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## MANUSCRIPT THESIS

# SEDIMENT TRANSPORT THROUGH HIGH MOUNTAIN STREAMS OF THE IDAHO BATHOLITH

A Thesis

Presented in Partial Fulfillment of the Requirements

for the

DEGREE OF MASTER OF SCIENCE

Major in Agricultural Engineering

in the

UNIVERSITY OF IDAHO GRADUATE SCHOOL

by

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April 1974

AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

This thesis of David R. Neilson for the Master of Science degree with major in Agricultural Engineering and titled "Sediment Transport Through High Mountain Streams of the Idaho Batholith" was reviewed in rough draft form by each Committee member as indicated by the signatures and dates given below and permission was granted to prepare the final copy incorporating suggestions of the Committee; permission was also given to schedule the final examination upon submission of two final copies to the Graduate School Office:

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FINAL EXAMINATION: By majority vote of the candidate's Committee at the final examination held on date of 3 May 74 Committee approval and acceptance was granted.

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GRADUATE COUNCIL FINAL APPROVAL AND ACCEPTANCE:

Graduate School Dean Edgar H. Grahn Date 7-10-74

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## ACKNOWLEDGEMENTS

I wish to express my thanks first and most importantly to my family, Claudia, Michele and Christopher, for without their support and patience, my involvement in this project may not have occured.

Special thanks are due Professor Myron Molnau, Major Professor and friend, for his help and understanding during the time I was involved in this project.

This project invisioned as an interdiciplinary study between the Agricultural Engineering, Entomology and Fisheries Departments at the University of Idaho allowed me to further my knowledge in a field other than my own. Therefore, I wish to express my thanks to Professor Ted Bjornn, also a committee member, and Lowell Stuehrenberg of the Fisheries Unit and Professor Merlin Brusven and Mick Sandine of the Entomology Department, Professor Dick Wallace and Mike Gibson for their aid in the field portion of the study. Also, thanks are due Professor Fred Watts of Civil Engineering not only for his help in this study but also for his quality classroom instruction.

Finally, I would like to thank the many people involved in the financial support of this project and especially the personnel in the Agricultural Engineering Department for their assistance.

ABSTRACT

The objectives of this study were to determine the carrying capacity, allowable amounts of sediment and methods to measure levels of fine sediments of 0.25 inches or finer in mountain streams in the Idaho Batholith. The sources and the effects of the sand size sediments once they leave the mountain Batholith streams are not considered.

Sediment discharge during the high water event of 1973, a year of minimal peak discharge, was insignificant. Projected transport rates using the Meyer-Peter, Muller formula, which shows good agreement with empirical data for Batholith streams, is presented. The allowable amount of fine sediments to enter these streams was determined by a sediment budget within limits established by the aquatic managers. A method of visually classifying the streambed, used by aquatic entomologists, correlated well with core samples for determining streambed composition.

The study revealed new areas of investigation and needs additional supporting data of its findings.

# INTRODUCTION

There has been much concern over sedimentation in spawning streams since the excessive sedimentation of aquatic habitat in the South Fork Salmon River after the 1964-65 winter storms. The South Fork is one of many streams located in a portion of Idaho called the Batholith, a large intrusive granitic body characterized by steep, mountainous terrain with a high erodibility and landslide potential. Streams in the Batholith have historically been primary spawning grounds for Idaho's salmon and steelhead runs.

This project was an interdisciplinary research effort with entomology, fisheries and engineering to determine effects of sediment on aquatic habitat in streams. The objectives of the engineering segment were: 1) to determine the potential sediment competency or carrying capacity of high mountain streams of the Idaho Batholith, 2) to determine the amount of sediment that can be allowed to enter these streams and still maintain good aquatic habitat within limits established by the habitat manager and 3) to survey and develop methods to measure the present level of sedimentation and related stream characteristics of several streams within the Batholith. The results would provide the information needed by aquatic managers to preserve the aquatic habitat in Batholith streams. All the data presented in this report are from natural streams in the Batholith and supported with natural stream data from other areas.

# LITERATURE REVIEW

## Prior Sediment Transport Studies

The literature contains little published data about sediment transport in steep, rough mountain streams. Most available data were derived from alluvial, sand bottom streams because of long standing problems with these streams. Several studies previously conducted in mountainous streams in other regions provide some insight into sediment transport phenomena, but lack actual determination of the bedload transport rate (Love and Benedict, 1948; Stewart and LaMarshe, 1967; Fahnstock, 1963). Studies in armoured streams in Oregon have been conducted on the movement of individual gravel size particles, but the results are limited outside the basalt areas (Milhous, 1972). A report from Canada on sediment transport measurement in a gravel bed river (Hollingshead, 1971) gives a good account of measured and calculated bedload transport rates. His results indicated the Meyer-Peter, Muller formula gave bedload transport rates higher than measured values. These measurements were obtained from a 1/4 inch mesh basket sampler.

Several studies have been conducted in the Batholith to determine sources and amounts of sediment produced by logging operations and roads (Platts, 1972; Megahan and Kidd, 1972). Others have reported on techniques to reduce sediment yields from various man-caused disturbances

(Hartsog and Gonsior, 1973). Also, a technique has been developed by Clayton and Arnold (1972) to assess the potential erodability and landslide hazard in the Idaho Batholith.

Sediment Transport Measurement

In streams, such as those of the Idaho Batholith, where the streambed material is predominately gravel and sand, most of the material moves as bedload. The bedload is the amount of material or quantity of sediment per unit time that moves past a section of stream by bouncing, rolling or sliding along the streambed. In the South Fork Salmon River, the streambed composition contained less than one percent below 0.074mm diameter (Platts, 1972). Platts also stated that suspended sediments have little effect on aquatic habitat when compared to the effect of bedload sediments. Therefore, bedload measurements are the most critical.

There are two basic methods for sampling the bedload: 1) direct methods in which a trap is extended across the stream catching the bedload and 2) indirect measurements in which bedload is collected from a narrow width with a portable sampler (Graf, 1971).

Bedload traps are slots, trenches or pits placed in the streambed which collect the bedload which is then removed and measured. These installations range from an elaborate apparatus of the slot-type constructed by the Soil Conservation Service on the Enore River in South

Carolina (where the entire 100 foot width was paved with concrete and the bedload dropped into slots and was then pumped out) to a semi-portable slot-type sampler used on Mountain Creek in South Carolina (Interagency Committee on Water Resources, 1963). The trap-type sampler, having slot widths from 100 to 200 times the grain diameter, is capable of sampling nearly 100 percent of the bedload. These installations have the disadvantage of being difficult and costly to place in the streambed and the trapped material must be pumped or dug out (Hubbell, 1964).

In indirect sampling with portable bedload samplers, only a portion of the cross-section is sampled. There are problems associated with the use of these devices. The introduction of an object into the flow pattern causes variations of the natural flow patterns on the streambed. Improper measurements may result if the sampler scoops up bed material or collects suspended load as it is lowered to the streambed. Due to uncertainties involved in sampling bedload with a portable sampler, each must include an efficiency coefficient or a ratio of material collected to actual sediment discharge. This is a coefficient that is not easily determined (Hubbell, 1964). They are usually calibrated in a laboratory flume where sediment rate can be controlled.

Early types of portable samplers include the basket sampler, a simple rectangular frame covered with wire mesh and open on one end. The pan type consists of a pan with a bottom and two sides having baffles to retard the water-sediment mixture, thus depositing the sediment within the pan. The pressure differential type sampler, in which the cross-section expands in the direction of flow causing a pressure drop at the entrance, has a greater sampling efficiency than other types of samplers (Hubbell, 1964). They are designed so the pressure drop compensates for the energy losses caused by the resistance of the sampler to the flow thus producing an entrance velocity approximately equal to that of the undisturbed stream. Figure 1 shows the velocity distribution in the sample intake chamber of a pressure differential sampler (Helley and Smith, 1971).

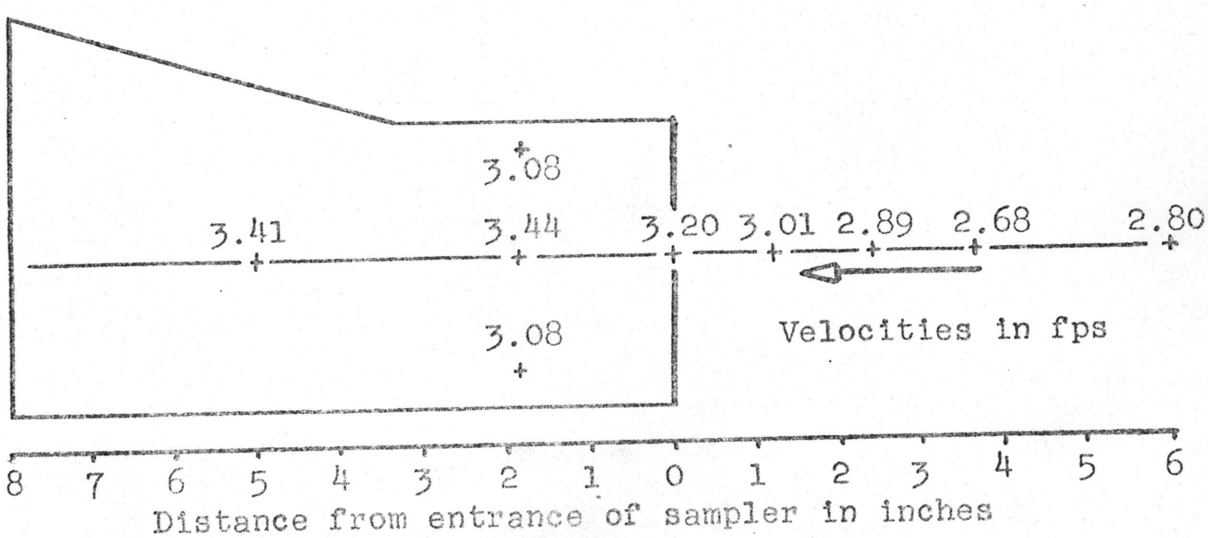



Figure 1: Streamflow velocities along centerline of sampler orifice, (Helley-Smith, 1971).

Recent portable bedload samplers are generally of the pressure differential type using either a net or baffles to collect the sediment. These developments have improved the hydraulic efficiency to near the 100 percent level while improving sampling efficiency to nearly 70 percent (Hubbell, 1964).

Selection of a Sampler

Selecting a portable bedload sampler depends on the type of material being carried by the stream and the velocity near the streambed. The velocity factor is important for hydraulic stability or the ability of the sampler to maintain a position in the stream flow. A pressure differential type should always be used to improve the efficiency of sampling. A comparison of common types of samplers are shown in Table 1.

In streams of the Idaho Batholith, the transported material is predominately sand and fine gravel which moves during the high flow period. This requires a high degree of hydraulic stability. The Helley-Smith sampler was determined to be the best available. A picture of the portable sampler is shown in Figure 2. The details of construction and instructions for the use of the sampler are given by Helley and Smith (1971).

Bedload Discharge Formulas

Many factors influence the rate of sediment transport such as water discharge, flow velocity, energy slope,

Table 1 : Summary of common bedload samplers.

| Type | Reference ** | Name | Date | Material * | Average Efficiency |
|---|---|---|---|---|---|
| Box-Basket | (A) | Muhlhofers | 1933 | Coarse gravels | 45% |
| " | (C) | Swiss Fed. Authority | 1930's | " | 50% |
| " | (A) | Nesper | 1930's | " | 40% |
| " | (A) | Ehrenberger | 1931 | " | 60% |
| Pan-Type | (C) | Polyakouv | 1930's | Sands | 60% |
| Pressure Differential Box-Basket | (C) | Karolyi | 1940's | Coarse sands & gravels | 45% |
| " | (C) | Vuv | 1950's | " | 70% |
| " | (C) | Arnheim | 1930's | " | 70% |
| " | (C) | Sphinx | 1950 | Sands | 90% |
| " | (B) | Helley-Smith | 1971 | Sands to gravels | to 90% |
| Pressure Differential Pan-Type | (C) | U.S. Corp | 1960's | Sands to gravels | 70% |
| " | (C) | Sirh | 1960's | " | 70% |
| Pit & Slot | (C) | | 1930's | Sands and larger | to 100% |

* Material best suited for sampling

** Reference:
(A) (Graf 1971)
(B) (Helley-Smith 1967)
(C) (Hubbel 1964)

Figure 2 : Photographs of the Helley Smith bedload sampler.

shear stress, bed configuration, intensity of turbulence, particle size, water depth, temperature, etc. Most sediment transport equations are developed by assuming a determinate relationship, at least statistically speaking, between sediment discharge and a dominant independent variable or variables selected from the list of influencing factors (Yang, 1973).

These formulas are generally characterized by the following form: $q_t = A\ (C - C_{cr})^B$ where $q_t$ is sediment discharge, A is a coefficient (usually a function of the particle size), B is an exponent, C is the dominant independent variable and cr subscript is for the critical condition (Yang, 1973). Most well-known bedload equations can be reduced to a function of velocity and particle size (Laursen, 1956).

Since the phenomenon of bedload transport is so complex and difficult to predict, it has led to many equations and relationships which have been developed under special laboratory and field conditions.

Every bedload equation relies on the experimental determination of its coefficients. Therefore, when selecting a bedload formula, care should be taken that the stream conditions closely approximate the conditions under which the formula is derived. Table 2 gives a summary of some common bedload formulas, including reference, date, type of dominant independent variable and bed material used to develop the necessary coefficients.

Table 2 : Bedload formulas summary.

| Formula | Ref. | Date | Type ☆ | Material mm ☆☆ | Comments |
|---|---|---|---|---|---|
| Duboys | B | 1879 | Shear Stress | .3 to 7.0 | |
| Donat | A | 1929 | Ave. Velocity | .3 to 7.0 | varied Duboys |
| Meyer-Peter | B | 1934 | Shear Stress | 3.1 to 28.6 | |
| Scholkitsh | B | 1935 | Discharge | .3 to 7.0 | |
| Shields | B | 1936 | Shear Stress | 1.1 to 2.5 | |
| Meyer-Peter, Muller | A | 1948 | Shear Stress | .3 to 28.6 | Factor for armour layer |
| Einstein Bedload | B,D | 1950 | Statistical | .3 to 28.6 | Probability of movement |
| Einstein Brown | B,D | 1950 | " | " | Varied Einstein's with same data |
| Laursen | B | 1958 | Shear Stress | .01 to 4.1 | |
| Blench | B,E | 1964 | | .3 to 7.0 | Good for depth/$D_{50}$ = 50 |
| Colby | B | 1964 | Ave. Velocity | .1 to .8 | Graphic relationship |
| Engelund-Hansen | B | 1967 | Shear Stress | .15 to .93 | |
| Yang | C | 1973 | Velocity-Slope | .15 to 1.71 | Unit stream power |
| Kalinske | A | 1947 | Shear Stress | sands | developed with uniform material |
| Simons et al | A | 1965 | Dune Height | .19 to .93 | Function of dune height |

Reference: A Graf, 1971
B Task Committee, 1971
C Yang, 1973
D Leliavsky, 1966
E Blench, 1969

☆ Type--Refers to the dominant independent variable from which the formula was developed
☆☆ Material--Refers size of bed material for which the formula coefficients were developed

Although several formulas were developed for gravel-bed streams, only the Meyer-Peter, Muller formula has been adopted to apply to armoured bed streams as characteristic of mountainous streams of the Idaho Batholith.

The Meyer-Peter, Muller formula was developed from extensive research in a laboratory flume with a 2 x 2 meter cross-section and a total length of 50 meters in Switzerland. The original Meyer-Peter formula, developed in 1934, was not at all successful with beds of a graded composition and a new relationship was developed in 1948. Muller, in 1943, calculated a roughness coefficient which is related to the largest particles in the top layer of the streambed. The size of sediment in the bed, for which 90 percent of the material is finer, is used to represent the largest grains of the armour bed (Graf, 1971).

The Meyer-Peter, Muller bedload formula was converted to the English system and generalized for the specific weight of water and quartz particles by the Bureau of Reclamation in 1960. The equation is as follows:

$$g_s = 1.606 \left[ 3.306 \left(\frac{Q_s}{Q}\right) \left(\frac{D90^{1/6}}{n_s}\right)^{3/2} dS - 0.627 D_m \right]^{3/2}$$

$g_s$ - Bedload transport (tons/day/foot width)

$Q_s$ - Discharge quantity determining bedload transport (cfs) function of $n_w$ and $n_m$

$Q$ - Total water discharge quantity (cfs)

$D_{90}$ - Armour size (mm) as approximated by the size of sediment for which 90% of the material is finer

$n_s$ - Weighted Manning's "n" value for the stream bed

$d$ - Depth of flow (feet)

$S$ - Slope energy grade line (feet/foot)

$D_m$ - Effective size of bed material $D_m = \sum \frac{(D_{m_i} P_i)}{100}$ (mm)

$n_w$ - Side wall roughness value

$n_m$ - Total channel roughness

$D_{m_i}$ - Mean diameter of a selected portion of distribution curve

$P_i$ - Percent of material within selected portion of distribution curve

For the condition at which bed material just begins to move, $D_m$ is replaced by the individual particle size D

$$dS = 0.0001624\ D$$

or shear stress $\gamma dS = 0.0001624\ D\ \gamma$ where: $\gamma$ - specific weight of water (62.4 pounds/cubic foot).

# FIELD PROCEDURE

The field work was carried out in streams near Stanley, Idaho (Figure 3 and Appendix A). It was decided to measure the bedload and water discharge during the spring runoff and to conduct stream surveys during the August low flow period. It was also planned to introduce sediment into a reach of stream during the low flow period to observe the effects of sediment on aquatic habitat and the physical characteristics of the stream.

## Stream Selection

Selection of the natural stream study sites was based on the following criteria: 1) accessibility for transport of equipment to the site, 2) well developed pool and riffle formation without braided reaches, 3) adequate fish and aquatic insect populations and 4) on the dump stream, its size and distance from the barrow area. Each study section consisted of at least 2 or 3 riffles and pools in a 600 to 1000 feet length of stream.

## Mapping

Measurements of the physical characteristics of each stream included detailed mapping of the stream configuration, water depth, velocity, discharge and streambed material.

