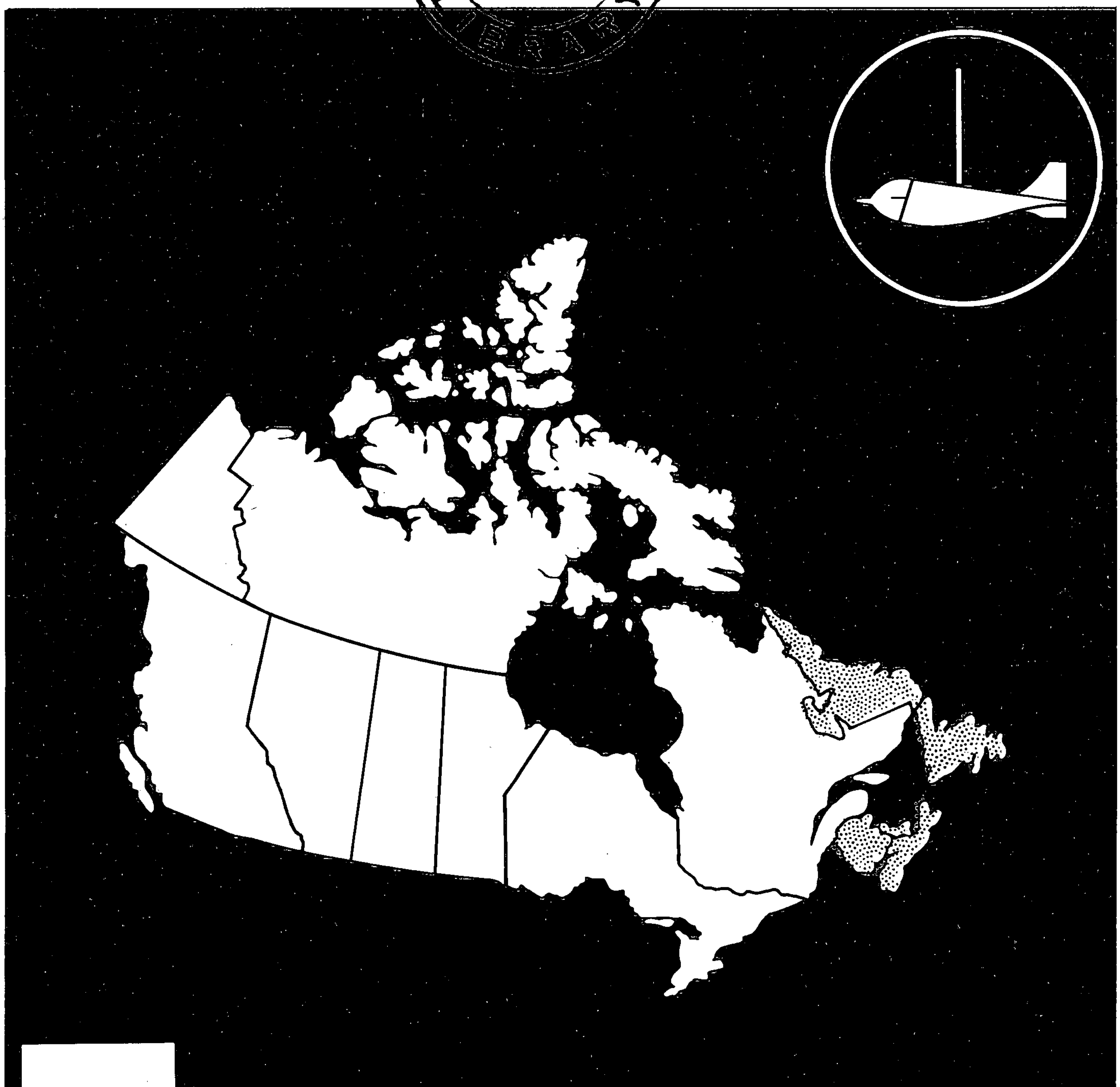
INTERPRETATION OF SEDIMENT DATA 1967 - 1985 ANNAPOLIS RIVER NOVA SCOTIA

IW/L - AR - WRB - 88 - 136



ESOURCES BRANCH
ATERS/LANDS DIRECTORATE

DIRECTION DES RESSOURCES EN EAU
DIRECTION GÉNÉRALE DES EAUX INTÉRIEURES ET DES TERRES

Canada

ATLANTIC REGION

INTERPRETATION OF SEDIMENT DATA

1967 - 1985

ANNAPOLIS RIVER

NOVA SCOTIA

IW/L-AR-WRB-88-136

prepared by:

R. A. POL

HYDROLOGY DIVISION
WATER RESOURCES BRANCH
INLAND WATERS/LANDS
CONSERVATION AND PROTECTION
ENVIRONMENT CANADA
DARTMOUTH, NOVA SCOTIA

MARCH, 1988

ABSTRACT

Sediment data have been collected at the hydrometric gauging station site, Annapolis River at Wilmot, from 1967 to the present as part of the ongoing Water Resources Branch National Sediment Surveys Program. This report deals primarily with suspended sediment data collected during the period 1968 to 1985, inclusive, and presents the collected data in various tabular, graphical and statistical ways. It also contains a basin description and a section on land use and river sediments. The suspended sediment program, operated by the Water Survey of Canada Division, is evaluated and recommendations are presented. This material is intended for Federal/Provincial coordinators of water agreements, Water Survey of Canada staff and users of sediment data.

The analyses and interpretations of the sediment data are for the purpose of assessing if sufficient data exist for load determinations. The interpretation of the suspended sediment data set showed that our knowledge of mean characteristics of the sediment regime can improve only slightly; therefore, it is being recommended that the sediment station be discontinued and that the resources be reallocated to obtain sediment data in areas where monitoring has not been done.

RESUME

Des données sédimentologiques ont été prélevées à la station de relevés hydrométriques de la rivière Annapolis à Wilmot à partir de 1967 jusqu'à présent. Ces prélèvements font partie du Programme national d'échantillonage sédimentologique de la Direction des ressources en eau.

Ce rapport traite principalement de données sur les sédiments en suspension rassemblées durant la période de 1968 à 1985 et les présente sous formes de tableaux, de graphiques et de statistiques. Le rapport comprend aussi une description du bassin, une section sur l'utilisation du terrain, ainsi qu'une section sur les sédiments de rivière. Le rapport fait une évaluation du programme sur les sédiments en suspension de la Division des relevés hydrologiques du Canada et offre aussi des recommendations. Ce travail sera utile aux coordonateurs des ententes fédérales-provinciales sur l'eau, aux employés de la Division des relevés hydrologiques du Canada et aux usagers de données sédimentologiques.

Les analyses et les interprétations effectuées sur les données sédimentologiques ont permis d'évaluer la suffisance des données sur les sédiments en suspension pour en calculer le débit solide. Celles-ci ont montré que notre connaissance du régime sédimentologique en terme de production moyenne n'augmenterait pas sensiblement avec plus de données et qu'ainsi l'échantillonage peut être interrompu et les ressources réaffectées pour recueillir des données sédimentologiques dans des régions où l'échantillonage n'a pas encoure été effectué.

ACKNOWLEDGEMENT

Thanks are expressed to Dave Wilson of the Lands Division of the Water Planning and Management Branch of Inland Waters/Lands, Atlantic Region who accompanied the author on a tour of the Annapolis watershed. Mr. Wilson took most of the photographs of the sediment sources in the basin and he also prepared the section on "Land Use and River Sediments" found in this report.

TABLE OF CONTENTS

LIST OF TABLES
(APPENDIX A)

LIST OF FIGURES
(APPENDIX B)

(cont.)

LIST OF FIGURES (cont.)
(APPENDIX B)

LIST OF PHOTOGRAPHS
(APPENDIX C)

(cont.)

LIST OF PHOTOGRAPHS (cont.)
(APPENDIX C)

INTERPRETATION OF SEDIMENT DATA 1967 - 1985 ANNAPOLIS RIVER NOVA SCOTIA

1.0 INTRODUCTION

1.1 Historical Perspective

Suspended sediment data have been collected on the Annapolis River at Wilmot, Nova Scotia, since December of 1967. Hydrometric data have been collected at this location since October of 1963. The sediment program was originally required to monitor freshwater sediment loadings into the Bay of Fundy and to collect suspended sediment data required for the tidal power studies (Pol, 1976). The data have been used by various researchers. The Water Survey of Canada Division of the Water Resources Branch of Environment Canada has a mandate for collecting the sediment data within the National Program of "Water Quantity Data".

Figure 1 shows the location of the Annapolis River in Nova Scotia. There are approximately 18 years of suspended sediment data available for interpretation on this river.

The term "sediment" is used herein to mean the characteristics of the suspended sediment regime, e.g., means, ranges, and variability of concentrations and loadings on various time scales.

1.2 Objectives

The objectives of the study are to:

1. Analyse and interpret the 1967 to 1985 sediment record for the purpose of assessing if sufficient data exist for load determinations.

2. Make recommendations concerning future data collection at this site.

These objectives are part of the mandate of the Hydrology Division of the Water Resources Branch. The information contained in the large data files created by the Water Survey of Canada Division is made more useful when analysed and presented for subsequent decision making. At the same time, the analysis provides insight into the sampling program and allows for recommendations to be given to the Water Survey of Canada Division program manager.

1.3 Report Format

This report is modelled on the existing series of sediment station analysis reports, issued by the Water Resources Branch, Environment Canada (Day and Spitzer, 1985).

2.0 BACKGROUND

2.1 Hydrometric Station Description

The Annapolis River at Wilmot gauging station has been operated on a continuous basis since 1 October 1963. This station has a stilling well with an A-35 Stevens strip chart recorder. The instrumentation is housed in a metal shelter on the right bank and on the upstream side of the road bridge near Wilmot. Streamflow measurements during high and medium stages are taken from the bridge. Low water and ice cover discharge measurements are made by wading, or through the ice, in the vicinity of the gauge.

The stage-discharge relationship for this station has been stable, with the present curve (No. 6) being used since 1975. The bed material is composed of a sandstone material with a gravelly texture. The stability of the measurement section is documented in Figure 2, where several cross-sections over the period of 1964 to 1984 are superimposed.

The Annapolis River at Wilmot has regulated flow. Water quality data are also available at this station.

2.2 Basin Description[1] and Hydrology

The principal tributaries of the Annapolis River are the Nictaux and Paradise Rivers, both of which have been exploited for hydroelectric power. These tributaries are below the hydrometric gauge at Wilmot. The Annapolis River flows into the Annapolis Basin, which forms a part of the Bay of Fundy.

The River Basin is bounded on either side by the North and South Mountains, with the river valley between them. Soil in the basin is generally fertile. Timber and pulpwood are taken from the North and South Mountains, and the uplands have long been famous for their apple orchards. Mixed farming and dairy farming are carried out in the valley.

The Annapolis River to the hydrometric gauge at Wilmot, which drains an area of some 546 km^2, has a circular shaped watershed approximately 25 km in diameter; the length (meander) of the river to Wilmot is approximately 45 km.

1. From Montreal Engineering Company, Limited, 1969.

There are no natural lakes of any consequence in the Annapolis River Basin to Wilmot. The Annapolis River at Wilmot discharge data are published as regulated. A small, run of the river, hydroelectric plant on the South Annapolis River at Berwick is one reason that this stretch of the river is classified as regulated. There are also numerous headwater dams on the tributaries of the Annapolis River.

The surficial hydrogeology of the Annapolis River valley above Wilmot consists of extensive deposits of glacial outwash and outwash-delta materials. The higher part of the North Mountain ridge has exposed bedrock on the surface or the thin glacial till cover is generally less than three feet (0.9 metres) deep. Surficial materials on the south side of the Annapolis River Basin consist predominantly of exposed bedrock and thin till cover, generally less than three feet (0.9 metres) deep. Numerous drumlins occur in the uplands together with a few kames and a few glacial outwash and outwash-delta deposits.

The main physical features and runoff characteristics of the Annapolis River above the Wilmot hydrometric gauging station are presented in Table 1.

2.3 Land Use and River Sediments

To assist in the determination of the factors influencing the high and the low sediment loadings recorded at the Wilmot Gauge site between 1967 and 1985, an analysis of the 1961, 1971 and 1981 land use statistics, activity and cover, generated by the Lands Division for the unpublished Annapolis Valley Fruitland Study were analyzed. Table 2 provides a general overview of land use trends for 89,107 hectares of land considered to fall within the influence of agricultural activity (having both potential and actual use) in the Annapolis Valley. As such, these statistics provide a somewhat limited idea of forestry operations on the upper slopes of the North and South Mountains.

Based on the examination of general land use trends in the Valley, the area associated with agricultural production was looked at first, as this activity is an identified contributor of stream sediment. Since there is a decline in land area associated with agricultural activity in both the 1961-1971 and 1971-1981 periods (913 ha. and 357 ha., respectively), a direct correlation between the 1970 low and the 1979 high Annapolis River sediment loadings (Table 4) and agricultural activity, cannot be substantiated.

Continuing to look at general trends for other land uses, "urban related" is the category undergoing the largest amount of change. While the first period underwent an 8.4% increase in urban related activity, the 1971 to 1981 period increase was 19.6%. An increase of this magnitude cannot be dismissed as having no impact on the sediment loadings of the Annapolis River. More specifically, although a direct link between the high level of sediment in 1979 and a large construction contract for grading and graveling on Highway 101, from the Kings County line to the Vault Road (D. Rice-Smith, N.S. Dept. of Transportation, personal communication), cannot be established, it is possible the coincident road construction did have an impact on the amount of sediment reaching the Annapolis River.

One large amount of runoff from a limited amount of road and ditch construction, such as the example illustrated in Plate 1 could prove responsible for increasing the monthly average readings of sediment levels. The steep grade such as this one to the Fales River at Rockville Notch would generate high velocity flows during periods of precipitation and thaws. It should be noted that all photographs in this report were taken on a field reconnaissance of the Annapolis River basin to Wilmot in the late spring of 1987 after a rain storm. The Annapolis River reached a medium stage after this storm.

The area of change in land use in the "transportation and communication" class doubled, to 402 ha., in the 1971-1981 period over the earlier period. The fact that the major Highway 101 construction activity is complete (but is moving downstream) in that part of the Valley covered by the gauge at Wilmot, is one factor to be weighed in the future utility of this gauge location. Smaller road improvement and ditching construction is occuring throughout the watershed as illustrated in Plate 2. Additional sediment was observed to originate from a peat bog by way of a modified ditch north of Highway 101, one kilometre from Green Acres. Here black coloured water entered Walker Brook.

The greatest change in urban related activities was the subclass "dwelling". The statistics indicate a marked increase of nearly 4.5 times between the 1961-1971 period and the 1971-1981 period of the land occupied by dwellings. Urbanization, area wise, represents the largest single land use change in the Valley and as such must be considered to be responsible for part of the high sediment loadings in 1979. Unfortunately similar land use statistics from 1981 onward are not available for comparison with the sediment data available to 1985, inclusive.

Additional effort was focused on the subarea centered on Millville (subarea #3), one of five areas in the Fruitlands Study. Subarea #3 (22,270 ha.) falls totally within the watershed covered by the Wilmot gauge and occupies the largest part of the basin influencing the gauge at Wilmot, although, some of the watershed to the Wilmot gauge on the higher ground is outside of the Fruitlands Study boundary. The land use classes and subclasses were compared for the whole Valley study area (Table 2) against subarea #3 as follows: "agriculture" and subclass "orchards"; "total urban" and subclasses "dwelling" and "transportation"; "land in transition"; and "no perceived activity". The trends differed little between the whole and subarea #3. The main exception is the extent of orchards.

More specifically, in the 1961-1981 period, there was a decline in the area of orchards in the Valley as a whole whereas subarea #3 realized an increase of 239 ha. Therefore, on a long-term basis there should be a decrease in sediment originating from areas planted to orchards as orchards represent a very stable land cover class (were soil loss is concerned), especially on the moderate slopes as indicated in Plate 3 located between North Kingston and Weltons Corner. On that same basis, a greater possibility exists for residues reaching streams from the additional use of chemical sprays used to control such things as insects and weeds. The light areas in Plate 4 indicate grass under the fruit trees killed by sprays. The major concentration of orchards is located just north of Aylesford.

In the short-term, there was likely some bare soil associated with the transition from "forage crops" to "orchard" in subarea #3. The area involved accounted for 192 ha. in the 1971-1981 period. The statistics available cannot be tied to the individual high and low sediment load years.

There are several streams noted to be transporting high levels of sediment during the field reconnaissance. Perhaps the most notable was Watton Brook which enters the Annapolis River just to the northeast of the Wilmot gauge location. Watton Brook (Plate 5) carried a high concentration of a red coloured sediment even at the upper reaches. At the confluence of Watton Brook and the Annapolis River there was a ribbon of heavily sediment laiden water entering and flowing intact downstream along the right bank of the Annapolis River past the gauge site. In the background of Plate 5 (Watton Brook) the ploughed soil indicated by the arrow is a dark reddish brown sandy clay loam surface soil over a reddish brown sandy clay loam to clay loam subsoil of the Middleton soil series. These soils are found along the base of the escarpment and up on North Mountain. The steepness of the slopes to which the Middleton soils are associated require the use of agricultural conservation practices to prevent the transport of soil by streams as small as Watton Brook.

On the south side of the watershed streams appear to be carrying minimum levels of sediment. The sand and gravel deposits on the eastern side of the basin above the gauge have resulted from ice-contact processes that produced features such as kame terraces. Numerous extraction sites mark these deposits on the landscape. Plate 6 shows a nearly dissected kame just south of Caribou Bog, two kilometres east of Aylesford East. In the same general area there are examples of abandoned extraction sites that have been levelled. A large area, susceptable to erosion, is shown in Plate 7 which is located one kilometre northeast of Rockland.

Skinner Brook, as shown in Plate 8 just southwest of Weston, had a high sediment load. Bank erosion is evident on this sinuous water channel. Another contributing factor to the sediment loading of Skinner Brook, be it an individually limited one, is the waste water outflow indicated by the upper arrow in Plate 9 located 30 metres upstream of the heavily grassed stream valley.

