig. 33 STREAM POWER VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF VS*Q SYMBOL IS VALUE OF CODE

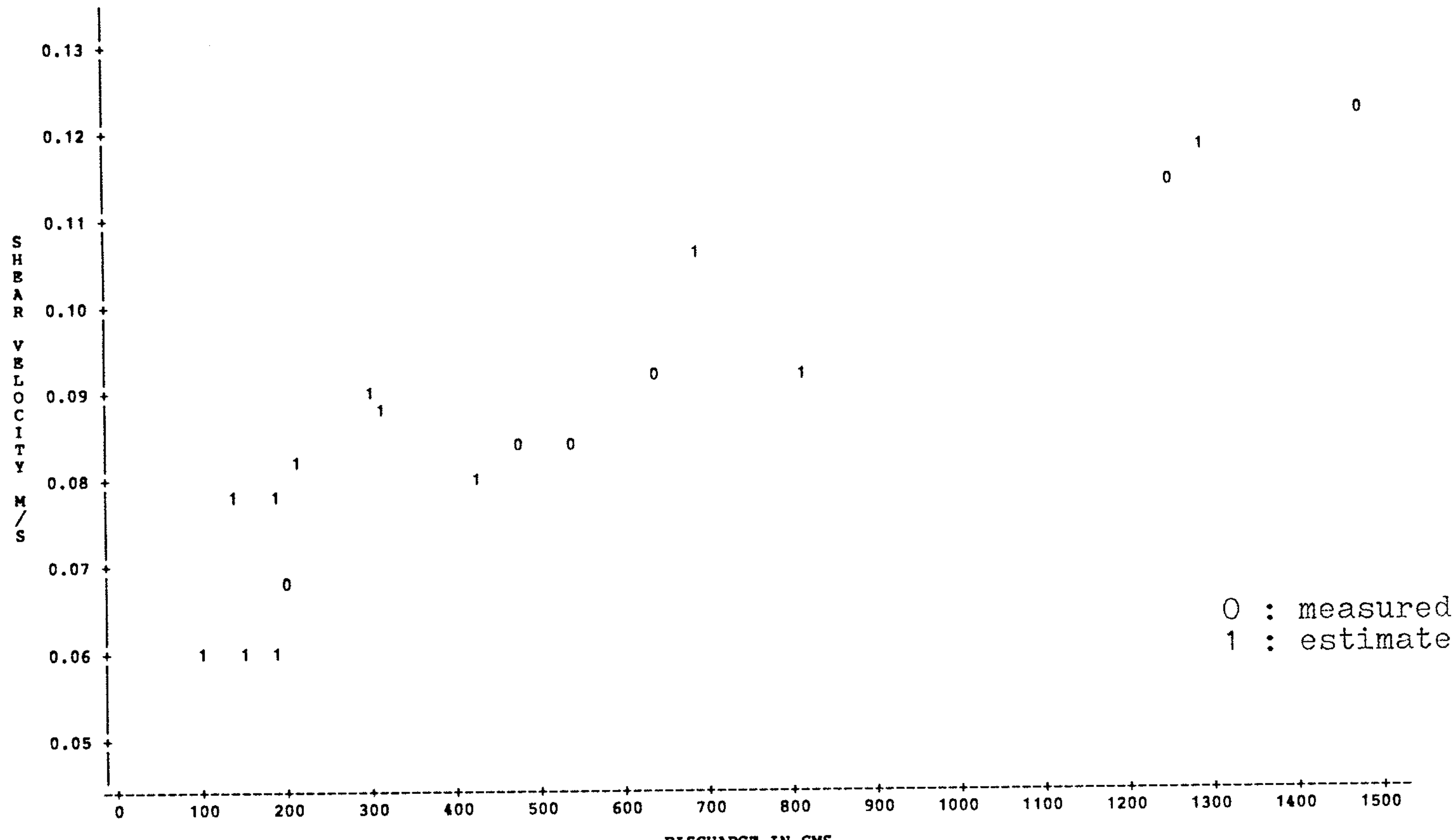



Fig. 34 SHEAR VELOCITY VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF VELOC*Q SYMBOL IS VALUE OF CODE

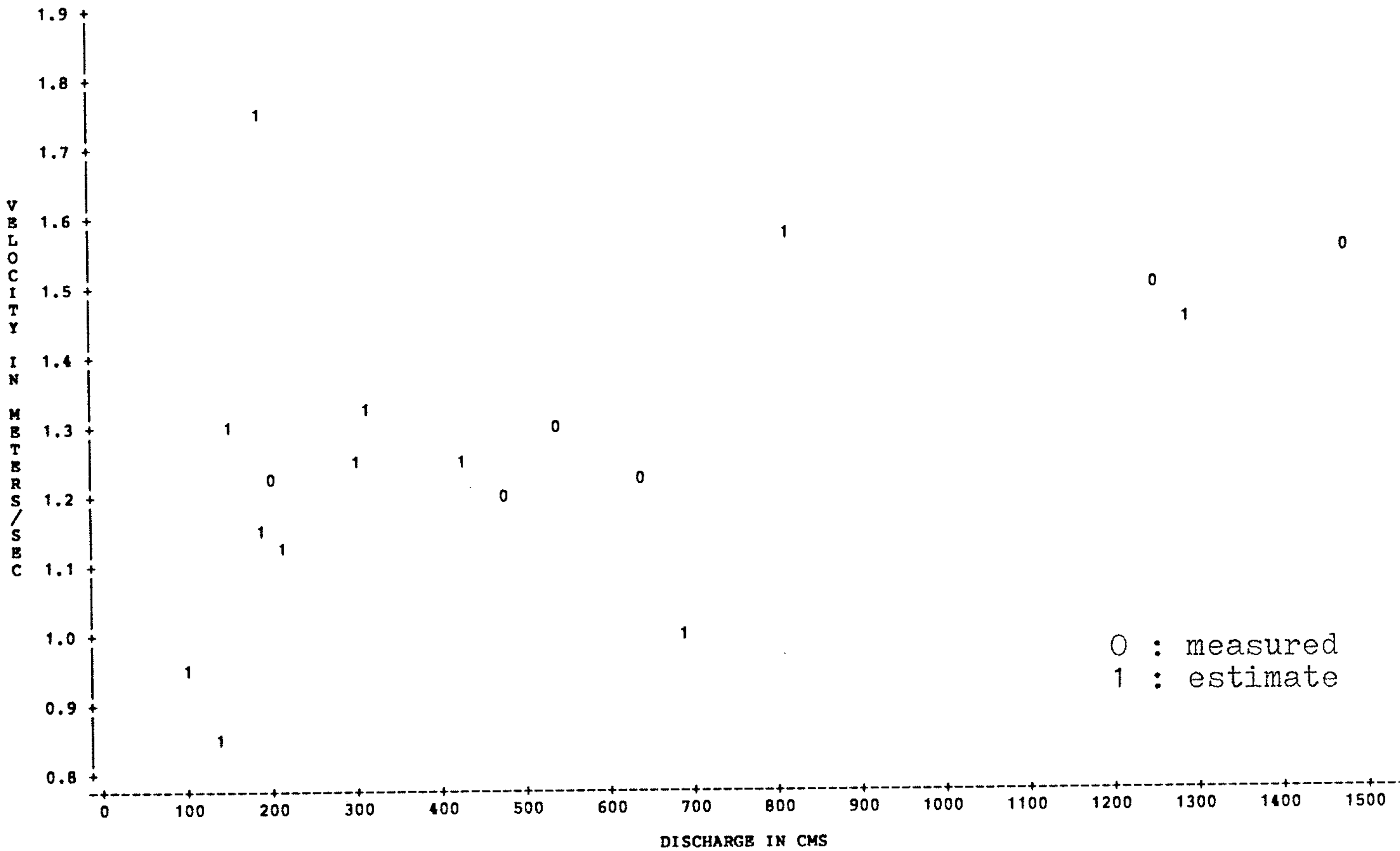



Fig. 35 VELOCITY VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF WIDTH*Q SYMBOL IS VALUE OF CODE

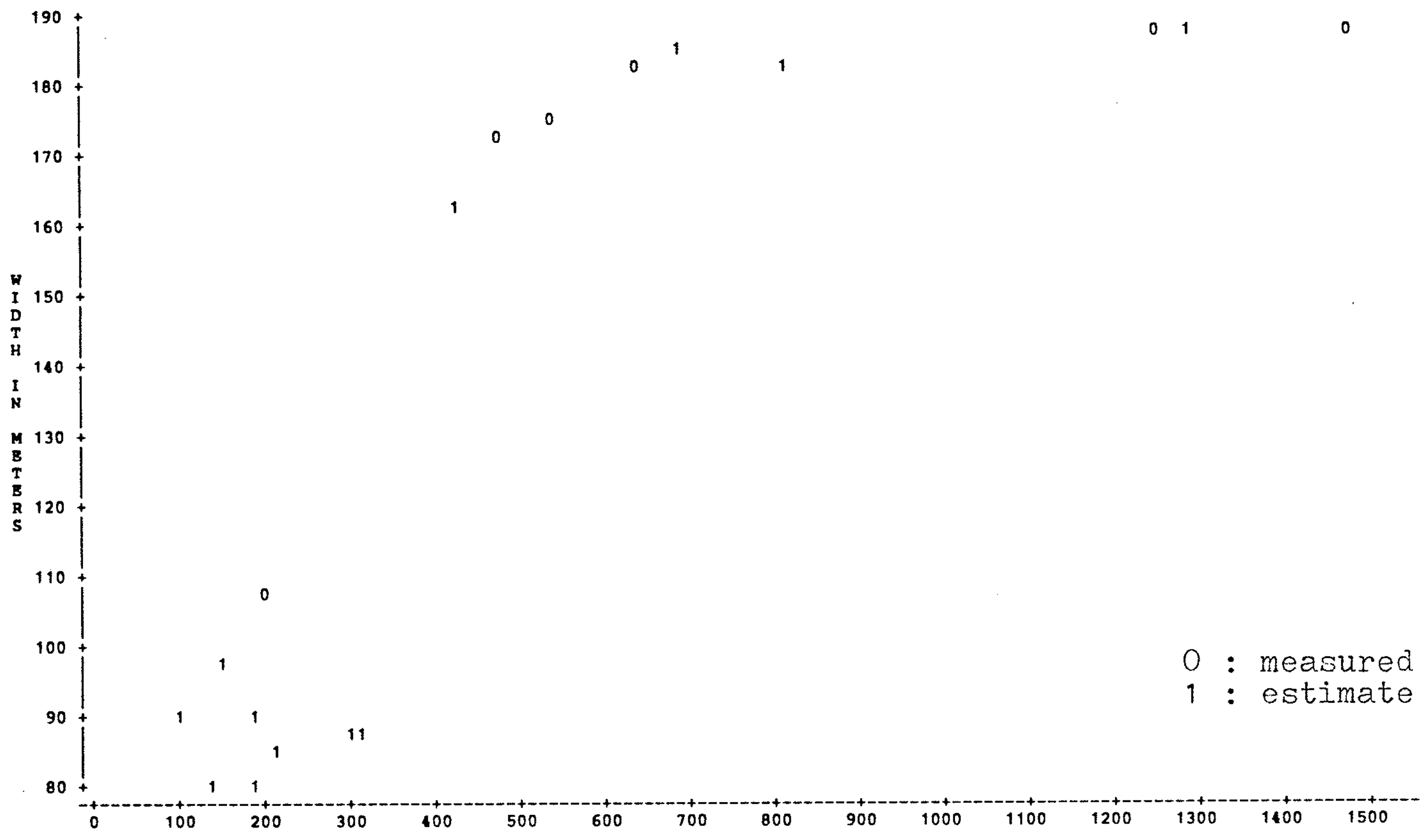



Fig. 36 WIDTH VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF D50*Q SYMBOL IS VALUE OF CODE

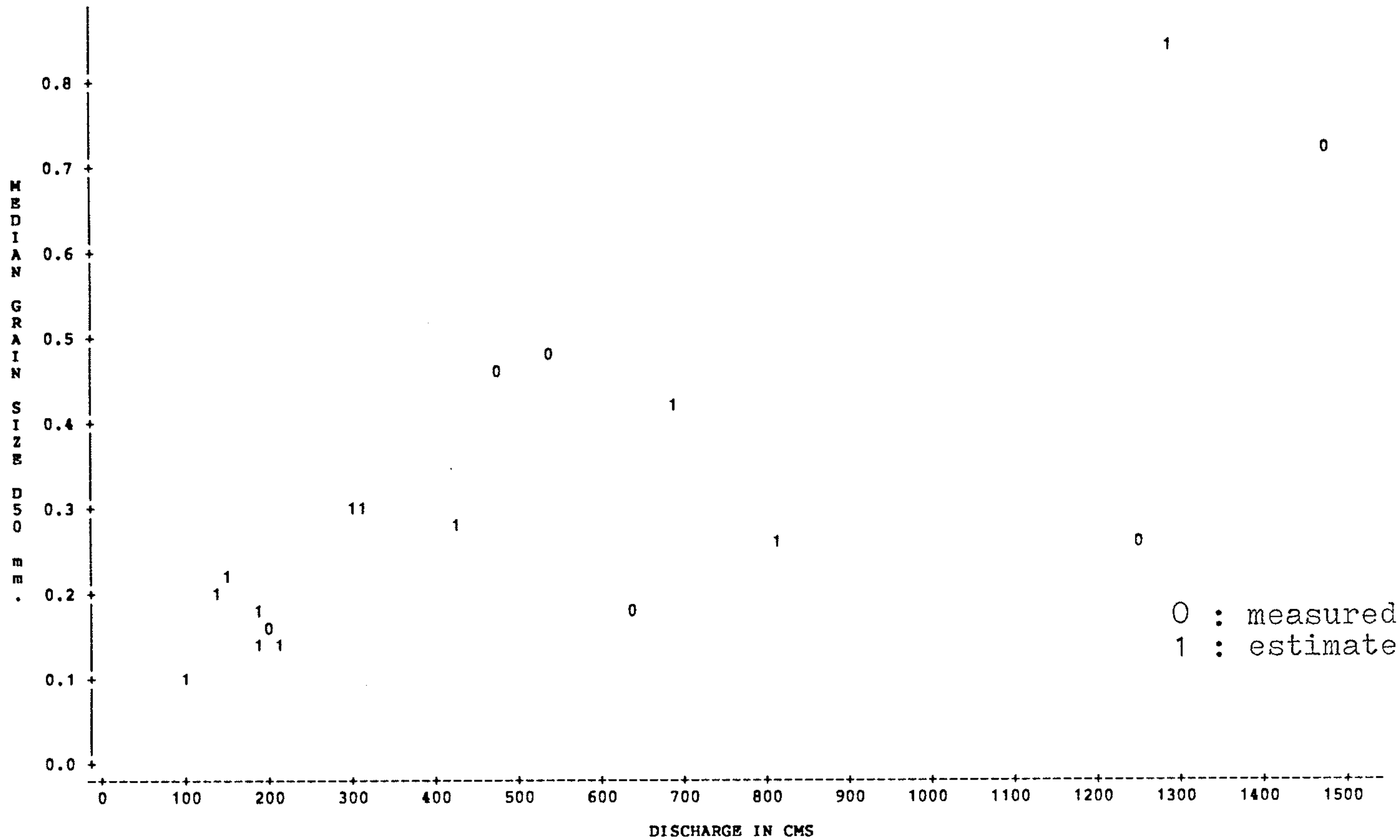



Fig. 37 MEDIAN GRAIN SIZE VS. DISCHARGE AT HOLLAND

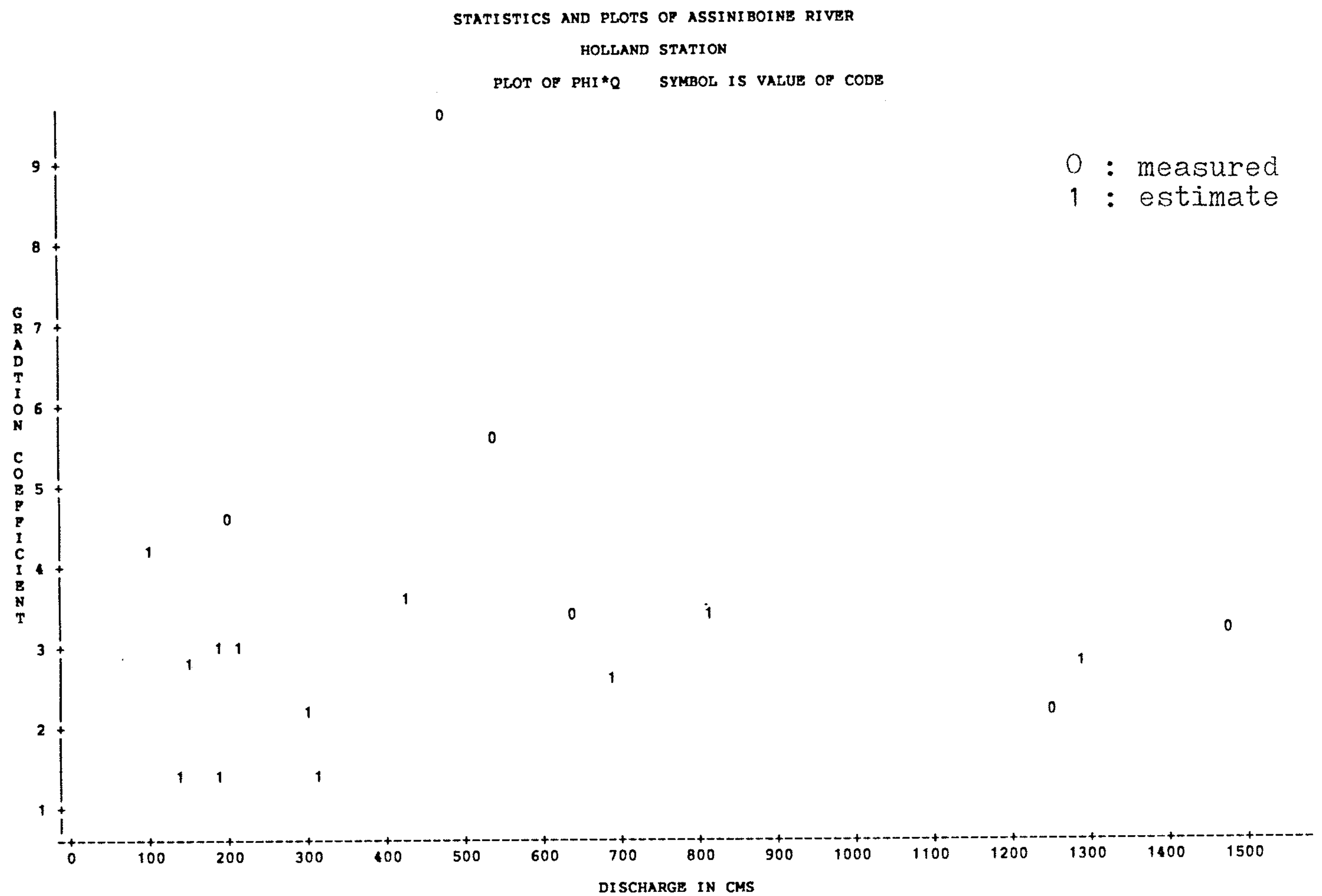



Fig. 38 GRADATION COEFFICIENT VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF FROUDE*Q SYMBOL IS VALUE OF CODE

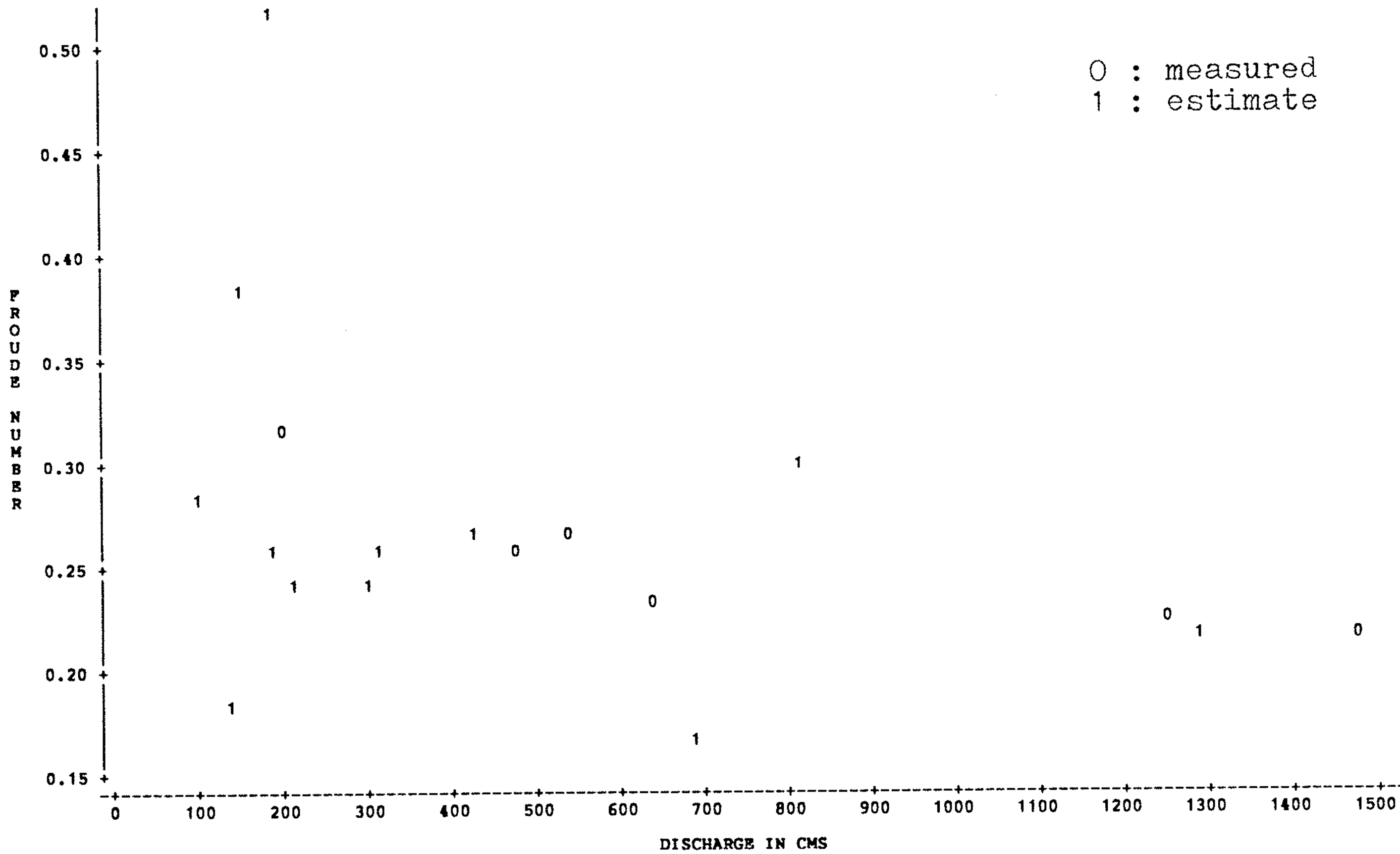



Fig. 39 FROUDE NUMBER VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF CHEZY*Q SYMBOL IS VALUE OF CODE

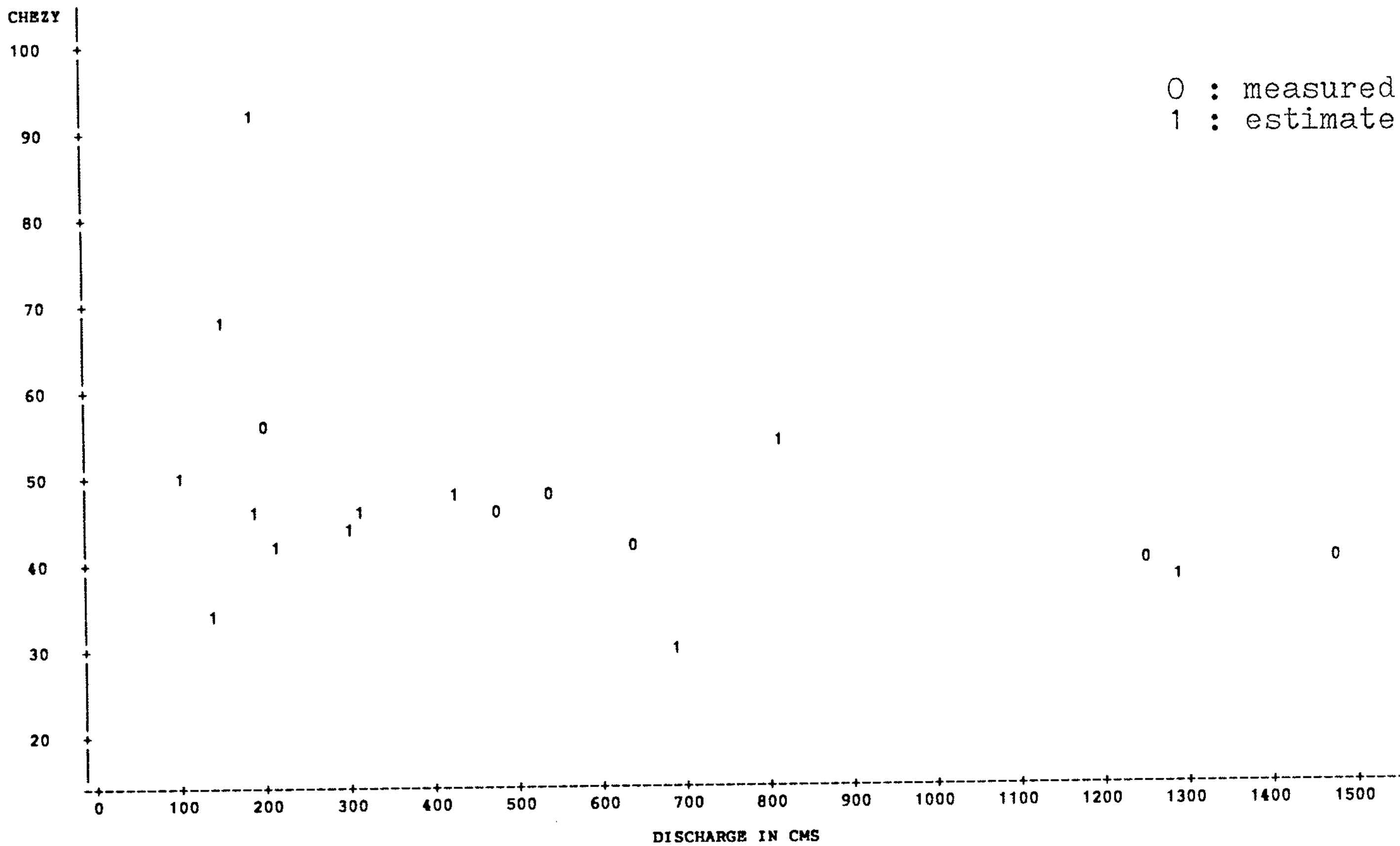



Fig. 40 CHEZY VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*SLOPE SYMBOL IS VALUE OF CODE

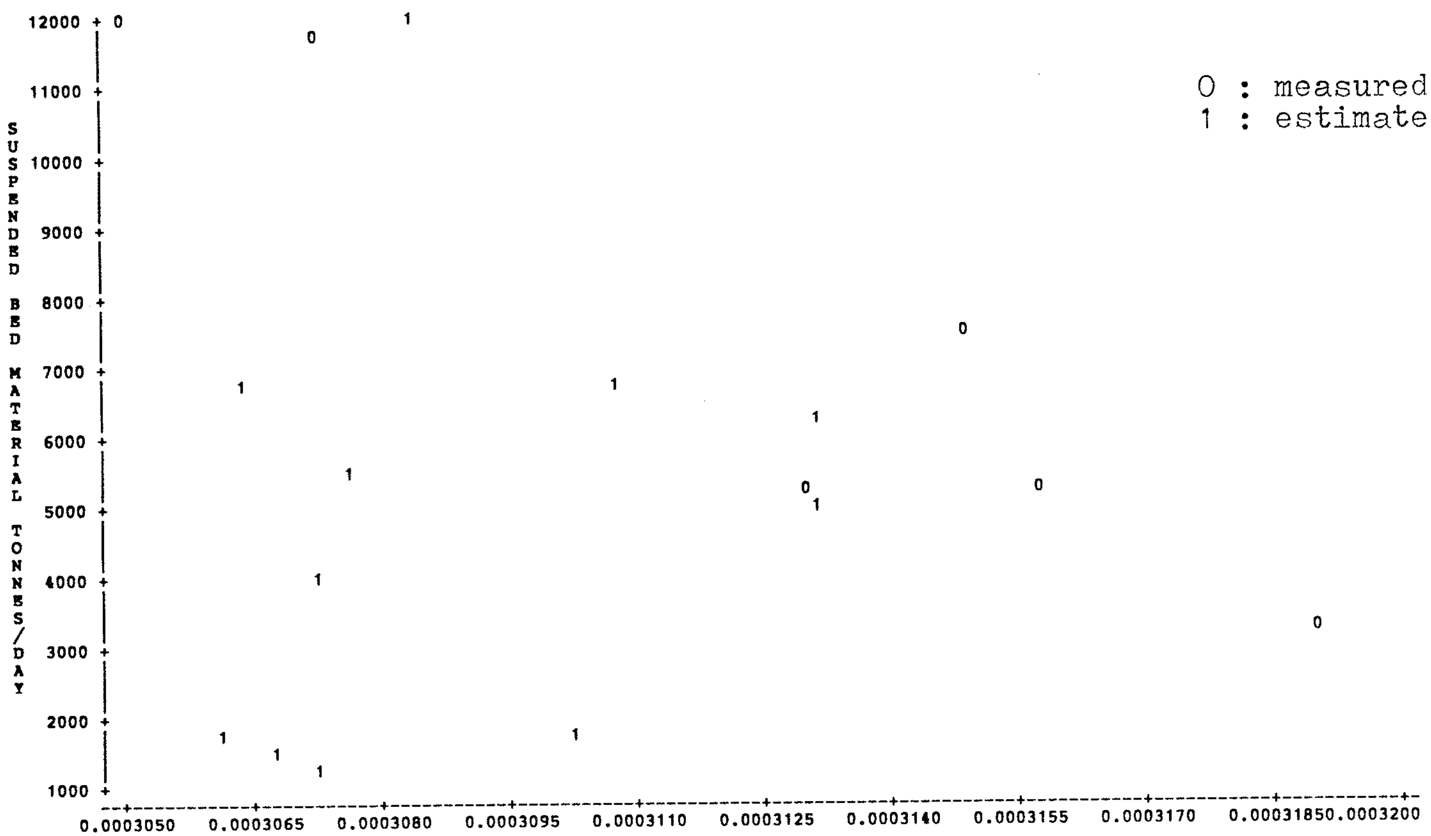



Fig. 41 QSBM VS. SLOPE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*Q SYMBOL IS VALUE OF CODE

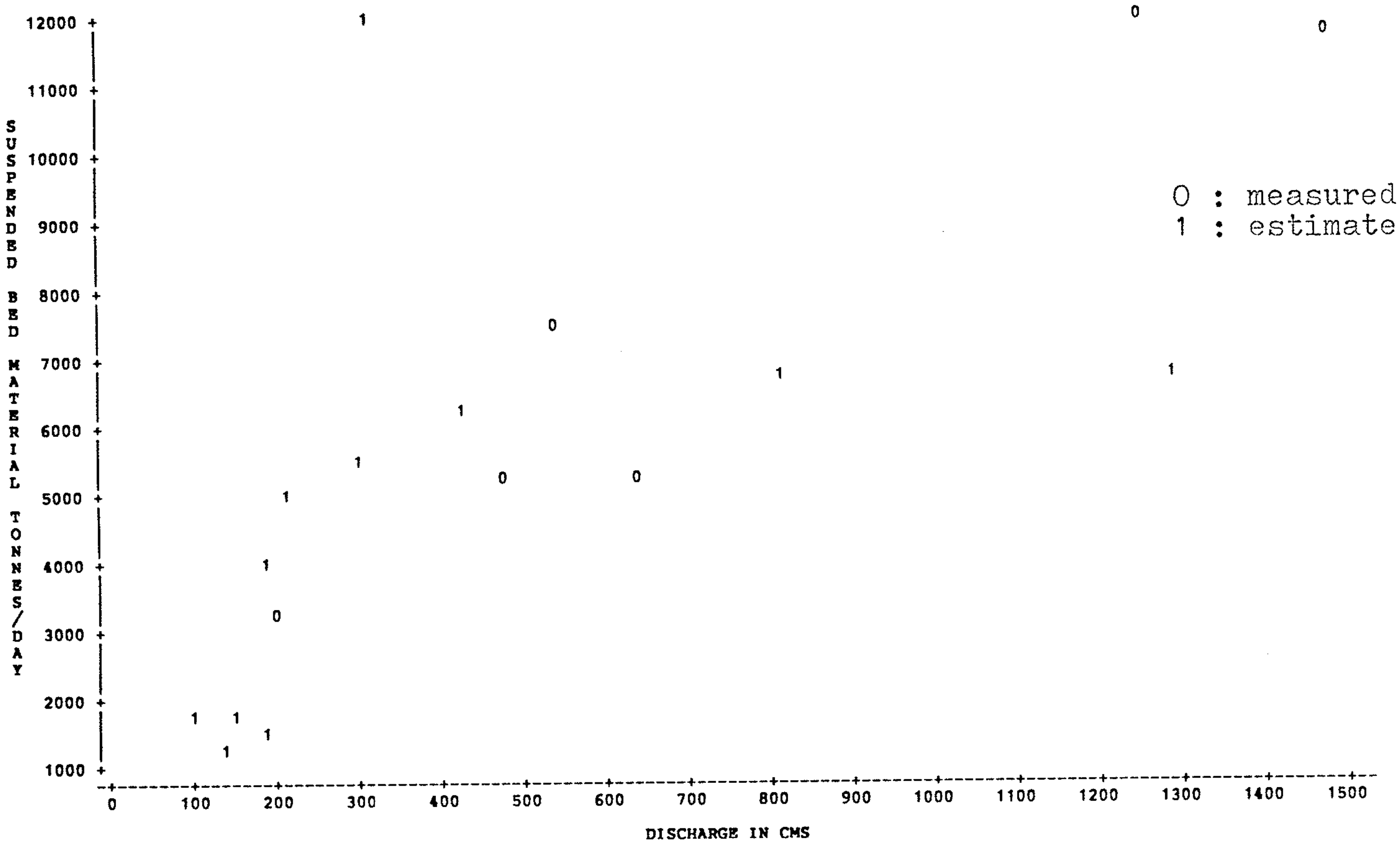



Fig. 42 QSBM VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*VELOC SYMBOL IS VALUE OF CODE

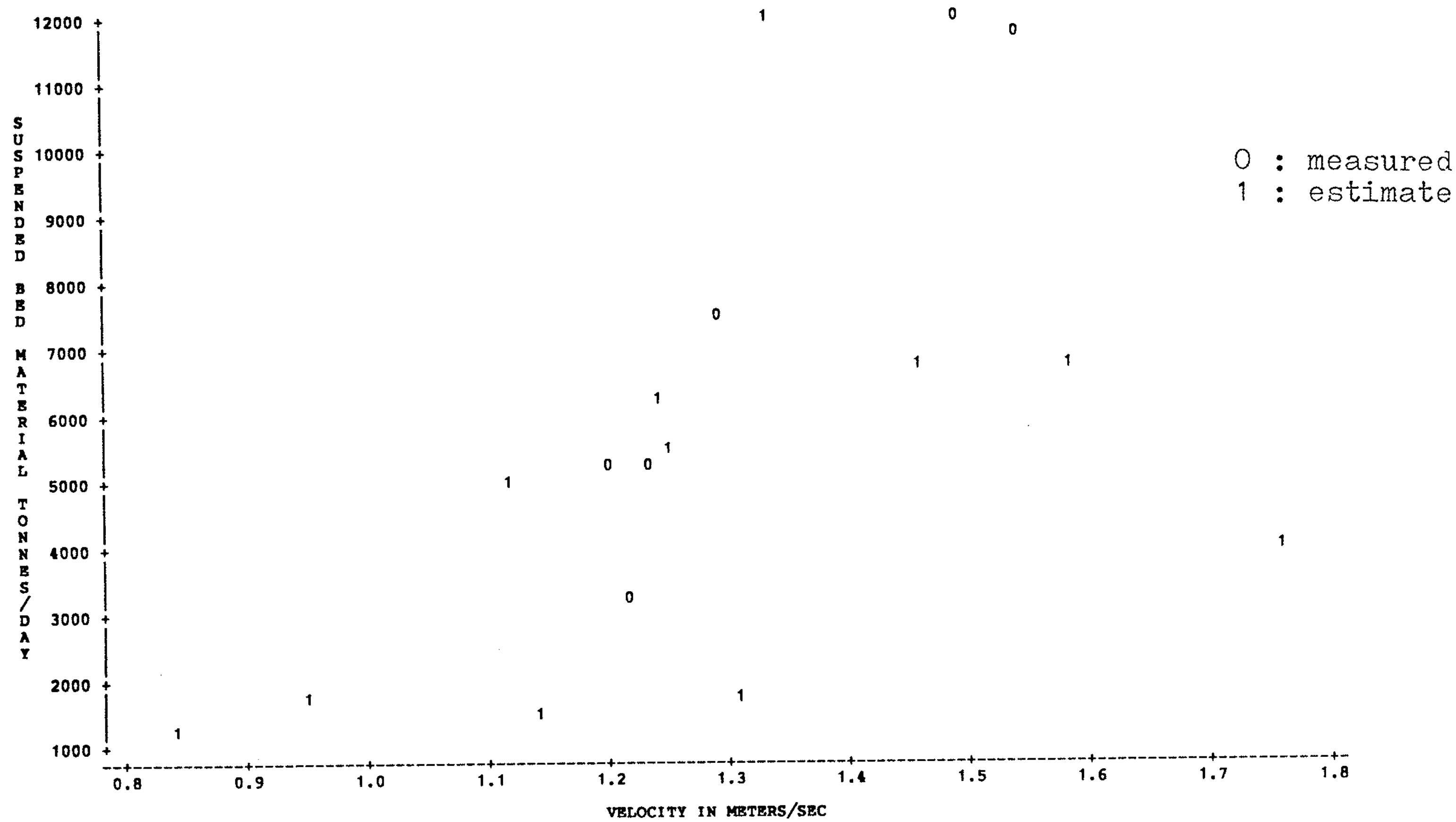



Fig. 43 QSBM VS. VELOCITY AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*DEPTH SYMBOL IS VALUE OF CODE

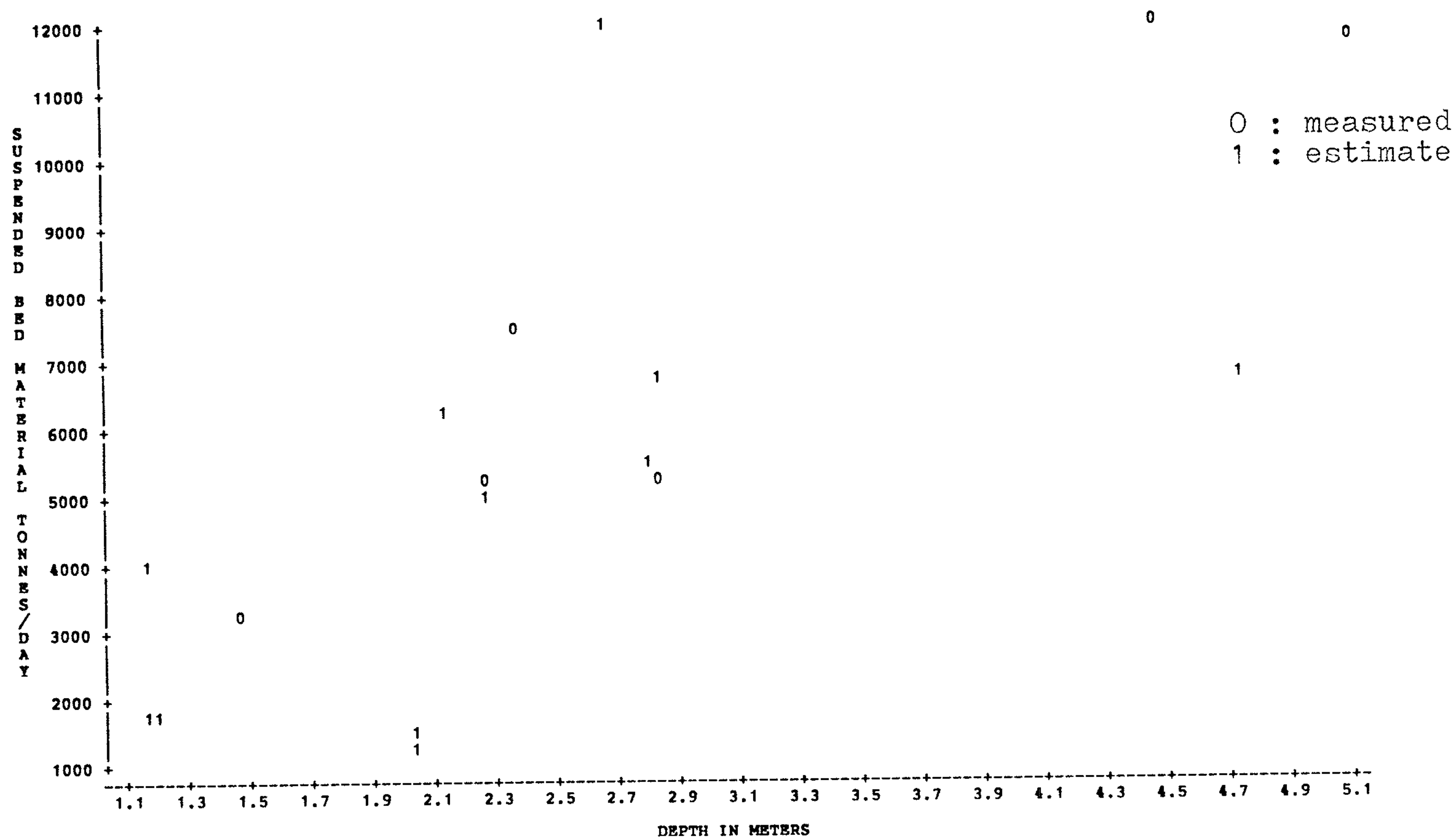



Fig. 44 QSBM VS. DEPTH AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*FROUDE     SYMBOL IS VALUE OF CODE

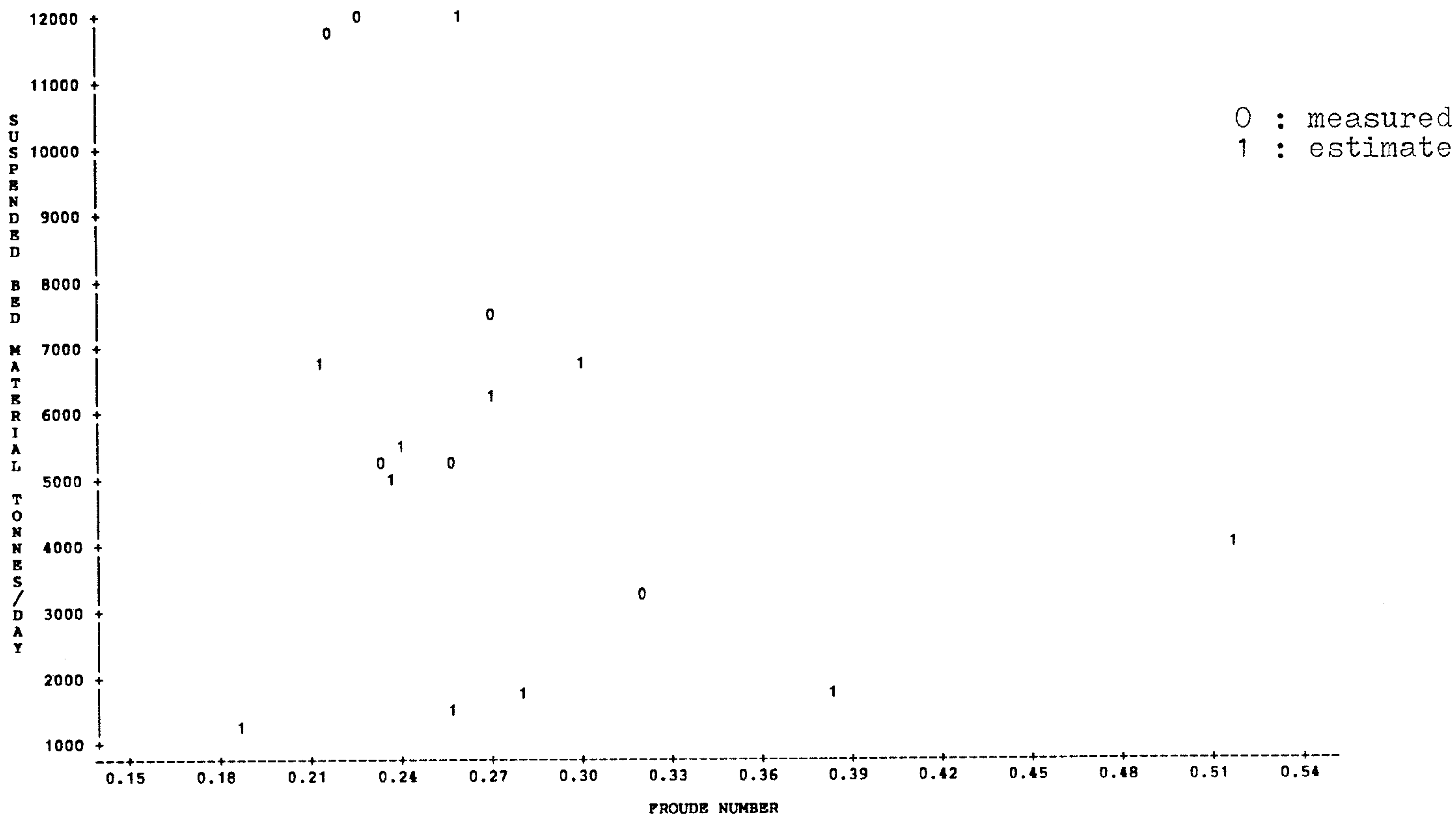
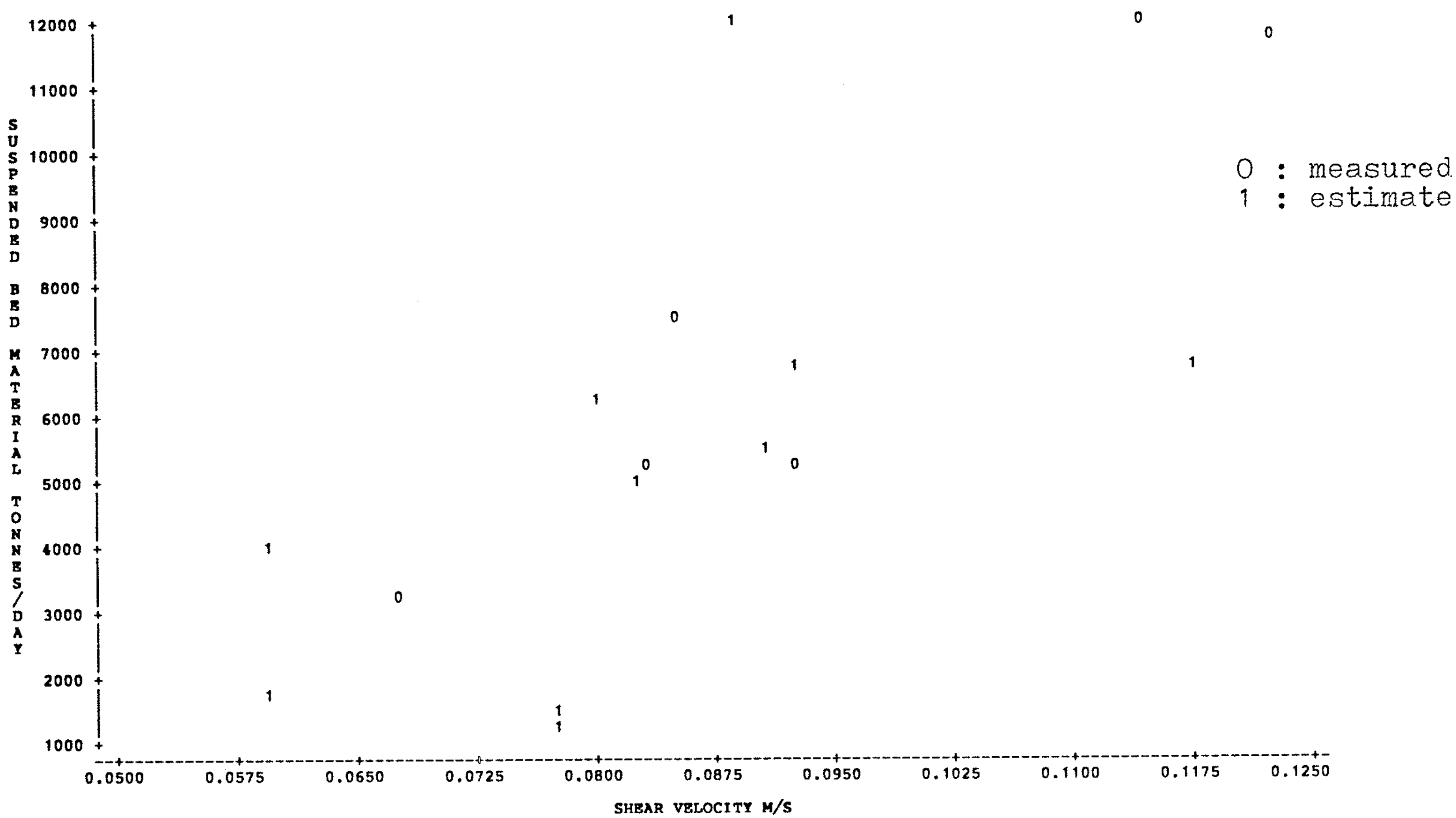



Fig. 45 QSBM VS. FROUDE NUMBER AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*VS SYMBOL IS VALUE OF CODE



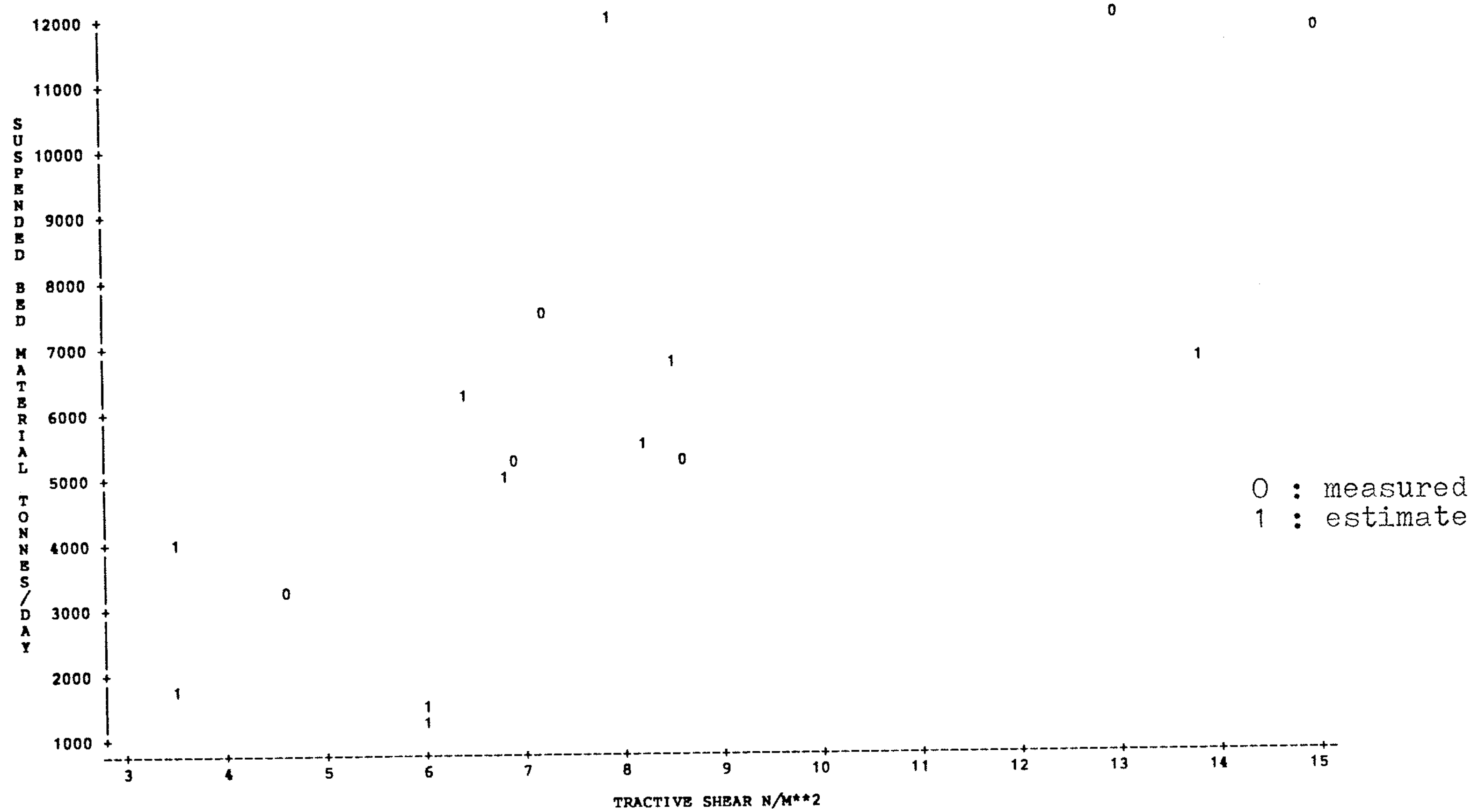

NOTE: 1 OBS HIDDEN

Fig. 46 QSBM VS. SHEAR VELOCITY AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*SHEAR    SYMBOL IS VALUE OF CODE




NOTE: 1 OBS HIDDEN

Fig. 47 QSBM VS. TRACTIVE SHEAR AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QSBM*POWER SYMBOL IS VALUE OF CODE

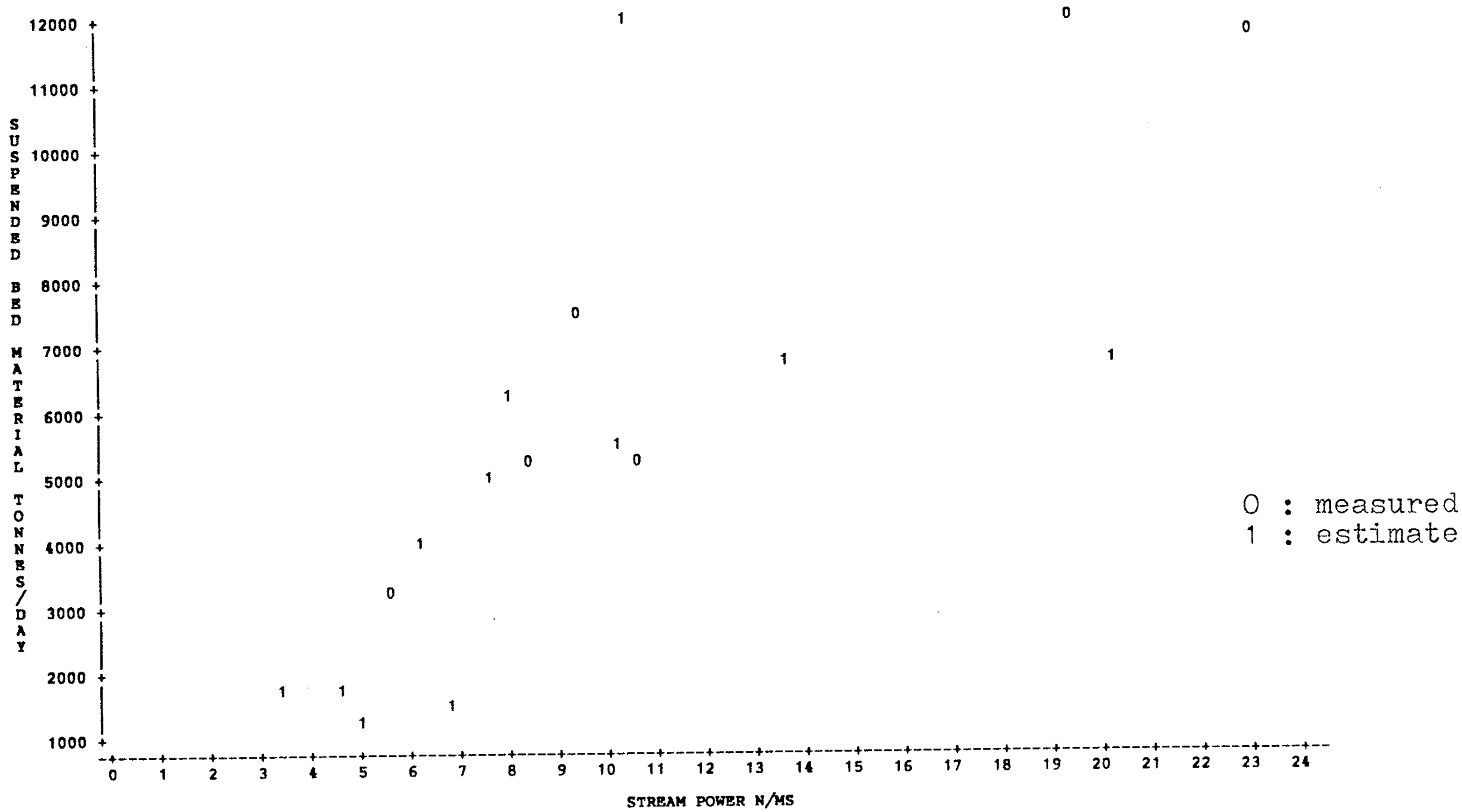



Fig. 48 QSBM VS. STREAM POWER AT HOLLAND

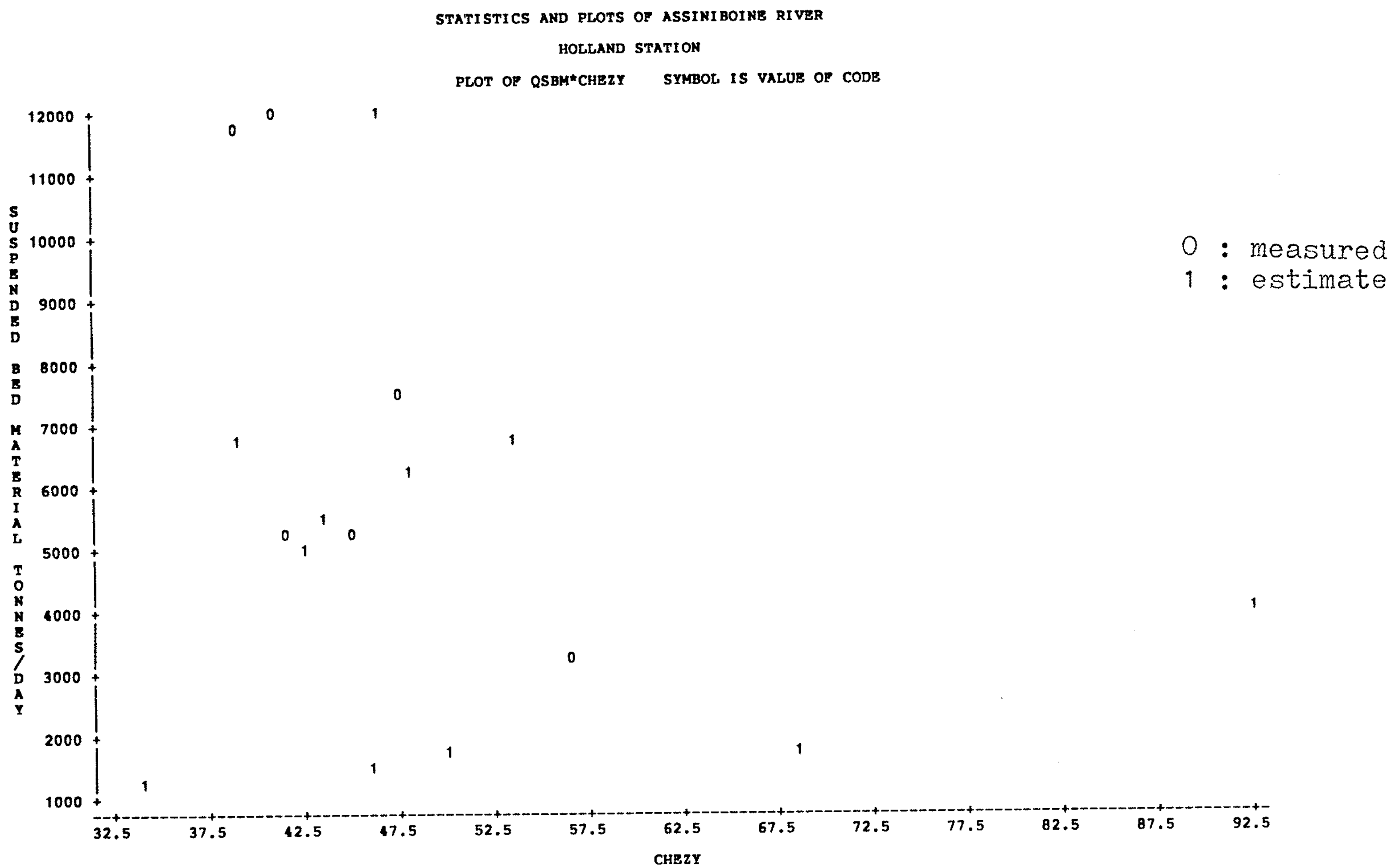



Fig. 49 QSBM VS. CHEZY AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*SLOPE SYMBOL IS VALUE OF CODE

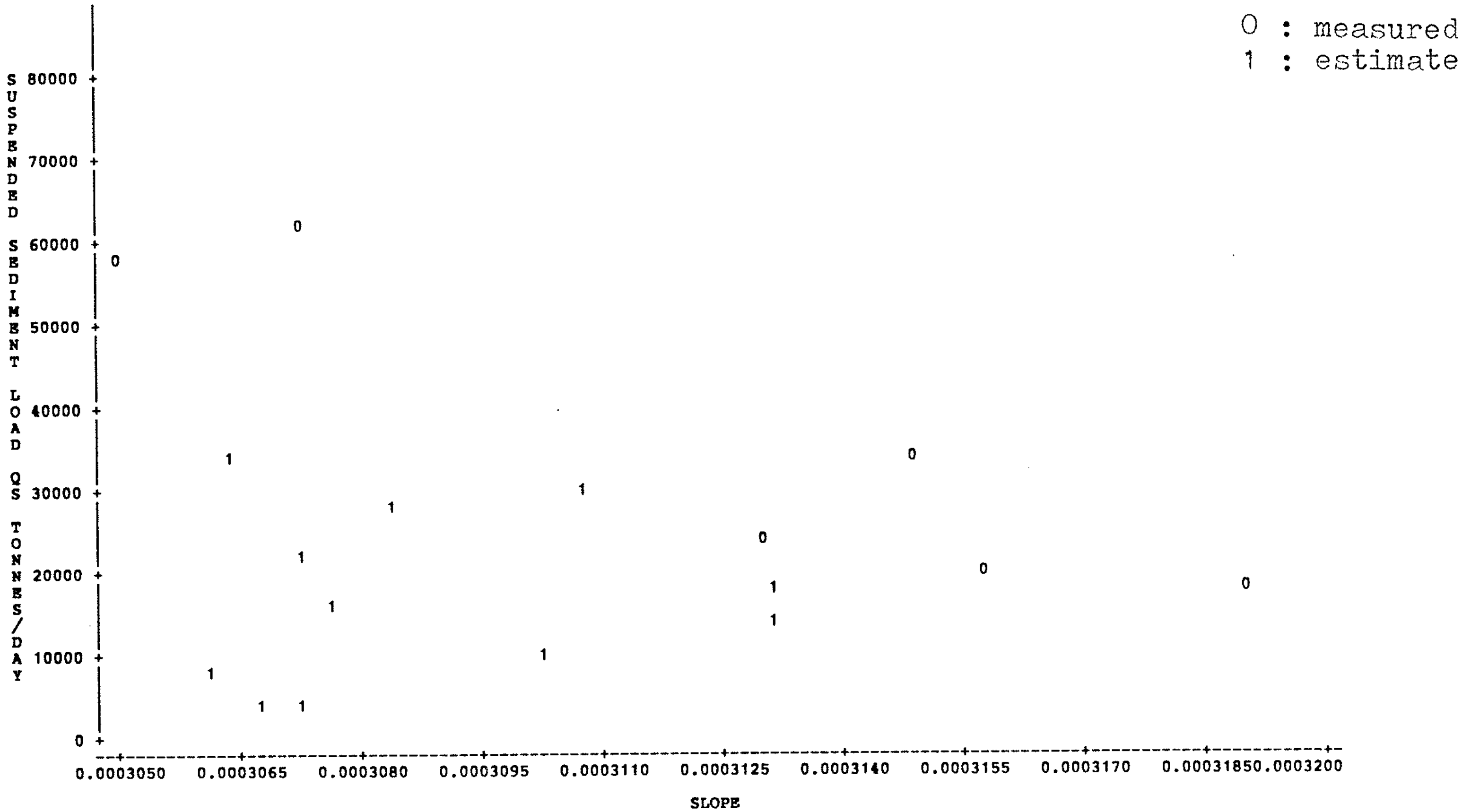



Fig. 50 QS VS. SLOPE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*Q    SYMBOL IS VALUE OF CODE