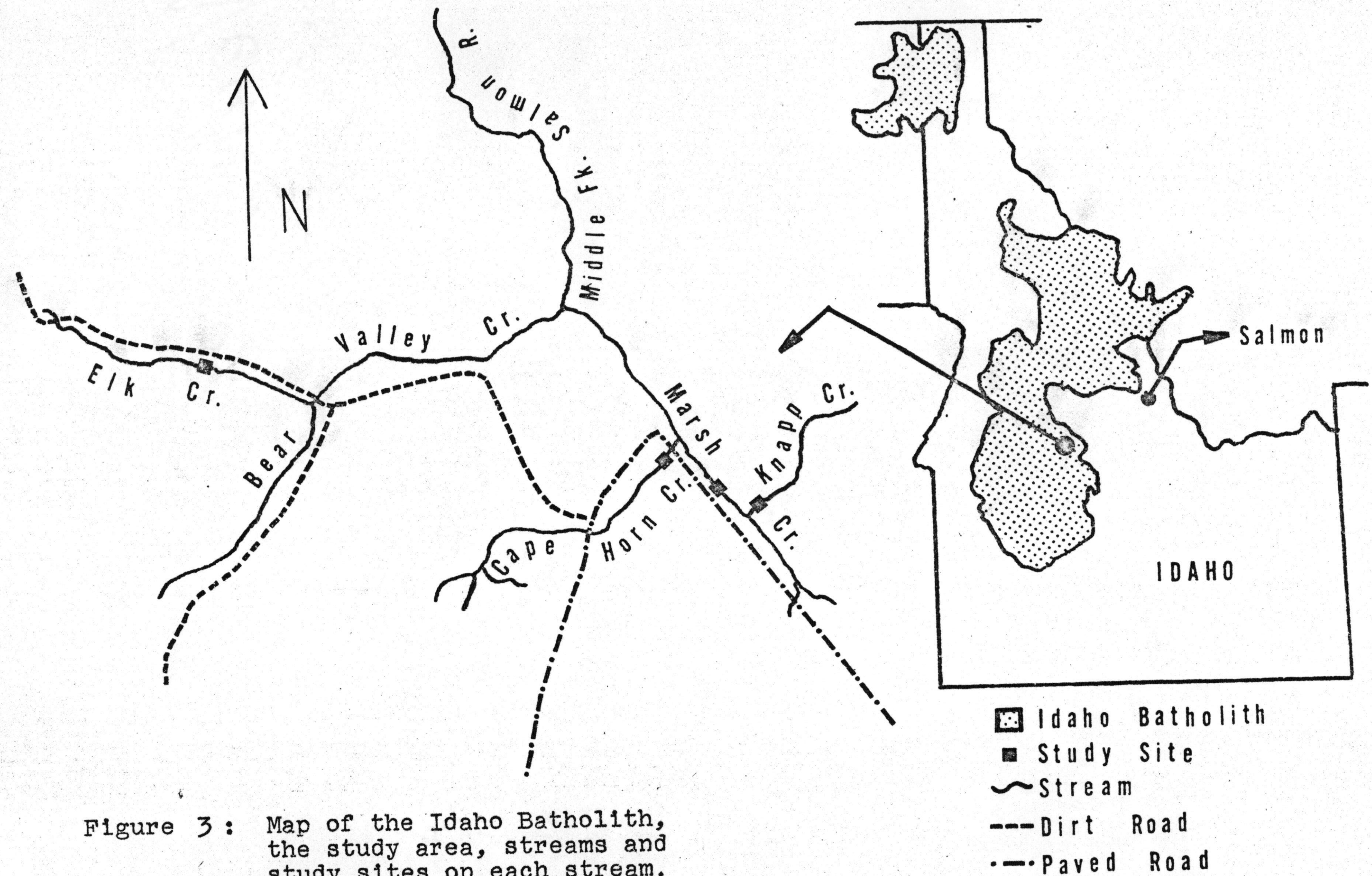



Figure 3: Map of the Idaho Batholith, the study area, streams and study sites on each stream.

A stadia survey was used to map the stream configuration. A reference bench mark was established at each stream sutdy section and survey stakes, used as guide points, were placed at 20 to 30 foot intervals or at characteristic points (Beginning and end of pools or riffles, points, logs, etc.). By zeroing the lower motion to magnetic north, the azimuth angle and distance by stadia were used to plot the stream boundaries.

The depth and velocity at mid-depth at various cross-sections were determined with a Gurley pygmy current meter according to the procedure described by Buchanan and Somers (1968).

Discharge Measurements

Stream discharge was determined by wading into the stream with the current meter (Buchanan and Somers, 1968), except when the stream flow was too deep and/or swift for wading. During large flows, a dye dilution technique was used to measure the discharge. A portable injection tank manufactured by Aerofeed Corporation was used to inject the tracer dye at a constant rate. Rhodomine WT was selected as the best dye for use in natural, silt-free streams (Wilson, 1968). The injection point was established at the most accessible location on the stream. The sampling point was then located approximately 100 stream widths downstream from the injection point to insure complete lateral mixing of the dye

(Replogle and others, 1966). A time period equal to three times the observed time of travel of a stick on the water surface was used as the time for the dye concentration to stablize at a plateau value at the sampling point. Grab samples were then taken at one-minute intervals for five minutes. Other samples taken included the concentration of dye in the injection tank and the background fluorescence of the natural stream water. The concentration of the dye was analyzed with a Fluoro-Microphotometer according to the procedure in ANINCO Fluoro-Microphotometer Catalog no. 4-7102A. Discharge obtained with the dye dilution technique were similar to those obtained with a current meter.

Streambed Material

The streambed material composition was determined by core sampling, streambed surface classification and measurement of the armour material.

The core sampler described by McNeil and Ahnell (1960) was used to determine the composition of the bed material to a depth of 6 to 8 inches. The grain size distribution was determined by sieve analysis both in the field, using a volumetric analyzer described by McNeil and Ahnell (1960) and in the laboratory, where dry sieve analysis was conducted for more detail and to check field analysis. Three core samples were taken from one pool on each stream and at least nine were taken from one riffle on each stream. Each riffle was divided into squares of one to two feet and the sampling point randomly selected from the grid.

Streambed surface classification consisted of analyzing the surface layer of the bed material at one-foot intervals along two or three transect lines established across each riffle within the study section. Three criteria were used to classify streambed surface: size of the dominant streambed surface material, imbeddedness of dominant material with fines, and the dominate size of the material surrounding the dominant material. The surface was visually analyzed according to the procedure given in Appendix B. This system is a modification of a system used by Prather (1971). The observations were based only on the surface materials and does not include deeper sediments. In addition to the transect observations, the bottom materials were classified for the entire study section using this same system. By walking observation, the various bottom materials were classified and sketched onto the stream map using the guide points established in the initial boundary survey as the location reference.

The armour material was sampled using a 3 foot by 3 foot rectangular frame with wires stretched at 4 inch intervals which forms a grid having 36 intersections. Nine randomly selected grid intersections were then painted with red paint. The armour material was sampled by placing the grid on the streambed. The rock located under a red grid intersection was then picked up by hand and measurements taken on three axis: the major or longest dimension, intermediate axis or sieve diameter and the third axis perpendicular to the other two.

In order to establish a relationship between armour particles and the streambed shear stress, the depth corresponding to the highest visible high water mark was assumed responsible for the deposition of the existing armour layer. The average depth and average armour particle at each grid location across the streambed at a riffle, a pool (if possible) and a transition, between the pools and riffles of two different streams were used to form the shear stress relation.

## Bedload Discharge Sampling

Bedload discharge was sampled with a Helley-Smith sampler designed for use on streams with gravel beds (Helley and Smith, 1971). Several streams were sampled during the spring runoff. It was observed that the sampler dislodged or scoured out sediments lodged between the armour particles when placed on a gravel streambed. Thus, samples were taken in culverts when possible. This provided a control of cross section and a stable bed "sill effect" for proper sampling. The sampler was lowered to the streambed with a hand rope on the smaller streams. For larger streams with high flow, a bridge board (Figure 4) was used to assist in lifting the 50

Figure 4 : Bridge board used to lift the Helley Smith sampler.

pound sampler. The transported bed material was caught in a fine mesh nylon bag attached to the sampler by a snap fastener. The bag was removed and emptied into numbered jars for analysis at a later time.

During low flow periods, a small sheet metal pressure differential sampler (Figure 5) was used. This sampler would trap the bed material passing over a 2 inch x 8 inch x 18 inch sill set parallel to the streambed. The sill was allowed to remain in place for a minimum of 24 hours before any samples were taken. The sampler was anchored to the sill by rods and wingnut fasteners on the sampler. Care was taken to not disturb the area upstream from the sampler by approaching and working only downstream of the sampler. Samples were washed into numbered jars for later analysis.

During sample analysis, hydrogen peroxide was used to remove organic matter from the sample (Guy, 1969). Excess water was drained from each sample and the volume of the sediment material was measured in a volumetric analyzer (McNeil and Ahnell, 1960). The sediment volume was converted to pounds per day for the entire stream width.

Experimental Field Dump

Sediment was dumped on a section of Knapp Creek to determine its impact on the physical characteristics and aquatic habitat of the stream. This was accomplished

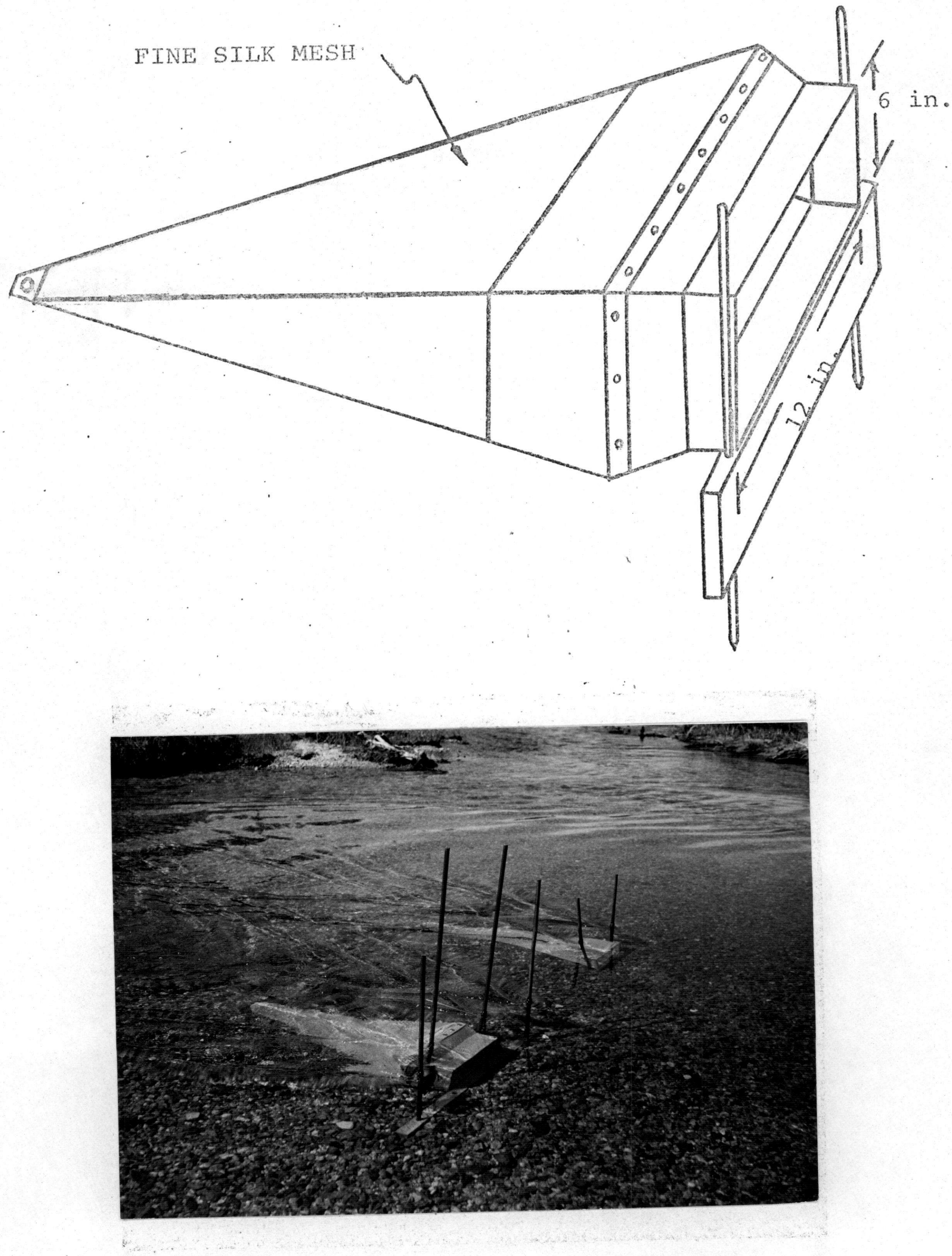



Figure 5: Portable pressure-differential bedload sampler used to measure stream bedload

by adding sediment in three stages and measuring changes in physical characteristics, fish and insect abundance and distributions at each stage. Sediment was taken from a nearby creek so as to assure that the added sediment would be the same as that resulting from some hypothetical watershed disturbance. The sediment was then deposited at the head of each pool and riffle where it was allowed to spread under the influence of the natural streamflow. Views of the stream both before and after the dump are shown in Figure 6.

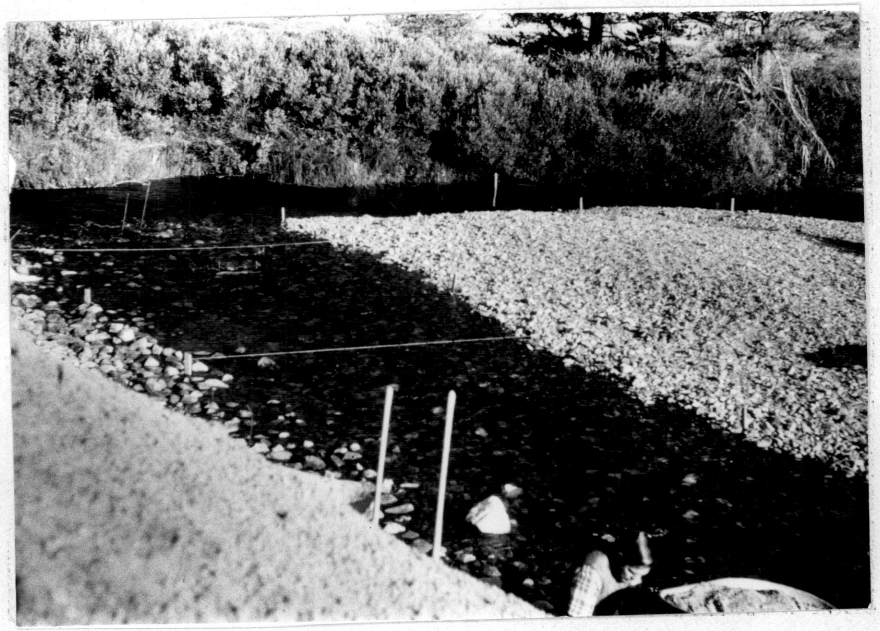


Figure 6 : Knapp Creek site before and after sediment dump August, 1973.

# RESULTS AND DISCUSSION

## Field Procedure

The results of the field measurements in the surveyed streams indicate the following: During the base flow period, August, sediment transport occured only in trace amounts (Table 3). Since only small quantities of sediments were collected in the sampler and only one to four samples were taken per stream, these results are of little comparative value. During the spring runoff of 1973 a year of low peak discharge, (260 cfs or a 1.4 year peak event) measured sediment transport was again insignificant (less than one ton per year).

Measurements of the streambed composition or the portion of fine sediment of 0.25 inches or smaller on riffle areas indicated Capehorn and Knapp Creeks with about 30% fines were moderately sedimented, Marsh Creek with 35% fines was slightly heavier sedimented and Elk Creek with 47% fines average over the two year period was heavily sedimented (Table 3). The streambed composition in terms of the $D_{35}$, $D_{50}$, $D_m$, $D_{90}$, % finer than 0.25 inches and the visual surface classification are summarized in Table 6 for each location and date. The amount of fines present in the overall channel decreased as the overall channel slope increased (Table A-1).

The experimental field sediment dump in Knapp Creek showed that some sediment can be transported during

Table 3: Volume of flow, sediment discharge and composition of bed materials in pools and riffles of the four study streams.

| Study Stream | Date | Composition of Bed Material (percent finer than 1/4 inch) | | Water Discharge c.f.s. | Sediment Discharge pounds per day |
|---|---|---|---|---|---|
| | | pool | riffle | | |
| Marsh Creek | 8- 8-72 | 44 | 35 | 42.1 | 7.1 |
| Cape Horn Creek | 8-12-72 | 51 | 27 | 40.8 | 7.9 |
| | 8- 8-73 | -- | 28 | 28.9 | T |
| Elk Creek | 8-15-72 | 61 | 42 | 71.9 | 3.7 |
| | 8-18-73 | | 52 | 31.1 | T |
| Knapp | 8- 1-73 | 31 | 31 | 4.7 | T |

T Trace

Table 4 : Streambed composition.

| Date | Location | Section | $D_{35}$ | $D_{50}$ | $D_m$ | $D_{90}$ | % finer .250" | Streambed Surface Classification: D.M. | D.M.I. | S.M. | D.M. D.M.I. | D.M. D.M.I. S.M. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-27-73 | Knapp | Test Riffle I | 8.0 | 22.4 | 32.3 | 99.1 | 31 | 5 | 4 | 3 | 7 | 12 |
| 8-13-73 | " | " | 4.0 | 12.0 | 25.9 | 81.3 | 42 | 5 | 2 | 2 | 4 | 9 |
| 8-23-73 | " | " | 4.7 | 14.1 | 25.6 | 73.7 | 39 | 5 | 3 | 2 | 5 | 10 |
| 7-27-73 | " | Test Riffle II | 12.0 | 21.7 | 23.1 | 48.1 | 28 | 4 | 3 | 2 | 5 | 9 |
| 8-13-73 | " | " | 3.0 | 8.1 | 16.5 | 48.3 | 46 | 4 | 2 | 2 | 4 | 8 |
| 8-23-73 | " | " | 5.5 | 14.1 | 20.7 | 66.0 | 37 | 4 | 3 | 2 | 5 | 9 |
| 7-28-73 | " | Test Pool I | 11.0 | 26.6 | 32.0 | 83.8 | 28 | 4.5 | 4.5 | 2 | 6.5 | 11 |
| 8- 1-73 | " | " | 1.2 | 1.6 | 3.2 | 16.5 | 84 | 1 | 1 | 1 | 2 | 3 |
| 7-28-73 | " | Test Pool II | 4.9 | 22.7 | 30.9 | 83.8 | 33 | 4 | 4 | 2 | 6 | 10 |
| 8-72 | Capehorn | Primary Riffle | 12.0 | 18.8 | 28.2 | 80 * | 27 | 4 | 4 | 2 | 6 | 10 |
| 8-73 | " | " | 11.6 | 22.9 | 30.1 | 80 * | 28 | 4 | 4 | 2 | 6 | 10 |
| 8-72 | " | Pool | 1.5 | 5.5 | 19.3 | -- | 51 | 5 | 3 | 1 | 4 | 9 |
| 8-72 | Elk | Upper Riffle | 4.0 | 9.4 | 22.1 | 35 * | 32 | 3 | 3 | 2 | 5 | 8 |
| 8-73 | " | " | 4.0 | 6.3 | 17.9 | 40.0 | 44 | 3 | 3 | 2 | 5 | 8 |
| 8-72 | " | Lower Riffle | 2.2 | 5.9 | 10.7 | 34 * | 51 | 2.5 | 3 | 2 | 5 | 7.5 |
| 8-73 | " | " | 2.6* | 3.5 | 8.9 | 39.9 | 60 | 3 | 2 | 2 | 4 | 7 |
| 8-72 | " | Pool | 3.5 | 4.2 | 7.2 | 25.0 | 61 | 3 | 2 | 1 | 3 | 6 |
| 8-72 | " | Run | 2.0* | 4.3 | | 50.0* | 55 | 3 | 3 | 2 | 5 | 8 |
| 8-72 | Marsh | Primary Riffle | 6.2 | 18.0 | | | 34 | 3.5 | 4 | 2 | 6 | 9.5 |
| 8-72 | " | Lower Riffle | 6.6 | 14.2 | | | 36 | | | | | |
| 8-72 | " | Pool | 4.9 | 10.1 | | | 44 | | | | | |
| 7-26-73 | Knapp | Upper Control Riffle | 5.8 | 18.8 | 24.5 | 61.0 | 36 | 4 | 4 | 3 | 7 | 11 |
| 7-26-73 | Knapp | Lower Control Riffle | 12.4 | 26.8 | 27.3 | 71.1 | 27 | 5 | 4 | 3 | 7 | 12 |

* from extension of grain distribution curves

the base flow period if the streambed surface material becomes filled with excess fines. The difference between the change in pool volume and the volume of sediment dumped (Table 5) indicates some material was transported from the pools, especially pool II between August 1 and 2 where a negative difference of 29 cubic feet of material was measured. The large plus difference in pool II between August 6 and 9 would indicate some sediments were transported from the area above test pool II. The decrease in material finer than 0.25 inches between August 13 and 23 on test riffles I and II (Table 6) also indicates that such transport could have taken place.