Additional sediment sources result from the removal of tree cover on the moderate slopes for the purpose of creating additional agricultural land as illustrated in Plate 10, one kilometre east of Dempsey Corner. In the same field, Plate 11 shows a drainage ditch transporting soil down slope. Small pools at road culverts tend to act as settlement ponds. In contrast, these locations also attract cattle which add another destabilizing effect to the stream bank (Plate 12, foreground).

Throughout the drainage area there were various means of directly and indirectly controlling materials reaching the water courses. These included the following: the holding tank (Plate 13), covered piles (Plate 14), limiting cattle access to stream-crossings (Plate 15), leaving stream banks heavily vegetated and having small ponds at culverts (Plate 16) and creating larger ponds utilizing natural depressions (Plate 17). The raised culvert in Plate 16, although there is a benefit in aerating the water, is determental to optimum fish movement.

Stream bank erosion, on a meandering streach of the Annapolis River, is shown in Plate 18; note the slumping right bank and the trampled soil (by cattle) on the left bank. Plate 18 is located one kilometre south of Auburn.

Federal establishments can have a large environmental impact on the Annapolis drainage basin. C.F.B. Greenwood alone occupies the majority of the 1,800 ha. classed as "institutional" activity.

Several water related issues were observed in the basin during the field trip. Included are complaints, of iron in the wells, by residents in the Torbrook Mines area; the point sources of polution from the waste disposal site in the Vault on Wiswal Brook and a streamside site where agricultural chemicals were mixed just northeast of Melvern Square; the water in this location was milky in appearance. The later activity likely is representative of many other similar operations associated with orchards and other agricultural crops in the Valley. A similar but of a greater milky appearance was noted in a tributary of the Black River one kilometre east of Tremont.

In conclusion, land conservation practices are needed as the topography of the Valley, with its ice-contact features (created in past glacial times) located at the base of steep slopes, are susceptable to considerable erosion by high velocity brooks. These relatively short flashy brooks and rivers drain the upper portions of the North and South Mountains adding to their power to cut and carry sediments.

3.0 SEDIMENT TRANSPORT DATA

3.1 Data Collected

The available data set for the Annapolis River at Wilmot consists of the following:

1. suspended sediment concentrations of depth-integrated samples;

2. suspended sediment loads;

3. particle size analyses of suspended sediment of depth-integrated samples;

4. particle size analyses of bed material samples;

5. dissolved solids concentrations;

6. water temperatures.

In this report only the first two data sets outlined above are considered. To interpret the other data or to draw any conclusions may be misleading due to the limited amount of information available in the data sets.

3.2 Sampling Procedures and Equipment

Table 3 shows the number of days in each month when sample concentrations were collected, over the period 1967-85. These samples were collected using manual sampling and seasonal operation in 1967. From 1968 through 1985 data were collected using manual sampling and continuous operation throughout the whole year. The sampling effort is concentrated during the period November through May, inclusive, when flows and sediment loads are higher than the dry weather period, June through October. The higher frequency of sampling during high flow periods is illustrated by Figure 3, a flow duration curve and sediment sampling bar chart. This shows, for example, that 55% of the samples were collected during the higher flows (13 m^3/s or greater) that occurred over 30% of the time. The sediment loadings that occurred over 30% of the time have a magnitude of 10 tonnes per day or greater (Figure 4).

The sediment samples are taken by an observer from a single vertical, using a D49 sampler. The single sampling vertical is referenced as a chainage point of 15.0 metres from the right bank on the road bridge near Wilmot.

Detailed sediment sampling over the cross-section were carried out at this site. This consisted of collecting depth-integrated samples at five or six locations across the river. These detailed surveys were used to obtain correction coefficients to be applied in calculating the mean sediment concentration for the cross-section from the single sampling vertical. The coefficients were not found to be significant (approximately equal to "1") and are not used in the calculations.

Bed material samples were taken from this site during the period 1973, 1977 and 1978. Water temperature information is also available.

3.3 Data Presentation

Calculated daily mean concentrations, suspended sediment loads, and grain size analyses of bed material and of suspended sediments are contained in the annual sediment data publications for Canada, issued since 1965, e.g., "Sediment Data, Atlantic Provinces, 1984" Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa, Canada, 1986 (Environment Canada, 1965 to 1985). The Annapolis River data set starts in the 1967 issue.

Table 4 presents a summary of the flow and suspended sediment data by year. Monthly and annual sediment loads are listed in Table 5 for the period of record to 1985.

3.4 Representativeness of Sediment Period of Record

Frequency plots of annual maximum daily discharge and annual flow volume for the 1964 to 1985 hydrometric record are shown in Figure 5. The years in which sediment loads were not measured (1964 to 1967, inclusive) are indicated by a circle around the data. Based on these drawings, it appears that the sediment program operated throughout the entire range of discharges. The annual maximum daily sediment load and total annual load, for the period 1968 to 1985, are also shown in Figure 5. It should be noted that the fit of the three parameter log-normal distribution to the sediment data is not as good as that of the discharge data set.

Another method of illustrating the representativeness of the period of record to the long-term conditions is shown in Figure 6. The sediment program began during a period in which both flow and suspended sediment load were near to mean conditions. From that point onward, the flow and suspended sediment data sets do not appear to show trend or of being anomalous in the statistical sense.

It should be noted that the above paragraphs are only for the 1964 to 1985 period. Although the range in flows is good, it by no means covers the entire range of flows possible at this site.

4.0 INTERPRETATION OF SEDIMENT DATA

4.1 Suspended Sediment Loads

The annual flow volume in cubic decametres recorded at the Wilmot station is shown on Figure 7. The period of record begins in 1964, however, for this report the mean has been calculated since 1968. This corresponds to the sediment data period of record. A mean value of 409,000 dam^3 is shown on this figure. By dividing by the drainage area in square kilometres the mean depth of runoff over the basin is found to be about 750 mm. Figure 7 also displays the suspended sediment load in tonnes passing by the Wilmot station each year. The mean value of 4,750 tonnes is seen on this figure. Assuming, like the above data, that the production of suspended sediment is uniform over the basin a unit value of 8.7 tonnes/km^2 is calculated. However, sediment production is more likely to be from relatively few areas and most probably the river banks themselves. Therefore the unit value must be taken with this qualified assumption at all times. The annual data sets used to produce Figure 7 are tabulated in Tables 5 and 6. The annual distribution of flow and sediment resemble one another quite closely.

From Table 5, the range of annual suspended sediment data is seen to vary from a low of 2,930 tonnes in 1970 to a high of 8,530 tonnes in 1979. This range includes nearly a three fold variation. Comparing the range in flow volume over the same time period shows only a two fold variation. This leads to conclude that more than runoff influences the suspended sediment movement. The numerous physical characteristics, some static, some dynamic, are influencing the sediment movement at times more than the basin runoff. The suspended sediment movement within a year varies considerably. From Figure 8, it can be seen that most sediment moves during the November to May, inclusive, time period. The line showing sediment load on Figure 8 is the mean of all daily values in the years 1967 to 1985, inclusive.

The amount of flow or suspended sediment in any month can be expressed as a percentage of the annual value. Figure 9 shows the relative percentages for each month. The dominant sediment related flow characteristics are the winter and spring months when approximately 75% of the sediment load flows past the gauge at Wilmot.

Natural variation from year to year gives scatter to a time series, however, at times change may tend to go in one direction more often. Mass curves are useful to show if trends are occurring. Figure 10 is a plot of cumulative sediment and flow data. Some variation, as expected, is seen but overall the line is not showing a change in angle. It appears that during the sampling period that a near steady state condition exists. Further tests were done on the data sets using non-parametric tests to look for trend, homogeneity, etc. The annual total discharge data set did not display trend. Also, as expected, no trend was found in the suspended sediment data set.

Annual sediment loadings are not from an equal production throughout each year. A large fast runoff could produce most of the years sediment. Figure 11 illustrates how short duration events can include a significant proportion of the seasonal and therefore annual loadings. This plot shows the annual total discharge and the annual total load, for there respective periods of record. The maximum loads occurring in the 1% and 10% of the annual period, 3.7 and 36.5 days, respectively, are also shown. On average, the maximum 3.7 day load carries 14% of the annual total load. The maximum 36.5 day load carries about 33% of the annual load. Total discharge ranged between 6% and 26% of the total annual for the 1% and 10% of period, respectively. Figure 12 also illustrates that the majority of the sediment load carried by the Annapolis River for the period 1967 to 1985 occured over a short period of higher flows. It can be seen that 60% of the total suspended load was carried in about 10% of the time (Figure 13).

The limited record length affects the precision of the long-term estimates of mean conditions, i.e., discharge, load and concentration. As each year of successive data are gathered more of the variability is seen in the long-term data set. The relationship between the standard error of estimate for total annual discharge and record length is shown in Figure 14. The same diagrams for total annual load and mean annual concentration are shown in Figures 15 and 16, respectively. After eighteen years of sediment records and twenty-two years of discharge the standard error of the mean is reduced to about 5%. The percentage gain in the standard error of the mean discharge, load or concentration for each additional year of record is less than 1%. An extension of these data indicates that further data would not substantially improve the standard errors of estimate for mean annual discharge, load, or concentration. The outliers found in Figure 16 are due to the fact that the first two annual concentrations in this time series were of the same value. The standard error of the mean in this case became the value of zero, thus the two outliers.

A relationship exists between the sediment movement and basin runoff. Figure 17 shows the relationship between daily mean discharge (m^3/s) versus daily mean suspended sediment (mg/l) for all days sampled in 1984. Table 7 presents the same information for other selected years and for the period of record, 1967 to 1985. The average standard error of estimate obtained for these relationships was ±88%. Table 7 also presents instantaneous discharge versus instantaneous sediment for the 1984 sampling year for various time periods. The higher water periods, e.g., January to March, had the best value of standard error (±47%), whereas the low water period of July to September had the worst value (±86%).

Figure 18 depicts the rating relationship of total annual discharge (dam^3) versus total annual suspended load (tonnes). Figures 19 and 20 present similar information but, on a monthly and mean monthly basis. Table 8 summarizes the rating relationships. The annual and mean monthly ratings had the superior standard errors of estimate.

5.0 PROGRAM EVALUATION AND RECOMMENDATIONS

The suspended sediment data collection program at the Annapolis River at Wilmot hydrometric gauging station represents sediment loadings and yield from an agricultural environment. It is believed that most of the river sediments are produced by the agricultural activities and by stream bank erosion.

The mean annual sediment load was 4,750 tonnes for the 1968 to 1985 period of record. The annual loads have varied by a factor of three between the smallest to largest annual total loads. Over the same period, the annual flow volume varied by a factor of two. More than 80% of the sediment load is transported during the seven months of November through May.

The findings of this interpretation indicate that the data collected to date are sufficient to define the present-day suspended sediment regime of the Annapolis River. In particular, the analyses indicate the following:

(1) the range in the sampled data is good, i.e., it covers the range of recorded flows for the period of record used;
(2) estimates of the <u>mean</u> characteristics of the suspended sediment regime can only be improved slightly, if activities in the basin do not change substantially;
(3) annual variability is well documented for the period of record used;
(4) any presence of trend in the data set is not noticeable for the period of record used.

It should be noted that our knowledge of how representative these data are of long-term conditions is inadequate. However, for many engineering needs sufficient data now exist, i.e., total annual loading can be approximated within ±17% using the discharge as the estimator. To estimate sediment concentrations or loadings on a daily, monthly, or seasonal basis, using only the discharge as the independant variable, however, would produce results with much larger errors.

There is little justification for continuing the program to quantify naturally occuring sediment at the Annapolis River at Wilmot. Steady state conditions will never exactly exist, however, the variation from year to year is not great enough to continue measuring the baseline suspended sediment movement. Before contemplating discontinuation of the program, however, there are two points that should receive consideration. One is that the Annapolis River at Wilmot is the only station within the sediment zone as outlined by T. Ingledow & Associates Limited in 1970, in an agricultural environment. The other point is that in a recent assessment of sediment issues in the Atlantic Provinces (Washburn & Gillis Associates Ltd., 1985), it was recommended that a basic network of long-term stations be retained.

In the opinion of the author further intensive data collection will not improve our knowledge of the sediment transport, especially on an annual basis. Therefore it is recommended:

(1) To eliminate the sampling program on the Annapolis River at Wilmot in fiscal year 1988/89;

(2) To relocate to another site within the same sediment zone. This is the only sediment station in Nova Scotia in an agriculturally active area and although sediment production above this site is not varying substantially, there may be other areas within this zone where erosion and deposition are not the same;

(3) Research involving multiple regression techniques relating sediment loadings versus watershed physiographic and hydrologic parameters is needed. The relationships developed only between total flow and total sediment are considered to be adequate, but it would be even better to relate sediment movement to physical and climatic parameters (slope, soil type, rainfall intensity, etc.) in addition to the flow parameter. These parameters, at present, are not available in computerized data sets ready for use. The existing data set (suspended sediment loads) from the Annapolis River would provide a good basis for this research.

6.0 REFERENCES CITED

1. Pol, R.A., "Assessment of Sediment Survey Program in the Atlantic District", IWD, WRB, Environment Canada, July, 1976.

2. Day, T.J. and Spitzer, M.C., "Sediment Station Analysis: Highwood River near The Mouth, 05BL024", report no. IWD-WNR-WRB-SS-85-1, Sediment Survey Section, Water Resources Branch, Environment Canada, Ottawa, September, 1985.

3. Montreal Engineering Company, Limited, "Maritime Provinces Water Resources Study, Stage 1" for the Atlantic Development Board, Volume Four, Nova Scotia, Book 3, January, 1969.

4. Environment Canada, 1965 to 1985. "Sediment Data Canadian Rivers", Water Resources Branch, Ottawa. Published annually and in a new format starting in 1984.

5. T. Ingledow & Associates Limited, "Hydrometric Network Plan for the Provinces of Newfoundland, New Brunswick, Nova Scotia and Prince Edward Island", prepared for the Government of Canada, Department of Energy, Mines and Resources, December, 1970.

6. Washburn & Gillis Associates Ltd., "Freshwater Sediment Data Collection and Use in the Atlantic Provinces", Consulting Report, prepared for WRB, Atlantic Region, May, 1985.

APPENDIX A
(Tables)

TABLE 1

Main Physical Features and
Runoff Characteristics of the Annapolis River at Wilmot
Period 1963 to 1985

Drainage Area (km^2)	546
Length (Meander) (km)	45
Average Fall by Meander (m/km)	5
Average Elevation (m)	131
Area of Lakes (percentage of D.A.)	1
Total Area of Lakes and Swamps (percentage of D.A.)	2.70
Recorded Minimum Daily Discharge (m^3/s) (on September 6, 1978)	0.331 E
Recorded Maximum Daily Discharge (m^3/s) (on January 16, 1978)	145 A
Recorded Maximum Instantaneous Discharge (m^3/s) (on January 16, 1978)	161 A
Mean Annual Runoff (m^3/s)	12.5
Mean Annual Runoff (mm)	722
Mean Annual Precipitation (mm) (period 1951 to 1980)	1250

A - Manual Gauge
E - Estimated

TABLE 2

LAND USE IN THE ANNAPOLIS VALLEY, NOVA SCOTIA
ALL AREAS IN HECTARES

Land Use	1961		1971		1981		Land Use Change 1961-71	Land Use Change 1971-81
Agriculture	48 504		47 591		46 734		-913	-857
Orchards		5 618		5 820		5 418	-798	-303
Forestry	68		214		173		146	-14
Extractive	228		409		453		206	44
Recreation	102		173		196		71	23
Urban Related	6 093		6 654		8 284		561	1 630
Dwelling		4 176		4 495		5 758	290	1 292
Transport & Communications		75		271		673	196	402
Manufacturing		47		91		154	43	59
Commercial		40		57		76	17	19
Institutional		1 753		1 769		1 800	15	31
Land in Transition	1 649		1 220		1 374		-409	154
Unused Land	32 453		32 836		31 681		383	-1 155
No Perceived Activity		31 710		31 775		30 910	65	-866
Formerly used Land		743		1 061		771	318	-289
Total	89 107		89 107		89 107			

TABLE 3

Summary of Suspended Sediment Sampling Strategies

Showing Number of Days Sampled Each Month

Month

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Total
1967												16	16
68	6	7	24	11	6	12	4	2	4	5	8	14	103
69	14	3	10	17	4	4	3	2	2	4	7	11	81
1970	4	6	8	8	9	5	4	4	4	7	13	5	77
71	6	4	11	18	13	5	4	13	5	7	6	7	99
72	12	3	16	11	15	5	5	5	4	9	16	8	109
73	7	8	15	6	7	8	11	7	5	5	9	16	104
74	7	4	11	10	6	5	6	3	8	10	9	9	88
1975	5	0	10	15	4	6	4	4	4	4	7	5	68
76	6	11	8	7	6	3	5	5	4	5	3	2	65
77	0	1	11	13	4	4	4	4	6	10	7	11	75
78	16	3	4	9	4	3	4	3	2	3	1	3	55
79	14	2	11	4	6	3	3	4	4	4	5	3	63
1980	1	0	7	4	2	5	4	1	3	5	12	10	54
81	0	3	6	12	5	5	3	2	4	7	10	8	65
82	5	0	4	10	3	8	4	6	6	5	6	7	64
83	11	3	11	7	10	6	3	3	5	4	8	12	83
84	8	7	8	6	4	5	6	3	5	3	4	8	67
1985	1	2	11	12	11	9	4	4	3	3	30	27	117
Total	123	67	186	180	119	101	81	75	78	100	161	182	1453
% of Grand Total	9	5	13	12	8	7	6	5	5	7	11	12	100