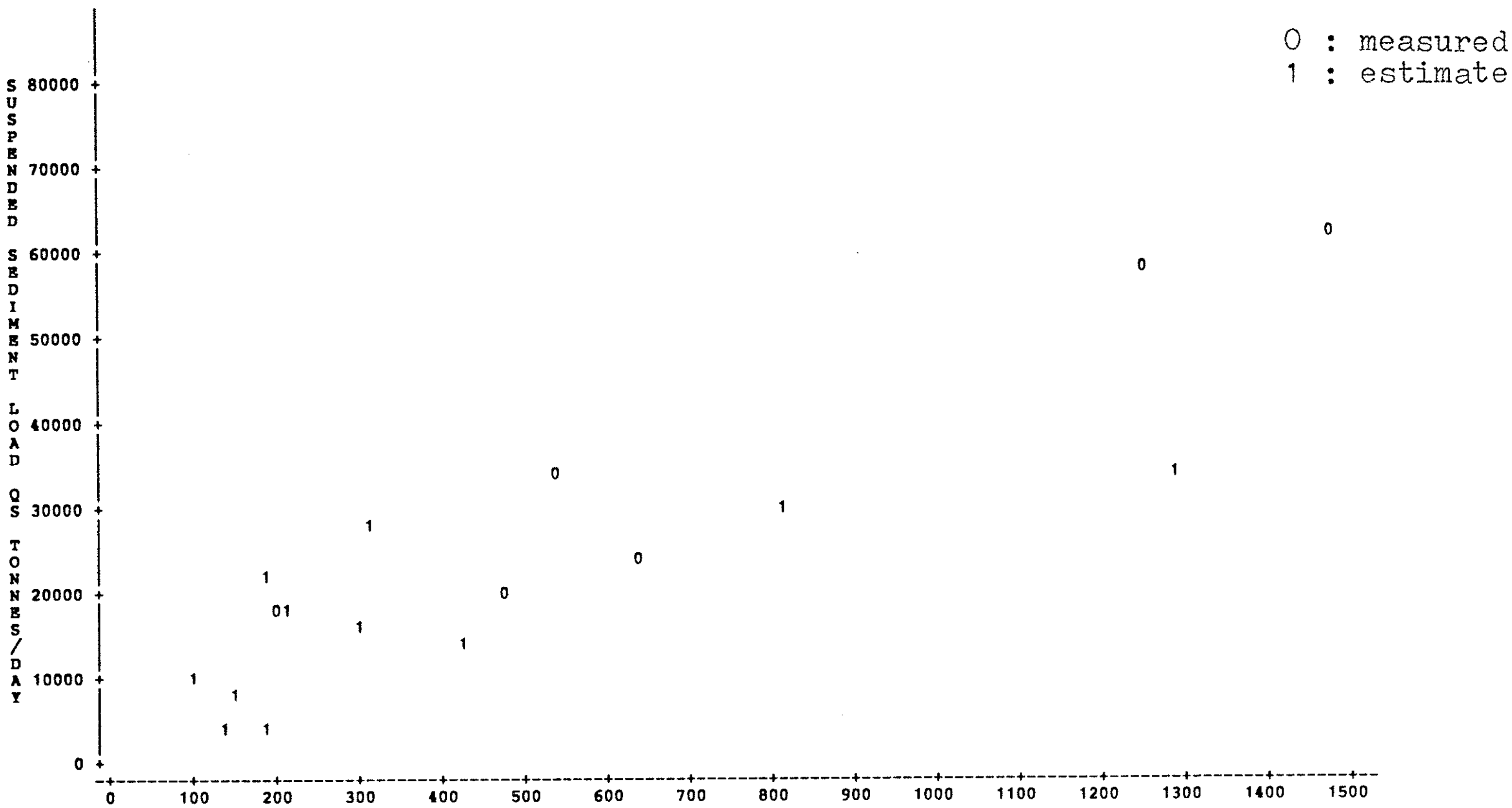



Fig. 51 QS VS. DISCHARGE AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*VELOC SYMBOL IS VALUE OF CODE

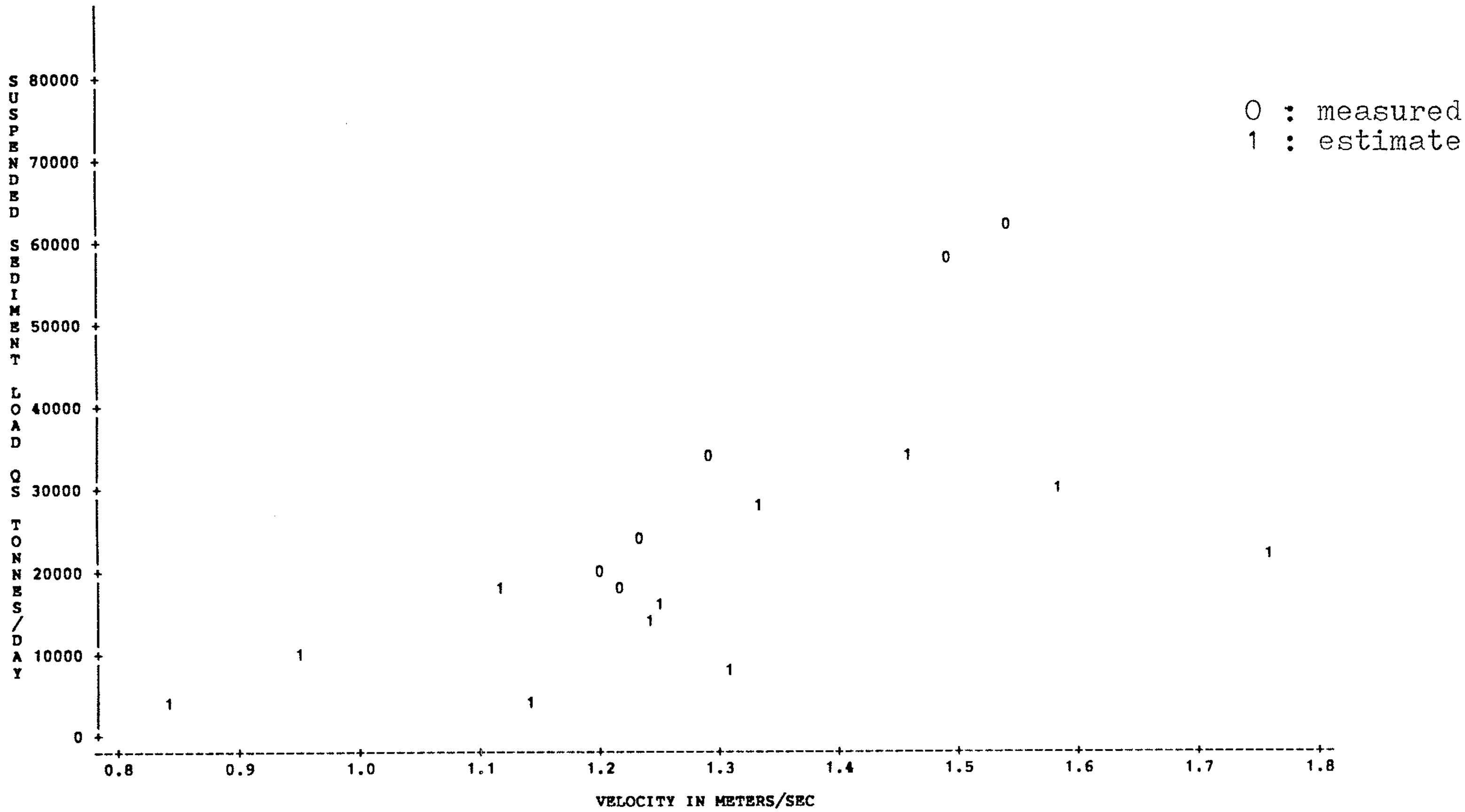
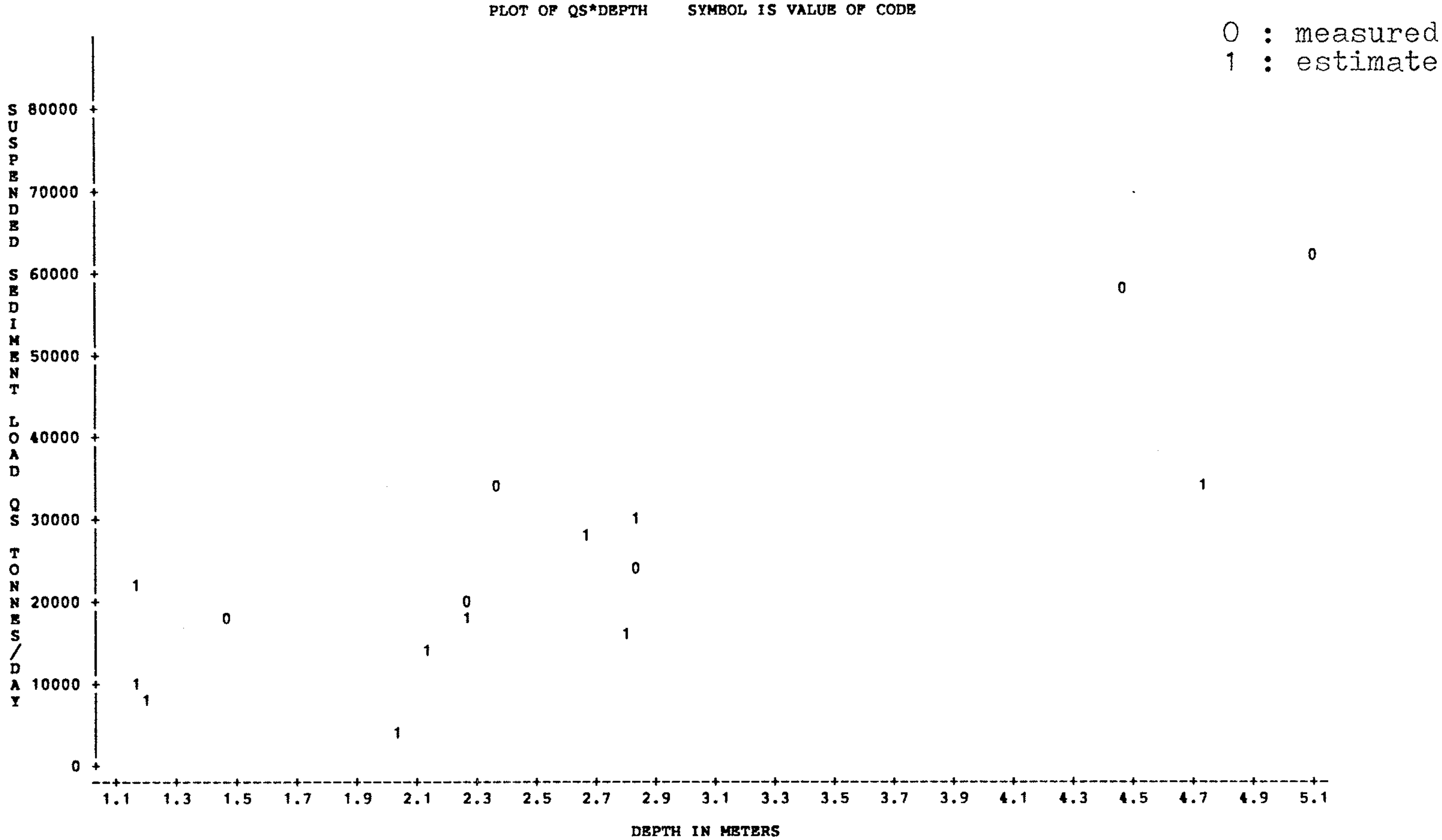



Fig. 52 QS VS. VELOCITY AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*DEPTH     SYMBOL IS VALUE OF CODE



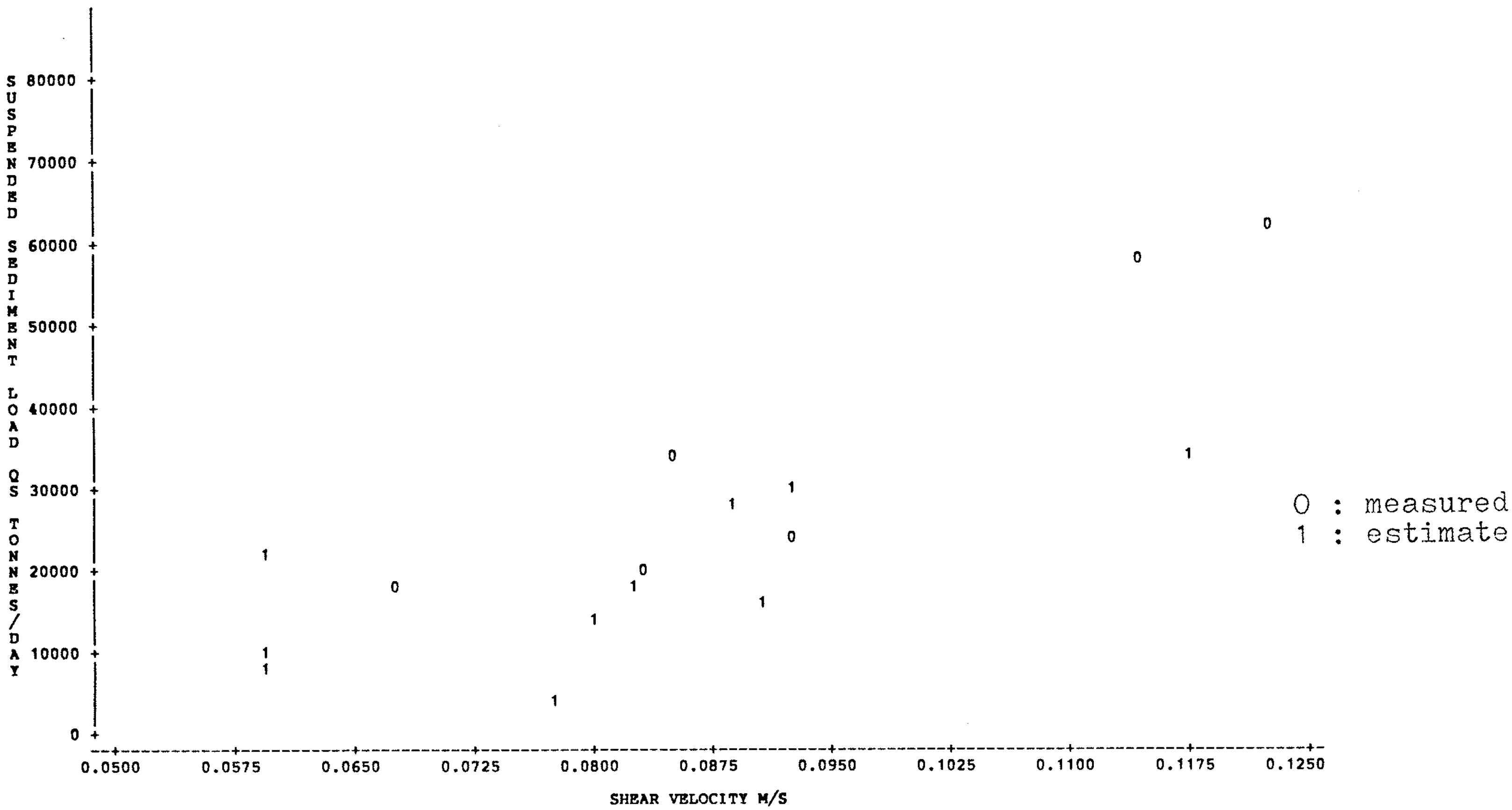

NOTE: 1 OBS HIDDEN

Fig. 53 QS VS. DEPTH AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*VS SYMBOL IS VALUE OF CODE



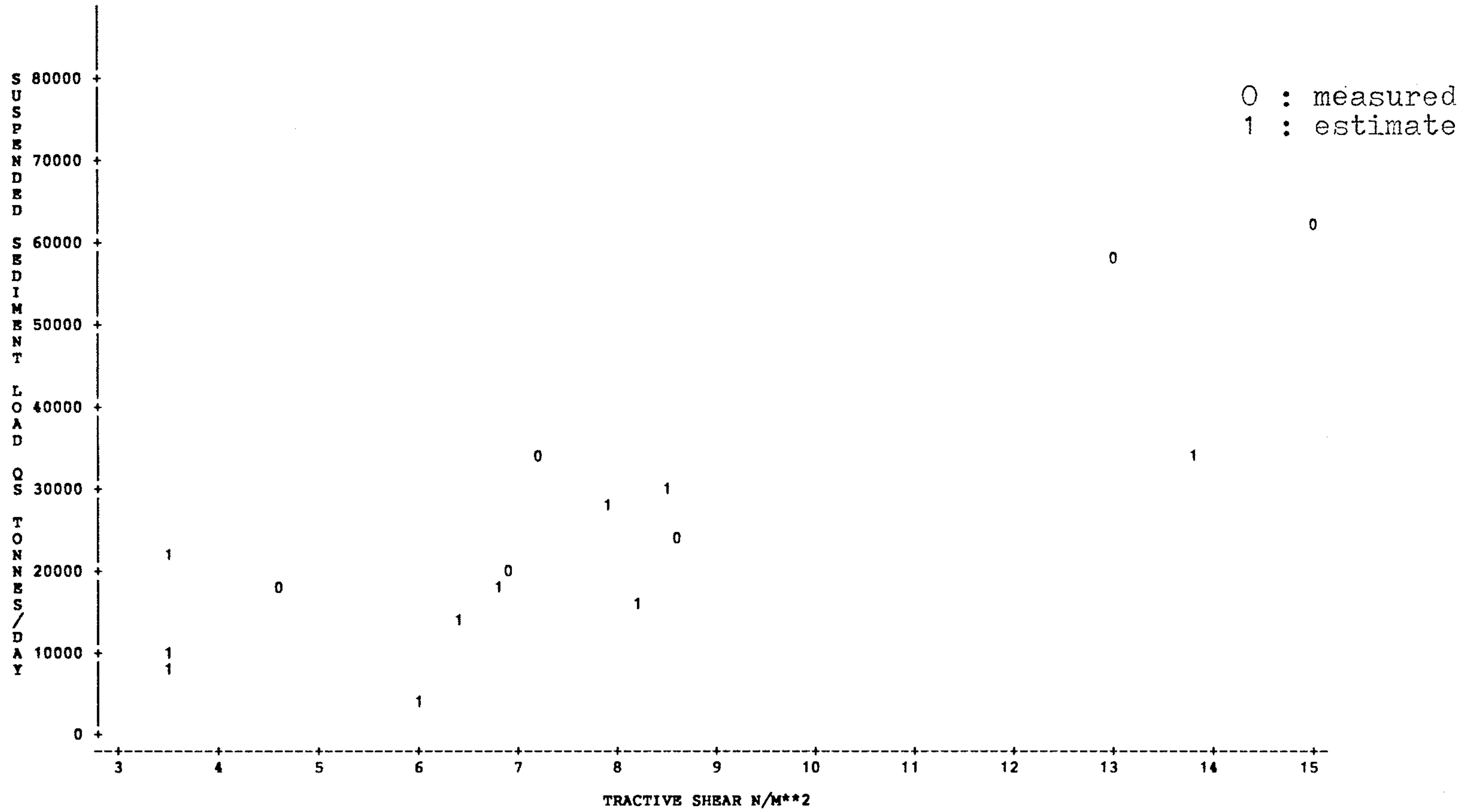

NOTE: 1 OBS HIDDEN

Fig. 54 QS VS. SHEAR VELOCITY AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*SHEAR    SYMBOL IS VALUE OF CODE




NOTE: 1 OBS HIDDEN

Fig. 55 QS VS. TRACTIVE SHEAR AT HOLLAND

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STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*POWER SYMBOL IS VALUE OF CODE

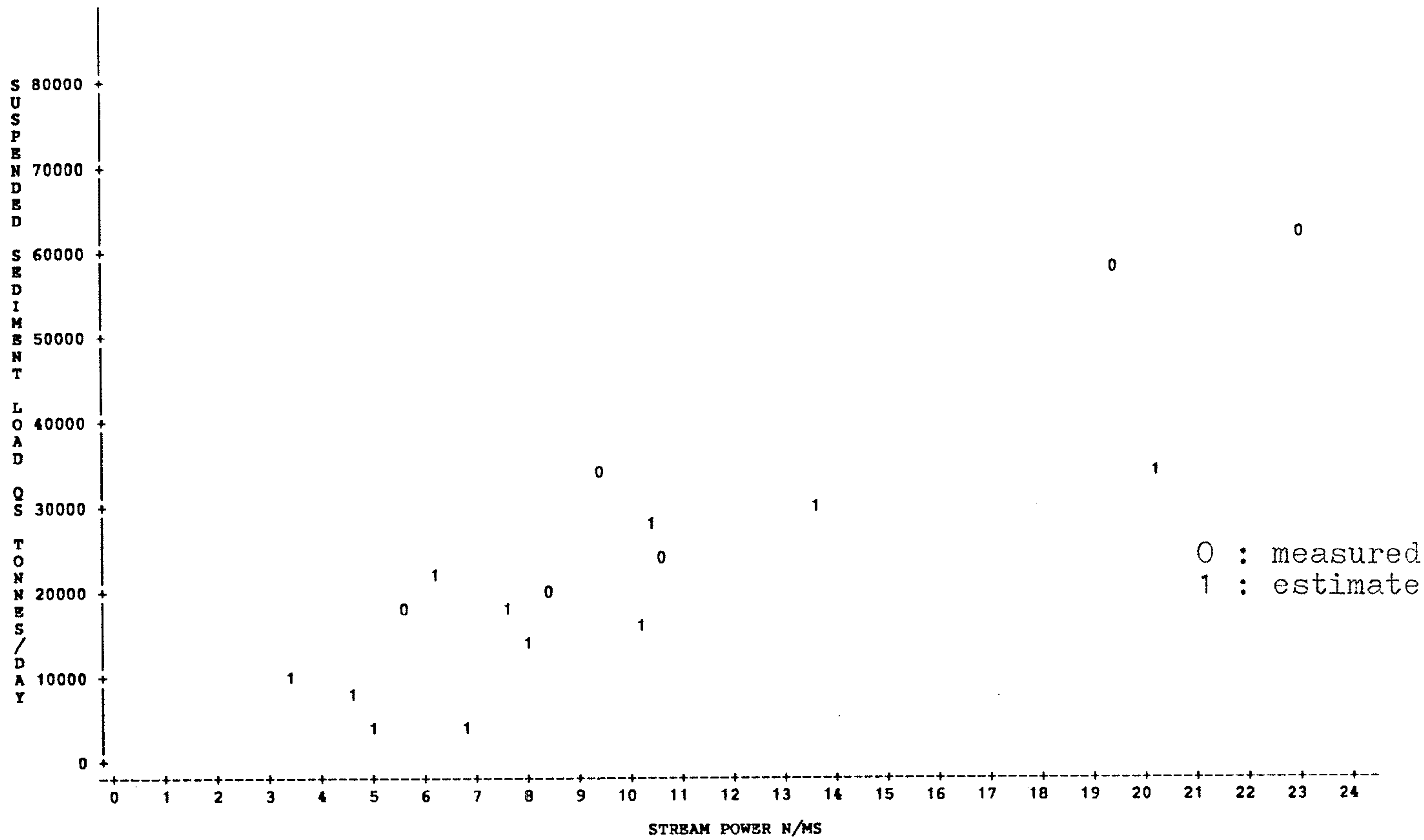



Fig. 56 QS VS. STREAM POWER AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*FROUDE SYMBOL IS VALUE OF CODE

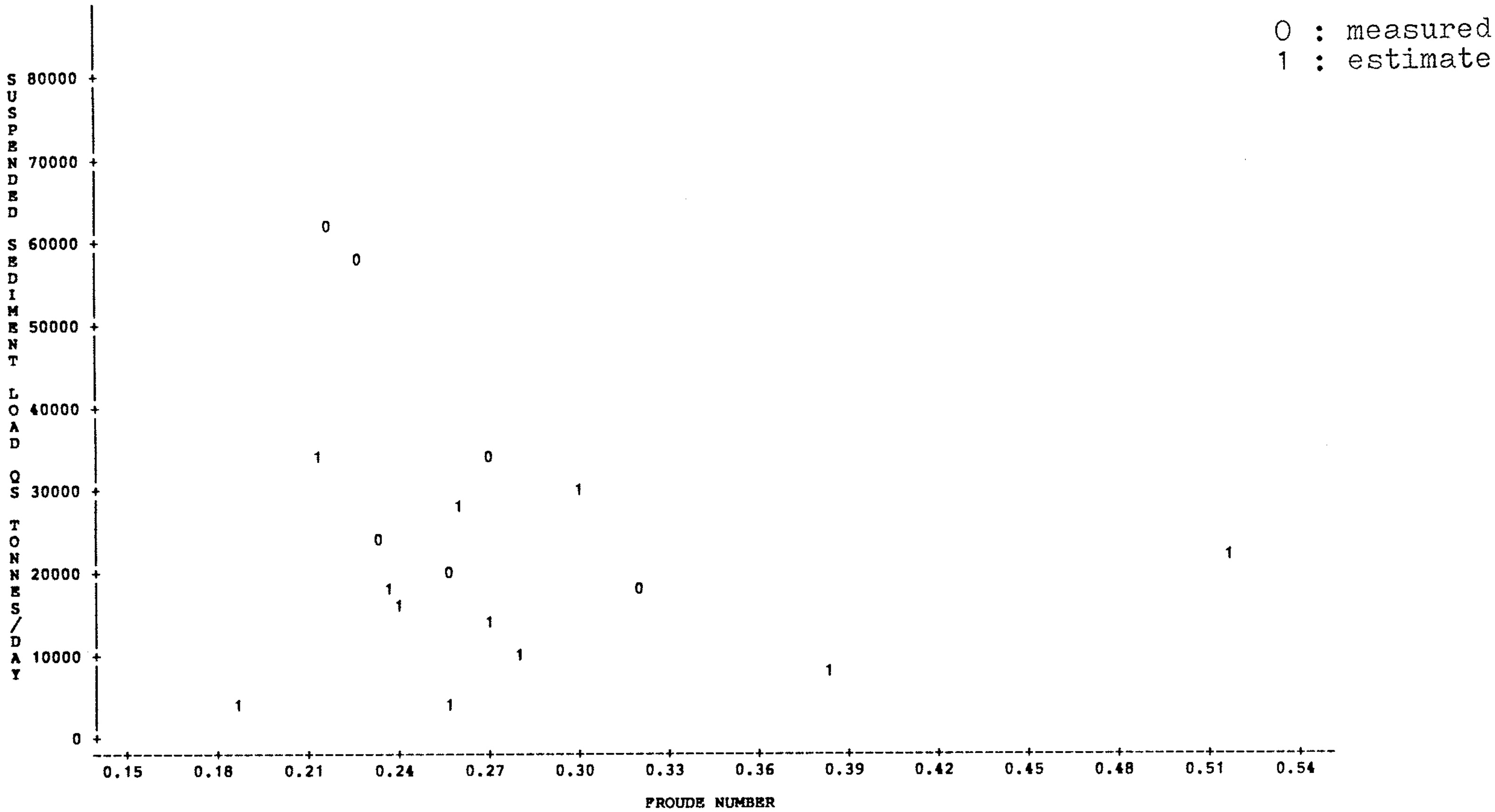



Fig. 57 QS VS. FROUDE NUMBER AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HOLLAND STATION

PLOT OF QS*CHEZY    SYMBOL IS VALUE OF CODE

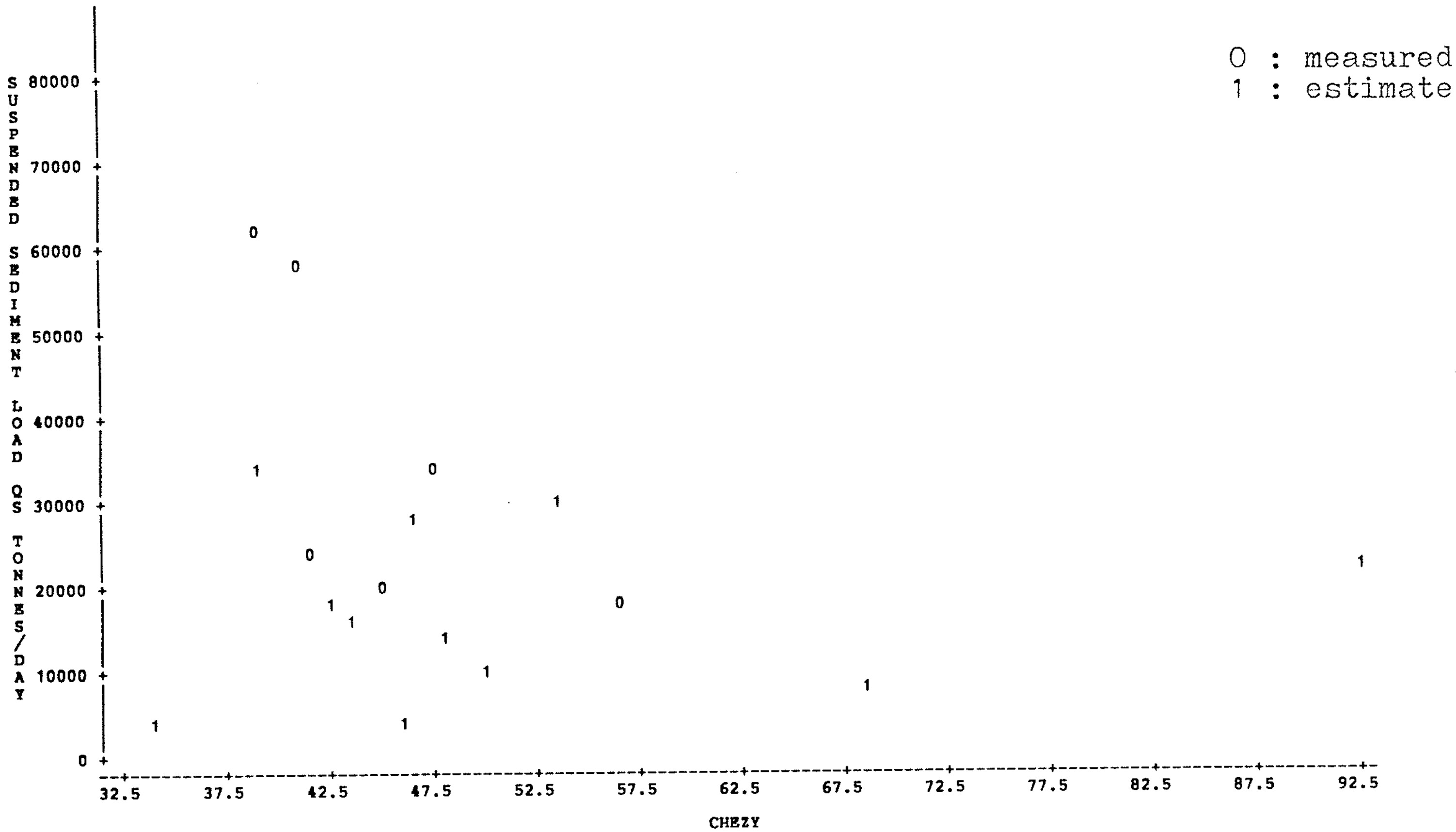



Fig. 58 QS VS. CHEZY AT HOLLAND

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF SLOPE*Q SYMBOL USED IS 0

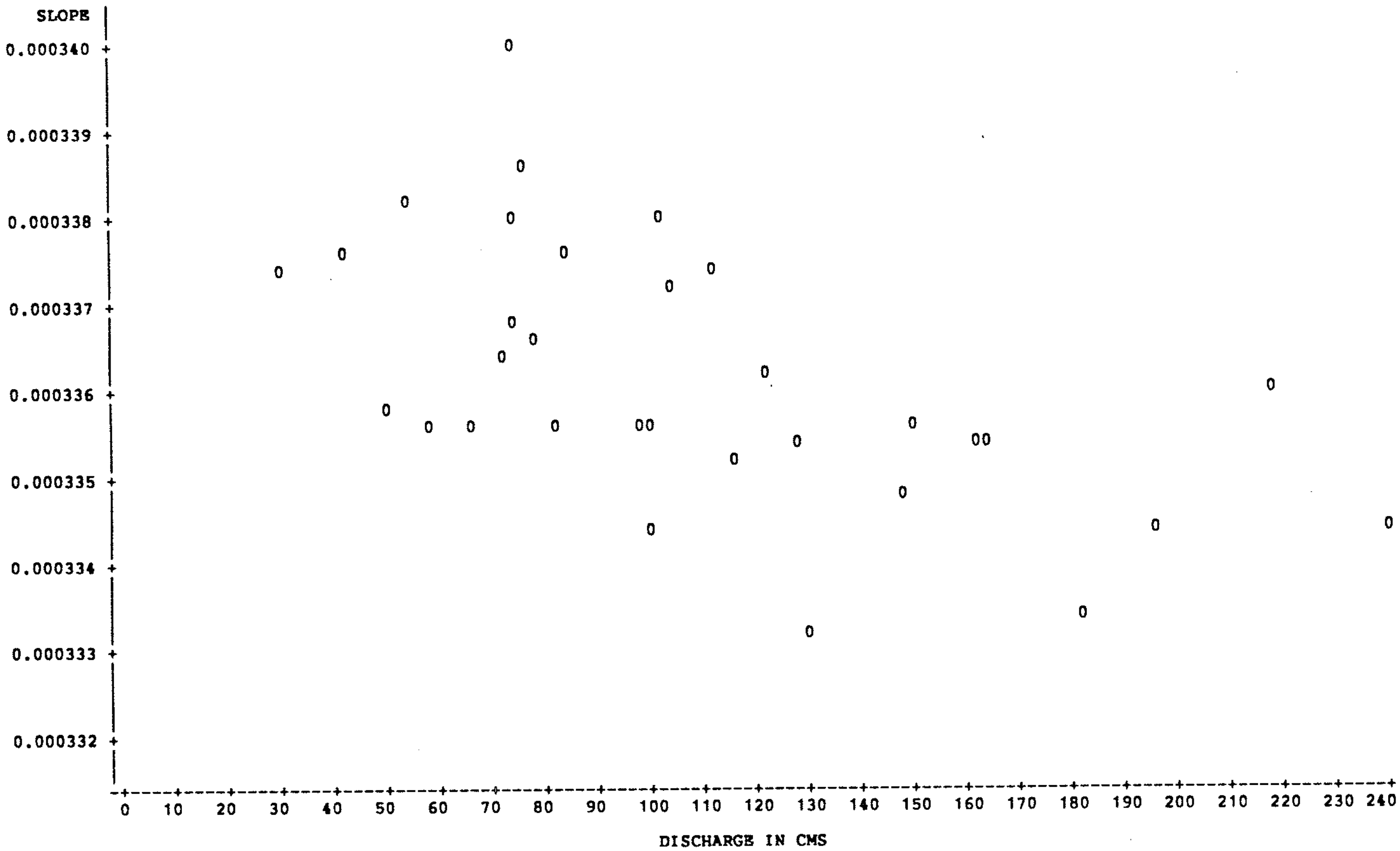



Fig. 59 SLOPE VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF VELOC*Q SYMBOL USED IS 0

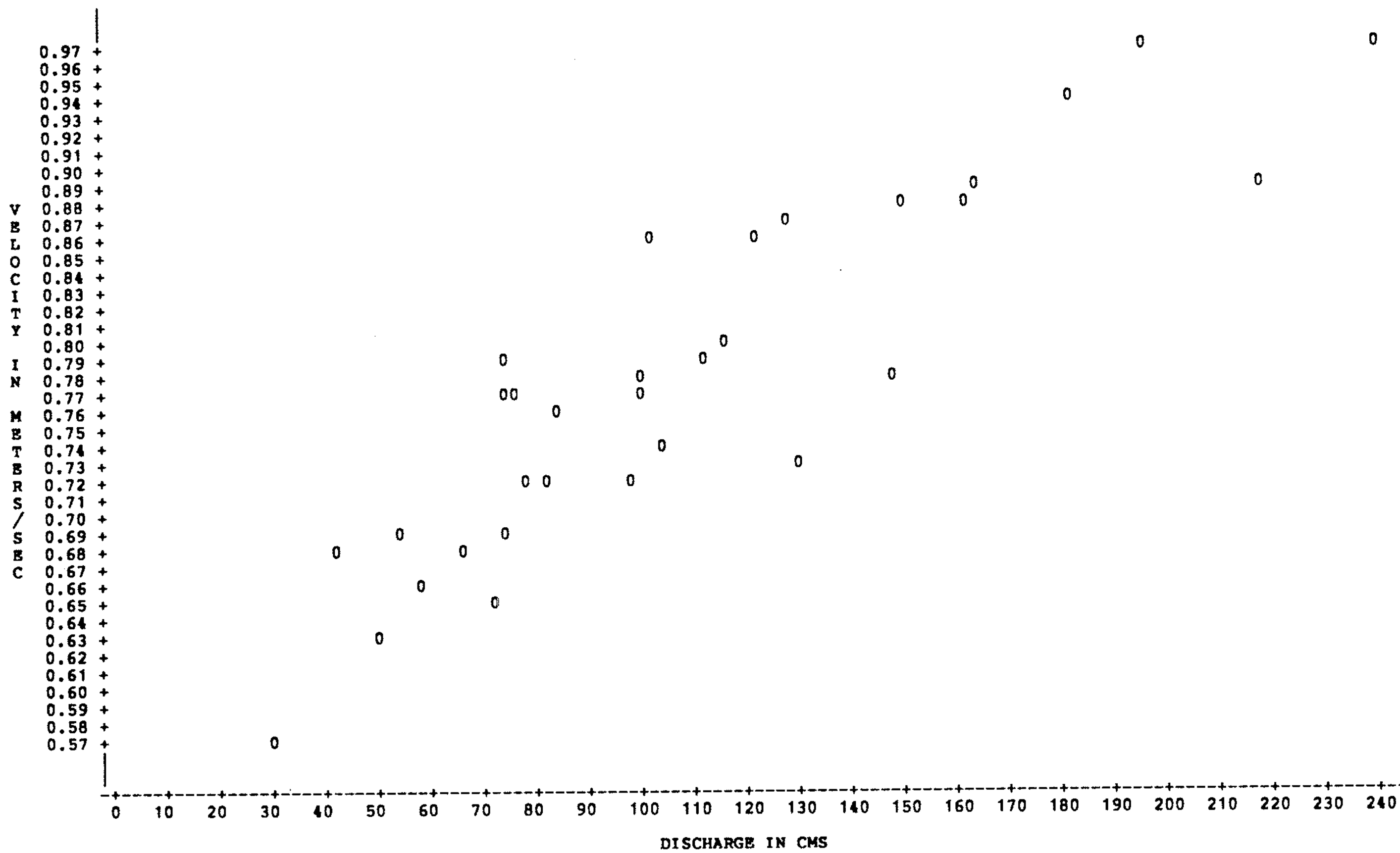
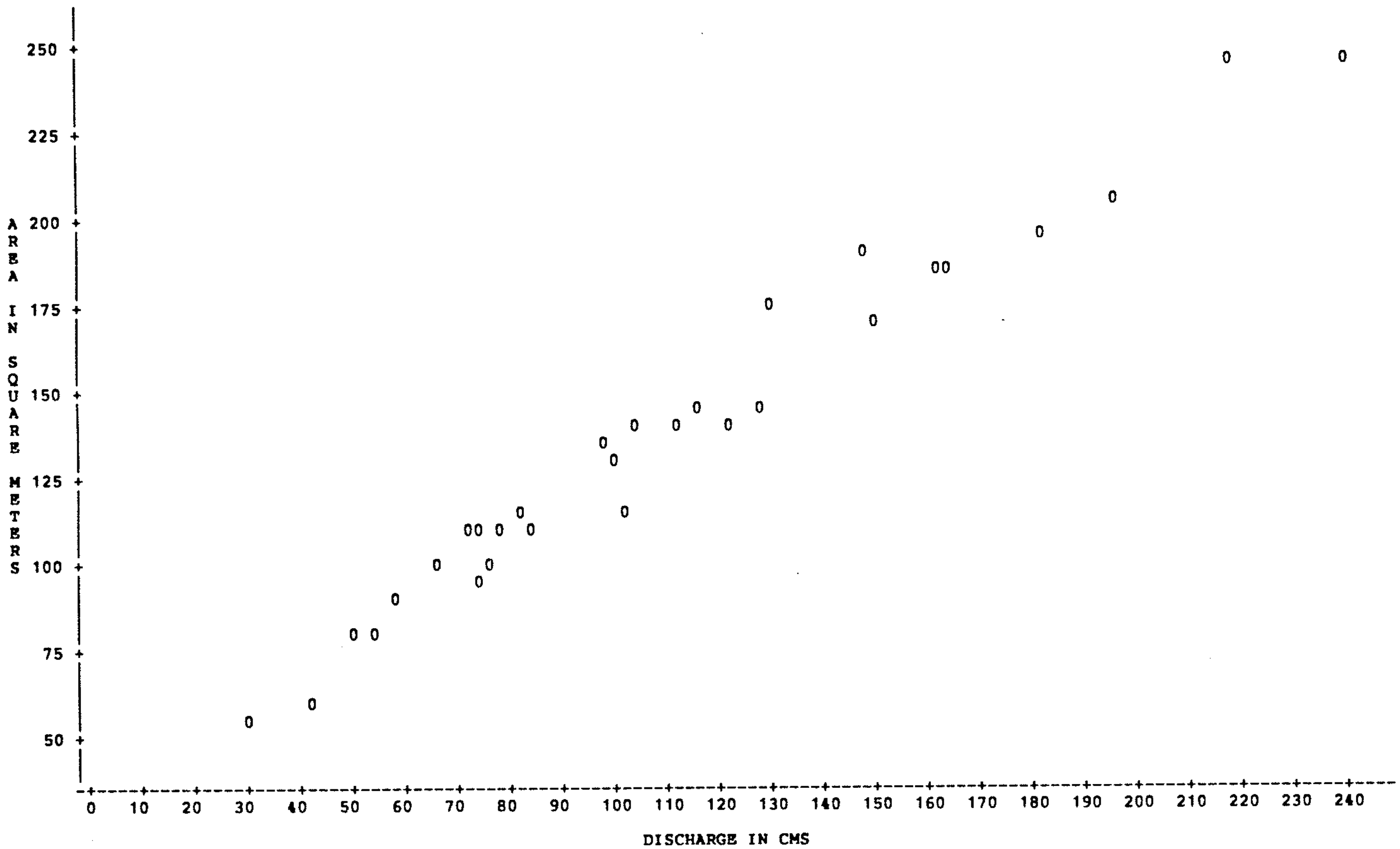



Fig. 60 VELOCITY VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF AREA*Q SYMBOL USED IS 0



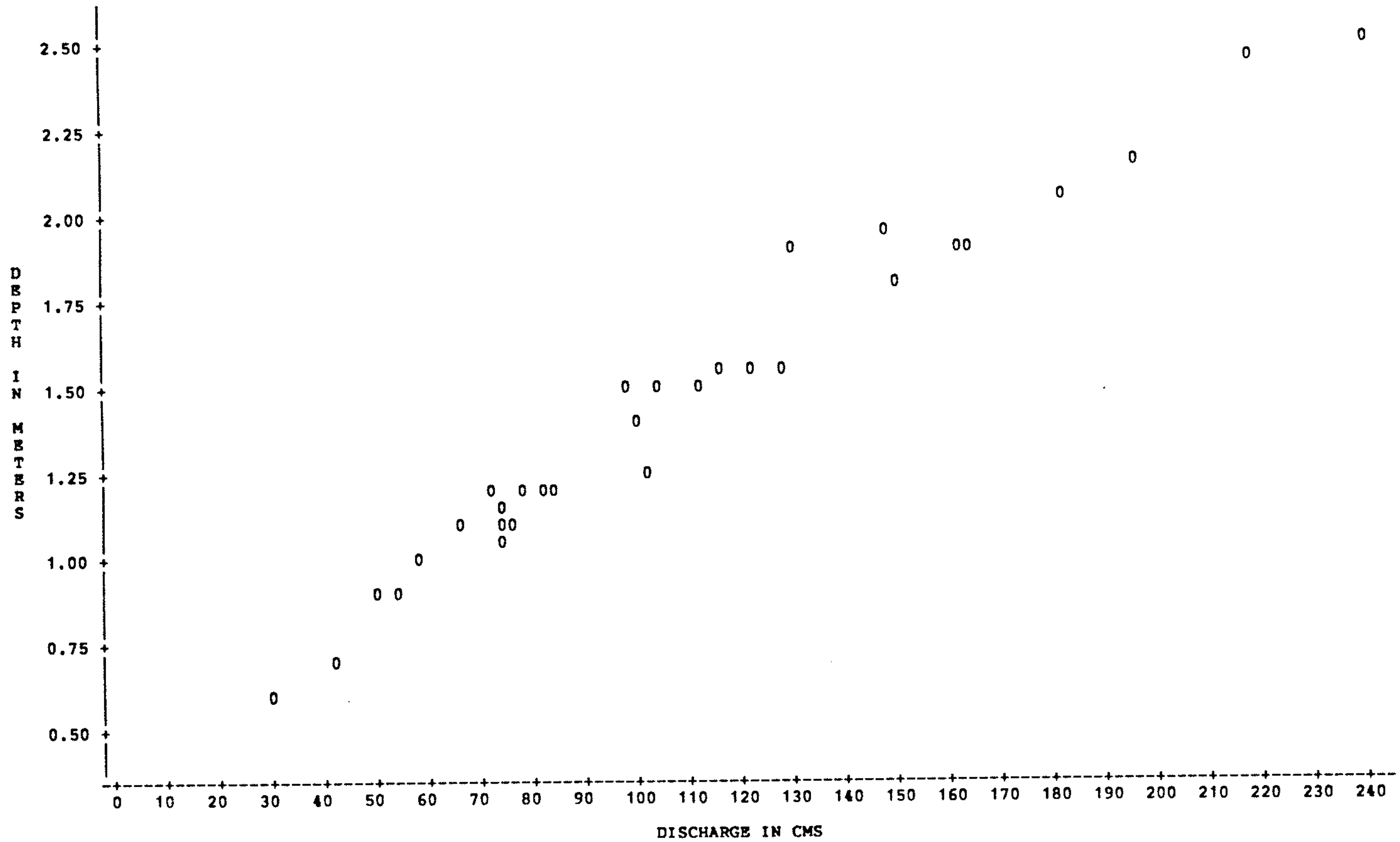

NOTE: 2 OBS HIDDEN

Fig. 61 AREA VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF DEPTH*Q SYMBOL USED IS 0



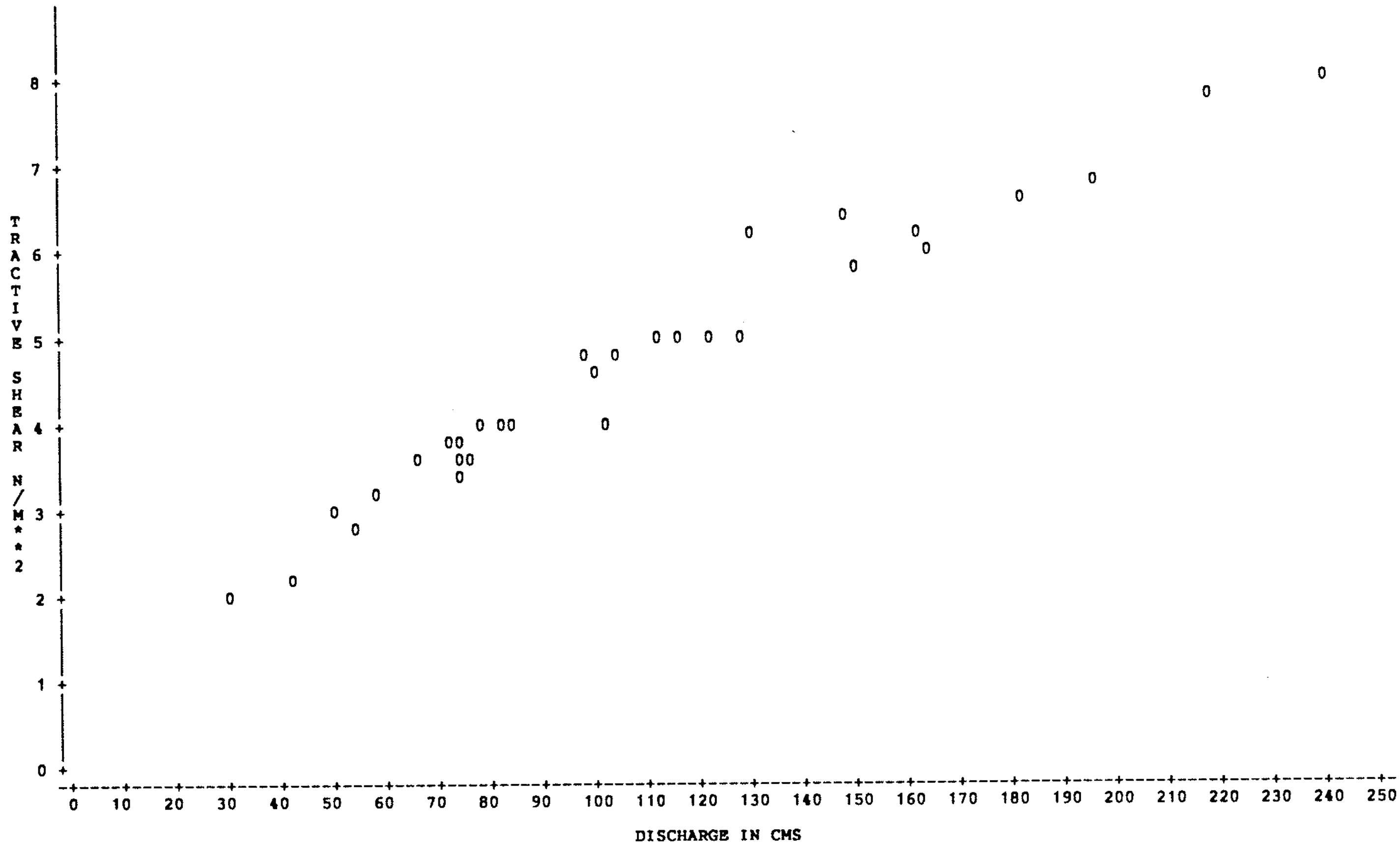

NOTE: 1 OBS HIDDEN

Fig. 62 DEPTH VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF SHEAR*Q SYMBOL USED IS 0



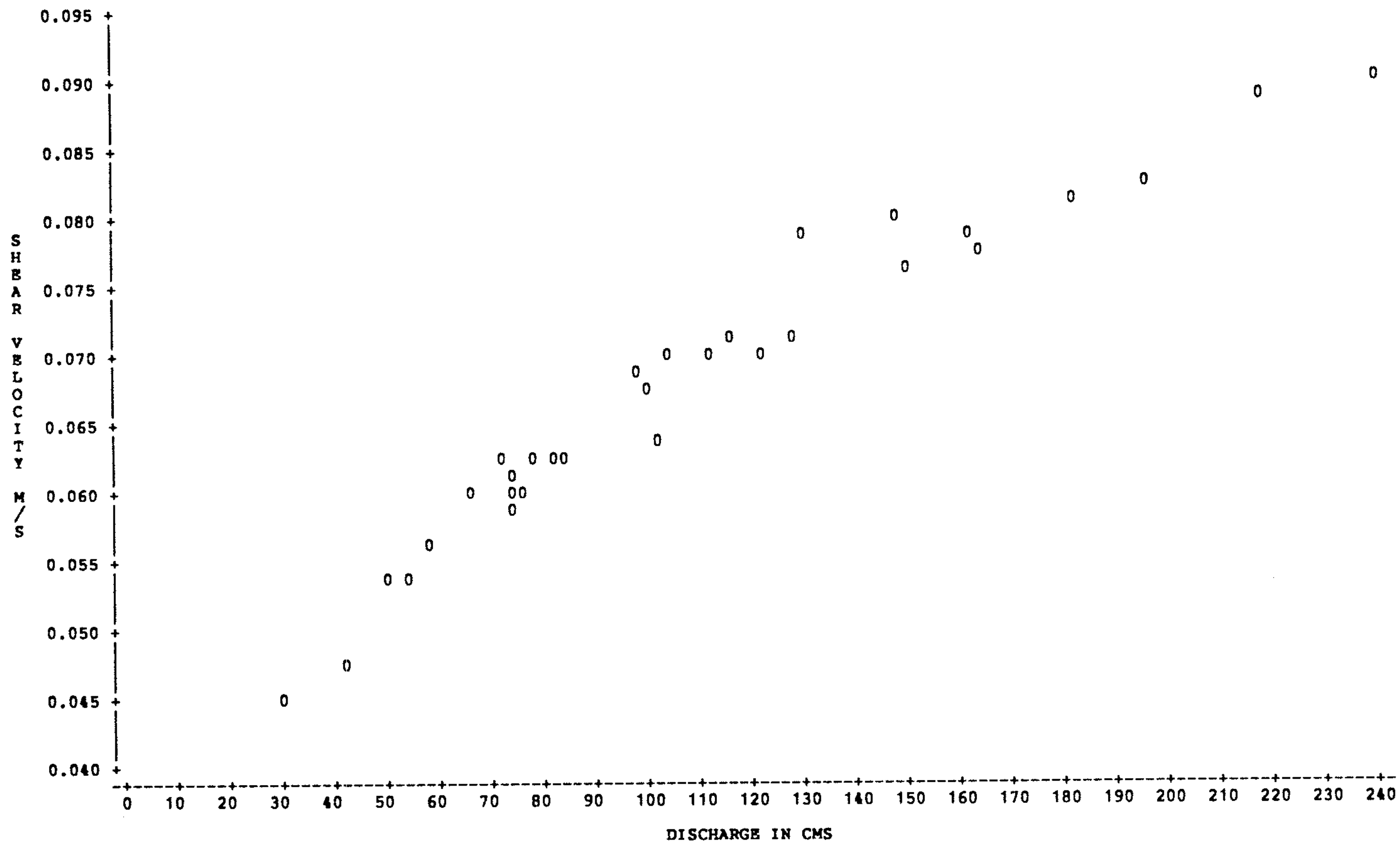

NOTE: 1 OBS HIDDEN

FIG. 63 TRACTIVE SHEAR VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF VS*Q SYMBOL USED IS 0



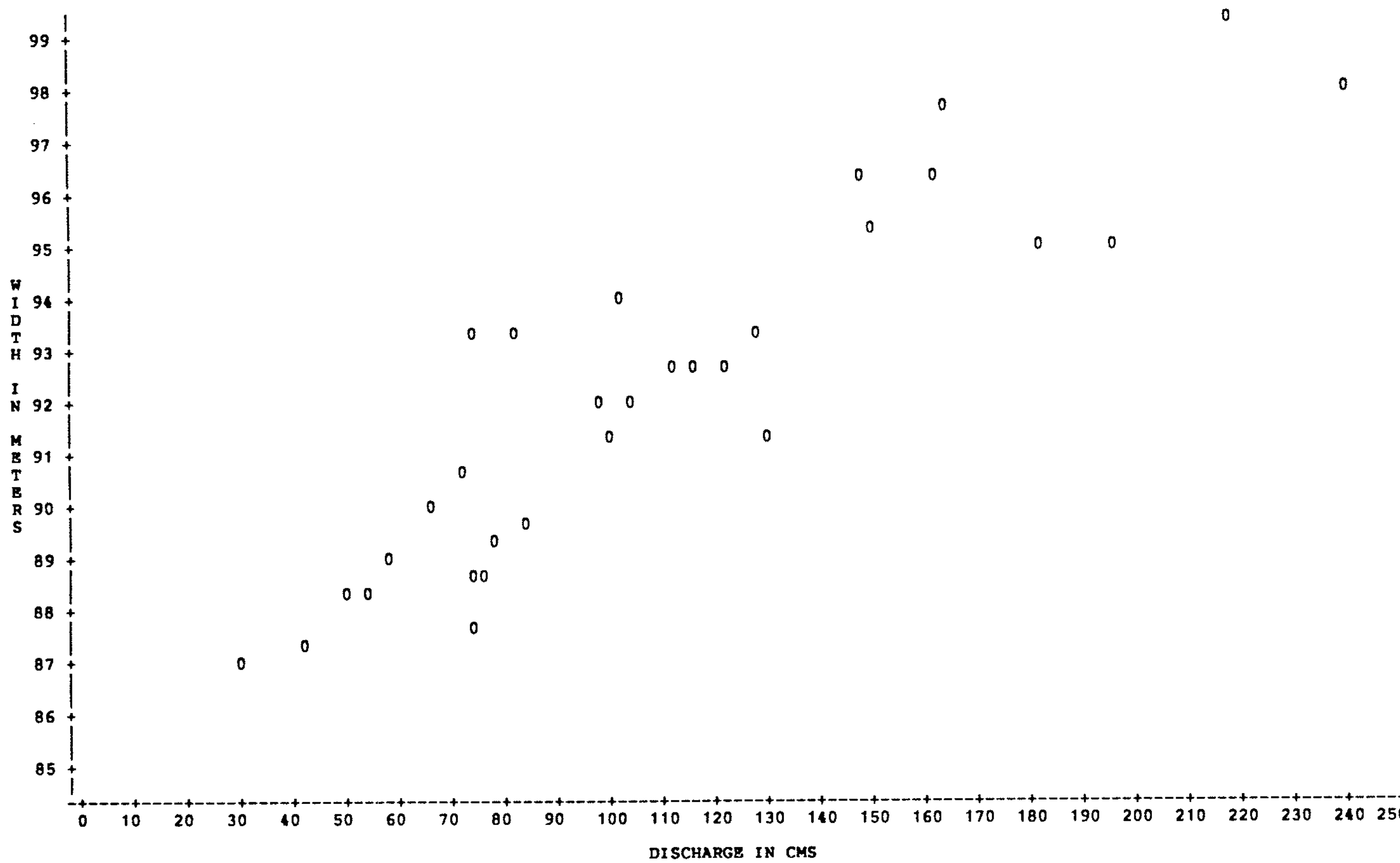

NOTE: 1 OBS HIDDEN

FIG. 64 SHEAR VELOCITY VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF WIDTH*Q SYMBOL USED IS 0



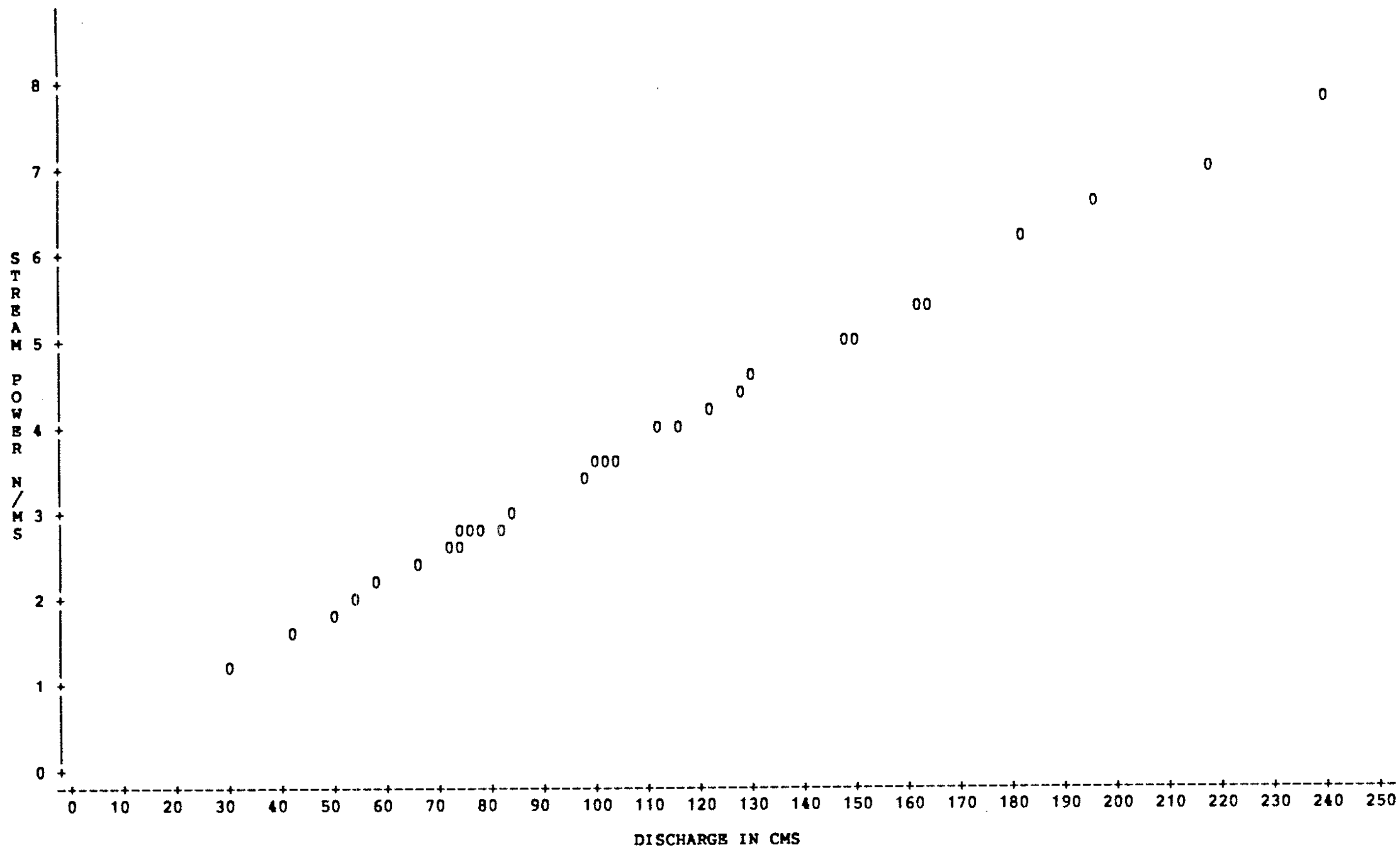

NOTE: 1 OBS HIDDEN

Fig. 65 WIDTH VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF POWER*Q SYMBOL USED IS 0




NOTE: 2 OBS HIDDEN

Fig. 66 STREAM POWER VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF CHEZY*Q SYMBOL USED IS 0

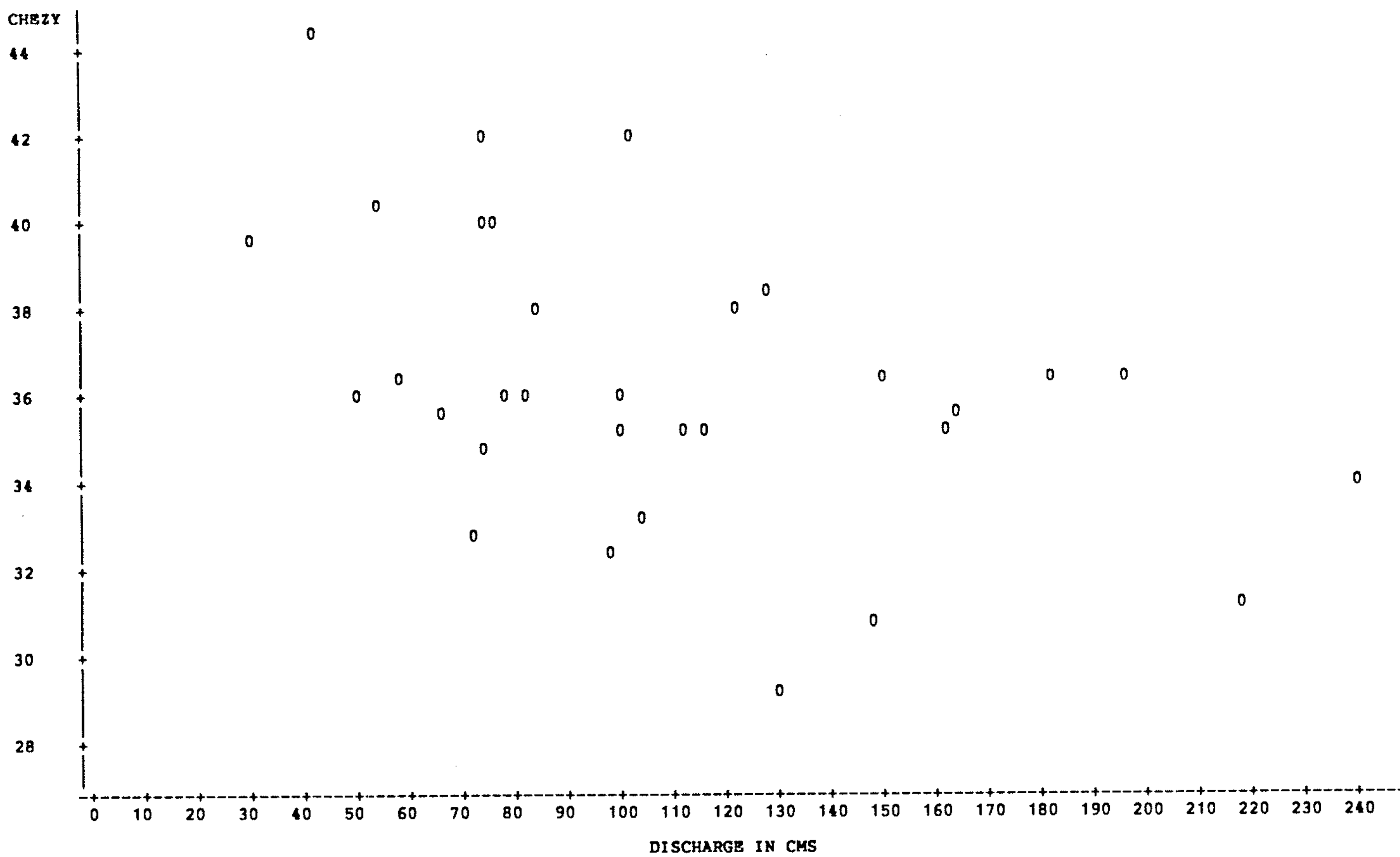



Fig. 67 CHEZY VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF FROUDE*Q SYMBOL USED IS 0