As fine sediments were dumped at the upstream end of the riffle, they would spread downstream and across the stream until they became trapped between the larger bed particles and filled the voids. As more fines were added, this sandy fan would expand downstream. This would continue until all the surface voids and spaces between larger particles were filled. Once this level is reached, some of the fines work deeper into the streambed or remain on the riffle until a greater discharge occurs.

Visual observations during the dump revealed that as fines were added, many larger particles that would not ordinarily be transported were dislodged and transported. The following factors were probably the cause of this phenomenon: 1) increased velocity from reduced cross-sectional area and bed smoothing with the sand particles,

Table 5: Pool volume in Knapp Creek pools dump area.

| Date | Location | Average Depth ft | Pool Volume ft$^3$ | Change in Pool Volume ft$^3$ | Volume Dumped ft$^3$ | Difference * |
|---|---|---|---|---|---|---|
| 7-27-73 | Pool I | 1.32 | 920 | | | |
| 8- 1-73 | Pool I | | | 280 | 284 | - 4 |
| 8- 2-73 | Pool I | .92 | 640 | | | |
| 8- 2-73 | Pool I | | | 215 | 203 | +12 |
| 8- 6-73 | Pool I | .61 | 425 | | | |
| 8- 6-73 | Pool I | | | 147 | 149 | - 2 |
| 8- 9-73 | Pool I | .40 | 278 | | | |
| 7-27-73 | Pool II | .84 | 387 | | | |
| 8- 1-73 | Pool II | | | 106 | 135 | -29 |
| 8- 2-73 | Pool II | .61 | 281 | | | |
| 8- 2-73 | Pool II | | | 46 | 54 | - 8 |
| 8- 6-73 | Pool II | .51 | 235 | | | |
| 8- 6-73 | Pool II | | | 87 | 54 | + 33 |
| 8- 9-73 | Pool II | .32 | 148 | | | |

* Difference between change in pool volume and volume dumped

Plus (+) means pool volume decreased more than was dumped possibly washed from riffle above

Minus (-) means pool volume decreased less than amount dumped possibly due to fines transported from the section

Table 6 : Riffle size, streambed composition and volume of fines in study streams.

| Date | Location | Section | Area $ft^2$ | Dump $ft^3$ | Bed Composition to 6" $D_m$ | Bed Composition to 6" % Finer 0.25" | Material in Section less than 0.25" | Material per 100 $ft^2$ cu ft (1) |
|---|---|---|---|---|---|---|---|---|
| 7-27-73 | Knapp | Test Riffle I | 720 | | 32.3 | 31 | 112 | 15.5 |
| 8- 1-73 | " | " | " | 122 | -- | -- | -- | -- |
| 8-13-73 | " | " | " | | 25.9 | 42 | 151 | 21.0 |
| 8-23-73 | " | " | " | | 25.6 | 39 | 140 | 19.5 |
| 7-27-73 | " | Test Riffle II | 300 | | 23.1 | 28 | 42 | 14.0 |
| 8- 1-73 | " | " | " | 41 | -- | -- | -- | -- |
| 8-13-73 | " | " | " | | 16.5 | 46 | 69 | 23.0 |
| 8-23-73 | " | " | " | | 20.7 | 37 | 56 | 18.5 |
| 7-26-73 | " | Upper Control Riffle | 460 | | 24.5 | 36 | 83 | 18.0 |
| 7-26-73 | " | Lower Control Riffle | 330 | | 27.3 | 27 | 45 | 13.5 |
| 8-72 | Capehorn | Primary Riffle | 3660 | | 28.2 | 27 | 494 | 13.5 |
| 8-73 | " | " | " | | 30.1 | 28 | 512 | 14.0 |
| 8-72 | Elk | Upper Riffle | 2080 | | 22.1 | 32 | 333 | 16.0 |
| 8-73 | " | " | " | | 17.9 | 44 | 458 | 22.0 |
| 8-72 | " | " | 3880 | | 10.7 | 51 | 989 | 25.5 |
| 8-73 | " | " | " | | 8.9 | 60 | 1164 | 30.0 |

(1) Using 6" sampling depth $6" \times \frac{ft}{12"} \times$ Fraction finer than 0.25" x Riffle area

2) bombardment of larger particles with the smaller ones and 3) lifting effect caused by sand scouring from under the larger particles.

During the low flow period, most of the added sediments were trapped in the pools (Figure 7). The pools would fill until the depth was about the same as on the riffle areas. The fine sediments in the pools were observed to form the characteristic wave and ripple of a sand bed stream.

Sediment Transport Capacity Calculation

One of the primary objectives of this study was to develop a method of determining the sediment carrying capability of Batholith streams. This section presents a procedure for use by aquatic biologists, often with little hydraulic experience and a minimum of available data.

From a review of available bedload discharge formulas and actual stream data, the Meyer-Peter, Muller formula appears to be the one most applicable to streams of the Idaho Batholith. This formula is the only one that includes a separate term considering the armour layer. Also the Meyer-Peter, Muller incipient motion relationship shows reasonable agreement with shear stress and armour particle diameter as measured in two of the study streams (Figure 8). The four circled points came from an area where channel alterations had occured and the existing armour may not be the result of the present channel

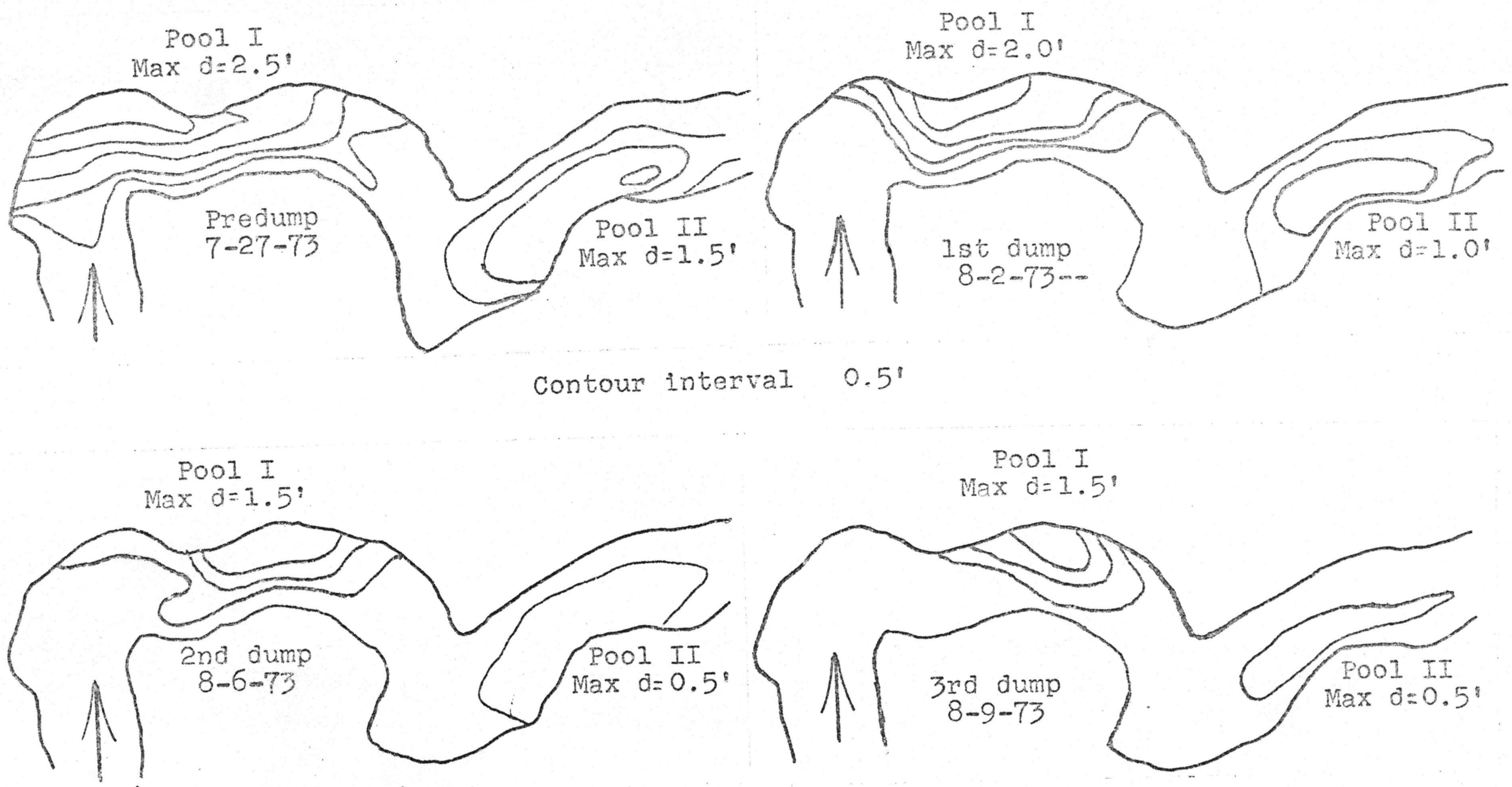



Figure 7: Knapp Creek dump site.

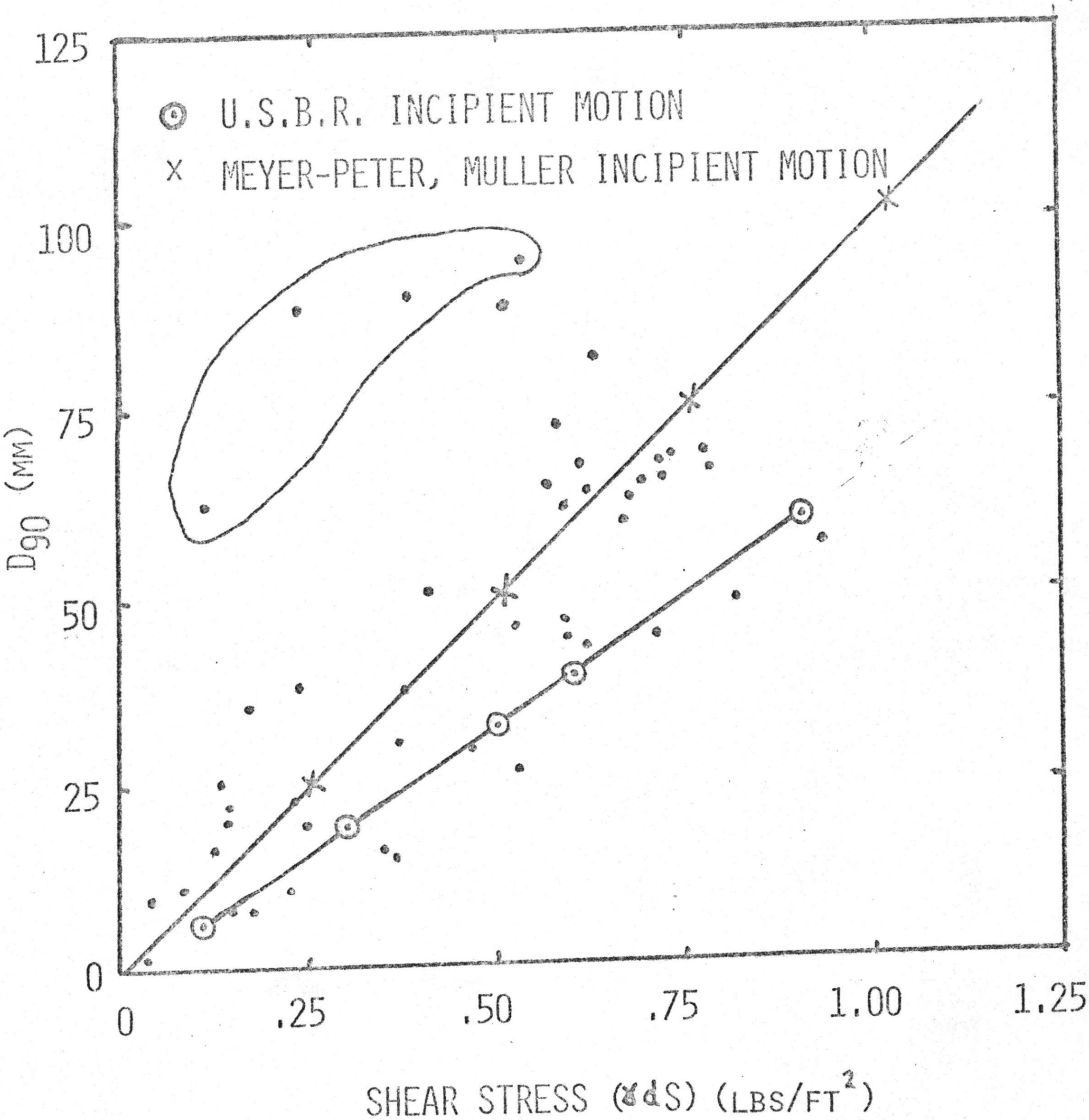



Figure 8 : $D_{90}$ verses shear stress as measured in Capehorn and Knapp Creeks.

configuration.

Characteristics of pools caused by their location on curves or physical barriers like downed trees, falls, and rock intrusions result in complex phenomena such as back surges, secondary currents, variable roughness, etc., which make transport practically impossible to predict. However, by assuming the pools and riffles are in equilibrium, i.e., material that is transported through the riffles is also transported through the pools on a yearly basis, the transport calculation can be simplified. This assumption is supported by the well developed pool and riffle formations in the heavily sedimented Elk Creek, but it is possible the pools are only scoured once every few years. Also, a study of the individual gravel size particles using tracer methods indicated most particles recovered tended to be located in riffles or intermediate locations and not in pools (Milhous, 1972). This is an invalid assumption when streams with high carrying capacities become very heavily sedimented as did the South Fork Salmon River between 1965 and 1969. In this case sediment can be transported in riffle areas and deposited in pool during low flow periods and years of minimal peak discharge.

The Meyer-Peter, Muller formula (see page 11) is divided into static variables, those not changing during the sediment transport period, and dynamic variables, those which do change. The static varibles are $Q_s/Q$, $D_{90}$, S, and $D_m$. For Batholith streams, where the width is at least twenty times the depth in riffle areas, the $Q_s/Q$ ranges from 0.90 to 1.00 when $n_w/n_s = 1.0$ (Figure 2 of Sheppard, 1960). Therefore, a constant value of 0.95 was chosen for this term. Although the slope, S, varies with discharge, it changes very little during the transport period as shown in Table 7 and Figure 9. Table 7, showing the variation of slope on Capehorn Creek with stage, and Figure 9, from Leopold and Wolman (1957) indicate that the high flow slope on a pool and riffle, meandering stream approaches the overall channel slope of that section. The mean diameter, $D_m$, and 90% diameter, $D_{90}$, which are computed from bed material samples, are assumed constant during the transport period. This would not be true when large amounts of fine sediments (less than 0.25 in.) are entering the stream during the transport period. An adjustment in the $D_m$ can be made by using the relationship developed between $D_m$ and the volume of fines in cubic feet per one hundred square feet of streambed surface to a depth of six inches as shown in Figure 10. The relationship is used when known amounts of fine sediments are entering the stream and combined with the prior $D_m$ level, the figure can be used to vary the $D_m$ appropriately.

The dynamic variables of depth, d, and Meyer-Peter, Muller "$n_s$" vary with stream discharge and are therefore related to the stream hydrograph and discharge frequency relations. The depth is related to discharge by a rating curve or depth-discharge relation for the riffle areas.

Table 7: Variation in water surface slope of Capehorn Creek in 1973.

| Section | Stage (ft) | | |
|---|---|---|---|
| | 9.16 | 8.92 | 8.26 |
| Transition | .0051 | .0059 | .0054 |
| Riffle | .0047 | .0048 | .0055 |
| Pool | .0035 | .0036 | .0005 |
| Overall | .0049 | .0050 | .0038 |

Overall for a 1000' section

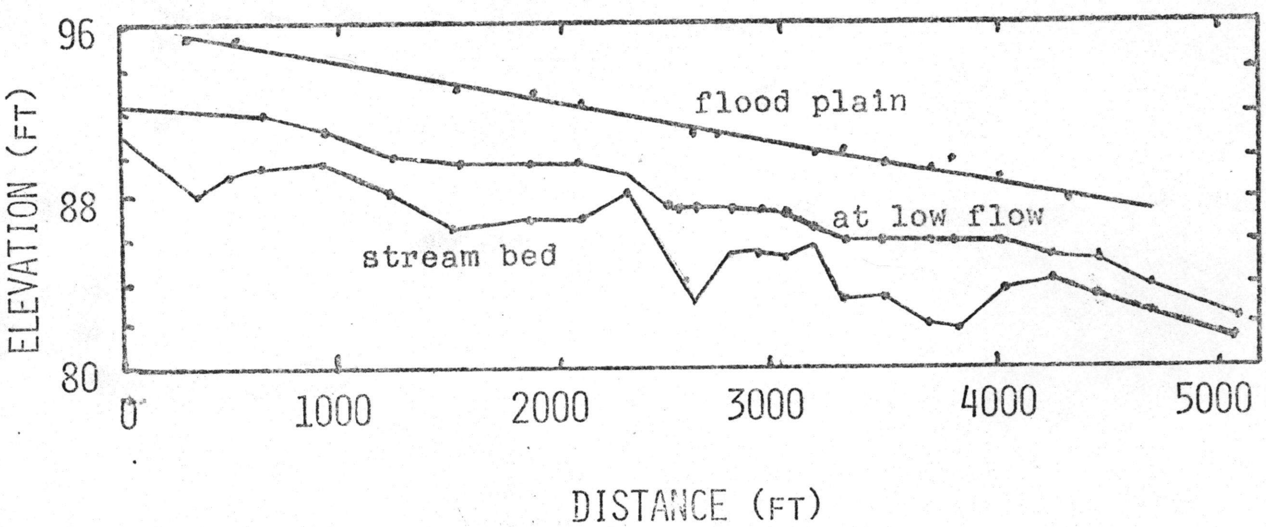



Figure 9: Variation in water surface slope on a pool and riffle stream from Leopold and Wolman, (1957).