Table 4

Summary of the Flow and Suspended Sediment Data Analyses

at the Annapolis River at Wilmot Hydrometric Gauging Station

Annual Statistics

Year	Number of days Sampled	Mean Discharge (m^3/s)	Mean Concentration (mg/1) Cal.[1]	Ave.[2]	Total Load (tonnes)	Basin Yield (tonnes/km^2)
1967	16	--	--	--	--	--
1968	103	12.7	11	8	4 590	8.4
1969	81	11.4	9	8	3 240	5.9
1970	77	9.83	9	6	2 930	5.4
1971	99	14.9	9	6	4 090	7.5
1972	109	17.6	10	7	5 370	9.8
1973	104	14.2	13	10	6 020	11.0
1974	88	13.6	11	9	4 860	8.9
1975	68	12.3	11	8	4 110	7.5
1976	65	15.9	15	9	7 570	13.9
1977	75	17.5	11	8	5 900	10.8
1978	55	9.33	13	6	3 930	7.2
1979	63	18.5	15	10	8 530	15.6
1980	54	9.51	12	8	3 470	6.4
1981	65	15.6	11	7	5 200	9.5
1982	64	10.5	10	6	3 330	6.1
1983	83	9.08	14	9	3 950	7.2
1984	67	10.8	12	8	4 210	7.7
1985	117	9.91	13	8	4 150	7.6
	Mean :	13.0	12	8	4 750	8.7
	Standard Dev. :	3.1	2	1	1 490	2.7

1. Calculated using the function: $c = r/q$ where c = sediment concentration, r = sediment load, and q = flow.

2. Mean of daily concentrations.

TABLE 5

SUMMARY OF MONTHLY AND ANNUAL SUSPENDED SEDIMENT LOADS
ANNAPOLIS RIVER AT WILMOT

	TOTAL LOADS IN TONNES												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1967	---	---	---	---	---	---	---	---	---	---	---	1470	----
1968	223	95	1140	330	98	634	81	56	43	191	890	802	4590
1969	356	395	544	665	253	15	37	64	61	54	121	672	3240
1970	63	466	507	654	368	89	37	17	15	313	316	82	2930
1971	157	825	527	661	681	131	17	662	82	50	121	179	4090
1972	450	381	928	453	1580	152	55	96	20	419	676	163	5370
1973	752	463	815	130	168	358	1010	355	22	18	223	1710	6020
1974	325	280	673	395	174	134	98	22	701	676	805	576	4860
1975	365	84	764	782	307	147	46	34	20	116	702	740	4110
1976	862	1750	843	584	506	49	479	36	32	229	259	1940	7570
1977	402	120	896	982	389	496	148	254	401	831	305	680	5900
1978	2280	62	353	671	70	131	39	19	12	35	18	243	3930
1979	2700	617	1460	594	541	274	51	502	72	311	741	679	8530
1980	245	14	759	503	133	99	391	19	15	113	590	591	3470
1981	159	1010	701	514	247	211	43	31	71	576	936	700	5200
1982	394	299	474	985	220	104	54	14	15	14	99	656	3330
1983	277	120	1190	481	781	250	29	22	41	18	47	696	3950
1984	278	854	931	816	270	245	213	216	165	22	23	174	4200
1985	41	579	1150	452	687	650	128	76	24	39	255	74	4150
MEAN	573	467	814	592	415	232	164	139	101	224	396	675	4750
S.D.	729	436	289	217	360	188	246	189	176	252	322	527	1490
% of Mean Annual	12.0	9.7	17.1	12.4	8.6	4.8	3.5	2.9	2.1	4.6	8.2	14.1	100

TABLE 6

SUMMARY OF MONTHLY AND ANNUAL FLOWS
ANNAPOLIS RIVER AT WILMOT

MONTHLY AND ANNUAL MEAN DISCHARGES IN CUBIC METRES PER SECOND FOR THE PERIOD OF RECORD

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1963	---	---	---	---	---	---	---	---	---	10.9	24.3	14.5	---
1964	10.9	12.0	20.8	41.1	7.26	3.54	3.92	3.78	3.17	6.06	7.84	35.8	13.0
1965	17.2	10.7	17.0	16.4	7.25	3.23	1.92	1.66	0.986	2.00	4.04	7.27	7.46
1966	8.67	12.4	24.9	12.8	7.74	4.60	2.20	1.77	1.45	5.87	5.34	8.97	8.05
1967	9.59	7.21	14.8	29.2	36.1	5.33	2.51	1.66	1.93	7.28	14.4	33.2	13.7
1968	13.3	8.18	37.2	15.8	6.85	16.2	4.07	2.37	2.19	4.52	14.8	26.1	12.7
1969	21.4	19.9	16.2	29.7	12.3	3.88	2.11	2.23	2.00	1.99	6.08	20.0	11.4
1970	7.65	19.0	8.99	17.8	10.9	5.17	2.91	2.68	2.16	11.1	18.0	12.6	9.83
1971	10.6	26.8	20.2	36.0	19.7	7.63	3.02	19.4	5.03	4.08	8.04	18.8	14.9
1972	23.3	15.0	28.6	22.5	38.9	7.62	4.90	4.24	2.23	14.0	29.2	20.4	17.6
1973	23.4	14.8	30.1	14.1	11.2	12.5	18.5	11.6	2.72	2.67	7.15	20.7	14.2
1974	12.7	20.0	22.3	18.8	10.2	7.50	5.35	1.78	6.34	18.2	18.8	21.2	13.6
1975	14.3	7.16	19.0	36.0	14.6	6.55	1.95	1.47	1.83	4.22	11.9	27.9	12.3
1976	29.3	36.2	19.0	18.0	16.1	3.37	8.85	2.40	2.67	8.20	11.8	35.9	15.9
1977	19.9	10.6	26.4	37.1	14.4	13.0	6.02	7.01	9.30	26.7	14.3	25.4	17.5
1978	41.7	6.37	11.1	22.1	6.57	4.95	2.46	1.60	1.51	2.85	2.48	7.74	9.33
1979	40.8	22.4	42.2	18.9	17.7	9.75	3.89	8.59	4.99	10.4	23.4	18.3	18.5
1980	14.0	2.78	21.7	17.3	5.84	3.84	6.45	2.86	1.95	3.71	14.4	18.8	9.51
1981	15.5	42.4	17.9	24.7	10.8	7.33	3.85	2.95	2.99	12.2	22.8	26.3	15.6
1982	14.0	17.7	19.6	26.9	14.4	6.02	4.59	2.44	1.99	1.80	3.53	14.1	10.5
1983	9.03	7.16	25.6	16.5	15.4	9.35	3.14	2.26	2.04	1.53	3.44	13.2	9.08
1984	12.5	20.2	22.4	21.3	11.7	7.98	6.56	6.43	5.72	2.60	3.31	8.97	10.8
1985	5.16	13.1	22.5	20.3	16.3	13.7	5.80	3.98	2.72	2.20	8.40	5.33	9.91
MEAN	17.0	16.0	22.2	23.3	14.2	7.41	4.77	4.33	3.09	7.18	12.1	19.2	12.5
% of Mean Annual Total Flow	11.6	9.7	15.0	15.2	9.6	4.9	3.2	2.9	2.0	4.9	8.0	13.0	100

TABLE 7

ANNAPOLIS RIVER AT WILMOT
REGRESSION ANALYSIS
INSTANTANEOUS AND DAILY MEAN VALUES OF DISCHARGE VERSUS CONCENTRATION
ONLY SAMPLED CONCENTRATIONS

Daily Mean Discharge Versus Daily Mean Suspended Sediment

Year	r^2	Standard Error (%)
1968	0.179	± 74
1972	0.127	± 85
1976	0.357	± 95
1980	0.142	± 98
1984	0.448	± 77
1967-1985	0.205	± 96

Instantaneous Discharge Versus Instantaneous Suspended Sediment
For The Year 1984

Period	r^2	Standard Error (%)
Jan-Dec	0.426	± 78
Jan-Mar	0.251	± 47
Apr-Jun	0.003	± 74
Jul-Sep	0.336	± 86
Oct-Dec	0.091	± 68

Note: Discharge in m^3/s,
Suspended Sediment in mg/l.

TABLE 8

ANNAPOLIS RIVER AT WILMOT
REGRESSION ANALYSIS
MONTHLY AND ANNUAL VALUES OF DISCHARGE VERSUS SUSPENDED SEDIMENT

Quantity	r^2	S_e (%)
1. Total Annual Discharge (dam^3) vs. Total Annual Sediment Load (tonnes) Period 1968 to 1985	0.660	± 17
2. Monthly Total Discharge (dam^3) vs. Monthly Total Sediment Load (tonnes) Period 1967 to 1985	0.864	± 51
3. Monthly Mean Discharge (m^3/s) vs. Monthly Mean Suspended Sediment (mg/l) Period 1967 to 1985	0.294	± 49
4. Mean Monthly Total Discharge (dam^3) vs. Mean Monthly Total Sediment Load (tonnes) Period 1963 to 1985 for Discharge 1967 to 1985 for Load	0.983	± 9

APPENDIX B
(Figures)