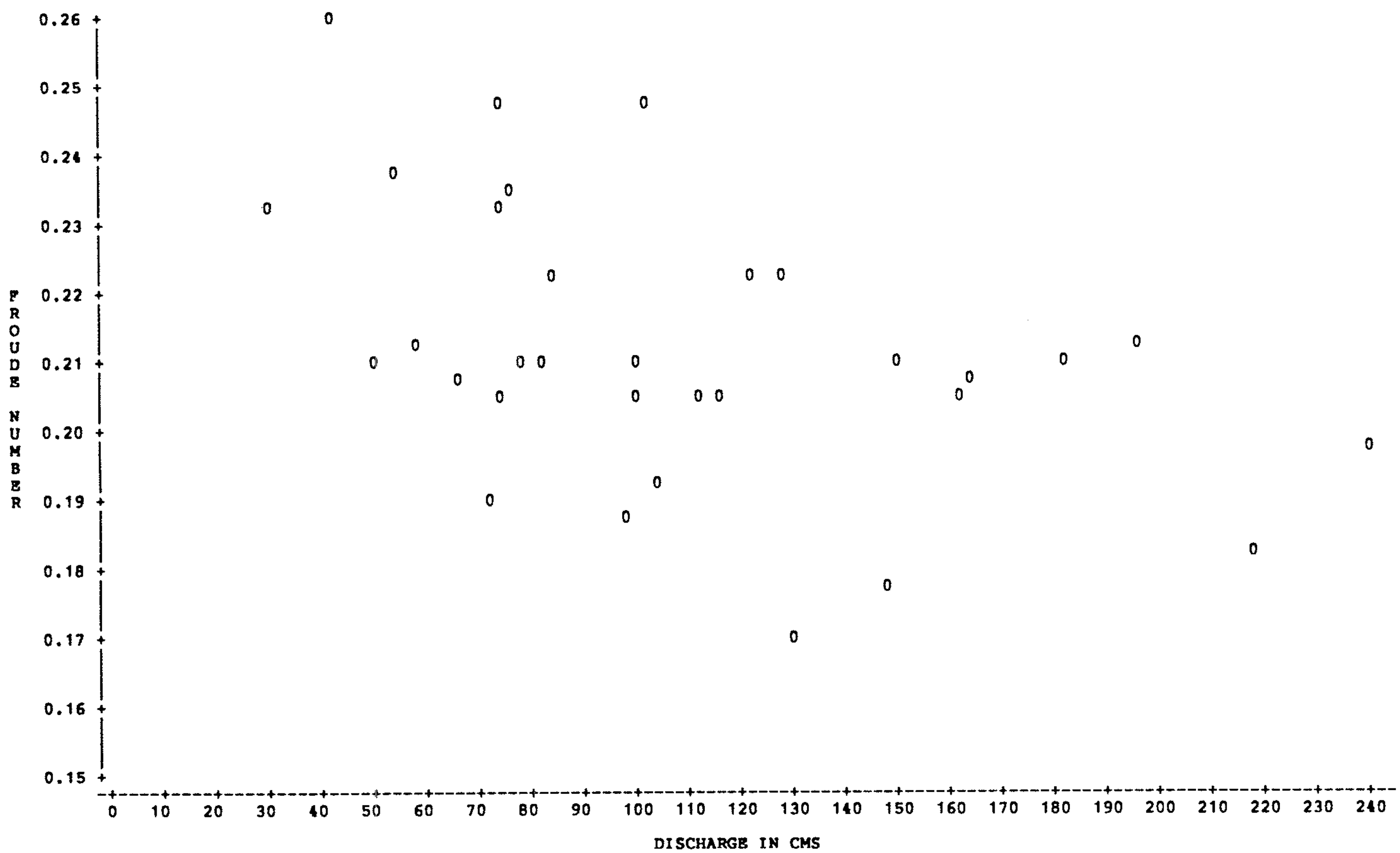



Fig. 68 FROUDE NUMBER VS. DISCHARGE AT PORTAGE BEFORE 1969

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STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF D50*Q SYMBOL USED IS 0

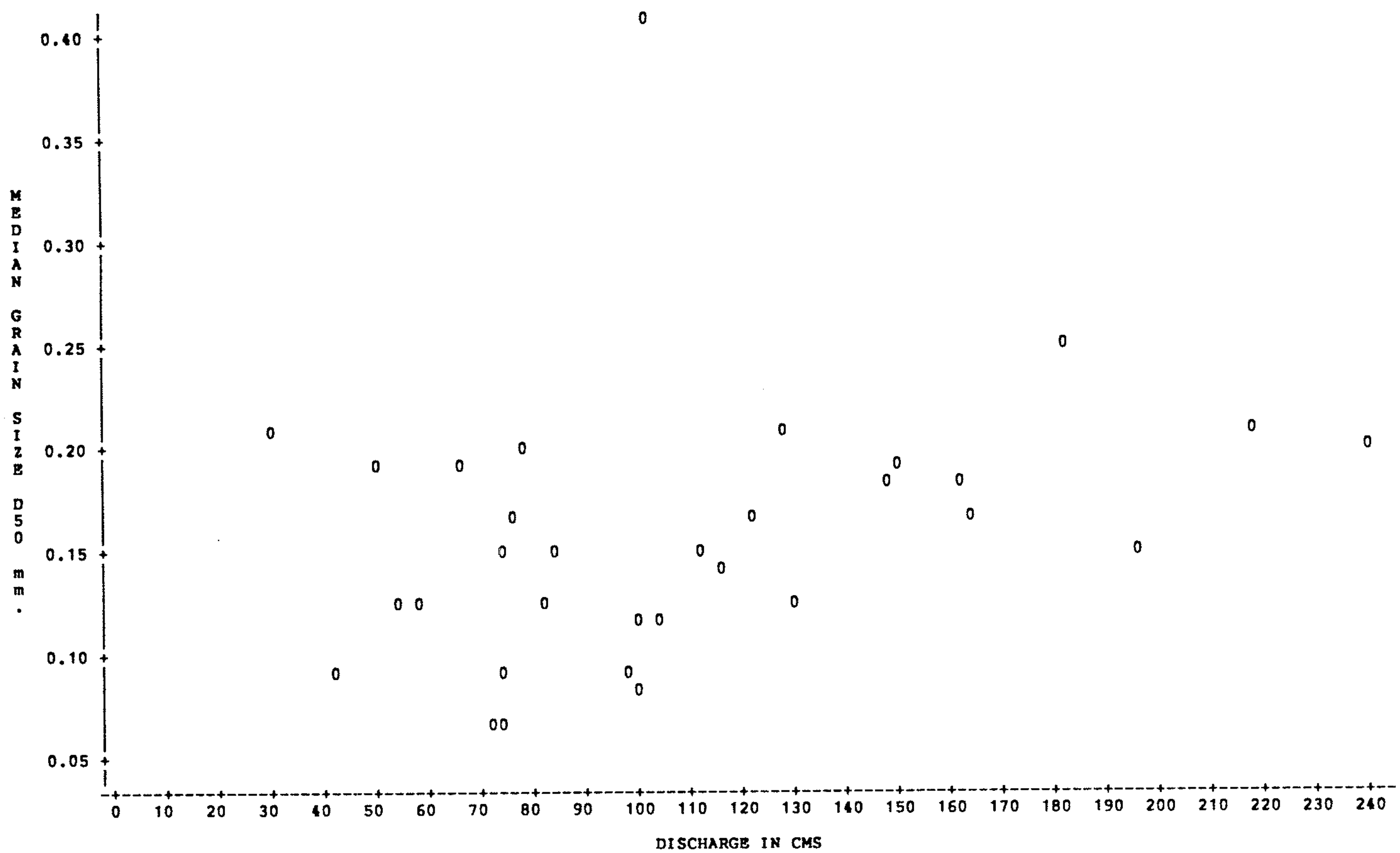



Fig. 69 MEDIAN GRAIN SIZE VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF PHI*Q SYMBOL USED IS 0

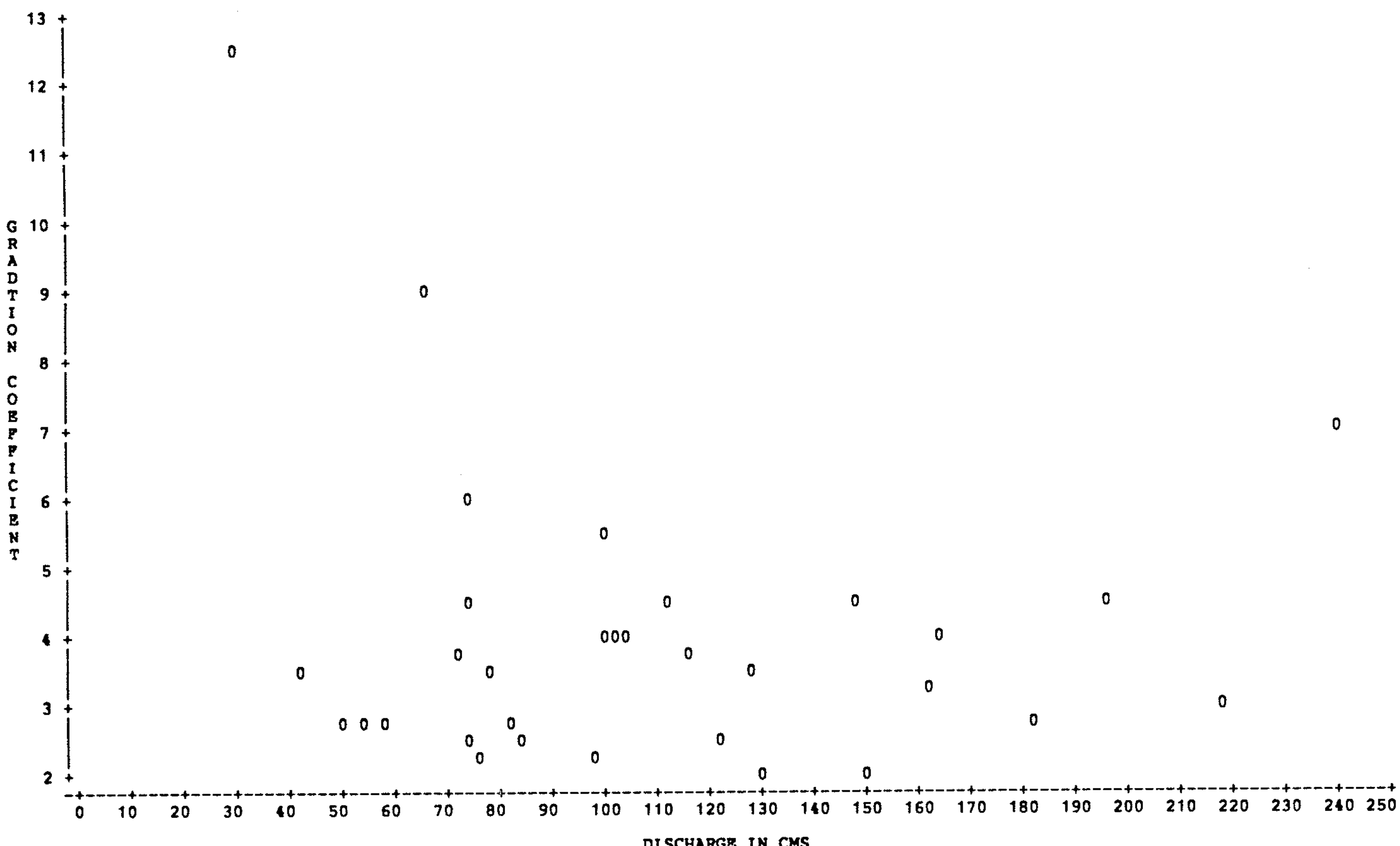



Fig. 70 GRADATION COEFFICIENT VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*SLOPE SYMBOL USED IS 0

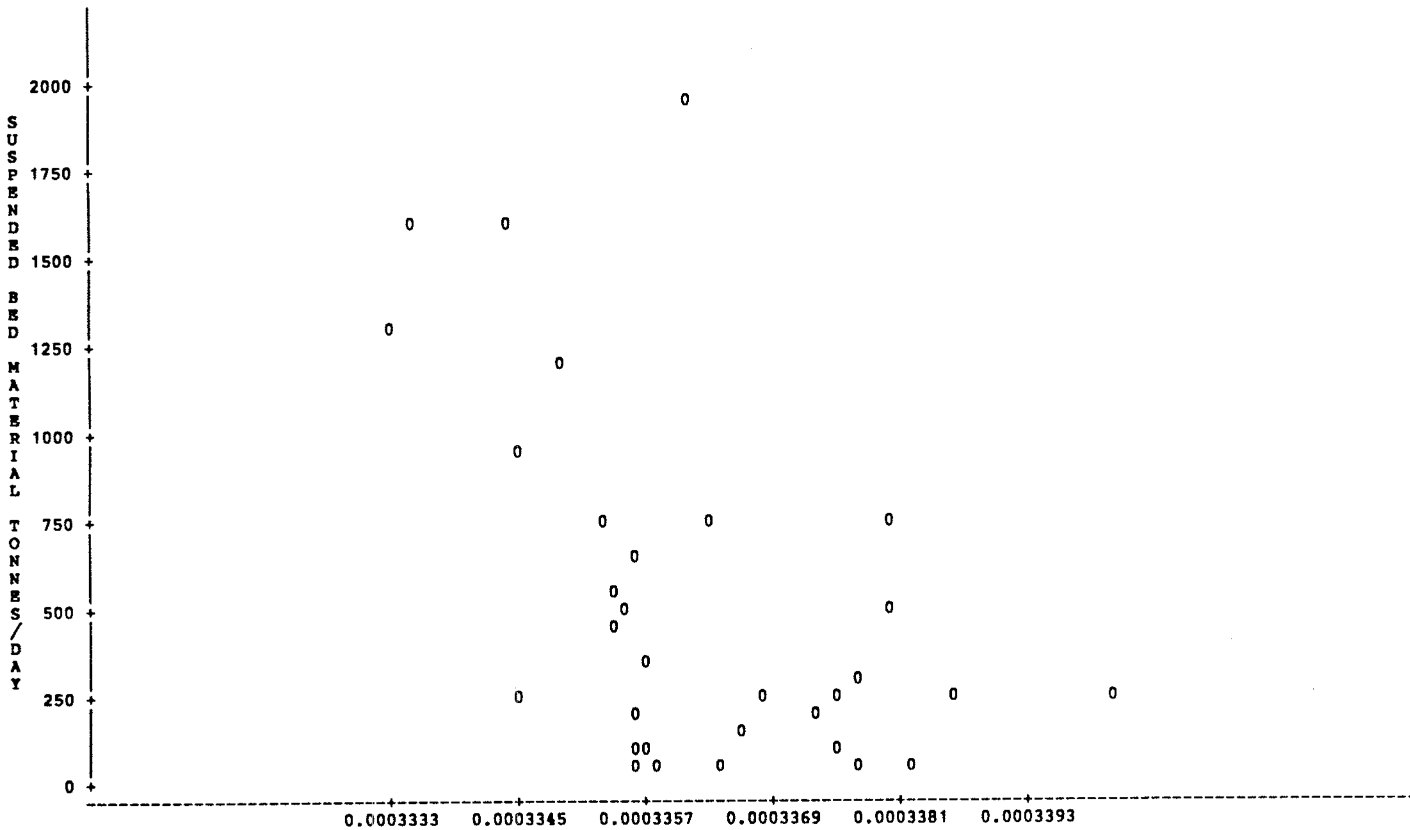
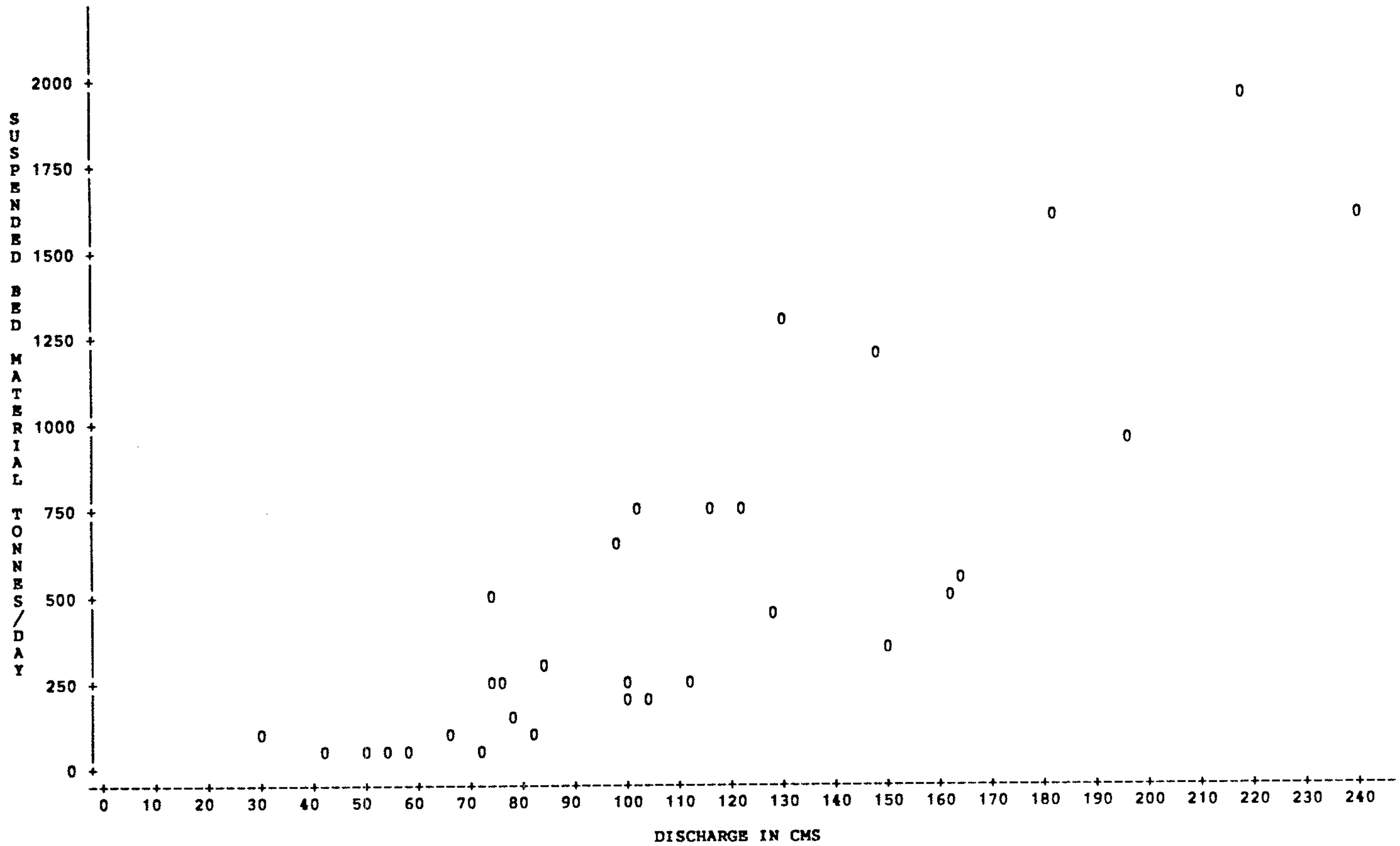



Fig. 71 QSBM VS. SLOPE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*Q SYMBOL USED IS 0



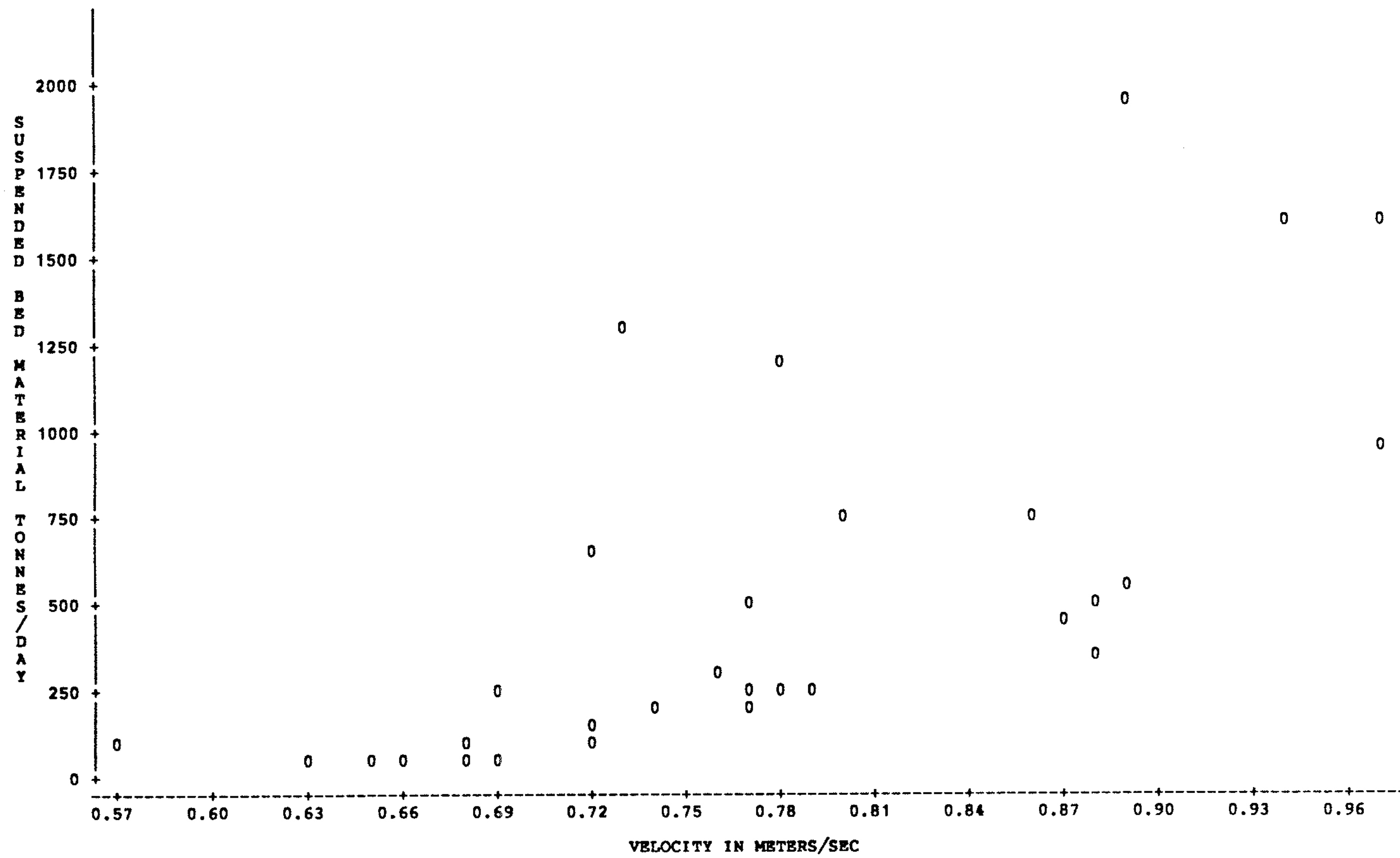

NOTE: 1 OBS HIDDEN

Fig. 72 QSBM VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*VELOC SYMBOL USED IS 0




NOTE: 2 OBS HIDDEN

Fig. 73 QSBM VS. VELOCITY AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*DEPTH SYMBOL USED IS 0

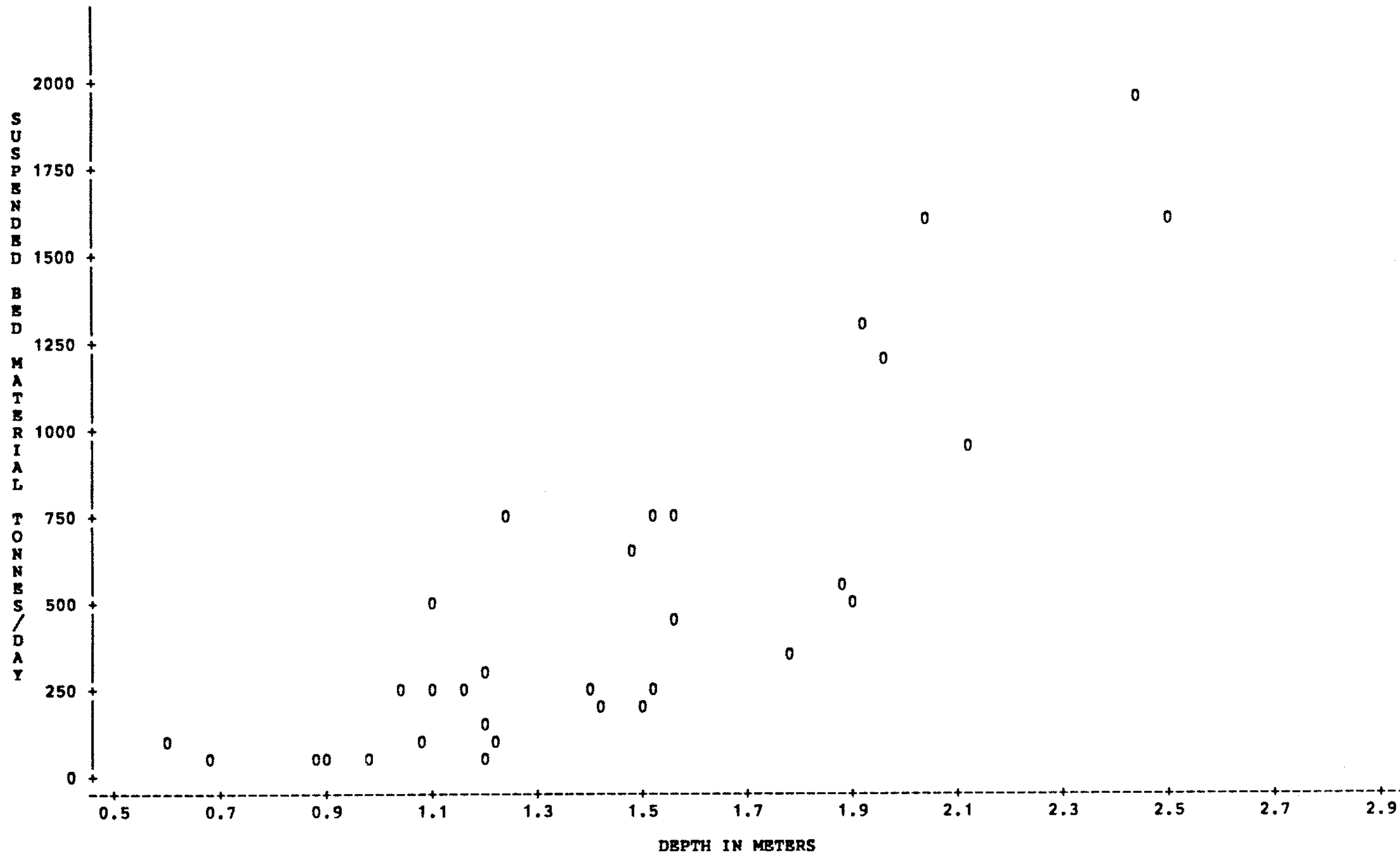



Fig. 74 QSBM VS. DEPTH AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*VS SYMBOL USED IS 0

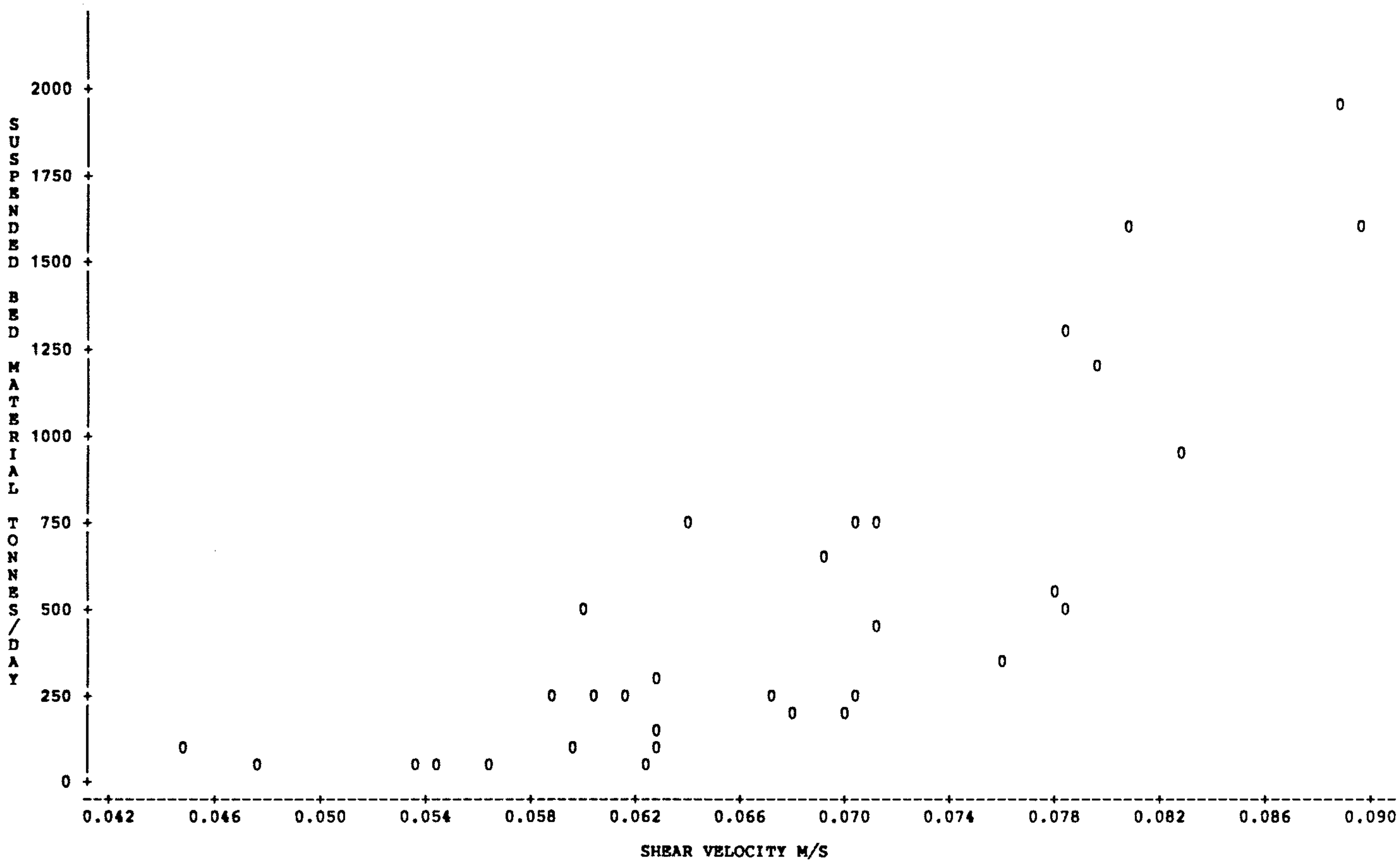



Fig. 75 QSBM VS. SHEAR VELOCITY AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*SHEAR SYMBOL USED IS 0

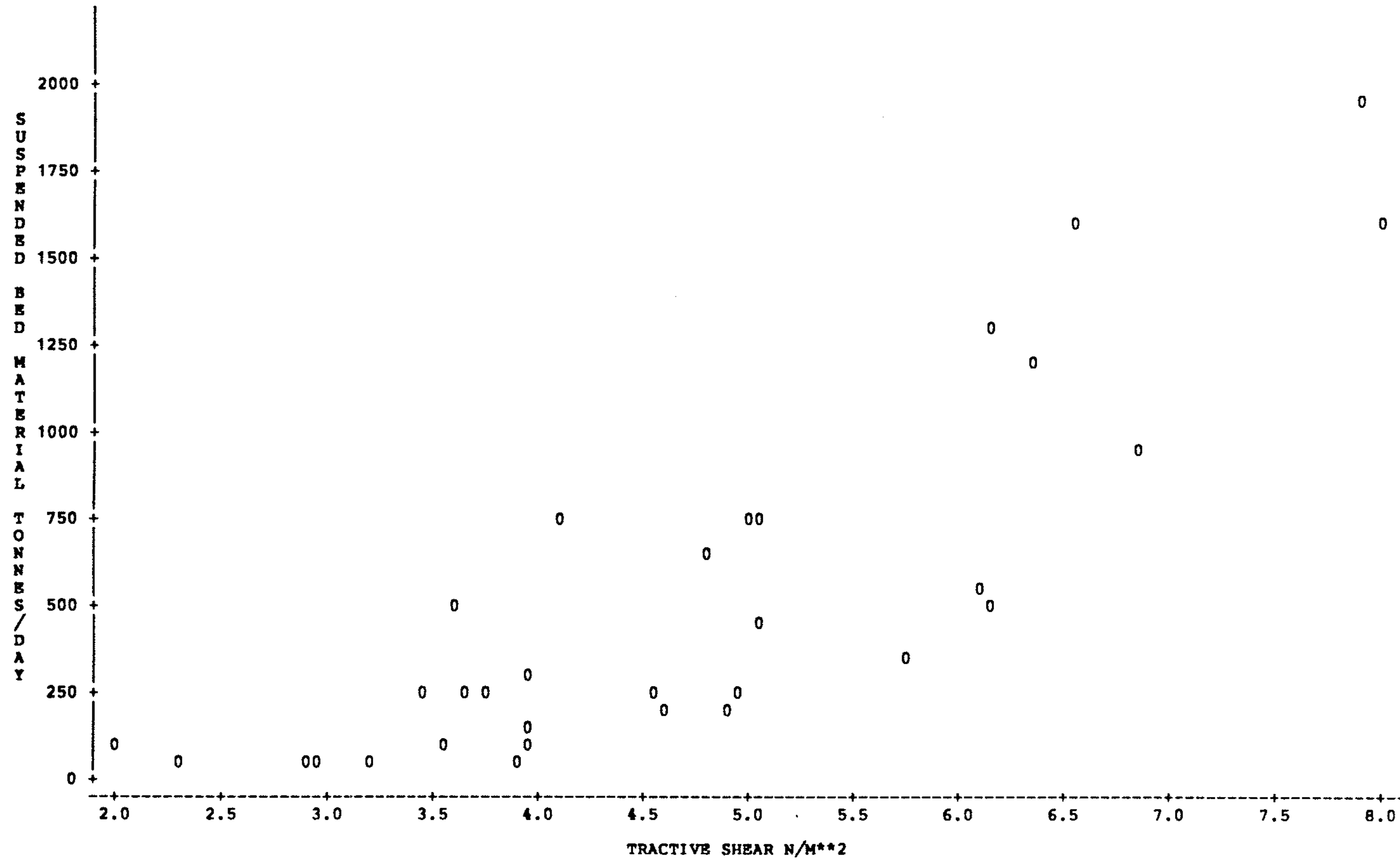



Fig. 76 QSBM VS. TRACTIVE SHEAR AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*POWER SYMBOL USED IS 0

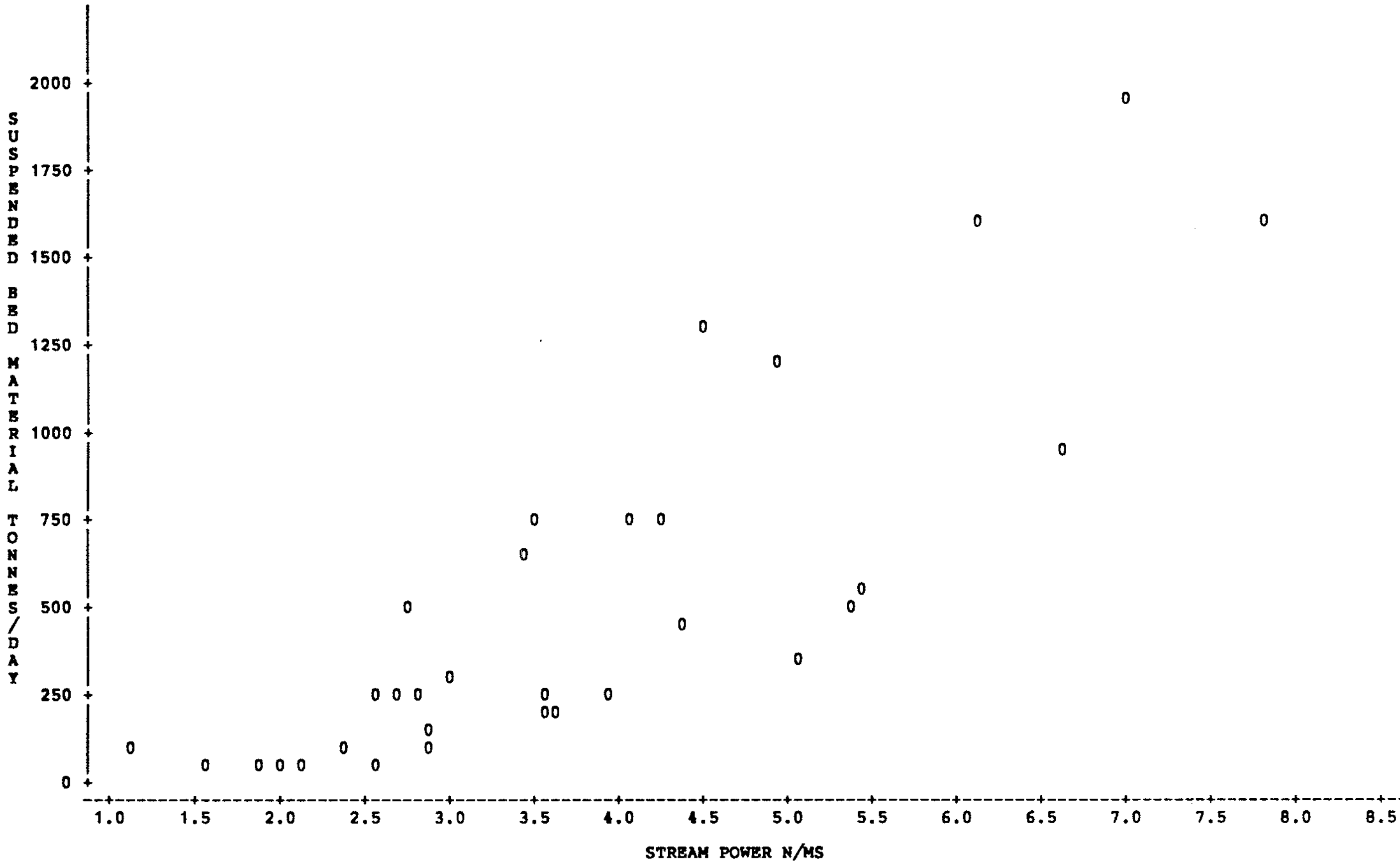



Fig. 77 QSBM VS. STREAM POWER AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*CHEZY SYMBOL USED IS 0

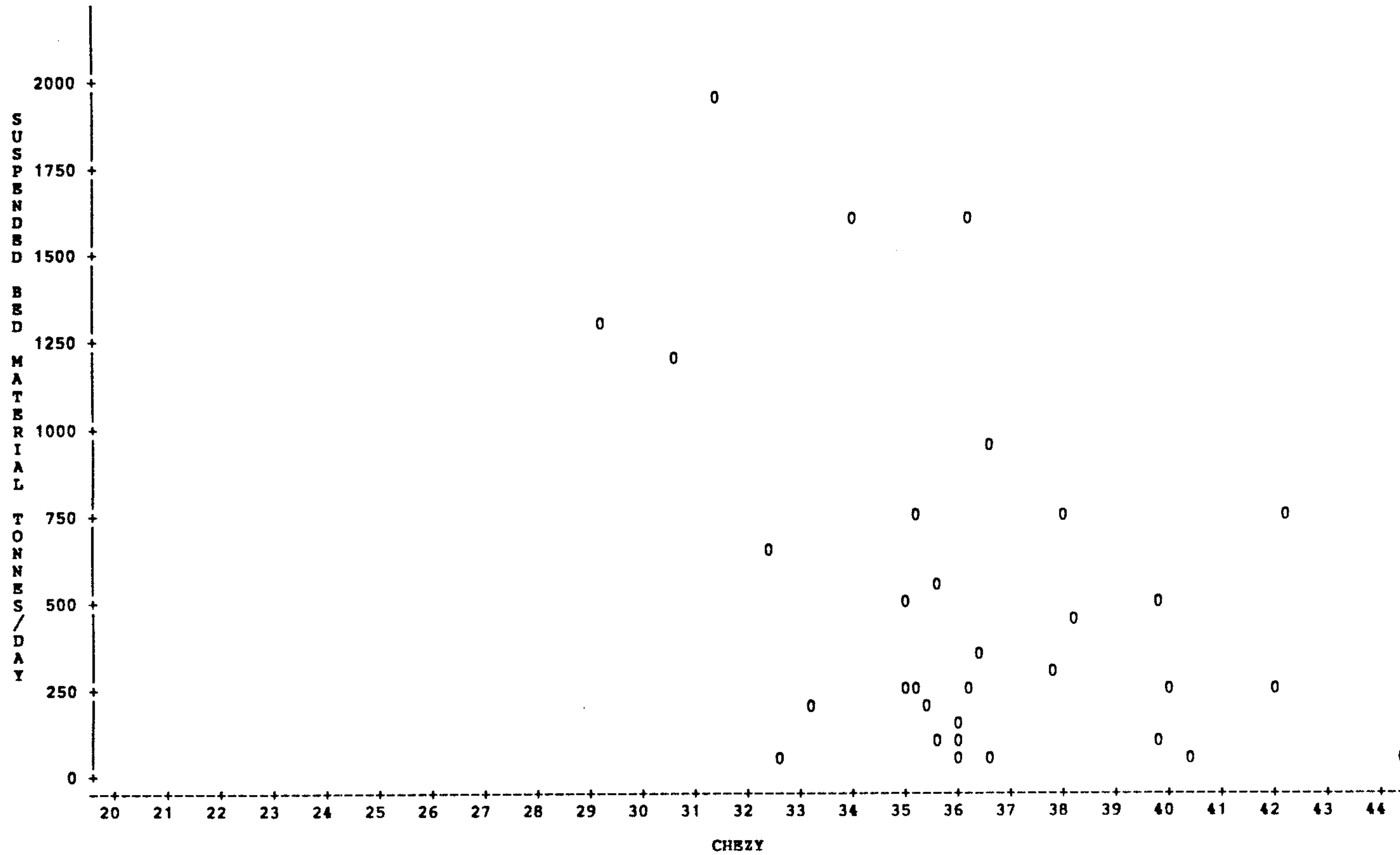



Fig. 78 QSBM VS. CHEZY AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QSBM*FROUDE SYMBOL USED IS 0

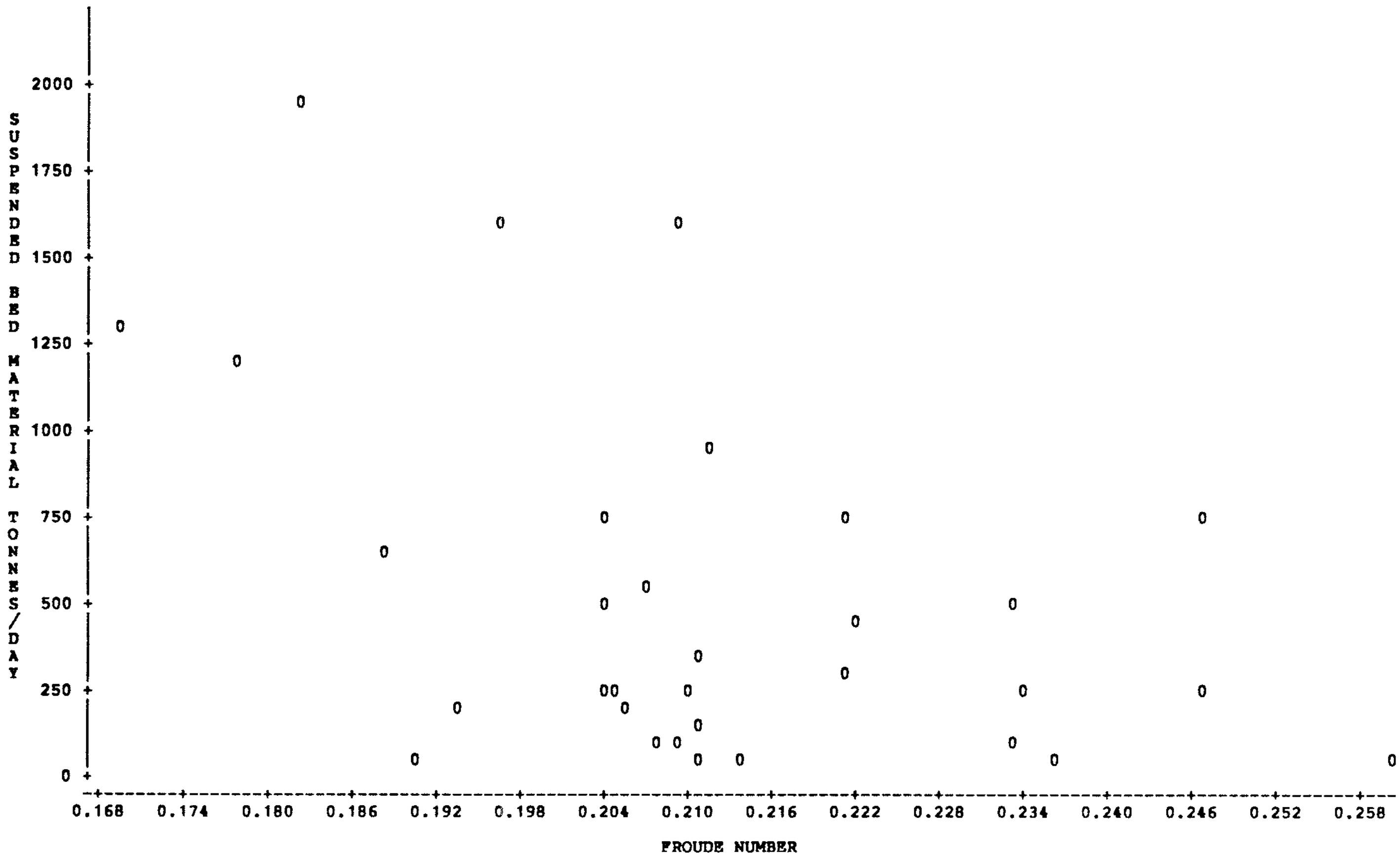
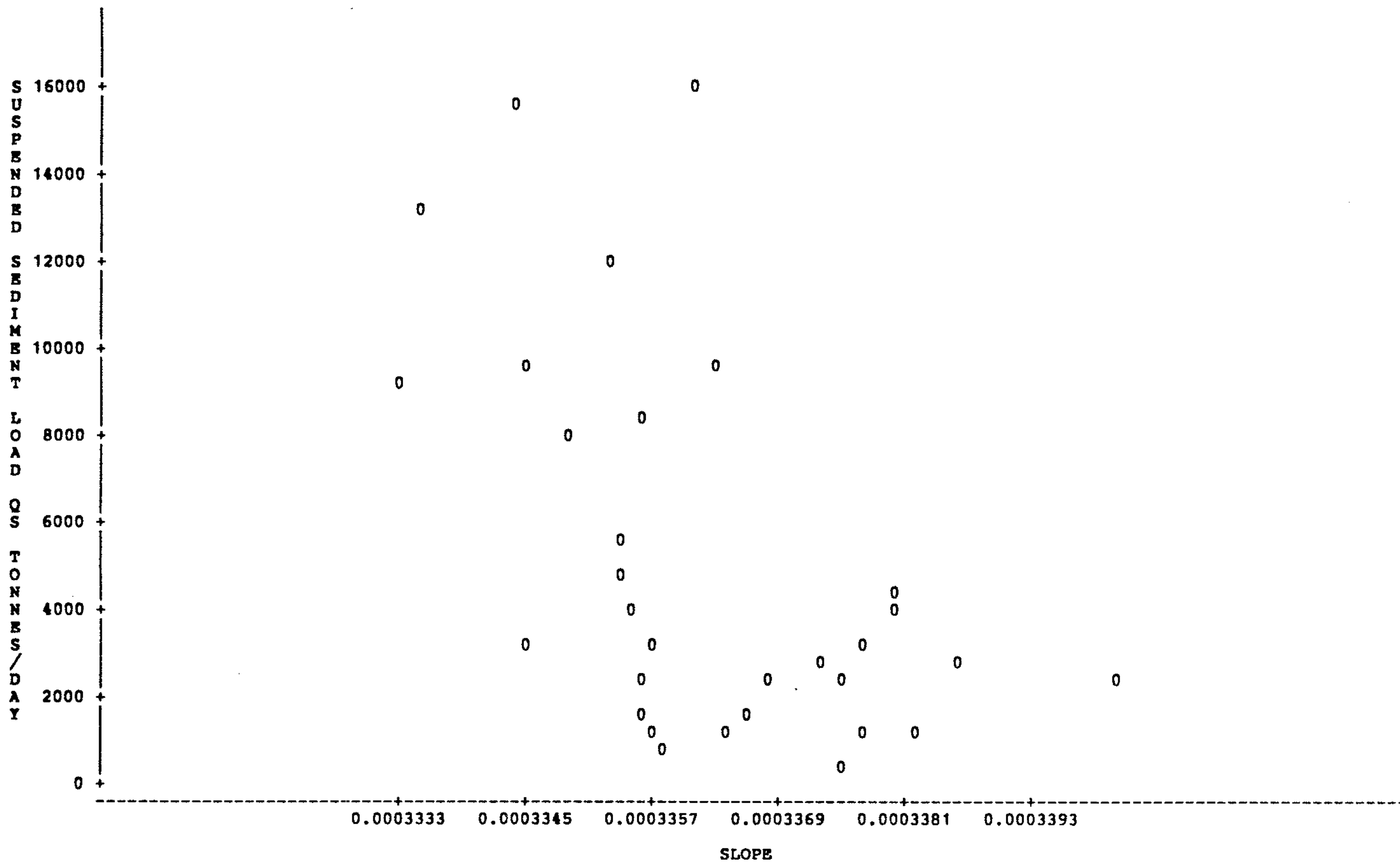



Fig. 79 QSBM VS. FROUDE NUMBER AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*SLOPE SYMBOL USED IS 0



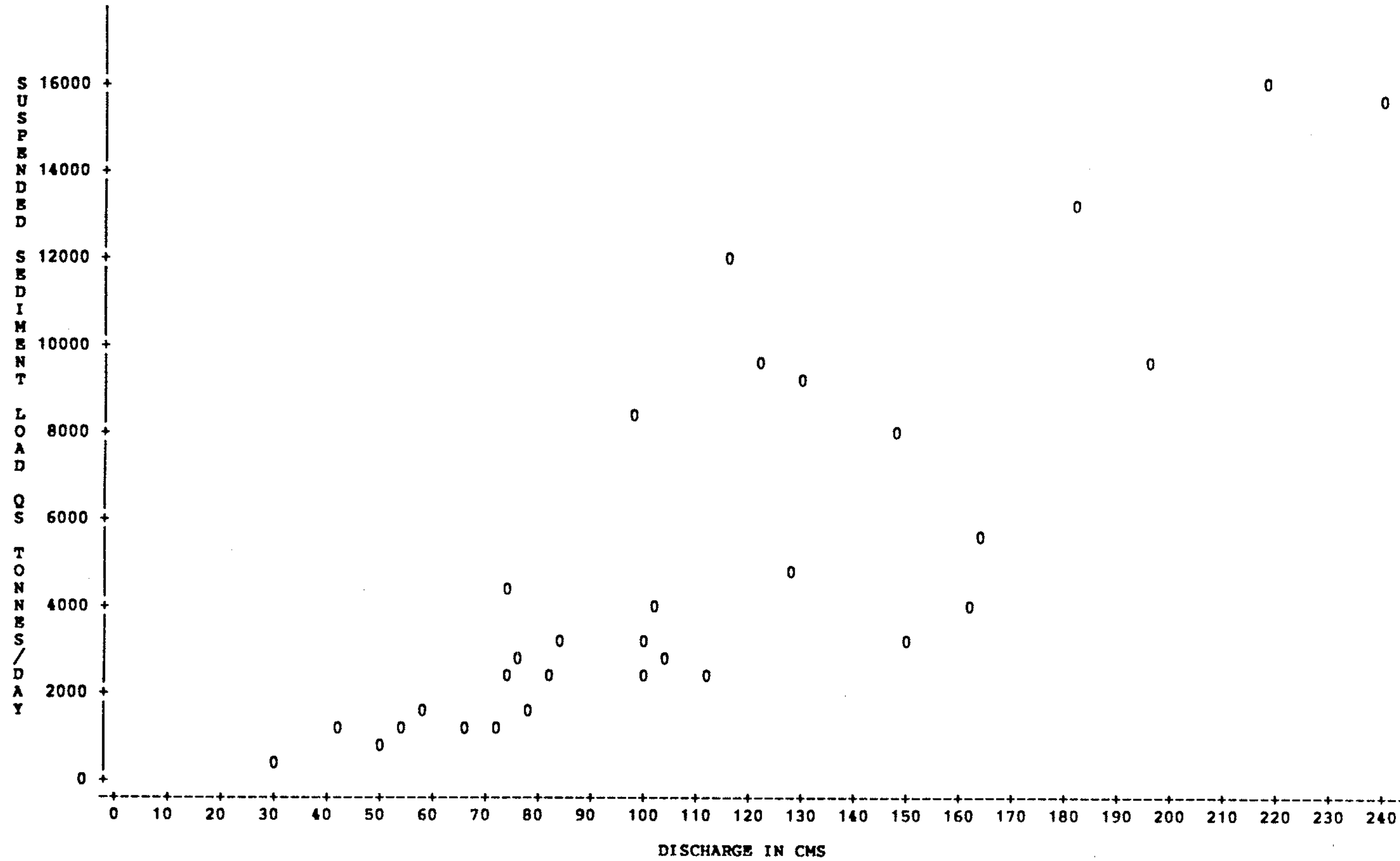

NOTE: 1 OBS HIDDEN

Fig. 80 QS VS. SLOPE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*Q SYMBOL USED IS 0



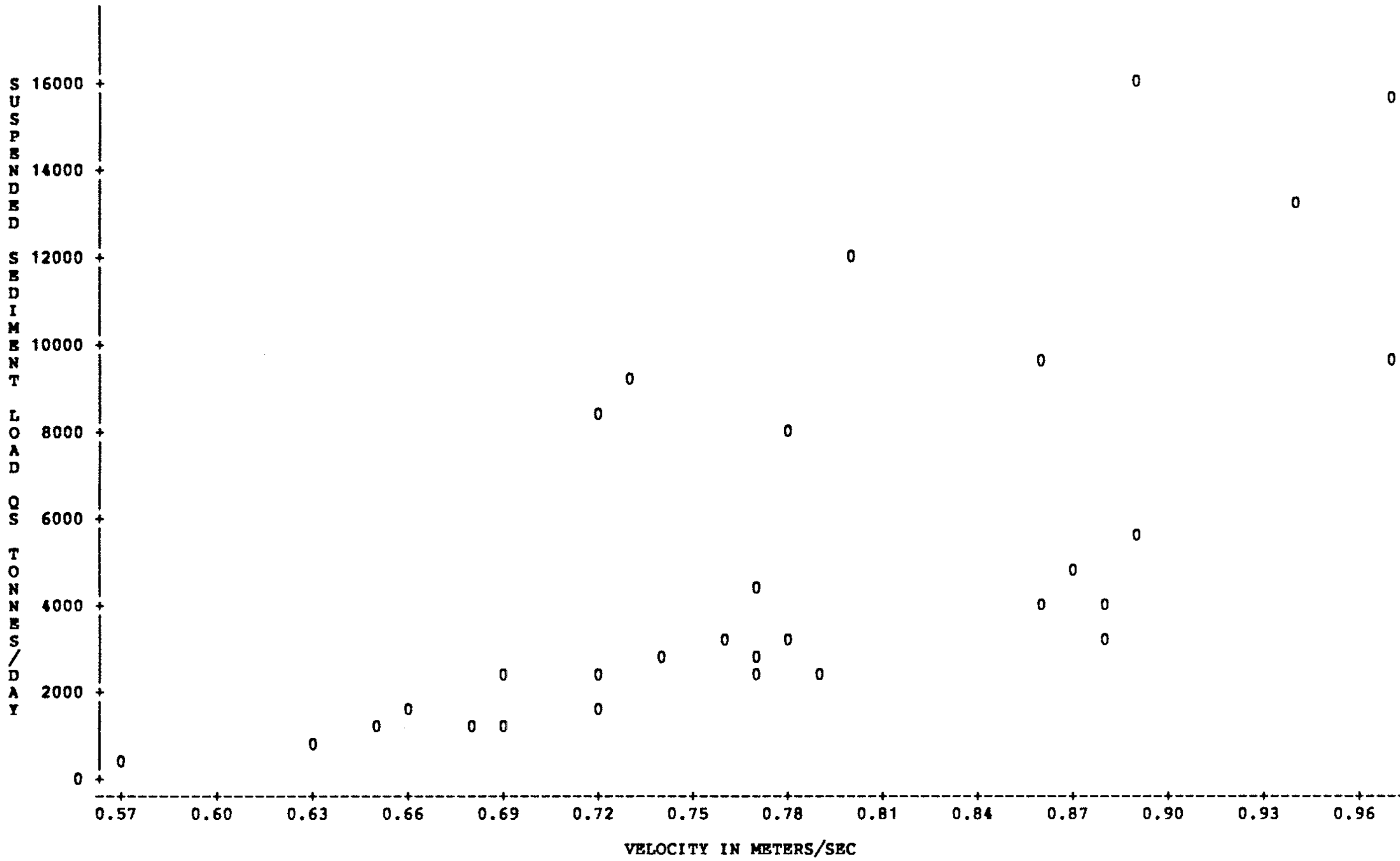

NOTE: 1 OBS HIDDEN

Fig. 81 QS VS. DISCHARGE AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*VELOC SYMBOL USED IS 0




NOTE: 2 OBS HIDDEN

Fig. 82 QS VS. VELOCITY AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*DEPTH SYMBOL USED IS 0

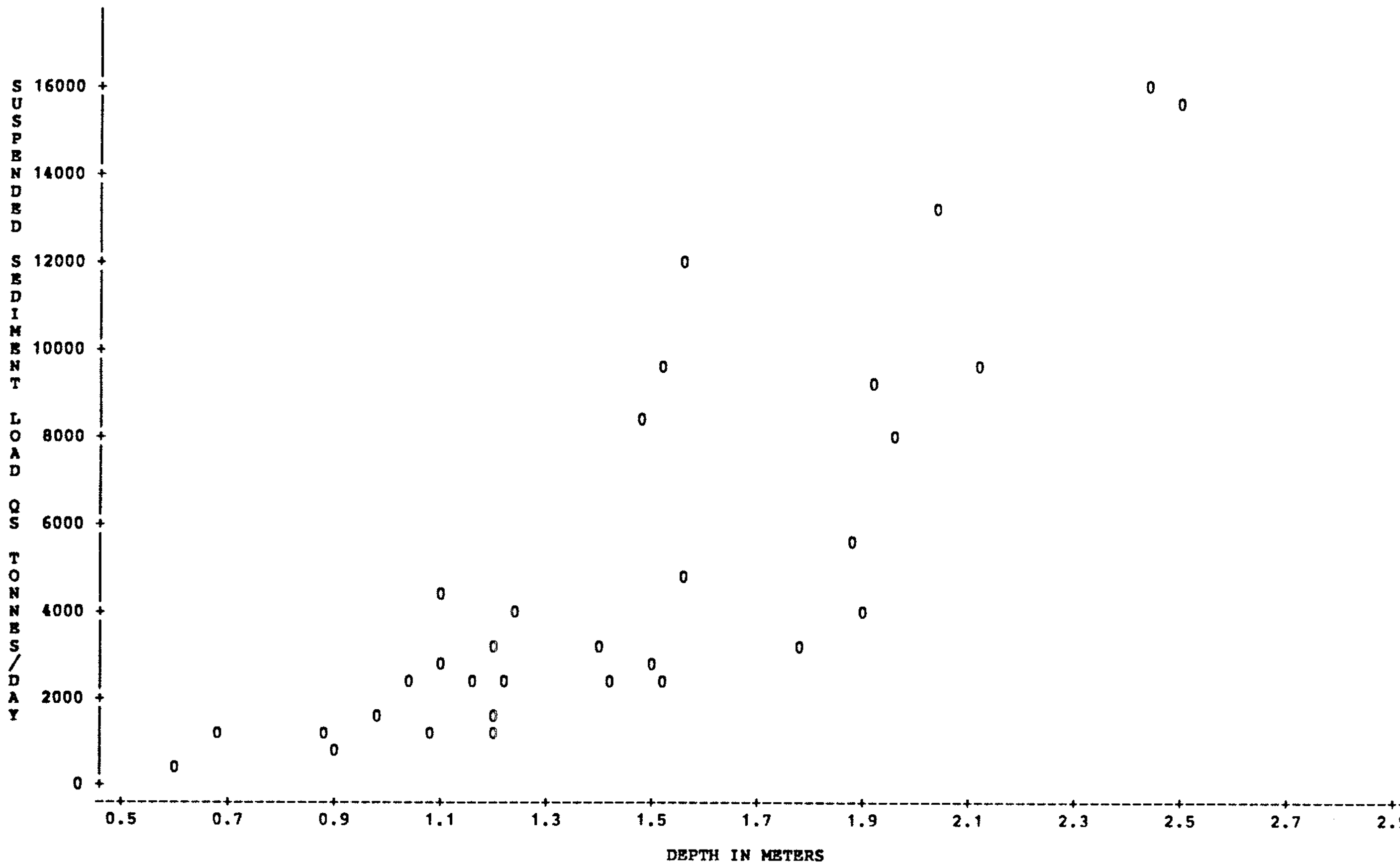



Fig. 83 QS VS. DEPTH AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*VS SYMBOL USED IS 0

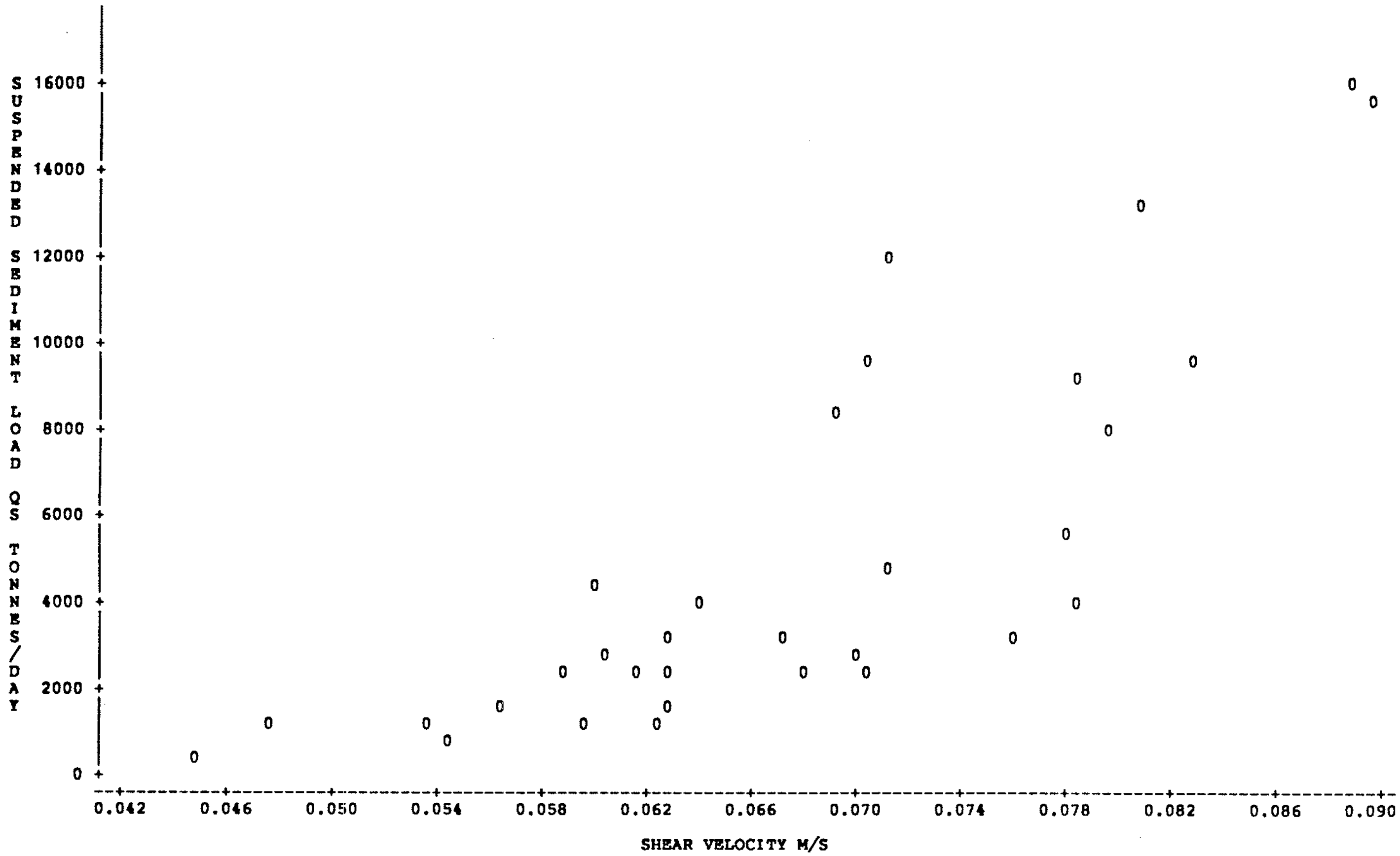



Fig. 84 QS VS. SHEAR VELOCITY AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*SHEAR SYMBOL USED IS 0