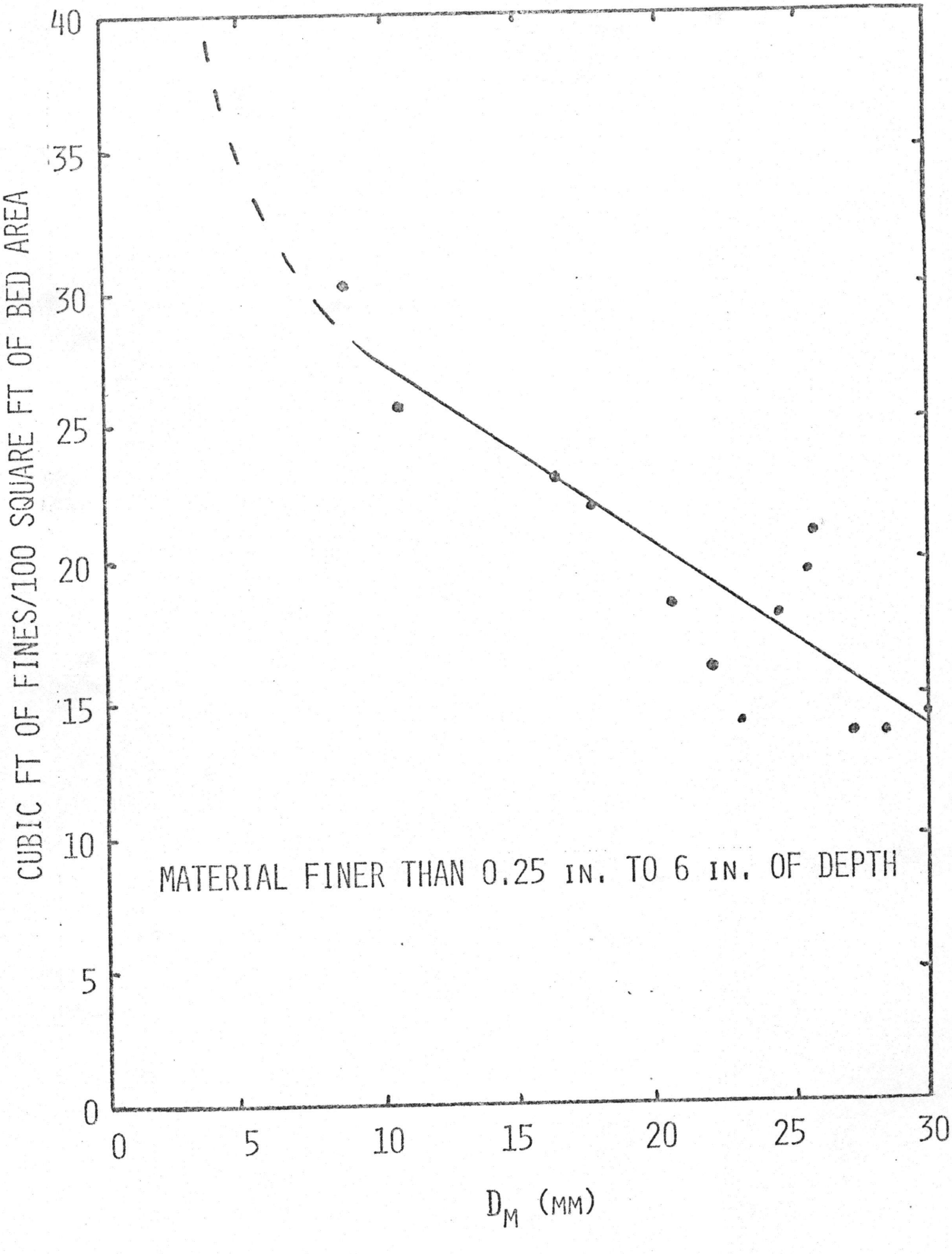



Figure 10: Effect of fine sediments on $D_M$ as determined from present condition in four Idaho Batholith streams.

The Meyer-Peter, Muller "$n_s$" is a factor to relate the Manning's "n" value variation for the total channel roughness and sidewall roughness as related to the channel depth-width ratio into a single function. The relative roughness, resistance to flow or Manning's "n" is assumed constant across the riffle section. Figure 11 supports this assumption by showing the average streambed surface particle size and the corresponding high flow depth which creates the flow resistance. Where the flow is deep, the particles are small thus the relative roughness should be constant. From a nomograph developed by the Bureau of Reclamation (Sheppard, 1960) if the "n" value is constant across the stream, the "$n_s$" value equals the overall Manning's "n" value.

The Meyer-Peter, Muller formula can be rearranged by grouping the static and dynamic variables into a generalized equation for the Batholith. Since it is a tractive force type equation, it contains a theoretical transport level minus a critical transport level or beginning-of-transport term.

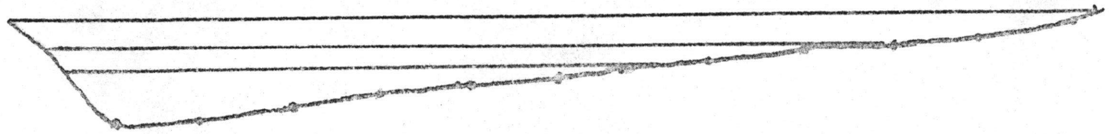
<u>The Meyer-Peter, Muller Formula</u>

$$g_s = 1.606(3.306 \frac{Q_s}{Q} \frac{D_{90}^{1/6}}{n_s})^{3/2} dS - 0.627D_m)^{3/2}$$

Rearrangement results in

$$g_s = 1.606(3.306 \frac{Q_s}{Q}(D_{90})^{1/4} S \frac{d}{n_s^{3/2}} - 0.627D_m)^{3/2}$$

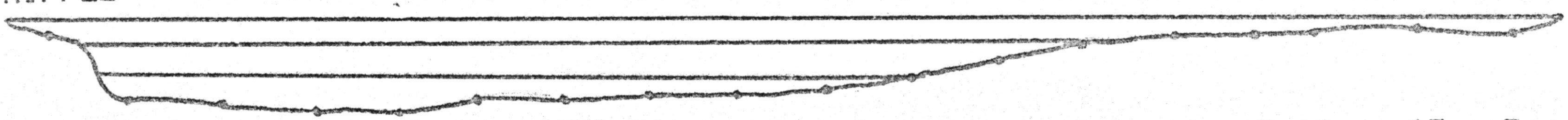
TRANSITION



$D_{90}$ (MM) 121 102 54 50 44 31 32 25 26 26 7 1

| | | | |
|---|---|---|---|
| High Water Marks | W = 39 ft | S = 0.005 | $d_{ave}$ = 2.00 ft |
| Low Flow | W = 19 ft | S = 0.006 | $d_{ave}$ = .82 ft |
| High Flow 1973 | W = 27 ft | S = 0.005 | $d_{ave}$ = 1.50 ft |

RIFFLE



$D_{90}$ (MM) 1 60 68 65 67 64 64 72 58 64 45 14 12 36 25 16 15 7

| | | | |
|---|---|---|---|
| High Water Marks | W = 54 ft | S = 0.004 | $d_{ave}$ = 1.92 ft |
| Low Flow | W = 29 ft | S = 0.005 | $d_{ave}$ = .70 ft |
| High Flow 1973 | W = 36 ft. | S = 0.004 | $d_{ave}$ = 1.30 ft |

Figure 11: Cross-sectional profiles of two sections on Capehorn Creek showing average armour particle ($D_{90}$) at each point and corresponding width, slope and average depth at various flow stages shown.

This equation can be reduced to

$$g_s = 1.606\ (T - T_{cr})^{3/2}$$

$$\text{or } 1.606\ (C_T \cdot d/n_s^{\,3/2} - T_{cr})^{3/2}$$

Where $3.306\ (Q_s/Q)(D_{90})^{1/4}\ S$ is a coefficient of sediment transport, $C_T$, such that the theoretical transport level, T, is $d/n_s^{\,3/2} \times C_T$. The critical transport level, $T_{cr}$, is then 0.627 $D_m$.

The $d/n_s^{\,3/2}$ term changes continually with discharge, therefore, the theoretical transport level, T, also varies. Sediment is only transported when T is greater than $T_{cr}$. Negative values indicate zero transport rate and equal values indicate the point of incipient motion. The daily sediment transport rates are calculated by raising the $T - T_{cr}$ to the three halves power and multiplying by 1.606. The total yearly sediment transport is calculated by summing the daily sediment transport amounts for the year. The result of the calculations is expressed in tons per year per foot width which must then be multiplied by the average width of the riffle during the transport period. Since the transport rate is determined from the bed material present, it will vary as the bed composition changes. Changes can occur when fine sediments enter or leave the stream section. If known amounts of fine sediments are entering the stream, $D_m$ should be varied using Figure 10 and the transport rate will vary accordingly.

Since aquatic biologists are concerned with the material finer than 0.25 inches, the total transport of that size material or finer is determined by multiplying transport rate by the fraction of bed material finer than 0.25 inches. Figure 12, showing the relation of the portion of material finer than 0.25 inches and the sum of three components of streambed surface classification, can be used to determine the amount of fines present in the streambed. All of these steps are presented later in this report as a stepwise procedure for determining total transport during the year.

The amount of fine sediment that should be allowed to enter a stream before detrimental effects will occur on the aquatic habitat will depend on the amount of fines already contained within the stream channel section. Reports by Stuehrenberg (1974) and Sandine (1974) indicate the effects of fines on the aquatic habitat in the Idaho Batholith during this study. Bjornn (1969) indicated that when fines are present above the 20 to 30% level, they begin to become detrimental to the survival of preemergent steelhead trout and chinook salmon. The amount that can enter the stream is the difference between the present level and the allowable level plus the amount transported as determined by summing the yearly values for the period of concern. For example, if sediments are to enter the stream during a period of three years, three

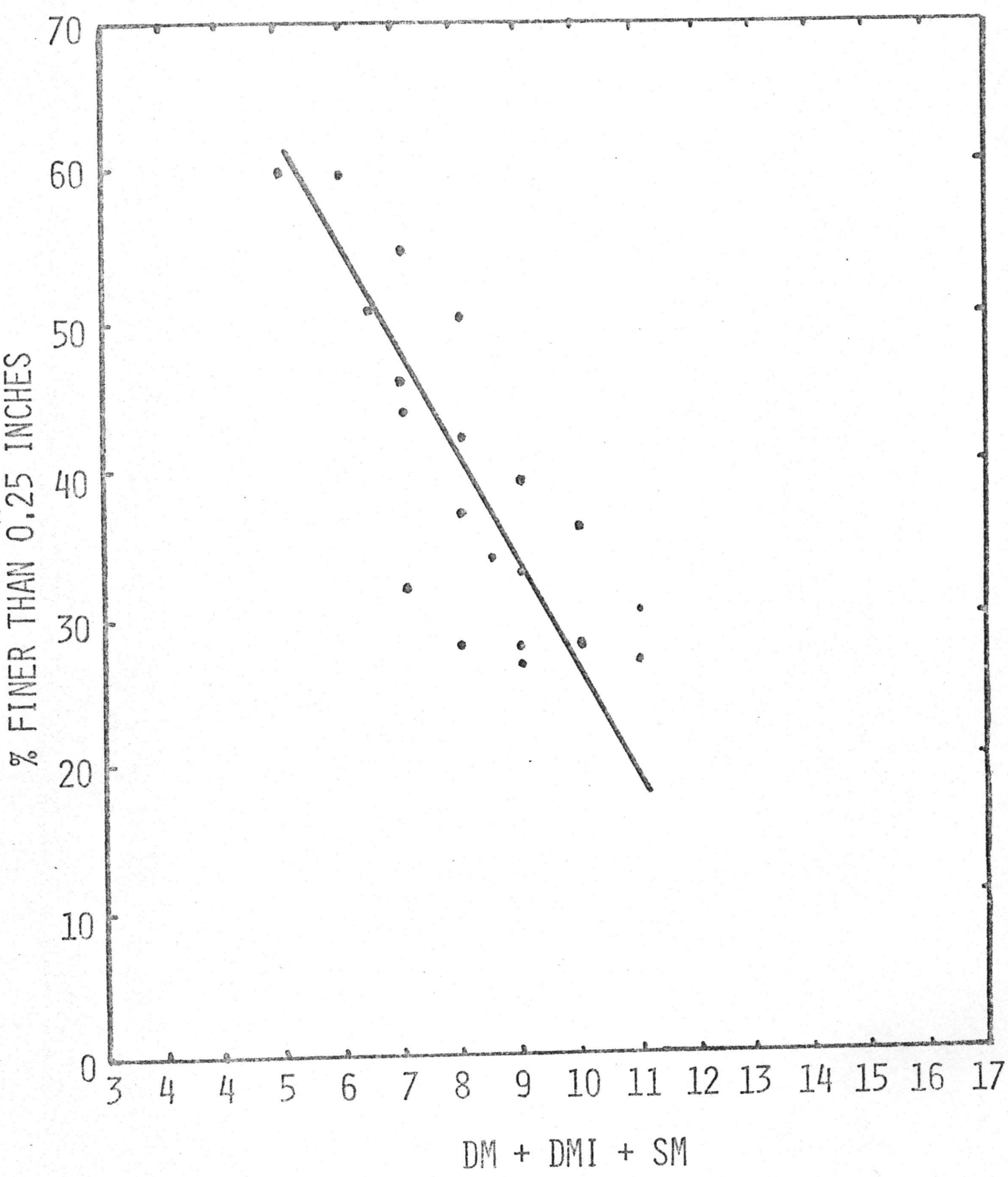



Figure 12: Percent of material finer than 0.25 in. verses streambed surface classification of three Idaho Batholith streams.

runoff events of some chosen frequency can be used to obtain a three year sediment transport amount for that stream.

Data Requirements for Application of the Meyer-Peter, Muller Formula to the Study Area

Some preliminary data are required to calculate sediment transport rates. These include stream flow records, depth-discharge relationships, streambed composition, and channel slope and width. These data are averaged over the entire stream or section of concern. This requires data collection at a minimum of two or three locations characteristic of the entire section.

Stream flow records are obtained from a gaging station on the stream or must be synthesized from neighboring streams of similar hydrologic and physiographic character. Several methods can be used including watershed models, the drainage basin area ratios or daily discharge correlations, preferrable during high flow periods, to synthesize stream flow records. A minimum of five years of record should be developed. A standard frequency curve (Linsley and others, 1958) and an average dimensionless hydrograph can then be constructed. The dimensionless hydrograph is formed by plotting the ratio of daily discharge to peak daily discharge verses days from the day of peak for a period of about 30 days before the peak to 60 days after the peak. In areas such as the

Idaho Batholith, where the major discharge event occurs in May or June during the spring snowmelt, as indicated by stream flow records, this average dimensionless hydrograph gives a good representation of the average high mountain (5000 ft and above) spring snowmelt event. Almost all sediment transport will normally occur during this spring event.

The bed composition can be determined from shallow core samples taken during low flow periods or a bed material analysis as described in Appendix B. When core samples are obtained, a standard grain size distribution curve is plotted and $D_{90}$ is picked from the curve while $D_m$ must be calculated (Appendix C).

If core samples are not available, then a classification of the surface material based upon the system described in Appendix B can be used. Figure 13 and Figure 14 were developed from data obtained in the study streams and can be used to determine $D_m$ and $D_{90}$ respectively. These curves were obtained from core samples, data and the overall average streambed surface classification values. The streambed analysis only relates surface characteristics, but used with a limited amount of core data, possibly three per riffle, would provide a good estimate of the overall bed composition.

The width, depth, and Manning's roughness "n" value vary with stream discharge. These relationships can be

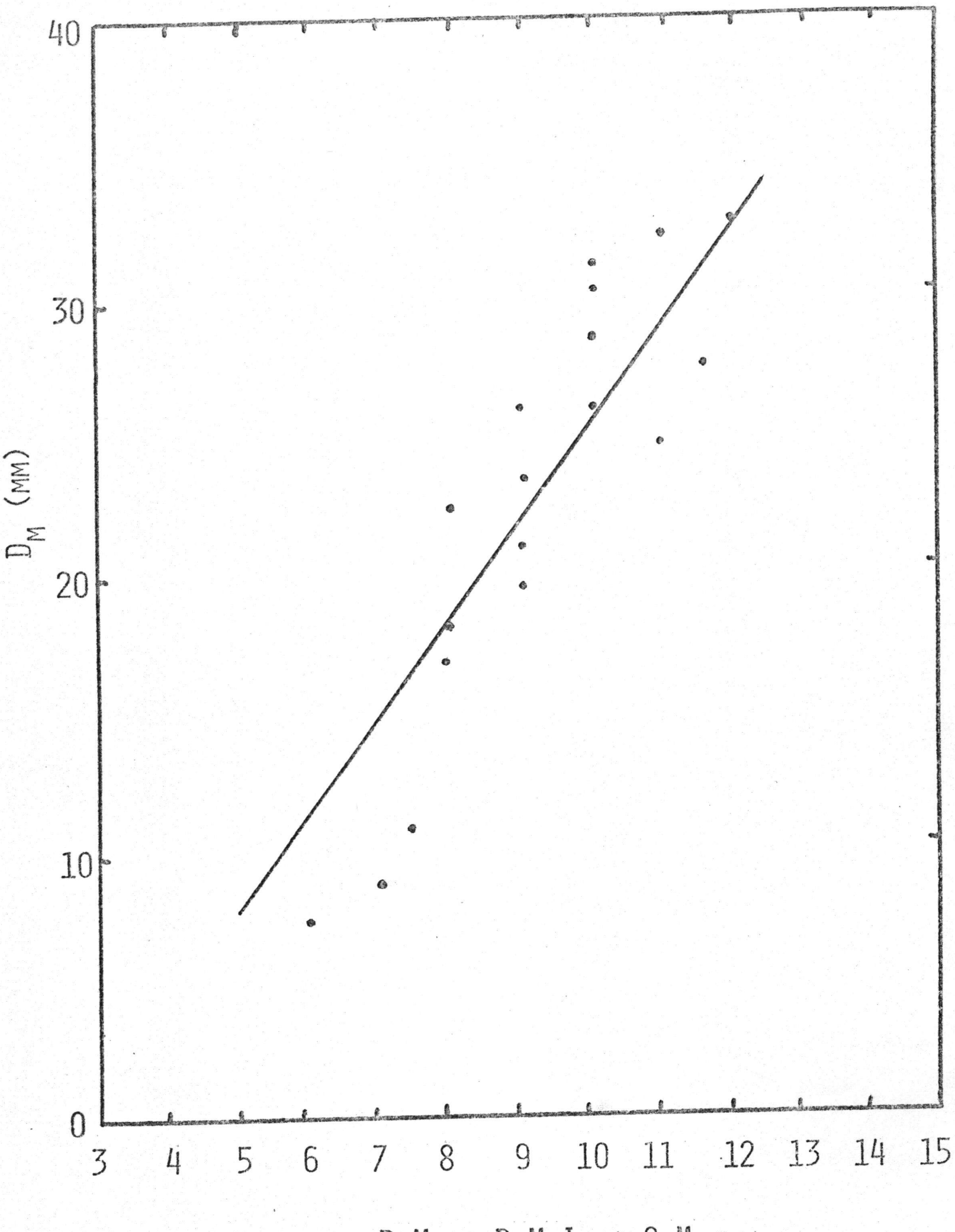



Figure 13: $D_M$ verses streambed surface classification as determined from observation on three Idaho Batholith streams.

