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THE UNIVERSITY OF ALBERTA

AN ANALYSIS OF THE RELATIONSHIPS OF SELECTED STREAMFLOW CHARACTERISTICS TO PHYSICAL GEOGRAPHIC PATTERNS IN THE PLAINS AREA OF THE CANADIAN PRAIRIE PROVINCES

by

© EDWARD SMITH SPENCE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOGRAPHY

EDMONTON, ALBERTA

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "An Analysis of the Relationships of Selected Streamflow Characteristics to Physical Geographic Patterns in the Plains Area of the Canadian Prairie Provinces," submitted by Edward Smith Spence in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Arleigh H. Laycock

Supervisor

Keith W. Hage

Supervisor

External Examiner

Date Dec. 18, 1970

ABSTRACT

This study is an examination of the relationships of selected streamflow characteristics to physical geographic patterns in the plains area of the Canadian Prairie Provinces. The aims of the study have been twofold, firstly, to develop a set of statistical relationships for the prediction of streamflow characteristics for ungauged basins, and secondly to add to our understanding of plains hydrology through the identification of physical geographic variables which are related to streamflow patterns. In view of the multivariate nature of the relationships being considered, a system investigation approach utilizing the statistical techniques of multiple regression and factor analysis was adopted.

A group of 161 study basins was selected for analysis. Each of these basins met defined criteria with regard to basin location, size of drainage area, available streamflow data, and natural flow conditions.

Four dependent variables: the mean annual yield, the mean 10 year yield, the mean annual flood, and the mean 10 year flood, were selected for analysis. The available annual yield and annual flood flow data series for each of the basins were compiled for the base period 1940 to 1969. Wherever possible, short-term records were extended by correlation with records from nearby longer-term stations. The actual estimation of the magnitudes of the dependent variables was made by frequency analysis of the available data series. These analyses were based on the assumption of the lognormal distribution and utilized a

least squares curve fitting technique.

Thirty-nine independent variables were estimated for each of the study basins. These variables were chosen on the bases of their theoretical relationships to streamflow and available data sources. The first group of 20 independent variables were measures of climatic patterns and were compiled from published climatic normal data. The other 19 independent variables, measures of other physical geographic patterns, were compiled from 1:250,000 scale topographic maps, and included measures of drainage area, basin topography, and vegetation.

The initial stage of the analysis was an examination of the relationships for the entire study area. Two approaches to these analyses were employed, firstly, a stepwise multiple regression analysis considering all of the independent variables, and secondly, a stepwise multiple regression analysis considering only those independent variables selected after factor analytic screening. The latter approach proved to be more satisfactory in that the signs of the regression coefficients conformed to physical expectations. In an effort to improve the predictive strength of the models, the second stage of the analysis involved the division of the study area into hydrologic regions. Two hydrologic regions were delimited; however, regression analyses for each of these regions did not result in appreciable improvement of the predictive power of the full study area models.

The regression models for each of the four dependent variables, as developed in this study, conform to physical expectations, are stable when tested with independent data and are statistically significant.

The standard errors of the estimates for the regression models were relatively large and limit the predictive applications of these relationships. On the basis of the available data, it has not been possible to establish strong predictive models. Several suggestions have been made for possible extensions of the present research with the aim of further improving this predictive strength.

ACKNOWLEDGMENTS

The contributions of several members of the faculty of the University of Alberta are acknowledged. In particular, I wish to thank Dr. Arleigh H. Laycock, the chairman of my supervisory committee, for stimulating my interest in plains hydrology and for his encouragement and helpful comments throughout the project. Thanks are also extended to Dr. M.C. Brown, Dr. R.B. Bryan and Dr. K.D. Hage of the Department of Geography and Dr. J.P. Verschuren of the Department of Civil Engineering for their critical reviews of the first draft of this thesis.

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CHAPTER 1

INTRODUCTION, THEORETICAL BACKGROUND AND METHODOLOGY FOR THE STUDY

1.1 INTRODUCTION

In Canada, we have a greater per-capita streamflow than in any other country in the world (Laycock 1967a, p.112). Over the years, many Canadians have grown complacent with regard to our vast and seemingly limitless water supplies. Recently in the face of rising pollution and growing competitive demands, regional water shortages have been recognized by the general public. People are now beginning to demand the careful planning, allocation and management of our available water resources. One of the areas of Canada in which regional shortages are particularly pronounced and where public awareness has been growing, is in the plains region of the Prairie Provinces. Here, the precipitation is low, evapotranspiration is relatively high, and the resulting water surpluses are limited and variable. One of the primary requirements of those faced with the task of planning for the future management of our water resources is for accurate estimates of the available naturally occurring supplies. It is to this need that the present study is addressed.

This study is an analysis of the relationships between selected streamflow characteristics and the climatic and other physical geographic patterns for the plains area of the Canadian Prairie Provinces. The streamflow characteristics selected for analysis in the present research are the annual yields and annual flood flows. The overall aim of the research is to increase our understanding of plains hydrologic patterns through the establishment of a series of statistical relationships for the prediction of streamflow characteristics in ungauged plains areas. It is intended that the analysis will identify the climatic and other physical geographic variables which are most closely related to the selected streamflow characteristics. These variables once identified will aid in determining the direction of future more specific process-oriented research into the hydrologic patterns of the area. The statistical models formulated will provide a basis for the preliminary estimation of available water resources. These estimates will have application in the planning of plains' water resource management for various uses including irrigation, pollution dilution and transport, municipal supply, recreation, flood limitation, and possible water export.

The following sections of this chapter include discussion of the role of geography in hydrologic research, the theoretical background to the present study as exemplified in the hydrologic cycle and basin water budget, the nature of available data and analysis techniques, and the proposed methodology for the present study.

1.1.1 Geography and Hydrologic Research

Before examining the theoretical background and proposed methodology of the present study, it is interesting to give a brief consideration to the role of geography and geographers in the science of hydrology. Hydrology, the science of water, is rapidly becoming one of the most interdisciplinary of all fields of scientific investigation.

The various points of view and techniques of such diverse disciplines as engineering, geology, meteorology, climatology, ecology, geography, economics, political science, law, and business administration are being brought to bear on the many and varied problems of this field.

The hydrologic interest of geographers seems to fall into two areas of concentration, physical hydrology and resource conservation and management. The former interest deals with physical research into the components and processes of the hydrologic cycle; while the latter area of interest considers water as a resource with particular emphasis on planning for conservation and management. The present study falls into the first grouping and is in fact a study of the physical relationships between variables in the hydrologic cycle.

The interest of geographers in physical hydrology and the hydrologic cycle has grown from a long standing involvement in the study of geomorphology, a field in which water is an extremely important agent (More 1967, p. 146). Physical hydrology holds the key to understanding the variable occurrence of water, both spatial and temporal, over the surface of the globe. In physical hydrology, geographers share their interests with engineers, geologists and other physical scientists. Within the broad field of physical hydrology, certain problems are essentially geographic in nature (Slaymaker 1969, p. 68). This is particularly true of the investigation of the spatial and temporal variations and co-variations of hydrologic variables. In this context, geographers have made significant contributions in a variety of regional studies including regional water balance and flood characteristic investigations. Some recent examples of such studies include the work of Laycock (1967);

Sanderson and Phillips (1967), Wong (1963), and Howe et al (1967).

The present study in its evaluation of the relationships between selected streamflow characteristics and climatic and other physical geographic patterns is typical of the application of a geographer's integrative approach to the multivariate problems of regional hydrologic study. This research is intended both to provide a set of statistical models for the estimation of selected streamflow characteristics, and to identify for further study the variables which are most important in determining these characteristics.

1.2 THE THEORETICAL BACKGROUND AND HYPOTHETICAL MODEL FOR THE STUDY

The theoretical rationale underlying the present research can be established through a consideration of the basic conceptual model of physical hydrology, the hydrologic cycle.

1.2.1 Streamflow in the Hydrologic Cycle

While the hydrologic cycle is an oversimplified model of the basic hydrologic principles and processes, it is a useful basis for initiating a discussion of the numerous variations and complexities associated with hydrologic phenomena. A general discussion and illustration of the cycle can be found in any basic textbook in hydrology (see for example Bruce and Clark 1966; Chow 1964; Linsley et al 1949; Meinzer 1942; Ward 1967; and Wilson 1969). In general terms, the cycle involves the movement of moisture from the land and water surfaces to the atmosphere, through the atmosphere and back to the surface of the globe, over or through the land, and back to the oceans and/or atmosphere. The major processes of interest to hydrologists are precipitation, evapotranspiration, surface runoff and groundwater flow (Wilson 1969, p. 3).

In any consideration of the hydrologic cycle, it is important not to overlook the complexities which underlie this seemingly straightforward model. The cycle may short circuit in numerous ways and is in fact a series of smaller interrelated cycles. The intensity and frequency of the various processes involved vary both spatially and temporally over the surface of the globe. These complex variations are the primary concern of the science of hydrology.

The hydrologic cycle may be viewed as being comprised of two divisions,each of which involves two phases: the atmospheric division including the vapour-phase and the precipitation-phase, and the surface division including the runoff-phase and evaporation-phase (Horton 1931, p. 192). Each of the divisions contain elements of transport, temporary storage, and changes in state. The present study, dealing with streamflow, is most closely related to the runoff-phase of the surface division. However, the cyclical nature of the processes involved does not allow for the isolated study of the runoff-phase; and it is therefore necessary to examine streamflow as an integral part of the hydrologic cycle.