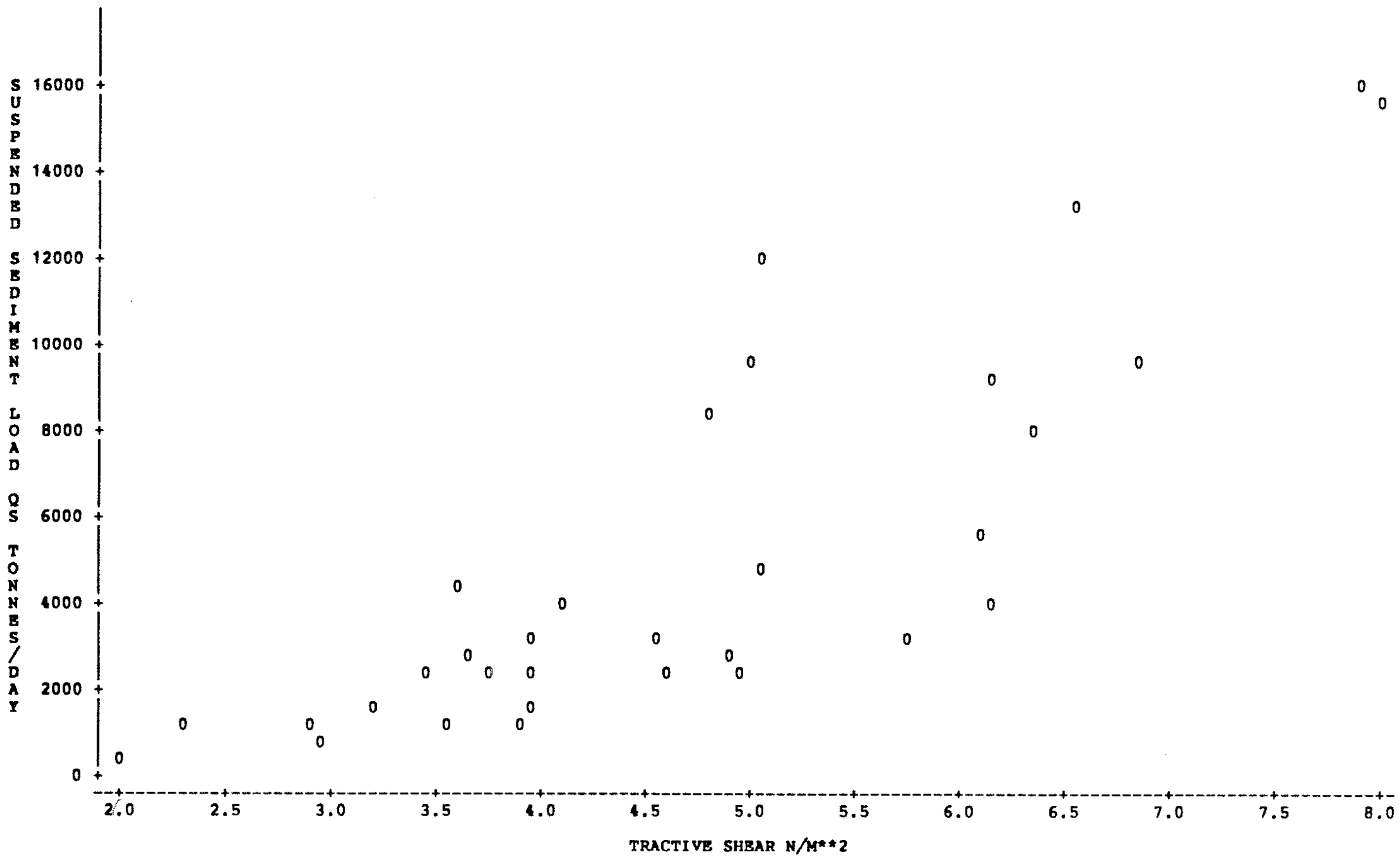



Fig. 85 QS VS. TRACTIVE SHEAR AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*POWER     SYMBOL USED IS 0

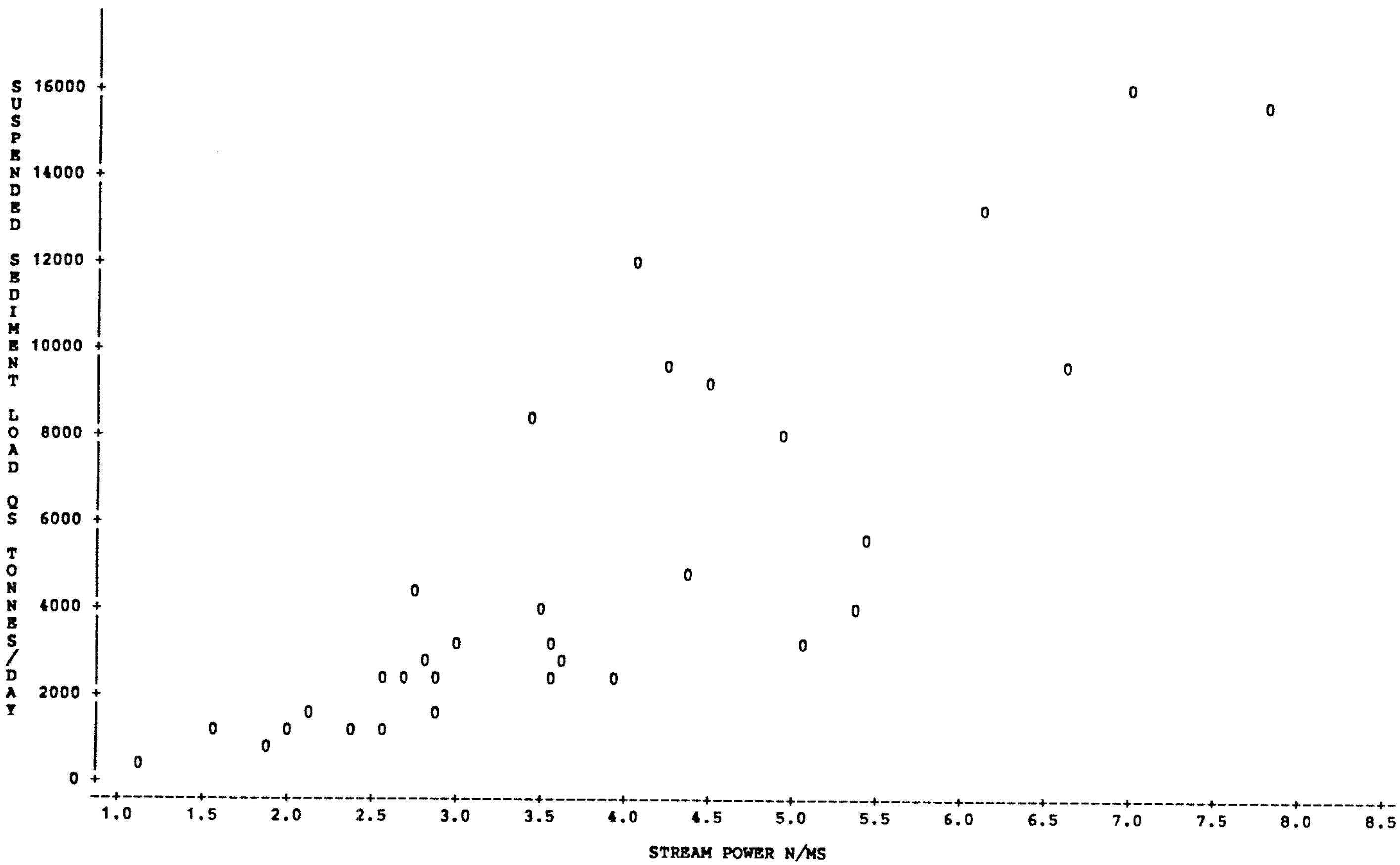



Fig. 86 QS VS. STREAM POWER AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE BEFORE 1969

PLOT OF QS*CHEZY SYMBOL USED IS 0

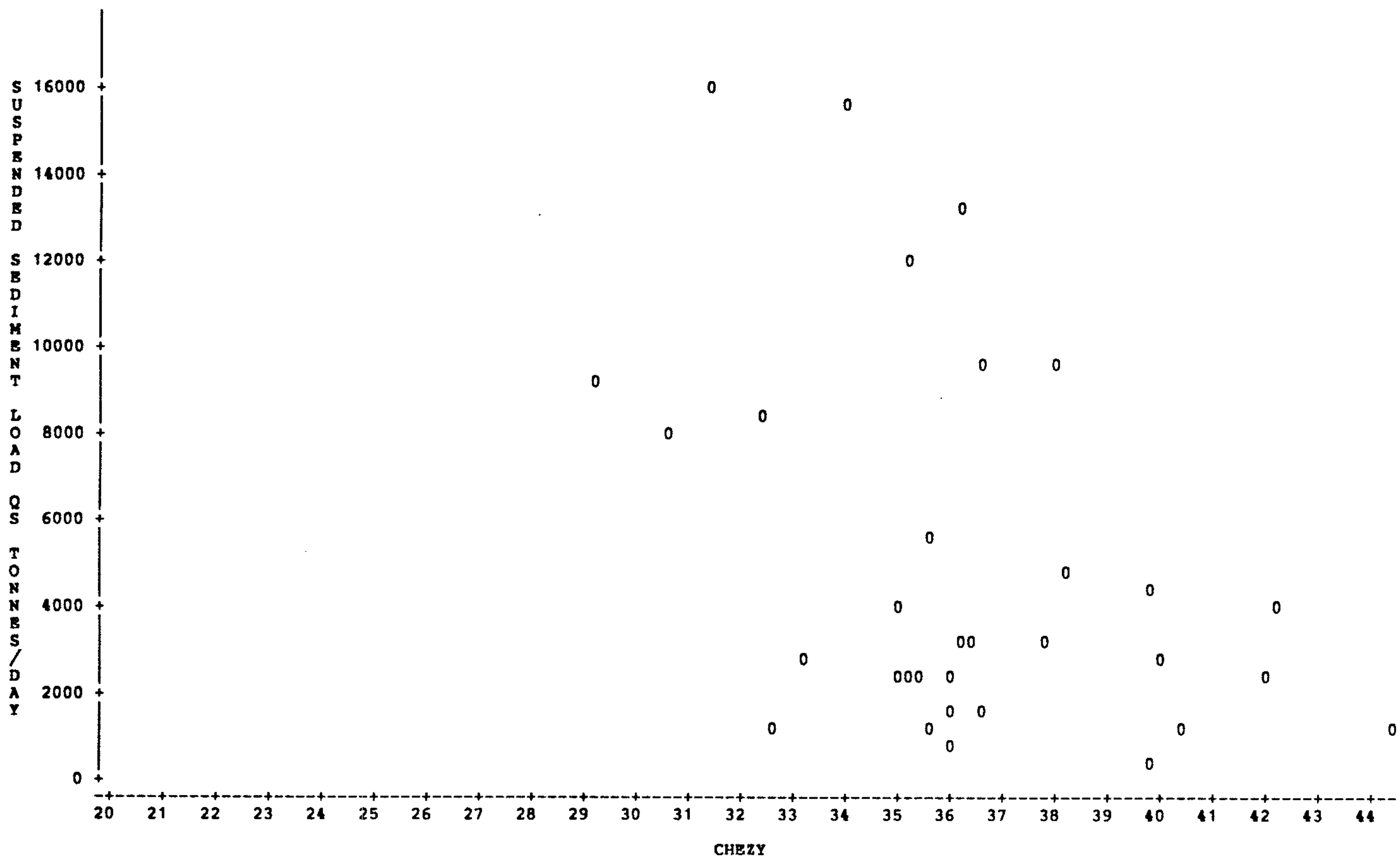



Fig. 87 QS VS. CHEZY AT PORTAGE BEFORE 1969

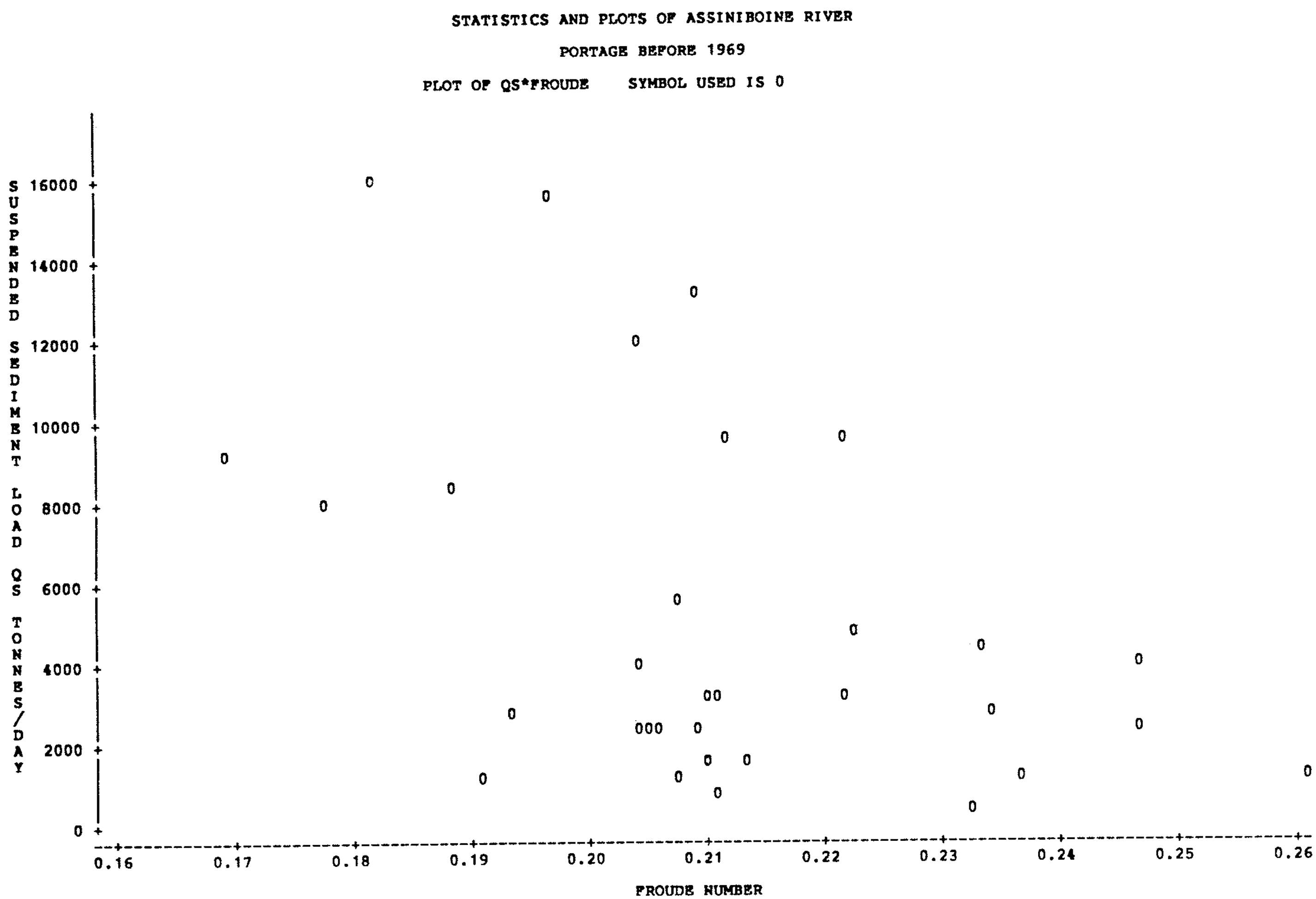



Fig. 88 QS VS. FROUDE NUMBER AT PORTAGE BEFORE 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF SLOPE*Q SYMBOL USED IS 0

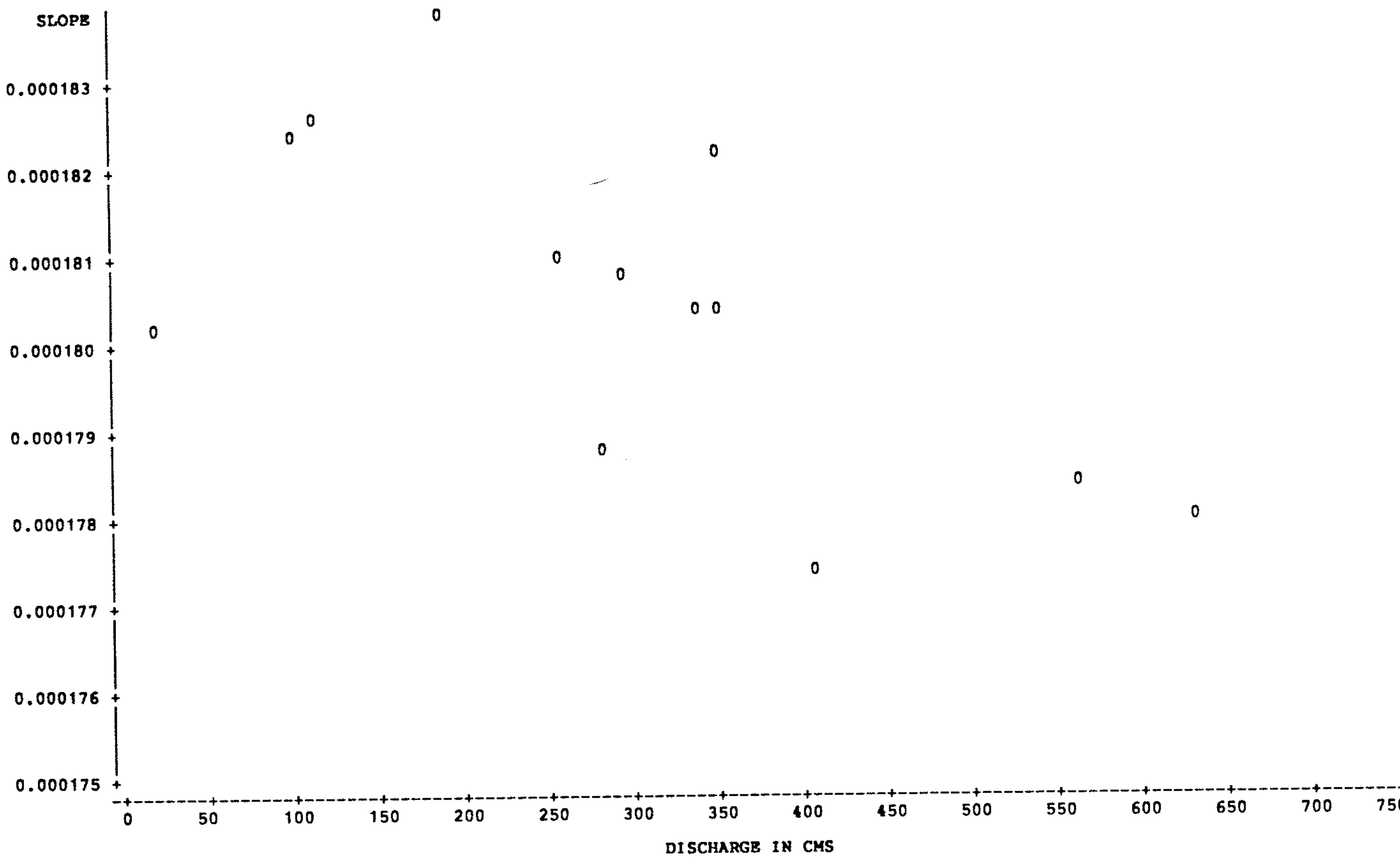
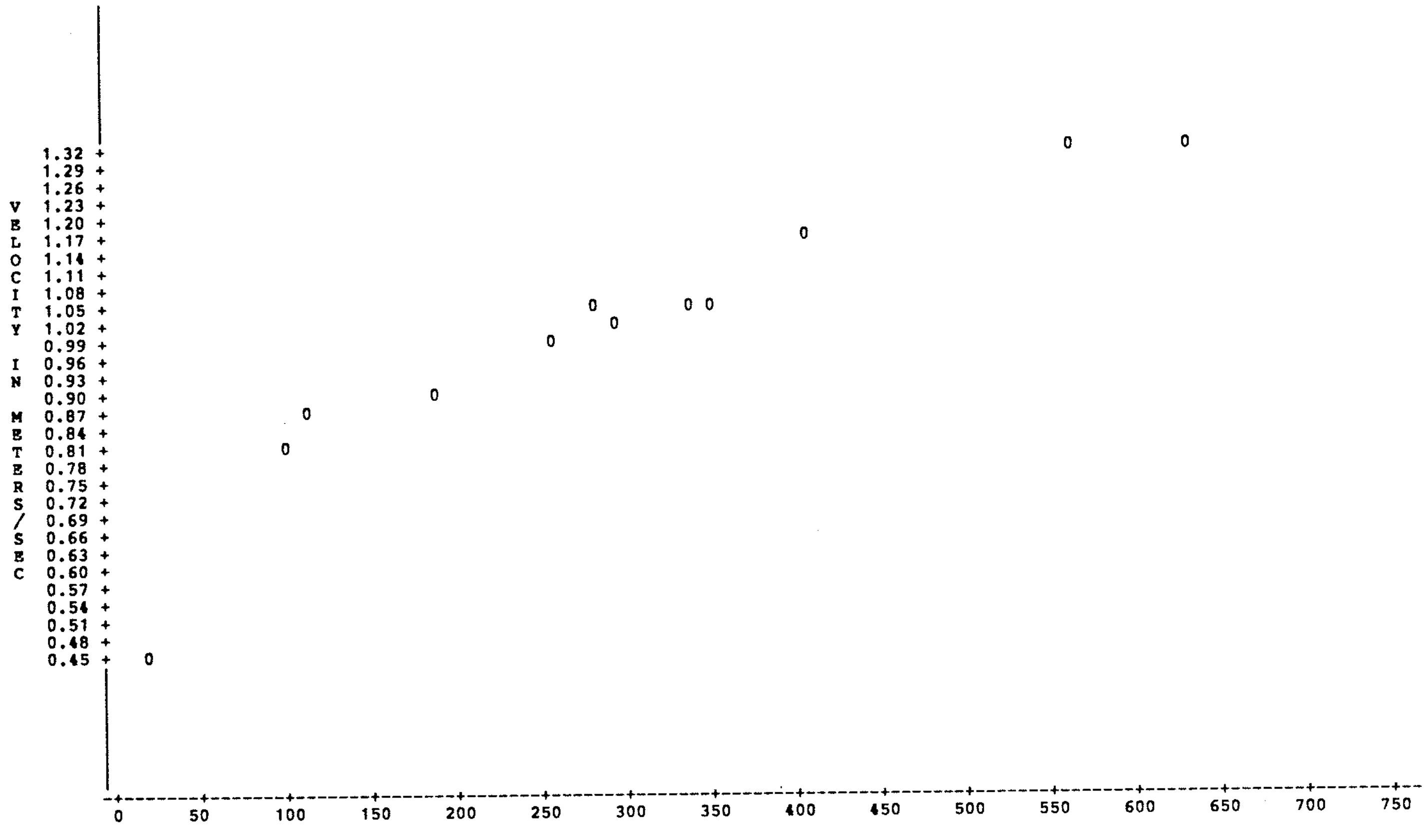



Fig. 89 SLOPE VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF VELOC*Q SYMBOL USED IS 0




NOTE: 1 OBS HIDDEN

Fig. 90 VELOCITY VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF WIDTH*Q SYMBOL USED IS 0

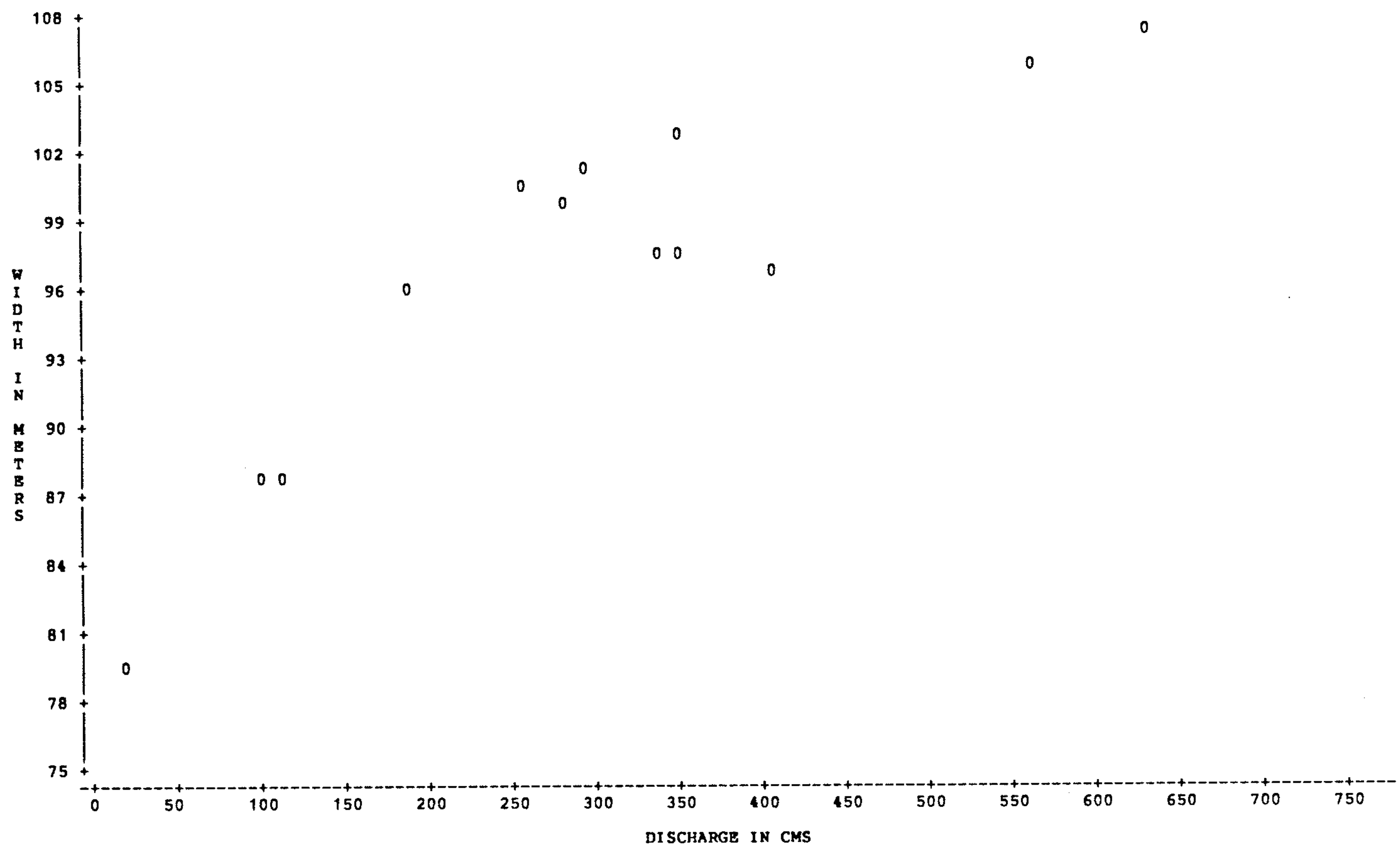
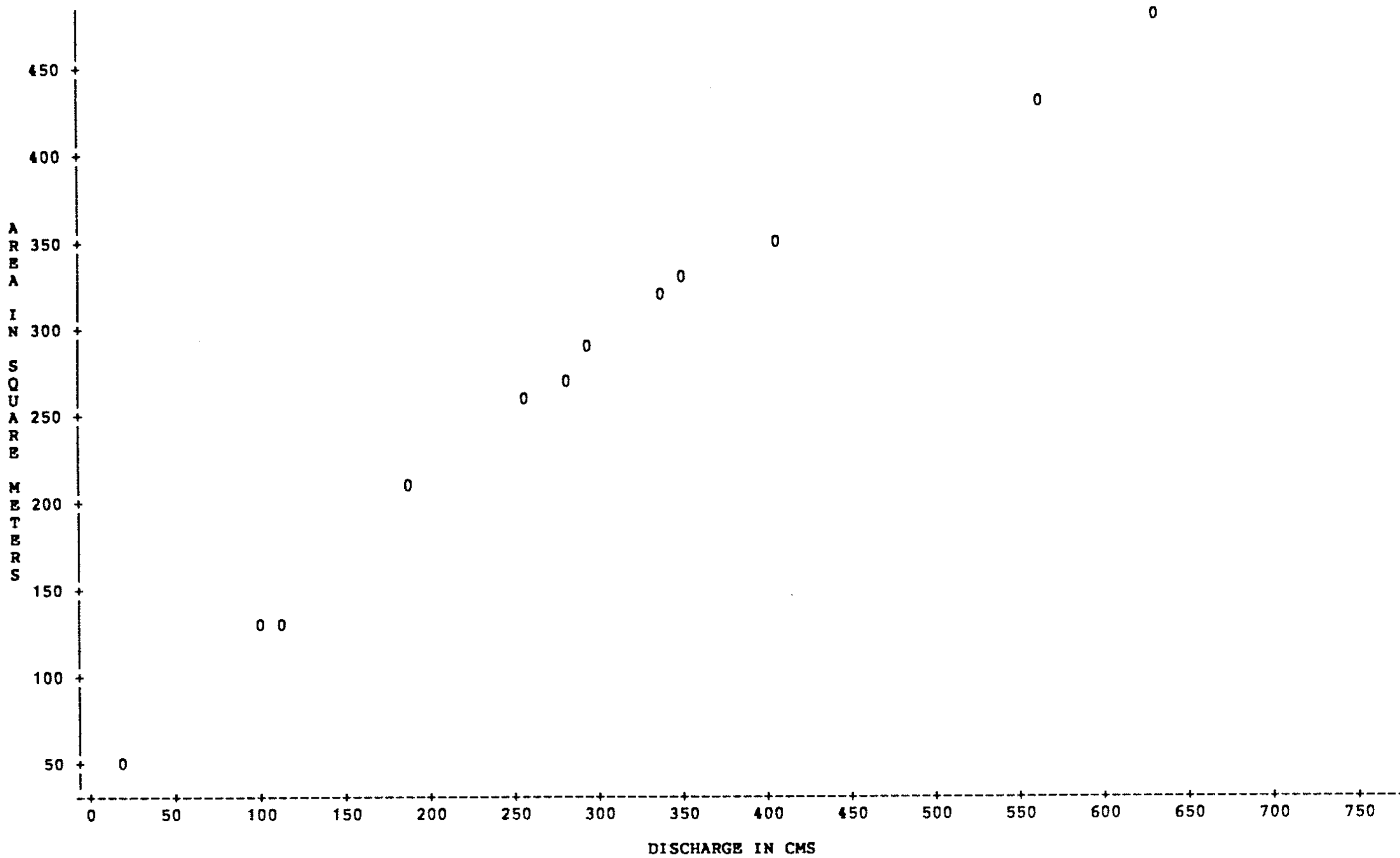



Fig. 91 WIDTH VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF AREA*Q SYMBOL USED IS 0




NOTE: 1 OBS HIDDEN

Fig. 92 AREA VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF DEPTH*Q SYMBOL USED IS 0

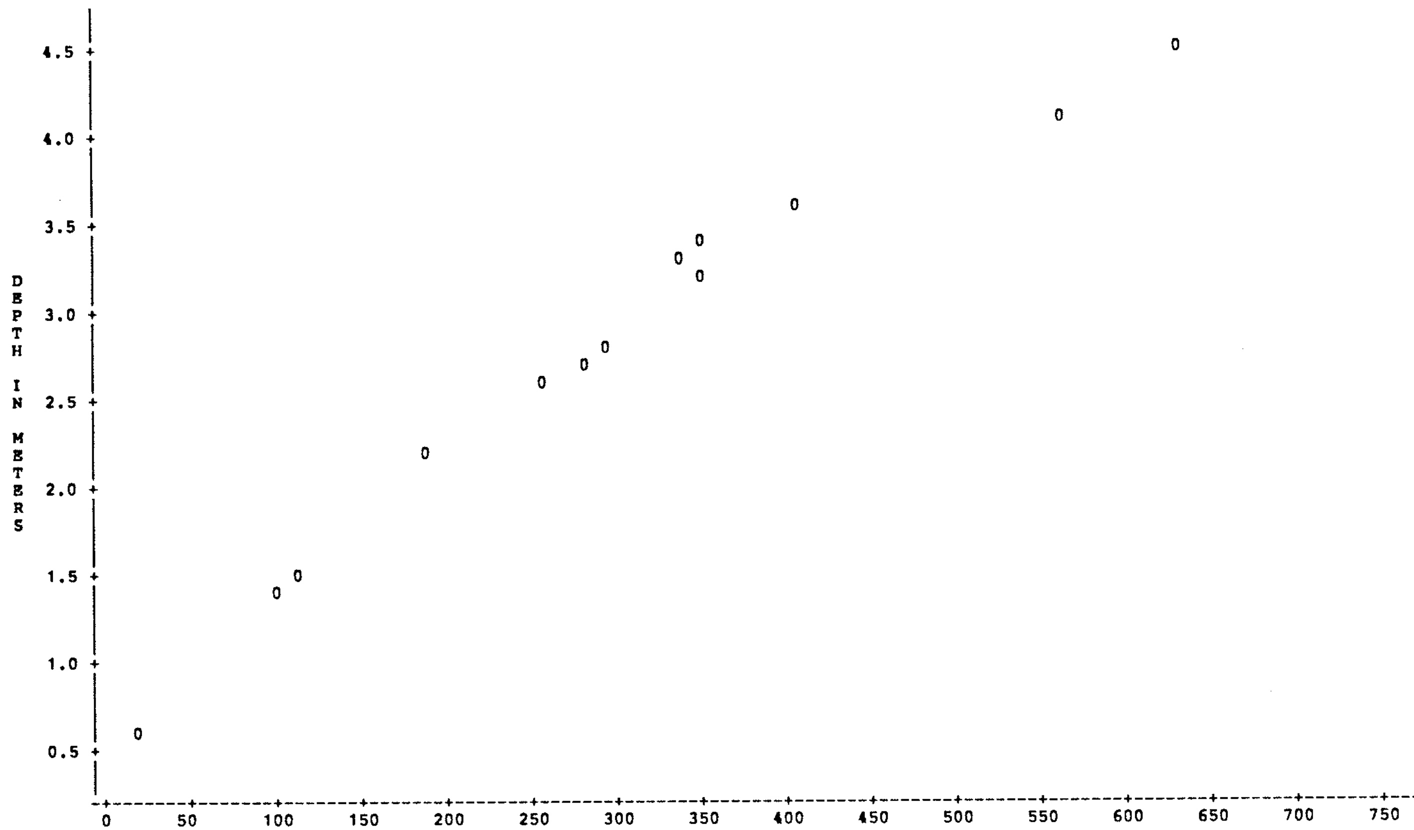



Fig. 93 DEPTH VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF SHEAR*Q SYMBOL USED IS 0

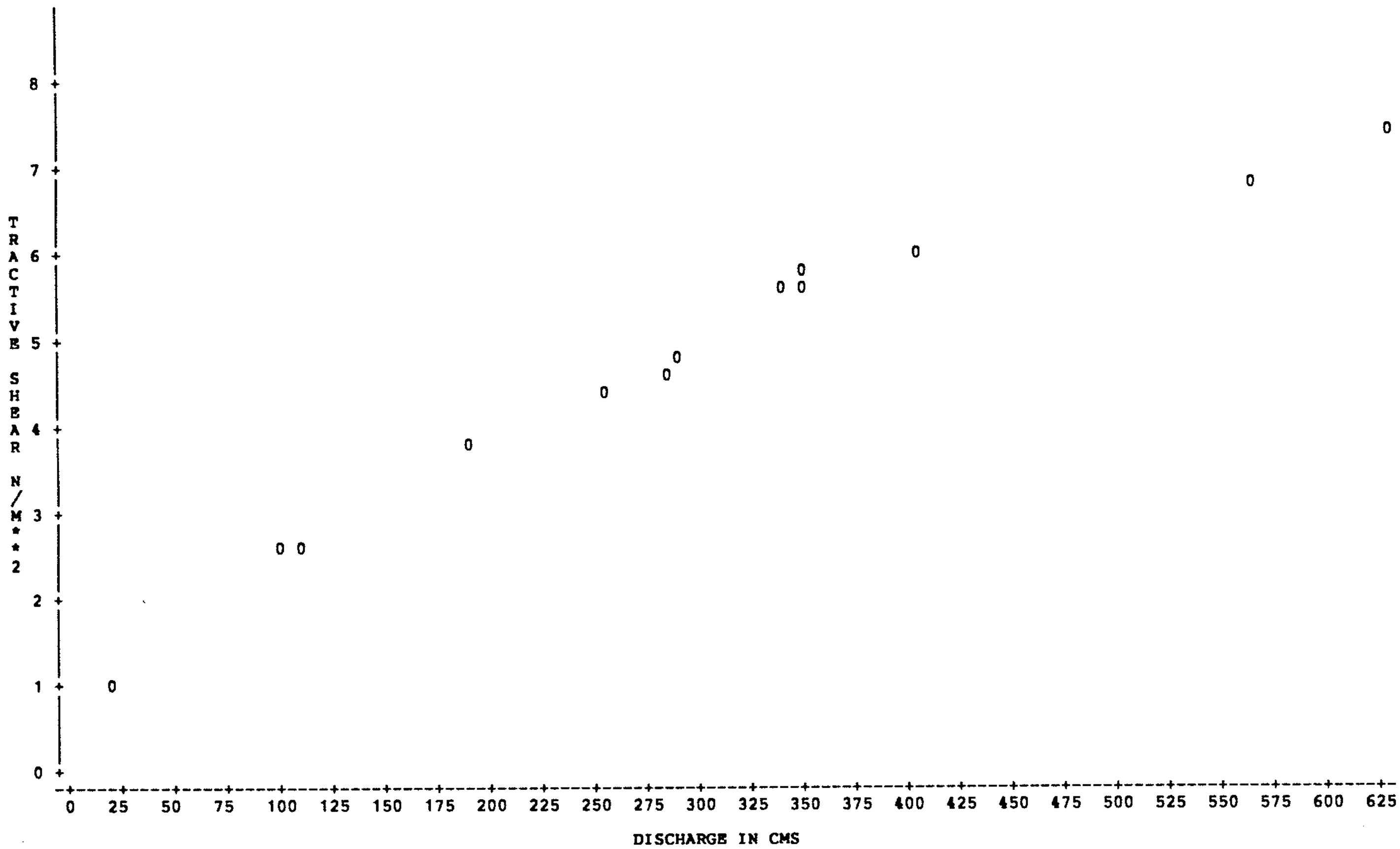



Fig. 94 TRACTIVE SHEAR VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF VS*Q SYMBOL USED IS 0

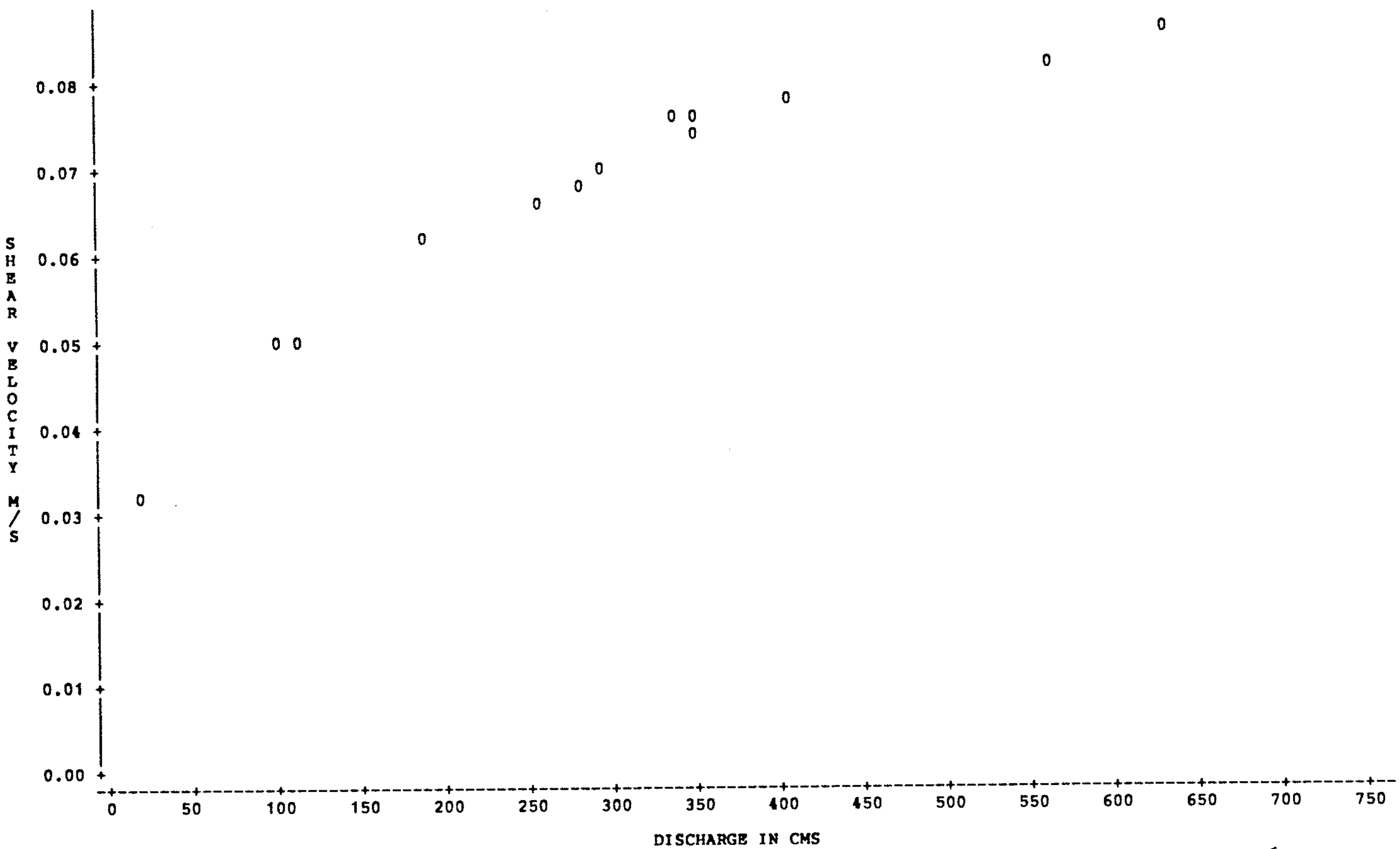



Fig. 95 SHEAR VELOCITY VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF POWER*Q SYMBOL USED IS 0

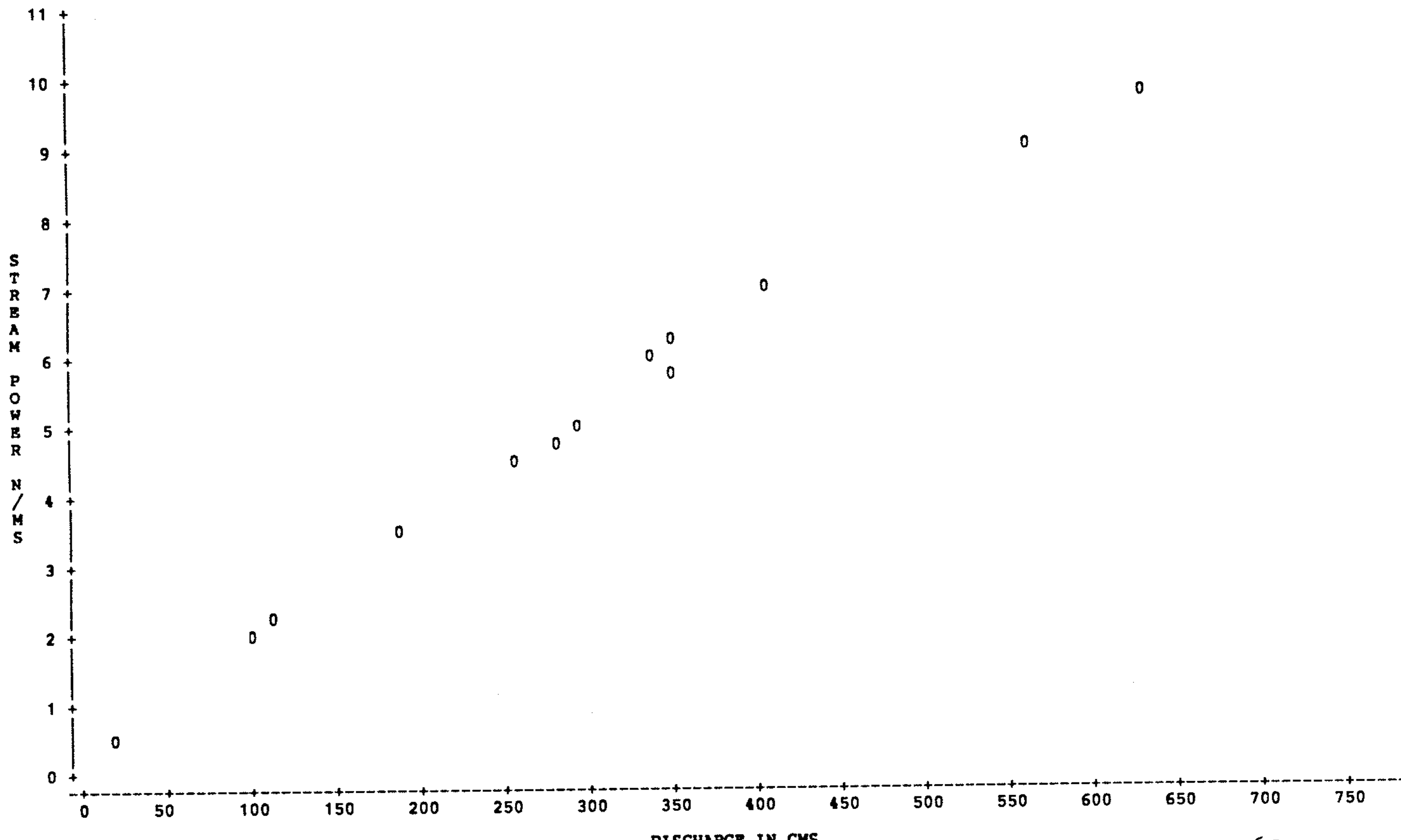



Fig. 96 STREAM POWER VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF D50*Q SYMBOL USED IS 0

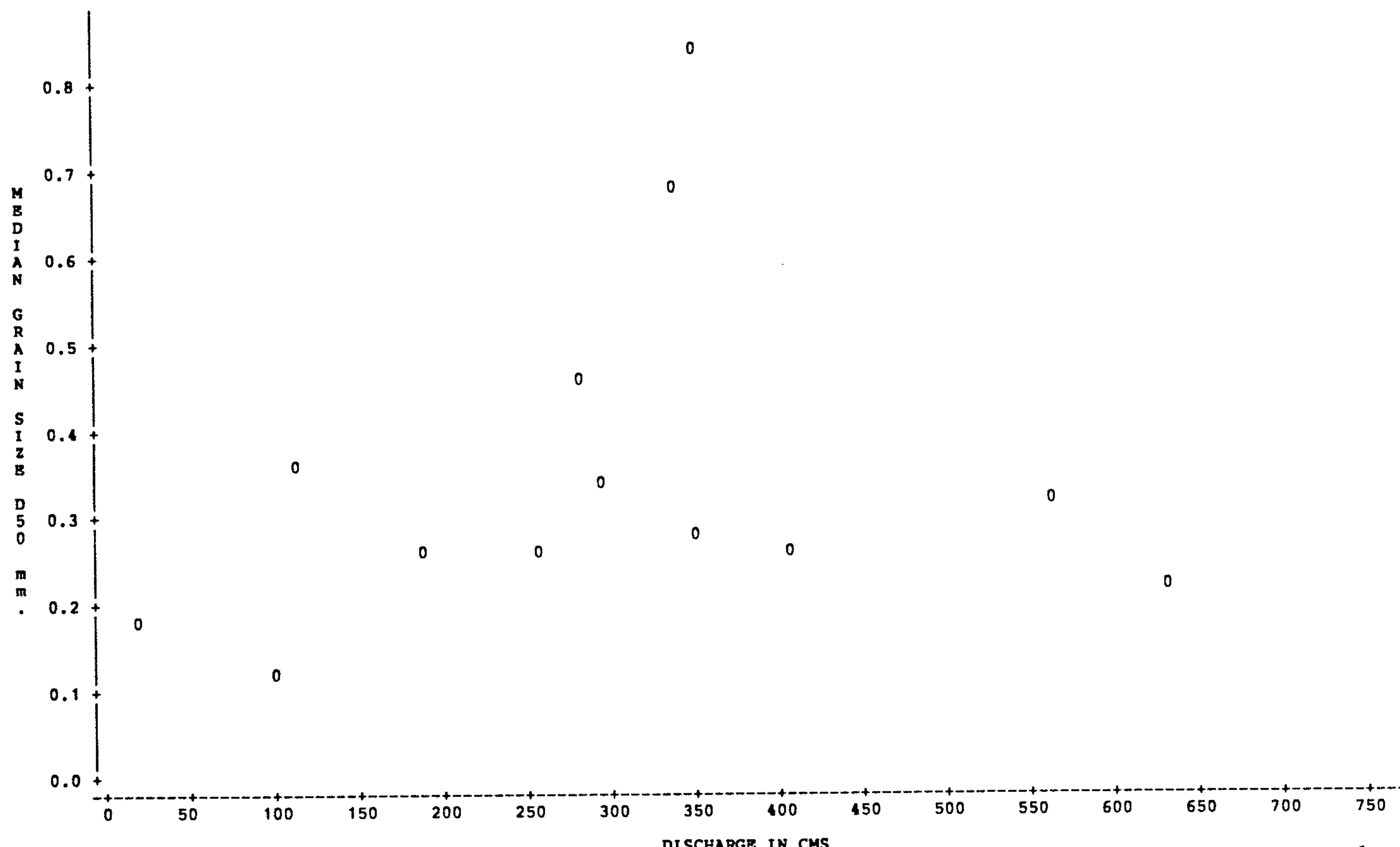
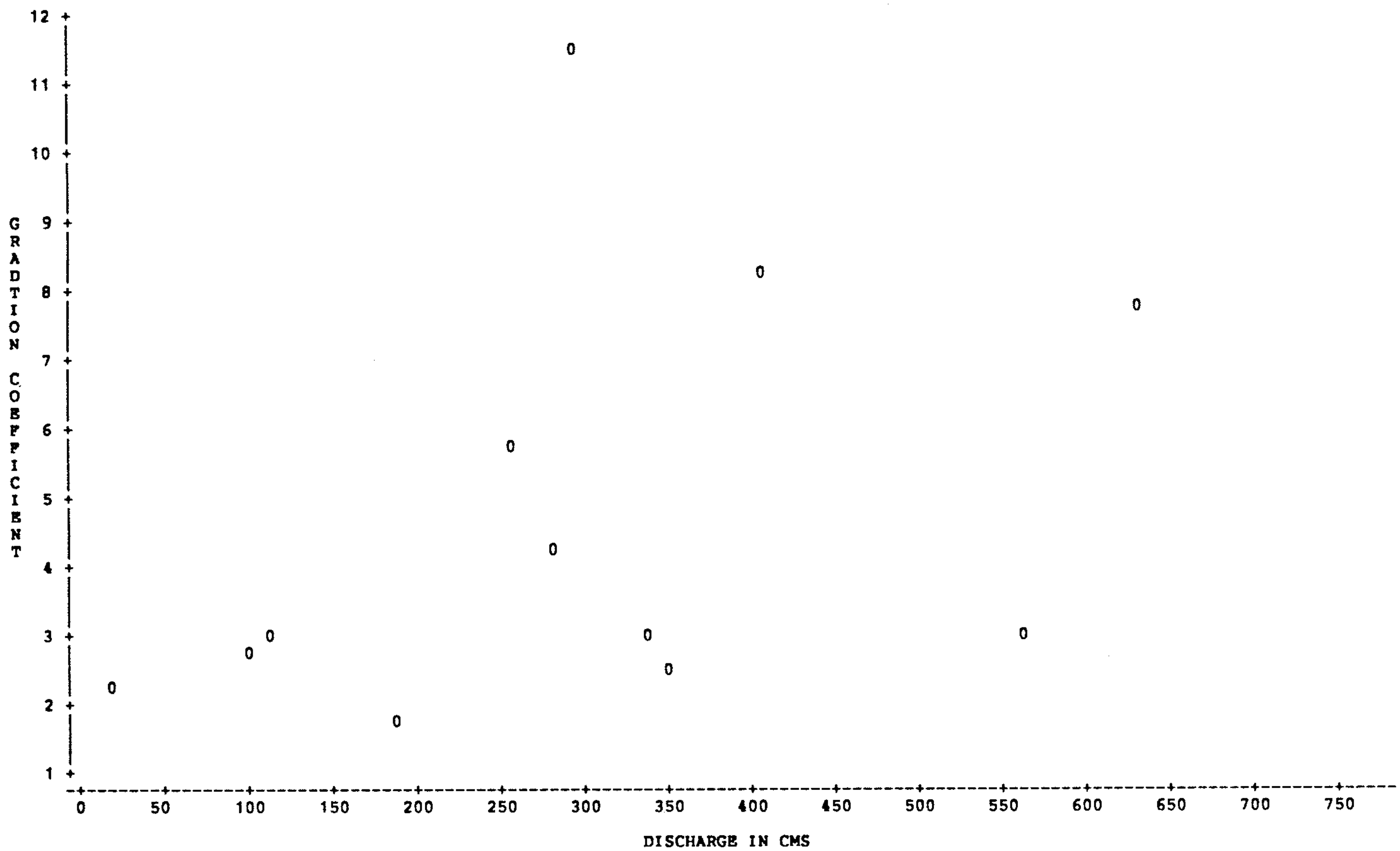



Fig. 97 MEDIAN GRAIN SIZE VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF PHI*Q SYMBOL USED IS 0




NOTE: 1 OBS HIDDEN

Fig. 98 GRADATION COEFFICIENT VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF CHEZY*Q SYMBOL USED IS 0

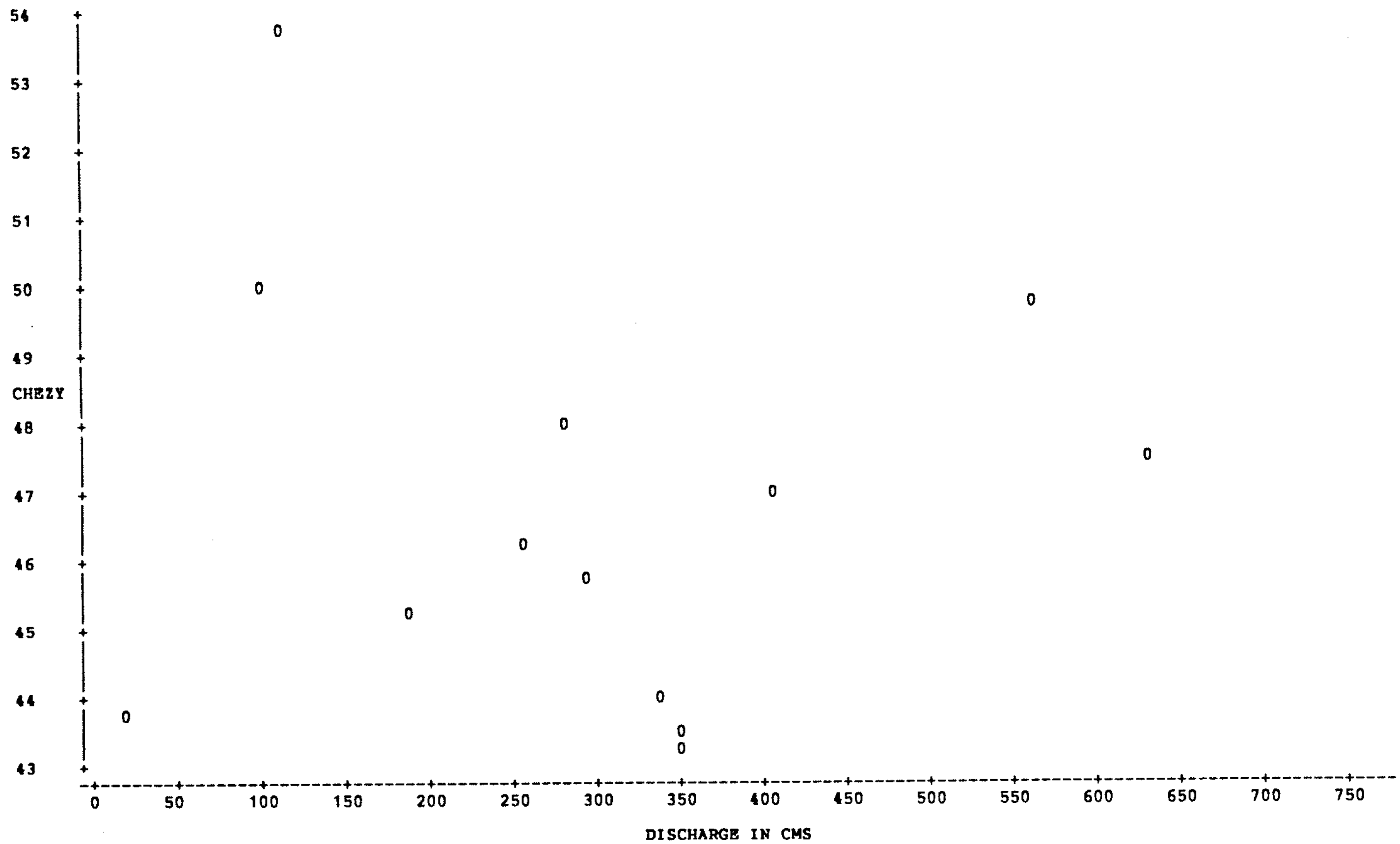



Fig. 99 CHEZY VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF FROUDE*Q SYMBOL USED IS 0

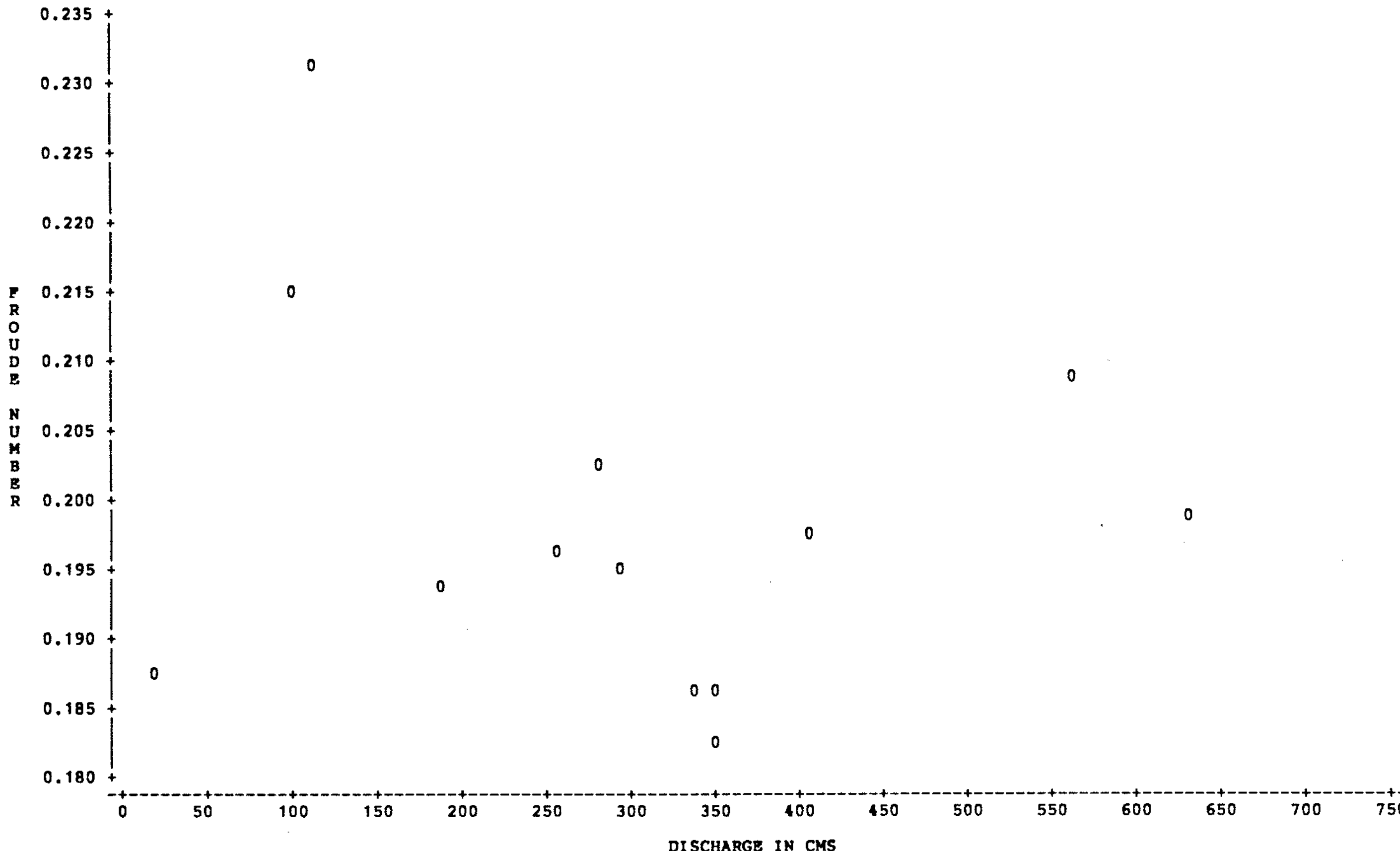



Fig. 100 FROUDE NUMBER VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*SLOPE SYMBOL USED IS 0

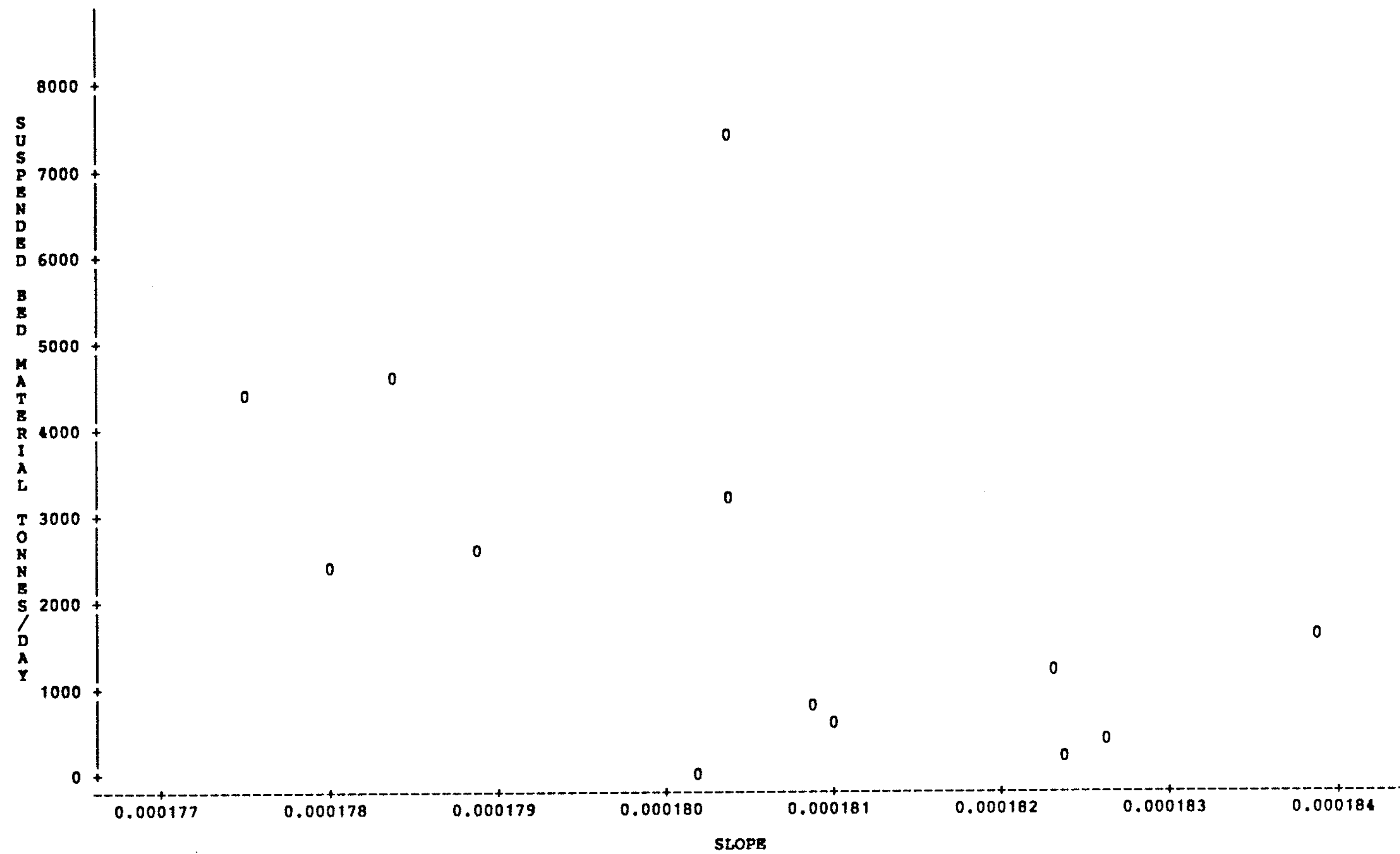



Fig. 101 QSBM VS. SLOPE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*Q SYMBOL USED IS 0