LOCATION PLAN
ANNAPOLIS RIVER BASIN, NOVA SCOTIA

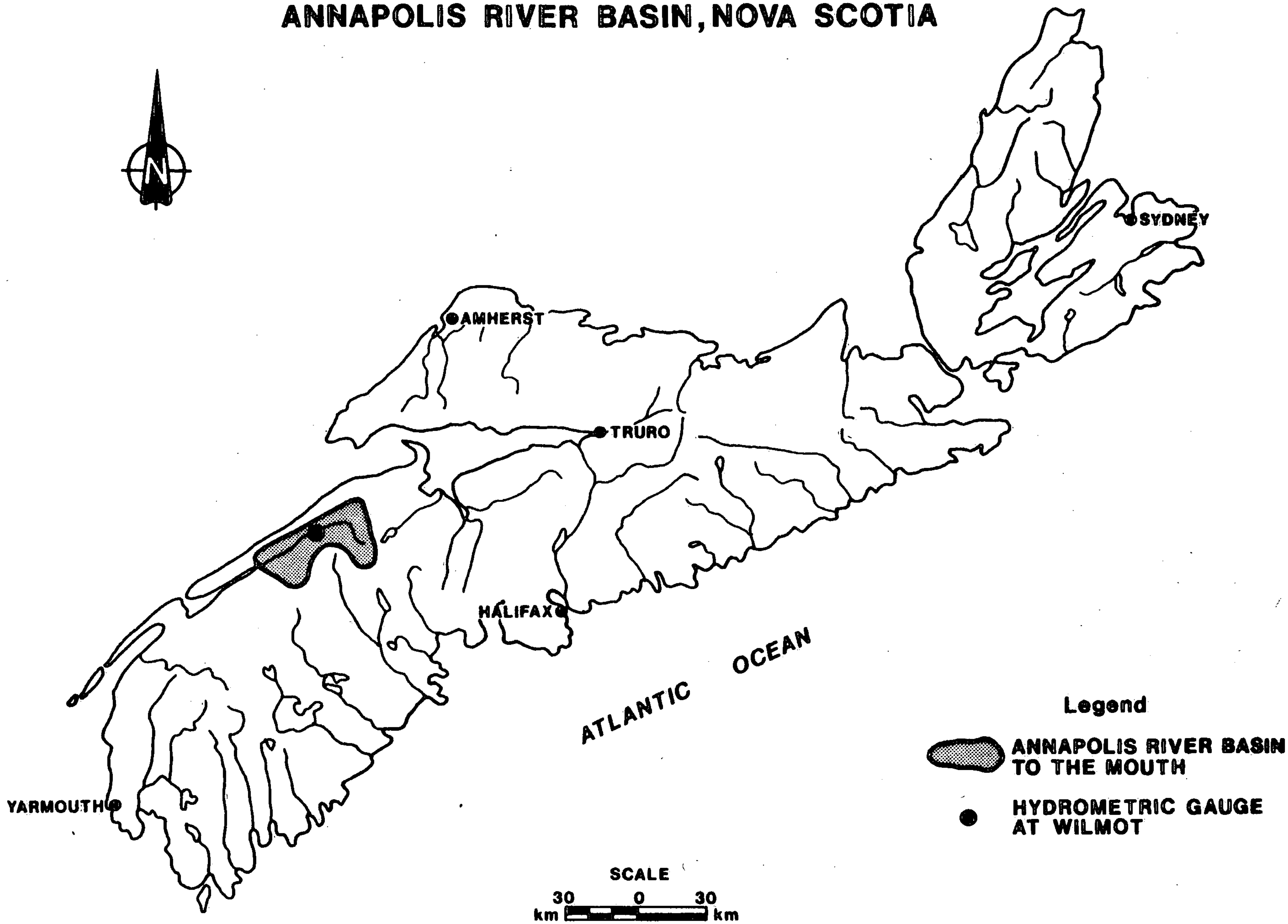


Figure 1

ANNAPOLIS RIVER CROSS-SECTIONS
HIGHWAY BRIDGE NEAR WILMOT

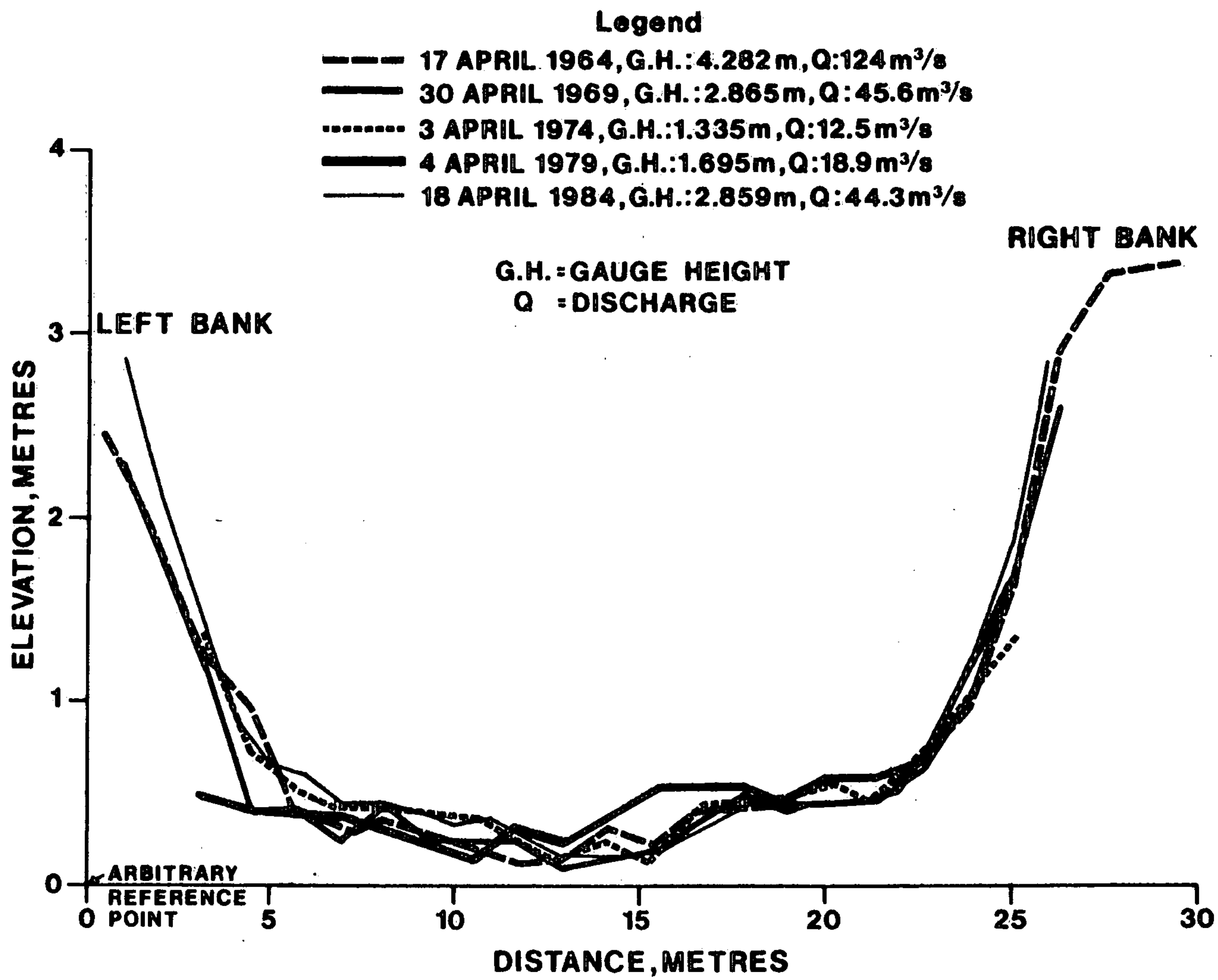


Figure 2

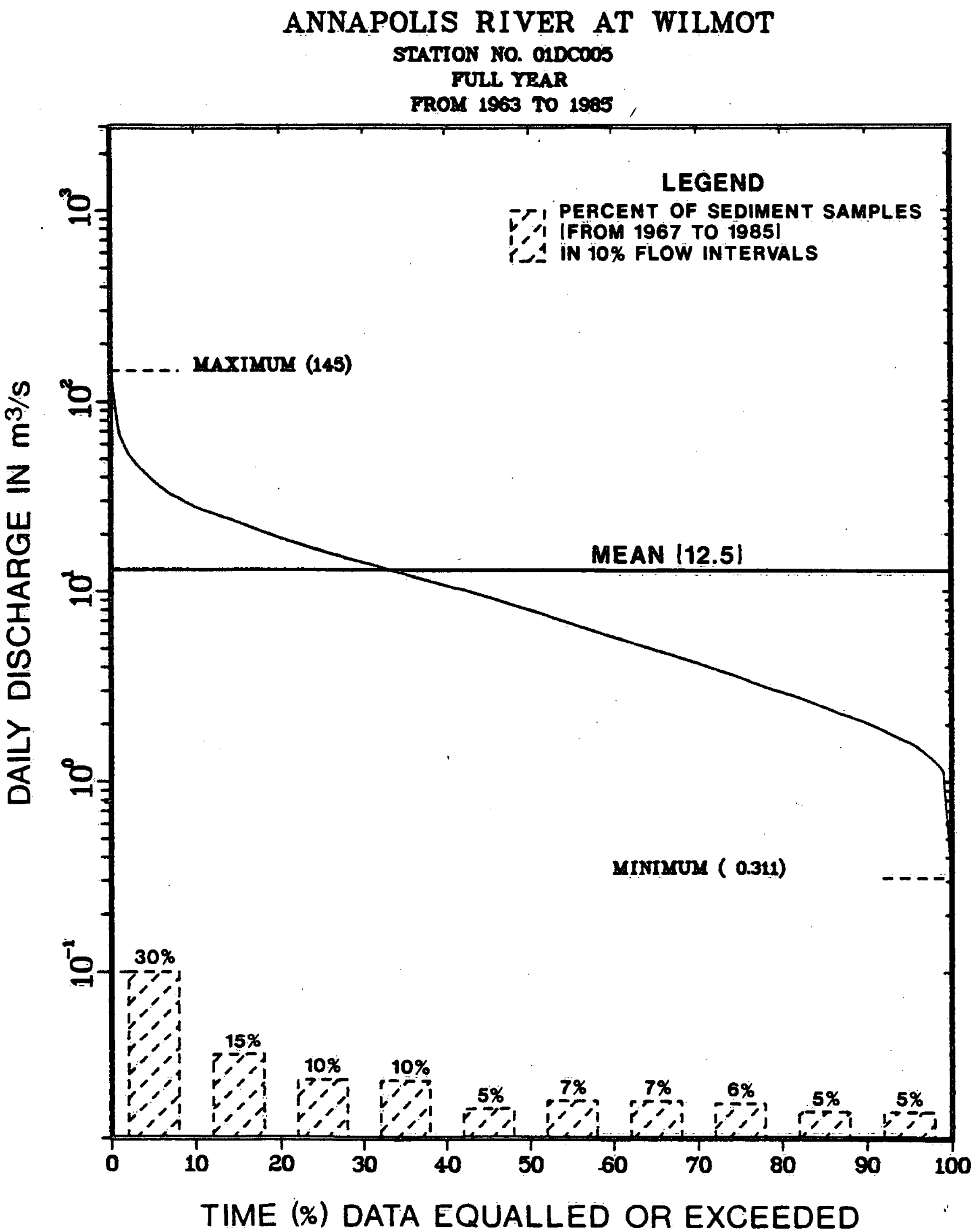


Figure 3 Flow Duration Curve and Sediment Sampling Bar Chart

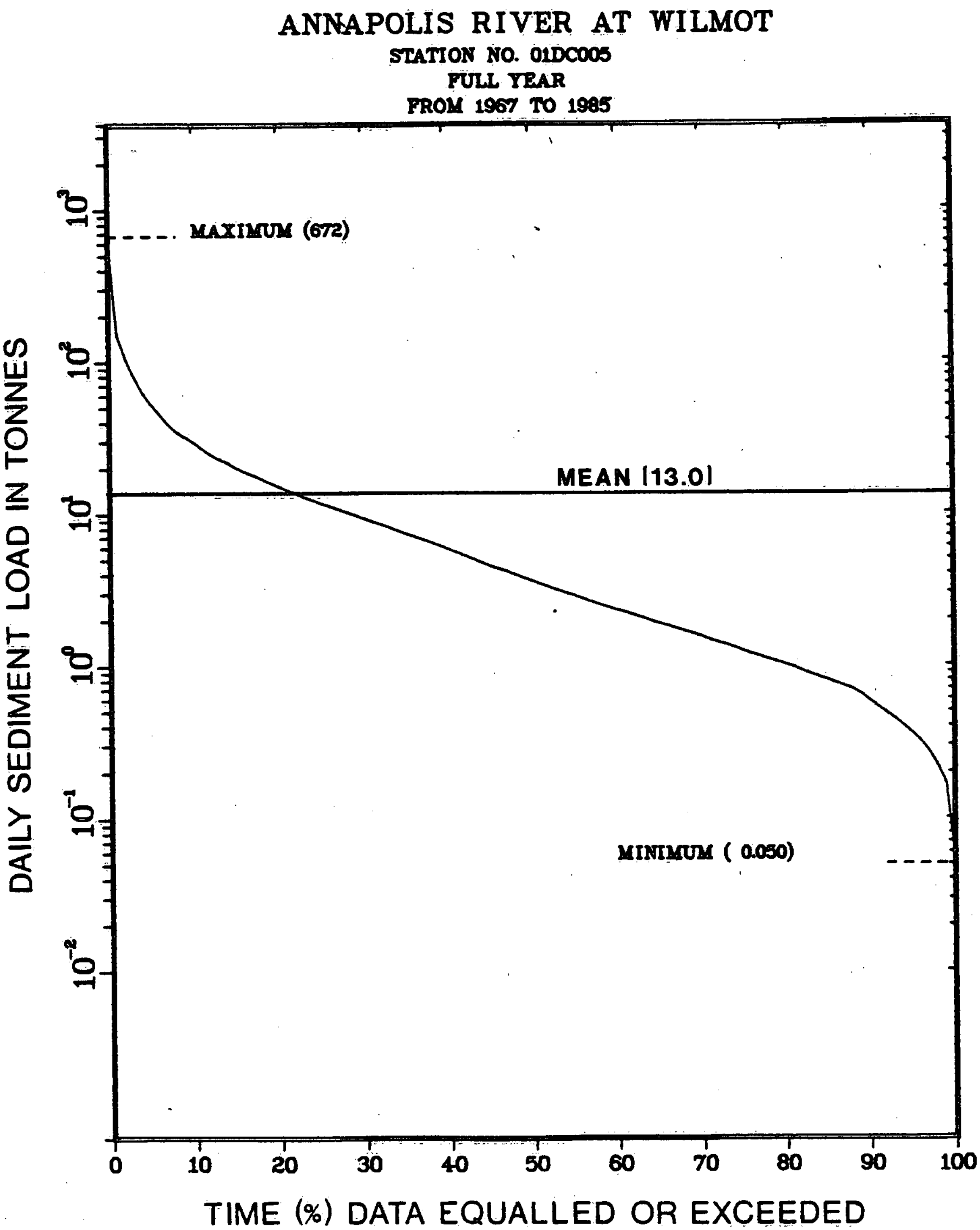
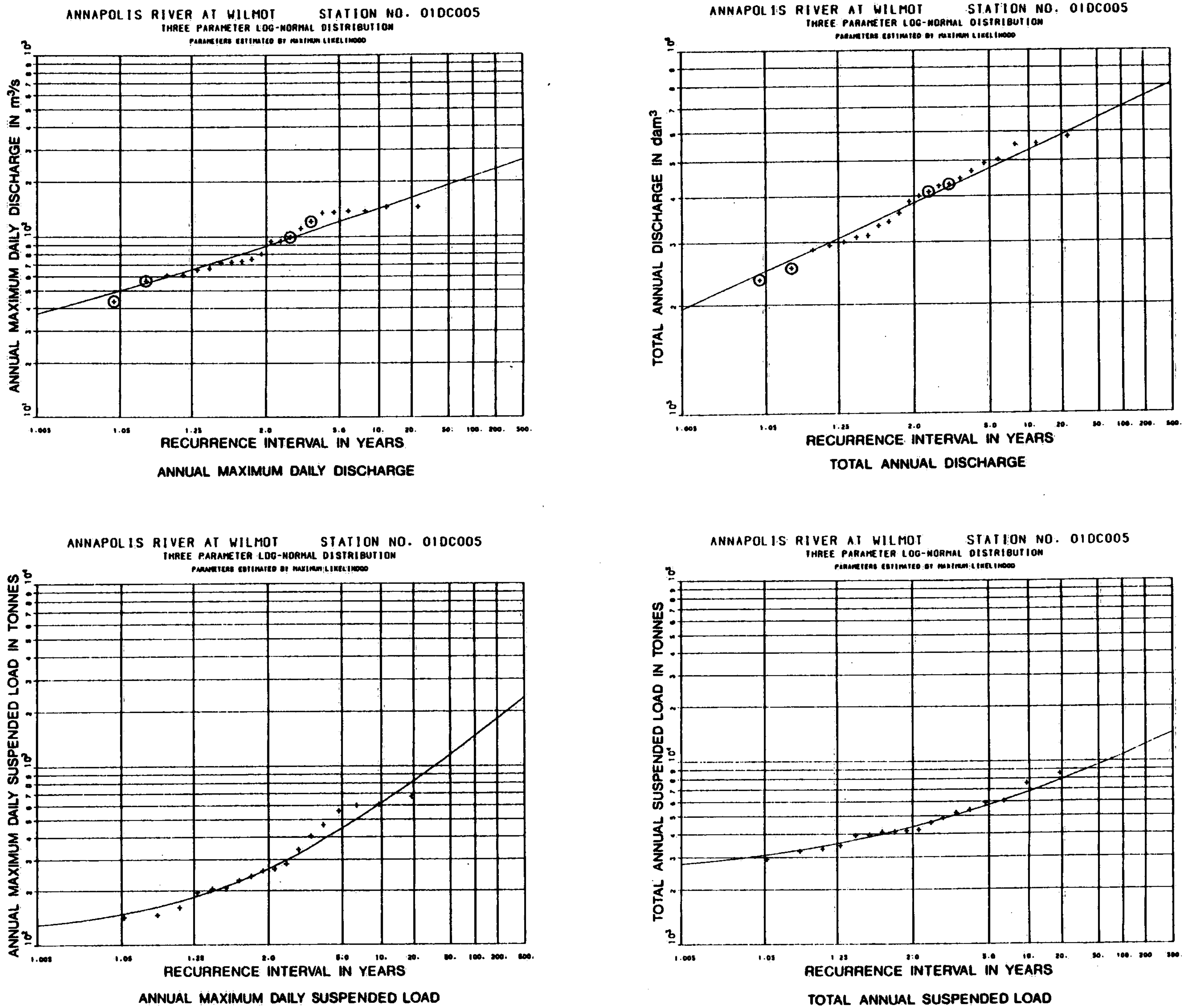


Figure 4 Suspended Sediment Duration Curve

Figure 5 Frequency Plots of Discharge and Suspended Sediment Load



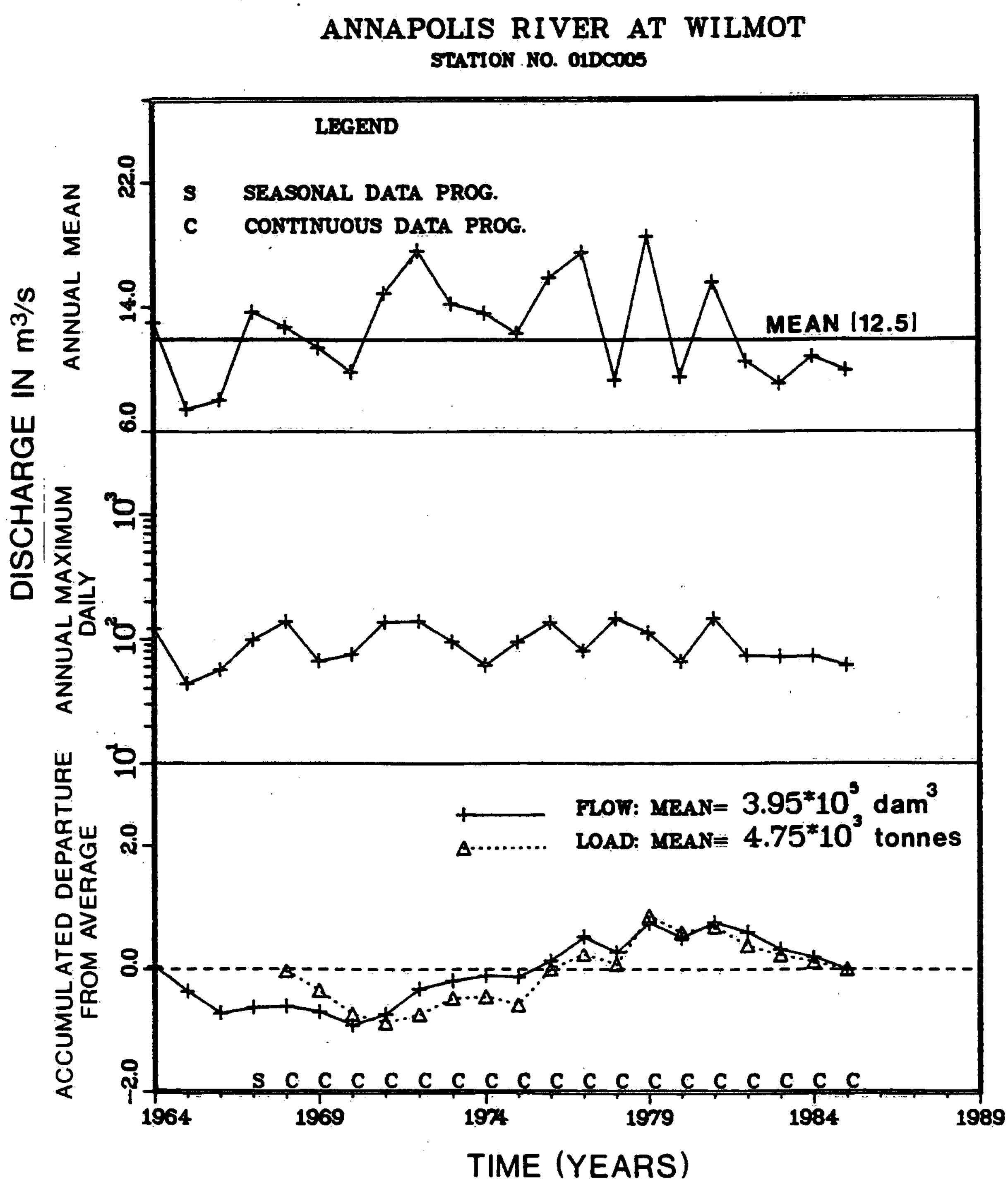
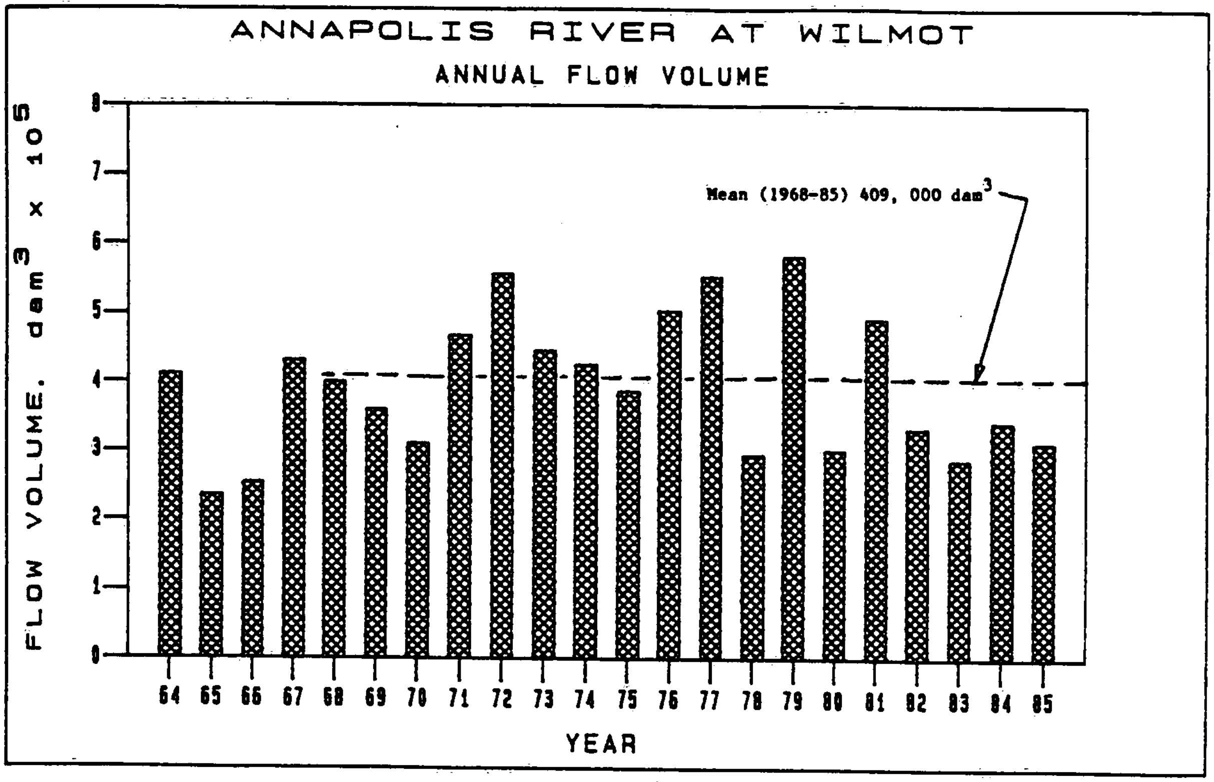