In order to illustrate the complex nature of the movement of moisture in the hydrologic cycle, it is useful to trace the moisture movement within the surface division of the cycle. The moisture input to the surface division is in a variety of forms including rain, snow, sleet,hail and condensation. This moisture supply either reaches water or land surfaces directly or is intercepted by vegetation. The intercepted precipitation either evaporates back to the atmosphere or eventually reaches the ground as stemflow or as drip. The moisture available on the ground surface if in the form of snow is held temporarily, pending melt, in snowpack storage. The moisture in liquid state available at the surface may follow one of three paths: it may evaporate, it may infiltrate the ground surface, or it may remain on the surface and move downslope as overland flow. The volume of water lost in evaporation from the surface depends on meteorological conditions and the available moisture supply. This available moisture supply is a function of the antecedent meteorological conditions, and the infiltration and overland flow processes. Of the moisture that infiltrates the ground surface a portion may move laterally through the soil layers as throughflow or interflow, and the remainder percolates to depth to join groundwater storage. Some of the soil moisture is evaporated directly from the soil surface and a portion is used by plants and released to the atmosphere as transpiration.

When soil moisture is at field capacity and additional moisture is available, there is a tendency for throughflow or interflow to take place; and moisture moves downslope through the soil, replenishing soil moisture deficiencies or joining streamflow in surface channels. The final portion of the moisture which infiltrated the ground surface percolates to depth and joins ground water storage. This moisture may also eventually find its way into streamflow after lateral movement along the water table. The third alternative remaining for the moisture on the surface of the ground, which neither evaporates nor infiltrates, is overland flow. This moisture is available in excess of the infiltration rate and moves downslope as overland flow. Some of this water is trapped in local depressions, depression storage, and is eventually evaporated or may infiltrate the surface. As overland flow moves over the surface, it is at all times susceptible to evaporation and infiltration if the necessary conditions are met. A portion of overland flow reaches stream channels and becomes streamflow. Thus, that portion of the precipitation input to the surface division of the hydrologic cycle, which finally appears as streamflow,is the result of a complex chain of interrelated elements of transport, temporary storages and changes in state. There are four sources of water in streams, direct precipitation on the water surface, interflow, groundwater flow and overland flow.

In order to further illustrate the complexities of the hydrologic cycle, it is advantageous to consider the surface division of the cycle as it is operative within a drainage basin. The basin is a convenient and logical unit for hydrologic study (More 1969, p. 67). Within a basin, the hydrologic cycle may be modeled in an input-output budget equation of the form:

$$I = O + \Delta S \tag{1-1}$$

where I - moisture inputs to the basin in the form of precipitation and groundwater flow

O - moisture outputs from the basin in the form of evaporation, streamflow, and groundwater flow

ΔS - changes in the amount of water in storage within the basin

Except under special geological conditions, the groundwater flow effects on the basin water budget may be considered negligible (More 1969, p. 67). It is possible to rewrite the above equation, ignoring groundwater effects, in the form:

$$P = QS + ET + \Delta S \quad (1\text{-}2)$$

where P - precipitation

QS - streamflow

ET - evapotranspiration

ΔS - changes in the amount of water in storage within the basin

In the preceding discussion of the movement of water through the hydrologic cycle, several forms of temporary storage were alluded to. The "ΔS", change in storage term, of equations 1-1 and 1-2 is intended to account for the combined effects of these variable storages; the most important of which include interception storage, snowpack storage, groundwater storage and channel storage. Equation 1-2 may be rewritten with an expanded "ΔS" term and with streamflow as the dependent variable in the form:

$$QS = P - ET \pm \Delta(INTS, SPS, DS, SMS, GWS, CS, \ldots.) \quad (1\text{-}3)$$

where INTS - interception storage

SPS - snowpack storage

DS - depression storage

SMS - soil moisture storage

GWS - groundwater storage

CS - channel storage

(after More 1969, p. 67)

If the movement of water through the surface division of the hydrologic cycle is reviewed, it is observed that equation 1-3 accounts for all of the major inputs, outputs, and temporary storages involved in this division of the cycle. On this basis equation 1-3 may be considered as providing a theoretically sound basis for the estimation of streamflow for any given basin for a fixed time period. However, it is not possible to measure accurately the parameters on the right-hand side of the equation. Each of these parameters is itself a variable which may be expressed as a function of several other variables or controls. For example, the change in interception storage is a function of such diverse factors as precipitation amount and intensity, vegetation type, and the season of the year; and the change in depression storage is a function of such factors as topography of the basin, antecedent moisture conditions, amount and intensity of precipitation, and infiltration rate. A similar multivariate relationship is involved in the estimation of each of the other terms in equation 1-3. For practical purposes, it is not possible to employ equation 1-3 to estimate streamflow; rather, it is necessary to consider the basic controlling conditions of the hydrologic cycle.

Meinzer (1942, p. 4) identifies three sets of conditions which control the hydrologic cycle; the nature and application of energy, the inherent properties of water, and the structure of the natural reservoirs and conduits. The basic energy source underlying all of the processes of the hydrologic cycle is the sun. Solar energy is the primary condition controlling the atmospheric division of the cycle and the evapotranspiration losses from the surface division. The second set of controlling conditions, the properties of water, in particular those properties which react to temperature variations and which produce changes in state, are closely related with the energy conditions in controlling rates and volumes of precipitation and evapotranspiration. The third set of controlling conditions, the structure of the natural reservoirs and conduits, is important both in the atmospheric and surface divisions of the cycle. Within the atmospheric division the influence of latitude and the topography, shape and size of continents control the climatic patterns governing the precipitation amounts reaching the surface. The character of the land surface has a great influence on the movement of the precipitated water on the surface. The geomorphology, geology, soil, and vegetation of a drainage basin exert control over the processes of the surface division of the cycle. These groups of controlling conditions when applied to equation 1-3 provide a basis for an approach to the estimation of streamflow.

Equation 1-3 is without practical application because of the difficulties associated with the estimation of the various parameters. If we consider the controlling conditions as applying to these parameters, it is possible to propose a second approach to the problem of streamflow estimation. The major input variable in equation 1-3 is precipitation; this variable is meteorological in nature and can be estimated from available climatic data. The evapotranspiration variable is also governed by meteorological conditions but with the additional control of available moisture supply. The available moisture supply is a complex function of the precipitation and change of storage terms. The major controlling conditions governing storage terms are the characteristics of the land surface. These characteristics can be described in terms of such physical geographic patterns as topography, geology and vegetation. On this basis, it is suggested that streamflow may be analysed as a function of both the prevailing meteorological conditions and of the other physical geographic patterns.

In the present study, it is proposed to examine the relationships of selected streamflow characteristics to the climatic and other physical geographic patterns for the plains region of the Canadian Prairie Provinces. The hypothetical model for the study is of the form:

STREAMFLOW CHARACTERISTICS = f (CLIMATIC PATTERNS AND OTHER PHYSICAL GEOGRAPHIC PATTERNS) (1-4)

It is intended that available data sources be utilized in estimating the parameters of the above expression.

As further background to the present research it is necessary to give consideration to the nature of hydrologic analysis and to the available techniques of analysis.

1.2.2 Hydrologic Analysis

The problem of analysing the relationships of precipitation to runoff as exemplified in the surface division of the hydrologic cycle is indeed a complex and difficult undertaking. Unfortunately, the multivariate nature of hydrologic processes often precludes their controlled study in a laboratory. The only alternative is to study these processes as they occur in nature. Such studies result in the researcher having to examine the integrated effects of numerous variables,none of which may be accurately measured and some of which are at the present time unmeasurable (Blench 1959, p. 37). Such studies, under natural conditions, require long-term observations over large areas in order to establish a useful data base. Even after such a data base is established, the multivariate nature of the relationships makes it impossible to accurately predict future conditions. For this reason, most hydrologic research adopts a methodology which assumes that future variations in the phenomena will reflect historical patterns (McLeod and Bruce 1959, p. 6). These problems, relating to the collection and analysis of hydrologic data, have resulted in the development of two seemingly separate approaches to hydrologic research.

The basic dichotomy in hydrologic studies has been recognized by several authors including Amorocho and Hart (1964) and Dawdy and O'Donnell (1965). The two approaches may be characterized as:

1) physical hydrologic investigations - with the emphasis on physical science research into the component phenomena of the hydrologic cycle

2) hydrologic system investigations - including both parametric and stochastic hydrologies, with the emphasis on the input-output relationships of the hydrologic cycle.

In the first case, emphasis is on the topics of study with the aim of complete specification of each of the elements of the hydrologic cycle. In the case of hydrologic system investigations, emphasis is on the methods of study with the aim of comprehensive simulation of the precipitation-runoff relationships. As both Amorocho and Hart (1964) and Dawdy and O'Donnell (1965) have pointed out, these seemingly divergent approaches are in fact highly interdependent. Developments in physical hydrologic investigations improve the theoretical basis of system investigation by reducing some of the subjectivity, particularly with regard to the choice of variables. Meanwhile, large scale system work is providing largely empirical relationships based on subjective decisions. These relationships have immediate practical applications, while aiding in the identification of areas for future intensive work by the physical hydrologists. As these two approaches continue their complementary development and integrate their findings, hydrologic models are becoming more complex and less subjective (Dawdy and O'Donnell 1965, p. 134).

In view of our incomplete knowledge of the physical hydrologic relationships of the plains, the present study lends itself to the system investigation approach. This approach to the analysis of streamflow characteristics allows for the best use of all available data. The following section considers the system analysis techniques as they have been applied in other similar research.