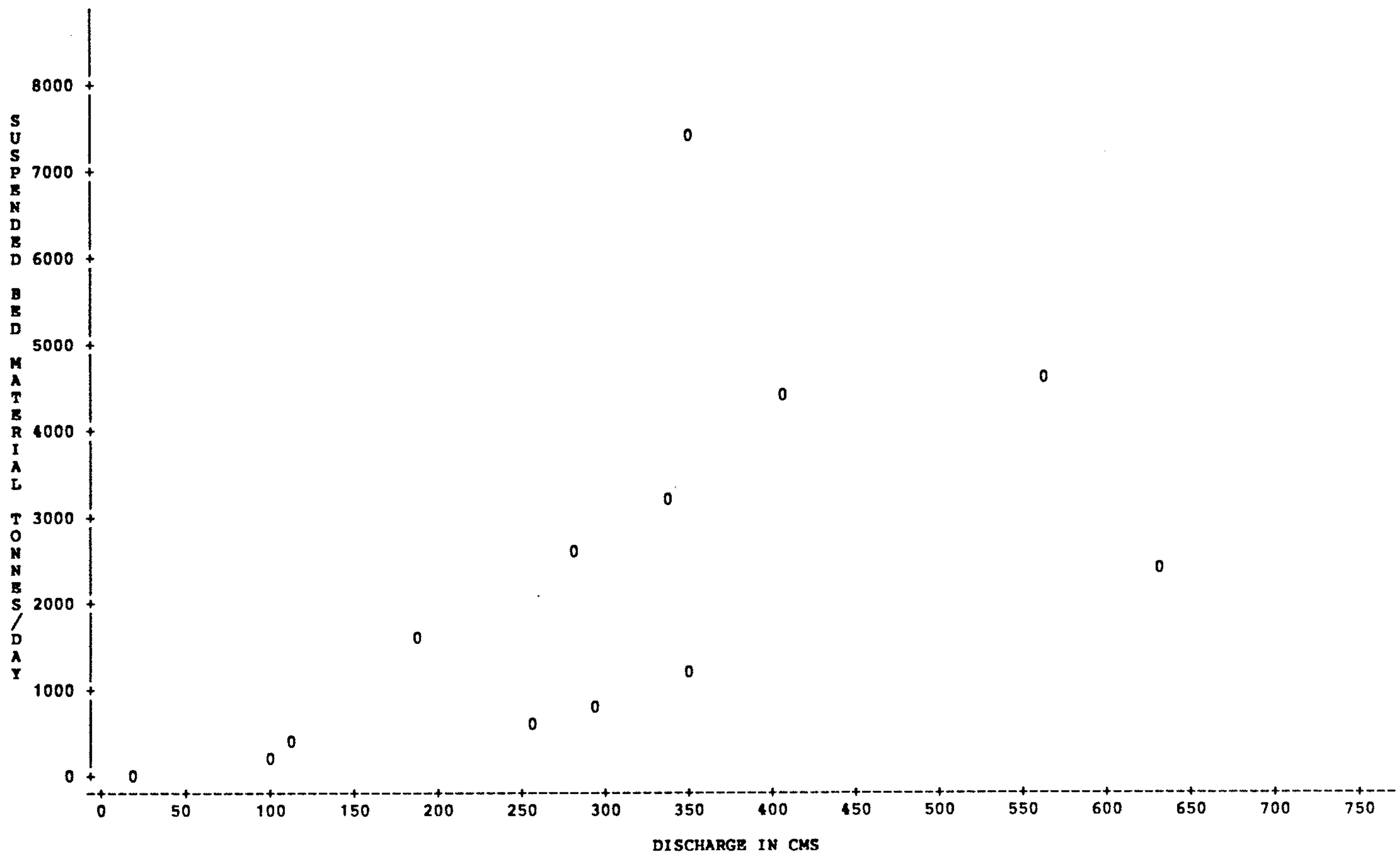



Fig. 102 QSBM VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*VELOC SYMBOL USED IS 0

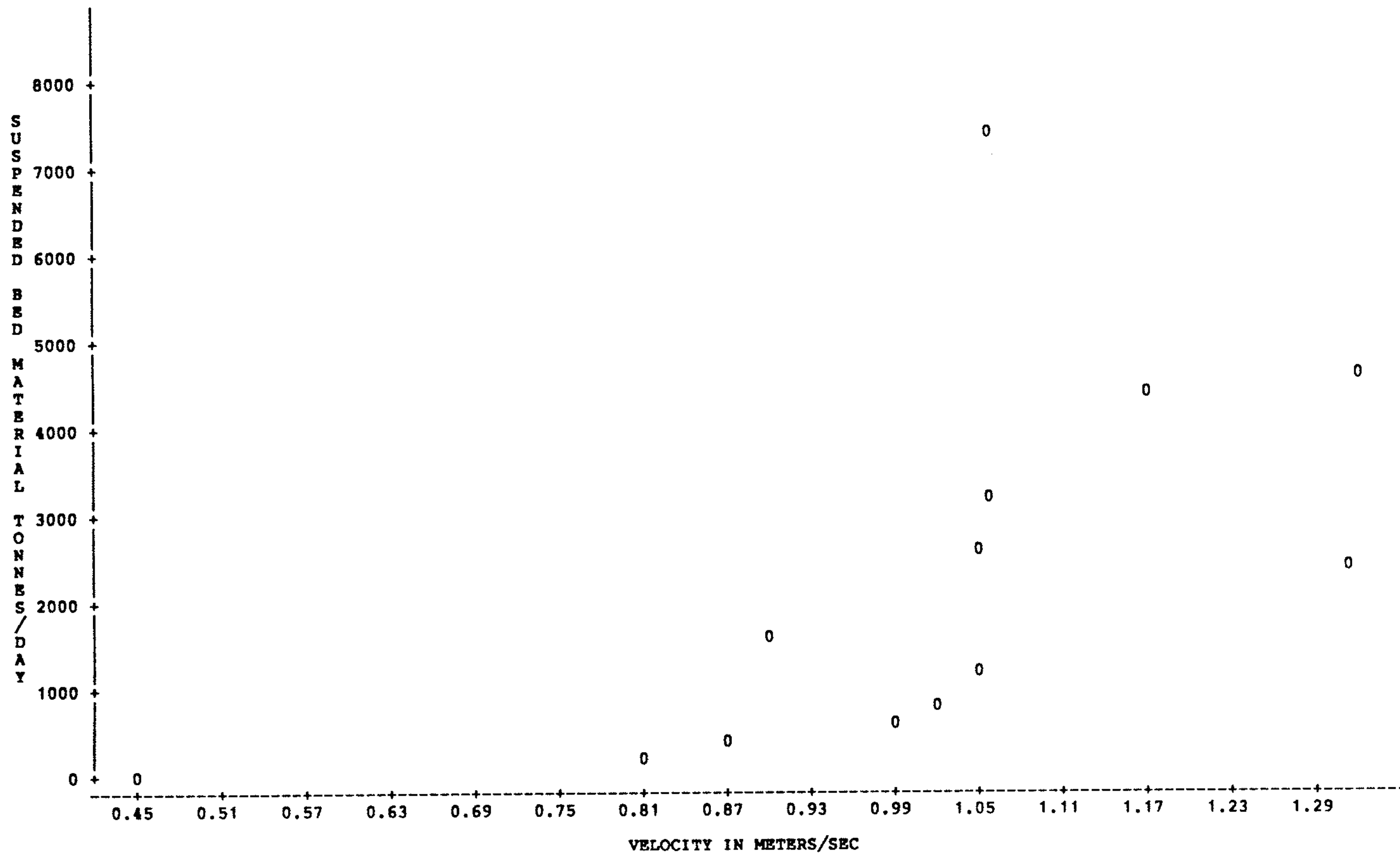



Fig. 103 QSBM VS. VELOCITY AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*DEPTH SYMBOL USED IS 0

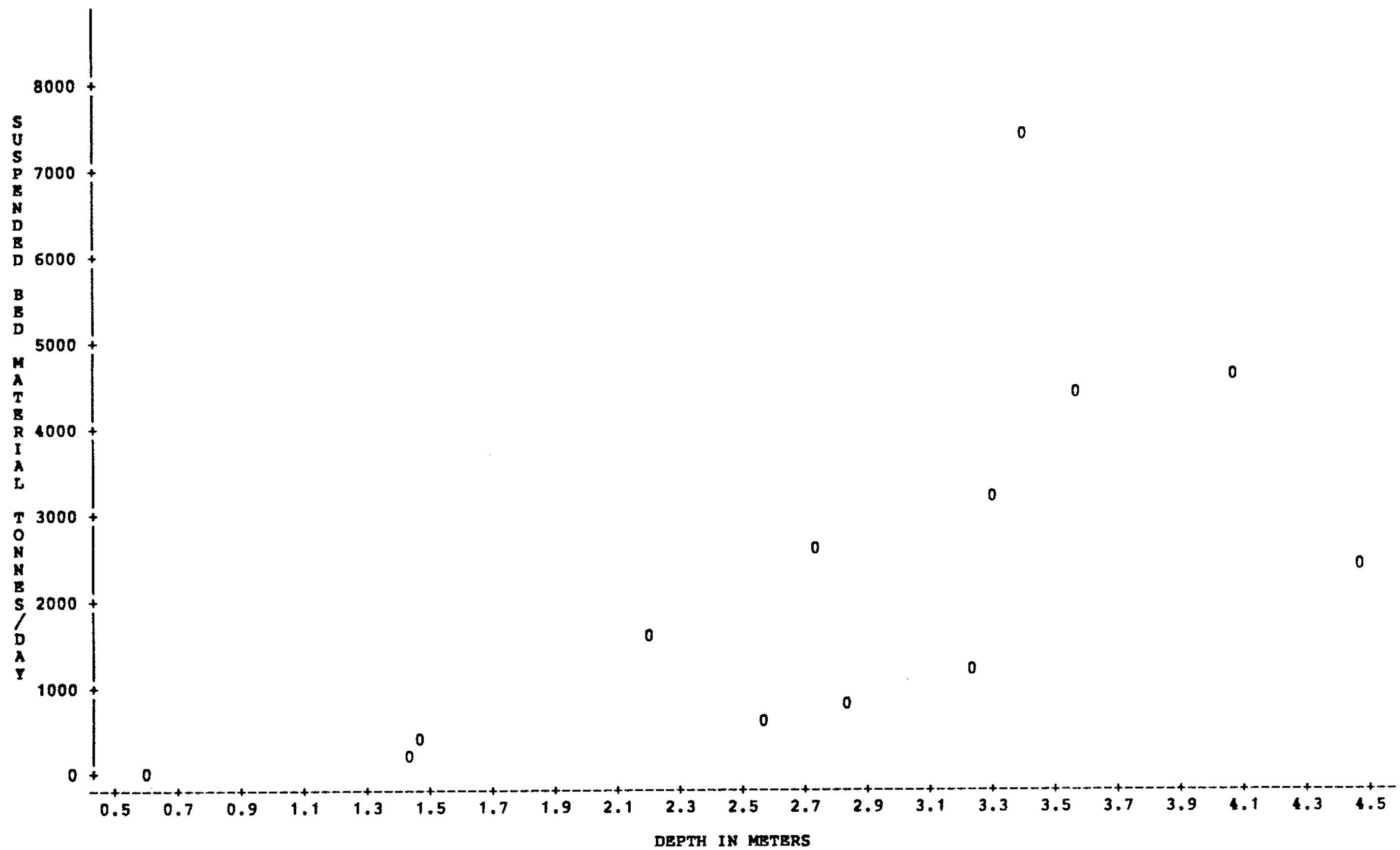



Fig. 104 QSBM VS. DEPTH AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*VS SYMBOL USED IS 0

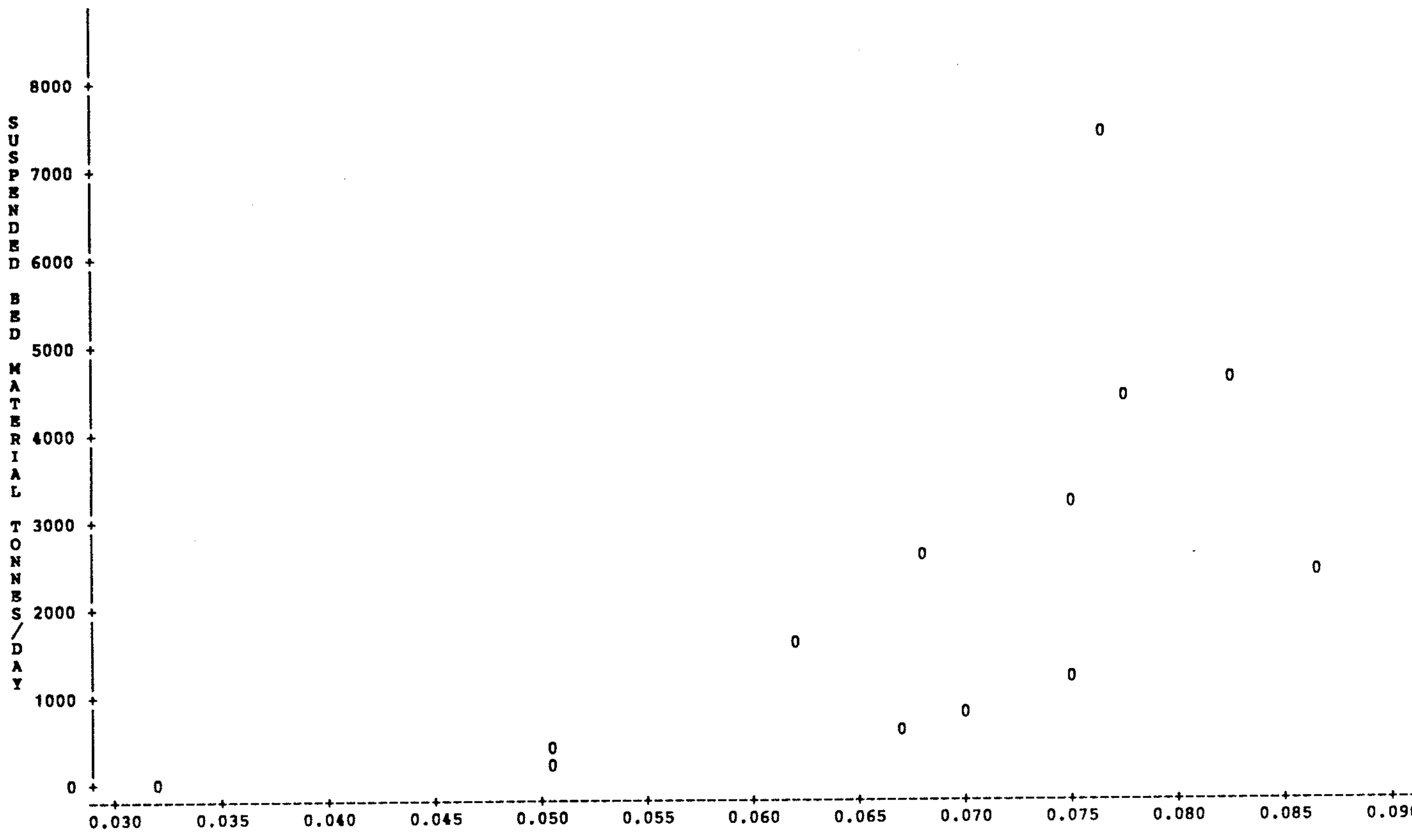



Fig. 105 QSBM VS. SHEAR VELOCITY AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*SHEAR SYMBOL USED IS 0

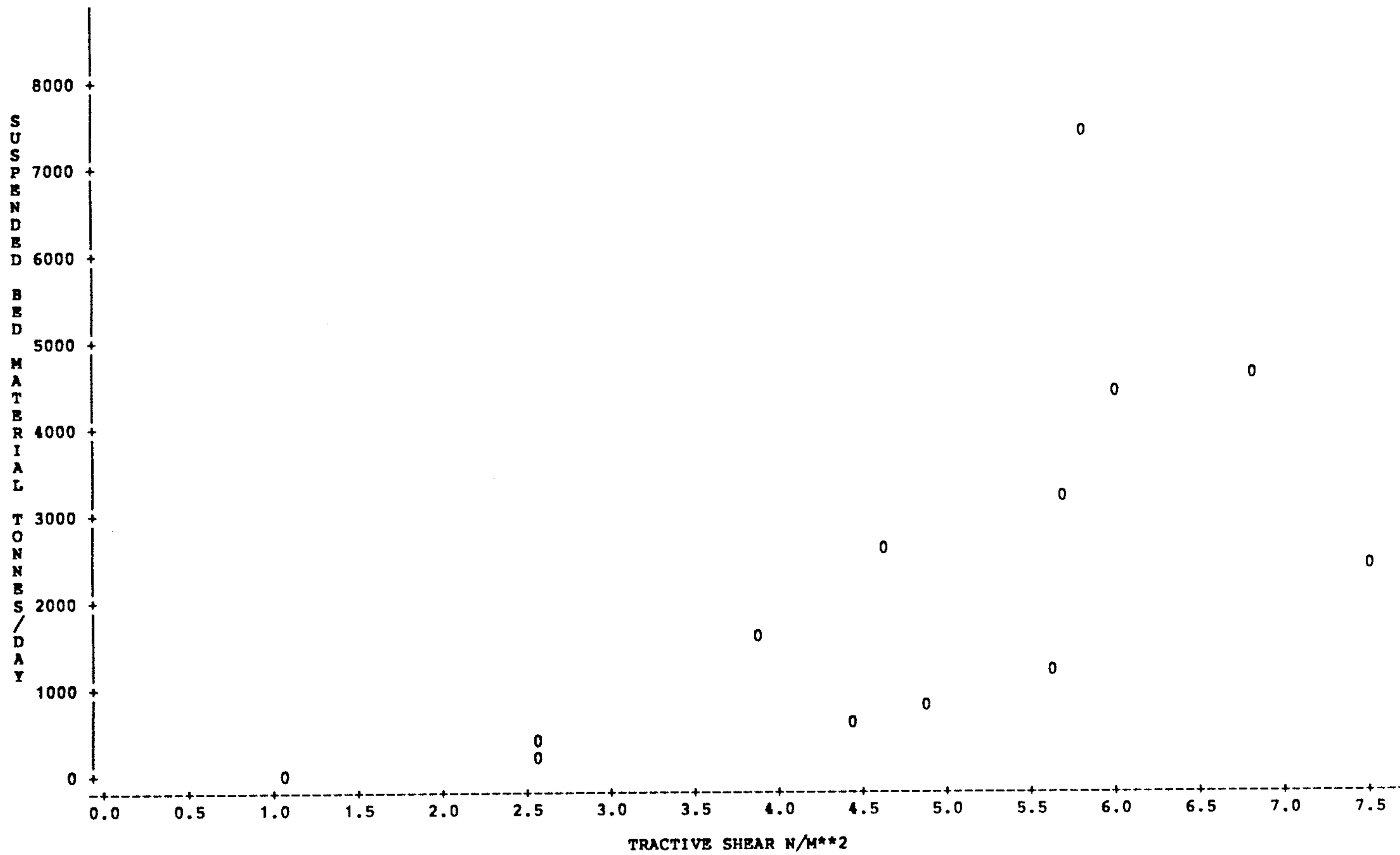



Fig. 106 QSBM VS. TRACTIVE SHEAR AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*POWER SYMBOL USED IS 0

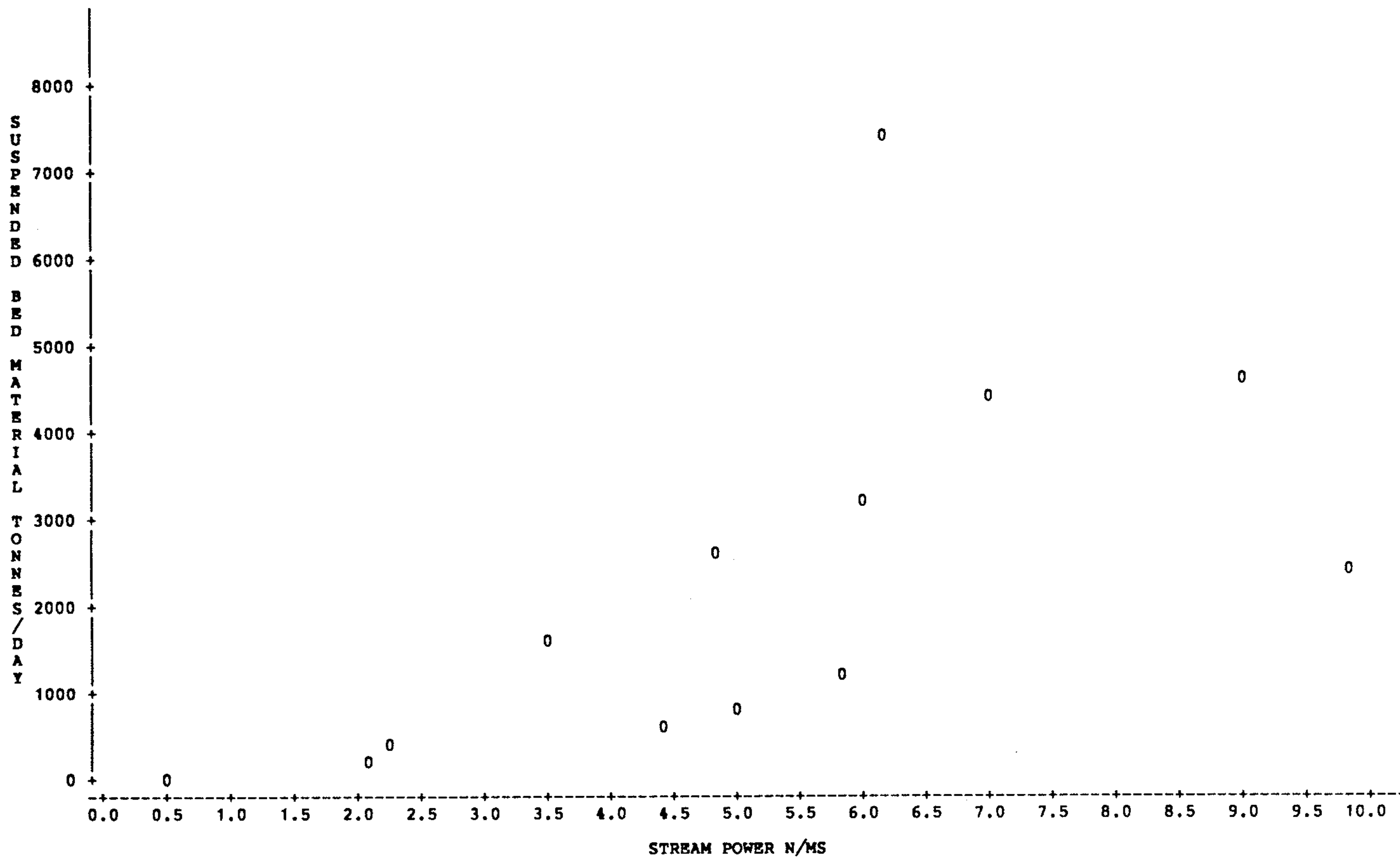



Fig. 107 QSBM VS. STREAM POWER AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*CHEZY SYMBOL USED IS 0

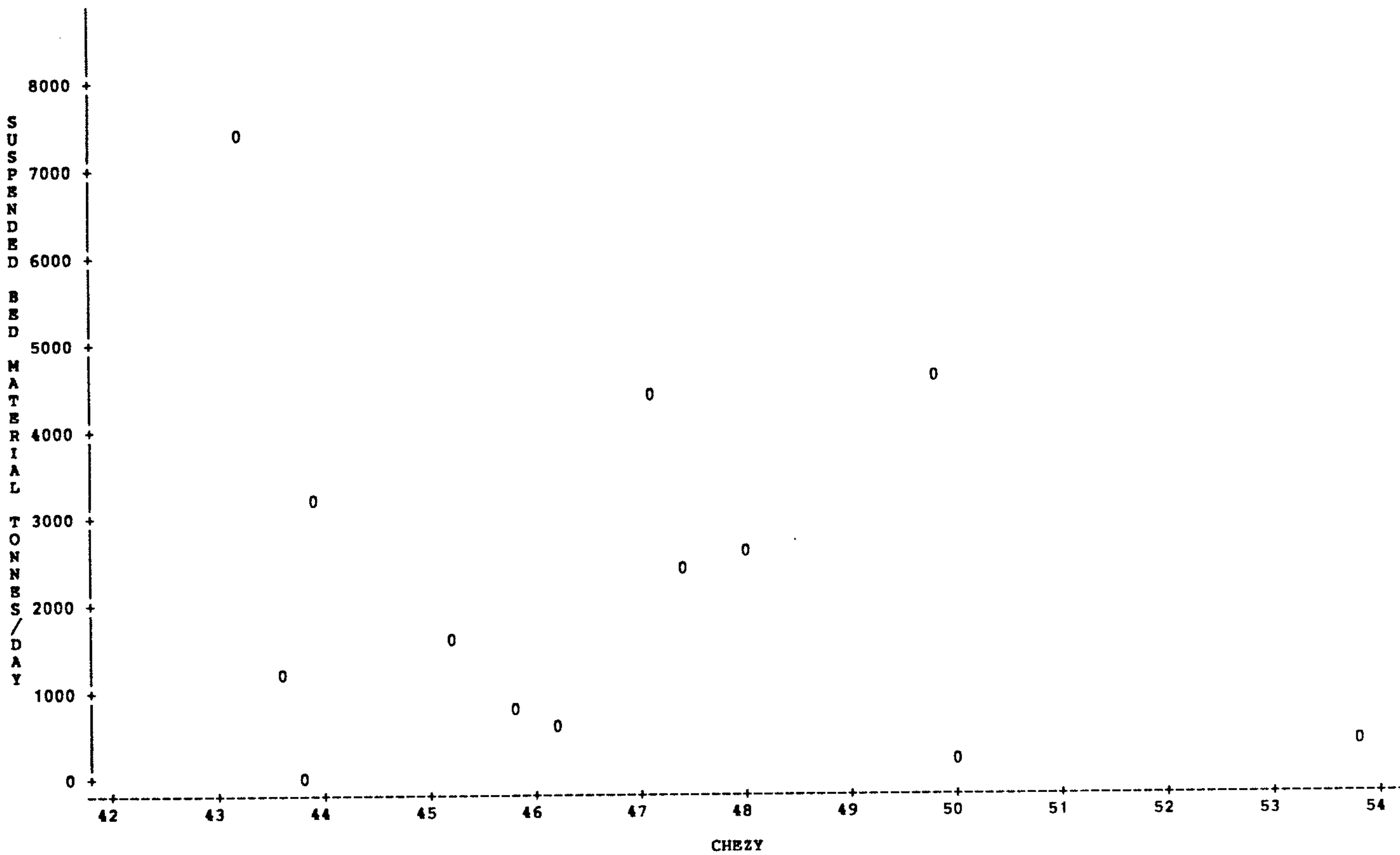



Fig. 108 QSBM VS. CHEZY AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QSBM*FROUDE SYMBOL USED IS 0

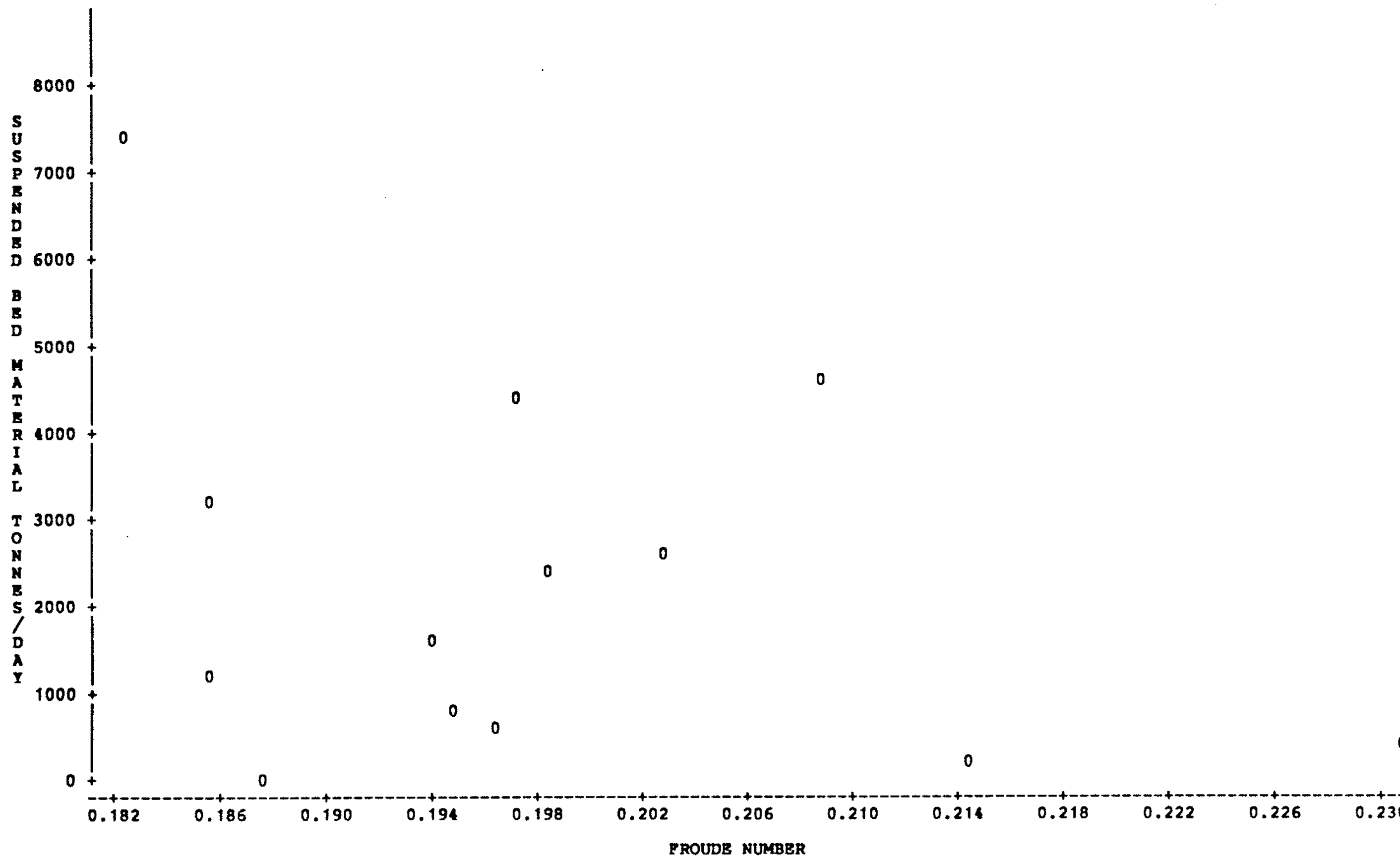



Fig. 109 QSBM VS. FROUDE NUMBER AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*SLOPE SYMBOL USED IS 0

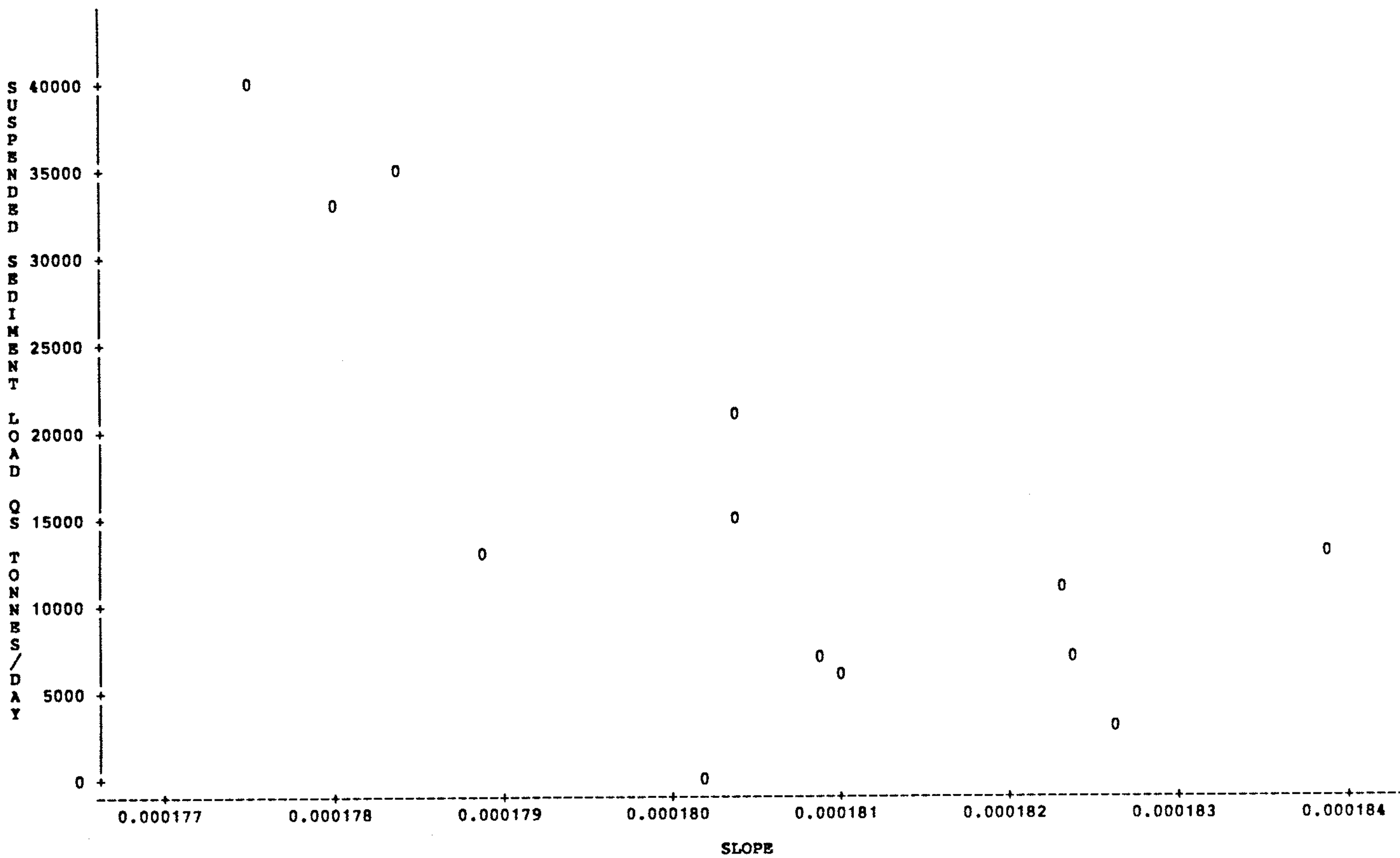



Fig. 110 QS VS. SLOPE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*Q     SYMBOL USED IS 0

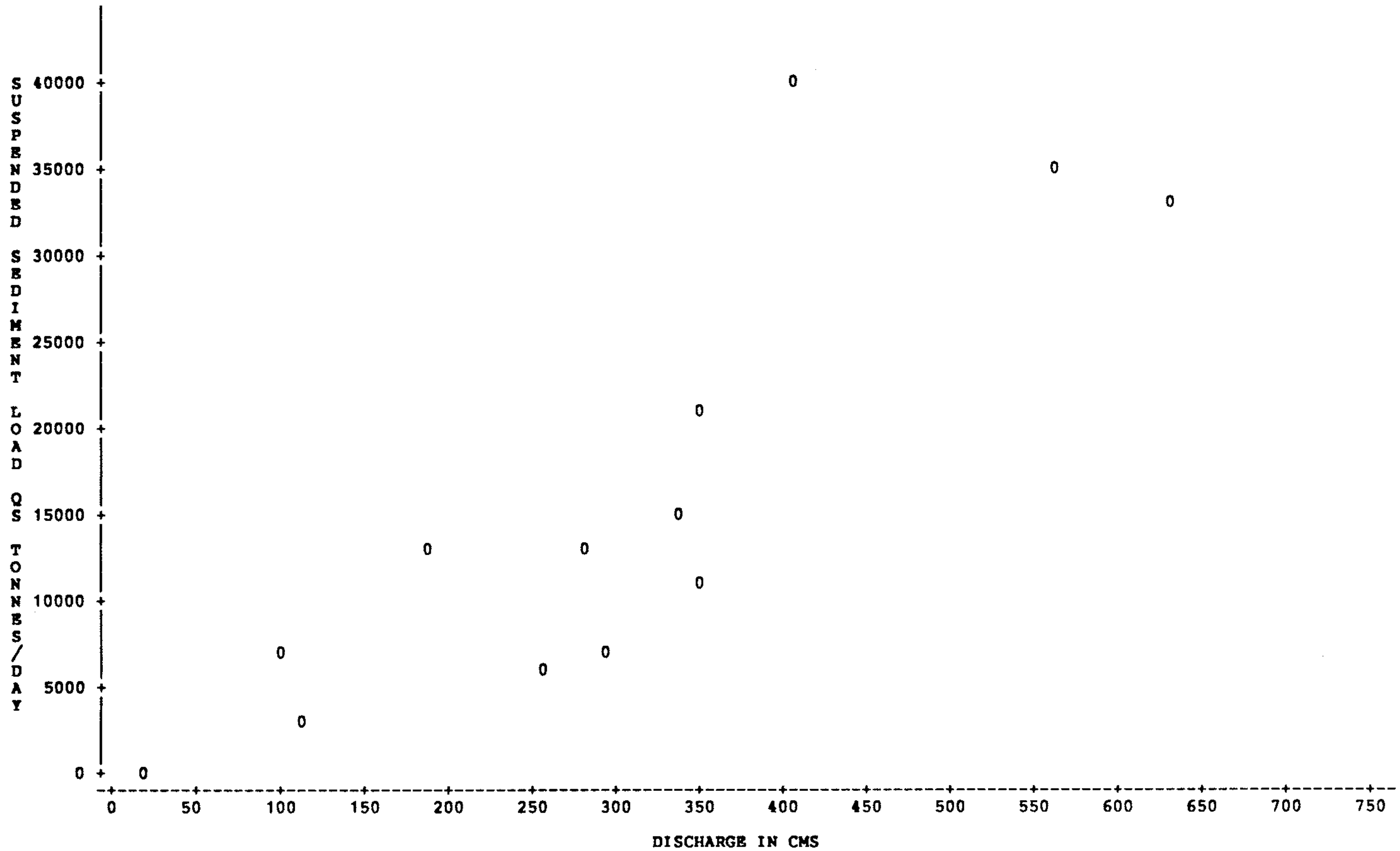



Fig. 111 QS VS. DISCHARGE AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*VELOC SYMBOL USED IS 0

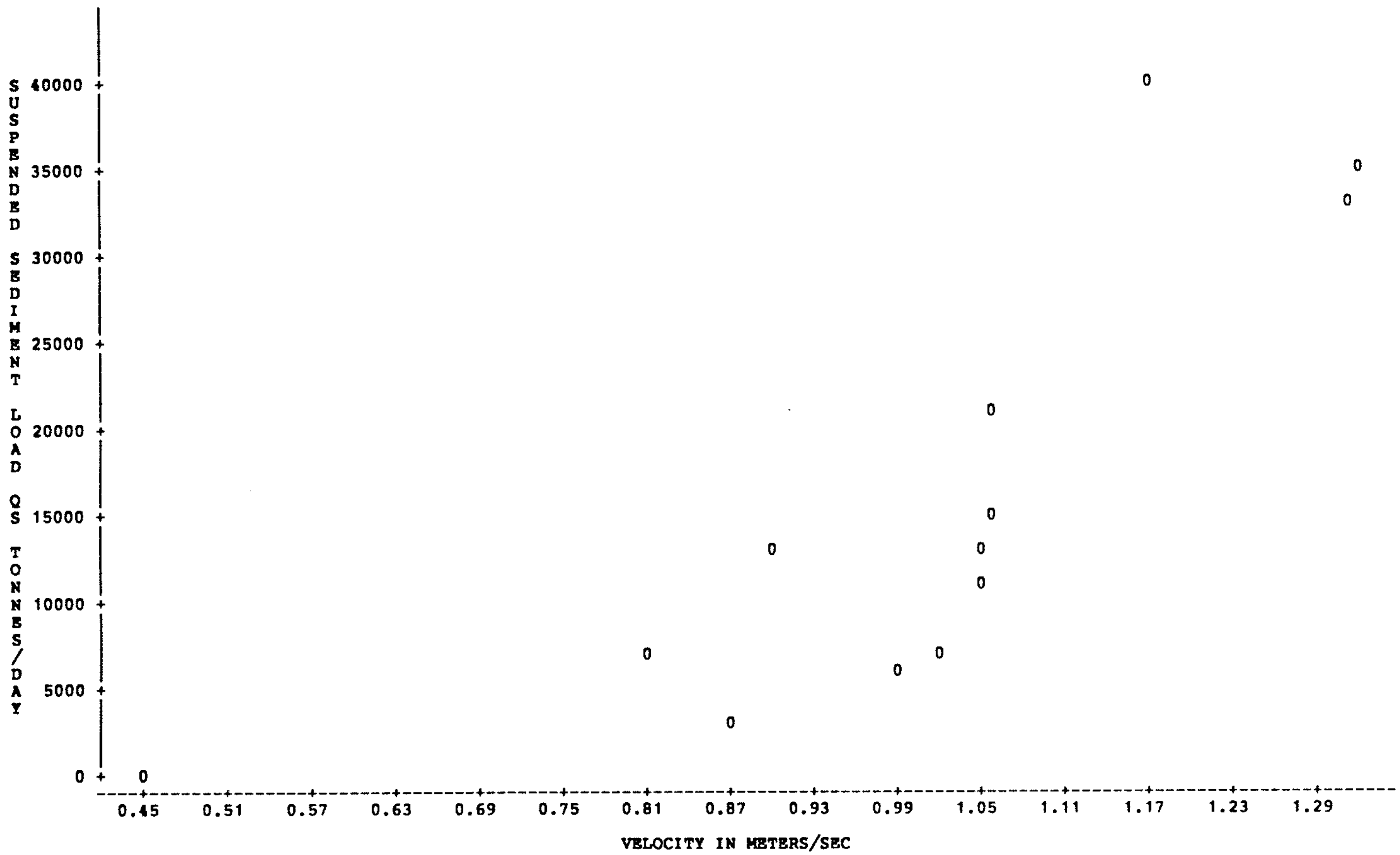



Fig. 112 QS VS. VELOCITY AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*DEPTH SYMBOL USED IS 0

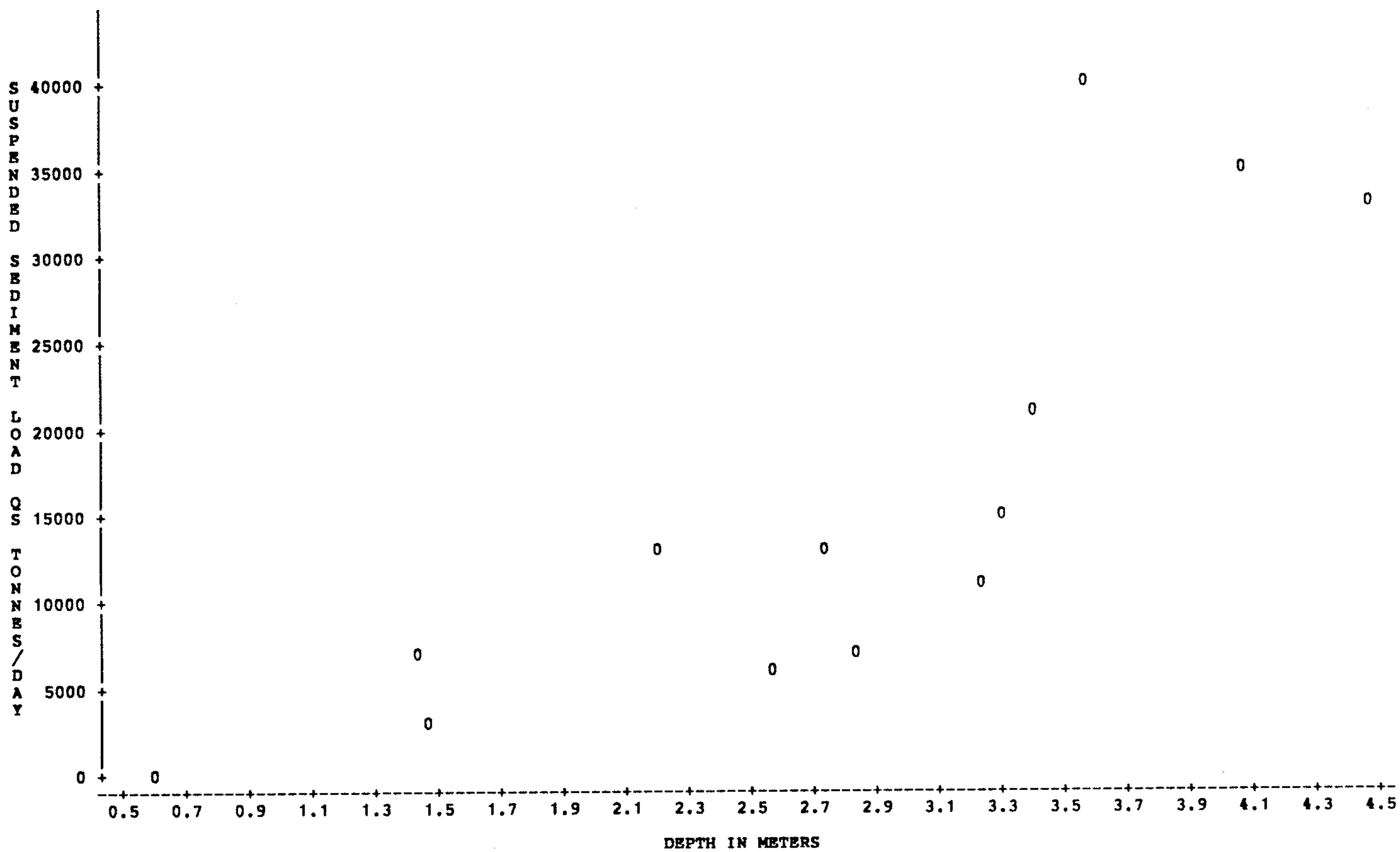



Fig. 113 QS VS. DEPTH AT PORTAGE AFTER 1969

11:17 THURSDAY, JUNE 20, 1985 156

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*VS SYMBOL USED IS 0

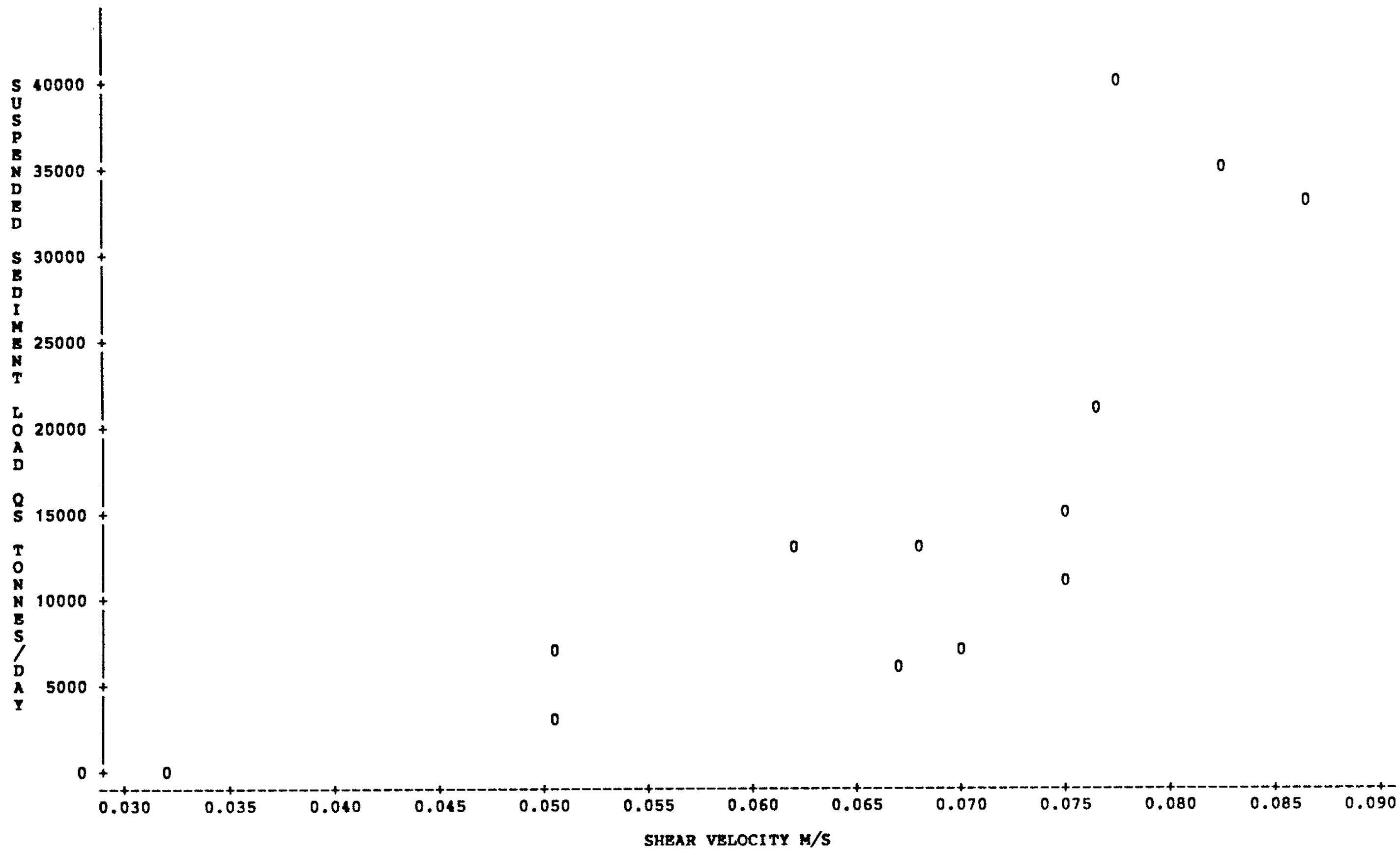



Fig. 114 QS VS. SHEAR VELOCITY AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*SHEAR SYMBOL USED IS 0

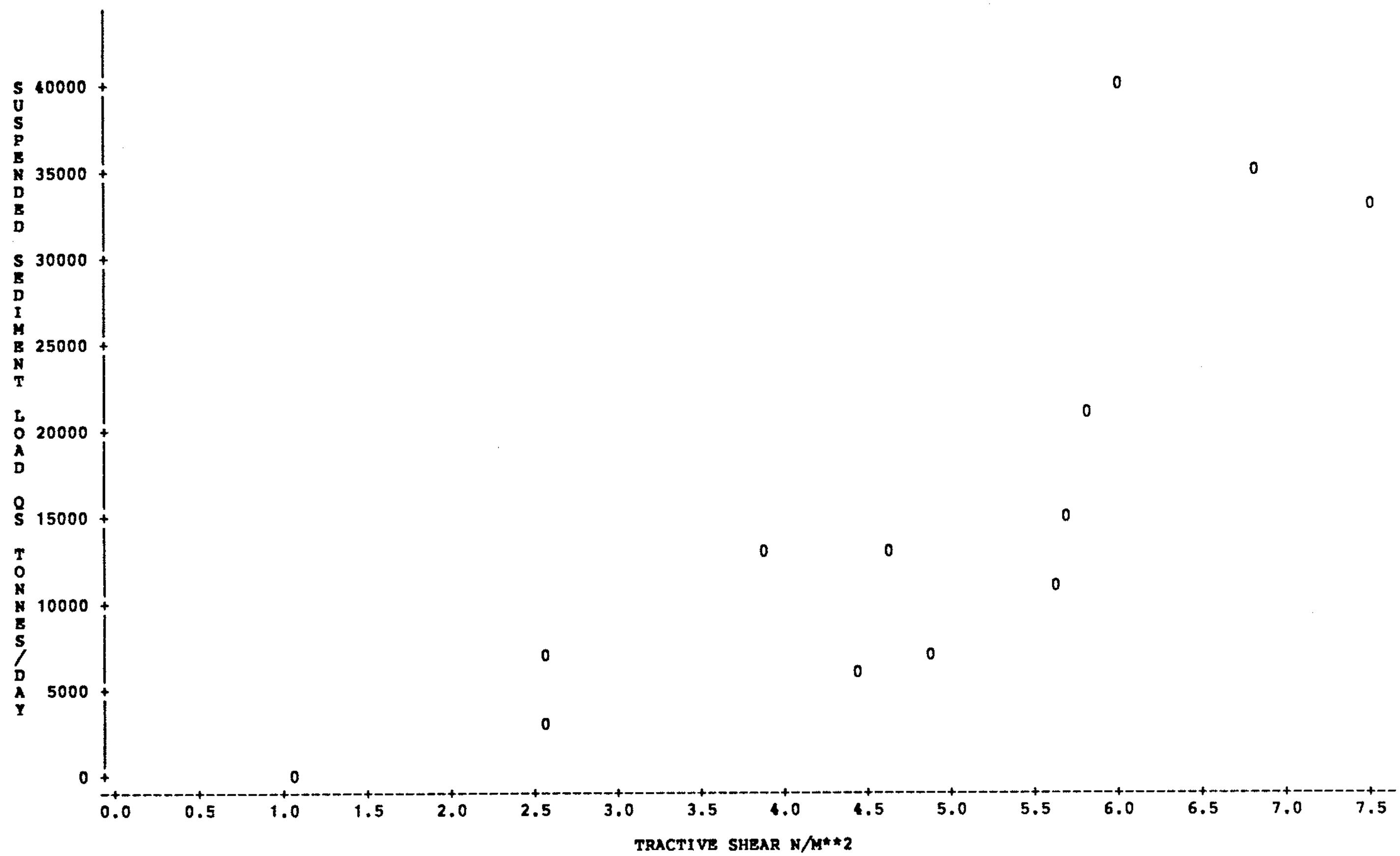



Fig. 115 QS VS. TRACTIVE SHEAR AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*POWER SYMBOL USED IS 0

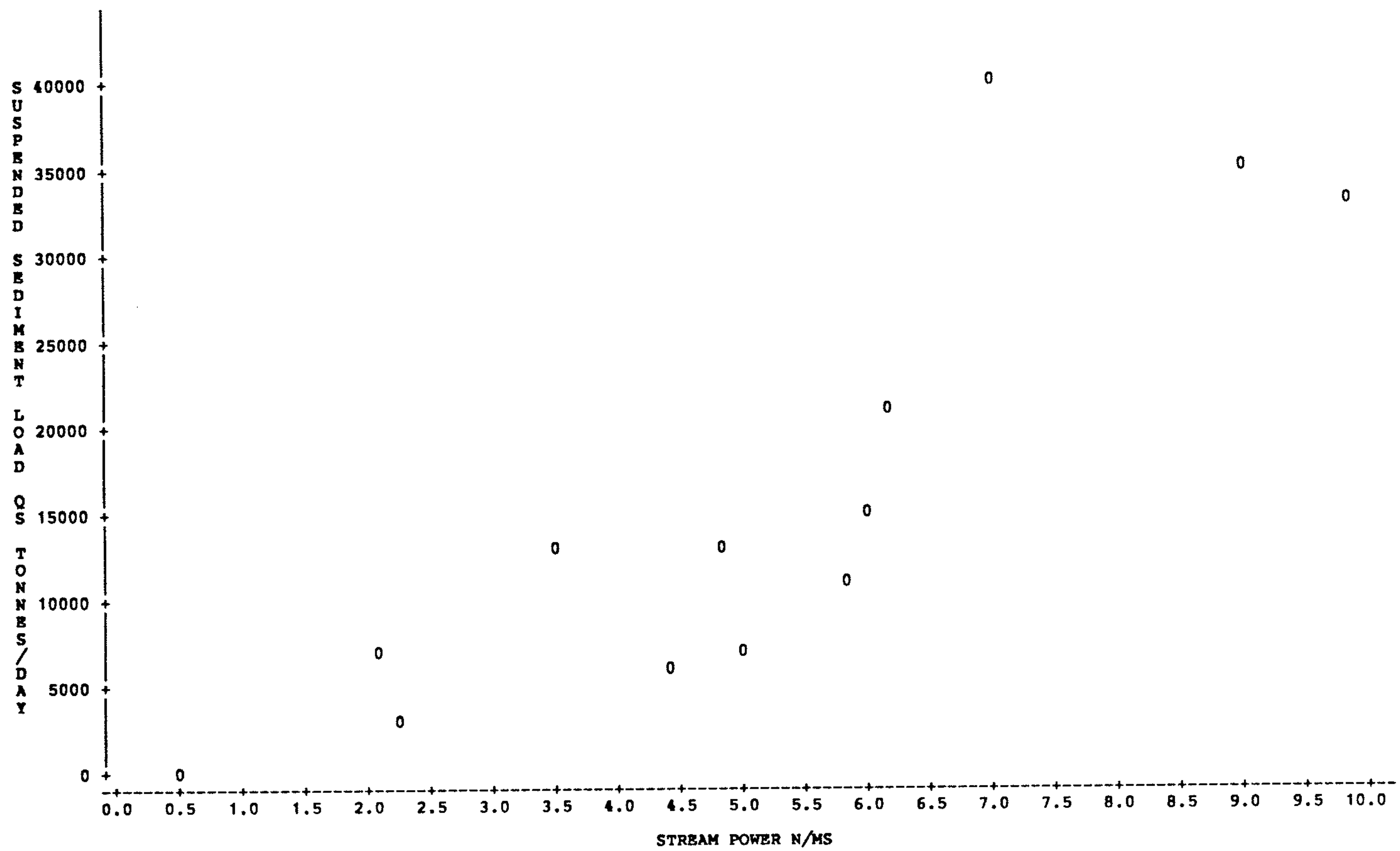



Fig. 116 QS VS. STREAM POWER AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*CHEZY SYMBOL USED IS 0

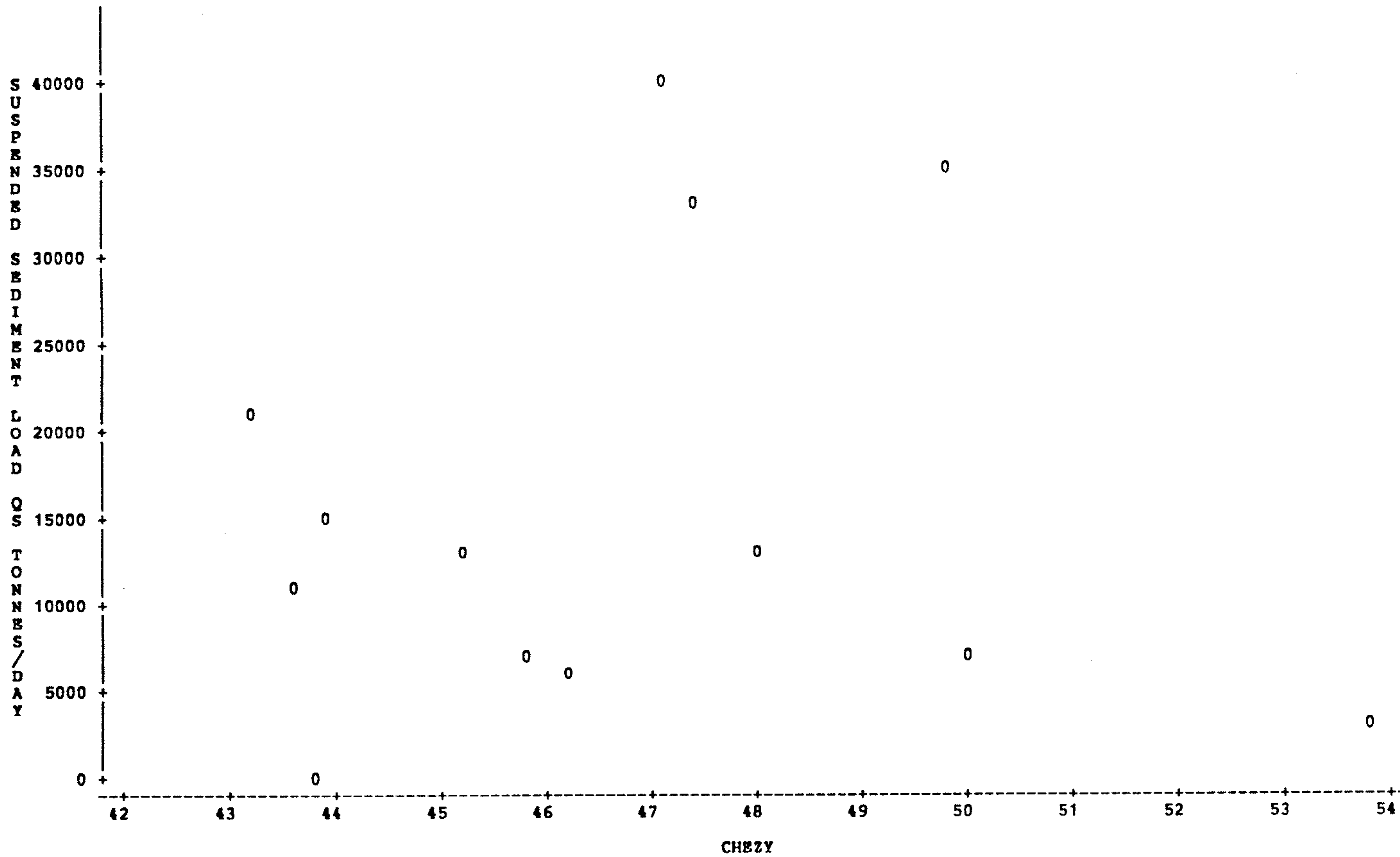



Fig. 117 QS VS. CHEZY AT PORTAGE AFTER 1969

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

PORTAGE FROM 1969 TO 1976

PLOT OF QS*FROUDE     SYMBOL USED IS 0

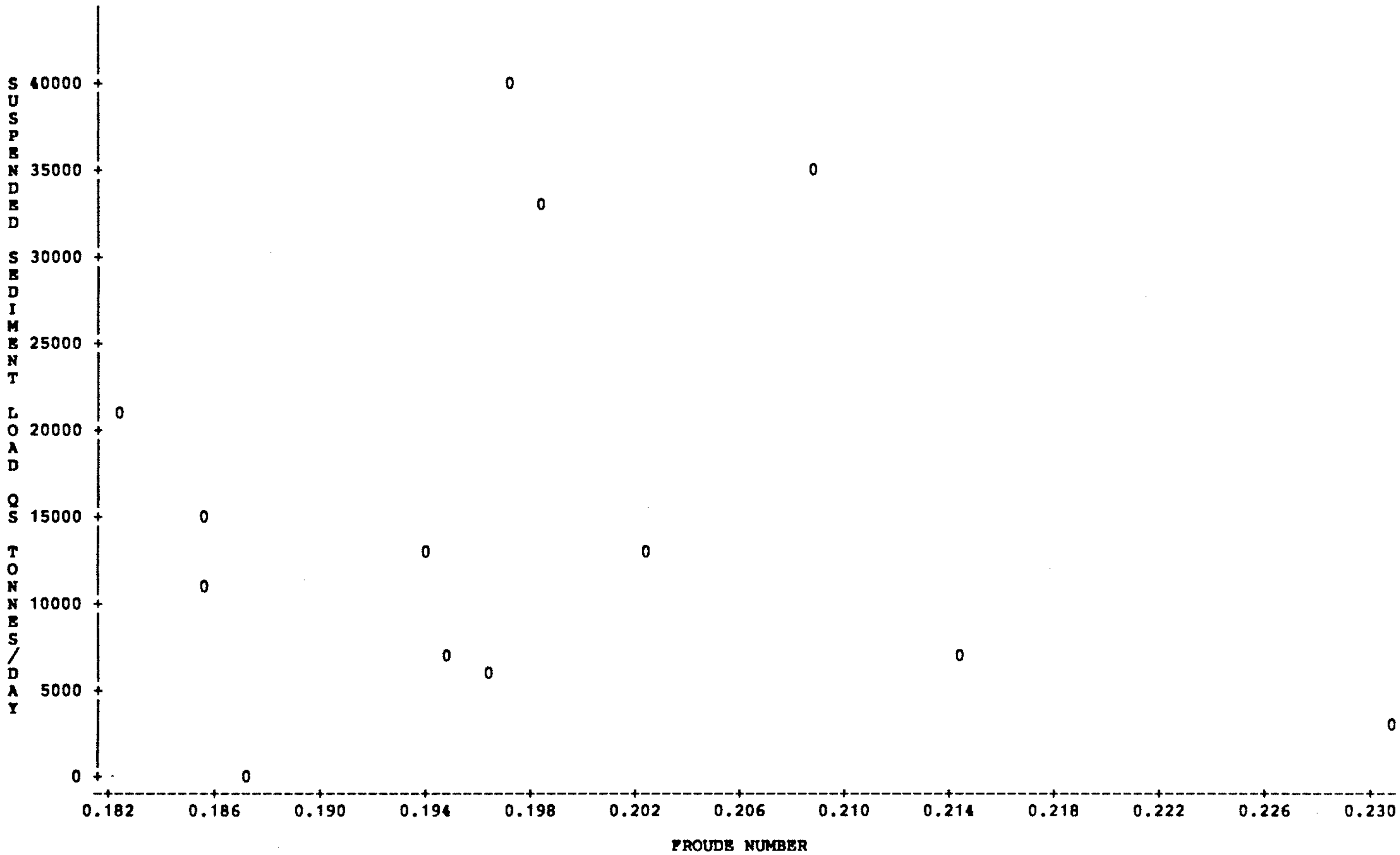



Fig. 118 QS VS. FROUDE NUMBER AT PORTAGE AFTER 1969

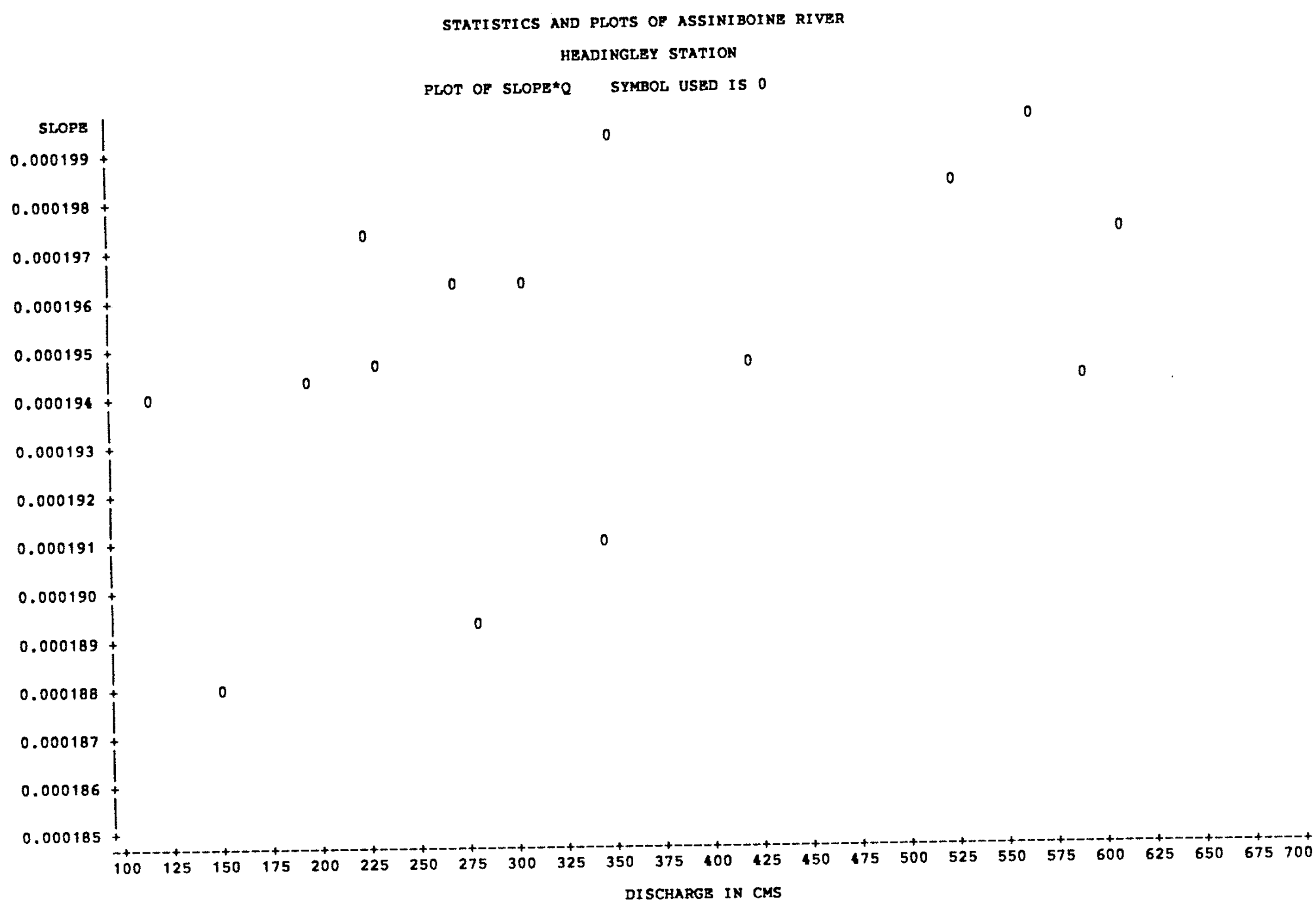



Fig. 119 SLOPE VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF VELOC*Q SYMBOL USED IS 0