Figure 6 Flow History During Sediment Sampling Program



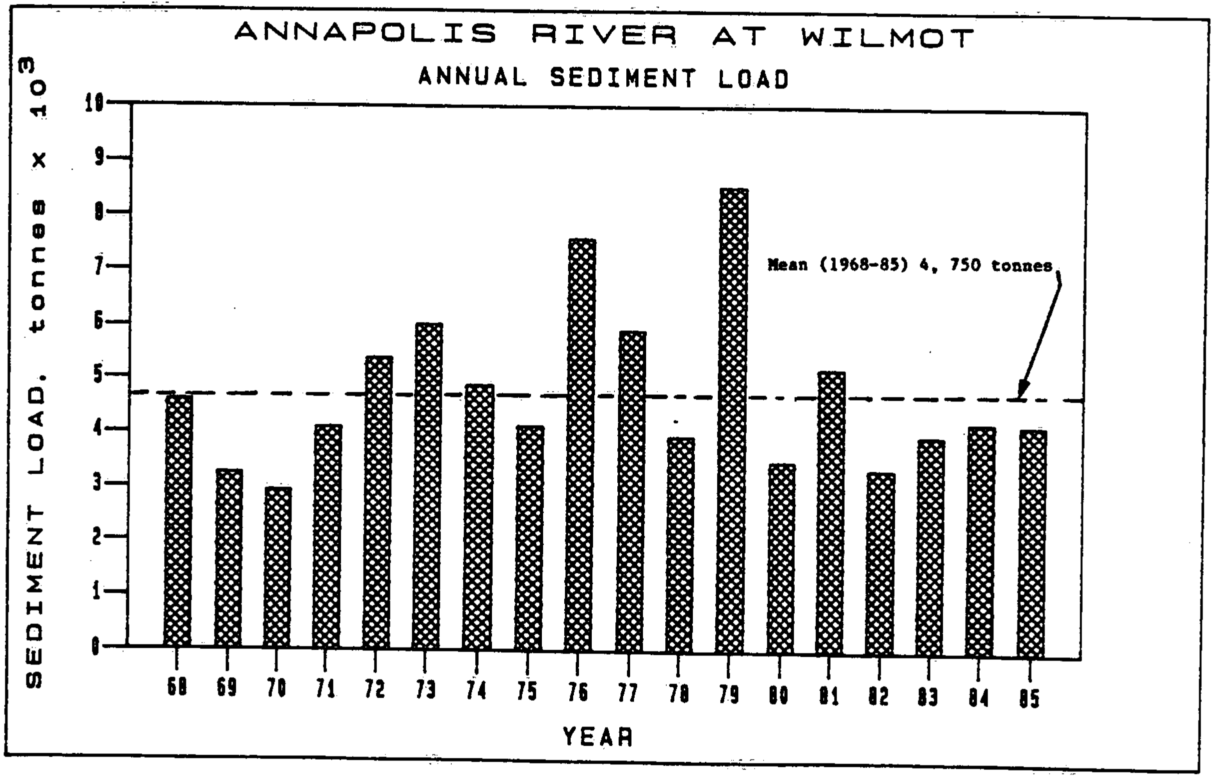


Figure 7 Annual Flow Volumes and Sediment Loads

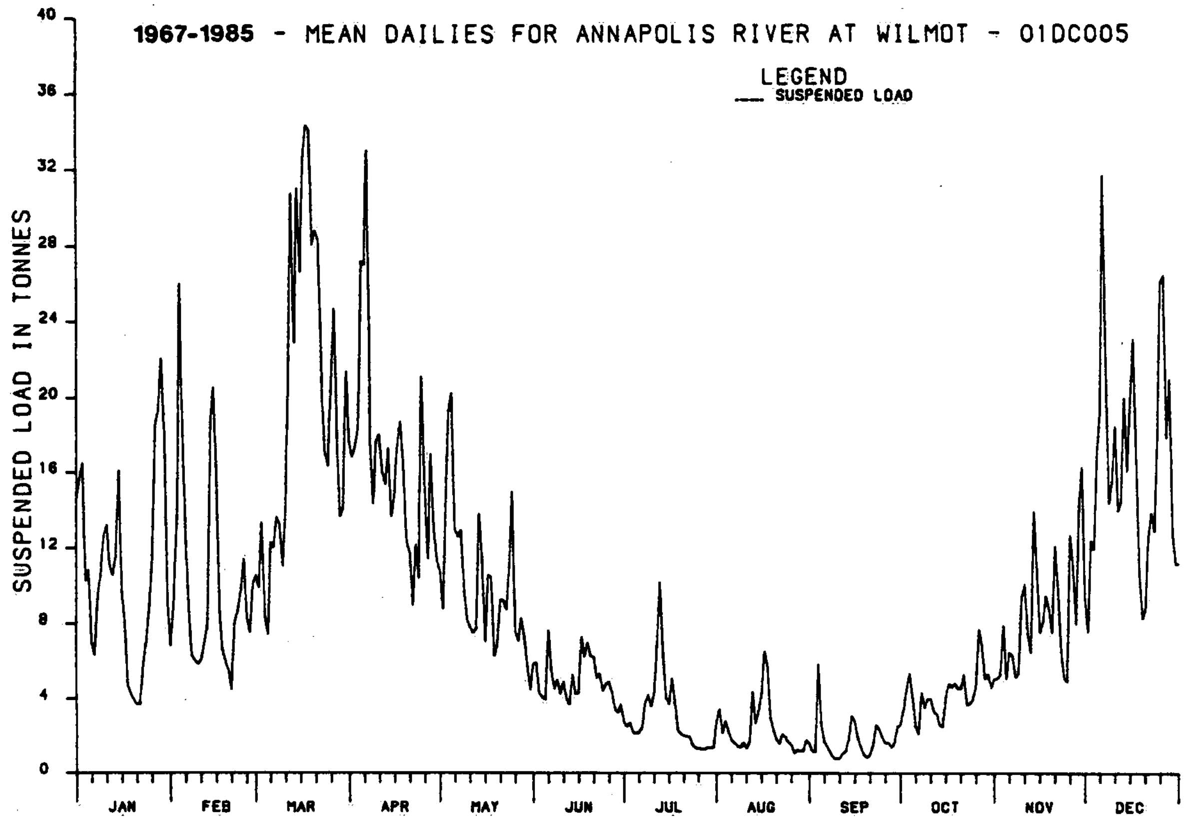


Figure 8 Mean Daily Suspended Sediment Load

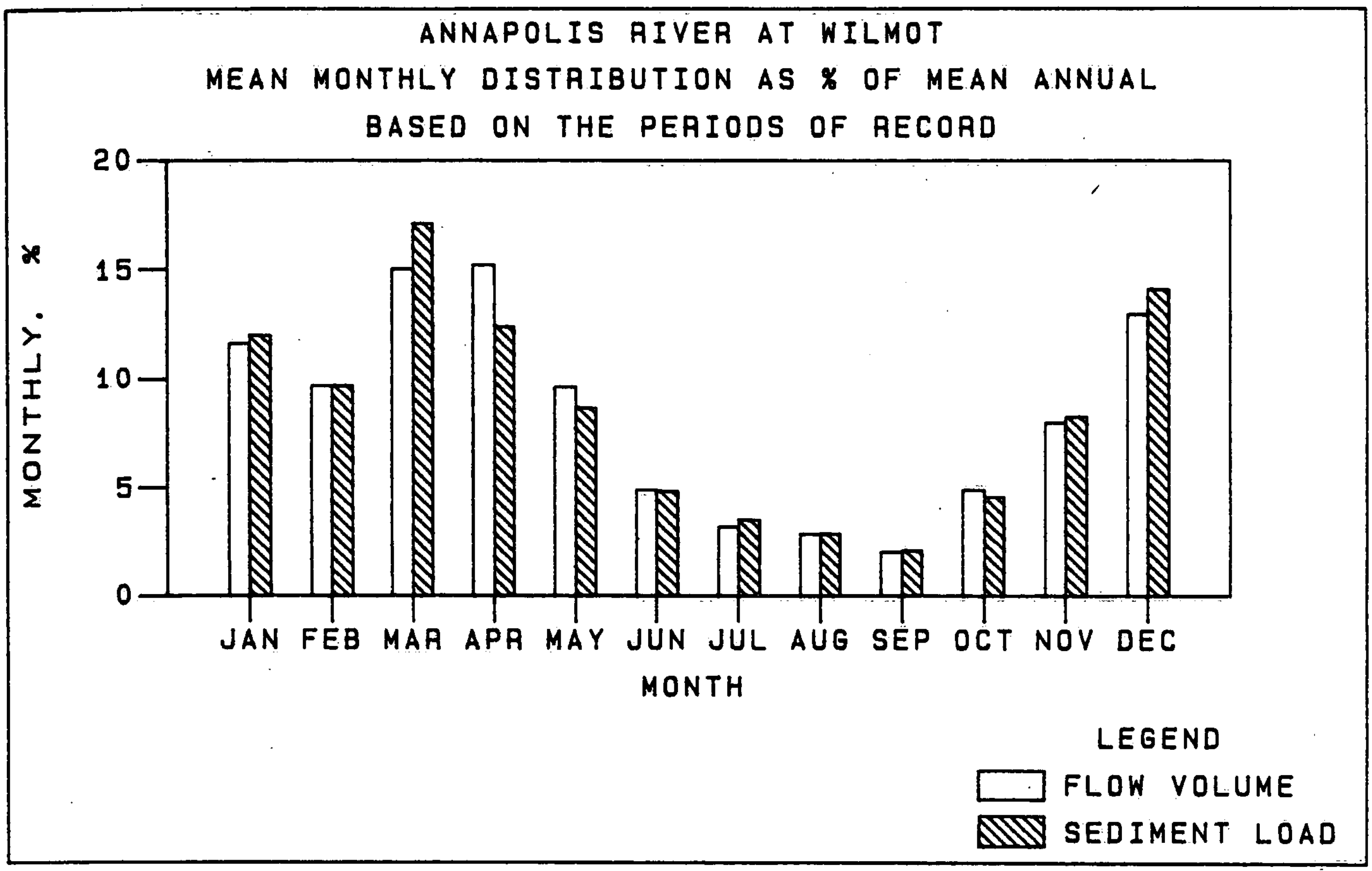


Figure 9 Mean Monthly Flow and Sediment Distribution as a Percentage of the Mean Annual Total

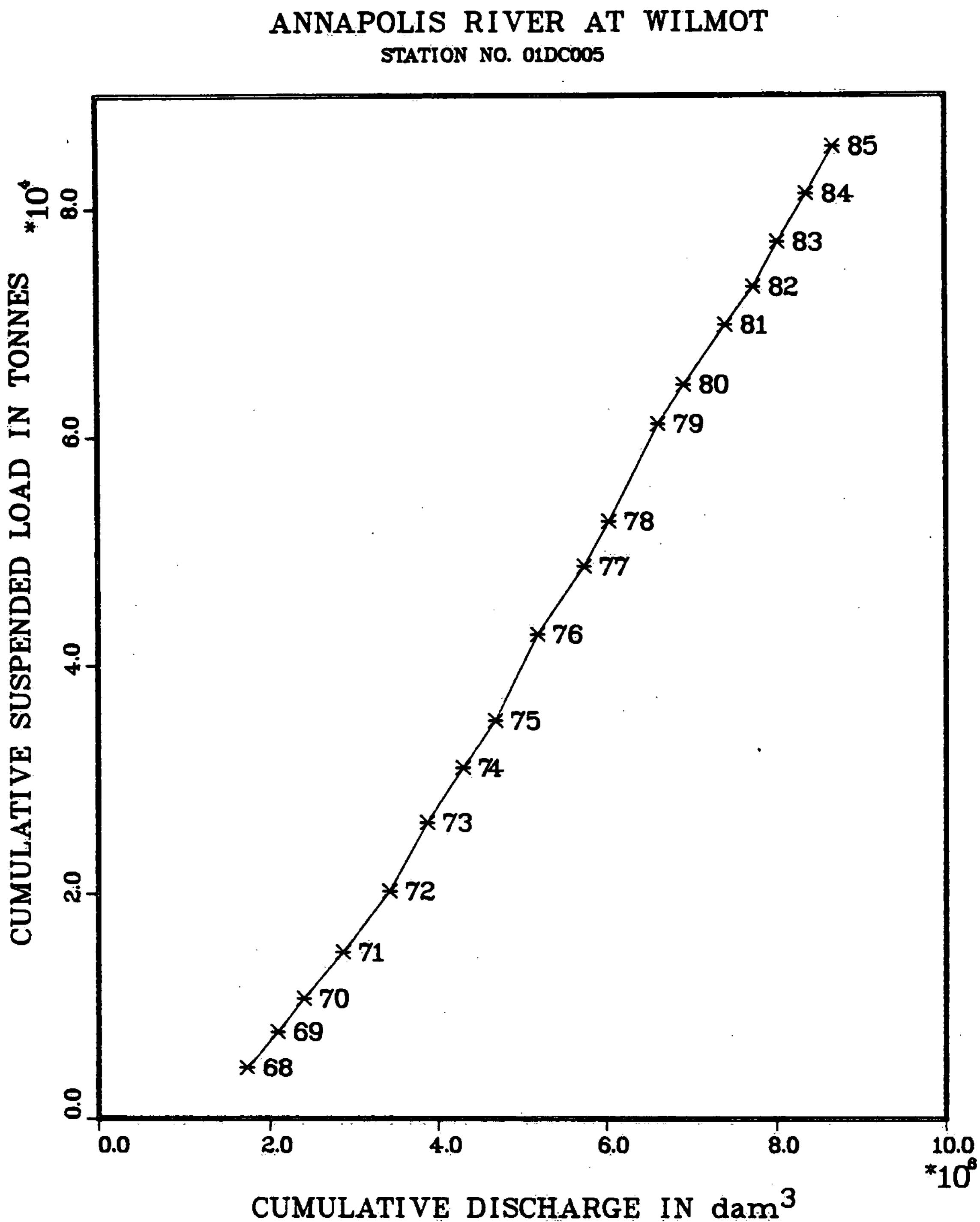
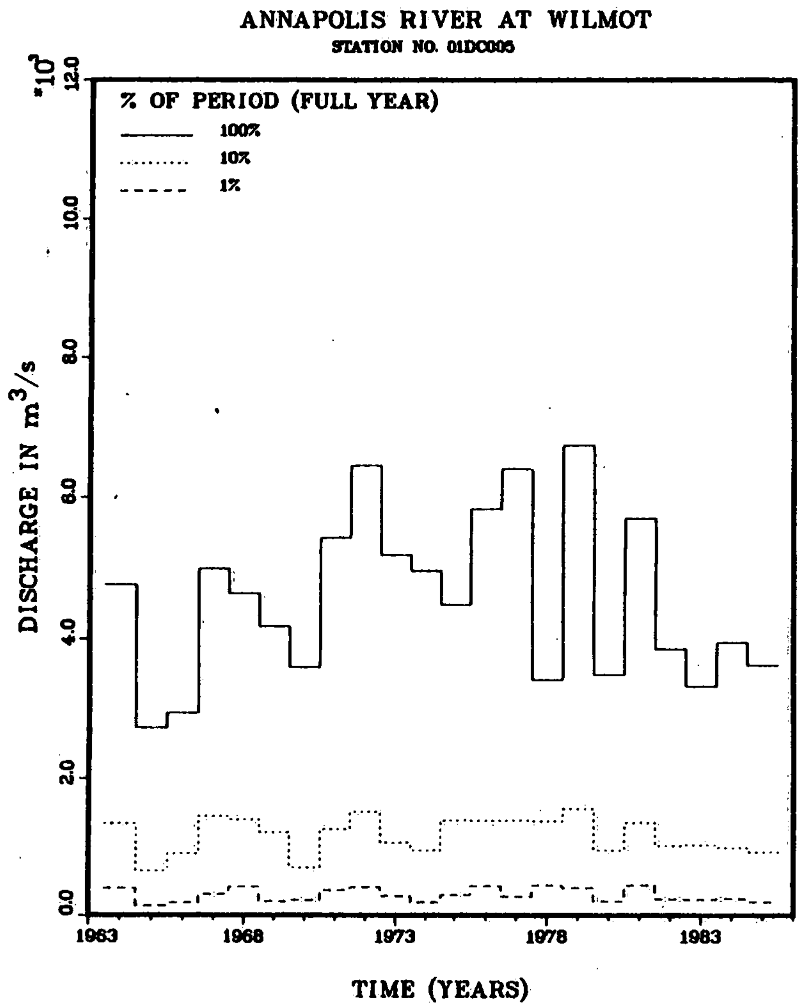


Figure 10 Cumulative Suspended Sediment Load Versus Cumulative Flow Volume, 1968 to 1985



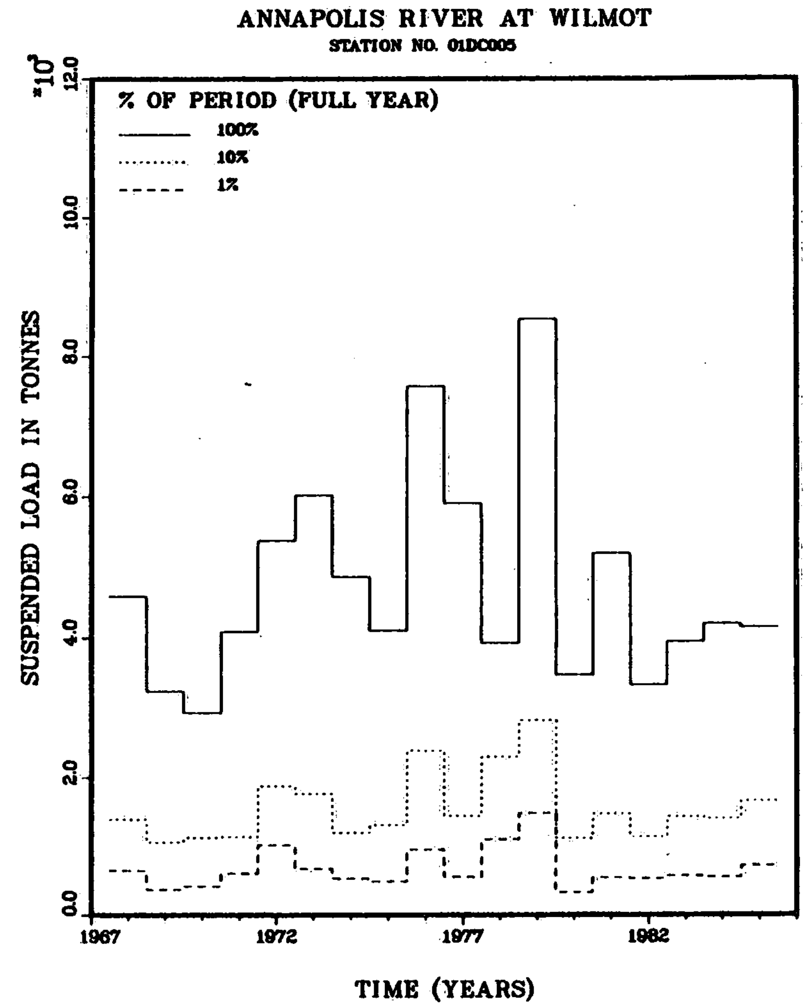


Figure 11 Contribution of Short Duration Events to Annual Discharge and Sediment Load