1.2.3 Techniques of Hydrologic System Analysis

Amorocho and Hart (1964, p. 309) have identified two principal groupings of analysis methods in hydrologic system investigations. The first grouping, parametric methods, aims at the development of relationships among the various physical parameters related to hydrologic events. These relationships are subsequently employed to generate or synthesize non-recorded data sequences. The second grouping, stochastic methods, aims at the study of the statistical characteristics of hydrologic variables. These characteristics are then employed in the production of non-recorded data sequences with which probabilities of occurrence are associated. As in most hydrologic analysis, these methods are based on the usual assumption that future variation in hydrologic patterns will be approximated by past patterns (McLeod and Bruce 1959, p. 6). A second assumption underlying these methods is that of time invariance or stationarity of the system under study (Amorocho and Hart 1964, p. 309). Both of these assumptions provide theoretical limitations on the resulting relationships.

The first assumption, that of dependence on historical data sequences, means that the results of the analyses can not be more precise than the original data (Slivitsky 1966, p. 185; and Amorocho and Hart 1964, p. 310). Therefore, any inhomogeneity, measurement errors, or incompleteness of the original historical data sets, will be reflected in the analysis results. It is most important that any limitations inherent in the data be recognized. The second assumption, that of time invariance of the hydrologic system,means that where changes in the system, either natural or artificial, have taken place, the relationships resulting from system investigation will not be valid for the prediction of future events.

There are several different parametric methods available to the hydrologic researcher (Amorocho and Hart 1964, p. 309). One of the most popular and useful is that of statistical correlation and regression analysis. In a regression model, a dependent variable is related to one or more independent variables. This relationship is expressed in the form of a regression equation. Several authors have discussed the application of these techniques in hydrology (Amorocho and Hart 1964;

Solomon 1966; and Stammers 1966). The applications and limitations of these techniques will be treated in more detail in a later chapter.

The second group of analysis techniques associated with system investigation, stochastic methods, involves the calculation of probabilities or frequencies of occurrence related to hydrologic events of given magnitudes (More 1967, p. 172). While it is not possible to accurately predict future hydrologic events, stochastic analysis techniques provide for the estimation of the probability of occurrence of an event of a given magnitude (Leopold 1959, p. 1). There are two approaches to stochastic analysis commonly employed in hydrologic research. The first approach, involving the so-called Monte Carlo techniques, is based on the assumption that the data are random and independent (Amorocho and Hart 1964, p. 318). These techniques involve the study of the frequency distribution of recorded data to establish the probabilities of occurrence for future events. In treating hydrologic phenomena with Monte Carlo techniques, it is important to insure the randomness of the original data. When the data are obviously non-random in their occurrence, the second approach to stochastic analysis, the Markov Chain approach, is employed. Such an analysis takes into account the non-random or carry-over effects in the data(More 1967, p. 173). When properly applied to suitable data, stochastic analysis has great practical application from an economic and design point of view (Kuiper 1959 and Leopold 1959).

Some of the most useful of the hydrologic system investigation work contained in the literature is the result of a combination of the parametric and stochastic analysis techniques. Probably the largest body of such research deals with the frequency analysis of flood flows. A comprehensive review of the historical development of flood analysis techniques was compiled by Jarvis and others (1936). This review has been updated in more recent papers by Benson (1962a) and Wolf (1966). The most promising of the analysis techniques are those which employ both stochastic and parametric techniques on a regional scale.

Probably the most serious problem relating to the stochastic analysis of hydrologic events is the lack of long-term data records. Any hydrologic record is considered to be a sample of the total population of events both past and future. Most available records are relatively short and therefore are small samples which may not give a true representation of the population (Benson 1962a, p. 15). Benson (1960) has demonstrated the high degree of variability involved in the use of such small samples in flood frequency analysis. He also illustrated the value of combining records for several stations with similar characteristics. By combining such records on a regional basis, it is possible to place much greater confidence in the resulting frequency analysis. There are numerous examples of such regional frequency analyses in the literature.

One of the most popular methods of regional flood frequency analysis is the index-flood method which has been described in detail by Dalrymple (1960). In this method, a group of single-station records are analysed and combined to provide a basic dimensionless frequency curve for the region. This curve is calculated in terms of the ratio of a flood to an index-flood. The magnitude of the index-flood for individual basins is then estimated by regression analysis in which the index-flood is related to basin area. This analysis may be extended to include as independent variables other hydrologic characteristics of the basins including measures of climatic and other physical geographic patterns. Within the literature, there are numerous examples of the application of this method of regional frequency analysis. Some of these studies include the work in Britain by Cole (1966), and by Howe et al (1967); the work in Canada by Durrant and Blackwell (1959), Coulson (1967a and 1967b), and Collier and Nix (1967); and numerous studies in the United States conducted by personnel of the Geological Survey (for a partial bibliography of these studies see Wong 1969, p. 303; and Benson 1962a).

An alternative to the index-flood approach has been proposed by Benson (1962a). This method employs multiple correlation and regression techniques to relate the magnitude of floods at any level of recurrence to the hydrologic characteristics of the basin. Where sufficient data covering both flood magnitudes and basin hydrologic characteristics are available, this method has several advantages over the index-flood method. Examples of the applications of this method are found in Benson's work in the New England States (1962b) and in the Southwest, (1964); and in Karuks' (1963) study of flood frequencies in Southern Ontario.

The system investigation approach has also been applied to other streamflow characteristics, notably to annual yields. In a recent paper Solomon et al (1968) employed multiple regression techniques to analyse the relationship of mean annual yield to various hydrologic characteristics as calculated on a grid square basis. Coulson (1967b) employed stochastic techniques in the frequency analysis of annual flows in Southern Ontario. Very recently, Benson and Carter (1969) and Thomas and Benson (1969) have combined the parametric techniques of multiple correlation and regression and the stochastic techniques of frequency analysis to analyse numerous characteristics of streamflow in several areas of the United States.

One of the problems common to most of the studies cited above has been that of multicollinearity, or the lack of independence, among the independent variables in the correlation and regression analyses. One solution to this problem seems to be in the use of multivariate analysis techniques such as factor analysis in conjunction with the multiple regression analysis. These techniques were employed successfully by Wong (1963) in a study of floods in New England. Another successful application of factor analytic techniques in hydrologic analysis was made by the Tennessee Valley Authority (1966) in the design of a hydrologic condition survey. The possible application of these techniques will be given further consideration in a later chapter.

The preceding overview of current methods in hydrologic system investigations has been included to provide some background to the proposed methodology for the present study. Many of the articles cited above are treated in more detail as they apply to the present research in the following chapters.

1.3 PROPOSED METHODOLOGY

In the present research, it is proposed to employ the techniques of hydrologic system investigation to study in the plains region of the Canadian Prairie Provinces the relationships in the hypothetical model:

$$\text{STREAMFLOW CHARACTERISTICS} = f\ (\text{CLIMATE AND OTHER PHYSICAL GEOGRAPHIC PATTERNS}) \qquad (1\text{-}4)$$

The analyses of this model are intended to add to our understanding of plains hydrologic patterns through the development of a set of predictive relationships.

It is beyond the scope of the present research to examine the above model for all possible streamflow characteristics. Rather, it is proposed to analyse the above model for two selected streamflow characteristics, annual yields and annual flood flows. Both of these selected characteristics have important practical applications in the planning of basin management programs.

As discussed in the preceding section, the present study lends itself to analysis by the techniques of hydrologic system investigation. It is proposed to employ on a regional basis the parametric techniques of multiple correlation and regression in conjunction with a stochastic analysis of the selected streamflow characteristics. Several approaches to this regional analysis will be considered.

Throughout the following sections of the thesis an attempt is made to discuss the methods employed in terms of the relevant literature and to report accurately and completely the results of the analysis as separate from the interpretation of these results. It is intended that the data and analysis of this research may serve as a basis for further work as our knowledge of plains hydrologic patterns improves.

In Chapter 2, the study area is defined and the general background on physiographic, climatic, and hydrologic patterns is provided. The available data sources are introduced and the study basins are chosen.

Chapter 3 contains the information relevant to the stochastic analysis of the dependent variables, annual yields and annual peak flows. The techniques of frequency analysis are discussed in detail and the step by step analysis of the data for the study area is presented.

Chapter 4 contains a discussion of the independent variables employed in the study. These variables, including various measures of climatic and other physical geographic patterns, are considered in terms of their theoretical relationships to the selected dependent variables, the available data sources, and the methods of measurement. These data are subsequently employed in the analyses discussed in Chapter 5.

A complete report on the application of the multiple correlation and regression analysis to the annual yield and the annual flood flow data, is contained in Chapter 5. The summary, conclusions, and suggestions for further research are the subjects of Chapter 6.

CHAPTER 2

THE STUDY AREA, MAJOR DATA SOURCES, AND CHOICE OF STUDY BASINS

2.1 INTRODUCTION

This chapter contains three major sections: the first is a delimitation of the study area and a discussion of its general physical geographic patterns, the second is a brief introduction to the data sources available for the study, and the third is an explanation of the choice of study basins.

2.2 THE STUDY AREA

2.2.1 Location and Boundary Definition

For the purposes of the current research, the study area, the Canadian Plains, have been delimited as that area of Alberta, Saskatchewan, and Manitoba which lies east of the Rocky Mountain Foothills and south and west of the Canadian Shield Margin. The location of the study area and its boundaries are illustrated on the Map, Figure 2-1.