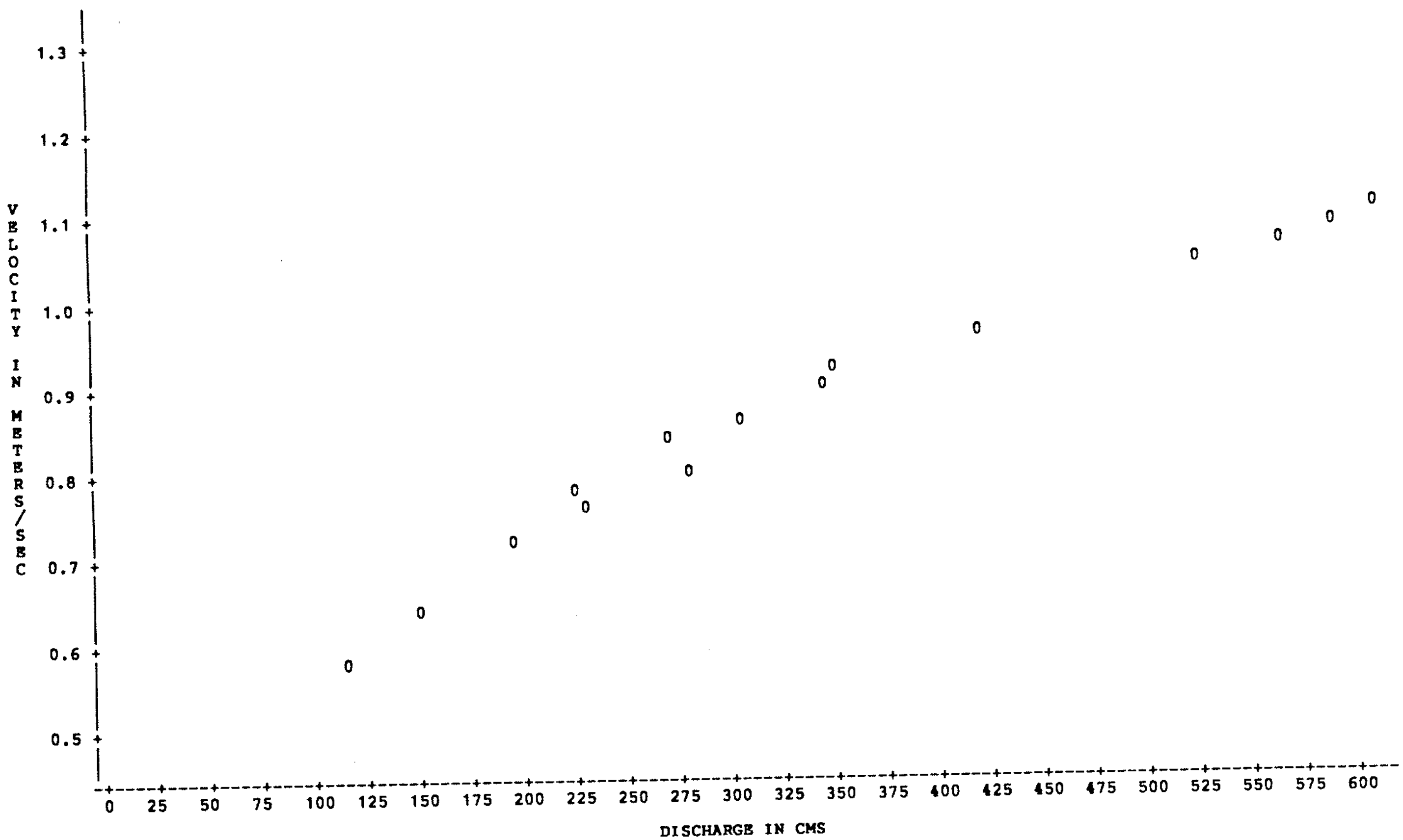



Fig. 120 VELOCITY VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF WIDTH*Q SYMBOL USED IS 0

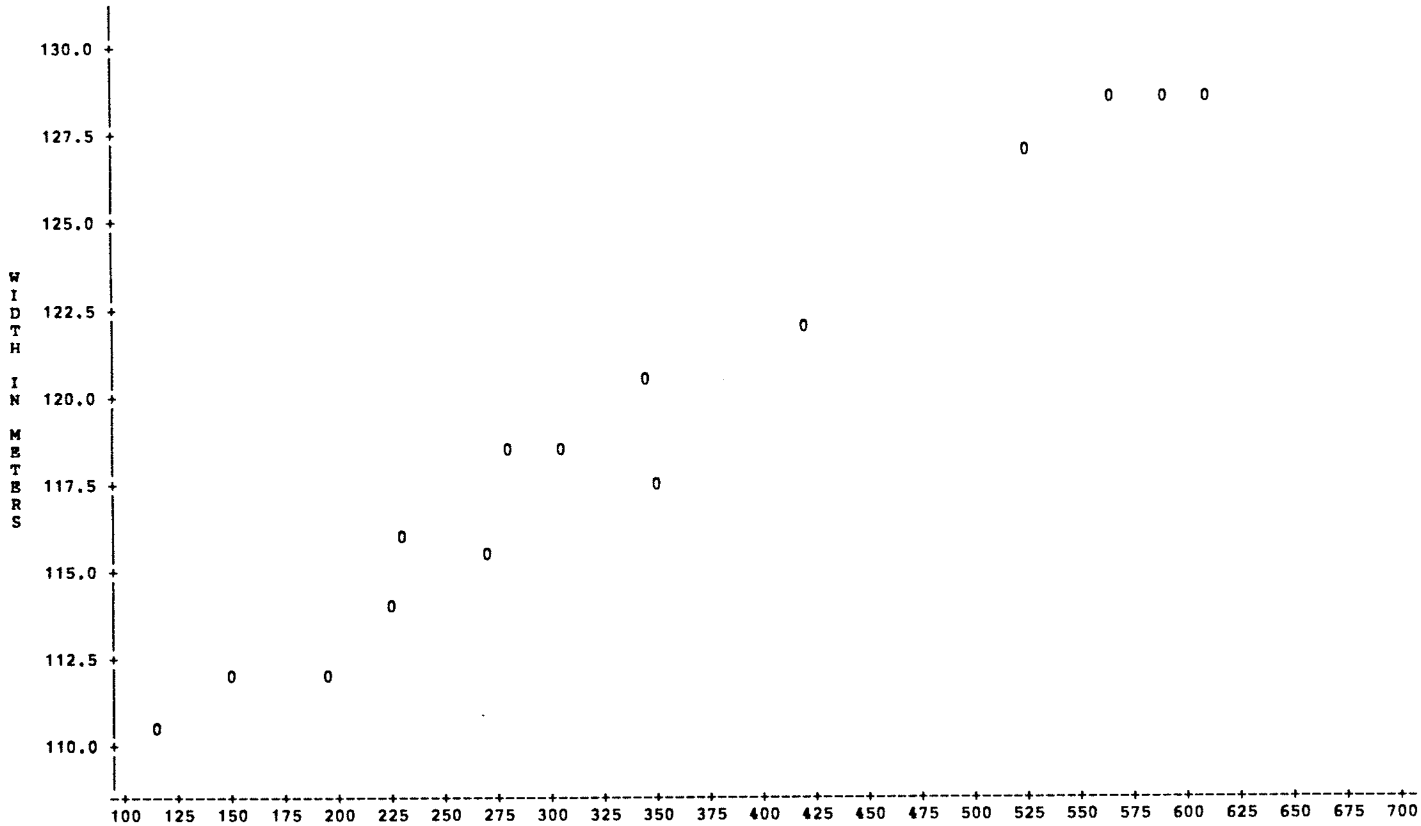



Fig. 121 WIDTH VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF AREA*Q SYMBOL USED IS 0

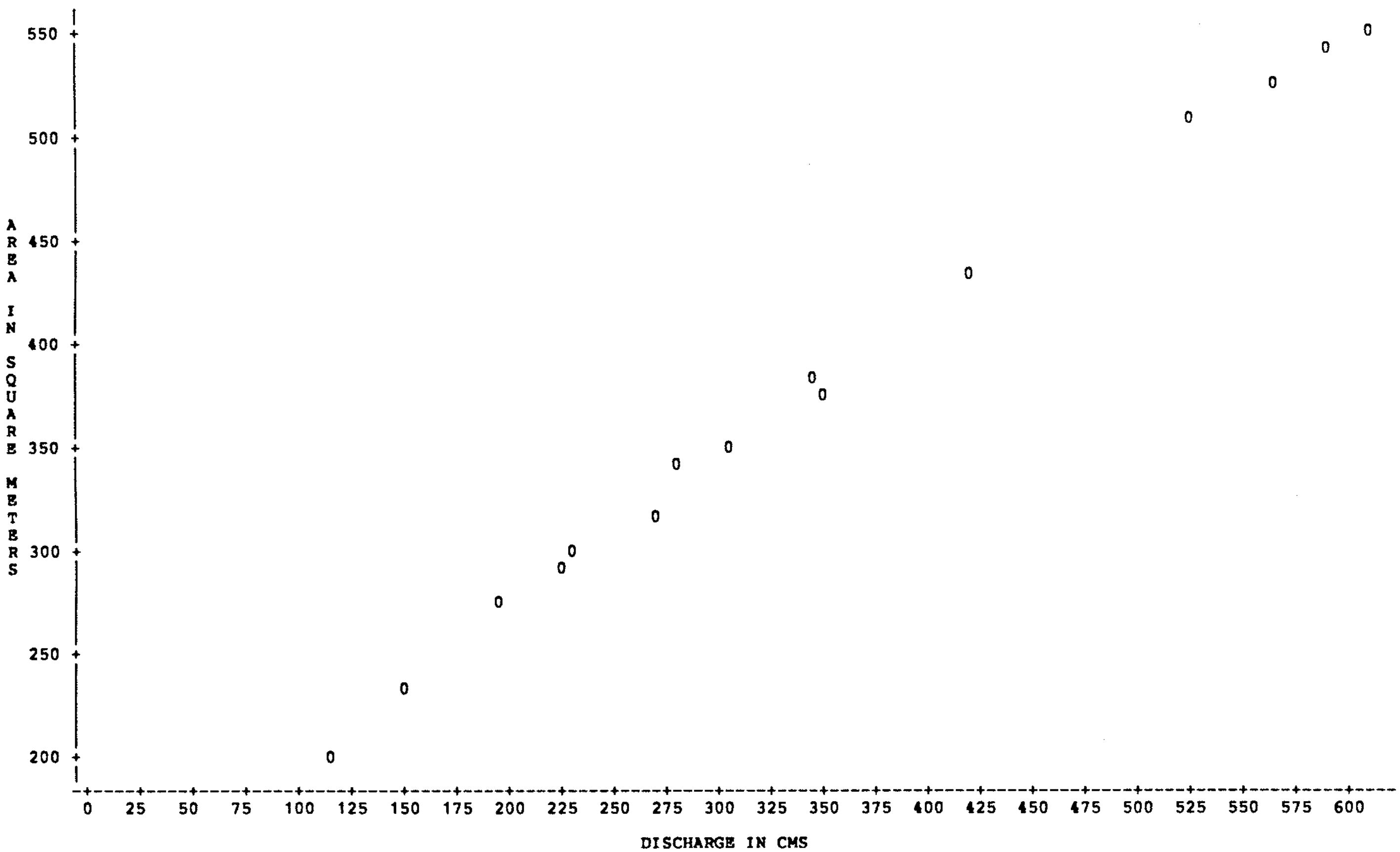



Fig. 122 AREA VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF DEPTH*Q SYMBOL USED IS 0

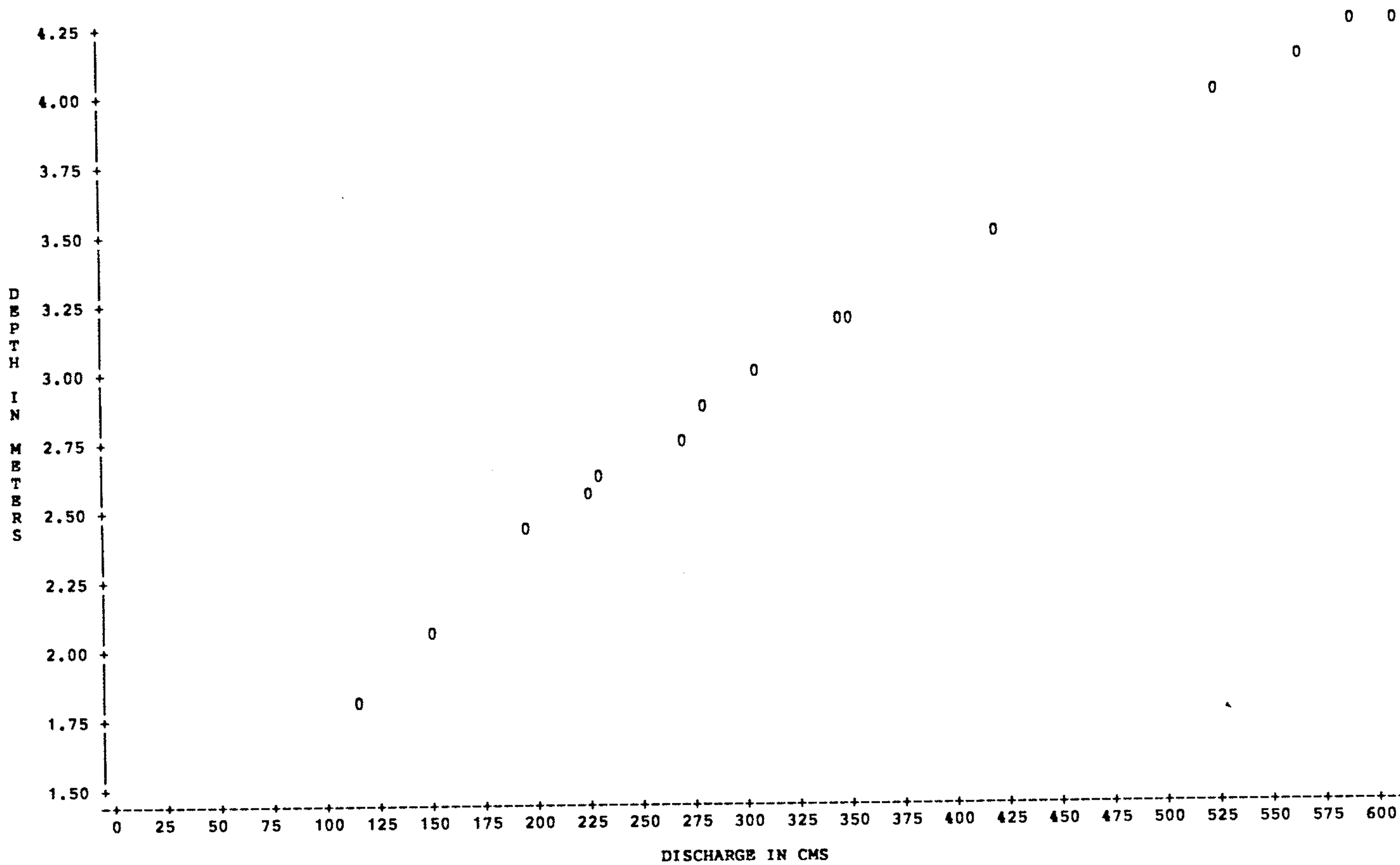



Fig. 123 DEPTH VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF CHEZY*Q SYMBOL USED IS 0

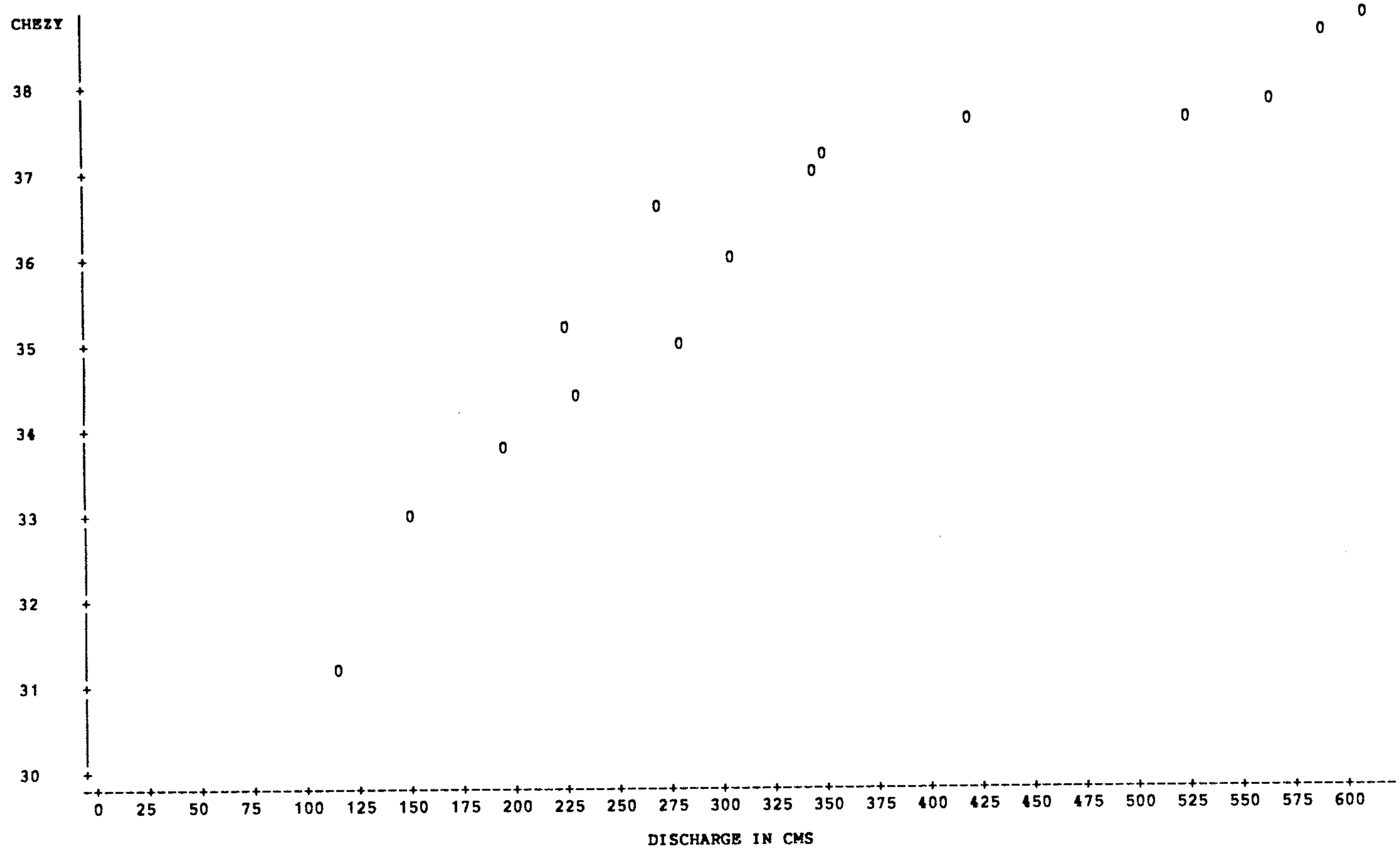



Fig. 124 CHEZY VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF FROUDE*Q SYMBOL USED IS 0

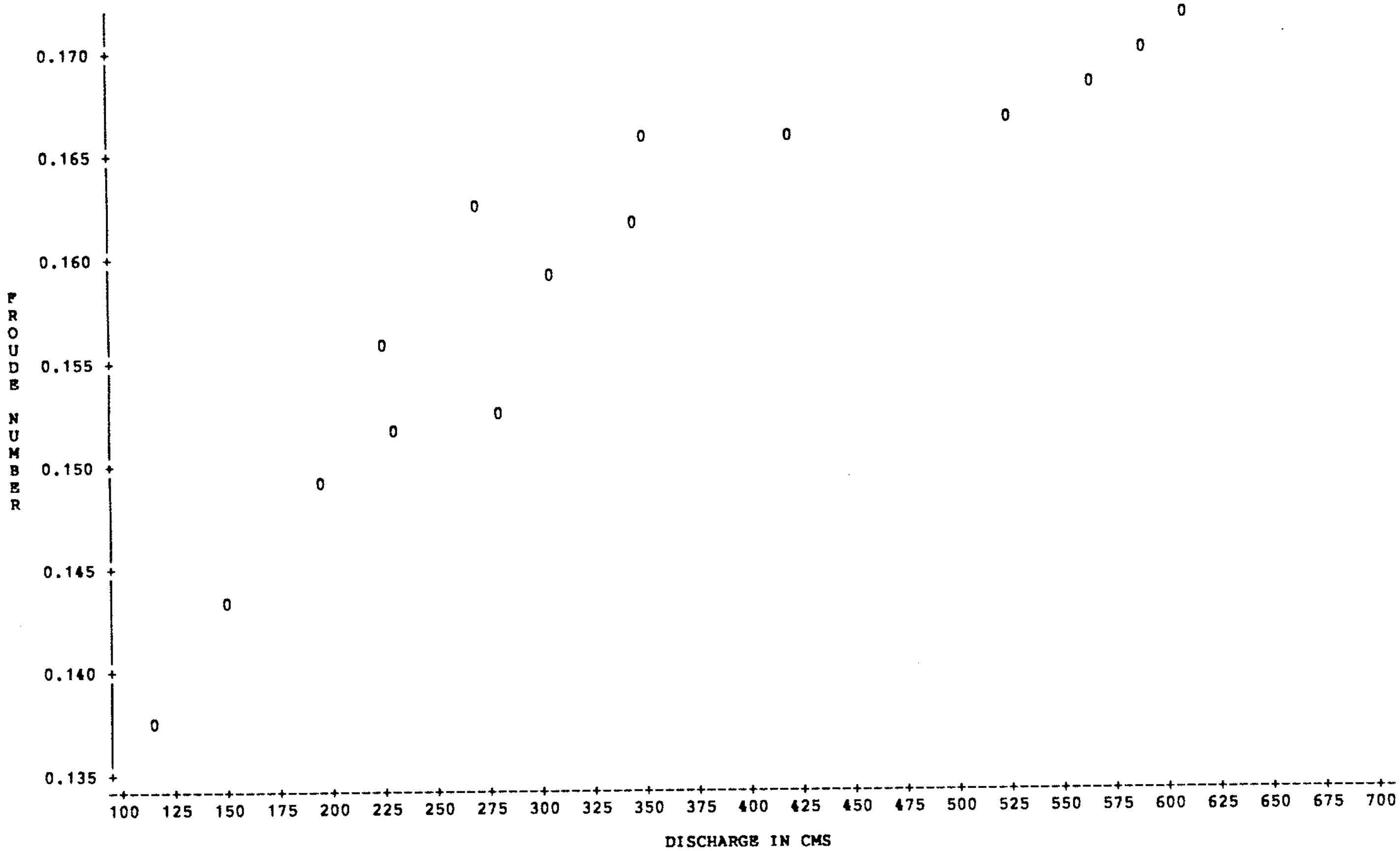



Fig. 125 FROUDE NUMBER VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF SHEAR*Q SYMBOL USED IS 0

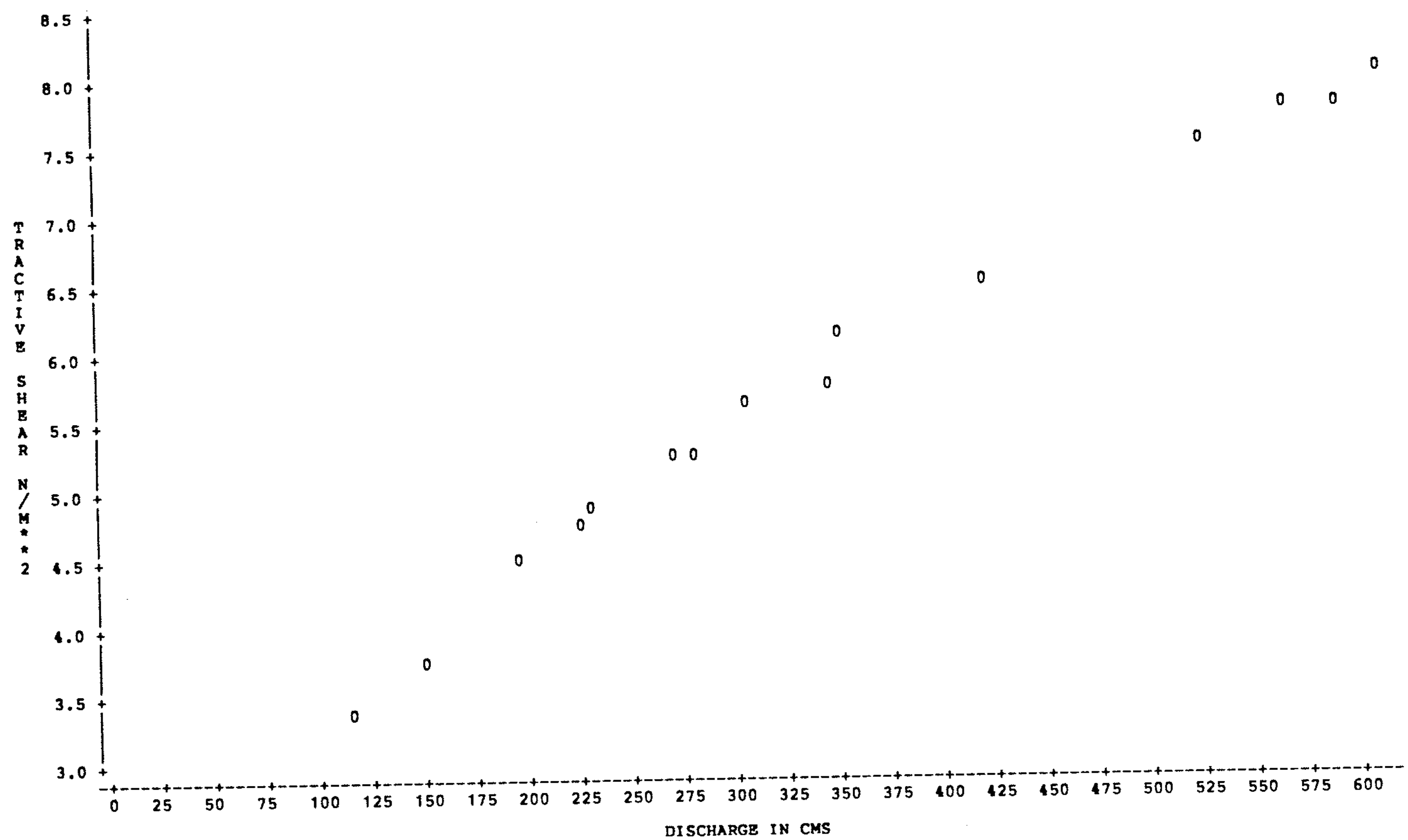



Fig. 126 TRACTIVE SHEAR VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF VS*Q SYMBOL USED IS 0

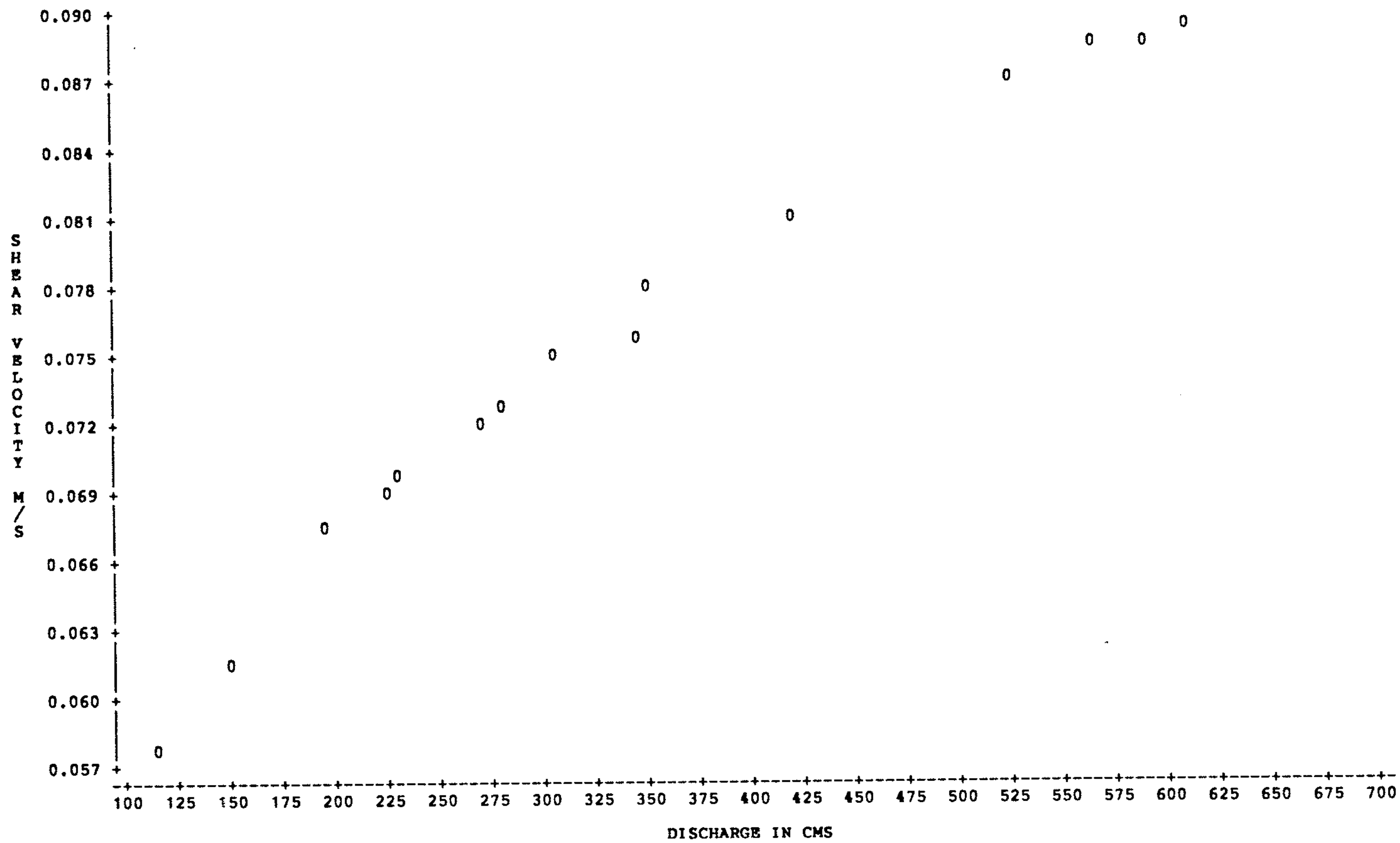



Fig. 127 SHEAR VELOCITY VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF POWER*Q SYMBOL USED IS 0

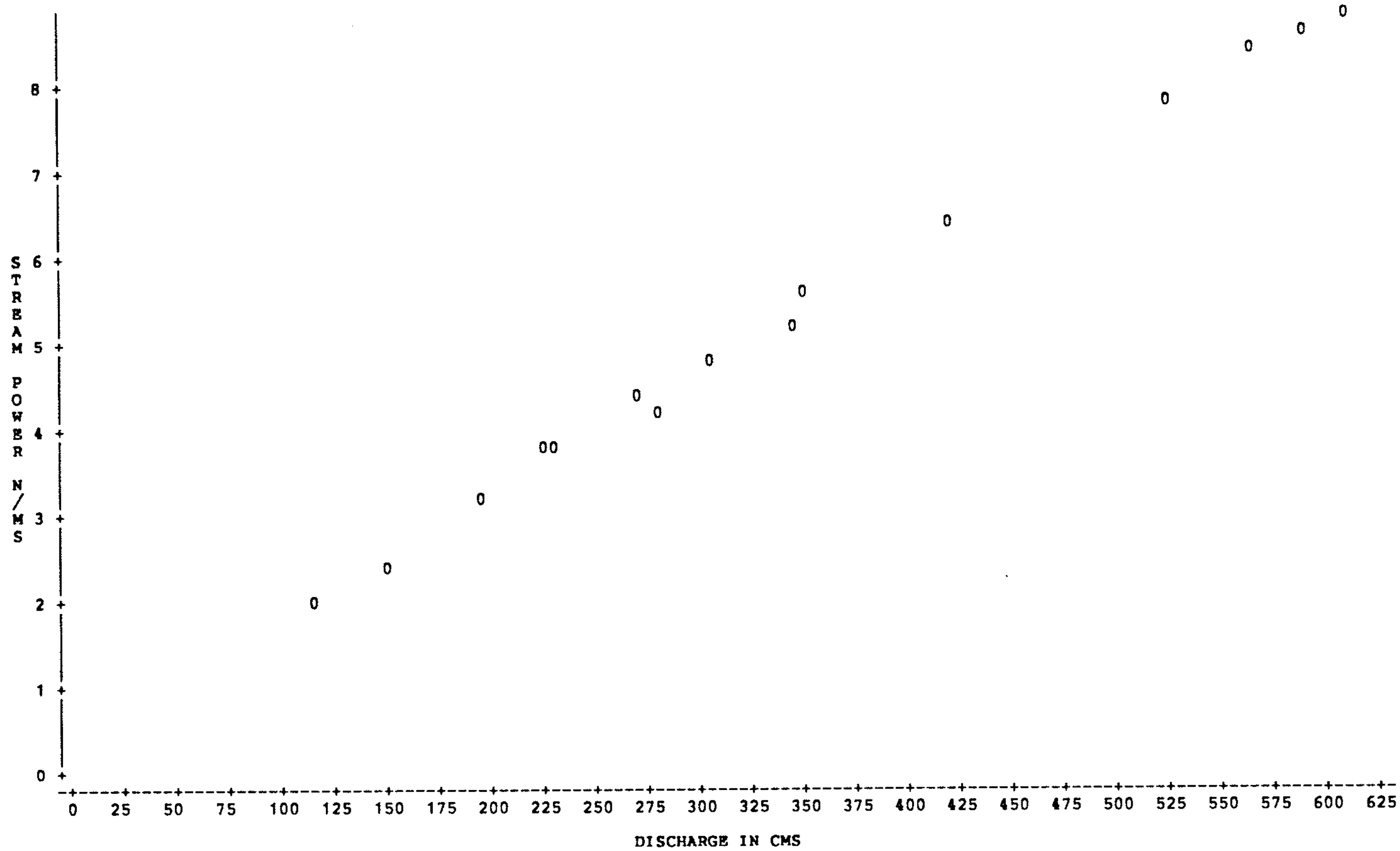



Fig. 128 STREAM POWER VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF D50*Q SYMBOL USED IS 0

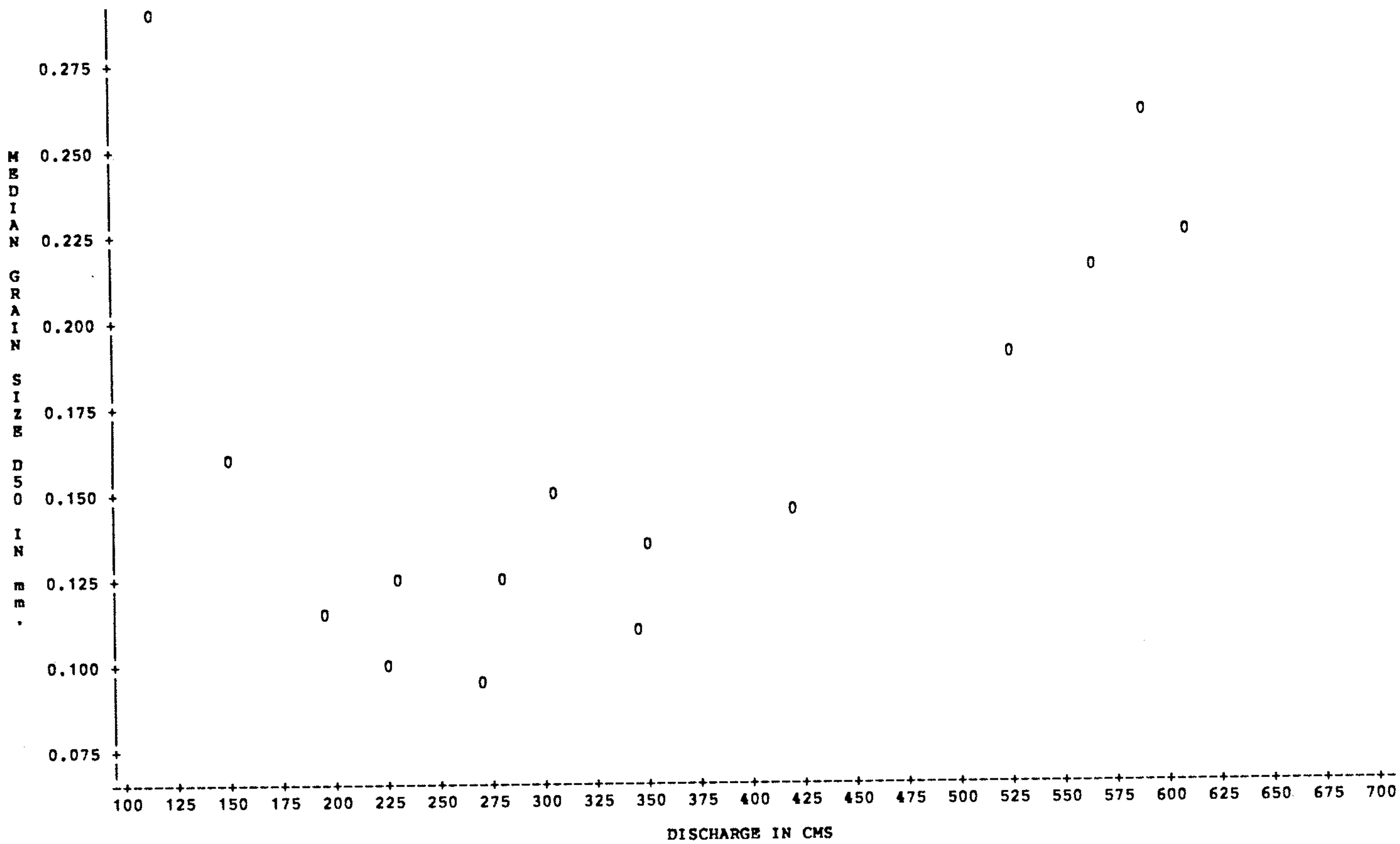



Fig. 129 MEDIAN GRAIN SIZE VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF PHI*Q SYMBOL USED IS 0

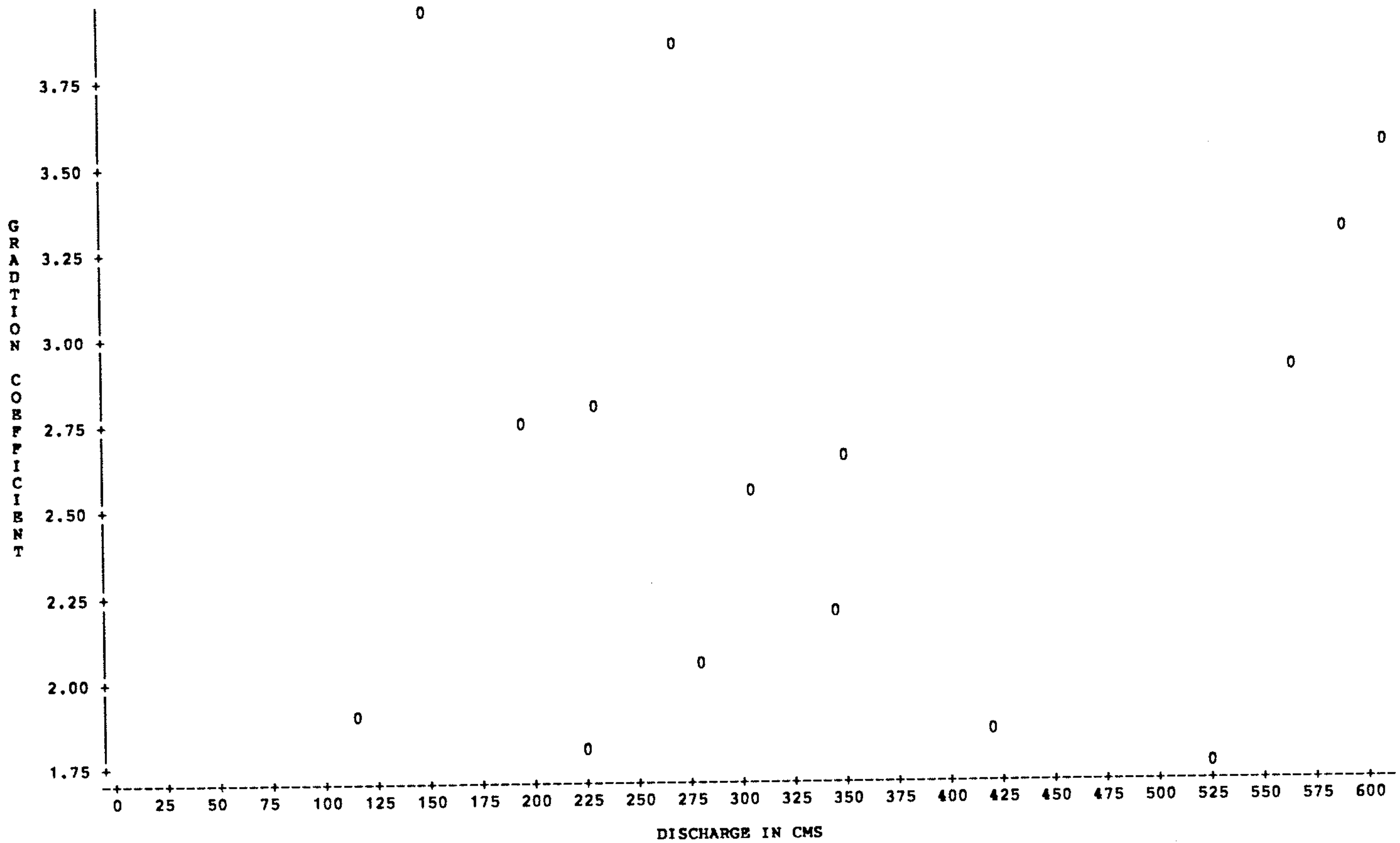



Fig. 130 GRADATION COEFFICIENT VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*SLOPE SYMBOL USED IS 0

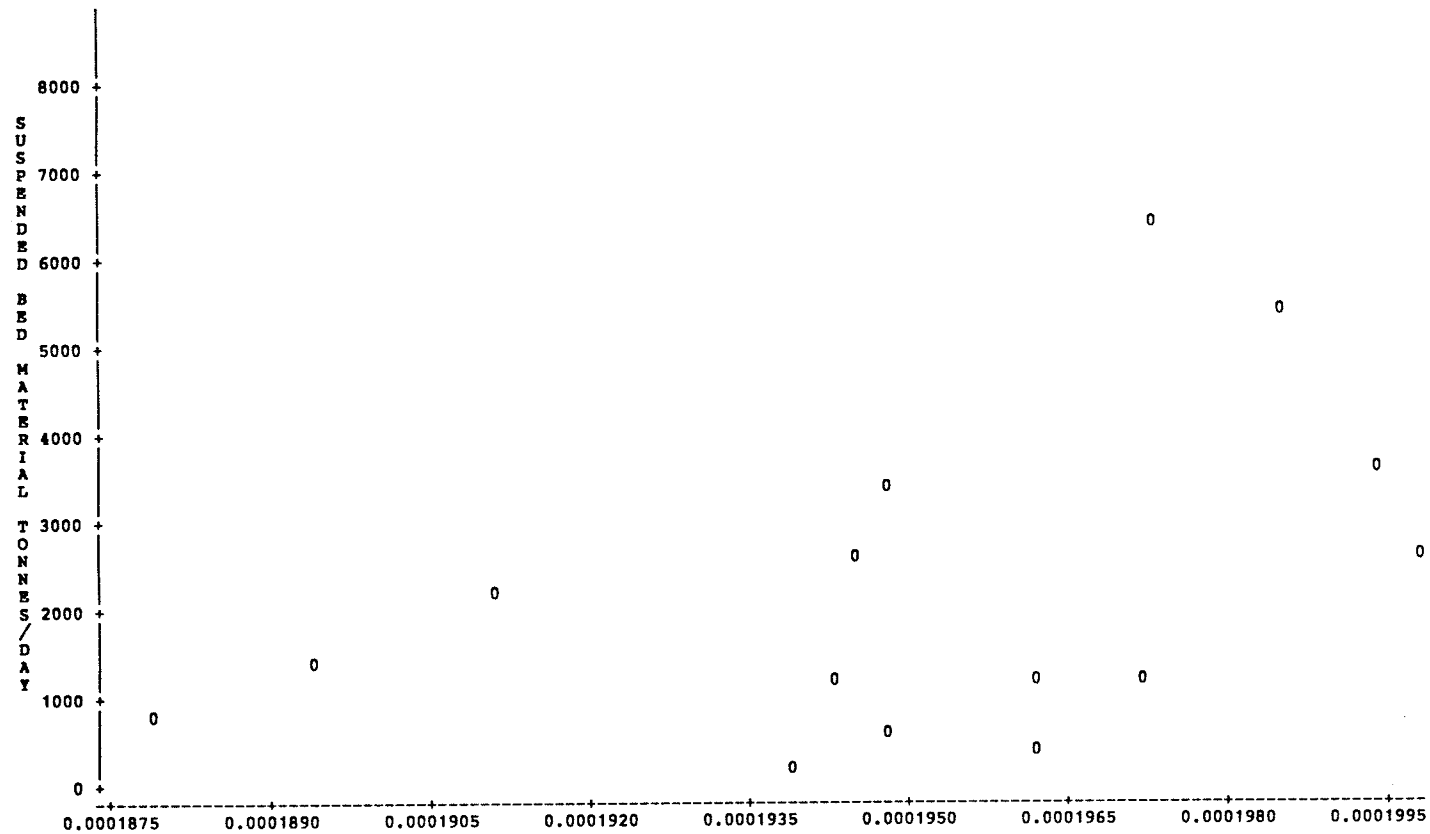



Fig. 131 QSBM VS. SLOPE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*Q SYMBOL USED IS 0

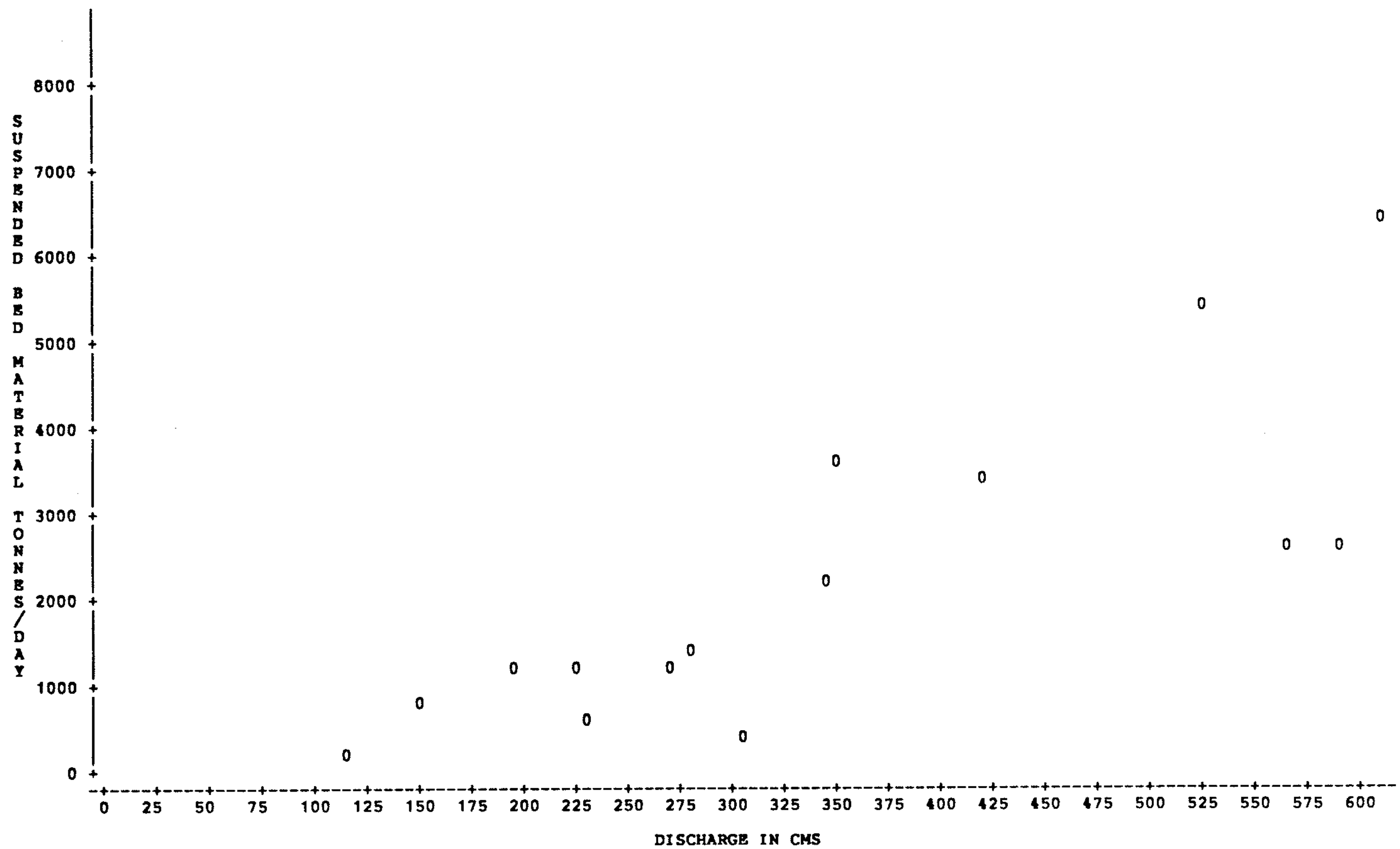



Fig. 132 QSBM VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*VELOC SYMBOL USED IS 0

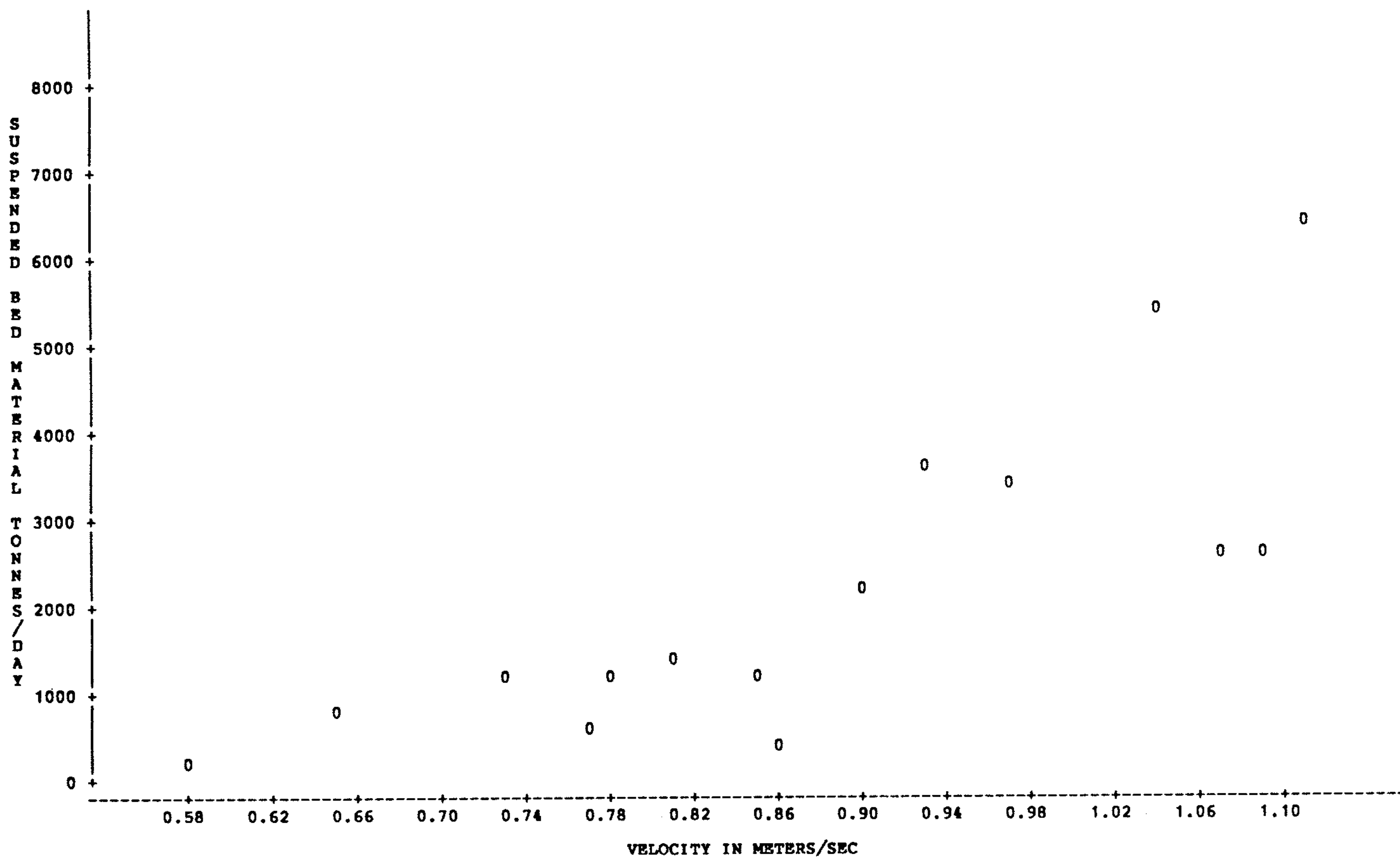



Fig. 133 QSBM VS. VELOCITY AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*DEPTH SYMBOL USED IS 0

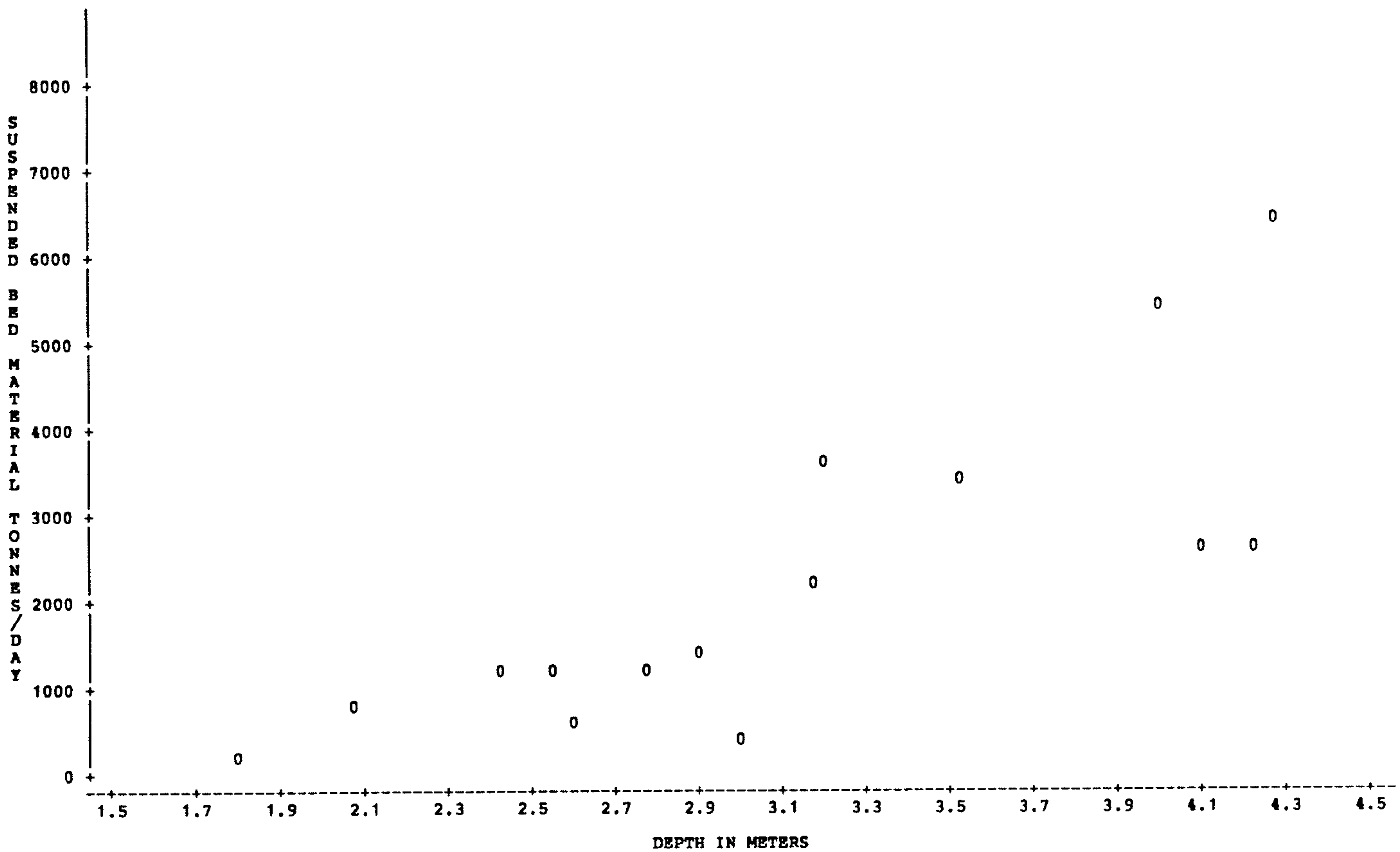
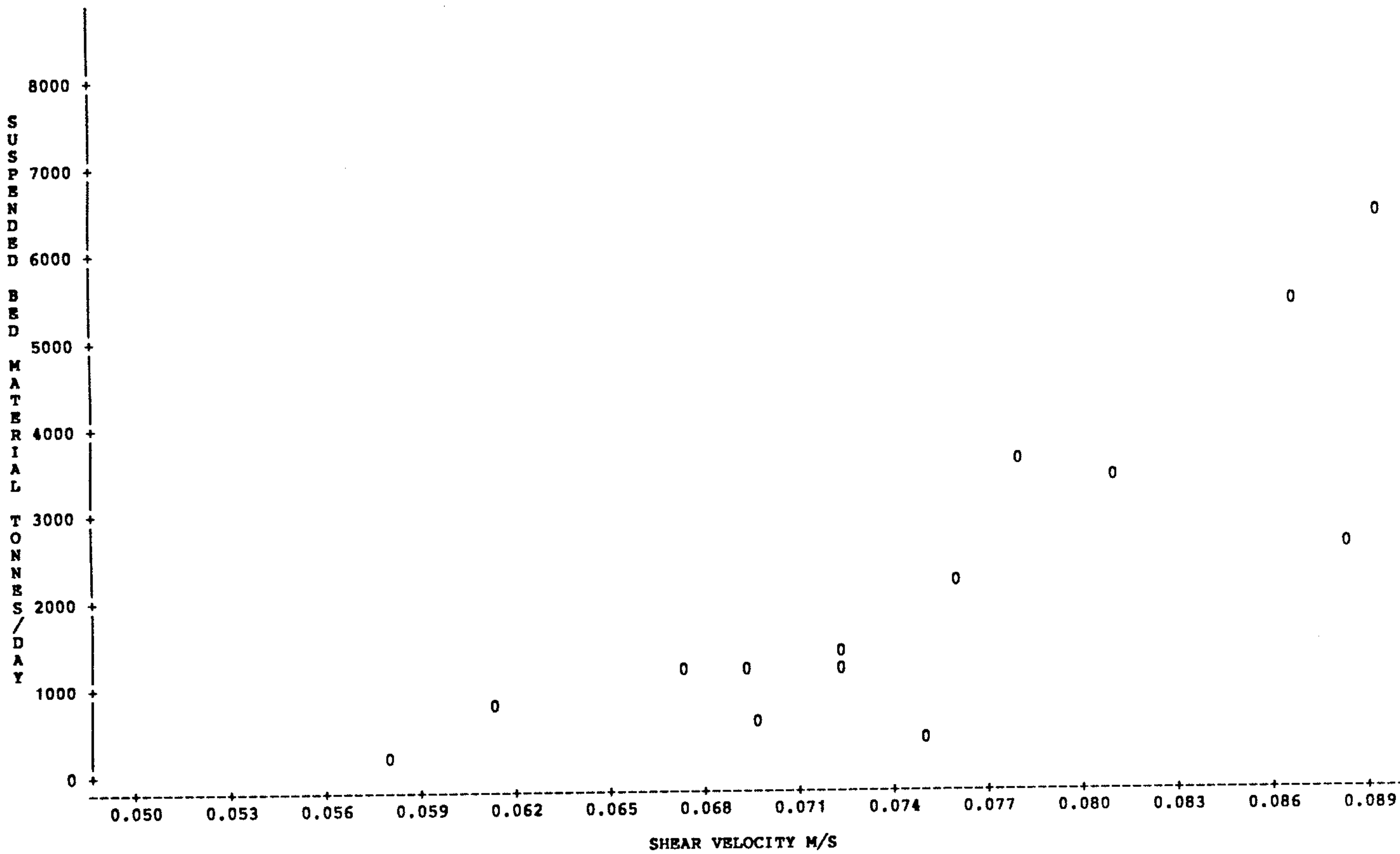