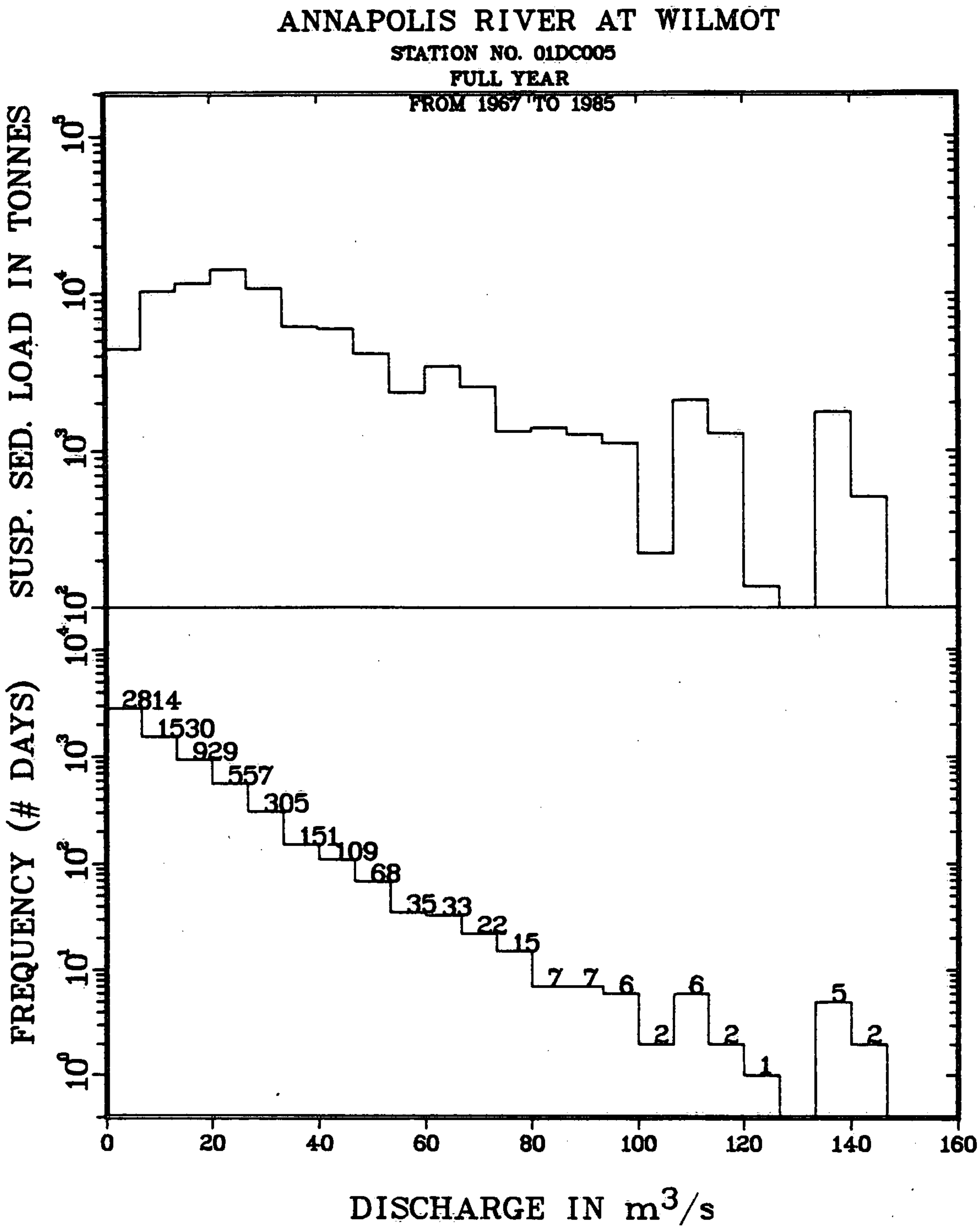


FIGURE 12 FREQUENCY OF OCCURRENCE OF DISCHARGE AND SUSPENDED SEDIMENT LOAD.

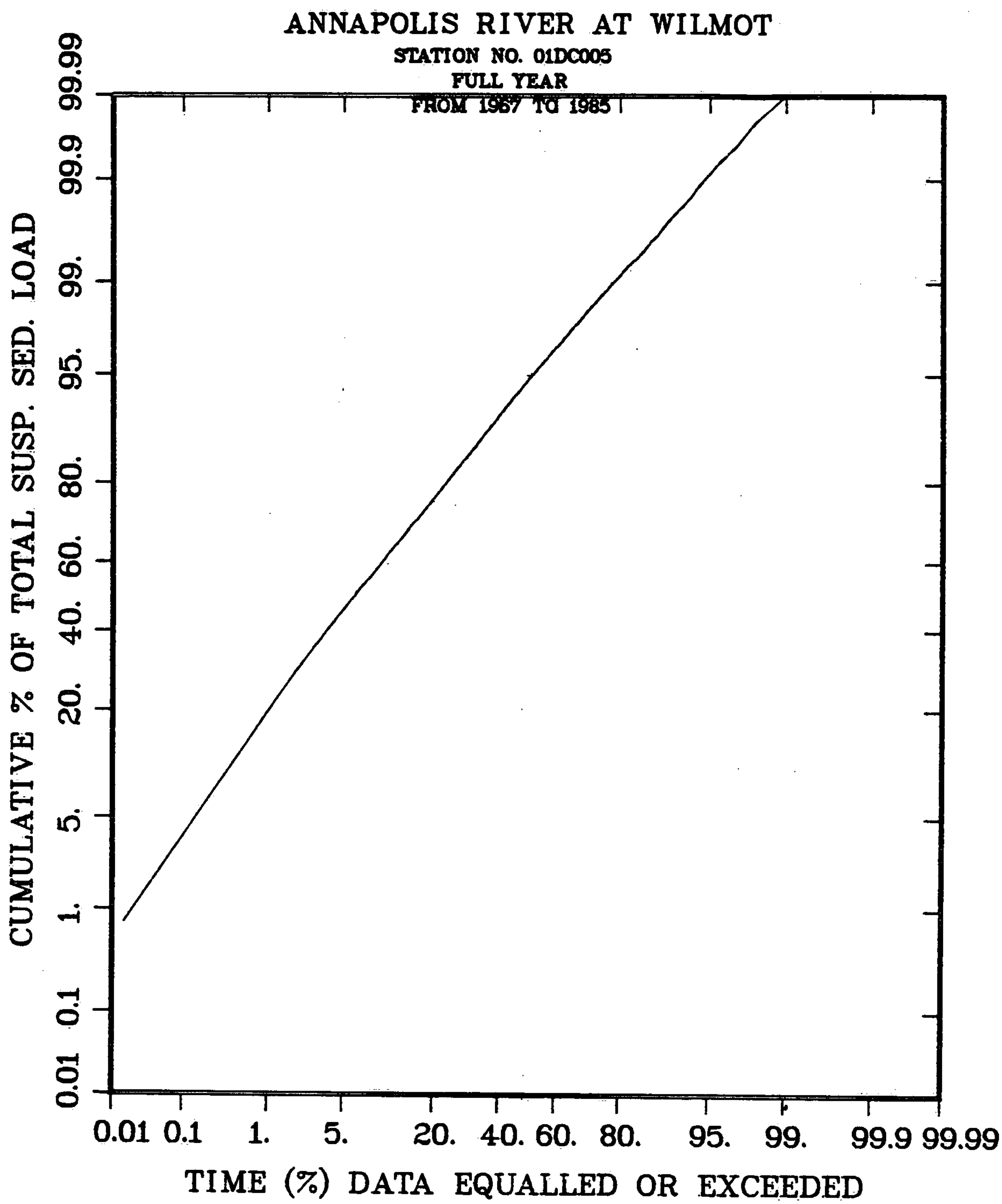


FIGURE 13 CUMULATIVE PERCENTAGE OF THE TOTAL SUSPENDED SEDIMENT LOAD VERSUS THE PERCENTAGE OF TIME DATA IS EQUALLED OR EXCEEDED.

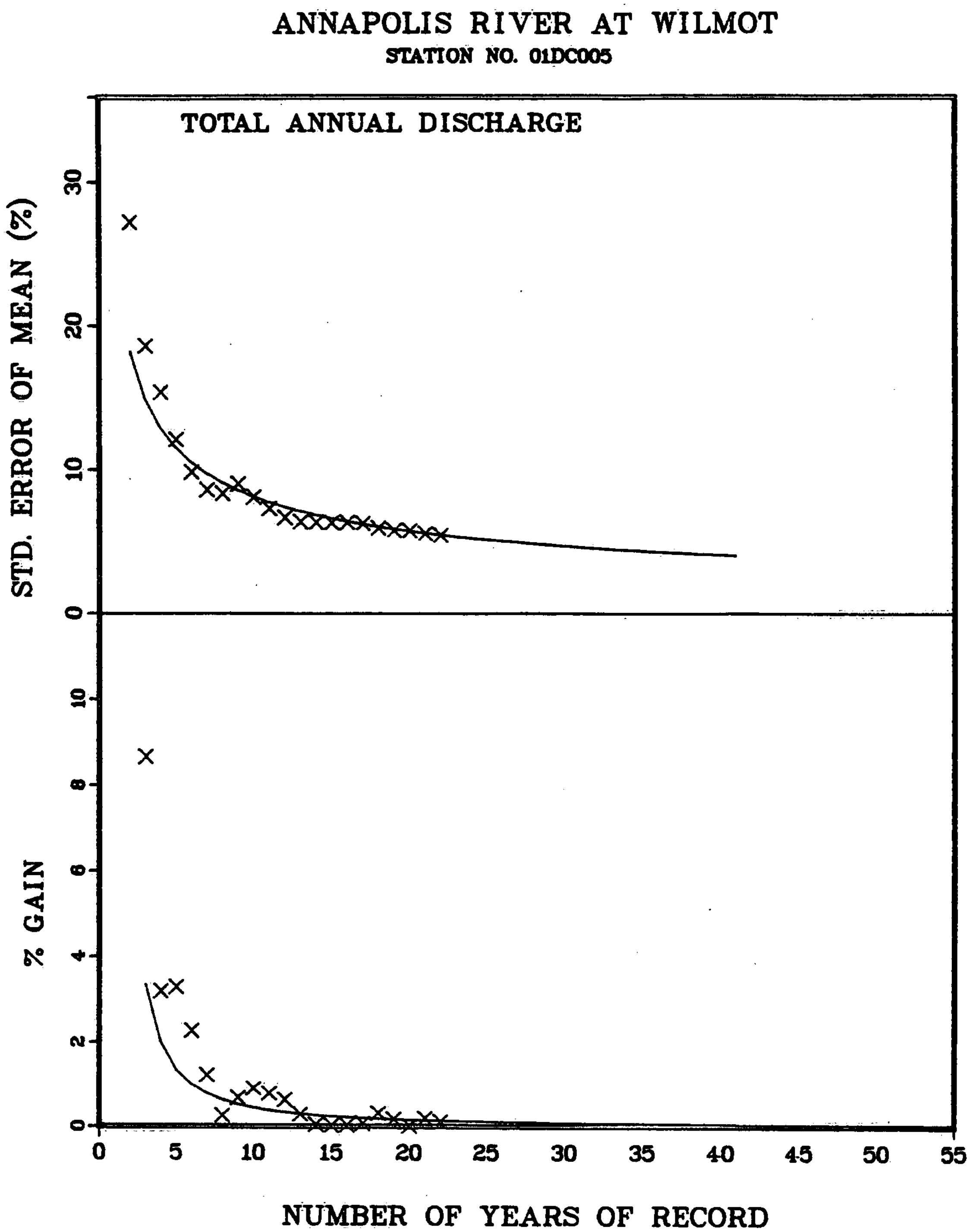


FIGURE 14 RELATION BETWEEN THE STANDARD ERROR OF THE MEAN ANNUAL TOTAL DISCHARGE AND RECORD LENGTH. THE PERCENTAGE GAIN IN THE STANDARD ERROR OF THE MEAN FOR EACH ADDITIONAL YEAR OF RECORD IS SHOWN IN THE BOTTOM HALF OF THE FIGURE.

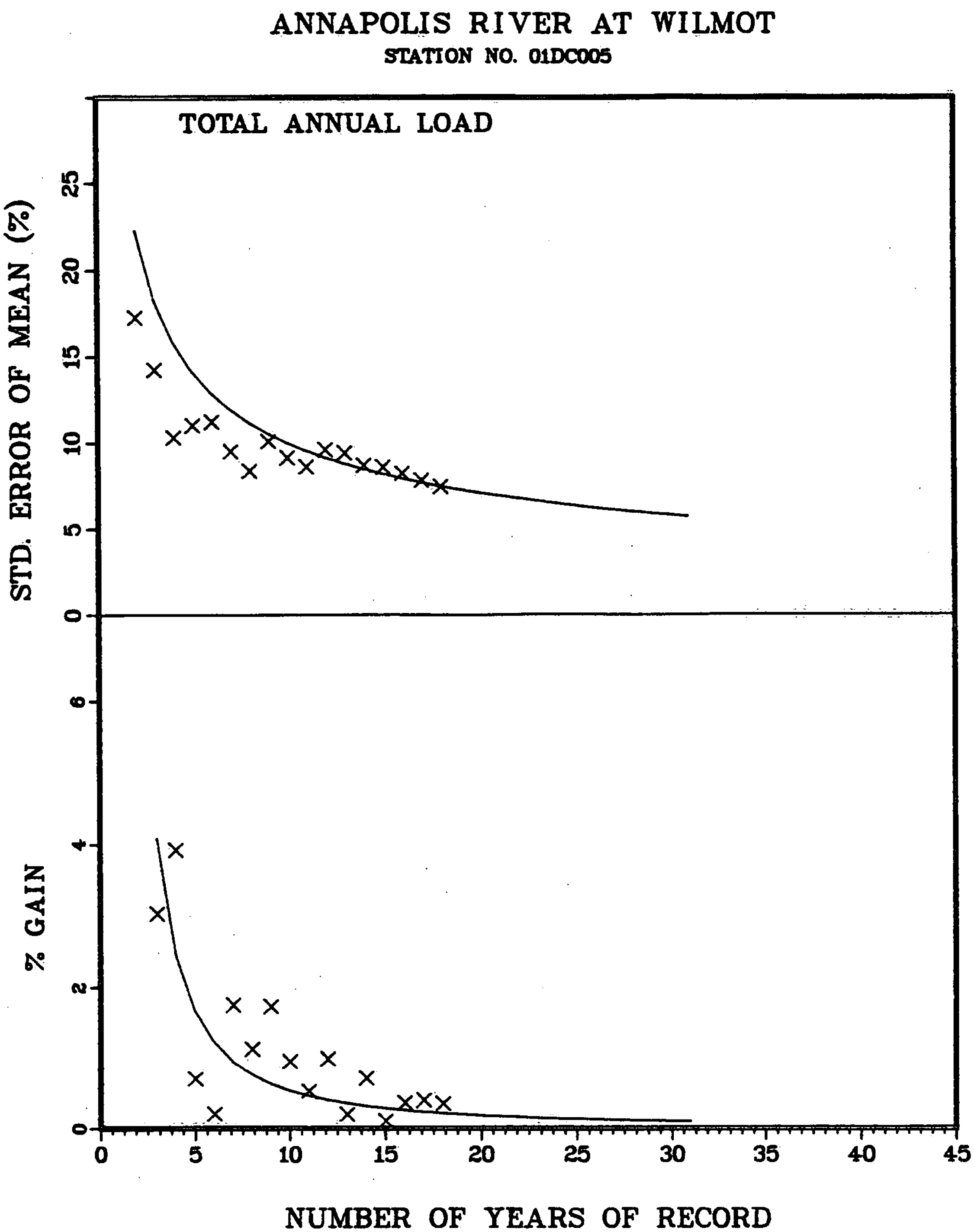


FIGURE 15 RELATION BETWEEN THE STANDARD ERROR OF THE MEAN ANNUAL TOTAL SUSPENDED SEDIMENT LOAD AND RECORD LENGTH. THE PERCENTAGE GAIN IN THE STANDARD ERROR OF THE MEAN FOR EACH ADDITIONAL YEAR OF RECORD IS SHOWN IN THE BOTTOM HALF OF THE FIGURE.

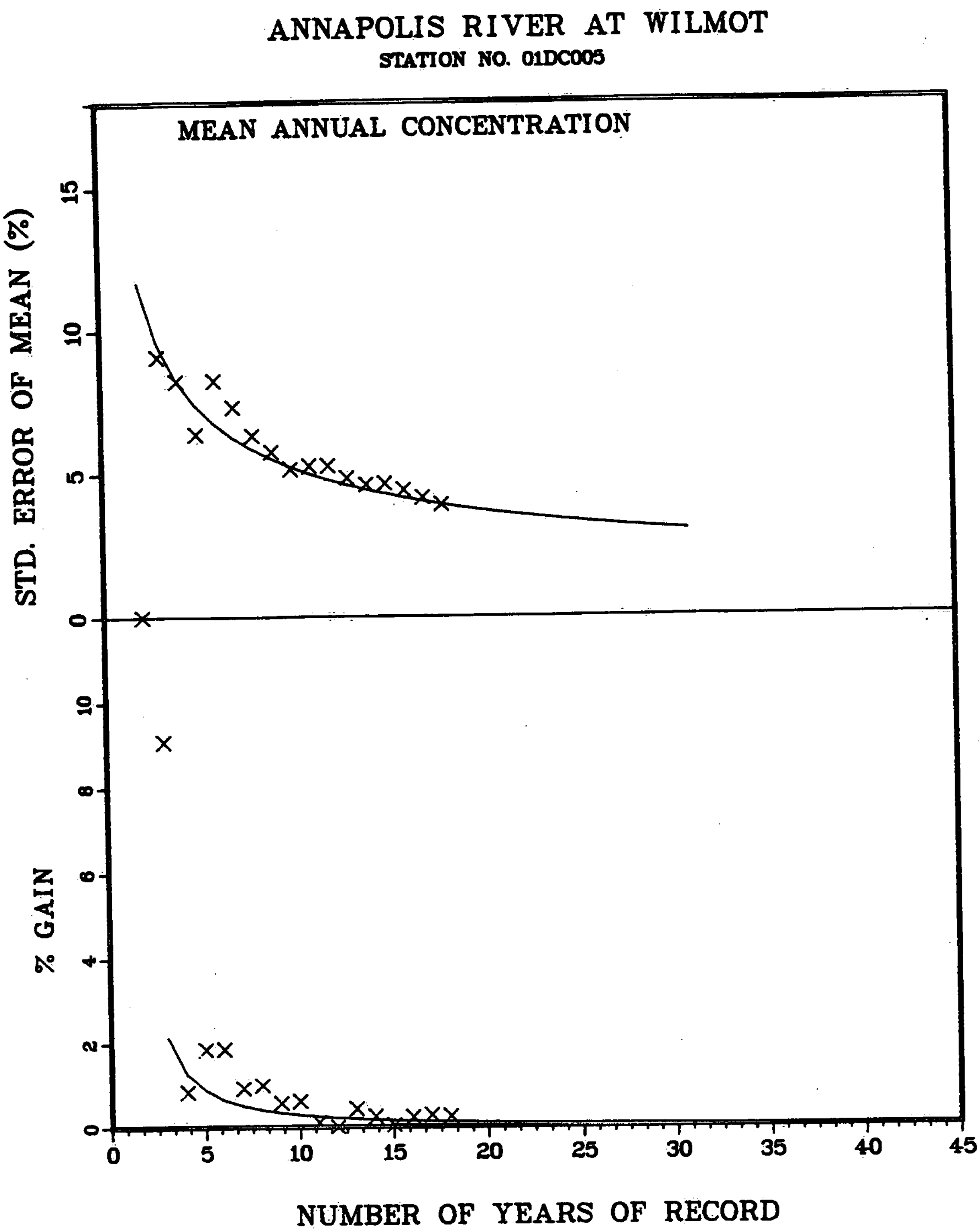


FIGURE 16 RELATION BETWEEN THE STANDARD ERROR OF THE MEAN ANNUAL SUSPENDED SEDIMENT CONCENTRATION AND RECORD LENGTH. THE PERCENTAGE GAIN IN THE STANDARD ERROR OF THE MEAN FOR EACH ADDITIONAL YEAR OF RECORD IS SHOWN IN THE BOTTOM HALF OF THE FIGURE.