The study area boundaries are the result of a consideration of both physiographic and political divisions. Both the sections of the western limit, and of the northern and eastern limits, which correspond to the margins of the foothills and shield respectively, are based on physiographic divisions. These physiographic boundaries mark distinctive changes in several physical patterns, including surficial and bedrock geology, and topography, all of which are significant hydrologic

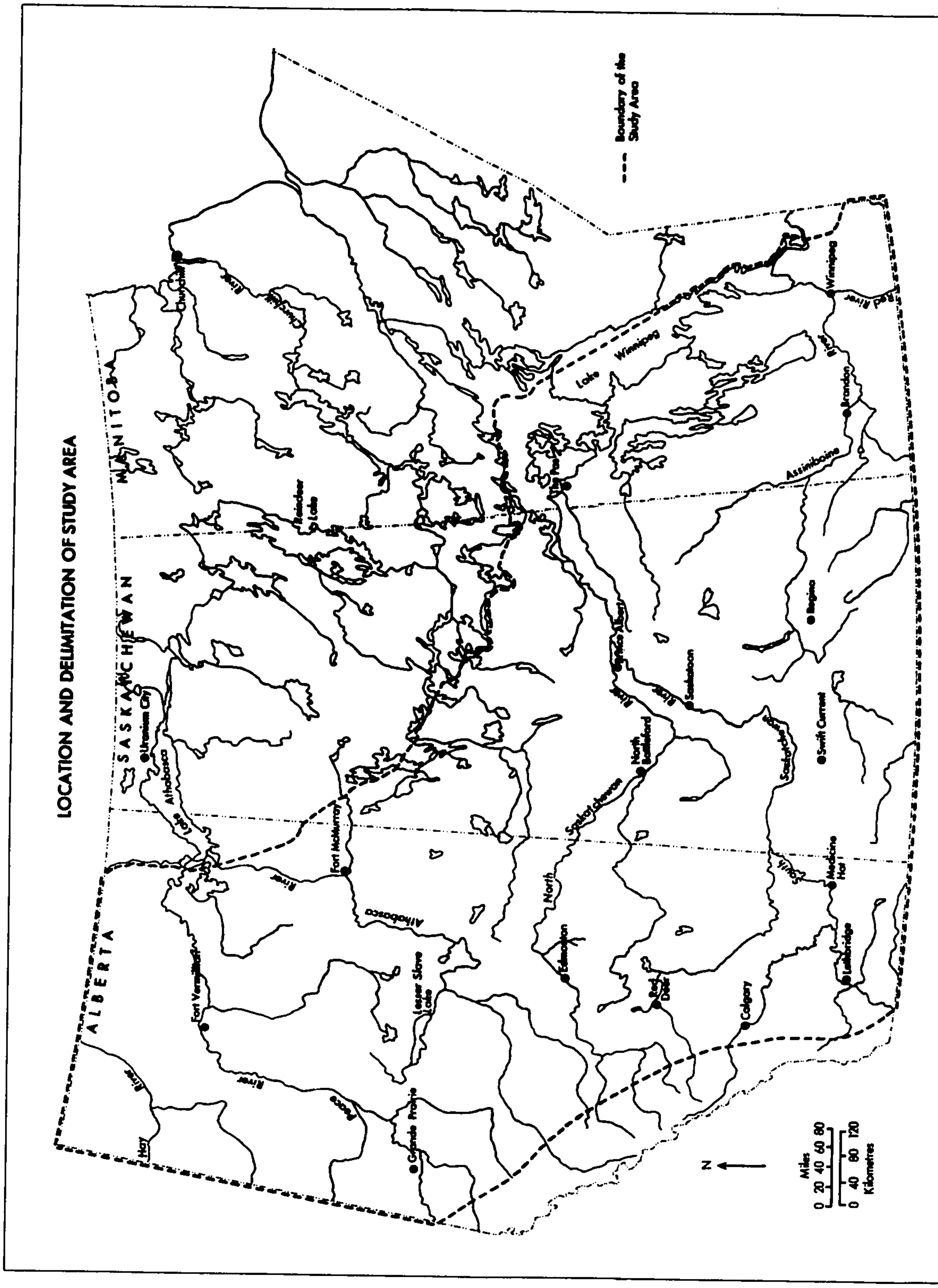

LOCATION AND DELIMITATION OF STUDY AREA
ALBERTA
SASKATCHEWAN
MANITOBA
Boundary of the Study Area
Fort McMurray
Edmonton
Calgary
Red Deer
Lethbridge
Medicine Hat
Swift Current
Regina
Saskatoon
North Battleford
Uranium City
Brandon
Winnipeg
Churchill
Fort Vermilion
Grande Prairie
Lesser Slave Lake
Lake Athabasca
Lake Winnipeg
Reindeer Lake
Athabasca
Assiniboine
Peace
Hay
Miles
0 20 40 60 80
0 40 80 120
Kilometres
N

Figure 2-1

variables. The actual placement of the boundaries is the result of a consideration of several references including The Atlas of Alberta (Government of Alberta and University of Alberta 1969), The Atlas of Saskatchewan (Richards and Fung 1969), The Economic Atlas of Manitoba (Weir 1960), The Atlas of Canada (Canada Department of Mines and Technical Surveys 1957), and maps of the Geological Survey of Canada (Bostock 1964, and Geological Survey of Canada 1970).

The other boundaries of the study area are coincident with political boundaries, the Alberta-British Columbia and Alberta-Northwest Territories boundaries in the north and west and the Canada-United States boundary in the south. These boundaries are arbitrary in their application to the present research as they do not have an hydrologic basis. However, some justification for them can be given on the basis of available data. A general lack of suitable long-term hydrometric records in Northeastern British Columbia and in the Northwest Territories precludes the inclusion of these areas in the present project; although, physiographically they are included in the Canadian Plains. The southern boundary, corresponding to the international boundary, marks the division of data collection responsibilities between the two nations. The present study depends on available Canadian data and is therefore limited on the south by the international border.

2.2.2 General Physical Geographic Patterns Within the Study Area

To provide some general perspective on the study area, a brief discussion of the general physical geographic patterns, under the headings of Physiographic Patterns, Climatic Patterns, and Hydrologic Patterns is presented.

2.2.2.1 Physiographic Patterns

The study area is physiographically within the "Interior Plains Province" as delimited by Bostock (1964) and the Geological Survey of Canada (1970). This large physiographic province is geologically a vast crescent-shaped sedimentary basin, overlying the precambrian basement rock, which rings the Canadian Shield from the United States border to the Arctic Coast (Clibbon and Hamelin 1967, p. 72). The general topography of the study area tends to be flat to rolling with a three fold zonal division existing from east to west. Three separate prairie levels have been identified. Each of the levels exhibits considerable local relief, the result of glacial erosion and deposition and of more recent fluvial action. Figure 2-2 is a generalized relief map of the study area showing the important features.

The most easterly of the prairie divisions, the First Prairie Level or Manitoba Lowland, has an average elevation of about 850 feet (a.m.s.l.) and extends from South-central Manitoba into West-central Saskatchewan (Weir 1960, p. 2). This Level is bounded on the east and north by the margin of the Canadian Shield and on the west by the Manitoba Escarpment. For the most part the Manitoba Lowlands are on the lacustrine plain of Glacial Lake Agassiz. The thickness of the lacustrine beds vary locally, relative to the length of the period of submergence, and results in some local relief generally less than 25 feet. The topography varies from the flat lacustrine deposits in the area west of Winnipeg to the low relief till plains of the Interlake and Westlake areas, where the surface is gently rolling with poor drainage. The flat areas are typical of localities where the lake sedi-