Fig. 134 QSBM VS. DEPTH AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*VS SYMBOL USED IS 0



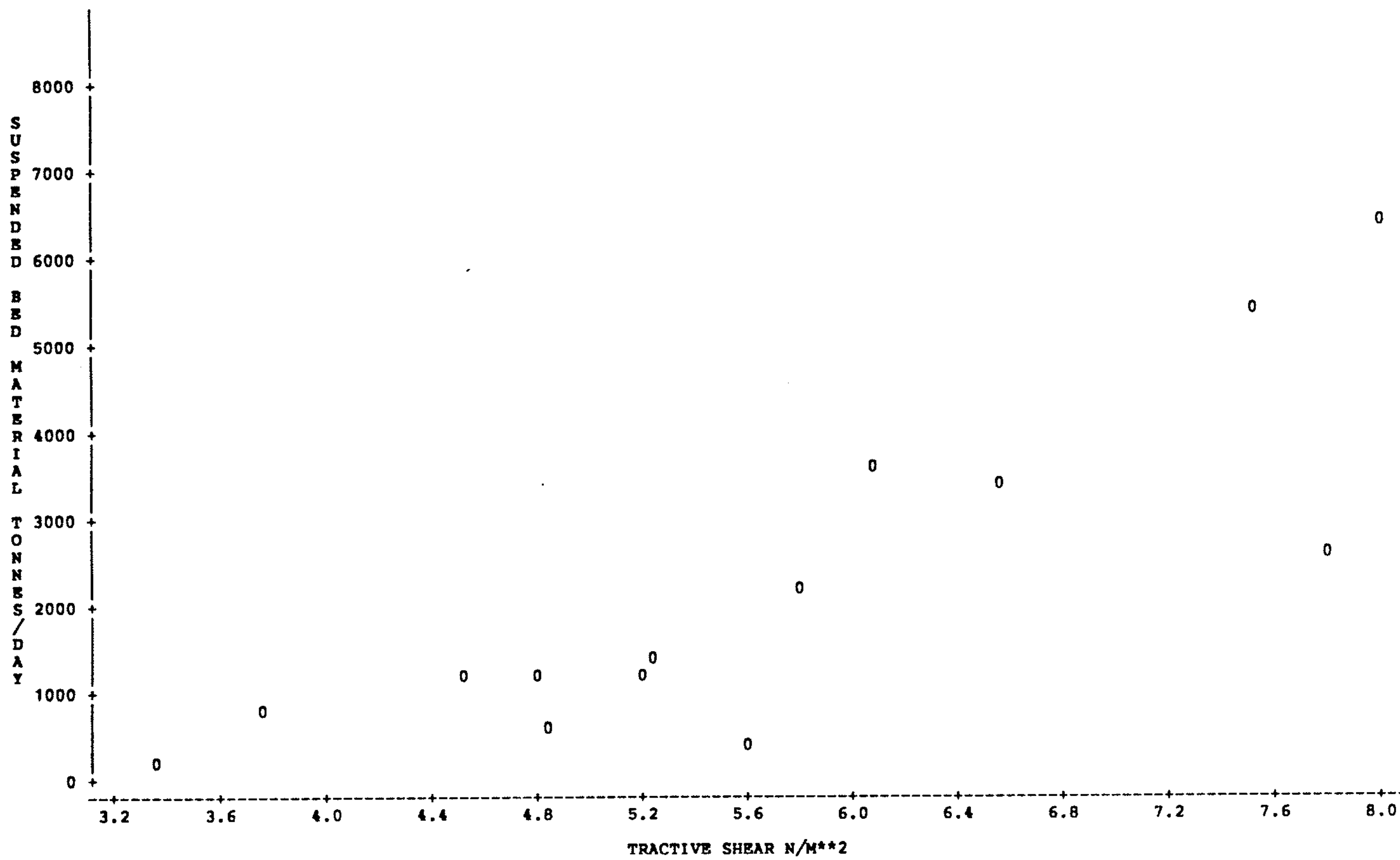

NOTE: 1 OBS HIDDEN

Fig. 135 QSBM VS. SHEAR VELOCITY AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*SHEAR SYMBOL USED IS 0




NOTE: 1 OBS HIDDEN

Fig. 136 QSBM VS. TRACTIVE SHEAR AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*POWER SYMBOL USED IS 0

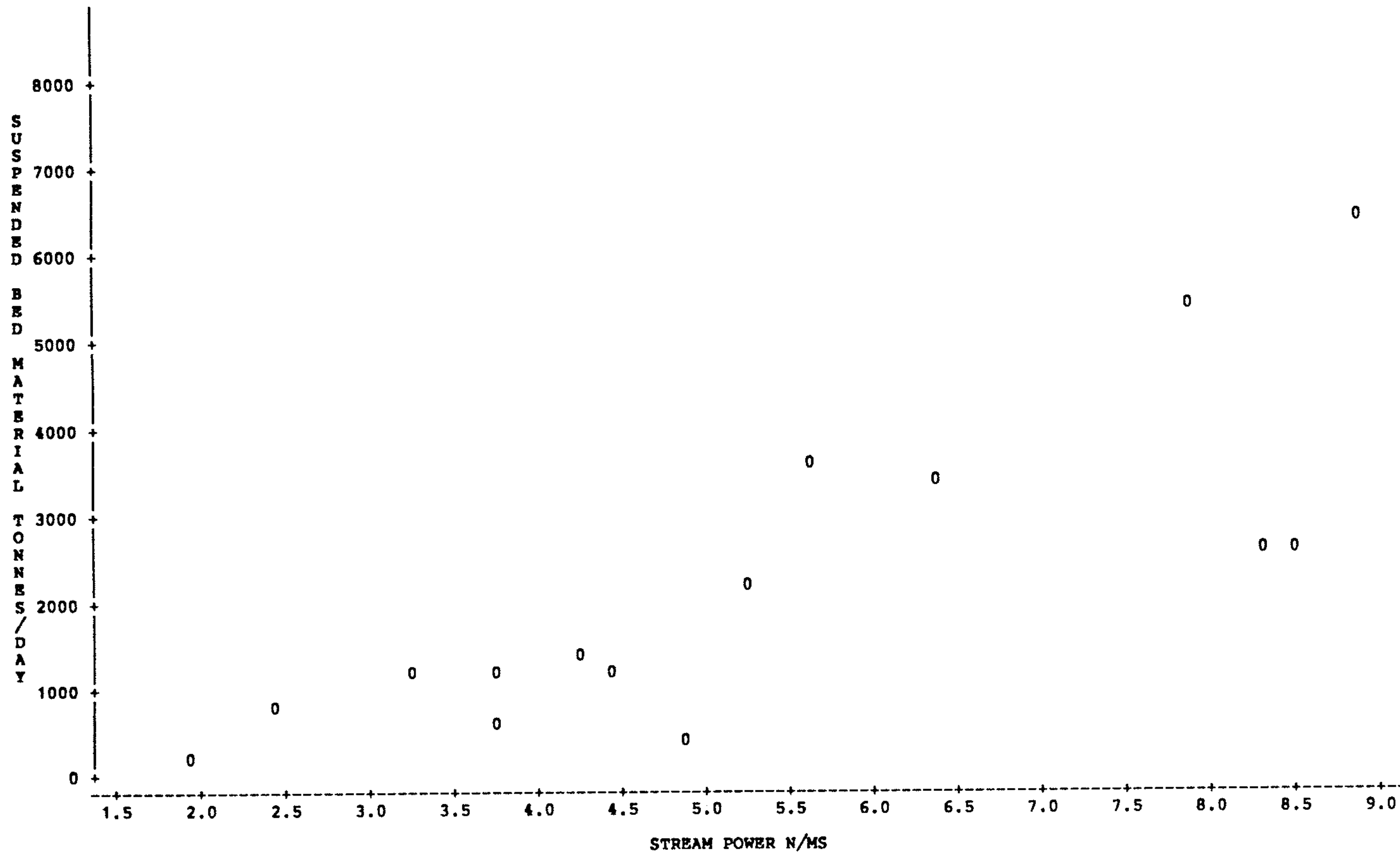



Fig. 137 QSBM VS. STREAM POWER AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*CHEZY SYMBOL USED IS 0

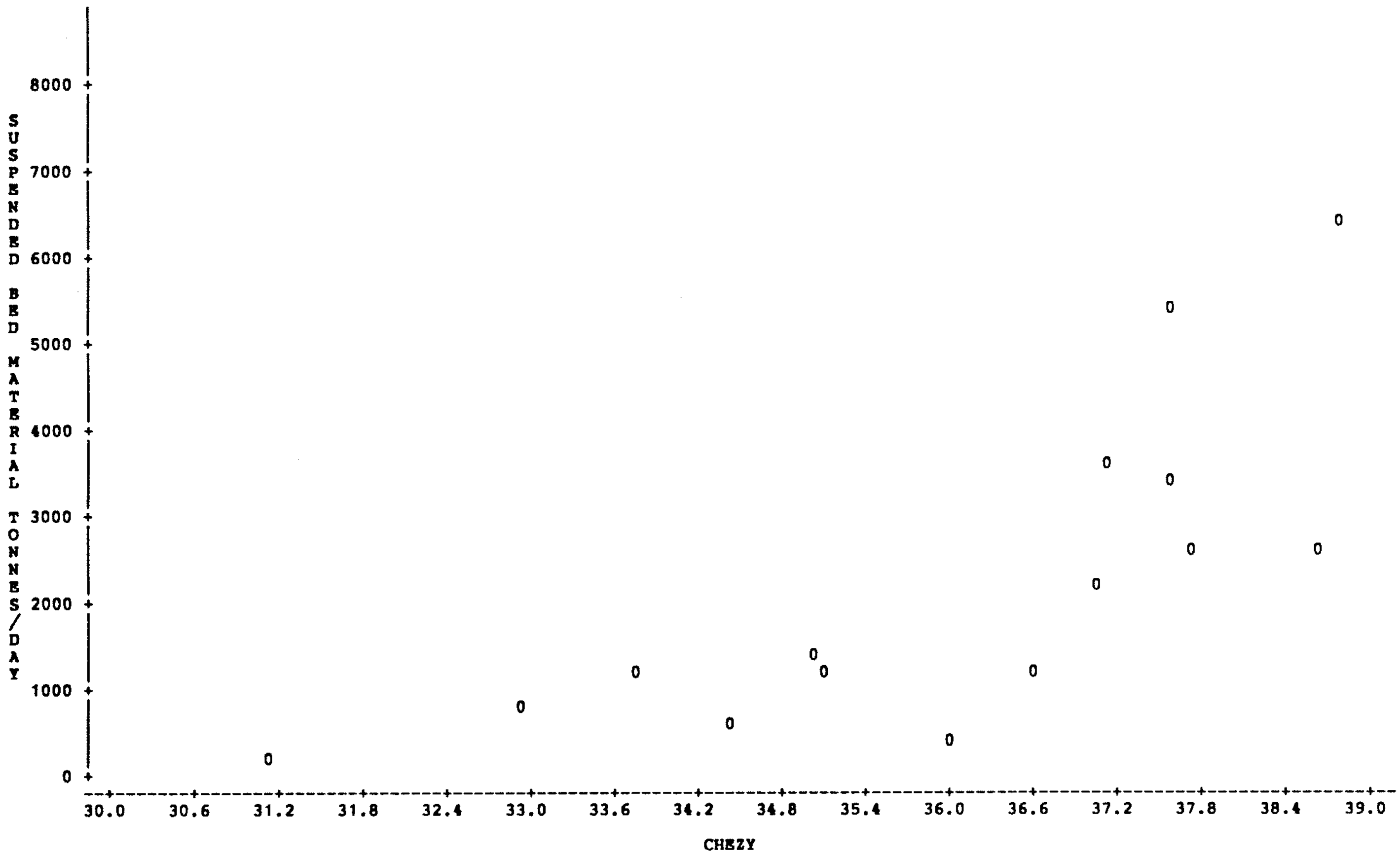



Fig. 138 QSBM VS. CHEZY AT HEADINGLEY

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STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QSBM*FROUDE SYMBOL USED IS 0

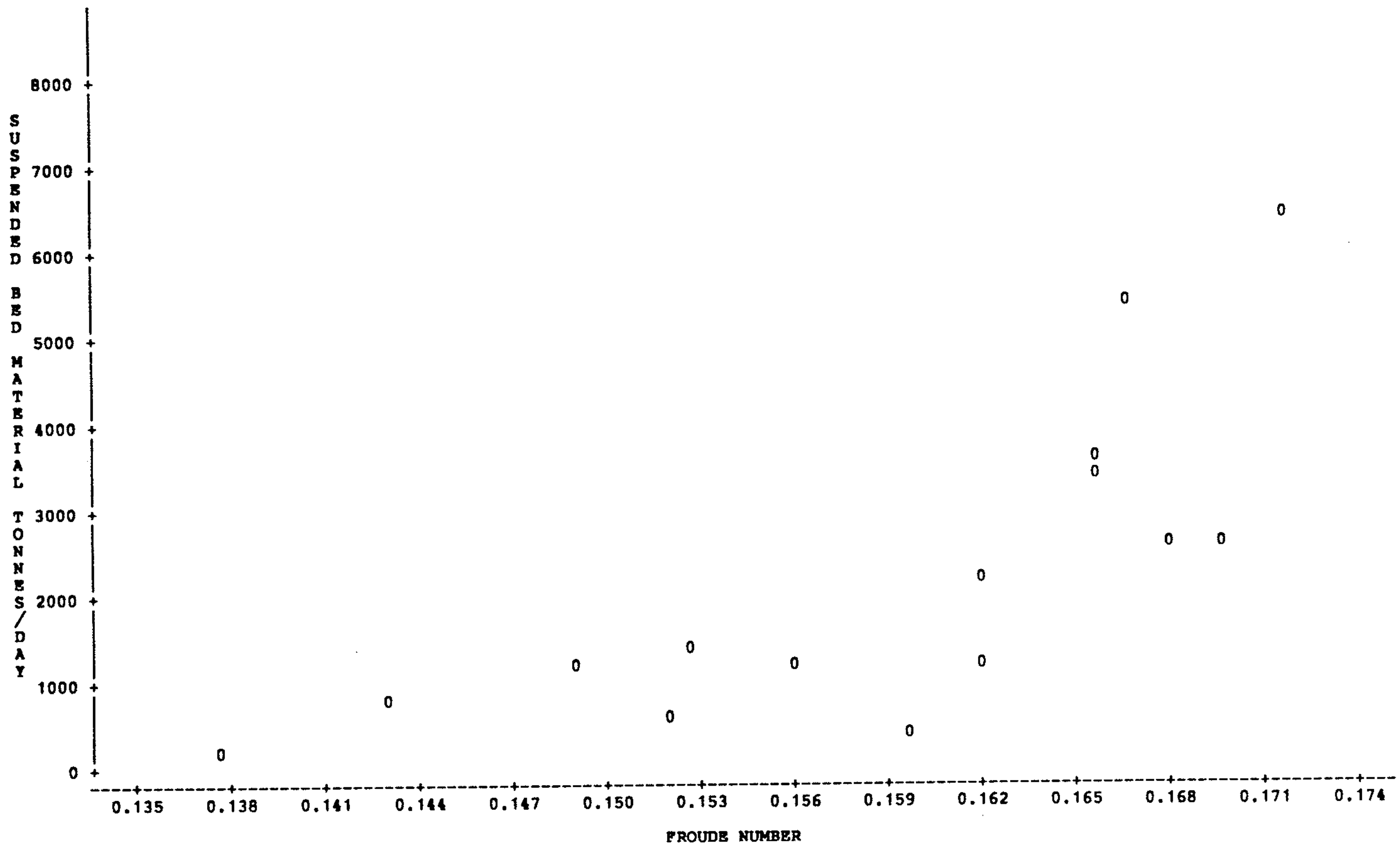



Fig. 139 QSBM VS. FROUDE NUMBER AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*SLOPE SYMBOL USED IS 0

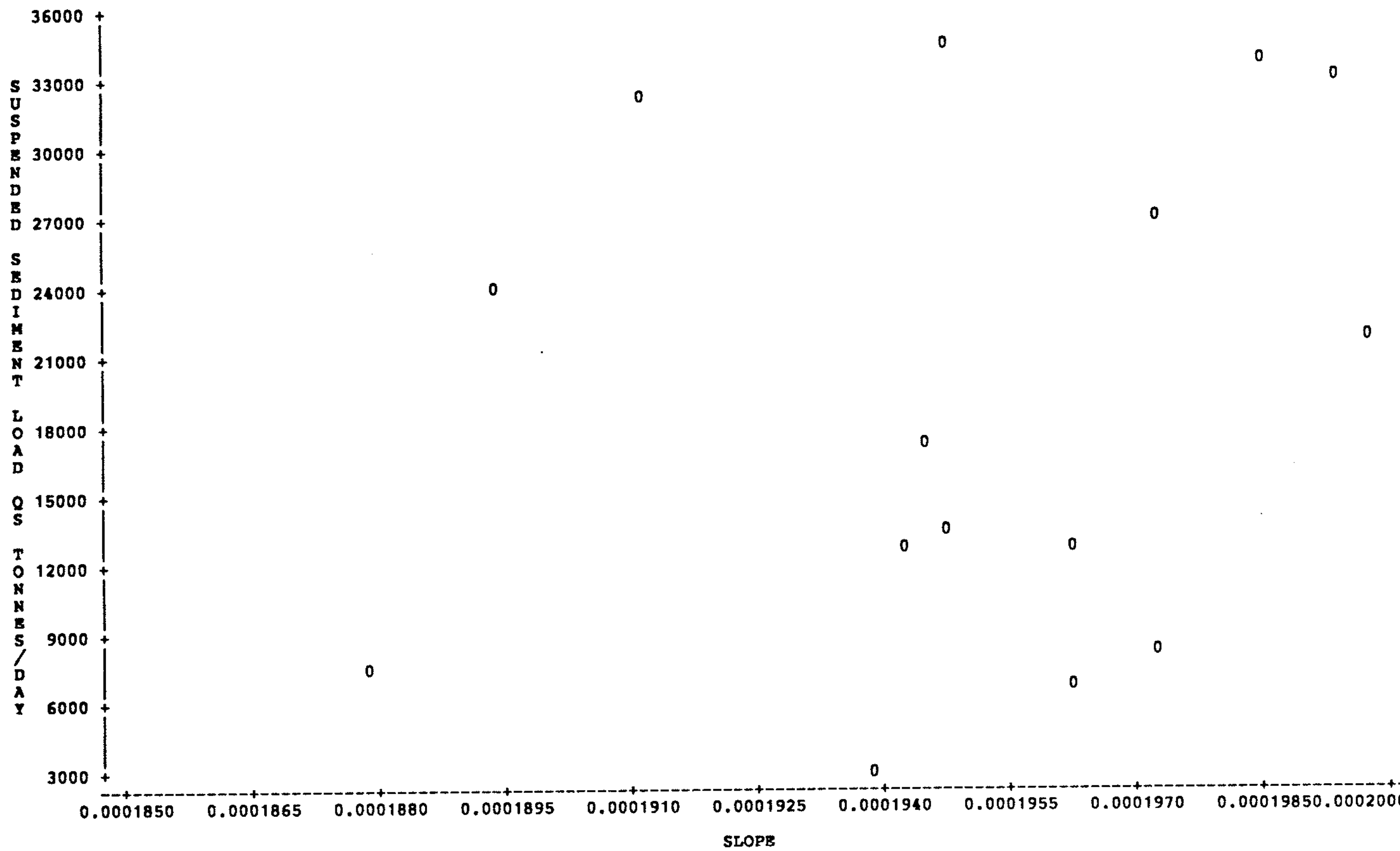



Fig. 140 QS VS. SLOPE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*Q SYMBOL USED IS 0

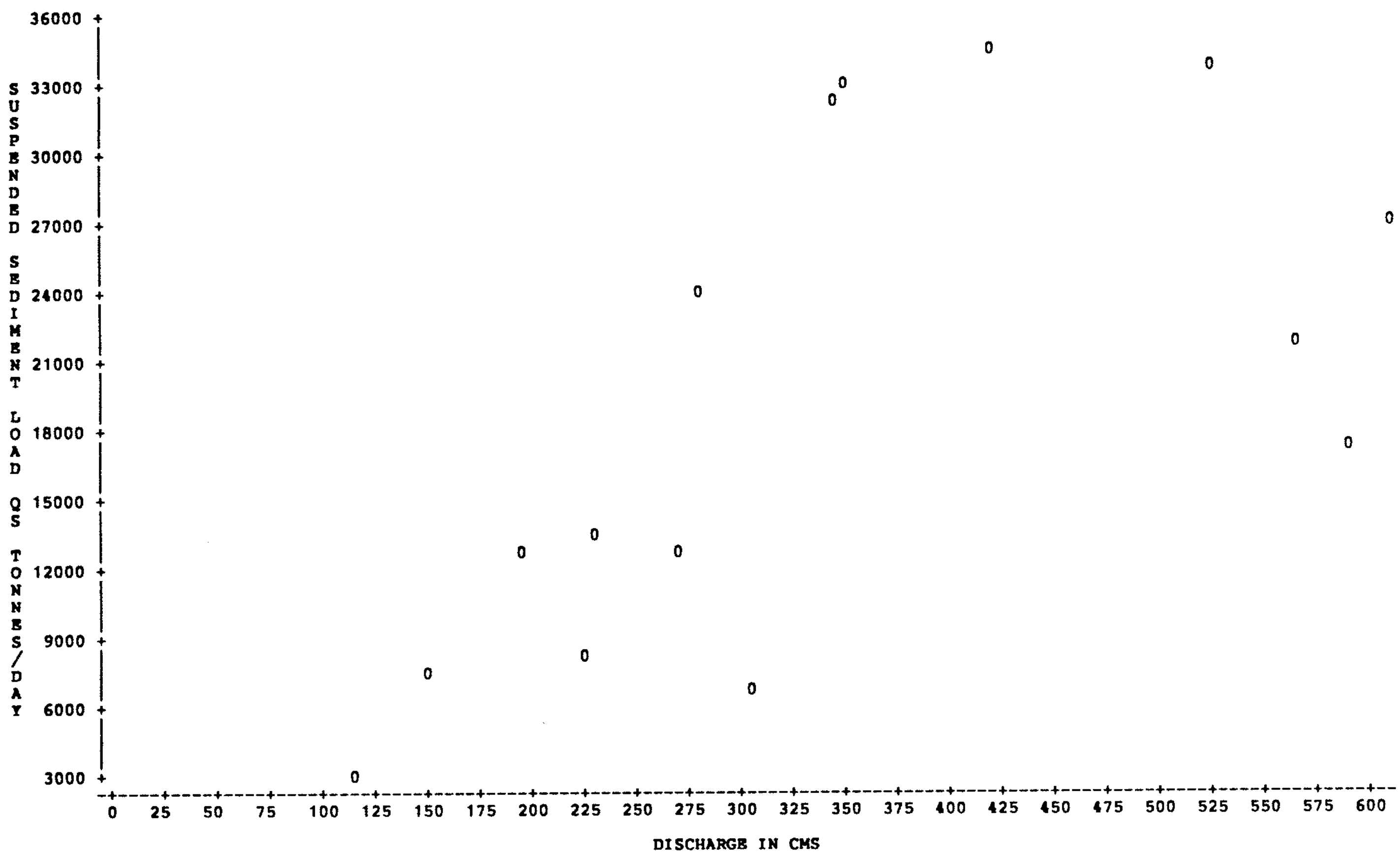



Fig. 142 QS VS. DISCHARGE AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*VELOC SYMBOL USED IS 0

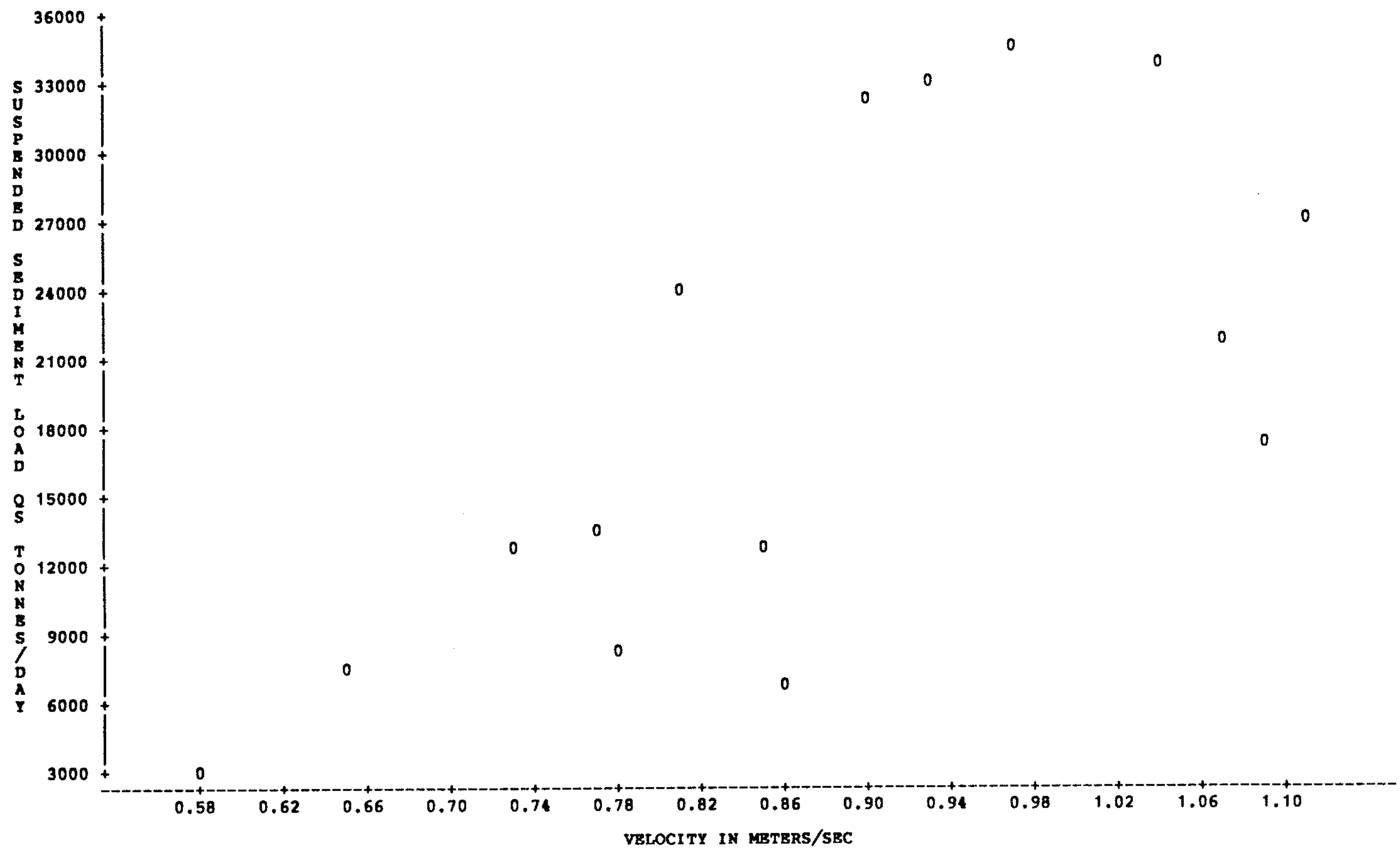



Fig. 143 QS VS. VELOCITY AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*DEPTH SYMBOL USED IS 0

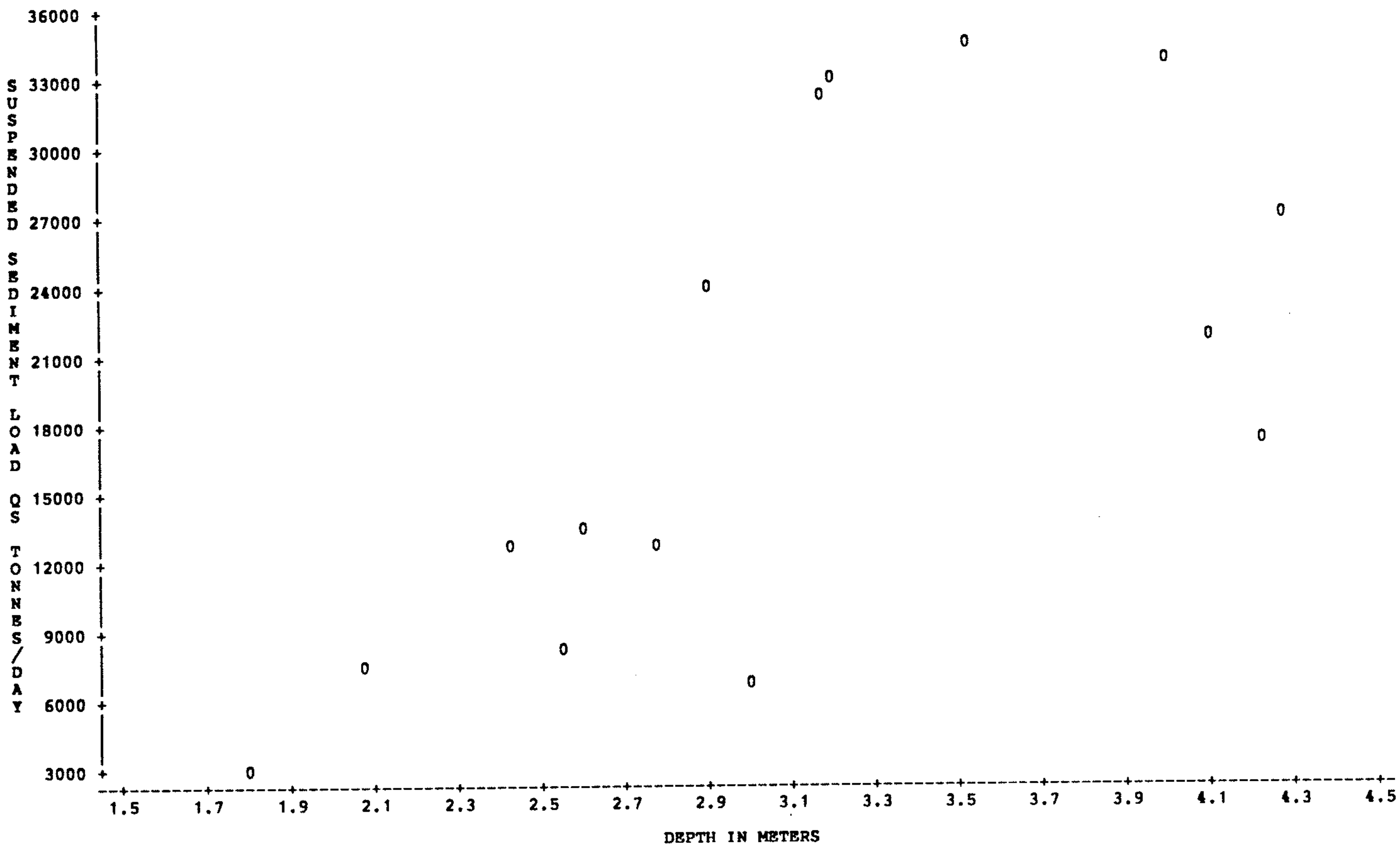



Fig. 144 QS VS. DEPTH AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*VS SYMBOL USED IS 0

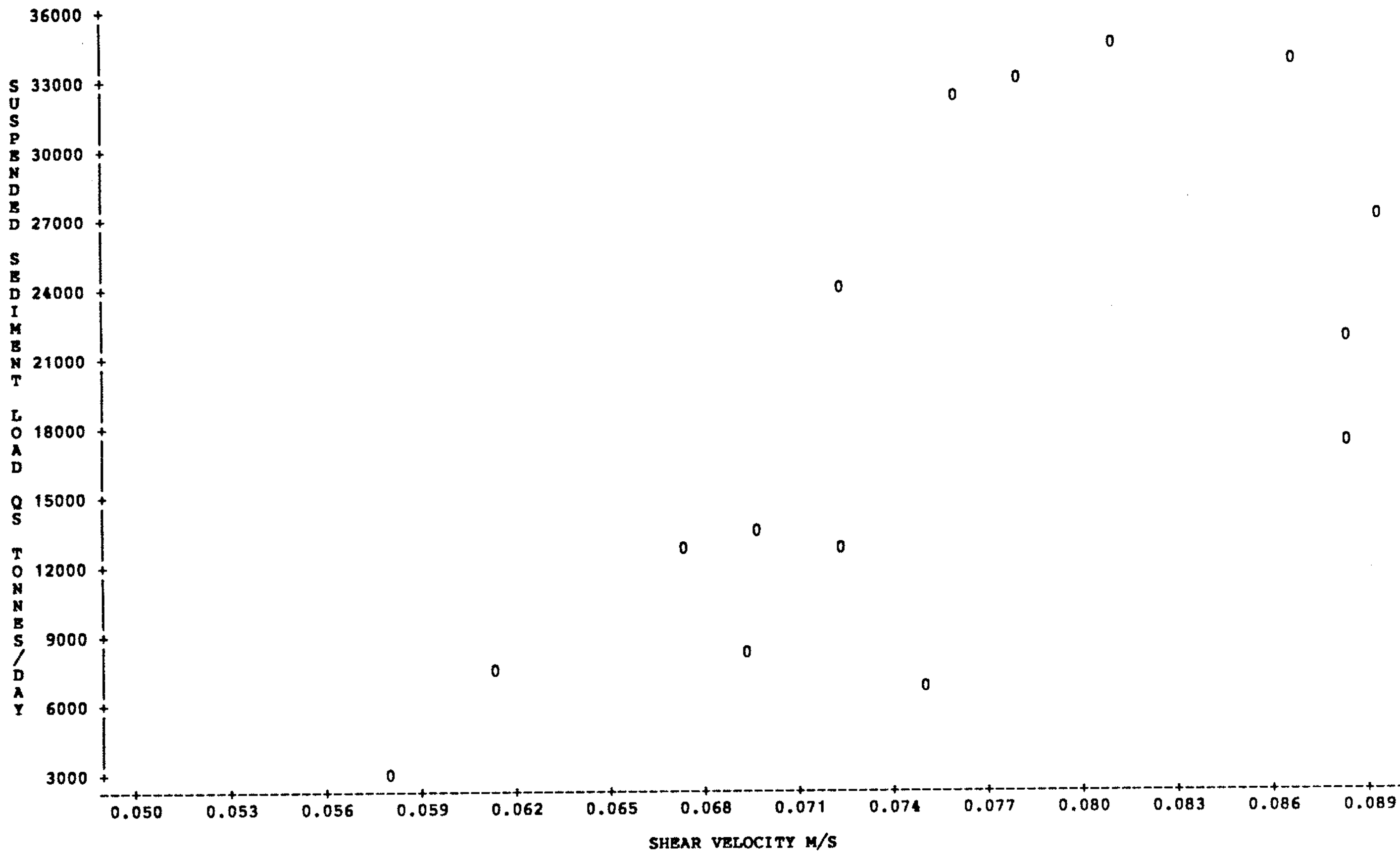



Fig. 145 QS VS. SHEAR VELOCITY AT HEADINGLEY

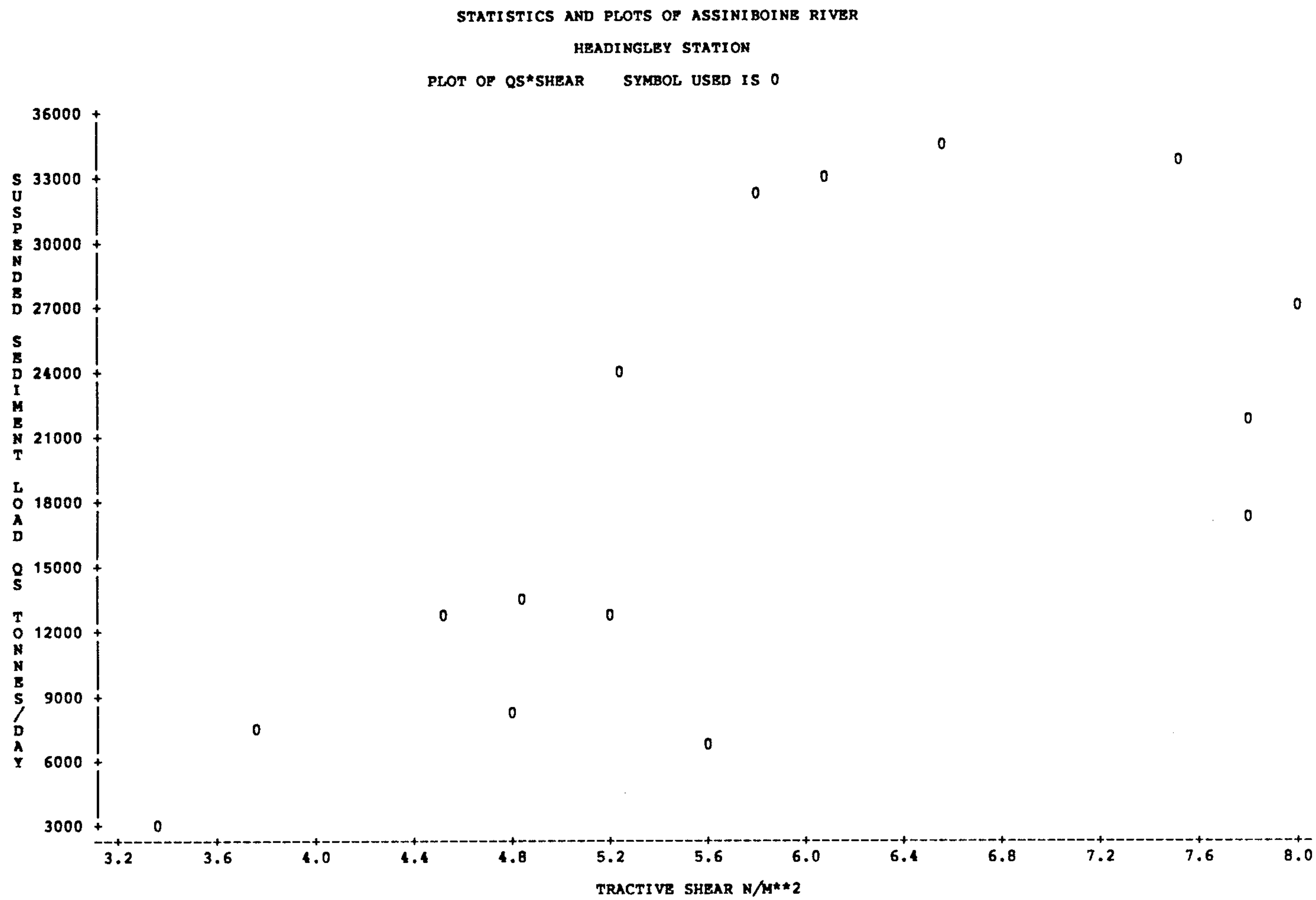



Fig. 146 QS VS. TRACTIVE SHEAR AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*POWER SYMBOL USED IS 0

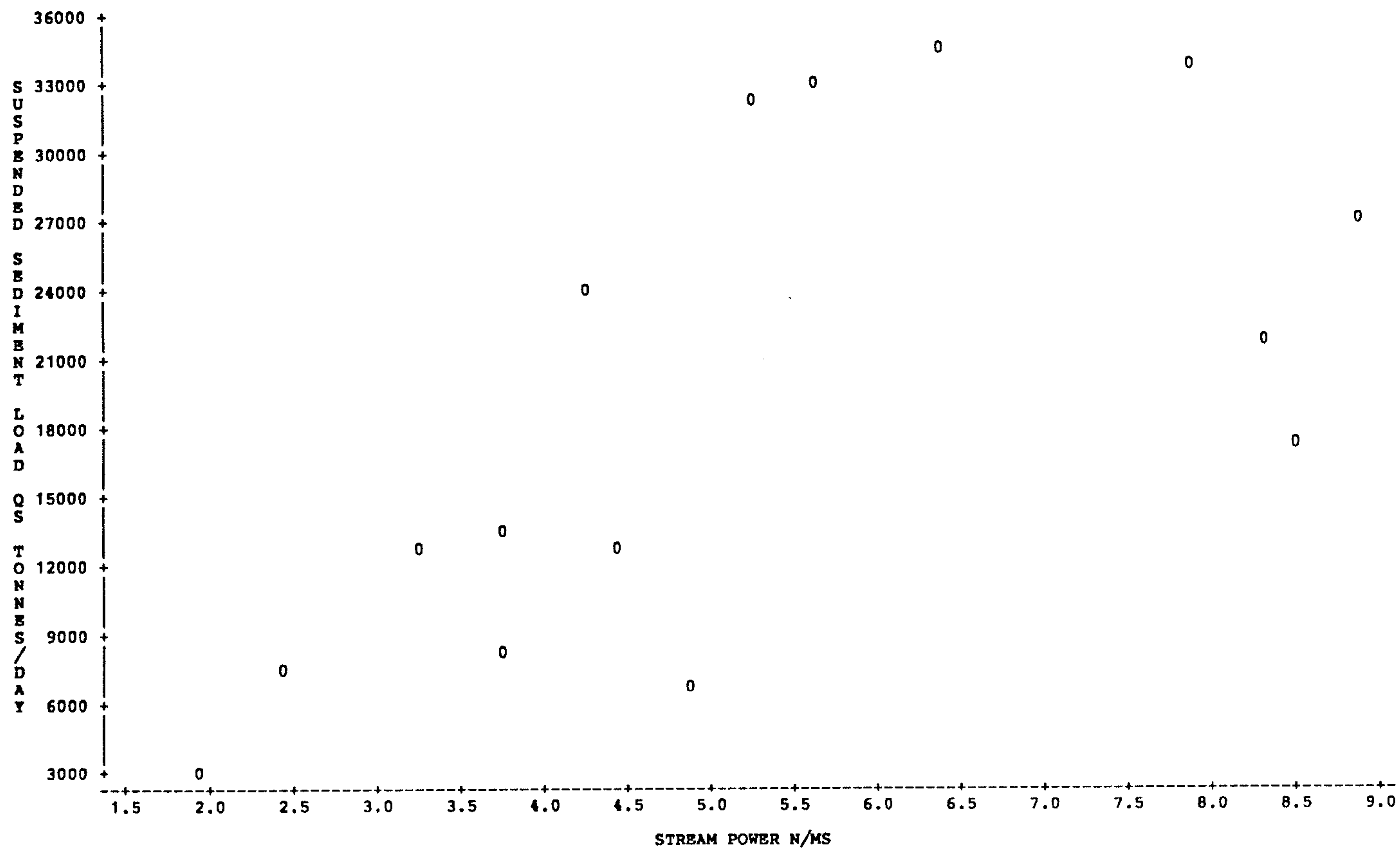



Fig. 147 QS VS. STREAM POWER AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*CHEZY SYMBOL USED IS 0

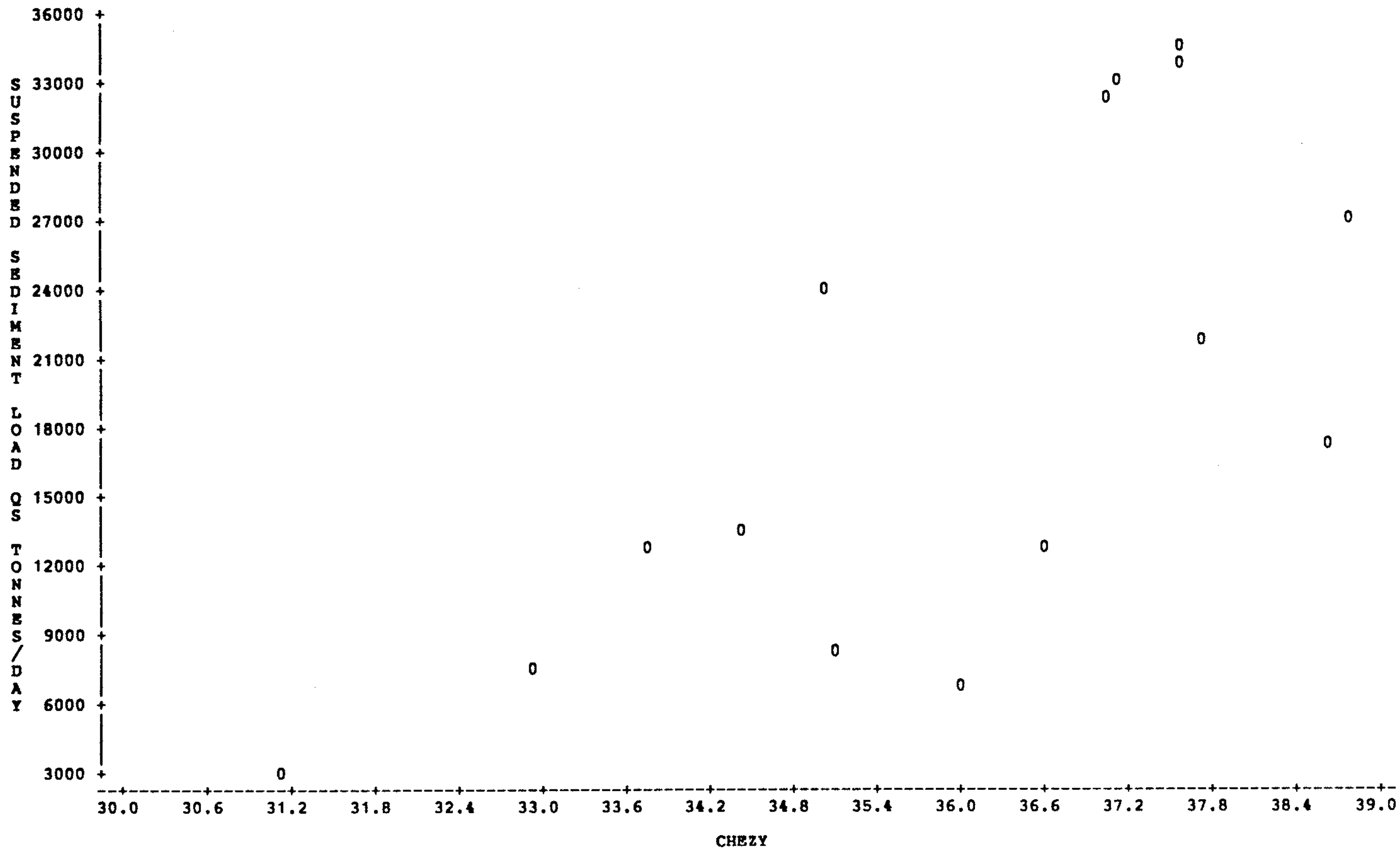



Fig. 148 QS VS. CHEZY AT HEADINGLEY

STATISTICS AND PLOTS OF ASSINIBOINE RIVER

HEADINGLEY STATION

PLOT OF QS*FROUDE    SYMBOL USED IS 0

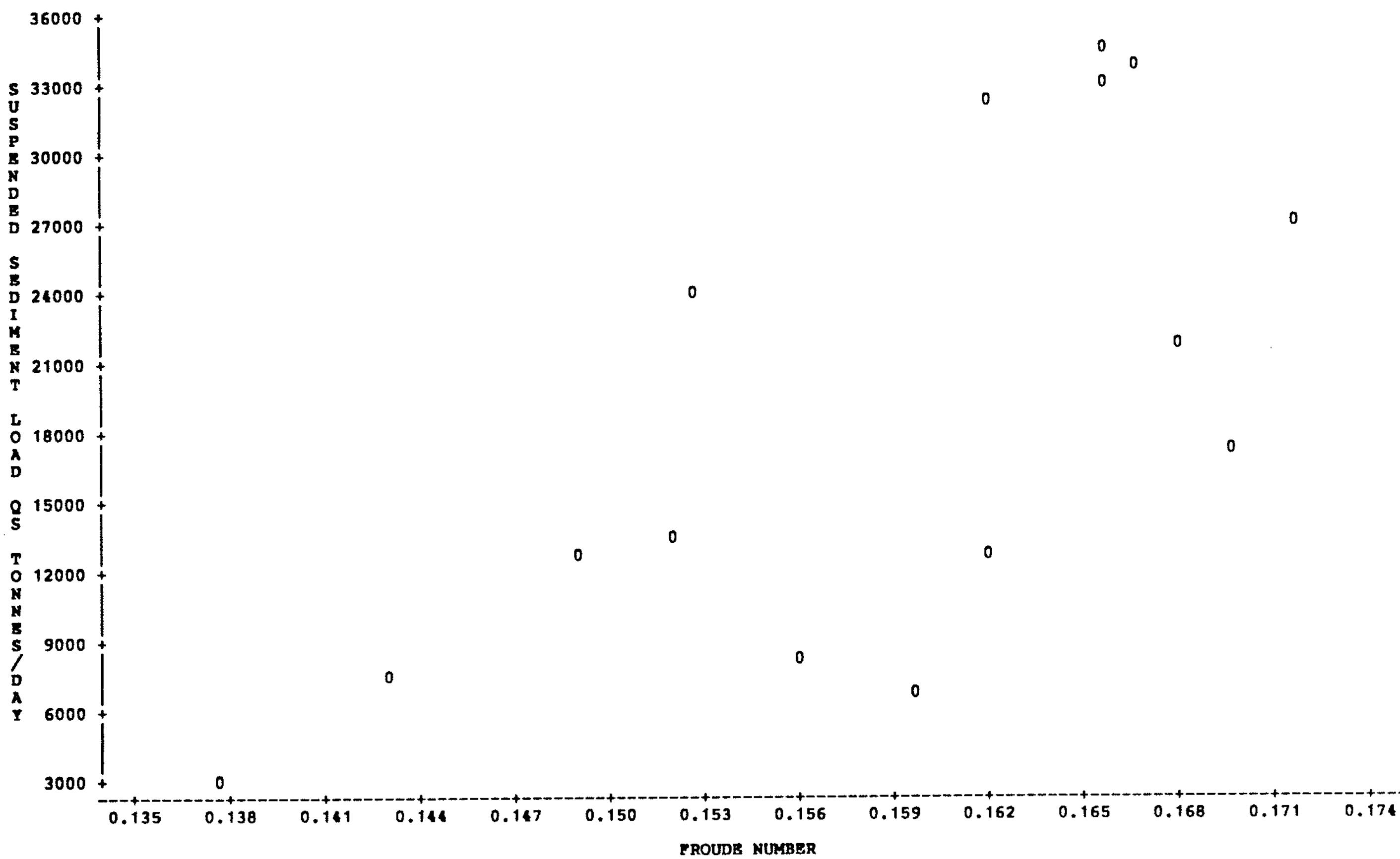



Fig. 149 QS VS. FROUDE NUMBER AT HEADINGLEY

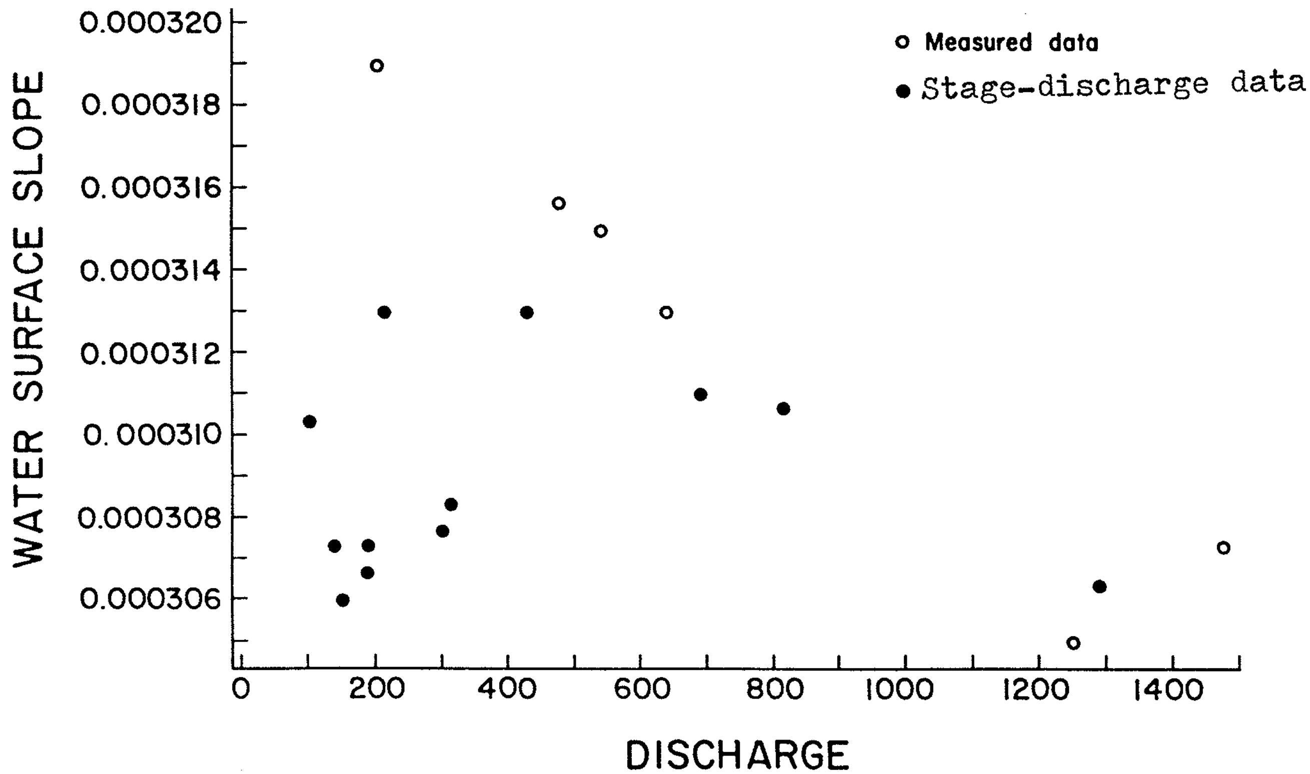
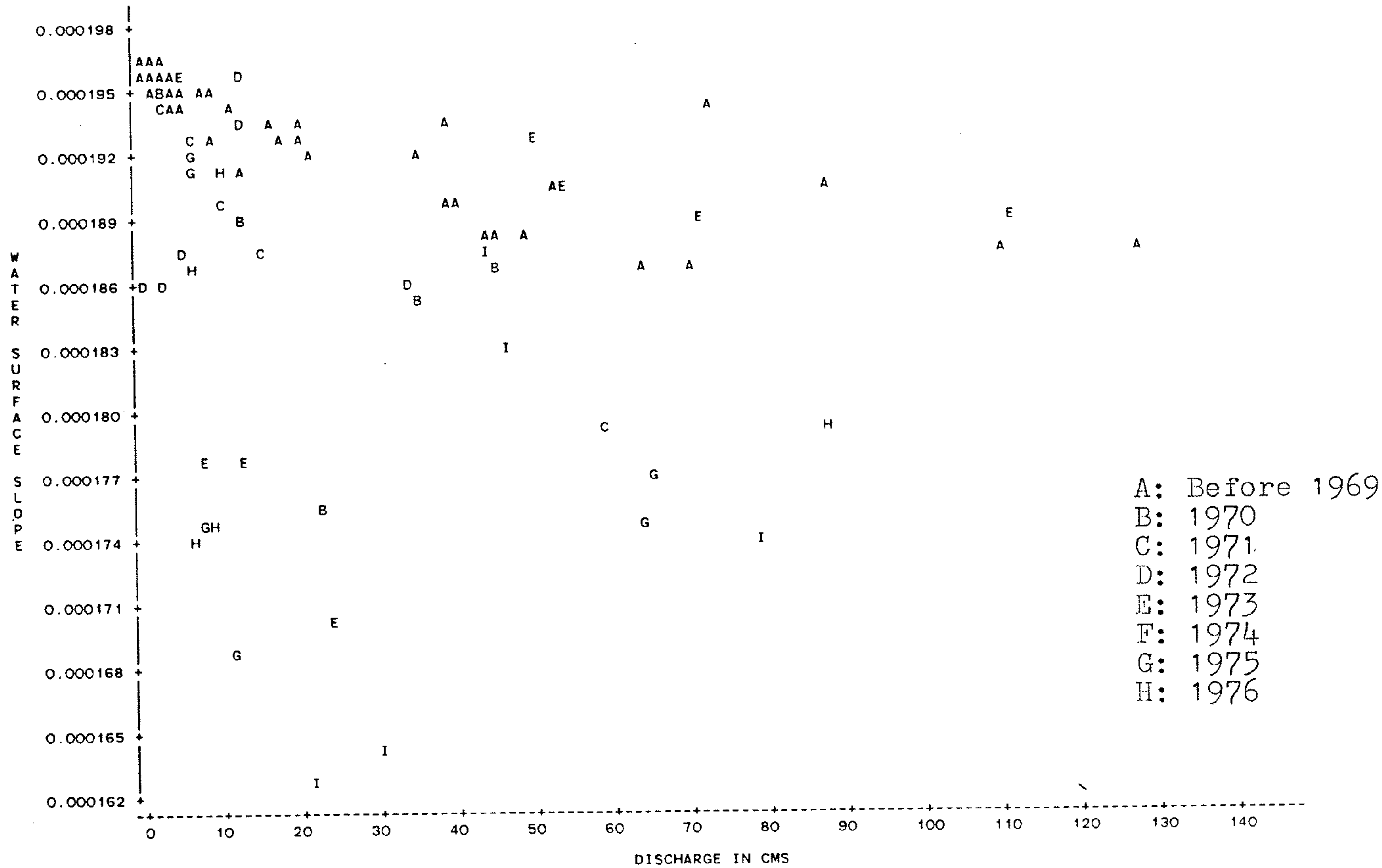



FIG. 149: Stage-discharge and measured data for slope vs. discharge at Holland.