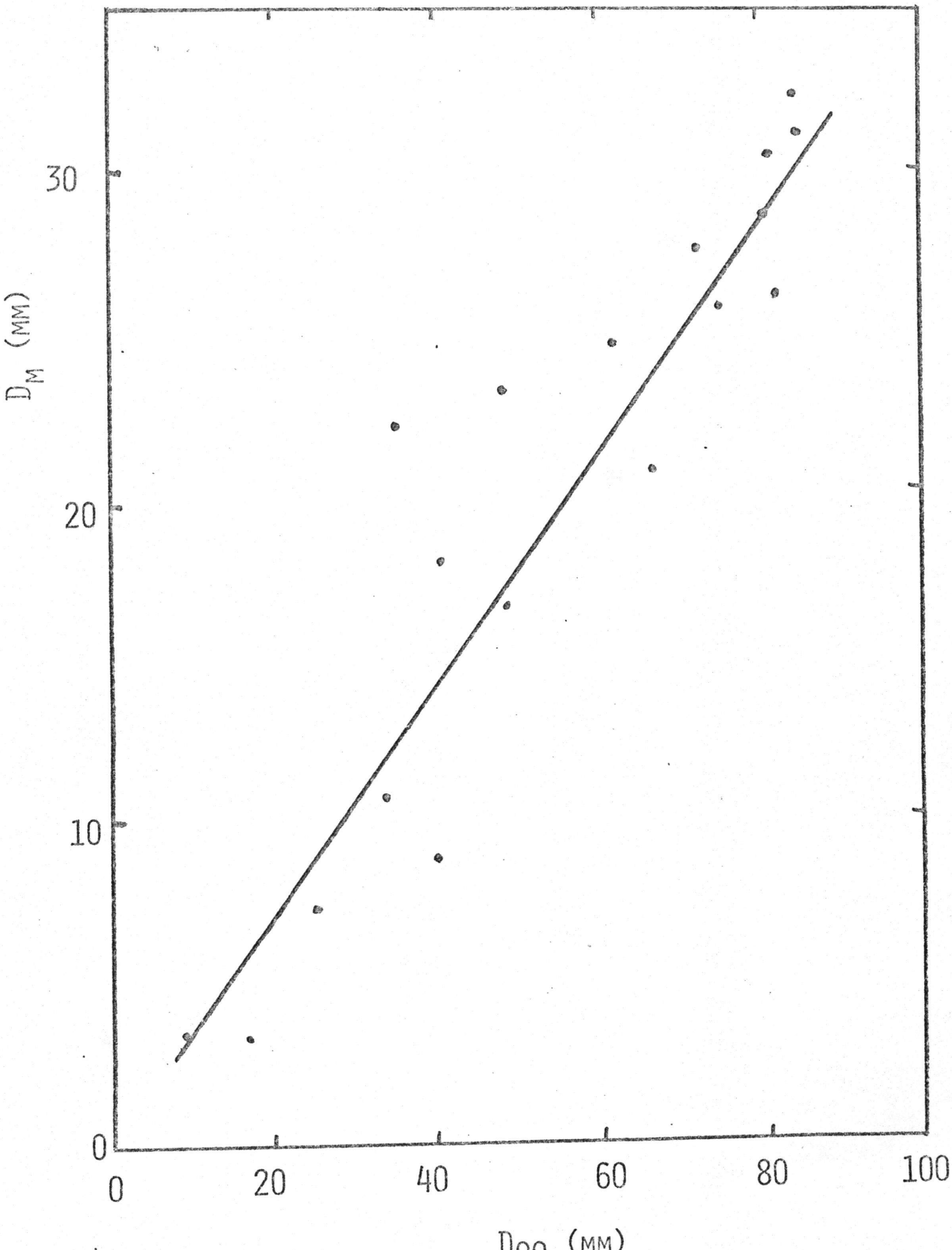



Figure 14: $D_M$ verses $D_{90}$ relationship as determined from four Idaho Batholith streams.

established by several methods. The first and best method uses the cross sectional profile of the streambed where at least two high water surface elevations and corresponding discharges are known. The width and average depth are measured from cross-sectional profiles. The "n" value is then calculated from Manning's equation using the overall channel slope, where $n = (1.5/Q)AR^{2/3}S^{1/2}$ and the hydraulic radius, R, is equal to the depth, d, for a wide channel.

A second method can be used if no high water data are available. This uses the high water marks visible along the stream channel to obtain the cross-sectional profile. Assuming they are the result of the average or two year event and the "$n_2$" varies from 0.025 to 0.035 depending on the streambed roughness, the corresponding discharge can be calculated from Manning's equation. Then by varying the Manning's "$n_2$" according to Figure 15 prepared from data on similar streams in Alberta, Canada, (Kellerhals and others, 1972) a Manning's "$n_{10}$" can be selected. A ten year event discharge is estimated from the two year discharge event and a knowledge of the discharge relationship for the area. The Manning's equation combined with the extended cross-sectional profile is used to determine the corresponding depth-width relationship for the ten year event. This data is used to plot the depth-"n" relationship which can be combined with the depth-discharge plot to form the $d/n^{3/2}$ curve.

The slope can be determined from published

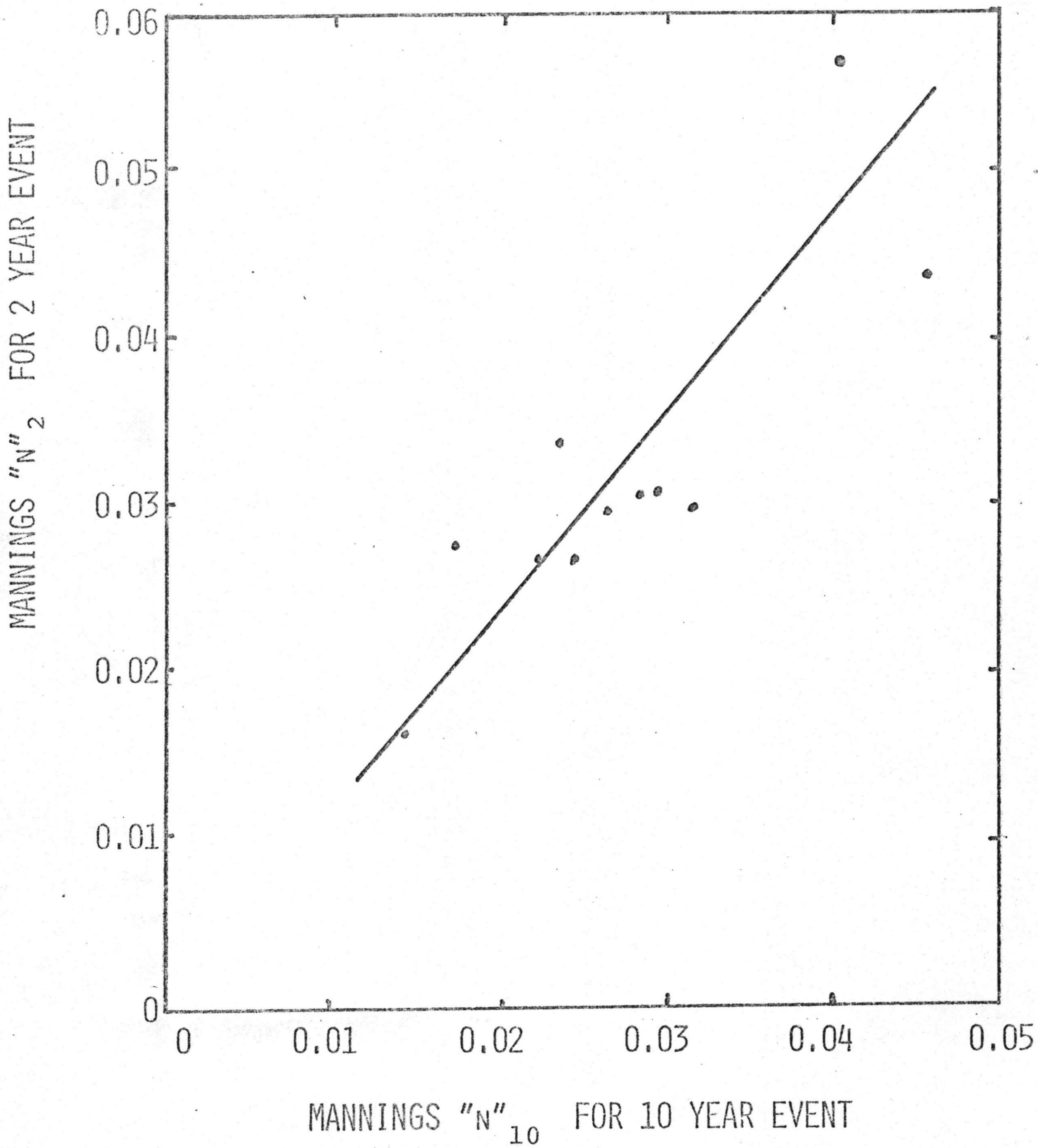



Figure 15: Variation in Manning's "n" between the two year runoff event and the ten year runoff e vent (Kellerhals and others, 1972).

topographic maps or from field surveys. The slope corresponding to the period of transport is the water surface slope during the spring runoff which can be approximated by the streambed slope. In Table 7, it was shown that the riffle slope approaches the approximate overall slope of the stream section during the transport period.

The selection of the return interval for the peak discharge event will depend on the present stream condition, allowable sedimentation, and the importance of stream or stream section. The average return interval would be the two year event which can be used in most determinations of a single year transport rate. If the transport rate over a period of years is to be calculated, such as three years, a one, a two and a three year event can be assumed to occur in this period. It should be recognized that for any given year, there is a 27% chance that the ten year event will occur within any three year period. The entire procedure of determining the transport of sediment through a stream section can be summarized as follows:

<u>Steps to determine transport of sediments</u>

Step 1. Accumulate the following basis data as previously described: a) frequency curve, b) dimensionless hydrograph, c) Q verses d curve, d) d verses "n" curve, e) bedmaterial composition and f) overall channel slope.

Step 2. Calculate d verses $d/n_s^{3/2}$ from Q verses d curve and d verses "n" curve and plot relationship

Step 3. Determine critical level of transport ($T_{cr}$) from Figure 16 using $D_m$.

Step 4. Determine the coefficient of theoretical level of transport ($C_T$) from Figure 17 using $D_{90}$ and S.

Step 5. Determine point of incipient motion $T = T_{cr}$ where $T_{cr} = C_T(d/n_s{}^{3/2})$ or $d/n_s{}^{3/2} = T_{cr}/C_T$.

Step 6. Determine depth of water over the riffle at the point of incipient motion from the d vs $d/n_s{}^{3/2}$ relation developed for the stream section (Step 2).

Step 7. The discharge at incipient motion is determined from the depth-discharge curve for the stream from d (Step 6).

Step 8. Select a peak discharge from the frequency curve developed for the stream section using the desired return interval.

Step 9. Obtain a runoff hydrograph by multiplying the dimensionless hydrograph by the selected peak discharge (Step 7).

Step 10. Draw a line on the hydrograph at the incipient motion discharge.

Step 11. Determine the mean daily discharge for each day the stream discharge is above the incipient motion level.

Step 12. The corresponding depth is then obtained from the depth-discharge curve.

Step 13. The results of Step 12 and Step 2 are combined to obtain $d/n_s{}^{3/2}$ for each day.

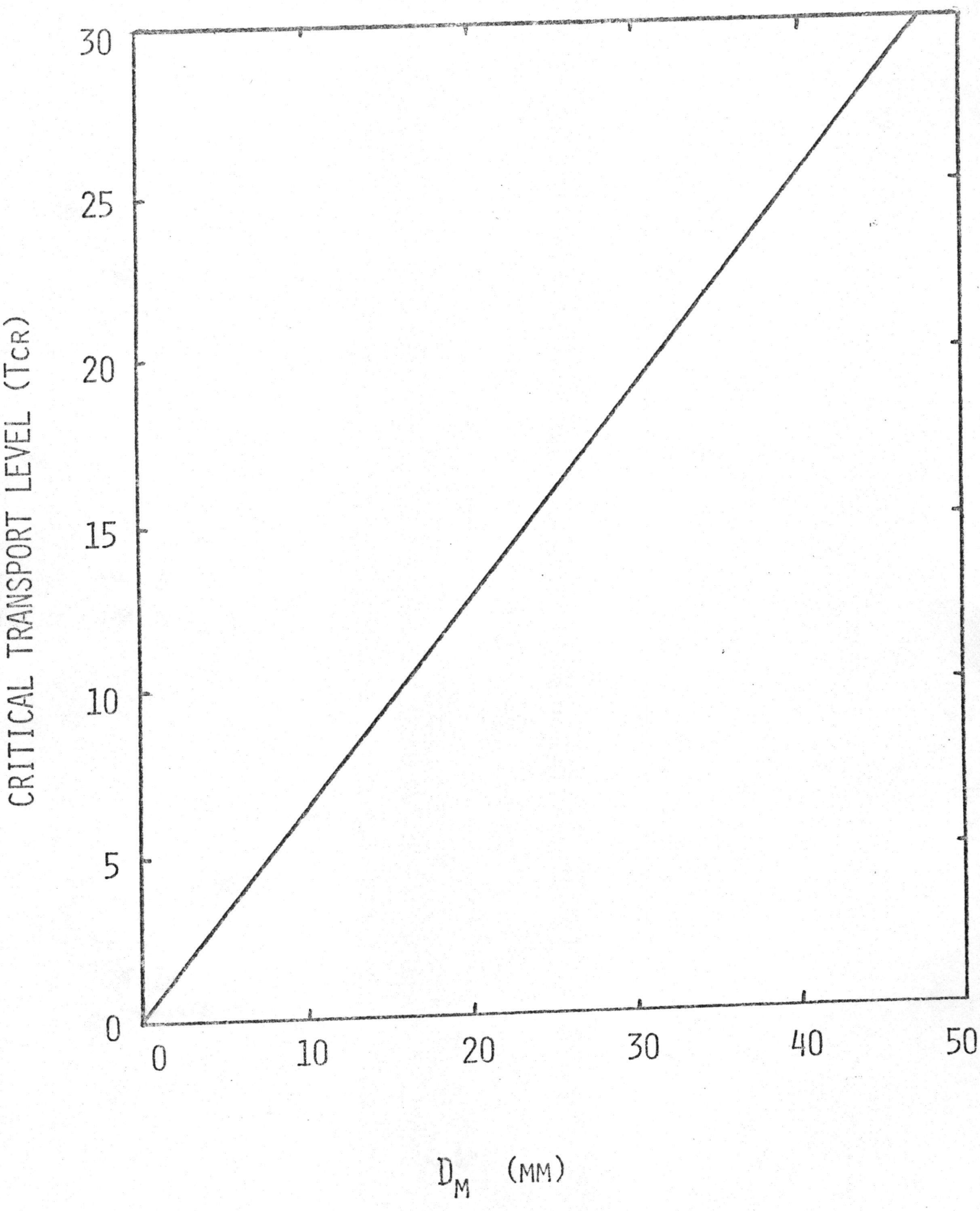



Figure 16: Computation of the critical transport level, $T_{CR}$, from $D_m$, $T_{CR} = 0.627\ D_m$.

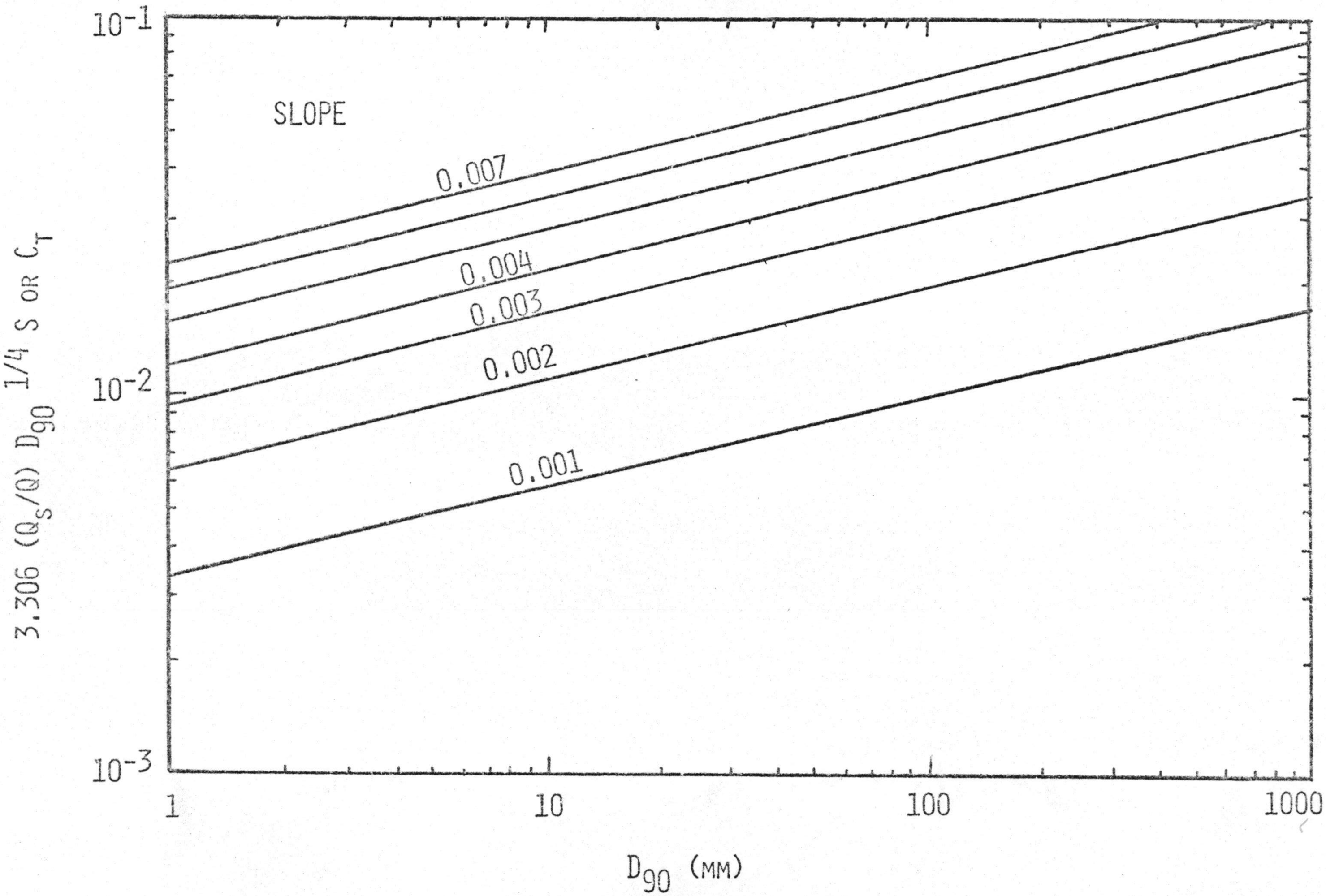



Figure 17: Computation of the coefficient of theoretical transport, $C_T$, from $D_{90}$.

Step 14. The theoretical level of transport, T, is determined by multiplying $d/n_s^{3/2}$ (Step 12) by $C_T$ (Step 4) for each day.

Step 15. Subtract the critical level of transport $T_{cr}$, (Step 3) from T in above step for each day.

Step 16. Raise $(T - T_{cr})$ to the 3/2 power and multiply by 1.606 or use Figure 18 to obtain the daily sediment transport.

Step 17. Sum the daily rates to give total yearly sediment transport rates per foot width.

Step 18. For the total yearly transport of fine sediment per foot width, multiply the total yearly transport by the average fraction of bed material finer than 0.25 inches.

Step 19. Finally, multiply the yearly sediment transport by the average width of the stream section for the total transport rate.

Example Transport Calculation

The following example is given to illustrate the use of this method for calculating sediment transport in Batholith streams. The example is for the lower portion of Capehorn Creek just upstream from the bridge on Highway 21 with a drainage area of 28 square miles.