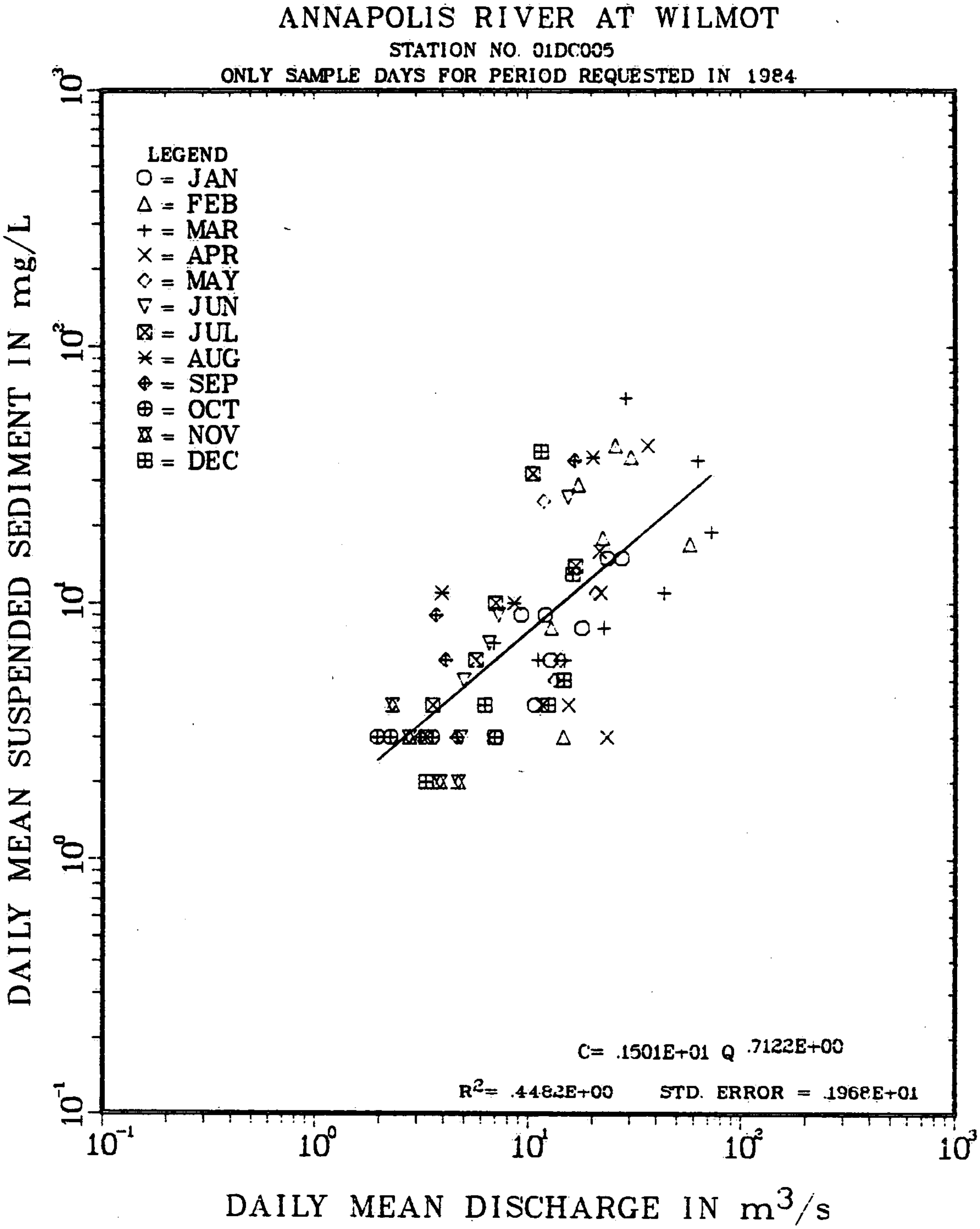


FIGURE 17 RATING RELATIONSHIP FOR DAILY MEAN DISCHARGE VERSUS DAILY MEAN SUSPENDED SEDIMENT.

ANNAPOLIS RIVER AT WILMOT
STATION NO. 01DC005

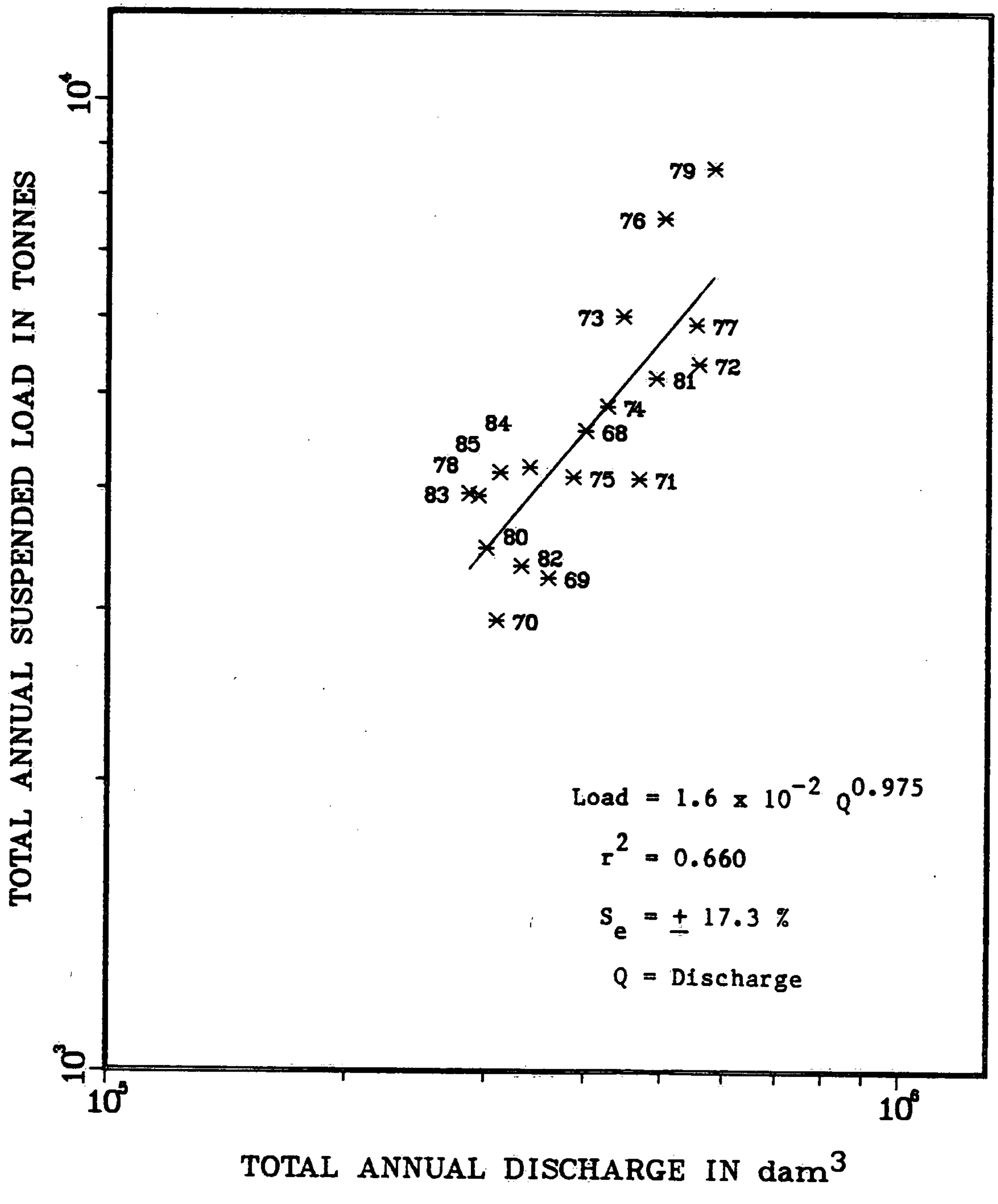


FIGURE 18 RATING RELATIONSHIP FOR TOTAL ANNUAL DISCHARGE VERSUS TOTAL ANNUAL SUSPENDED LOAD.

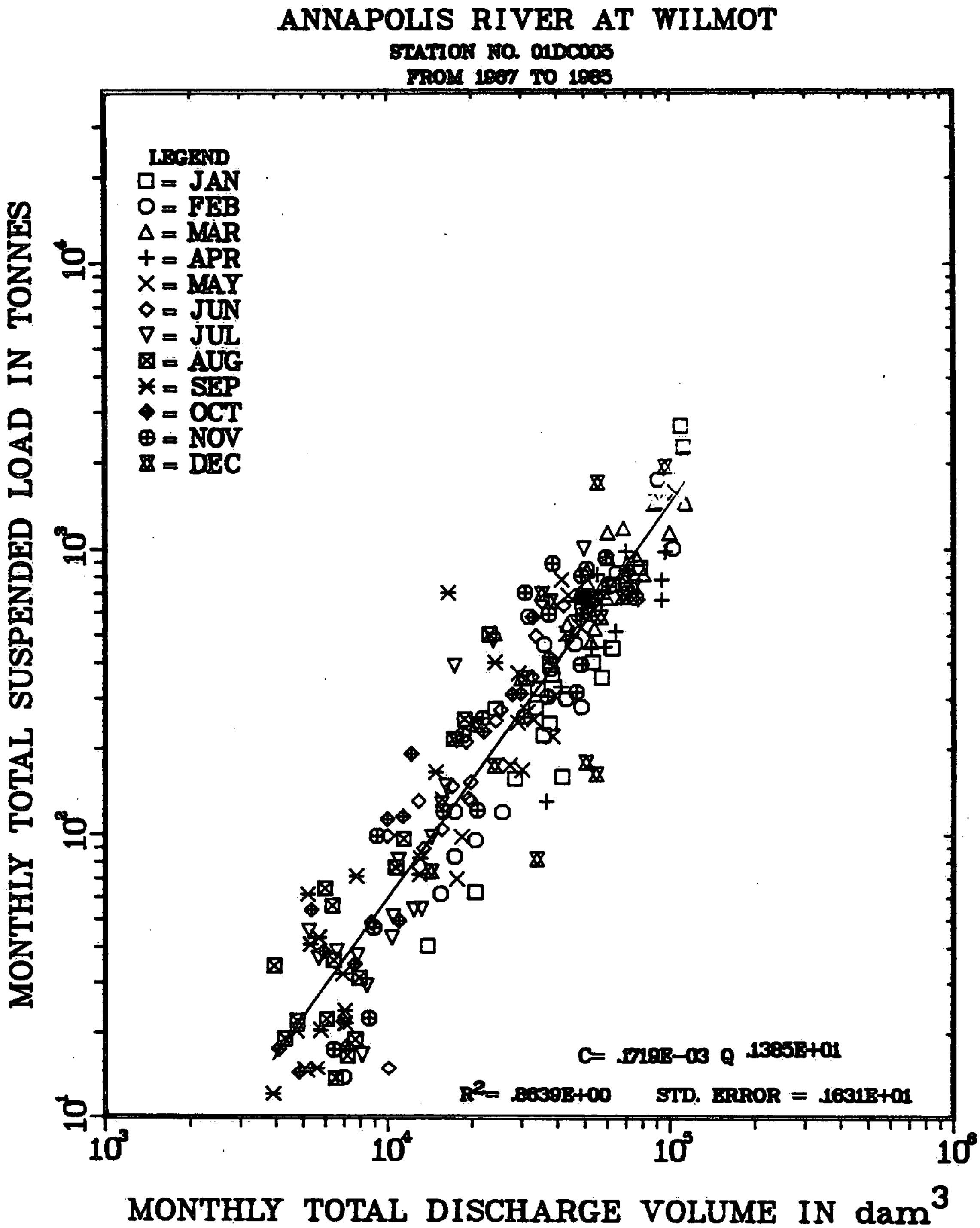


FIGURE 19 RATING RELATIONSHIP FOR MONTHLY TOTAL DISCHARGE VERSUS MONTHLY TOTAL SUSPENDED LOAD.

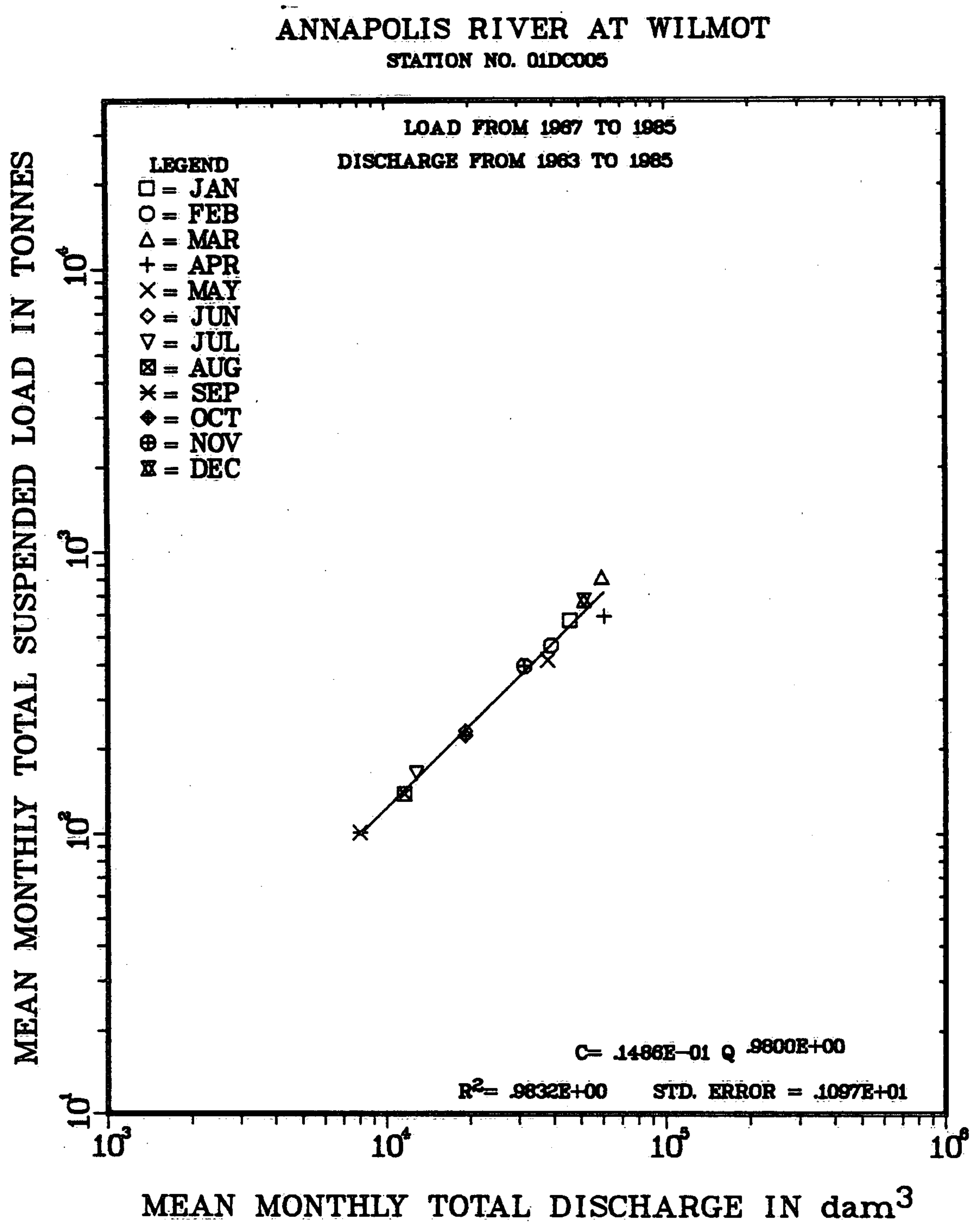


FIGURE 20 RATING RELATIONSHIP FOR MEAN MONTHLY TOTAL DISCHARGE VERSUS MEAN MONTHLY TOTAL SUSPENDED LOAD.

APPENDIX C
(Photographs)

Plate 1. Road and ditch construction, Fales River at Rockville Notch.