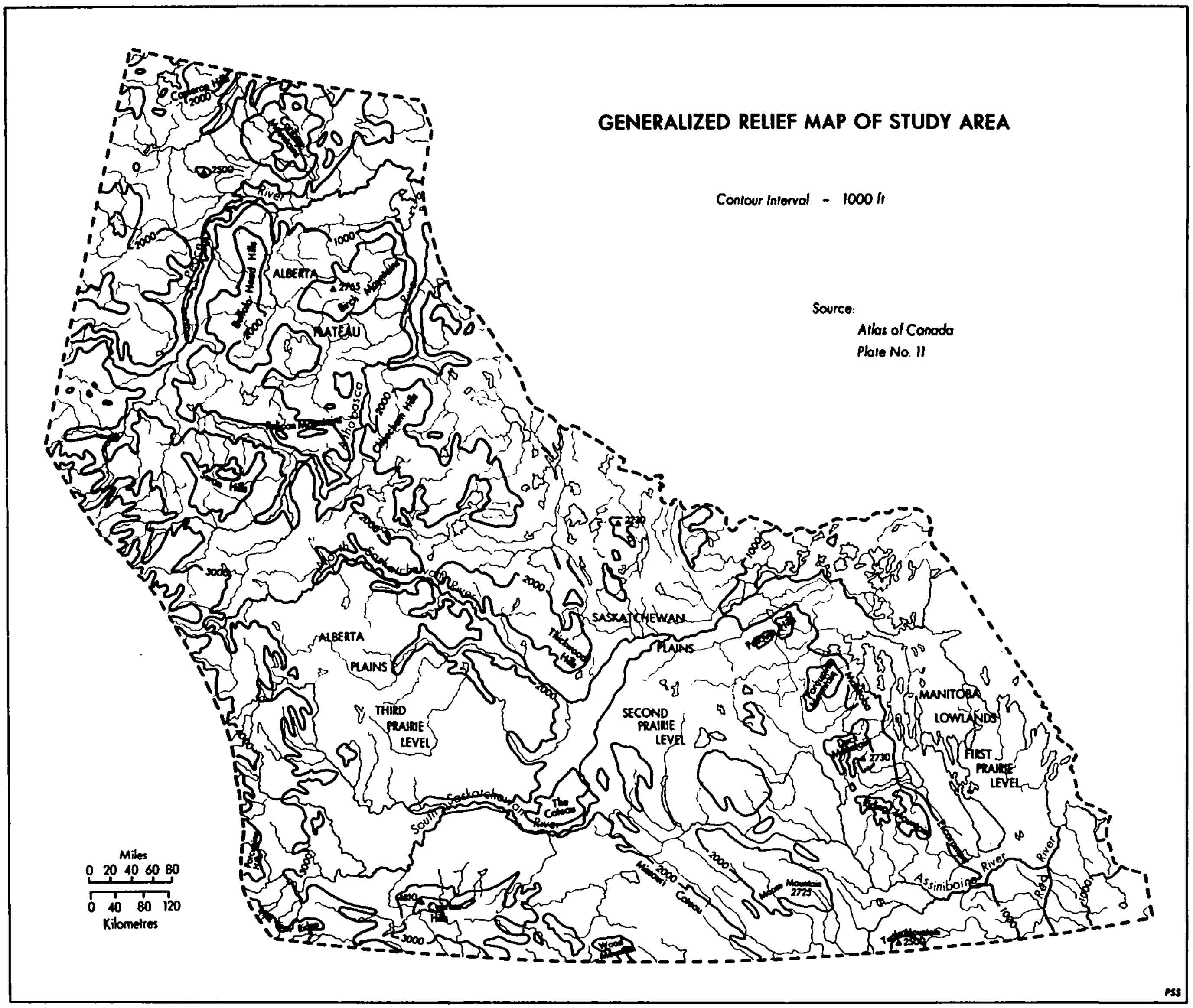

GENERALIZED RELIEF MAP OF STUDY AREA
Contour Interval - 1000 ft
Source:
Atlas of Canada
Plate No. 11
ALBERTA
PLATEAU
ALBERTA
PLAINS
THIRD
PRAIRIE
LEVEL
SASKATCHEWAN
PLAINS
SECOND
PRAIRIE
LEVEL
MANITOBA
LOWLANDS
FIRST
PRAIRIE
LEVEL
River
Athabasca
South Saskatchewan
River
The Coteau
Missouri Coteau
Moose Mountain
2725
Assiniboine
River
Red
River
2730
2765
2250
3000
2000
1000
2500
Miles
0 20 40 60 80
0 40 80 120
Kilometres
PSS

Figure 2-2

ments are thicker, and the rolling swell and swale topography is associated with areas of thinner lacustrine deposits where the topography of the underlying till plains still predominates.

The Manitoba Escarpment, the western limit of the Manitoba Lowlands, is a west dipping cuesta which extends from Southern Manitoba into East-central Saskatchewan and varies from 700 feet to 1400 feet in relief (Clibbon and Hamelin 1967, p. 72). The escarpment is breached in several locations by broad gentle valleys which have resulted from erosion by pre-glacial rivers (Weir 1960, p. 2). The remaining sections of the scarp rise to over 2000 feet (a.m.s.l.) as in the cases of Porcupine Mountain, Duck Mountain and Riding Mountain.

Westward from the Manitoba Escarpment extends the Second Prairie Level or Saskatchewan Plains (Richards 1969, p. 41). This division reaches northwest from Southwestern Manitoba and Southeastern Saskatchewan into Northeastern Alberta. The western limit of the Saskatchewan Plains is marked by the Missouri Coteau in the south and a discontinuous line of uplands, including the Birch Mountains and Cheecham Hills toward the northwest. The Saskatchewan Plains are characterized by more rolling topography than the neighboring Manitoba Lowlands. The average elevation is between 1500 and 2000 feet (a.m.s.l.). The surface is generally one of gently rolling ground moraine with some areas of lacustrine plains and hummocky or ridged uplands. The uplands are not abrupt features and generally have local relief of from 20 to 150 feet. Other local relief features include deep river valleys and glacial spillways. In the south there are a great many prairie potholes or sloughs associated with large areas of internal drainage.

The Third Prairie Level or Alberta Plains extends west from the Missouri Coteau to the Rocky Mountain Foothills. This prairie level has a greater diversity of local topography than either of the lower levels. It may be divided into two physiographic divisions along a line generally parallel to the Athabasca River and just to the south of the uplands of the Swan Hills, Pelican Mountains and Cheecham Hills. The northern division is known as the Alberta Plateau and the southern as the Alberta Plains (Bostock 1964, p. 20). The plateau region to the north is an area of uplands separated by large expanses of glacial lacustrine and more recent fluvial sediments which include the wide valleys of the Fort Nelson, Hay and Peace Rivers (Bostock 1964, p. 20). The southern division of the Third Prairie Level, the Alberta Plains, is generally covered with a blanket of glacial till. Locally this till plain has been bevelled to varying degrees during submergence under glacial lakes. The remainder of the till plains are of two basic types, ground moraine and hummocky moraine (Green and Laycock 1967, p. 81); the former being gently undulating swell and swale topography, while the latter, the result of deposition by stagnant or dead ice, are more rolling and rougher with poorly developed drainage. Throughout, the till plains are characterized by large areas of local drainage. The only locality in the entire study area which was not directly affected by continental glaciation is the Cypress Hills of Southeastern Alberta and Southwestern Saskatchewan. The Cypress Hills rise to a height of 1800 feet above the surrounding prairie. Several other upland areas in the Alberta Plains have been located on the map, Figure 2-2.

In summary, the general topography of the study area is relatively flat with local relief features, the products of glacial and fluvial erosion and deposition, predominating.

2.2.2.2 Climatic Patterns

The climate of the study area is relatively dry and continental. According to the Koeppen system of climatic classification, the study area spans three divisions: Dfc, Dfb, and BSk (Canada, Department of Mines and Technical Surveys 1957, Plate 30). The continental effect on the temperature regime of the study area results in an extremely high annual temperature range which varies from 48°F. (Calgary - Jan. 14°, July 62°) in the southwest of the study area, to over 70°F. (Ft. Vermilion - Jan. -9°, July 62°) in the north and 68°F. (Winnipeg - Jan. 0°, July 68°) in the east. From the temperatures listed, it can be observed that the winters are extremely cold while the summers are quite warm. Local variations in the temperature patterns result from relatively small topographic features (Longley 1967, p.56). The "chinook" is another significant feature of the climate of a portion of the study area. This westerly wind which results from the adiabatic warming of a pacific air mass sweeps across the prairies of Southern Alberta and Southwestern Saskatchewan bringing a sudden warming to temperatures in winter (Longley 1967, p. 55, and Chakravarti 1969, p. 60).

With respect to precipitation the study area is relatively dry; however, local variations and the seasonal distribution provide significant modifications to the pattern. The mean annual precipitation ranges upward from less than 12 inches in Southeastern Alberta and Southwestern Saskatchewan to over 20 inches in parts of Northern Alberta and Southern Manitoba. This pattern is illustrated in Figure 2-3 which is based on