Step 1. Given:

a) Frequency curve, Figure 19 developed from flow correlations with the Middle Fork Salmon

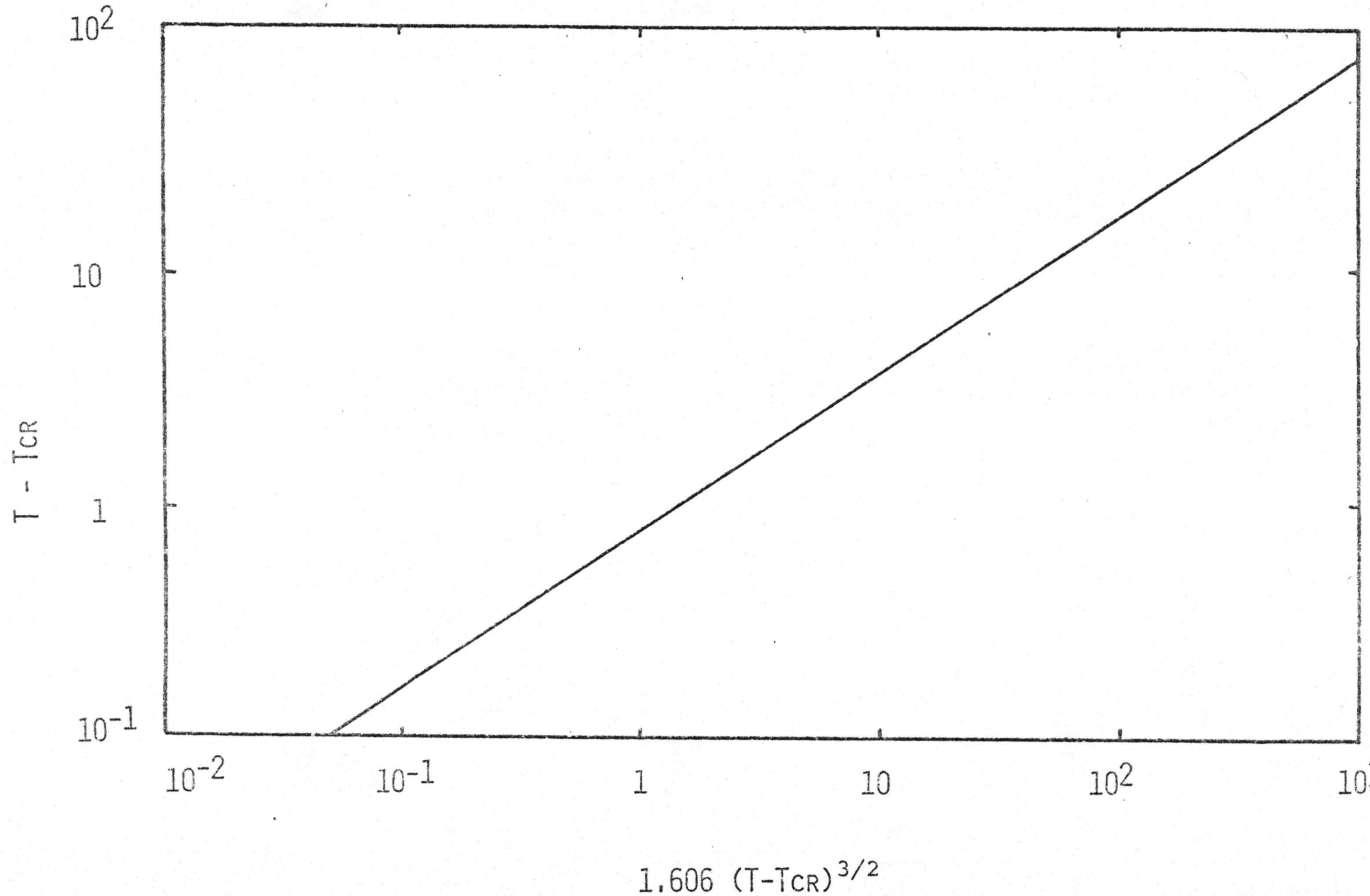



Figure 18: Computation chart for raising $T-T_{CR}$ to the 3/2 power and multiplying by 1.606.

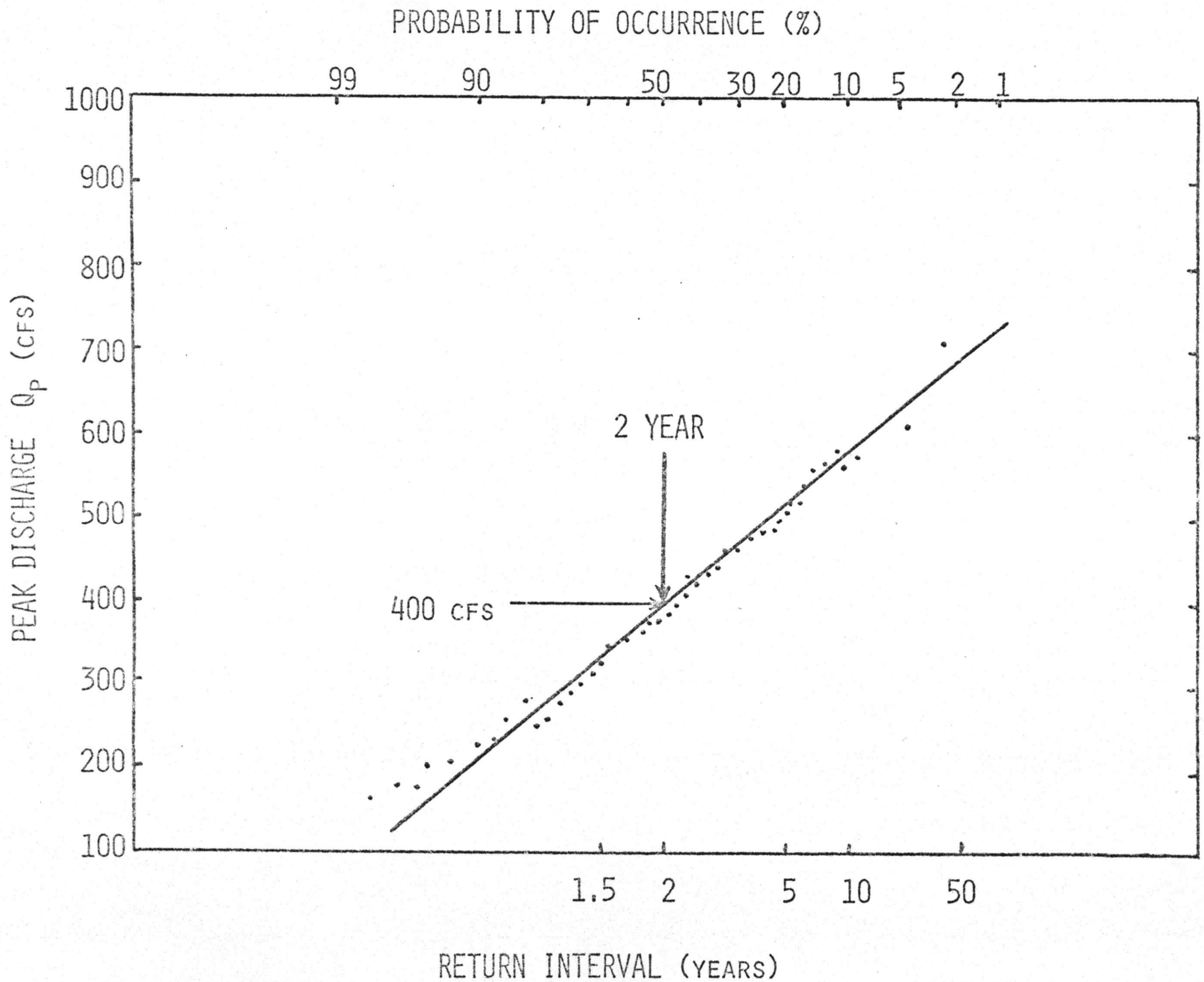



Figure 19: Frequency relationship of peak daily discharge for Capehorn Creek (1929-1971).

River near Capehorn (the closest gaging station) using 42 years of record.

b) Dimensionless hydrograph, Figure 20 also from the Middle Fork Salmon River near Capehorn using the most recent 10 years of record.

c) Q verses d, Figure 21

d) d verses "n", Figure 22

e) Streambed composition is (4,4,2) (see Appendix B).

f) from Figure 13, $D_m$ is 25mm and from Figure 14 $D_{90}$ is 72mm

Step 2. Compute d verses $d/n_s^{3/2}$, plot in Figure 23.

Step 3. Critical level of transport is 15.8 (Figure 16)

Step 4. Coefficient of actual transport is 0.046 (Figure 17) using channel slope of 0.005.

Step 5. Point of incipient motion $d/n_s^{3/2} = T_{cr}/C_T = 16.0/.046 = 348$

Step 6. Incipient motion riffle depth, d is 1.30 ft, Figure 23.

Step 7. Incipient motion discharge Q is 260 cfs, Figure 21.

Step 8. Peak discharge, $Q_p$ is 400 cfs using 2 year or 50% probability of occurance.

Step 9. Develop runoff hydrograph, Figure 24.

Step 10. Draw line at incipient discharge, Figure 24.

Step 11-19. Shown in Table 8.

By varying the return interval and streambed composition alternately and repeating the transport calculations,

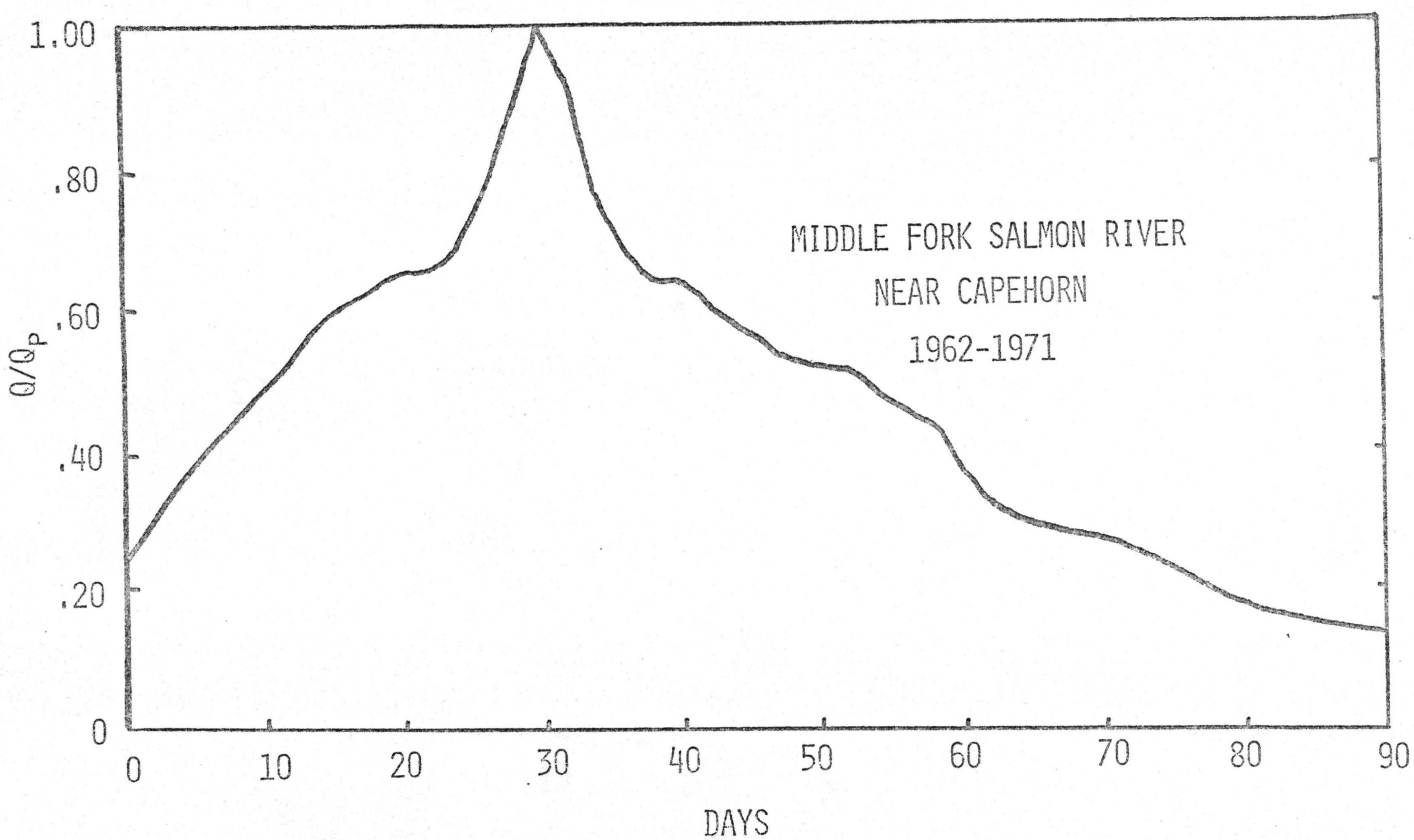



Figure 20: Dimensionless hydrograph.

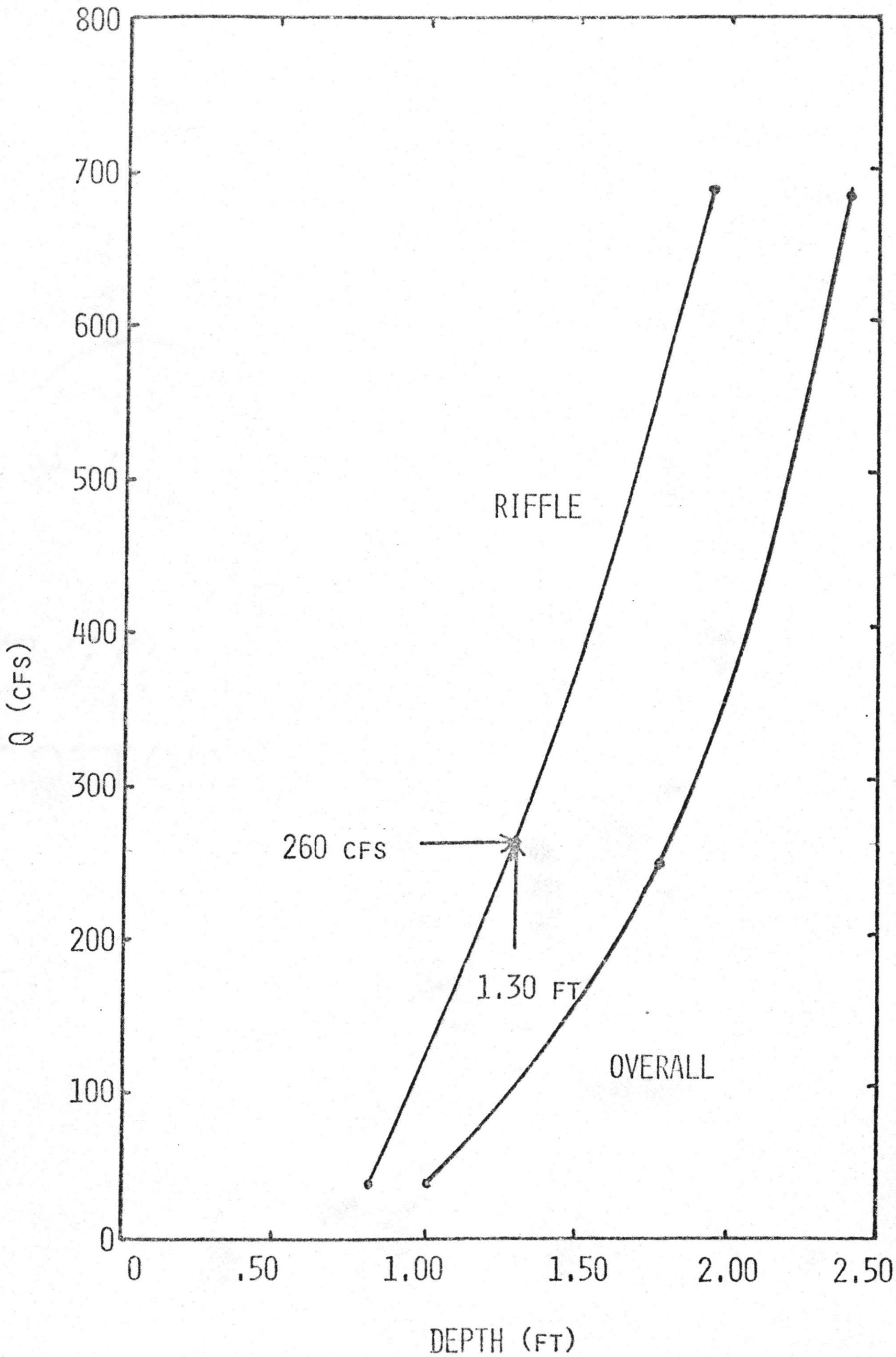



Figure 21: Depth verses discharge relationship for Capehorn Creek.

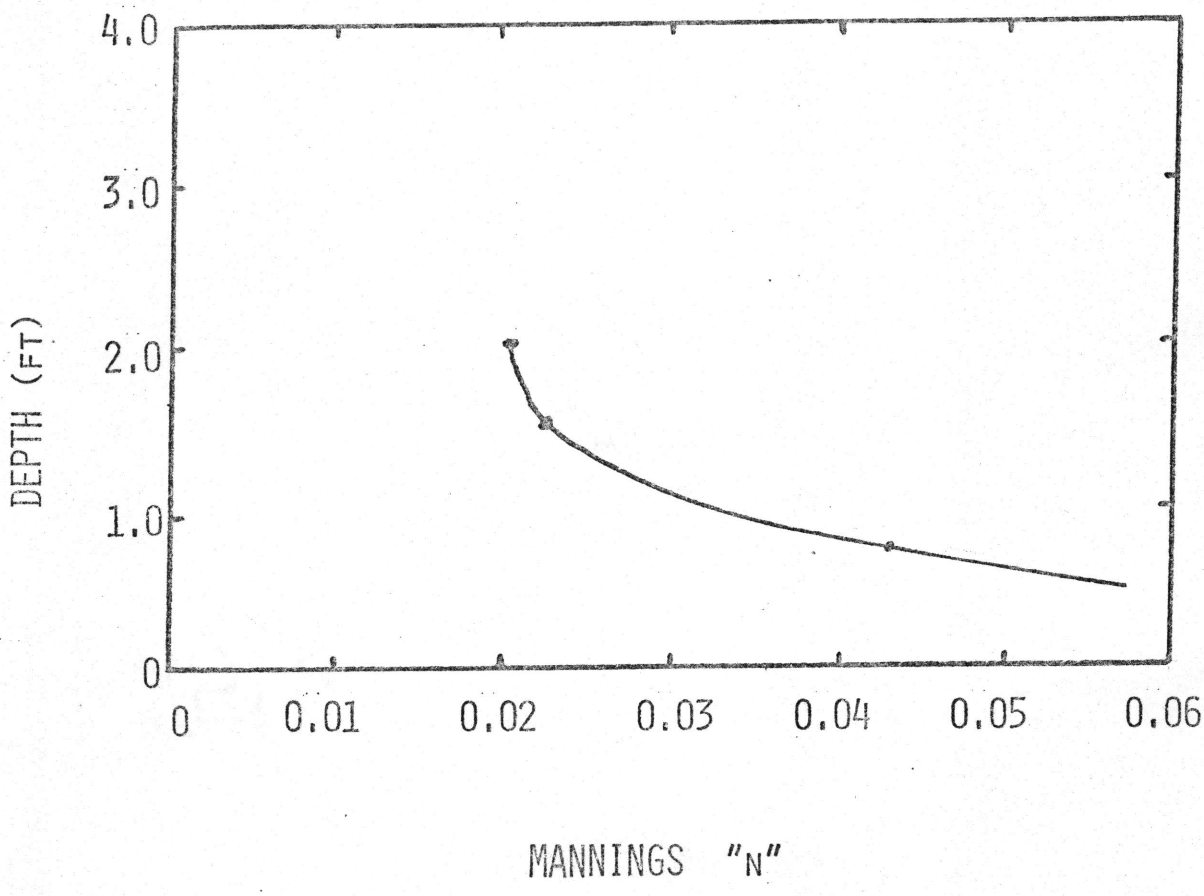



Figure 22: Depth verses Manning's "n" relationship for Capehorn Creek.