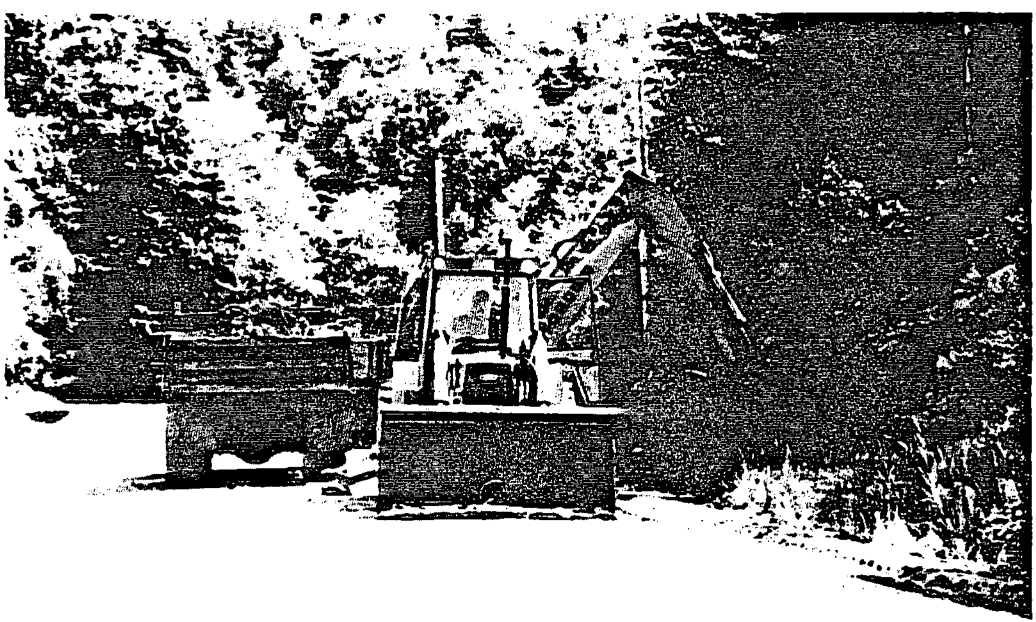


Plate 2. Smaller unpaved road improvement and ditching construction was noticed throughout the watershed.

Plate 3. Orchard on a moderate slope just above the valley bottom, located between North Kingston and Weltons Corner.

Plate 4. The light areas in this photograph show grass under young fruit trees killed by herbicide sprays. The tractor is cutting hay in what is a two crop system common in many orchards. The location is at Weltons Corner and McGee Brook.

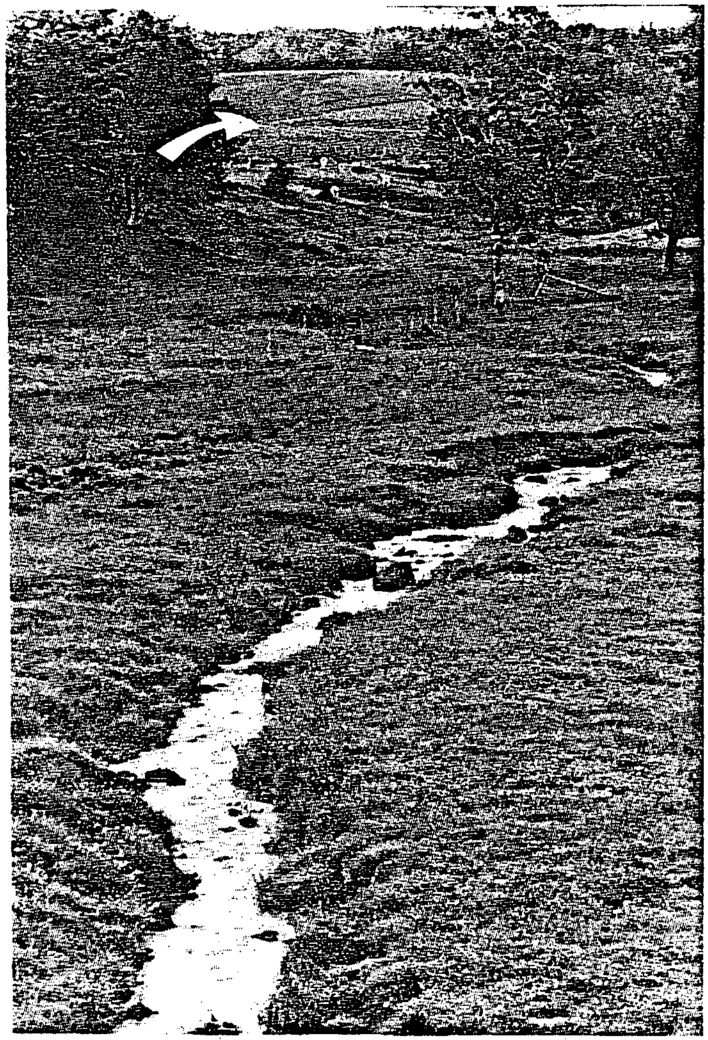


Plate 5. Watton Brook enters the Annapolis River just to the northeast of the Wilmot gauge. A high concentration of a red coloured sediment was noted on the field trip. The arrow indicates a ploughed field (of red soil) on a steep slope along the upper part of Watton Brook. As in other locations cattle have direct access to the stream bed.

Plate 6. This kame just south of Caribou Bog and two kilometres east of Aylesford East has nearly been dissected as a result of a sand and gravel extraction activity.

Plate 7. A large extraction site susceptable to erosion one kilometre northeast of Rockland.

Plate 8. Bank erosion is evident on the sinuous channel of Skinner Brook just southwest of Weston. A high sediment load was noted on the field trip.

Plate 9. Another source of sediment noted in Skinner Brook just west of Weston is this waste water outflow indicated by the upper arrow. The other arrow points to deposits from the outflow.

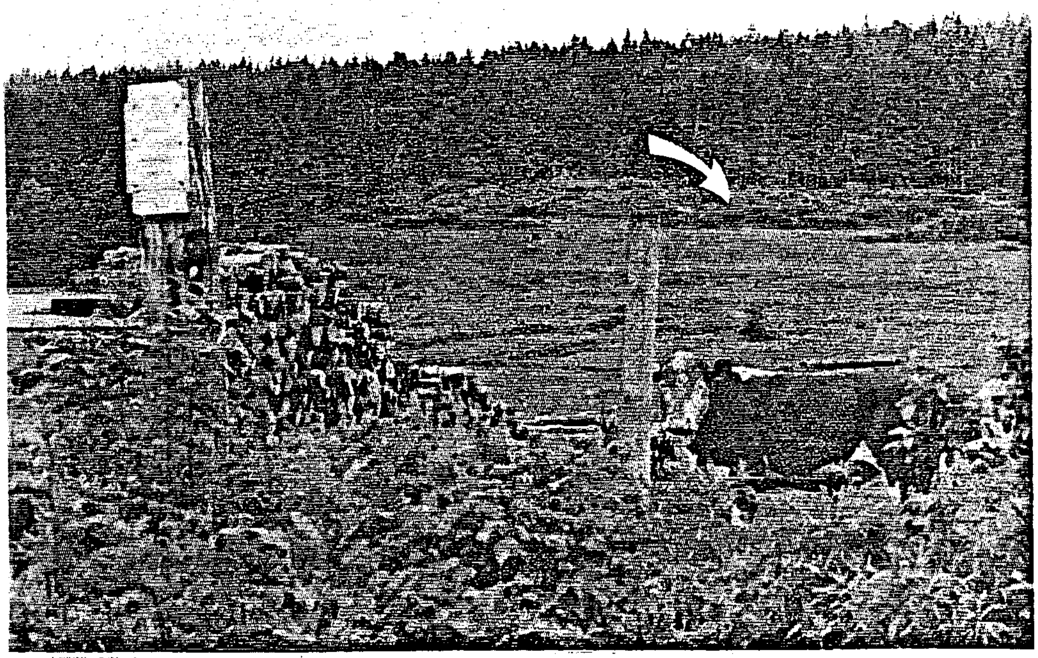


Plate 10. Additional sediment sources result from removal of tree cover (arrow) on moderate slopes for the purpose of creating additional agricultural land. This photograph was taken one kilometre east of Dempsey Corner.

Plate 11. In the same field as Plate 10 is shown a drainage ditch transporting soil down slope.

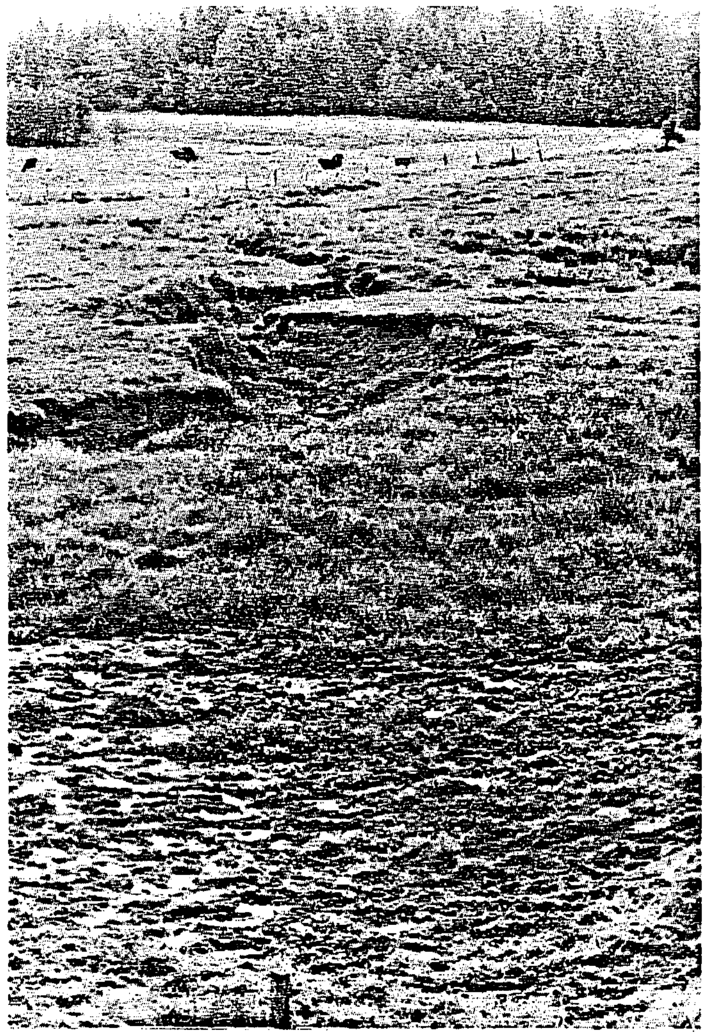


Plate 12. Small pools at road culverts tend to act as settling ponds, but these locations also attract cattle which adds another destabilizing effect to the stream bank. The trampled soil in the foreground of this photograph is an example of this process at Parker Brook.

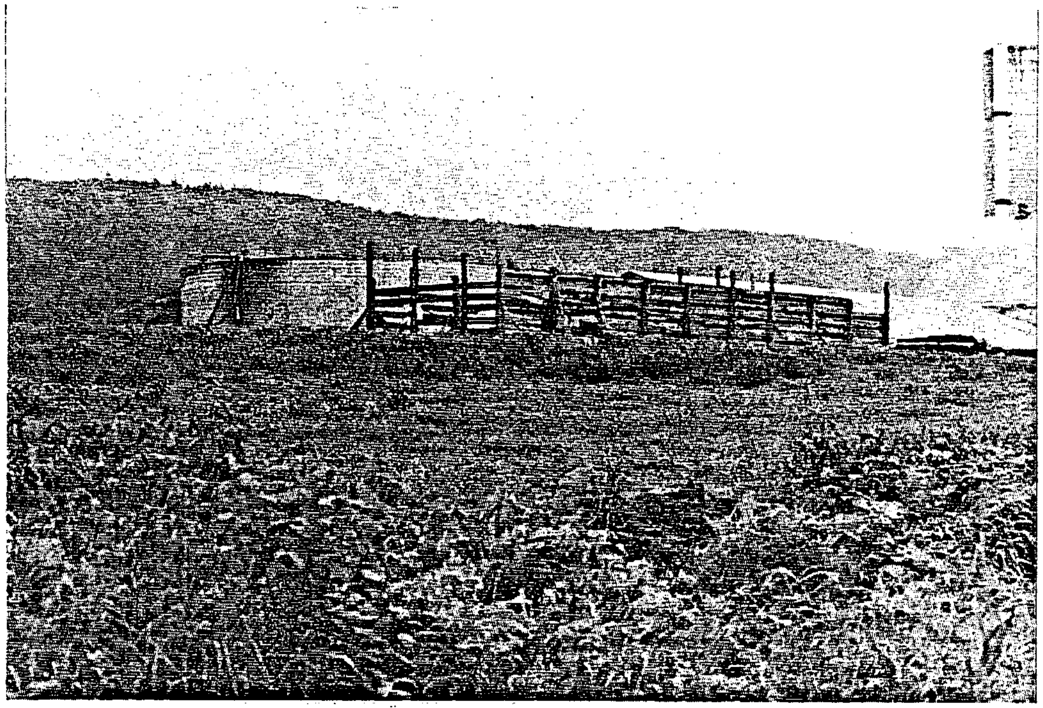


Plate 13. Throughout the drainage basin there were various large holding tanks controlling materials reaching the water courses. This tank is located on a large dairy operation at Parker Brook.

Plate 14. These covered piles limit materials reaching the water course. This photograph was taken near the community of Parker Road.

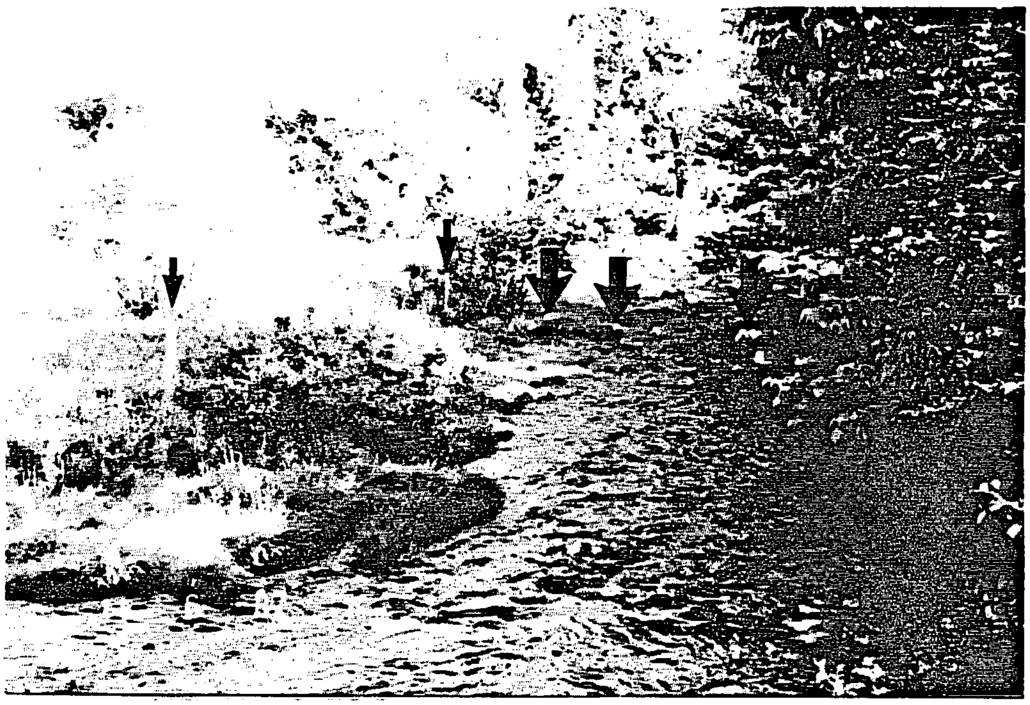
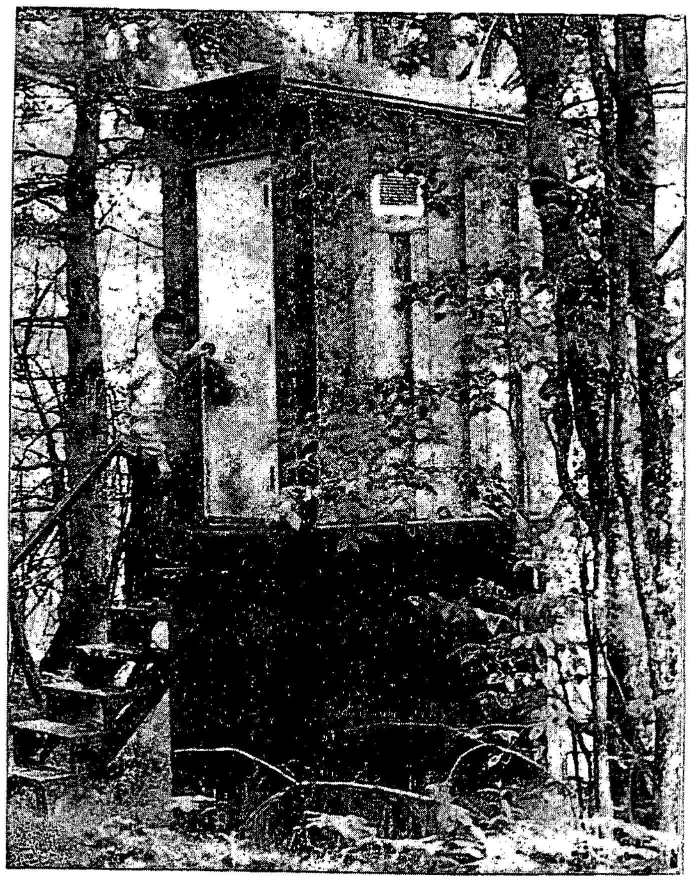


Plate 15. By limiting cattle access to stream-crossings also protects the river banks. The arrows show flagging on fence wire (larger arrows) running across the river and posts (smaller arrows) holding wire along the river bank indicating stream cattle crossing, i.e., cattle are not allowed to wonder along the river bank at will. The location is the Black River at Torbrook.

Plate 16. By leaving stream banks heavily vegetated and having small ponds at culverts helps to trap the sediment before it reaches the water course. The location is Patterson Brook one kilometre southwest of the community of Parker Road.

Plate 17. By creating larger ponds utilizing natural depressions also helps trap sediment. This photograph was taken near the community of Parker Road.

Plate 18. Stream bank erosion is shown here on the meandering Annapolis River one kilometre south of Auburn. Note the slumping bank and the trampled soil (by cattle) in the foreground. The angle from vertical of the elm tree (top arrow) is another indicator of the shifting stream channel.



Closing the door for the last time on the sediment program at the Annapolis River at Wilmot station.