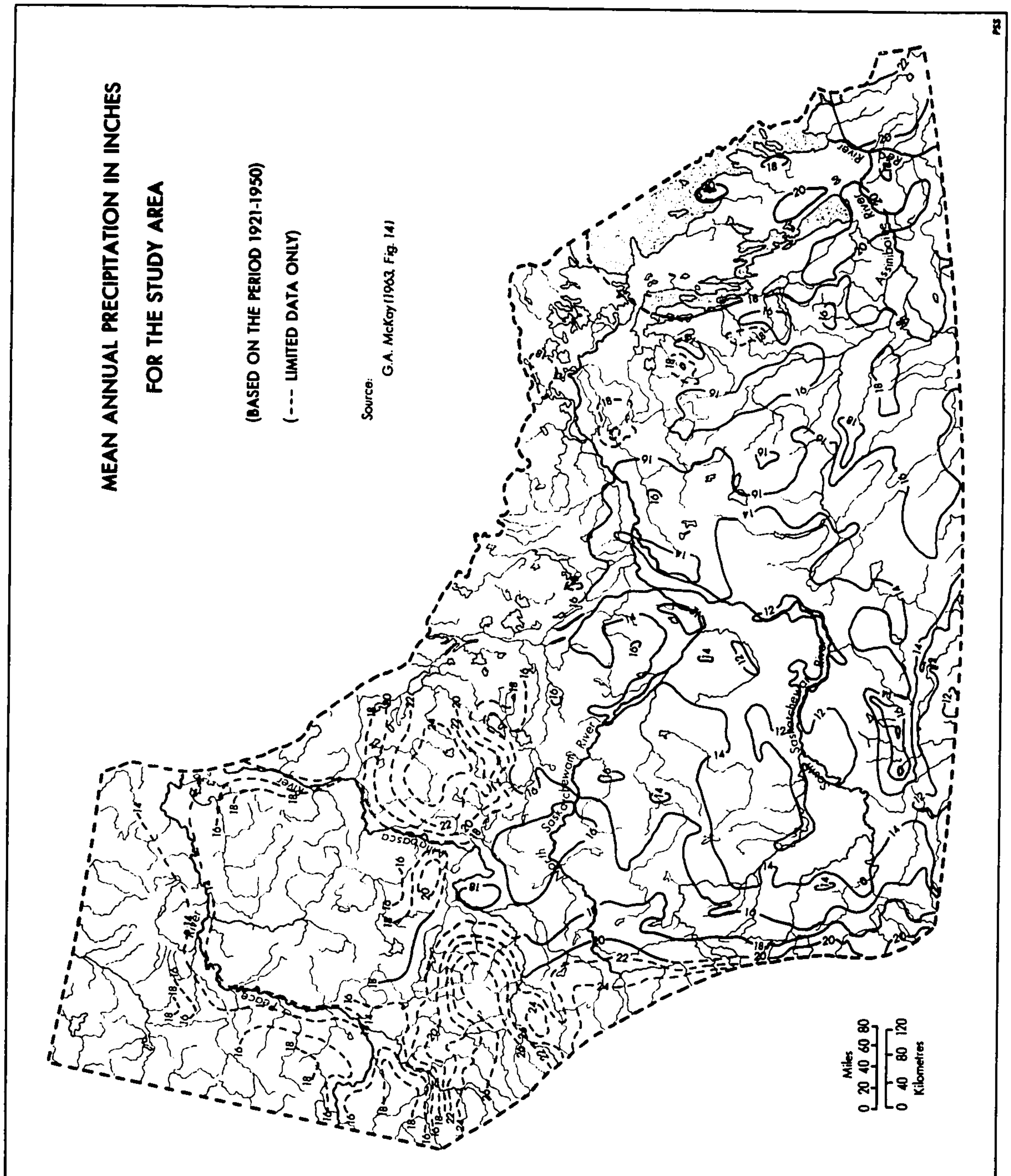

MEAN ANNUAL PRECIPITATION IN INCHES
FOR THE STUDY AREA
(BASED ON THE PERIOD 1921-1950)
(--- LIMITED DATA ONLY)
Source:
G.A. McKay (1963, Fig. 14)
Saskatchewan River
Assiniboine
Red River
Miles
Kilometres

Figure 2-3

Mc Kay's map of prairie precipitation (Mc Kay 1963, Figure 14). A comparison of Figures 2-2 and 2-3 readily illustrates many of the more important local variations in this pattern. Most of these variations are the result of topography. Examples of topographic influence on the precipitation patterns include the over 16 inches of precipitation in the Cypress Hills, the over 20 inches in the Swan Hills and comparable increases in other upland areas. These localized pockets of higher annual precipitation have important hydrologic implications. The seasonal distribution of precipitation is another factor which is important hydrologically. Throughout the study area there is a summer maximum of precipitation. The seasonal distribution is particularly important in supplying needed soil moisture during the growing season.

Probably the best composite picture of the climatic patterns within the study area can be given by a consideration of water balance patterns over the study area. Such a discussion follows.

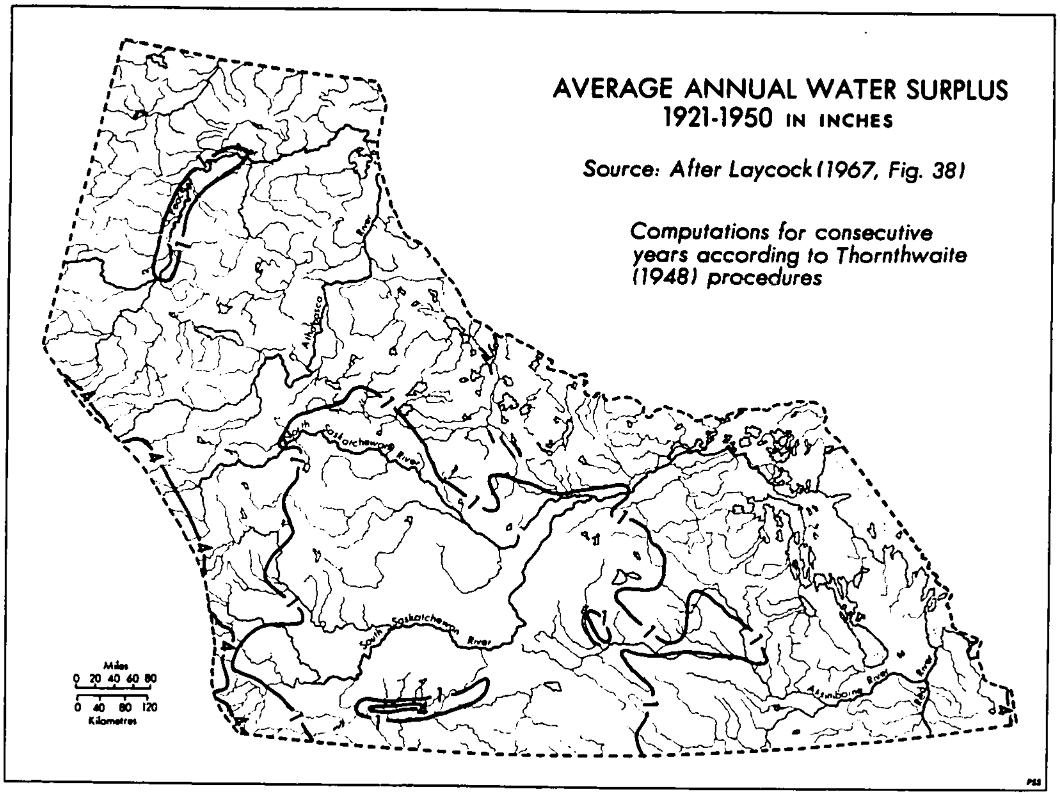
2.2.2.3 Hydrologic Patterns

This consideration of hydrologic patterns within the study area is divided in two sections; the first is a generalized discussion of water balance patterns and the second is a consideration of the typical annual hydrographs of streams within the study area.

One of the most valuable approaches to a consideration of regional water balance patterns is the application of Thornthwaite procedures to available climatic records of temperature and precipitation (Thornthwaite 1948 and 1957). In general terms, Thornthwaite water balance calculations employ the monthly temperature data in the estimation of potential evapotranspiration, which is subsequently subtracted from available water supplies (precipitation plus storage), the result being surplus if positive and deficit if negative. The calculations are made in the form of a running tally from month to month to give annual values. Thornthwaite procedures have proven to be very useful in defining regional hydrologic patterns. These techniques are based on temperature and precipitation data which are much more readily available than are other climatic records and hydrologic data.

Two studies, one by Sanderson and Phillips (1967) and the other by Laycock (1967), have examined in some detail the water balance patterns for the study area. The Sanderson and Phillips study employed published monthly climatic normals and the Thornthwaite 1957 procedures, while the Laycock study was based on 30 years of actual monthly temperature and precipitation data and the Thornthwaite 1948 procedures. The maps of average surplus which were derived in the two studies have been reproduced as Figure 2-4. The lower map which is the result of the Sanderson and Phillips study has been adjusted for measured runoff but is based on 30 year normal climatic data. The top map taken from the Laycock study is based on the average of the water surpluses calculated for each of the 30 years and has not been adjusted for measured runoff. Both maps show some adjustments for topography. While the isopleth intervals on the two maps differ making comparison difficult, it is possible to make several general observations. In the broadest sense, the two maps illustrate the same general patterns. Because of the different methods of calculation it should not be expected that they would correspond on a local scale. Throughout the study area, calculated annual water surpluses are small being less than 1 inch for large areas in the

AVERAGE ANNUAL WATER SURPLUS FOR THE STUDY AREA



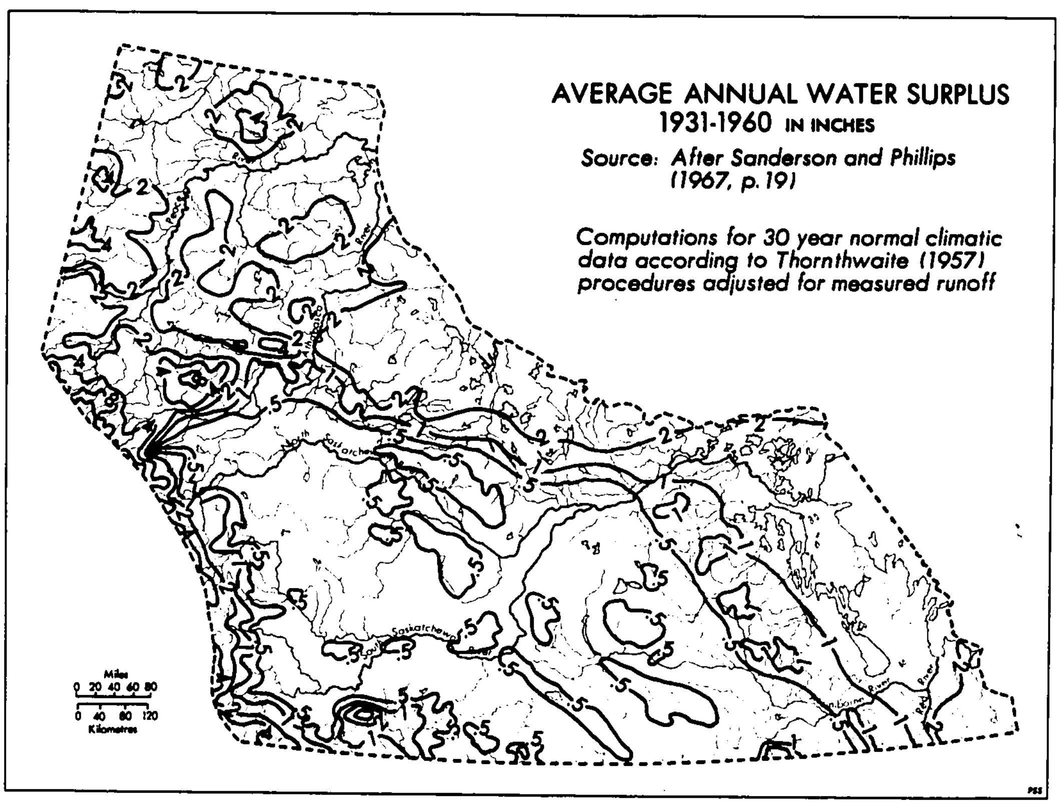


Figure 2-4

south and ranging upward toward the west, north and east. The effect of local topography on the magnitude of the surplus is evident if a comparison is made with the relief map Figure 2-2.