SLOPE VS. DISCHARGE AT RUSSELL 13:43 THURSDAY, MAY 23, 1985 3

PLOT OF SLOPE*QMET SYMBOL IS VALUE OF YEAR




NOTE: 18 OBS HIDDEN

FIG. 150: SLOPE VS. DISCHARGE AT RUSSELL

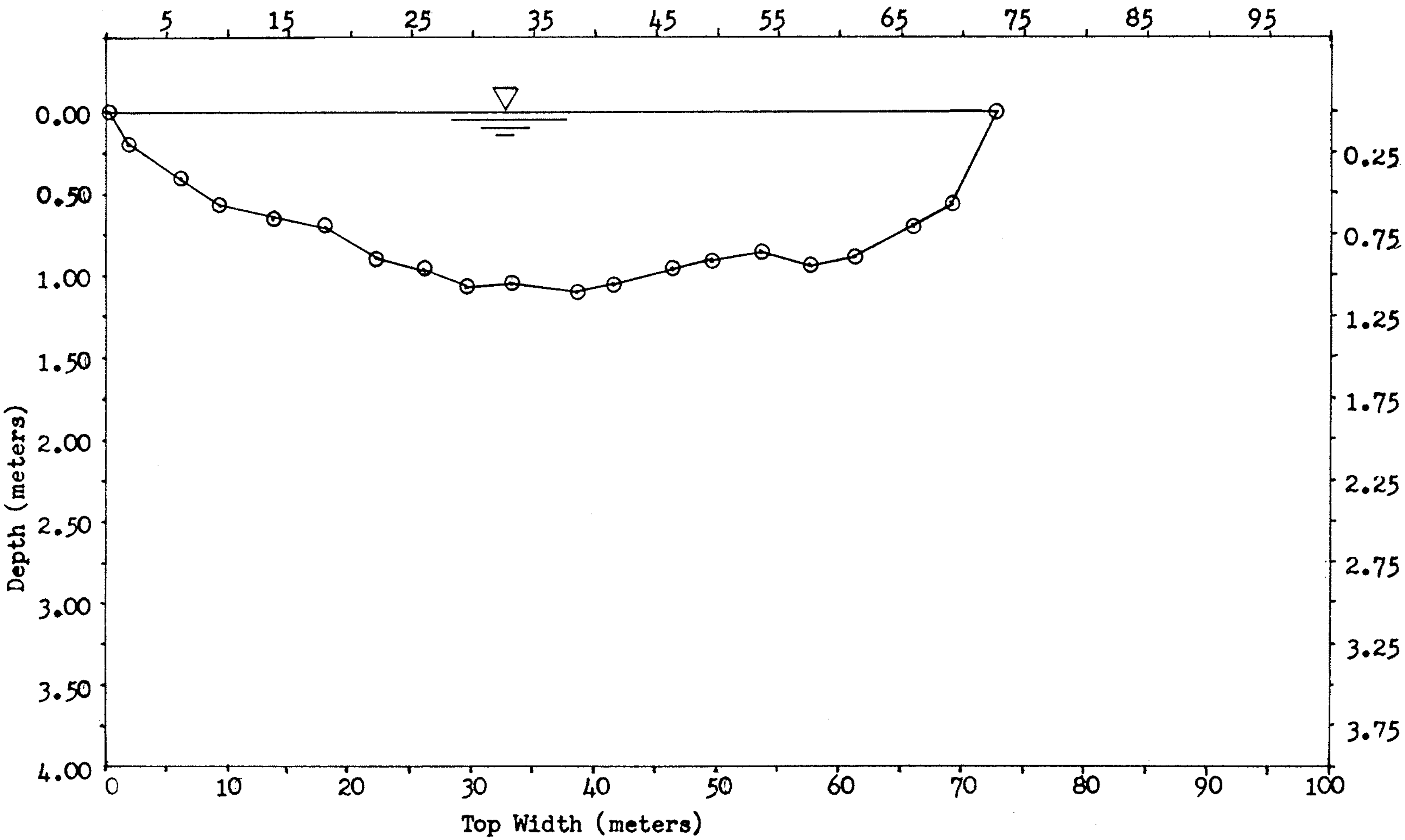



Fig. 151: MOBED CROSS-SECTION 1

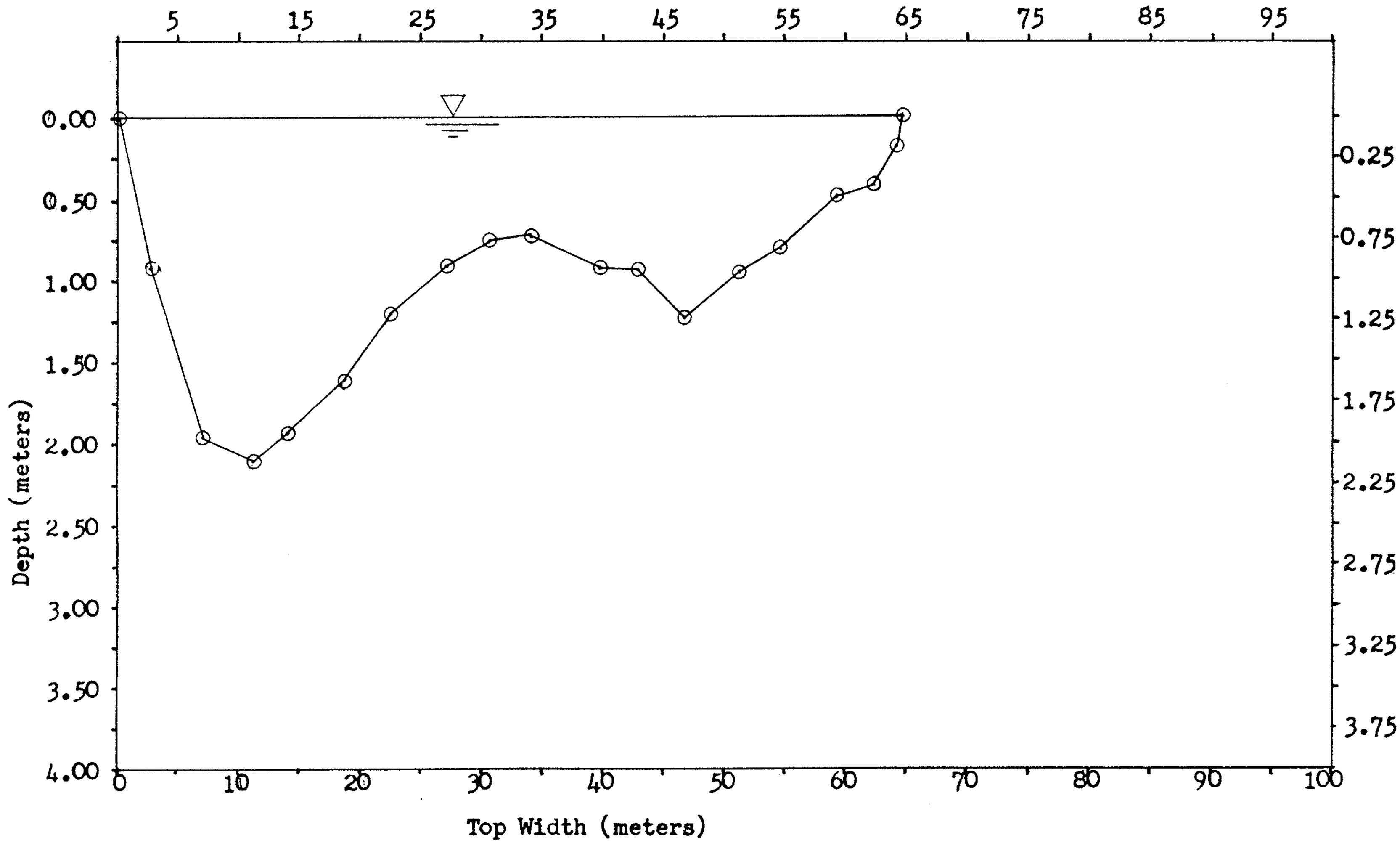



Fig. 152: MOBED CROSS-SECTION 2

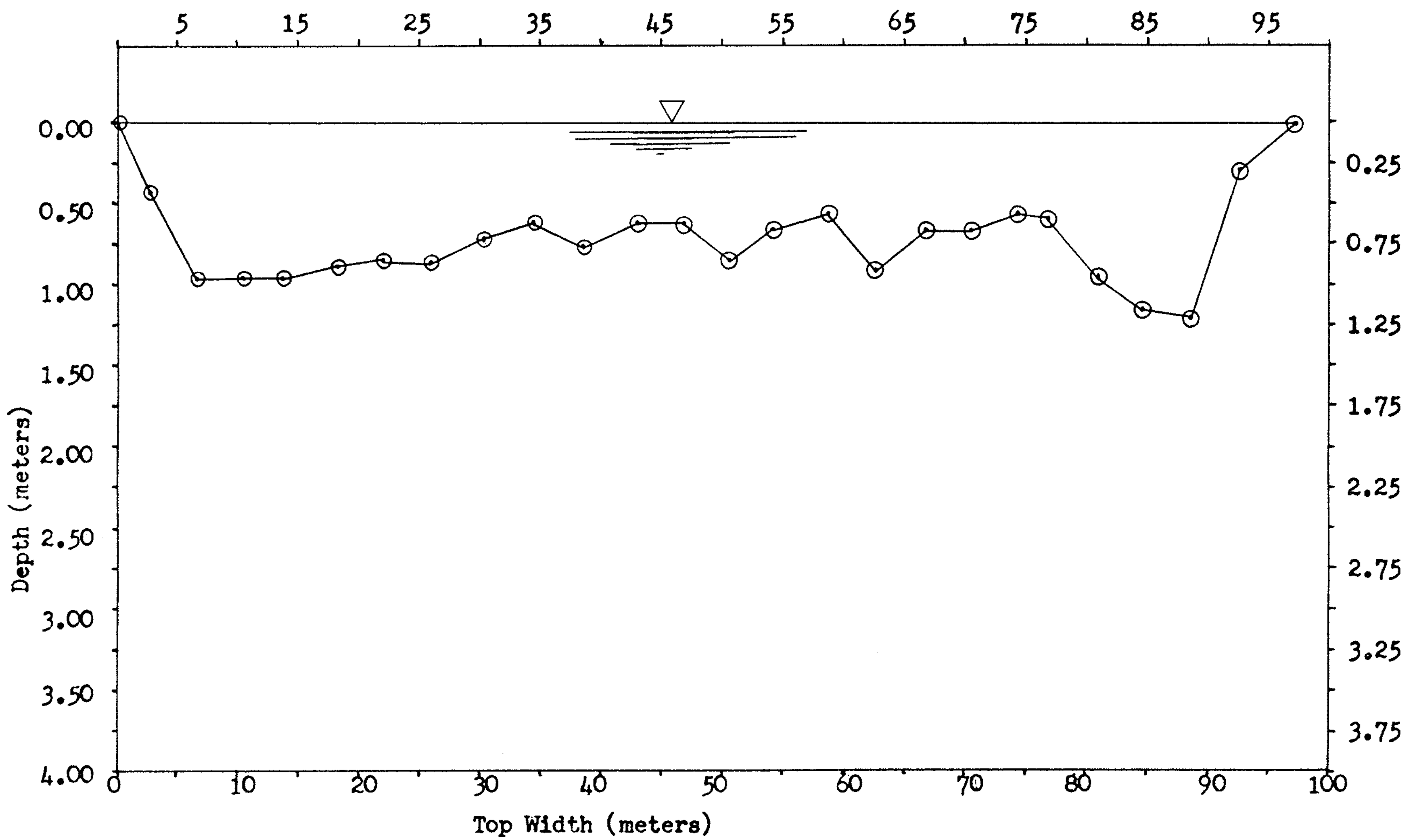



Fig. 153: MOBED CROSS-SECTION 3

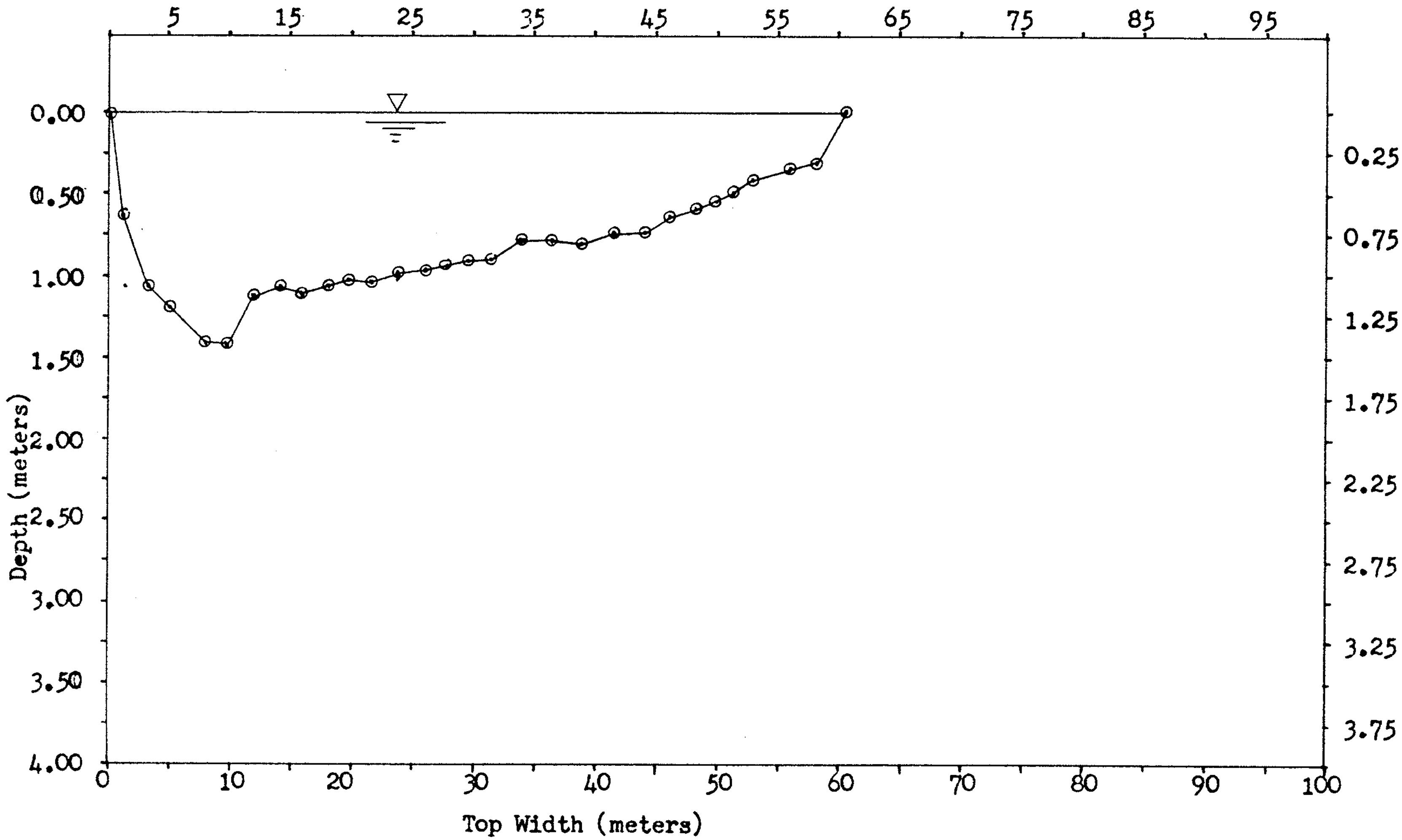



Fig. 154: MOBED CROSS-SECTION 4

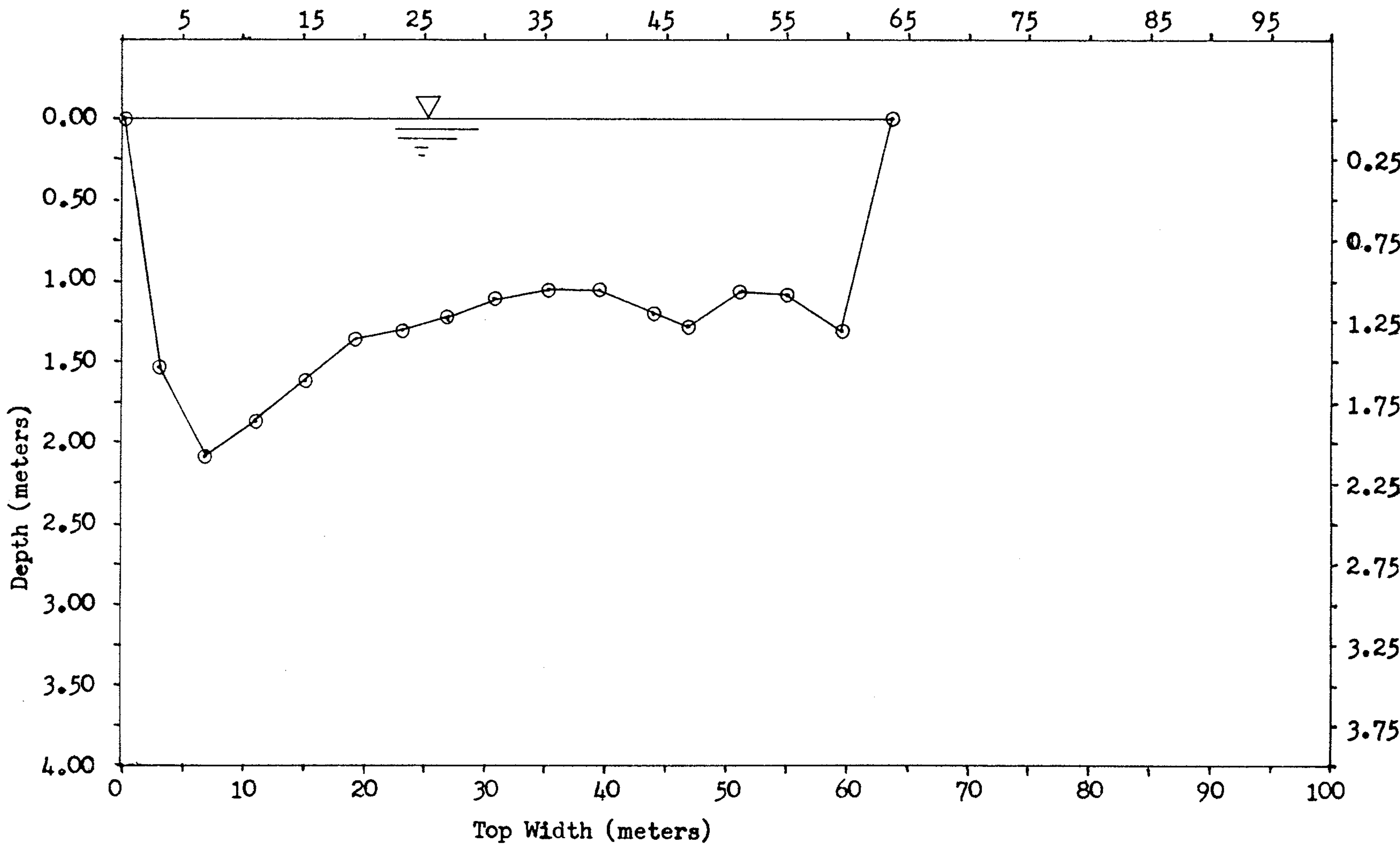



Fig. 155: MOBED CROSS-SECTION 5

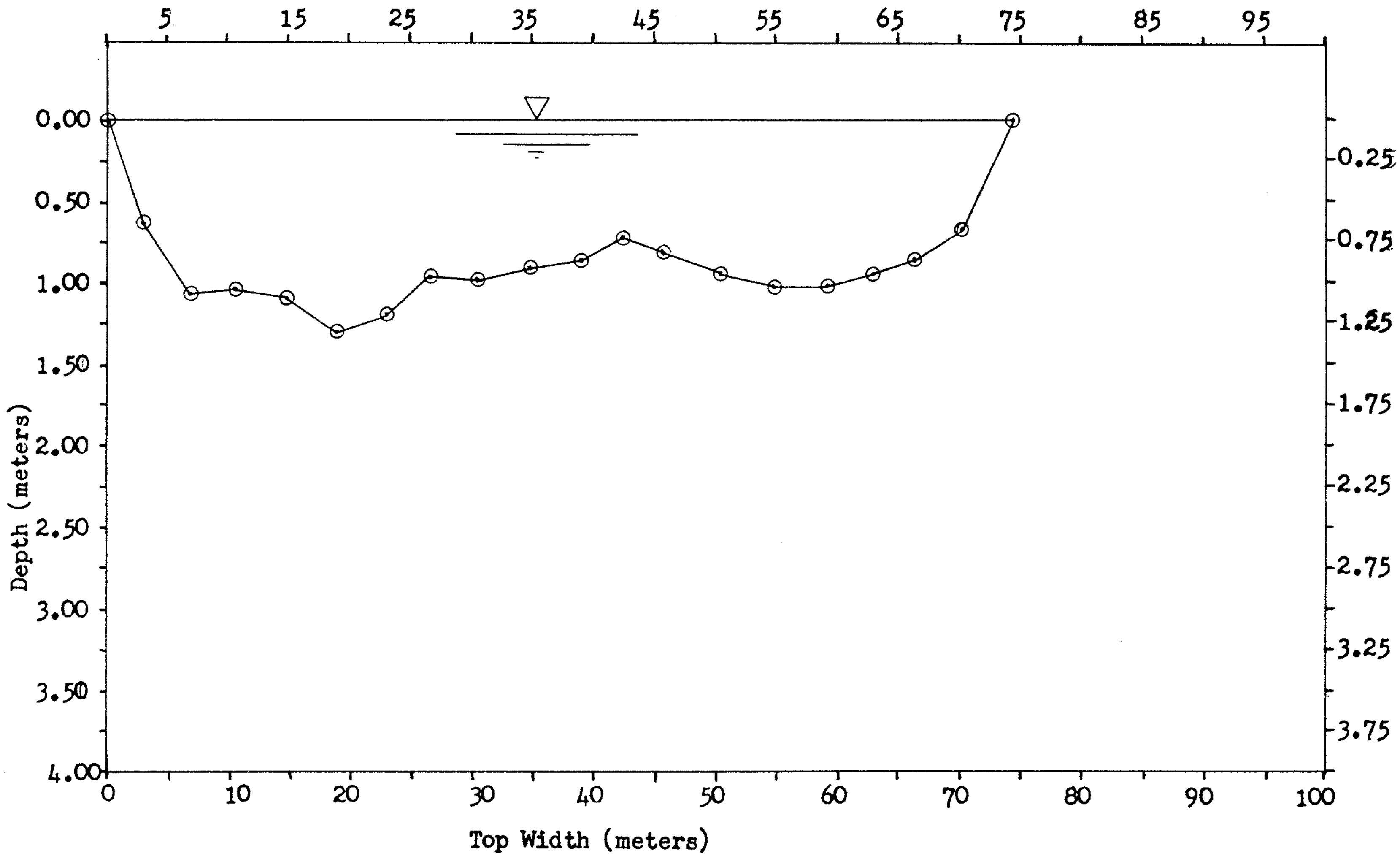



Fig. 156: MOBED CROSS-SECTION 6

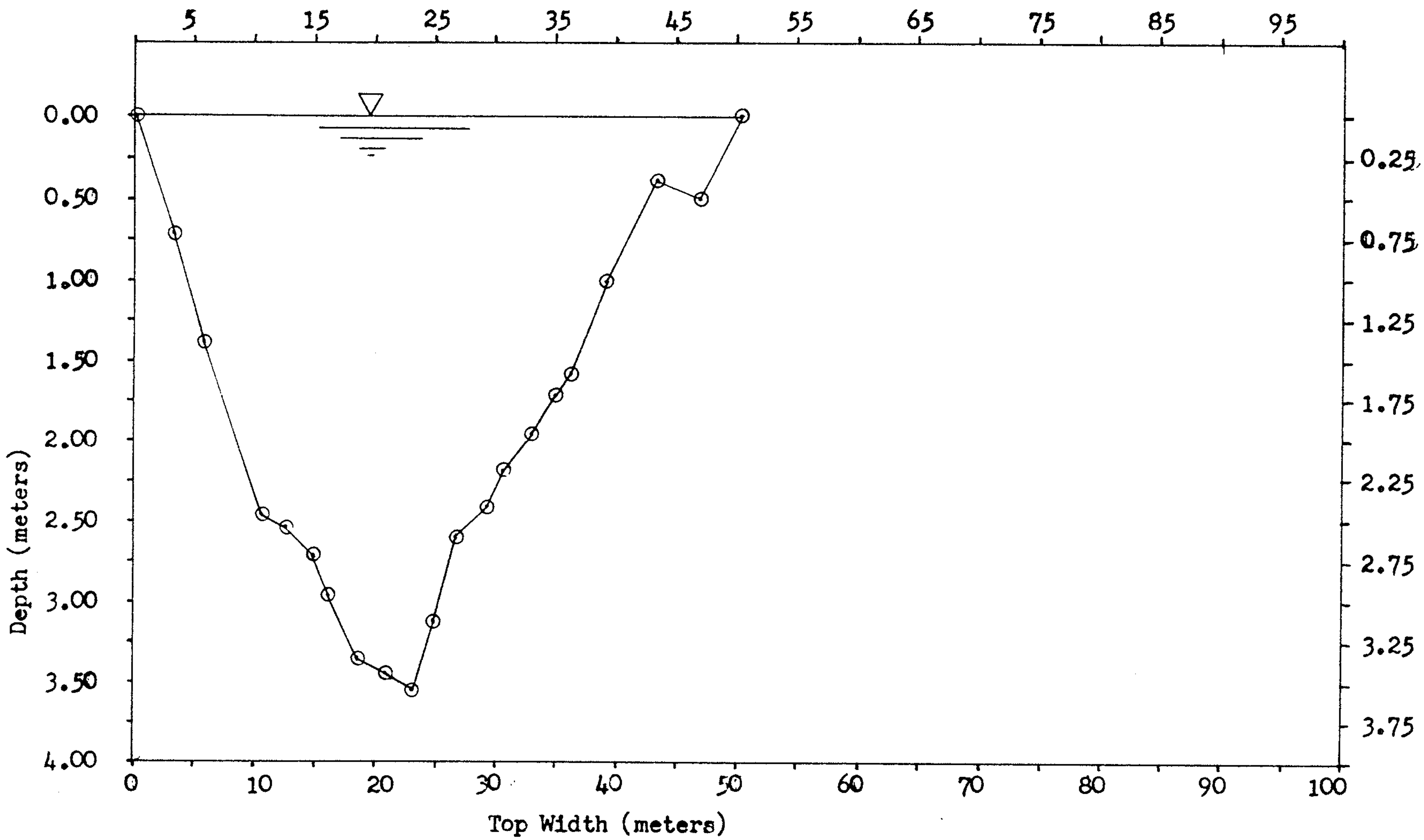



Fig. 157: MOBED CROSS-SECTION 7

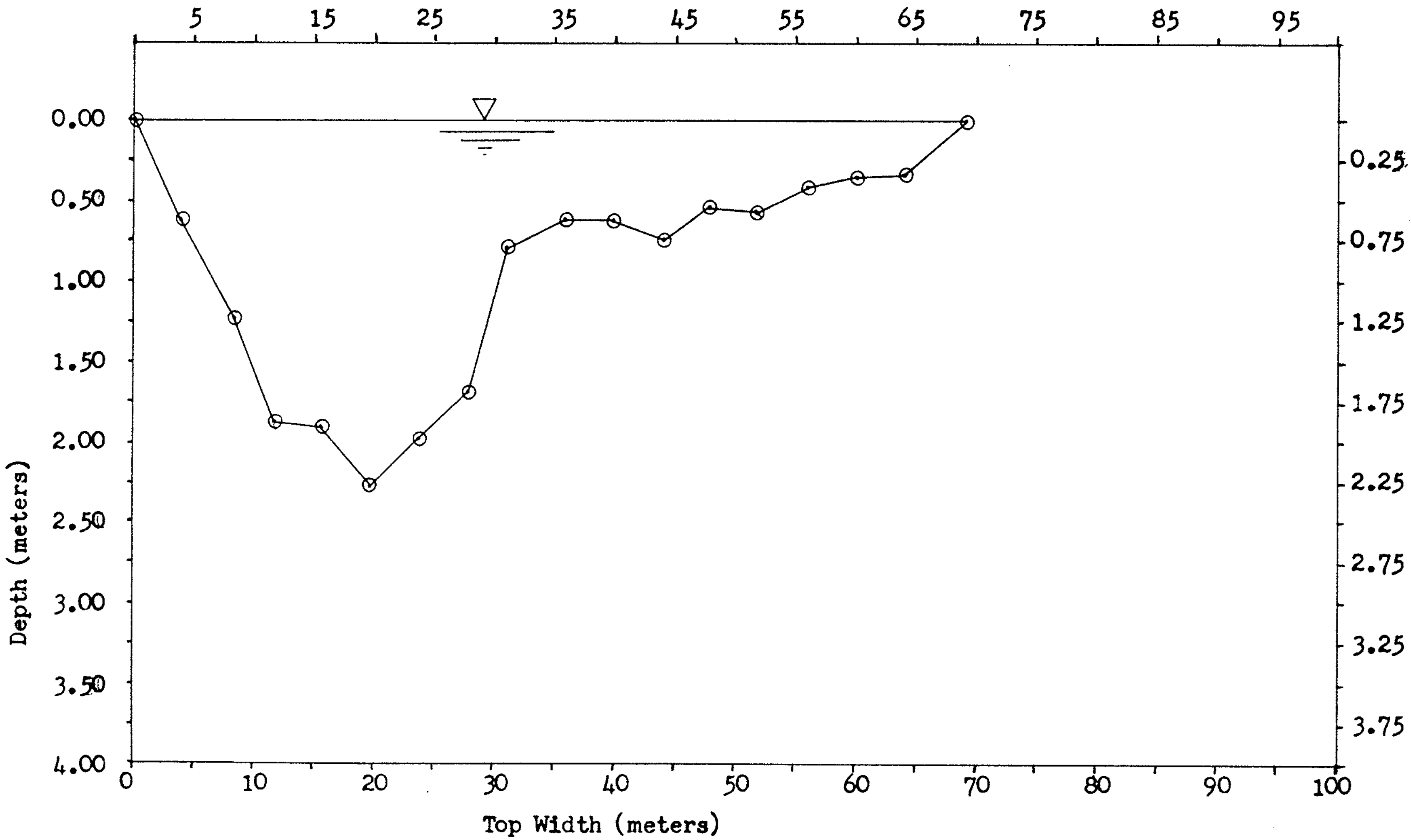



Fig. 158: MOBED CROSS-SECTION 8

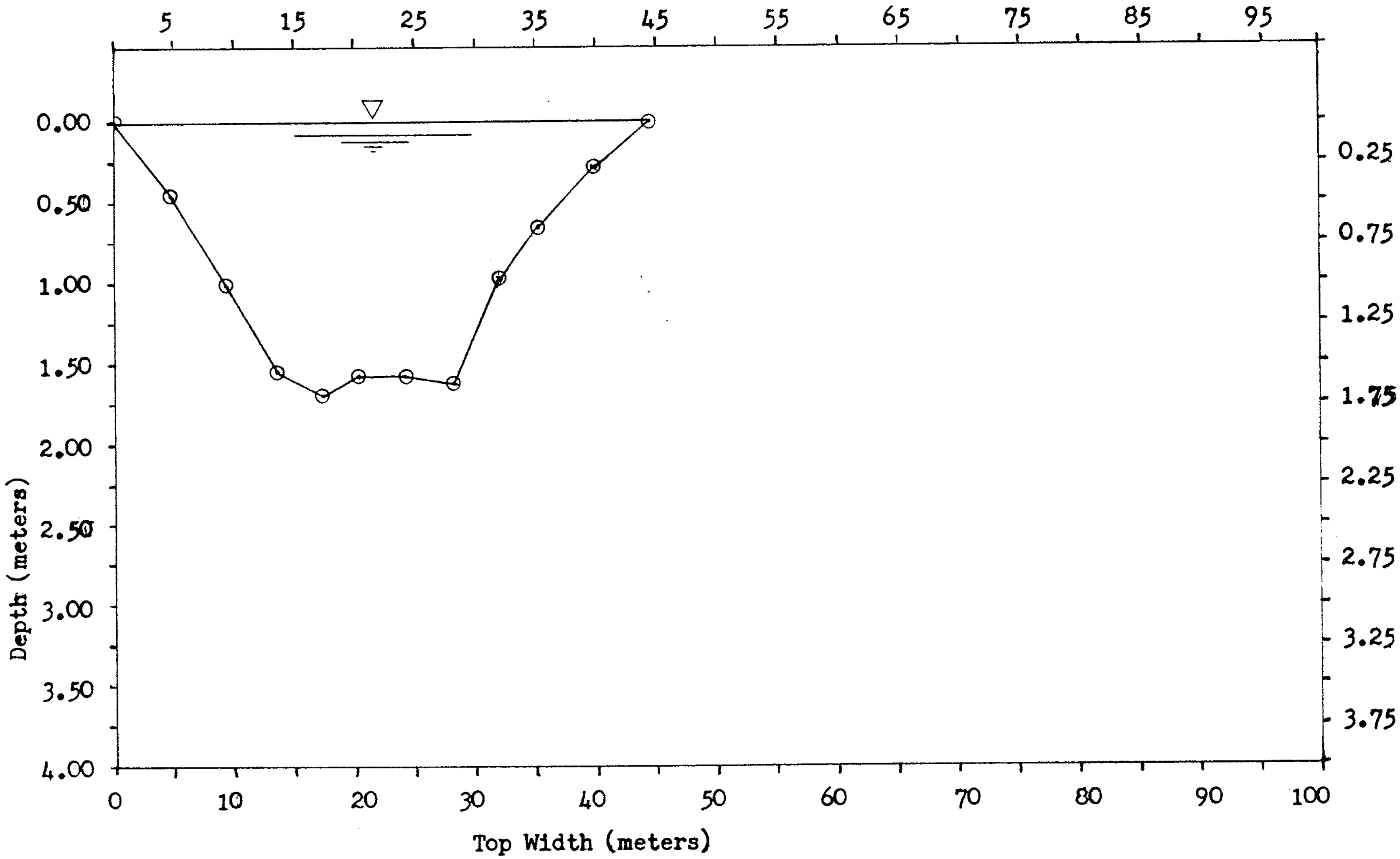



Fig. 159: MOBED CROSS-SECTION 9

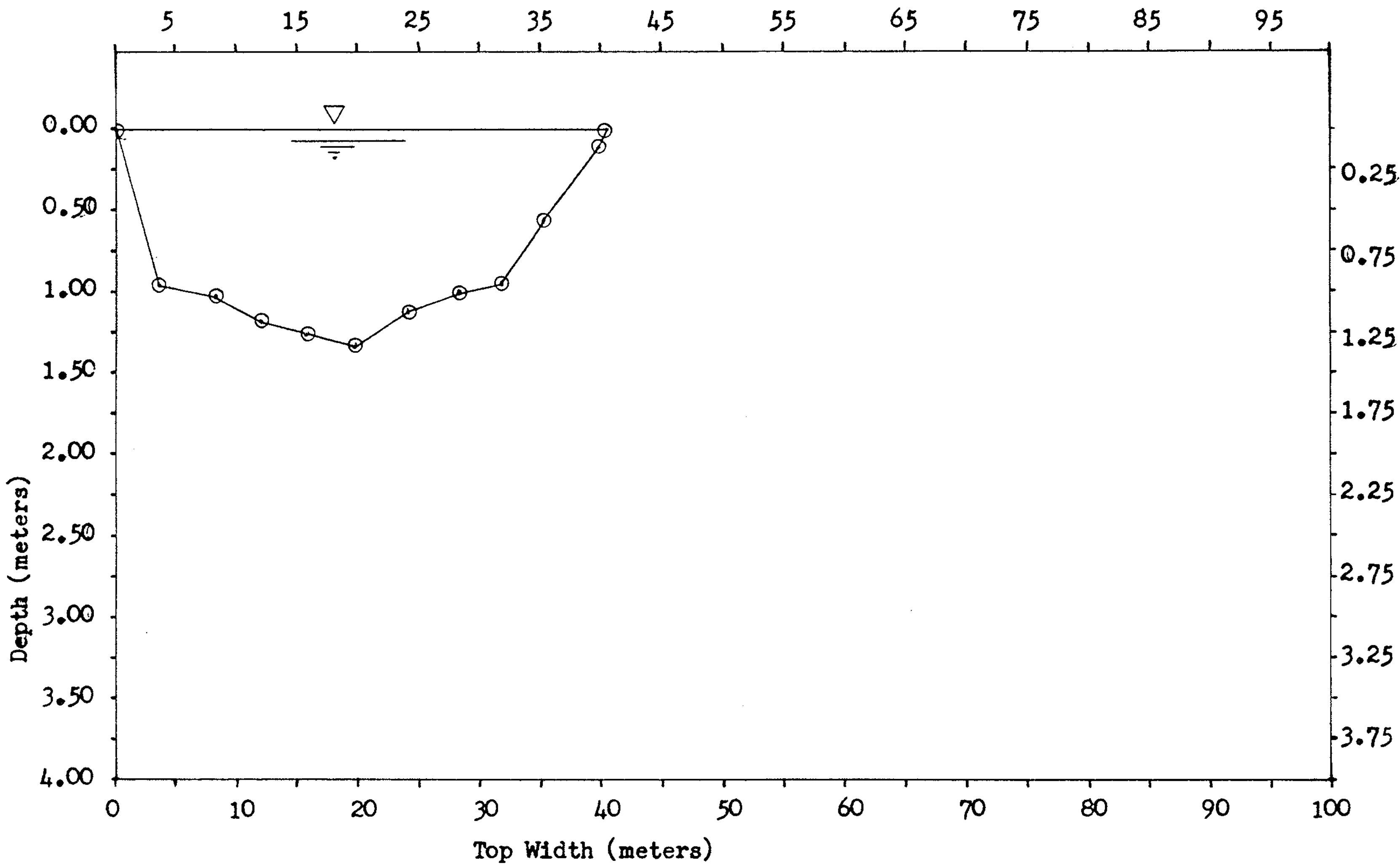



Fig. 160: MOBED CROSS-SECTION 10

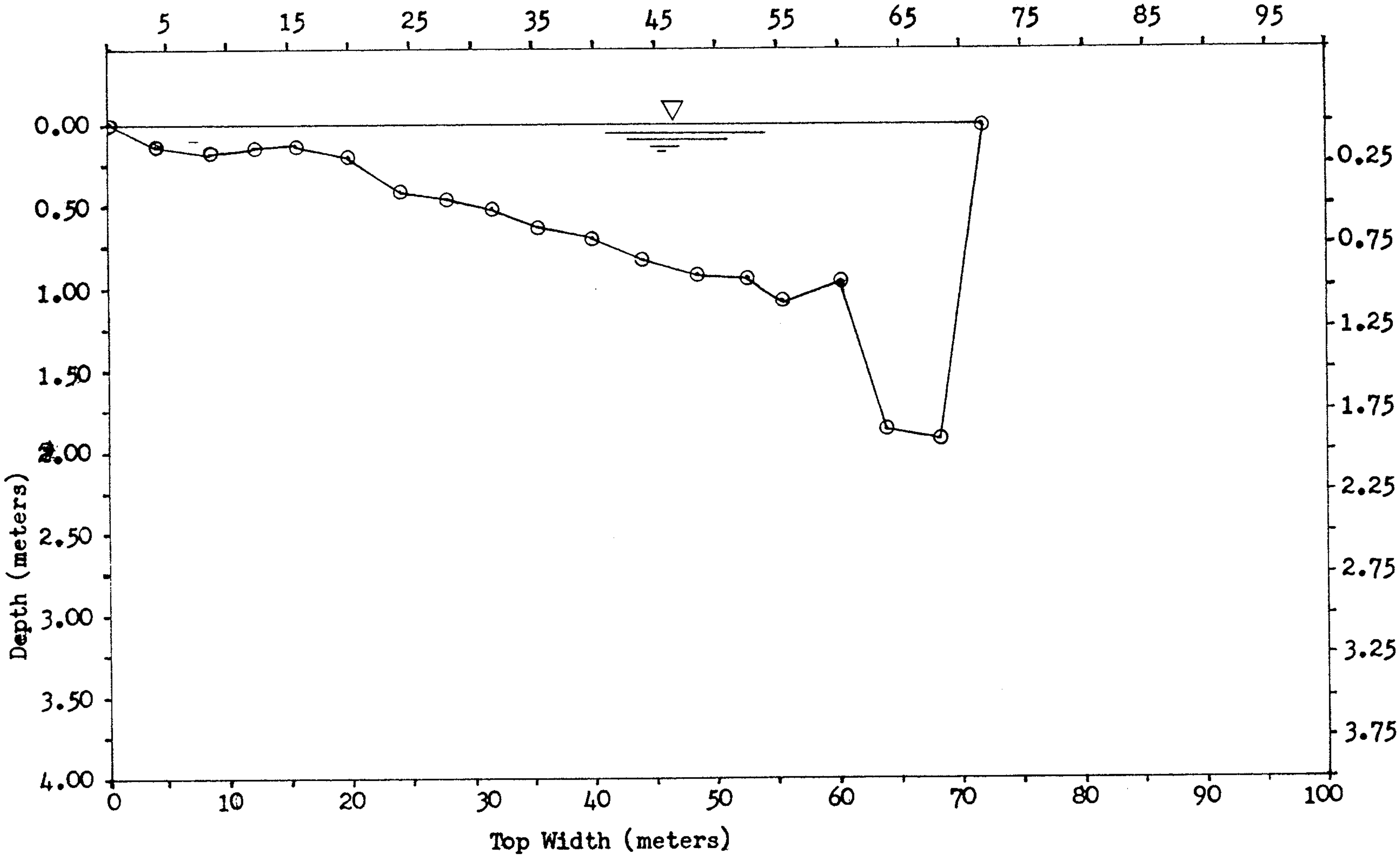



Fig. 161: MOBED CROSS-SECTION 11

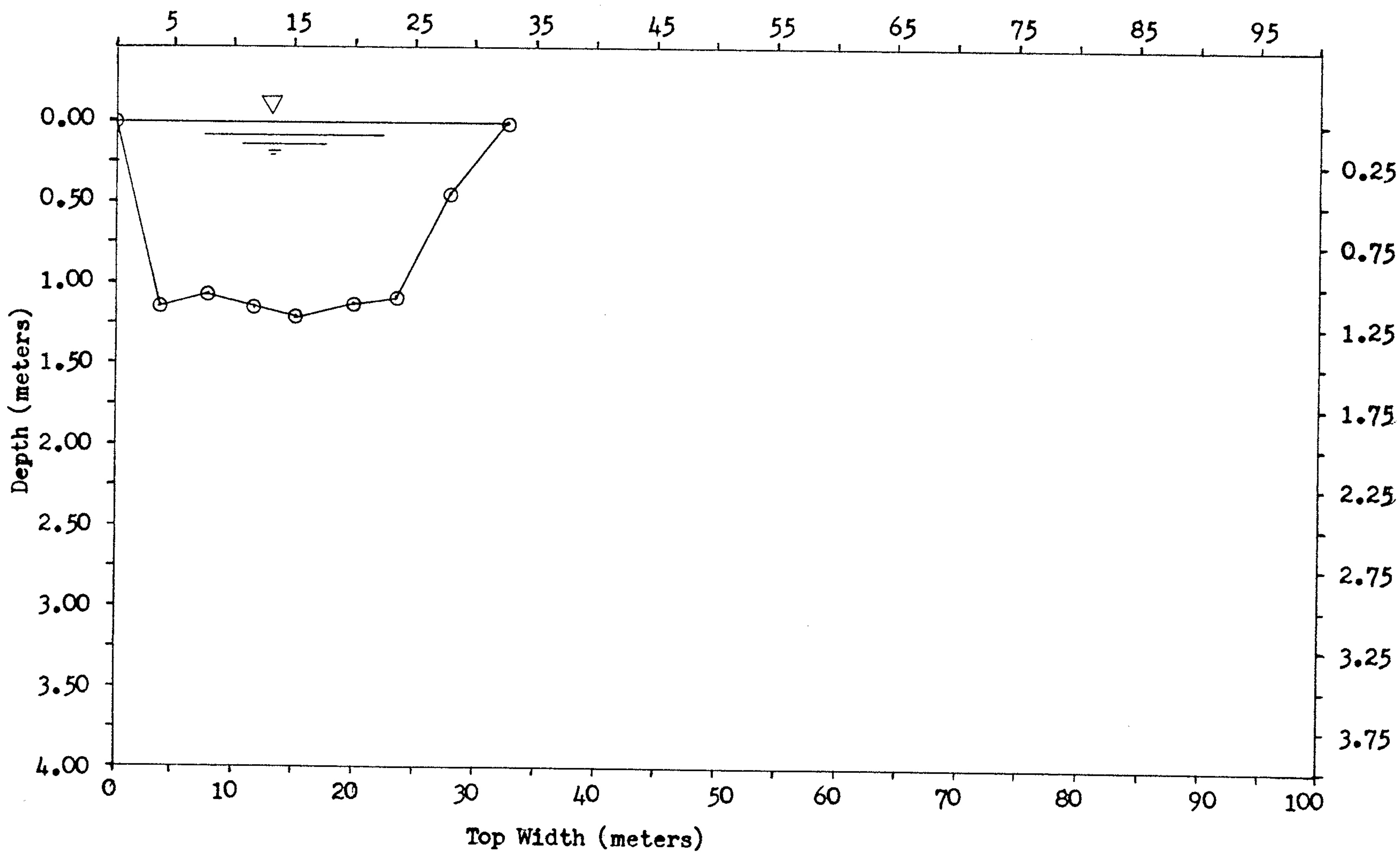



Fig. 163: MOBED CROSS-SECTION 13

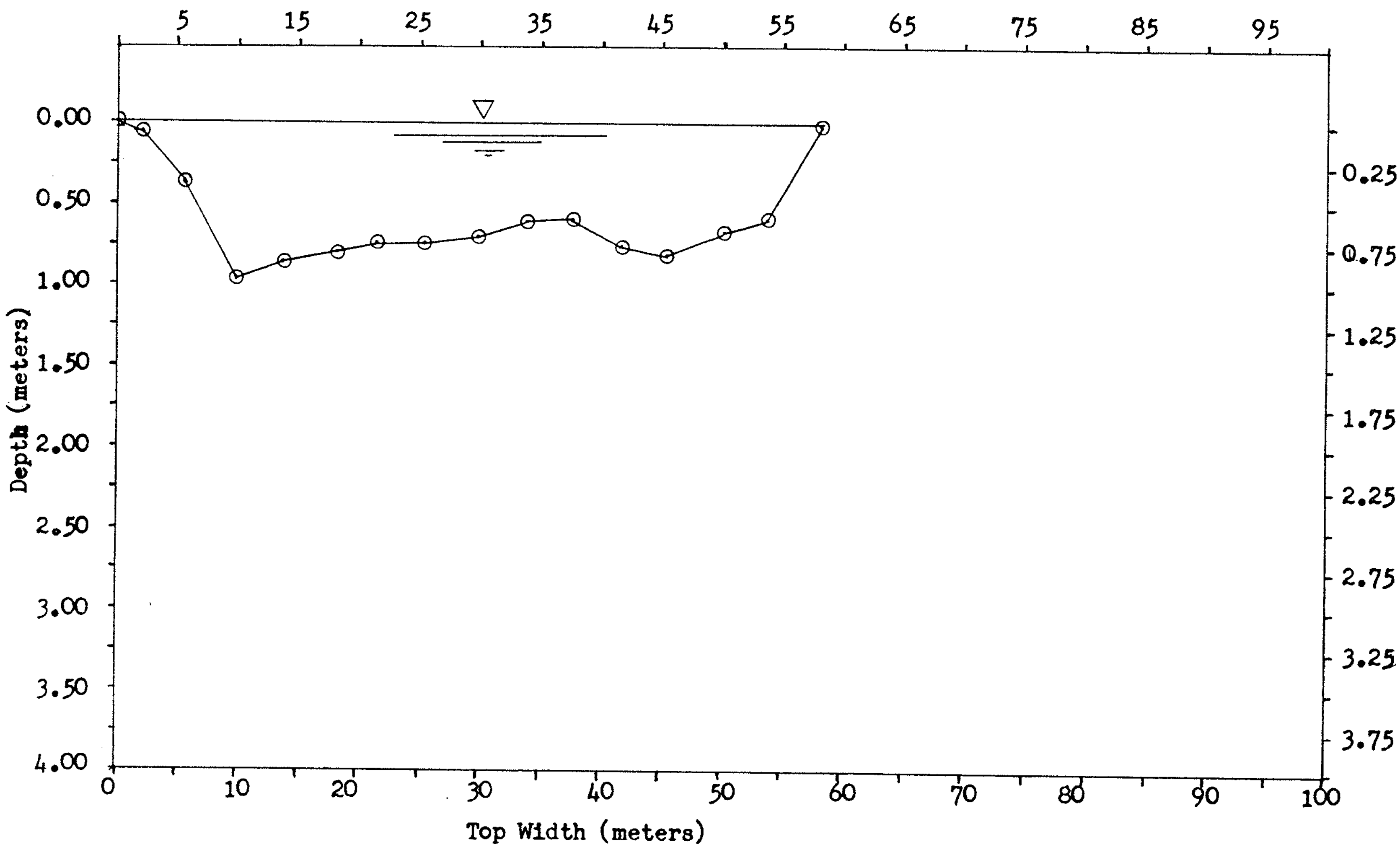



Fig. 164: MOBED CROSS-SECTION 14

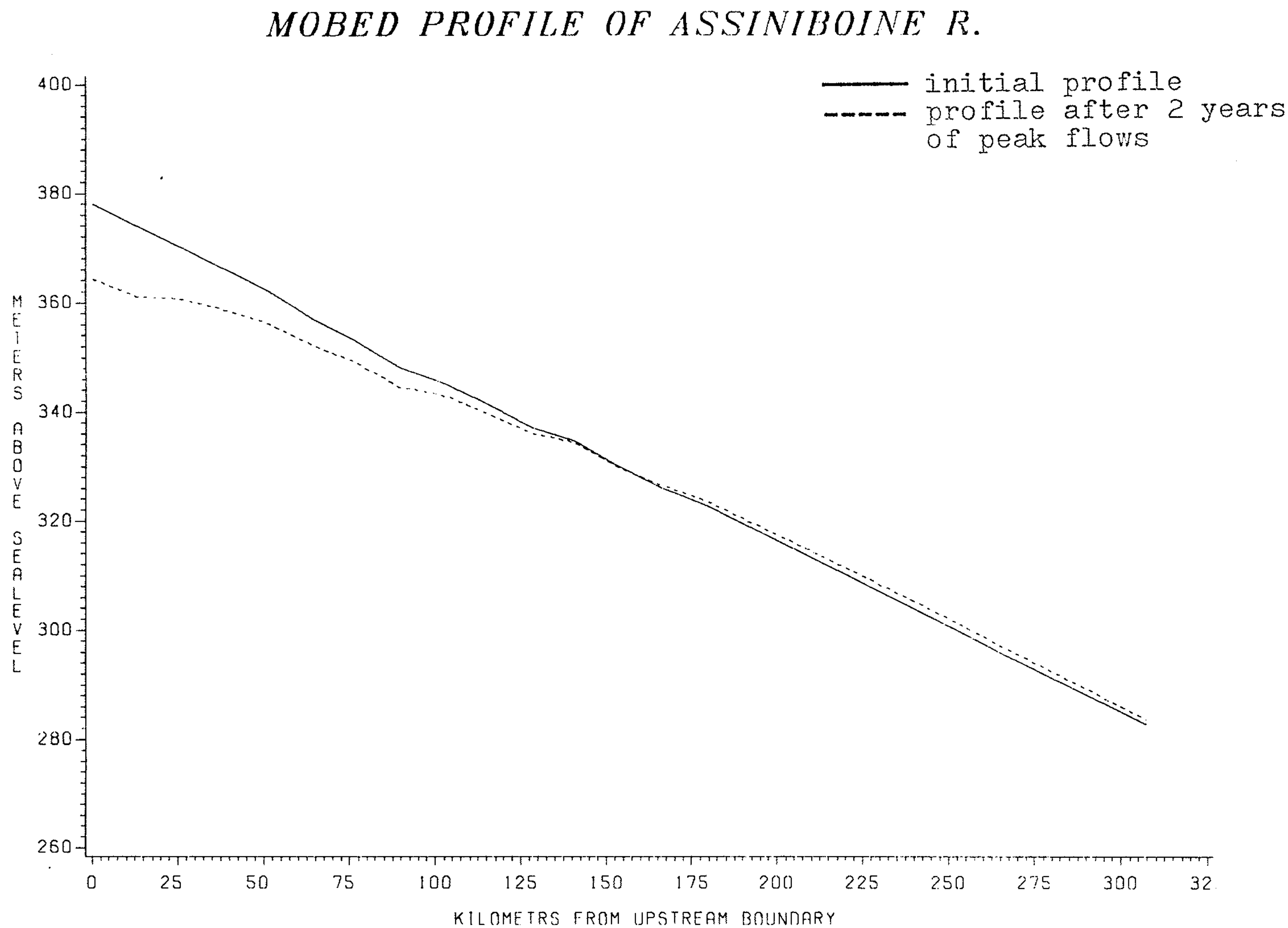



Fig. 165: PREDICTED MOBED PROFILE FROM BRANDON TO THE PORTAGE RESERVOIR

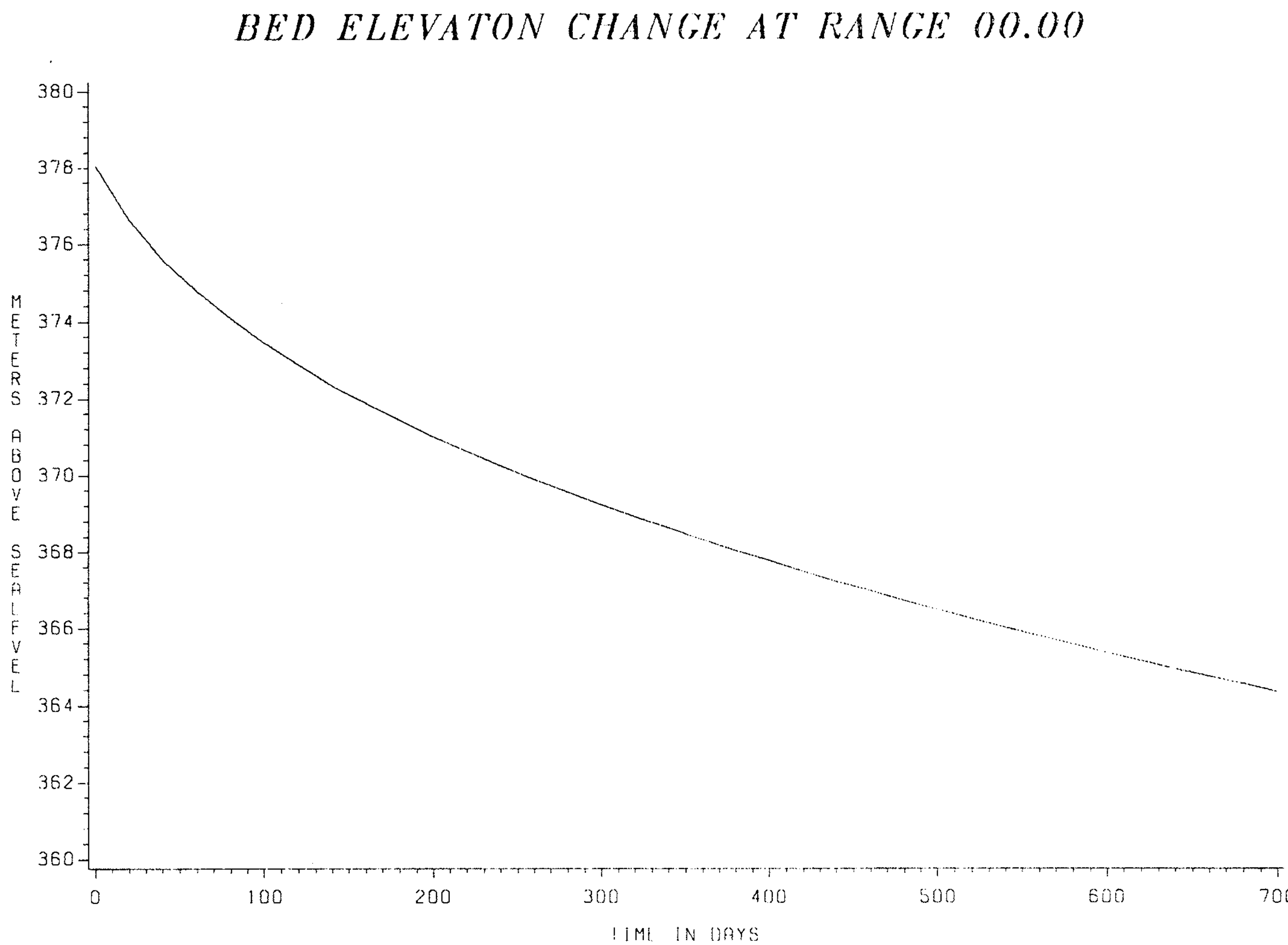



Fig. 166: CHANGE IN BED ELEVATION WITH TIME AT UPSTREAM BOUNDARY (BRANDON)

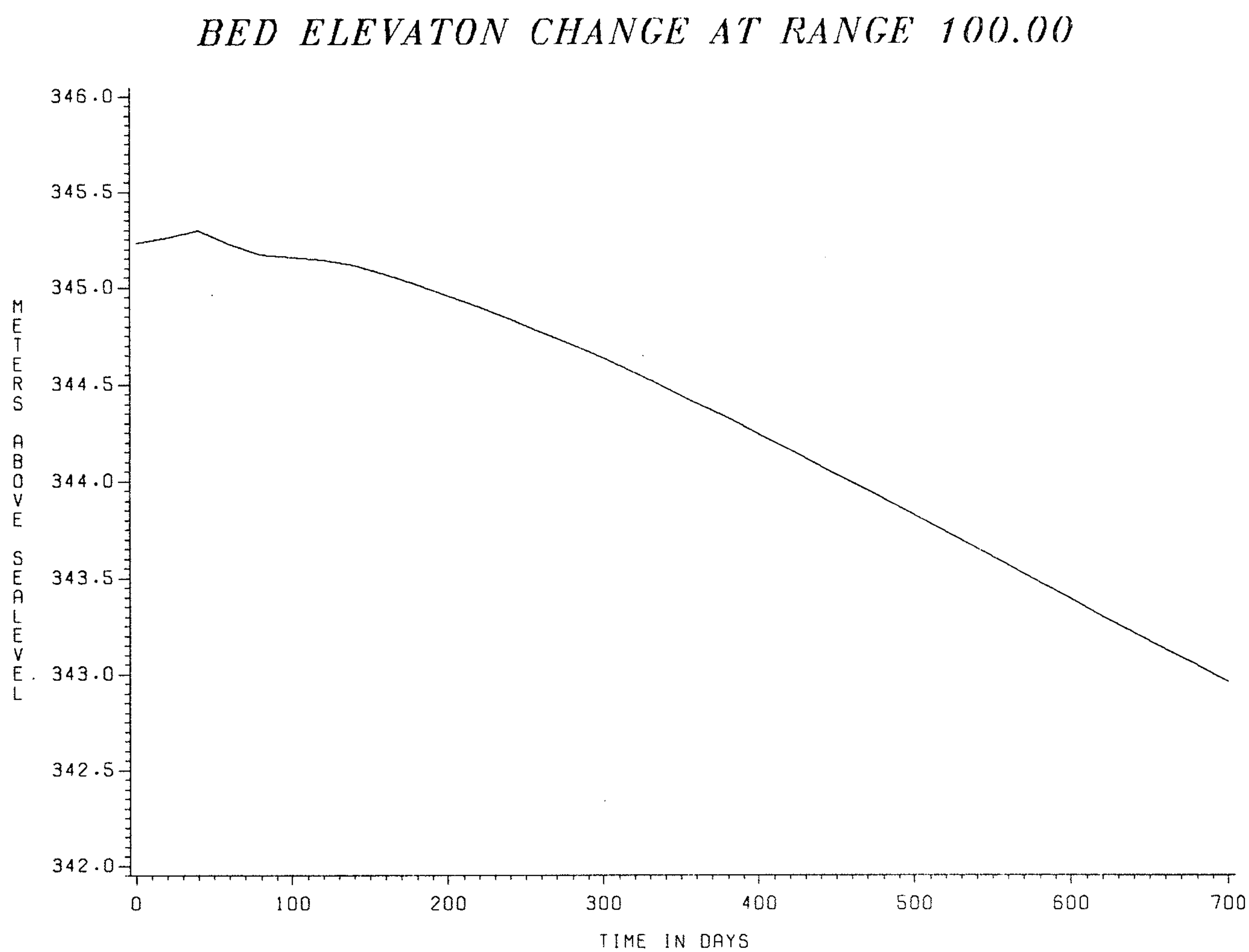



Fig. 167: BED ELEVATION VS. TIME AT 100 KILOMETERS

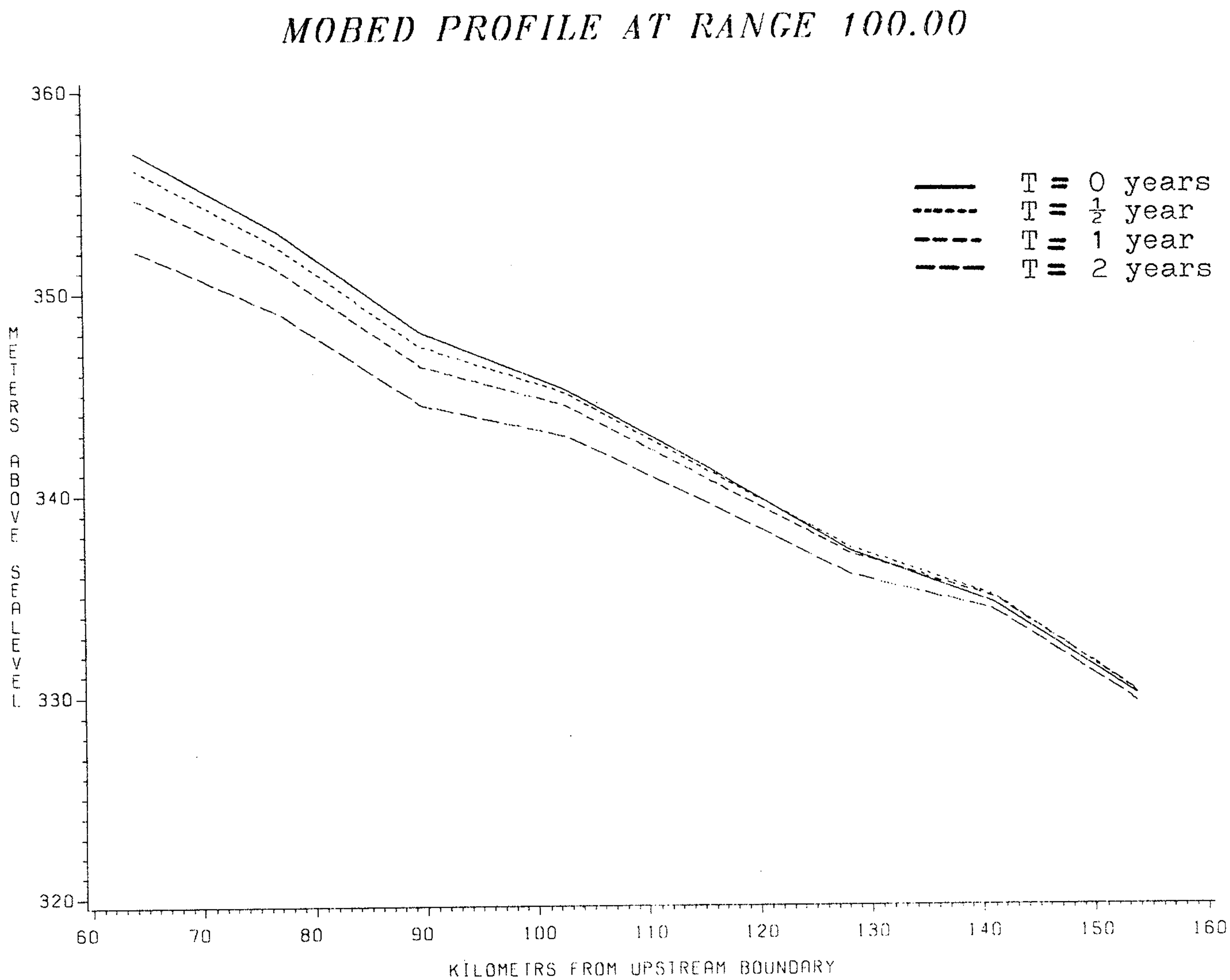



Fig. 168: ENLARGEMENT OF PROFILE THROUGH RANGE 100.00

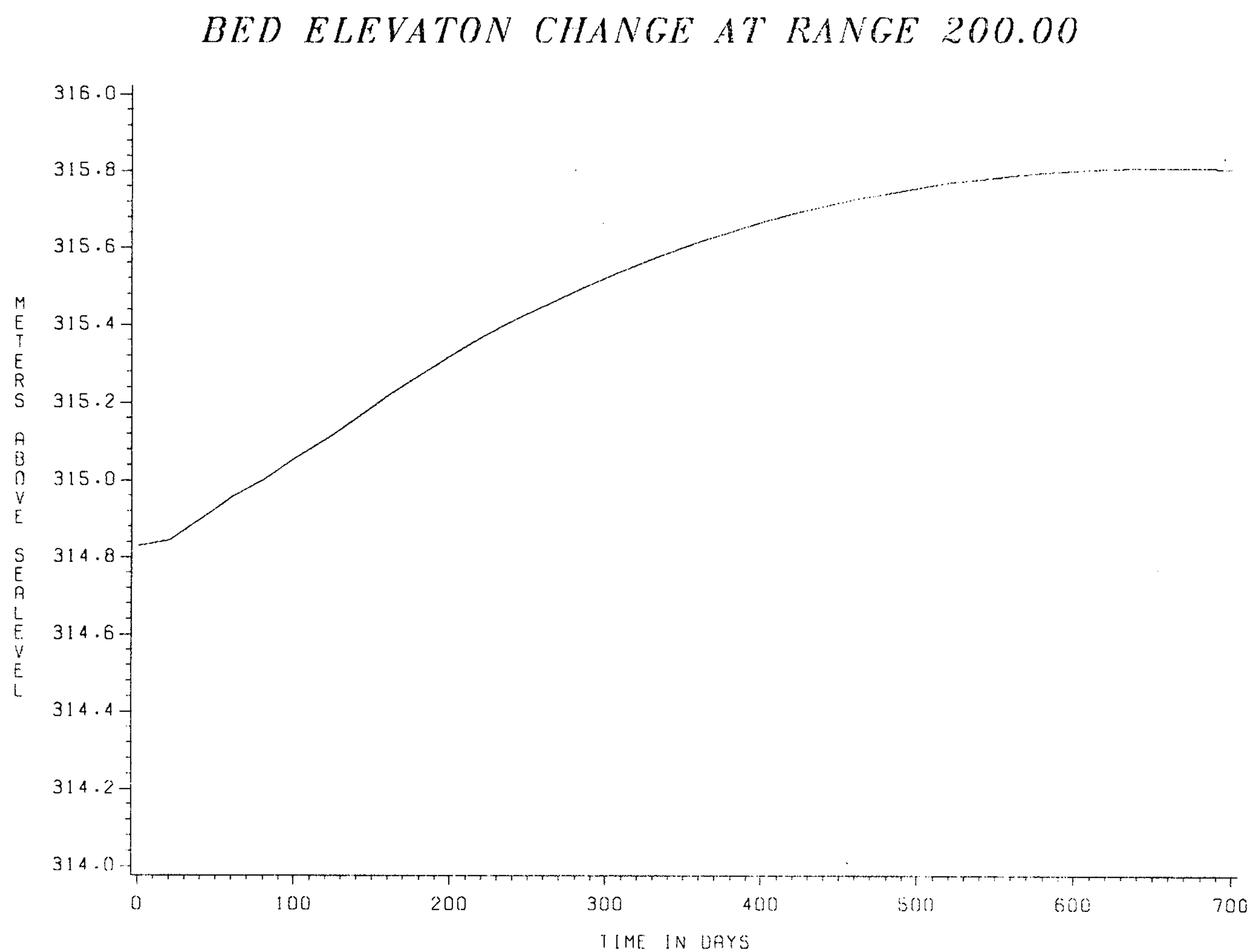



Fig. 169: BED ELEVATION VS. TIME AT 200 KILOMETERS

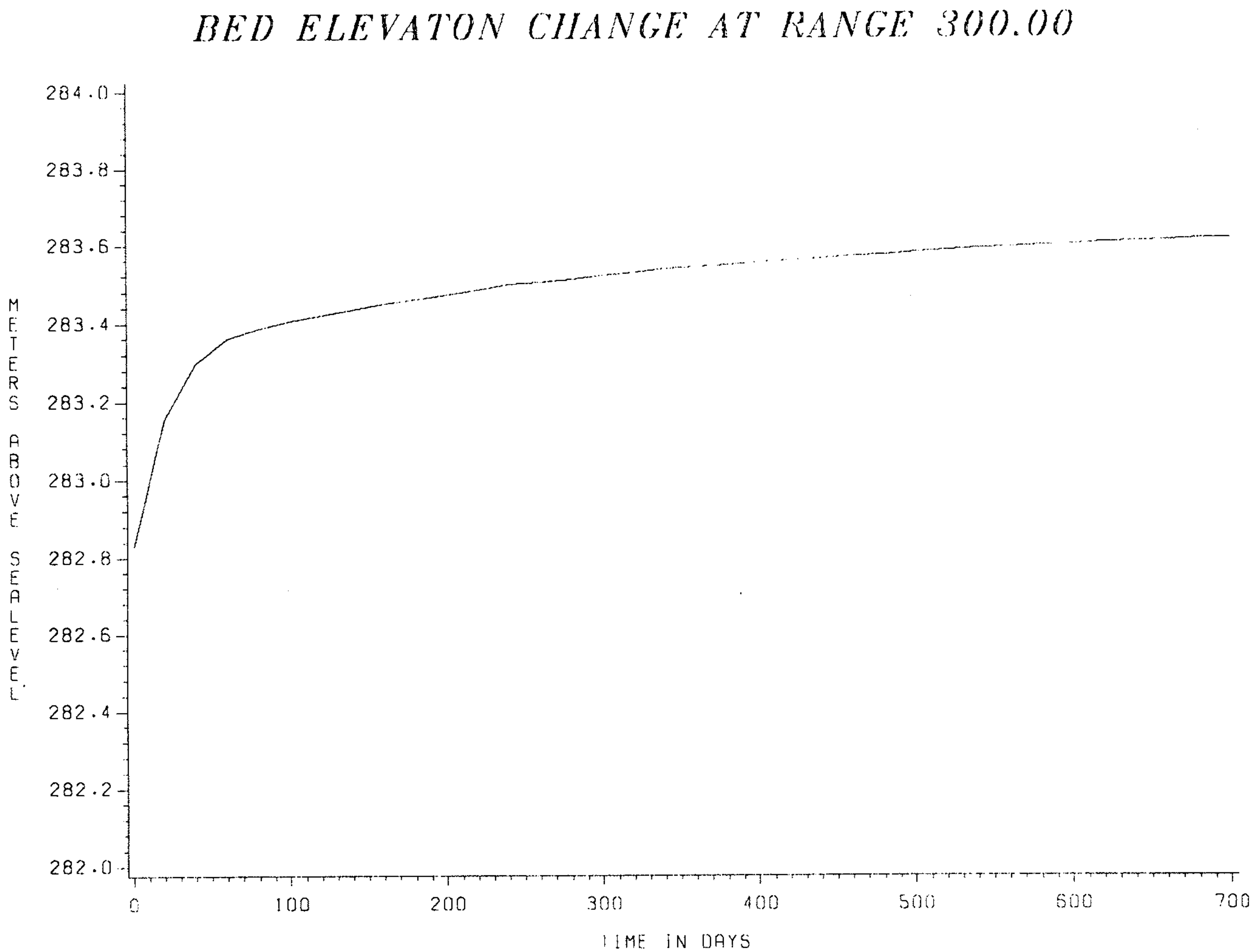



Fig. 170: BED ELEVATION VS. TIME AT 300 KILOMETERS (PORTAGE RESERVOIR)