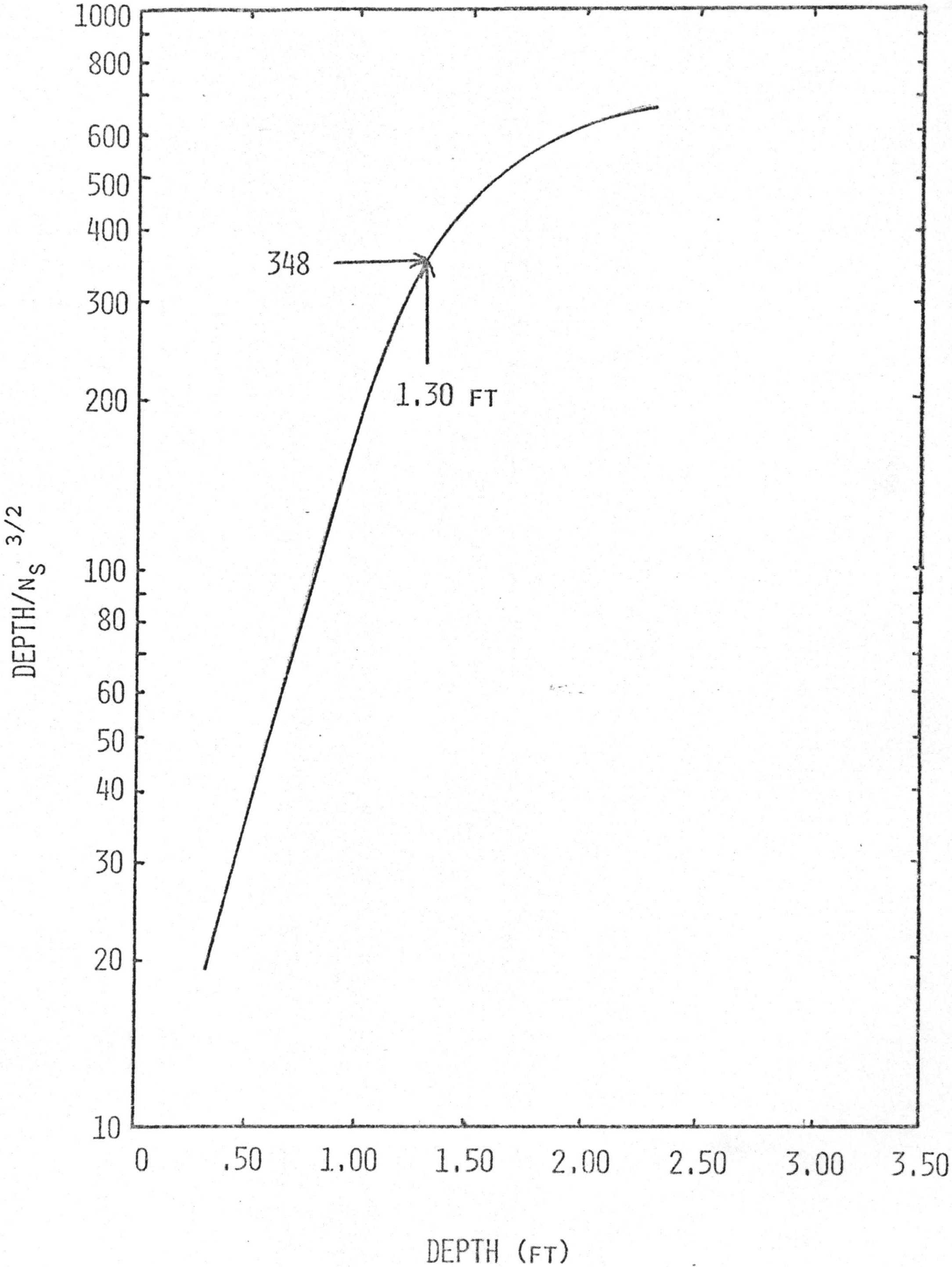



Figure 23: Depth/$n_s^{3/2}$ verses depth relationship for Capehorn Creek.

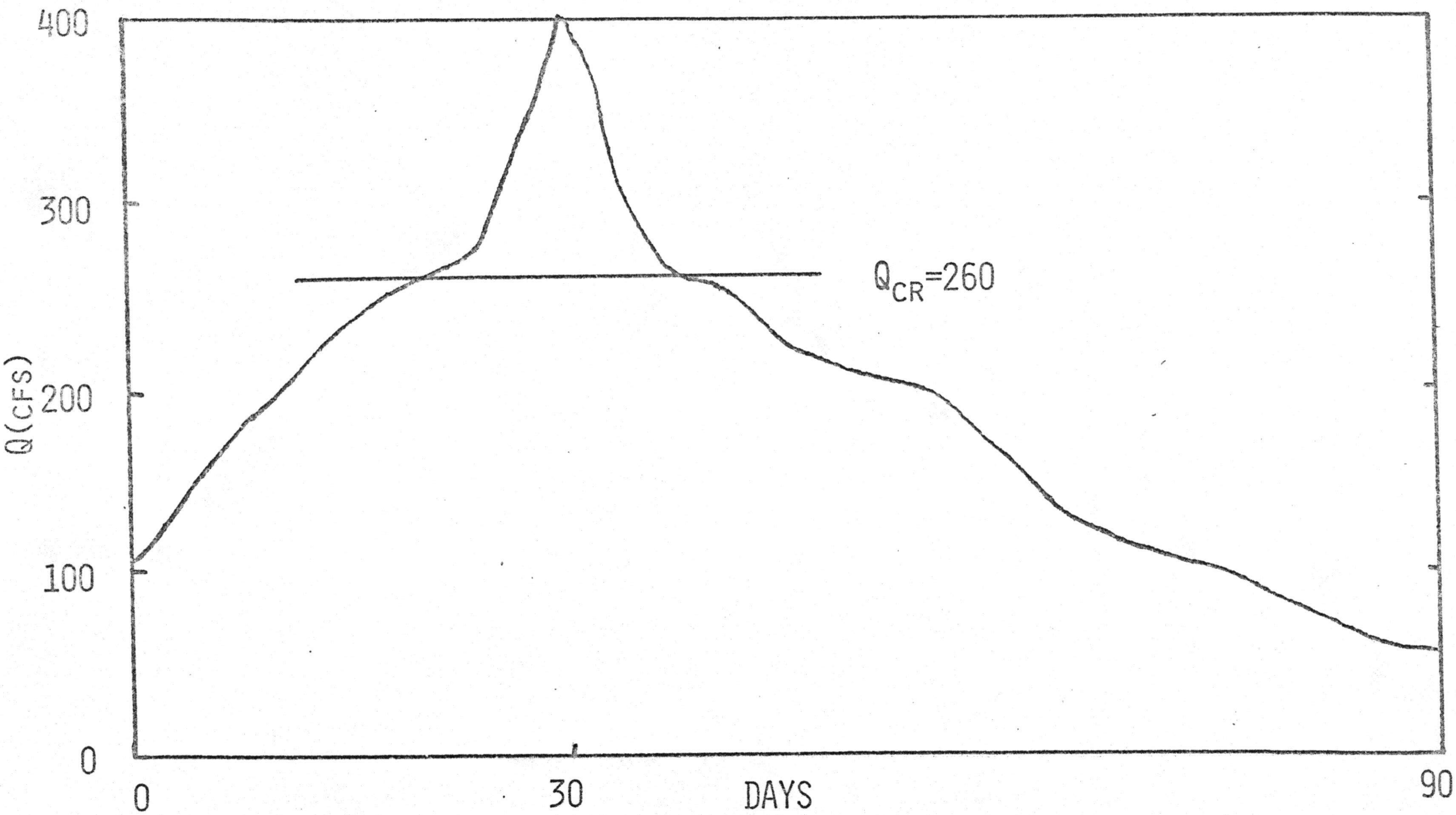



Figure 24: Hydrograph for Capehorn Creek.

Table 8: Summary of example transport calculations

| Period(1) | $Q_{ave}$(1) | $d_{ave}$(2) | $d/n_s^{3/2}$(3) | T(4) | $T-T_{cr}$(5) | $1.606(T-T_{cr})^{3/2}$(6) |
|---|---|---|---|---|---|---|
| 1-2 | 263 | 1.31 | 352 | 16.2 | .2 | .15 |
| 2-3 | 268 | 1.33 | 360 | 16.6 | .6 | .62 |
| 3-4 | 275 | 1.34 | 370 | 17.0 | 1.0 | 1.6 |
| 4-5 | 287 | 1.37 | 390 | 17.9 | 1.9 | 4.2 |
| 5-6 | 302 | 1.40 | 400 | 18.4 | 2.4 | 5.0 |
| 6-7 | 321 | 1.42 | 410 | 18.9 | 2.9 | 8.0 |
| 7-8 | 342 | 1.46 | 432 | 19.9 | 3.9 | 12.5 |
| 8-9 | 362 | 1.50 | 452 | 20.8 | 4.8 | 17.0 |
| 9-10 | 386 | 1.55 | 476 | 21.9 | 5.9 | 22.0 |
| 10-11 | 395 | 1.56 | 480 | 22.1 | 6.1 | 25.0 |
| 11-12 | 382 | 1.54 | 470 | 21.6 | 5.6 | 21.0 |
| 12-13 | 360 | 1.48 | 445 | 20.5 | 4.5 | 15.0 |
| 13-14 | 329 | 1.45 | 430 | 19.8 | 3.8 | 12.0 |
| 14-15 | 304 | 1.40 | 400 | 18.4 | 2.4 | 5.0 |
| 15-16 | 288 | 1.38 | 390 | 17.9 | 1.9 | 4.2 |
| 16-17 | 275 | 1.34 | 370 | 17.0 | 1.0 | 1.6 |
| 17-18 | 265 | 1.31 | 352 | 16.2 | .2 | .15 |
| | | | | | | 155.02 tons/yr/ft width Step 17 |

(1) Step 11 from Figure 23
(2) Step 12 from Figure 20
(3) Step 13 from Figure 22
(4) Step 14 $T = C_T \times d/n_s^{3/2}$ : $C_T$ from Figure 17 : $C_T = 0.046$
(5) Step 15 $T_{cr}$ from Figure 16 : $T_{cr} = 16.0$
(6) Step 16 from Figure 18

Step 18 155 tons/yr/ft width x .28 = 43.4 tons/yr/ft width

Step 19 using a width of 40 ft

40 ft x 43.4 = 1730 tons/yr

assuming 100 lbs/$ft^3$ or one ton = 0.74 $yd^3$

then total $q_s$ = 1280 $yd^3$/yr

a relationship such as Figure 25 can be developed to give sediment discharge rates at various return interval and streambed mean diameters. One weakness of the procedure is that $D_m$ and $D_{90}$ must be assumed to be related according to a relationship such as Figure 14.

Limitation of Study

This section presents the advantages, disadvantages and limitations of the various methods and prodedures used in the study. The prodedure to determine the streams carrying capacity was not verified by field measurements of bedload transport. It provides a good basis for further studies and at least gives some insight to the transport rate. The method is also limited to observation in two or three streams located in a small portion of the Batholith. When the existing armour layer is totally covered with fine sediments, the stream may react as a sand bottom alluvial stream. In that case another formula other than the Meyer-Peter, Muller formula, developed for these conditions, may be more applicable.

The procedure used to measure the physical characteristics of these streams involving detailed mapping of a stream section was used mainly for the aquatic life portion of the study since the low flow period when such mapping can be conducted is of little value in the prediction of the sediment transport rate. Only the streambed composition determined during the low flow

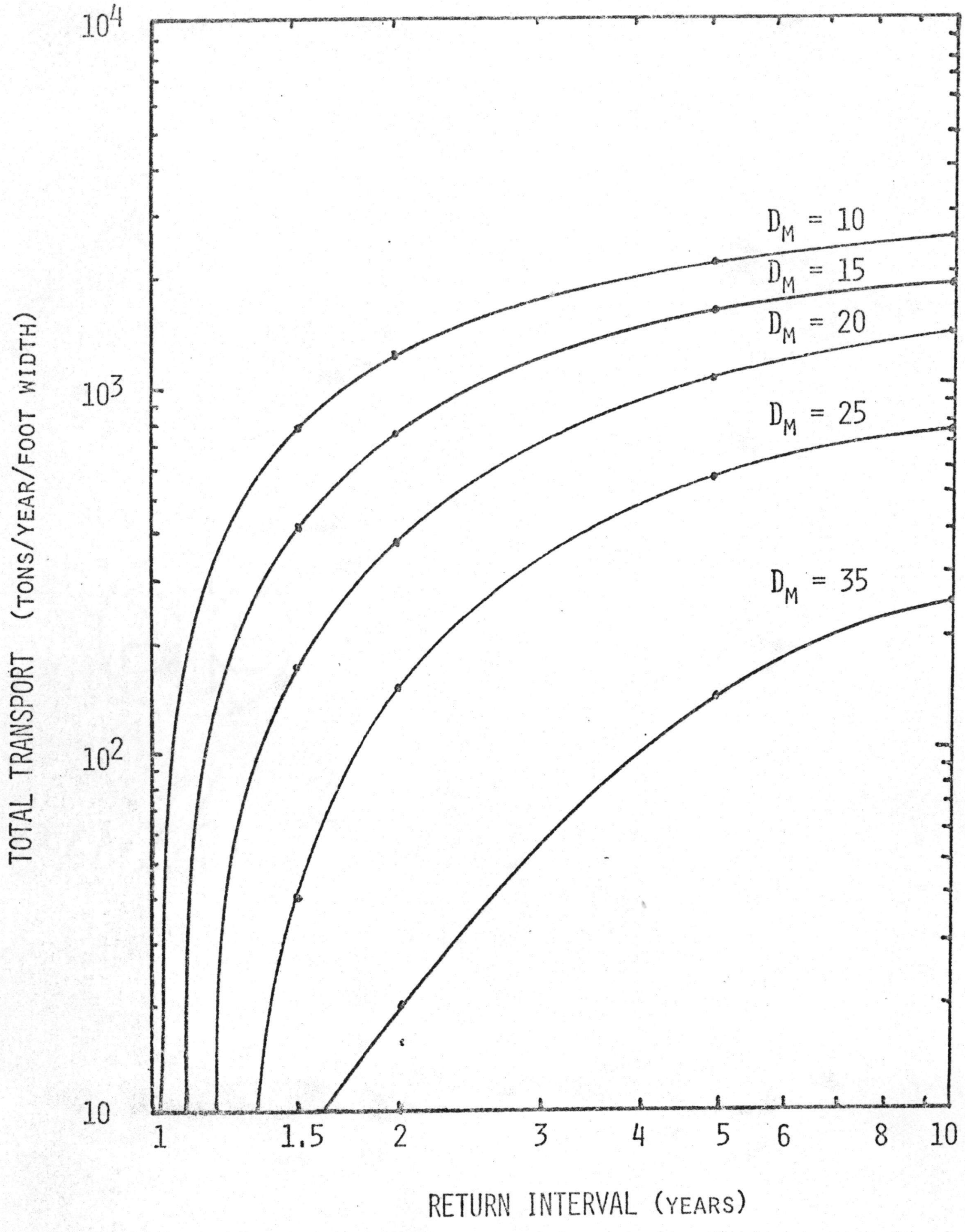



Figure 25: Total transport verses return interval for Capehorn Creek as determined from the Meyer-Peter, Muller bedload formula

period is necessary to predict the transport rate. Methods used to determine the streambed composition are far from adequate but lack for better methods.

# CONCLUSIONS

The following conclusions can be derived from the results of this study:

1. The carrying capacity of Idaho Batholith streams can be calculated using the Meyer-Peter, Muller bedload formula (Figure 25). The Meyer-Peter, Muller incipient motion relationship shows good agreement with data collected in two streams of the Batholith (Figure 8). In years such as 1973, the peak discharge is not large enough to move the armour layer and the resulting transport rate is insignificant (Figure A-2). During base flow periods, only trace amounts of sediments are transported (Table 3). If enough fine sediments of 0.25 inches or smaller are dumped on the riffle areas, some sediments would be transported but most would be trapped in the pools during the base flow period.

2. The amount of fine sediments that can enter these streams can be determined by a sediment budget. The amount allowed to enter equals the amount transported out of the stream section plus the allowable amount of storage of fines as established by the aquatic managers.

3. The level of fine sediments on riffle areas in the survey streams indicates Capehorn Creek and Knapp Creek (about 30% finer than 0.25 inches) are moderately sedimented, Marsh Creek (35% finer than 0.25 inches) is slightly heavier sedimented and Elk Creek (about 50%

finer than 0.25 inches in 1973) is heavily sedimented.

4. Improved techniques of measuring the streams physical characteristics include the streambed surface classification system (Appendix B) which could provide an effective means of visual determination of streambed composition (Figure 13) and the dye dillution technique proved to be an effective method of measuring stream discharge especially during high flow periods in Idaho Batholith streams.

5. The average water surface slope for riffle areas approached the slope of the overall channel reach (Table 7).

6. The Mannings roughness "n" value varied extensively from high to low flow periods, but changes very little during the high flow period (Figure 22).

## RECOMMENDATIONS

The following is a list of areas requiring additional investigation or data to support the findings of this report.

1. Additional measurements of sediment transport are needed to support the calculated transport rate during the high flow period.

2. Additional data on the correlation of the streambed surface classification system and bed composition as determined from core sampling and sieve analysis is required.

3. Further investigation of the variation in Mannings roughness "n" value and slope with stream depth on riffle area is required.

4. Measure and analyze the transport of the fine sediments used to fill the pools on the Knapp Creek dump site. This will give insight to fine sediment movement through pool areas.

5. Tracer studies should be conducted to determine the movement of individual particles within and along the streambed.

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# APPENDIX A

## DESCRIPTION OF STUDY STREAMS

A standard form was adopted to present the description of a stream or river in a manner that people throughout the world can relate to the stream (Neill and Galay, 1966). Although only a 600 to 1,000 foot portion of the streams were surveyed in detail, the entire stream is described with the use of 1:250,000 scale topographic maps. The following description is of Capehorn Creek. A comparison of all study streams is given in Table A-1.

1. GEOGRAPHIC FEATURES

(i) Location. See Figure 3.

(ii) Climate. Average annual precipitation, 30 to 40 inches and normal annual temperature of 36°F (Idaho Water Resource Board, 1968).

(iii) Geologic setting. Located in Idaho's Batholith, a large intrusive granitic body characterized by steep mountainous terrain with a high erodability and landslide potential. The average elevation of the drainage basis is approximately 7,000 feet, ranging from 6,000 to 10,000 feet.

(iv) Vegetation. Flood-plain vegetation consists of forest and meadow areas.