It should not be expected that water surplus patterns calculated by water balance procedures will correspond exactly with measured streamflow. This is particularly true in semi-arid and subhumid regions such as the study area (Laycock 1967, p. 35). The calculated water surplus represents the water left over after potential evapotranspiration and soil moisture requirements have been met. This surplus water may percolate to the ground water table or may runoff over the surface. As has been pointed out in the discussion of "Streamflow in the Hydrologic Cycle" of Chapter 1, the processes by which surface runoff and ground water become streamflow are complicated and depend on a great number of variables. It is these processes that are of major interest in the present study.

A second approach to describing the general hydrologic patterns of the study area is through an examination of annual hydrographs for typical streams within the region. There are two distinctive shapes of annual hydrographs commonly observed within the study area. Table 2-1 presents data on monthly runoff, expressed as percentages of annual flow, for three prairie rivers. These data have been taken from the preliminary map of "Mean Distribution of Runoff" as prepared for the forthcoming Hydrologic Atlas of Canada (Canadian National Committee of the I.H.D. 1969). The first two stations for which data are presented illustrate the annual runoff regime which is common to all rivers and streams which rise in the mountains. Although the North Saskatchewan River has a

TABLE 2-1 - MONTHLY STREAMFLOW AS A PERCENTAGE OF ANNUAL FLOW FOR SELECTED PLAINS' BASINS

Basin Name	Monthly Flow as a Percentage of Annual Flow											
	J	F	M	A	M	J	J	A	S	O	N	D
North Saskatchewan River at Prince Albert	1	1	2	8	12	18	21	15	11	6	3	2
South Saskatchewan River at Saskatoon	1	2	3	12	13	24	18	9	7	5	4	2
Assiniboine River at Headingly	1	1	2	22	26	17	12	6	4	4	3	2

Source: Canadian National Committee for the I.H.D. (1969).

slightly later peak than the South Saskatchewan River, both rivers illustrate the pattern of a gradual rise in streamflow volumes during spring leading to a peak in June or July, and a gradual falling off of flow into the fall. The gradual rise in the hydrographs for these basins is related to the successive melting of snow accumulations at successively higher elevations. The third river for which data are presented in Table 2-1, the Assiniboine River, has an annual regime which is typical of all streams which rise in the plains. The hydrographs for these streams are characterized by a sharp rise in flow toward a spring peak and a subsequent falling off through summer. The runoff regime for these streams is the result of the dominance of snowmelt as a source of plains' streamflow. In the present research, streams of this second type have been the objects of study. The large interregional streams, which rise outside the plains, have not been considered in the present study.

In general, the annual regime of the streams considered in the present study is characterized by an early spring peak flow resulting from snowmelt. The magnitude of the summer flows is the major regime variable within the study area. In the driest areas of the plains, in Southeastern Alberta and Southwestern Saskatchewan, most streams flow only during the spring period; and are generally dry during summer, flowing only as the result of heavy and prolonged rainfall. In the more humid regions of the study area, the summer rains and ground water discharge are sufficient to maintain some flow in all seasons of at least some years (Green and Laycock 1967, p. 87; and Raby and Richards 1969, p. 61). The groundwater contributions to streamflow in small plains basins are usually limited and on a local scale (Meyboom 1962). In view both of its limited importance and of the difficulties inherent in estimating this variable, groundwater contributions to streamflow have not been considered in the present study.

2.3 SOURCES OF DATA AVAILABLE FOR THE STUDY

The present project, an examination of the relationships of streamflow characteristics to climatic and other physical geographic patterns in the Canadian Plains, requires data to be collected for the study area on streamflow, climate and other physical geographic variables. This section is an outline of the major sources available for each of these data sets. (The period of record of interest is from 1940 to 1969).

2.3.1 Hydrometric Data

Hydrometric data are collected by various agencies and compiled for publication by the Water Survey of Canada. Prior to 1965 the Water

Survey was under the administration of the Canada, Department of Northern Affairs and National Resources, and all available hydrometric data were published on a regional basis. Data for the study area were published under the title "Surface Water Supply of Canada, Arctic and Western Hudson Bay Drainage" (Canada, Department of Northern Affairs and National Resources 1940-1964). Since 1965 the Water Survey of Canada has been under the Canada, Department of Energy, Mines and Resources and hydrometric data are published annually on a provincial basis (for the study area see Canada, Department of Energy, Mines and Resources 1965-1968a, 1965-1968b and 1965-1968c). The data in the above publications include all available measurements of lake levels and of stream stages and discharges.

Within the study area there are over 1400 active and discontinued hydrometric stations for which data are available. While these records vary in terms of type of data, length of record, and quality of data, all have been examined in selecting records for use in the present study. The criteria employed and the records chosen are discussed in the next major section of this chapter (2.4).

2.3.2 Climatic Data

In Canada available climatological data are compiled and published by the Meteorological Branch of the Canada, Department of Transport. In the present study, the major requirements for climatic data are for normals of monthly temperature and precipitation patterns. A series of catalogues have been published on a provincial basis detailing existing and discontinued climatic stations, their locations and the available data (for the study area see Potter 1965a, 1965b and 1965c). A second series of publications, Climatic Normals, Volumes 1 to 5 inclusive, list the monthly climatic normals for all climatic stations for which suitable records are available. (For the study area 1930-1960 period see Canada, Department of Transport, Meteorological Branch 1968 a, b, c, d and e). These two sets of publications are the sources for the basic climatic data employed in this study. The actual records used and the criteria for the choice of stations are discussed in Chapter 4, Section 4.2.2.

2.3.3 Other Physical Geographic Data

The third set of data required covers the broad category of other physical geographic patterns. While numerous sources of data might be employed here, the National Topographic series of maps forms the primary source for this project. The entire study area has been mapped at a scale of 1:250,000, and most of the southern areas are available at a scale of 1:50,000. The actual use of these map sets in the compilation of data on various physical geographic patterns is the subject of detailed consideration in Chapter 4, Sections 4.3.2 and 4.3.3.

2.4 THE CHOICE OF STUDY BASINS

In this section, the choice of study basins from the available records is outlined. Throughout the following chapters the term "study basin" is employed to refer to the gross topographic drainage area upstream from a given gauging site.

Within the terms of reference of the project, it was proposed to include all basins within the study area which met the following criteria:

1) Initially in order to be considered, a stream must have at some location an active or discontinued hydrometric

station for which the available records include daily discharge measurements

2) The hydrometric station under consideration must lie within the study area as previously defined in Section 2.2.1 of this chapter.

3) The gross topographic drainage area of the study basin must be greater than 50 square miles and less than 10,000 square miles

4) Within the base period 1940-1969, the hydrometric station must have a minimum of 5 years of daily discharge data for the open water season (March 1 to October 31)

5) The streamflow of the basin must be natural flow. That is, there must be no major storage works or diversions upstream of the hydrometric station concerned.

The above criteria were applied in the order as listed to the available records for each of the over 1400 active and discontinued hydrometric stations within the study area. This stepwise application of these criteria meant that a basin which did not qualify for inclusion in the study according to the first criterion was never tested under the succeeding criteria. Table 2-2 summarizes this stepwise elimination procedure which resulted in the final acceptance of 161 study basins from an original total of 1478 possible. The necessary information for the application of these criteria was taken from two sets of publications, "1968 Surface Water Data Reference Index" for each of the Prairie Provinces (Canada, Department of Energy, Mines and Resources 1969a, 1969b, and 1969c), and the "1967 Surface Water Data" for each of the Prairie Provinces (Canada, Department of Energy, Mines and Resources 1967a, 1967b and 1967c). A detailed explanation of the application of each of the criteria follows.

TABLE 2-2 - SELECTION OF STUDY BASINS FROM AVAILABLE HYDROMETRIC STATIONS

Province	Total Number of Hydrometric Stations Active and Discontinued	Criteria for Rejection of Basin					Selected Study Basins
		1) Lack of Discharge Data	2) Outside Study Area	3) Gross Drainage Area	4) Length of Records	5) Natural Flow	
Alberta	585	80	129	42	183	107	44
Saskatchewan	428	86	13	47	151	80	51
Manitoba	465	210	36	49	63	41	66
Totals	1478	376	178	138	397	228	161

The first criterion, that of available daily discharge measurements, is necessary to distinguish hydrometric stations for which discharge measurements are kept from those measuring lake levels or stream stages without conversion to discharge estimates. Of the total of 1478 active and discontinued hydrometric stations in the three Prairie Provinces up to 1968, 376 stations failed to meet this first criterion.

The second criterion, that the study basins lie primarily within the study area, imposes the geographic limits of the study. This criterion has been applied with a high degree of flexibility in that the physiographic boundaries are not accurately delimited and the political boundaries do not have an hydrological basis. Basins which include areas of foothills but not mountains have been included providing the gauging stations are within the plains. Basins which drain areas of the Canadian Shield have not been included. Where the study area boundary corresponds to a political division which has no hydrologic significance, and where a portion of an otherwise acceptable drainage basin lies outside the study area, the basin has been included in the study. Of the basins which qualified under the first criterion, 178 were eliminated because they were outside the study area boundaries.