(v) Channel pattern. Figure A-1 shows the stream study area (approximately 1,000 feet long). The stream is a typical pool-riffle mountain stream with some braided

Table A-1: Comparison of survey streams.

| Stream | Drainage Area $mile^2$ | Average August Discharge cfs | Overall Slope | Bed Material--Overall Average mm $D_{35}$ | $D_{50}$ | $D_m$ | $D_{90}$ | % finer 0.25" |
|---|---|---|---|---|---|---|---|---|
| Capehorn | 28 | 35 | .0050 | 8 | 15 | 26 | 80 | 35 |
| Knapp | 16 | 10 * | .0042 | 7 | 19 | 25 | 86 | 41 |
| Elk | 34 | 51 | .0038 | 3 | 6 | 13 | 39 | 51 |
| Marsh | 50 | 38 | -- | 6 | 14 | -- | -- | 38 |

* Above irrigation diversion and study area

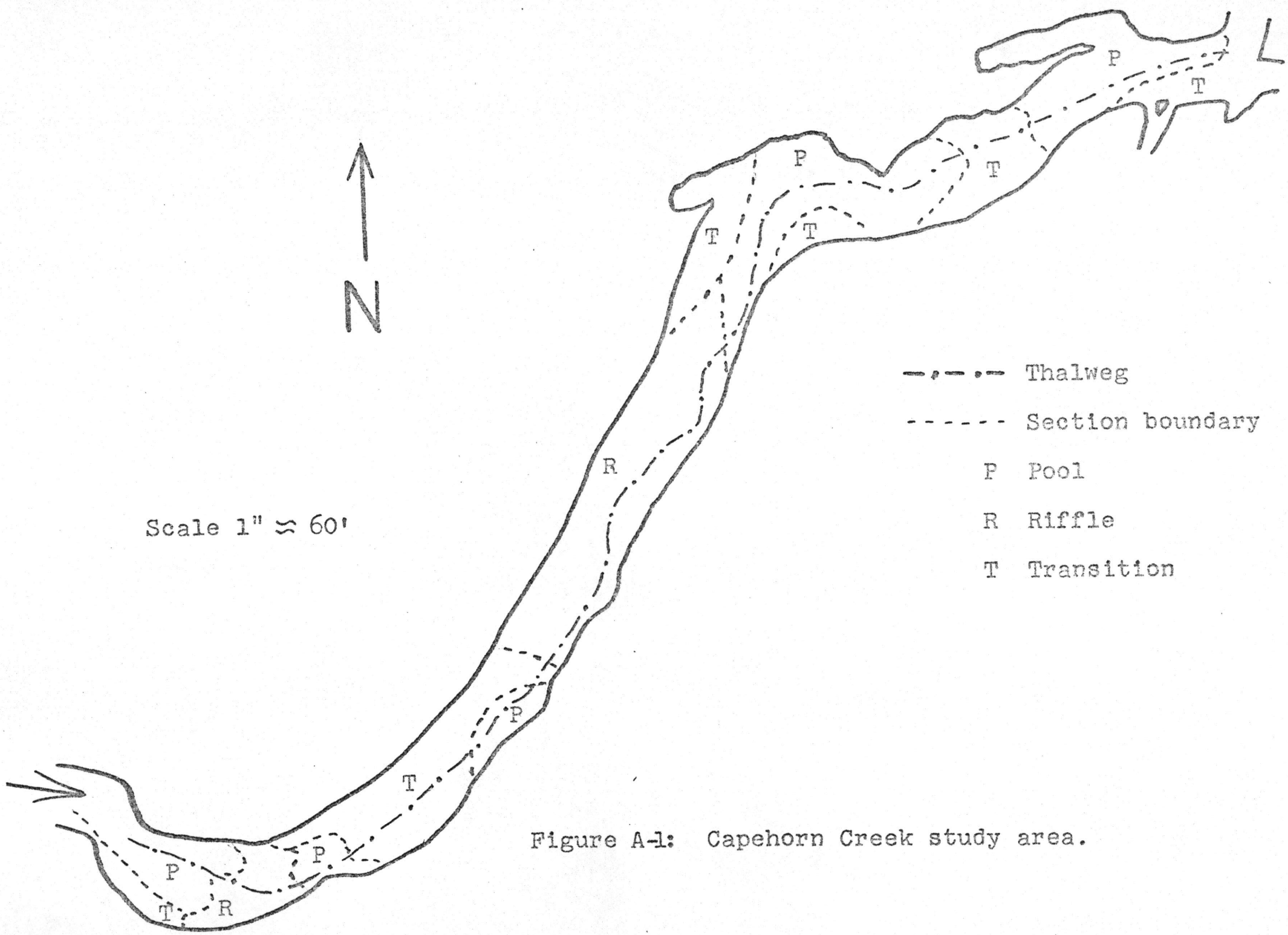



Figure A-1: Capehorn Creek study area.

reaches and extreme meandering, except for survey area.

Average meander wave length: 150 ft

Width of meander belt : 100 ft

Sinuosity index : 2.00

(vi) Drainage area. 28 square miles.

II. HYDROLOGIC AND HYDRAULIC DATA.

(i) Discharges and stages. Figure 21 shows discharge-stage relation for period of study. Figure 22 and Figure 20 show dimensionless hydrograph and peak discharge frequency chart developed for Capehorn Creek as determined from gaging stations on adjacent streams.

(ii) Temperature and ice conditions.

Range of water temperature: 32°F to 62°F

No data are available on ice cover, but fall, winter and spring air temperature averages are well below freezing.

(iii) Channel slope.

Average slope over 13 miles of stream length is 27 feet per mile.

Table 7 shows slope variation at several locations during various stages of flow.

(iv) and (v) Channel cross-sections, mean velocities and hydraulic roughness.

Table A-2 shows variations in average depth, width, cross-section area, mean velocity and Manning's "n" value at various discharge. Figure 11 shows the cross-sectional configuration of the streambed. The cross-section of the pools were not surveyed due to their depth.

Table A-2: Average cross-sectional properties, Capehorn Creek.

| Flow Condition | Section | Water Surface Width (ft) | Mean Depth (ft) | Cross-Section Area ($ft^2$) | Maximum Depth (ft) | Mean Velocity (fps) | Maximum Roughness Coefficient "n" | Slope ft/ft |
|---|---|---|---|---|---|---|---|---|
| Low Flow | Transition | 19 | .82 | 15.6 | 2.0 | 2.2 | .042 | .006 |
| | Riffle | 29 | .70 | 20.3 | 1.5 | 1.7 | .044 | .0055 |
| | Overall | 16 | 1.00 | 16.0 | 5.0 | 2.1 | .050 | .0050 |
| High Flow 1973 | Transition | 27 | 1.50 | 40.5 | 2.7 | 6.4 | .022 | .0050 |
| | Riffle | 36.5 | 1.30 | 47.5 | 2.3 | 5.5 | .021 | .0040 |
| | Overall | 24 | 1.80 | 43.2 | 6.0 | 6.0 | .026 | .0050 |
| Highest Flow @ high water marks | Transition | 39 | 2.00 | 78 | 3.6 | 8.7 | .020 | .0050 |
| | Riffle | 54 | 1.92 | 103.7 | 3.2 | 6.6 | .024 | .0040 |
| | Overall | 36 | 2.40 | 86.4 | 7.0 | 7.9 | .024 | .0050 |

III. MATERIALS AND SEDIMENT

(i) Bed-material.

| | |
|---|---|
| $D_{90}$ | 80.0 mm |
| $D_m$ | 25 mm |
| $D_{50}$ | 15 mm |
| $D_{35}$ | 8 mm |
| % finer than 0.25" | 35% |

Sieve diameter sizes are averages for the study section to a depth of about 6 inches.

(ii) Sub-bed and sub-surface materials. No data are available.

(iii) Bank-material. The banks are generally very sandy with some silt and gravel.

(iv) Suspended sediment. No measurements were taken, but there was no observed turbidity even during high discharges.

(v) Bed-load. Measurement are only available during a very low peak discharge year. Figure A-2 shows bed-load discharge based on calculations with the Meyer-Peter, Muller formula.

IV. CHANNEL PROCESSES. No data are available.

Knapp Creek, Marsh Creek, Elk Creek.

The other streams studied are hydrologically and physiographically similar to Capehorn Creek. The major difference is in the bed material, discharge, and associated drainage areas, as shown in Table A-1. Figure 3 shows their relative location within the Idaho Batholith.

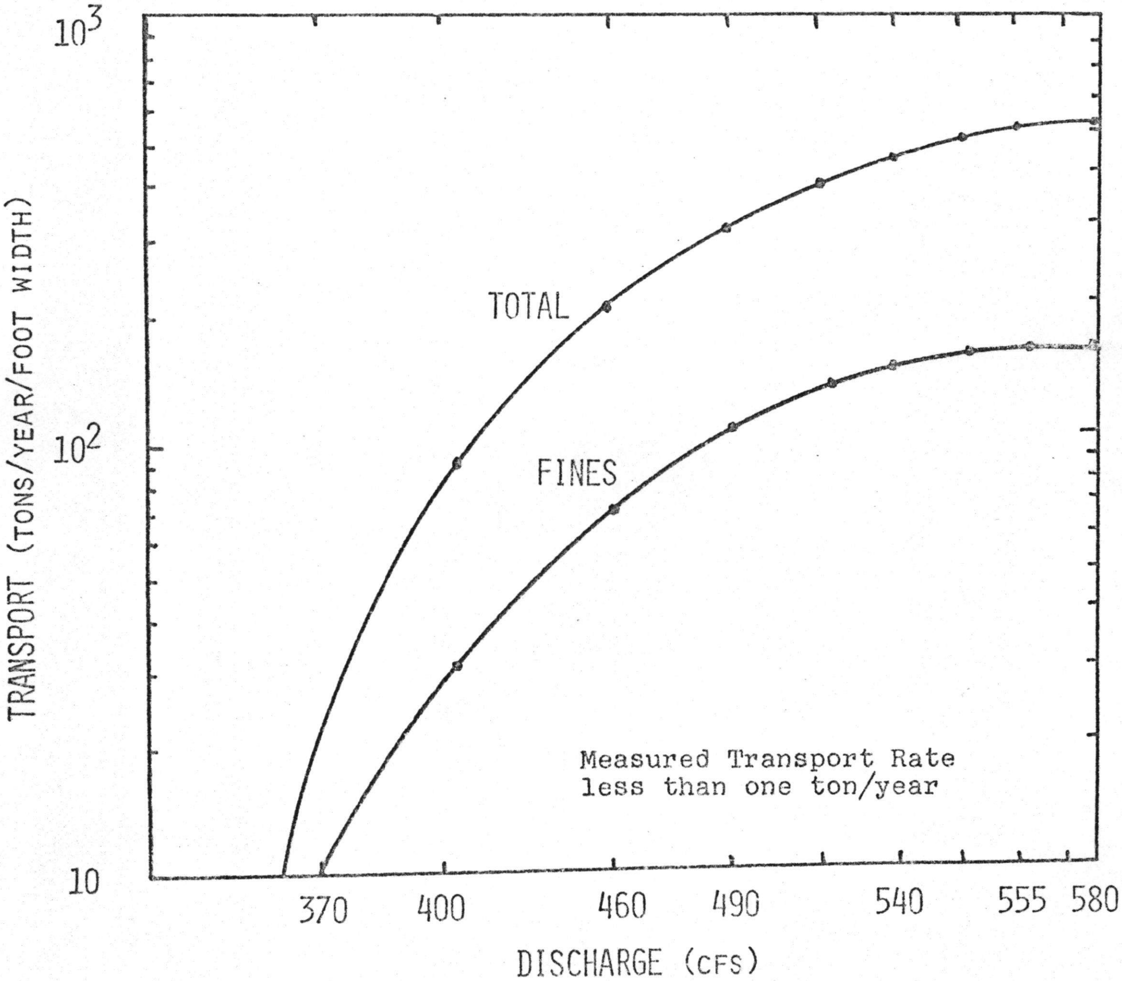



Figure A-3: Sediment transport rate for present conditions in Capehorn Creek.

# APPENDIX B

## STREAMBED SURFACE CLASSIFICATION

The streambed surface classification system is a method to visually classify the composition of the streambed surface material. Since it is a visual classification, judgement is very important which requires specific rules if there is to be any possibility of repeatability of observations. This system is a modification of a system in which only the cobble sized particles ($2\frac{1}{2}$ to 10 inches), the cobble imbeddedness and surrounding material are classified (Prather, 1971). Thus, when cobble particles are not present, only the surrounding material is classified. This modified system replaces the cobble factor with dominant (most abundant area wise) streambed surface material and the imbeddedness value becomes the imbeddedness of the dominant material (Figure B-1).

The visual classification of the dominant and dominant surrounding materials requires very little experience to accurately classify the bed material into broad classes. The average diameter of the bed material in the plane of the bed surface is used. This may require removing several of the particles in deeply imbedded areas to determine its dimensions.

The imbeddedness value is more difficult to determine. The degree to which the dominant particles are imbedded with fines (particles smaller than 0.25 inch) can

Table B-1: Streambed surface classification system.

Dominant Streambed Surface Material and

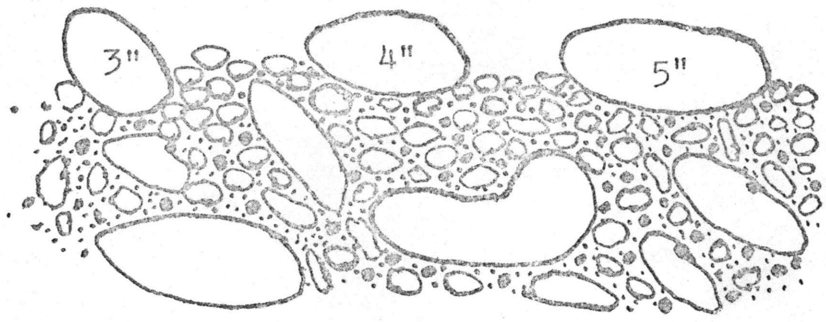
Dominant Surrounding Material

1. Less than 1/16" (sand) ( 1.6 mm)
2. 1/16 - 1/4" (fine gravel) (1.6 - 6.4 mm)
3. 1/4 - 1" (medium gravel) (6.4 - 25.4 mm)
4. 1 - 2 1/2" (coarse gravel) (25.4 - 63.5 mm)
5. 2 1/2 - 5" (small cobble) (63.5 - 127 mm)
6. 5 - 10" (large cobble) (127 - 254 mm)
7. Over 10" (boulder) ( 254 mm)

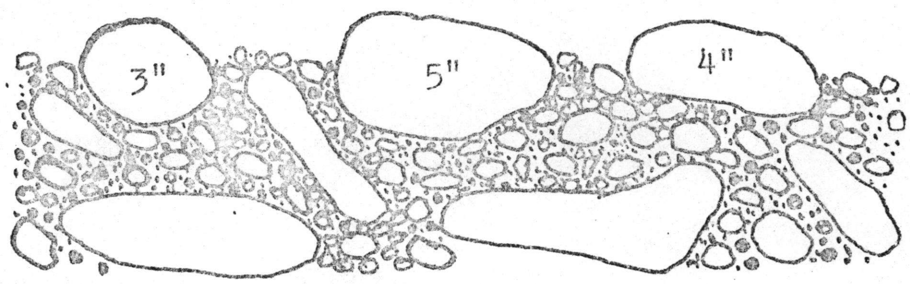
Dominant Material Imbeddedness Values

1. Dominant material fully imbedded with fines
2. Dominant material 3/4 imbedded with fines
3. Dominant material 1/2 imbedded with fines
4. Dominant material 1/4 imbedded with fines
5. Dominant material with no fine imbeddedness

be determined by manually gaging the depth of the fines relative to the dominant material size. When the dominant material is smaller than 0.25 inch, the imbeddedness value is meaningless and given a value of one or total imbeddedness. The following figures (Figure B-2) show example streambed cross-sections and the corresponding streambed surface classification. The first digit represents the dominant material size (D.M.), the second digit the dominant material imbeddedness value (D.M.I.) and the third the dominant surrounding material (S.M.). The relationship between this surface classification system to both the percent of material 0.25 inches or smaller and to the streambed geometrical mean diameter, $D_m$, as determined from core sampling, are shown in Figures 12 and 13 respectively.




5, 5, 3

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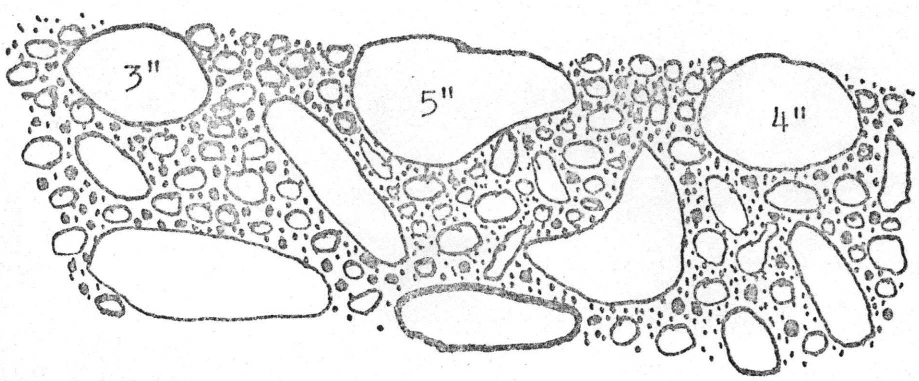
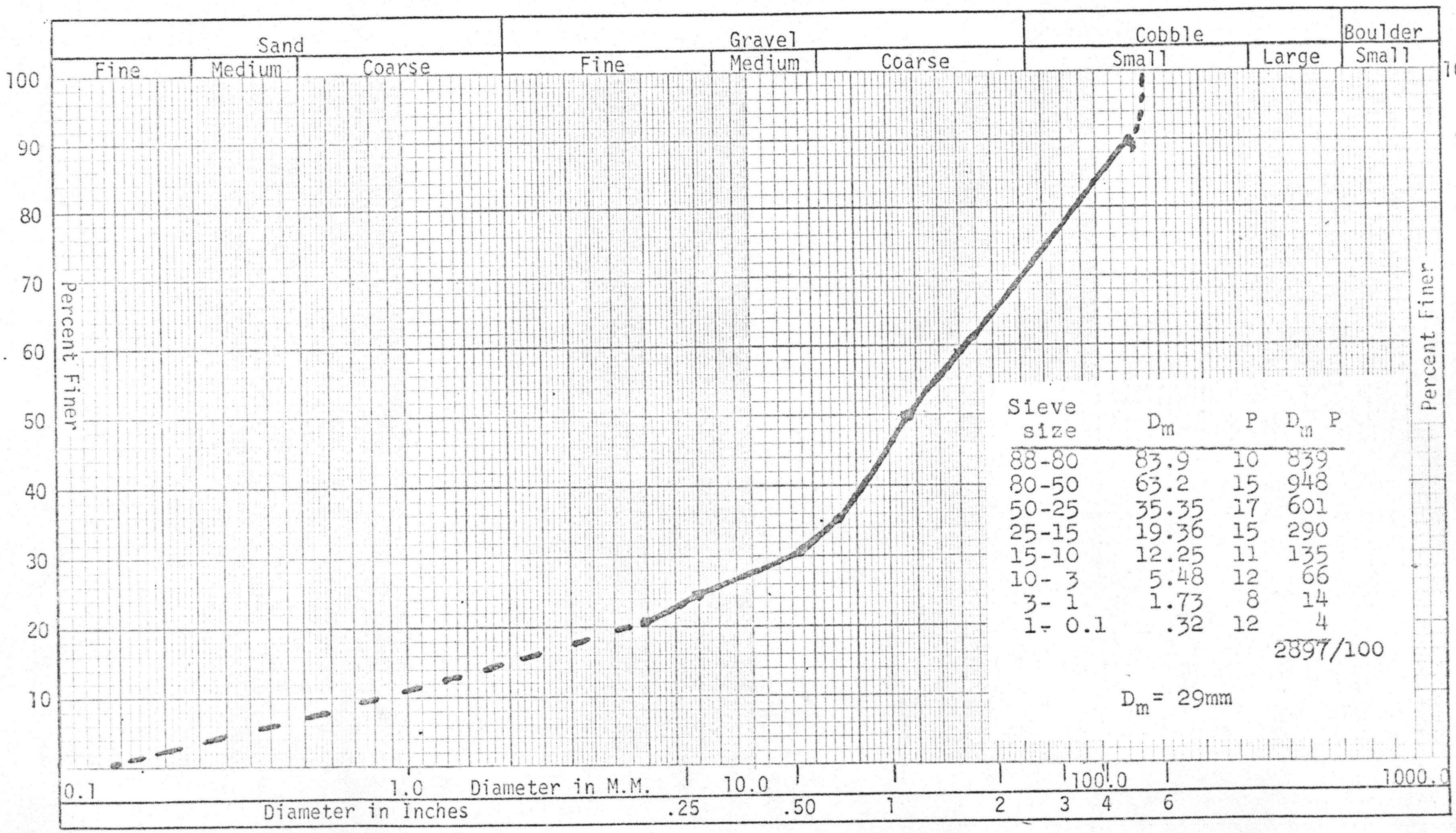



5, 1, 3

Particles finer than 0.25 in.

Dominant surrounding material 0.25 to 1.0 in.

Figure B-2: Streambed surface classification examples.




| Sieve size | $D_m$ | P | $D_m$ P |
|---|---|---|---|
| 88-80 | 83.9 | 10 | 839 |
| 80-50 | 63.2 | 15 | 948 |
| 50-25 | 35.35 | 17 | 601 |
| 25-15 | 19.36 | 15 | 290 |
| 15-10 | 12.25 | 11 | 135 |
| 10- 3 | 5.48 | 12 | 66 |
| 3- 1 | 1.73 | 8 | 14 |
| 1- 0.1 | .32 | 12 | 4 |
| | | | 2897/100 |

$D_m$ = 29mm

APPENDIX C: Example Mean diameter, $D_m$, calculation.