The third criterion relates to the scale of the basins included, and limits gross topographic drainage area to greater than 50 square miles and less than 10,000 square miles. Both of these limits are arbitrary in their absolute definition; however, a need is recognized for such limitations. The terms of reference and methodology for this study requires that measurements of various physical geographic patterns be made from topographic maps at a scale of 1:50,000 and smaller. At this scale, it would be difficult to measure patterns for areas less than approximately 50 square miles. The upper limit on drainage basin size of 10,000 square miles has been chosen to include most of the large relatively hydrologically homogeneous prairie basins, while eliminating the large interregional basins which are beyond the scope of this study. An additional group of 138 basins was eliminated on the application of this gross drainage area limitation.

The fourth criterion relates to the length of available record within the selected base period 1940 to 1969. The minimum acceptable length of continuous record of daily discharges for the March 1 to October 31 period was set at 5 years. Since many prairie hydrometric stations are shut down during the period November 1 to February 28, it is not practical in a study such as this to require data for the entire year; rather, a modified water year from March 1 to October 31 has been adopted. Since any period of record is statistically a sample of a very long or infinite series of possible observations, it is obvious that short records are of limited use because of the sampling error involved. For this reason a lower limit of 5 years of continuous record has been set. This limit corresponds to that recommended by the United States Geological Survey for use in regional flood frequency studies (Dalrymple 1960, p. 31). The choice of the 30 year base period 1940-1969 was based on several considerations. The most important reason for the 30 year base is that the available hydrometric records for prairie streams are generally quite limited and any period longer than 30 years would have only a handful of suitable records. The extent of the 30 year base period to 1969 was necessary in order that as many as possible of the new hydrometric stations established during the 1960s could qualify for inclusion. The application of this fourth criterion dealing with available records resulted in the elimination of a further 397 basins. Most of these basins fell into two groups, the first being discontinued stations for which a short period of record was collected prior to 1940 and the second group included the many new hydrometric stations which did not have 5 years of operation prior to 1969.

The final criterion used in the choice of study basins dealt with the nature of the streamflow relative to its alteration by man. Only basins with natural flow have been included as study basins. Any stations for which the published material indicated that major storage or diversion works were located upstream in the basin have been eliminated. This requirement was necessary since the project proposes to consider the natural relationships between streamflow and physical geographic patterns. The application of this final criterion resulted in the elimination of a further 228 basins.

Following the stepwise application of the 5 criteria, a group of 161 basins remained. These 161 basins form the basic sample of hydrometric records employed in the present study. The length of records, drainage areas, geographic distribution and other characteristics of the chosen basins are discussed in the following chapters.

2.5 SUMMARY

In this chapter the boundaries of the study area have been defined and some attention has been given to the general physiographic, climatic, and hydrologic patterns of the study area. The treatment of these patterns has been rather superficial; however, it has been included only to give the reader some general background to the study area. In the following chapters these patterns will be treated in more detail with regard to measurements for specific basins.

A second section of the chapter included a review of the major data sources available for the study. The actual use of these sources will be discussed in more detail in the sections of Chapters 3 and 4 to which they are relevant.

The final section of this chapter has been a discussion of the selection of study basins. A sample of 161 basins was selected on the basis of the stepwise application of five criteria. This sample of study basins represents the basic data set employed throughout the study. The data on streamflow patterns for these basins are compiled and analysed in Chapter 3 while the climatic and other physical geographic data are treated in Chapter 4.

CHAPTER 3

THE SELECTED STREAMFLOW CHARACTERISTICS: DATA COMPILATION AND SINGLE-STATION FREQUENCY ANALYSIS

3.1 INTRODUCTION

This chapter contains discussions of the data compilation and frequency analysis of the selected streamflow characteristics for the study basins. As outlined in Chapter 1, two sets of hydrologic data, the annual yields and the annual flood flows, have been selected for examination in the present study. These data are to be analysed by the probabilistic techniques of frequency analysis. These analyses will result in the estimation of parameters describing the magnitudes and frequencies of both annual yields and flood flows for each of the study basins. These parameters will be employed in later chapters as the dependent variables in the regional parametric analyses of the relationships of streamflow characteristics to climatic and other physical geographic patterns.

This chapter is composed of two major divisions. The first is a presentation of a general review of the techniques of frequency analysis as they are employed in hydrologic research. The second is concerned with the data compilation and single-station frequency analyses of the annual yield and flood flow records for the selected study basins.

3.2 FREQUENCY ANALYSIS TECHNIQUES IN HYDROLOGIC ANALYSIS

Frequency analysis techniques are a means of analysing the varibility of a data sample for the purpose of estimating the population variability. All hydrologic data vary with time; however, this variation is not usually sufficiently regular to be considered as cyclic (Leopold 1954, p. 1). In the absence of regular variations, it is not possible to employ past records as a basis for forecasting future events. It is, however, possible to employ such historical records as indications of the probabilities of occurrence of future events of given magnitudes. Such probabilities provide a useful framework for decisions relating to water management planning. Frequency analysis techniques as applied in the present study are intended to evaluate the variability of the streamflow characteristics under consideration.

In general terms, frequency analysis examines the relationship between the magnitude of a variate and its frequency or probability of occurrence (Riggs 1968, p. 1). This relationship is analysed by the fitting of a frequency curve to a sample data series. The frequency curve is fitted so as to estimate the frequency distribution of the population from which the sample has been drawn.

3.2.1 Basic Assumptions and Data Preparation

The analysis is based on several assumptions regarding the data sample being examined. The first assumption is that the data represent discrete independent random events. Some hydrologic data series, such as daily discharges, are obviously not random in their occurrence; and there is a definite dependence or carry-over effect between successive observations. Other hydrologic data series, such as annual yields or annual flood flows, tend to approximate random conditions. While there is a recognized tendency for these events to group as in the case of wet years and dry years, it is not generally possible to identify any regular patterns in this variation (Leopold 1959, p. 8; and Yevdjevich 1964). In the absence of regular cyclic variations, these data series are normally assumed for practical purposes to satisfy the assumption of random independent events (Yevdjevich 1963, p. 60).

A second assumption underlying the application of frequency analysis techniques is the requirement of time-stationarity of the processes governing the occurrence of the events being studied. This assumption implies that the processes which resulted in the sample data series must be consistent with the processes active at the present and in the future. Where conditions change either as the result of natural events as in the case of climatic change, or as the result of artificial changes as in the case of reservoir construction, the assumption of time-stationarity is violated and historical records will not provide a suitable base of the prediction of future patterns. In the case of artificial changes such as reservoir construction, it may be possible to make some adjustments in the analysis procedures (Yevdjevich 1963, p. 60).

Before proceeding with the frequency analysis of any hydrologic data series, it is imperative that the researcher recognize any limitations inherent in his data sample. In addition to compliance with the above assumptions, it is important that any data inhomogeneity, systematic observation errors and missing observations be noted and where possible corrected (Chow 1964, p. 8-18).

3.2.2 Application of Frequency Analysis Techniques

The literature dealing with the application of frequency techniques to hydrologic data is abundant but scattered through the journals of numerous disciplines (Leopold 1959, p. 1). There has been considerable debate with respect to the most suitable methodologies and their relative merits. In this section, an attempt is made to describe the basic methodologies and to point out some of the areas where considerable variations are possible. Some of these problems will be treated in greater detail in later sections of this chapter as they apply to the methodology adopted in the present study.

3.2.2.1 Return Period

The primary objective of frequency analysis is to determine the return period of events of given magnitudes (Chow 1964, p. 8-22). The return period, or recurrence interval, is defined as the average time period in which an event of a given magnitude is equalled or exceeded once. The procedures by which the return period of an event of given magnitude is determined involve the fitting of a frequency curve to describe the relationship of the magnitude of the events or variates to their return periods. Return periods may be alternately expressed as probabilities of occurrence. For any event the probability of occurrence is equivalent to the reciprocal of the return period and vice versa (Langbein 1960, p. 48). For example, an event with a return period of 10 years has a probability of occurrence of 0.1 in any given year.

3.2.3 Theoretical Frequency Distributions

The fitting of a frequency curve to the relationship of event magnitudes and return periods is usually based on the assumption that the population is distributed according to some theoretical probability density function. The assumption of a theoretical statistical distribution, which the sample data series is assumed to approximate, provides a basis for the fitting of a smooth curve to the data. The parameters of the assumed distribution are calculated on the basis of the sample data series.

Hydrologists have attempted to justify the assumption of a single theoretical distribution for application to various types of hydrologic data. To date, it has not been possible to generalize the choice of distribution. As a result both of the sampling variability and of the variability of basin conditions from area to area, several theoretical distributions have been employed in hydrologic research (Riggs 1968, p. 3). Benson (1962a,p. 7) examined the application of several distributions to flood flows for 100 of the longest flood records in the United States. He found no one type of frequency curve gave consistently better results over the entire country. Markovic (1965) completed a similar investigation of theoretical distributions applied to annual runoff data from over 400 basins in the western United States and Canada. He also found it impossible to identify a single distribution which consistently provided the best fit. Several authors have attempted to provide a theoretical justification for the application of a particular distribution to certain hydrologic series. Chow's (1954) paper dealing with the Lognormal Distribution, and Gumbel's (1941) paper dealing with the Type I Extremal or Gumbel Distribution are examples of such attempts to give theoretical justification to one distribution over all others for particular data sets. Unfortunately, the assumptions on which such discussions have been based are open to question; and researchers continue to be faced with a choice of the best theoretical distribution for a given study (Benson 1962a,p. 9-10).

There are several different theoretical distributions which have been employed in hydrologic research. It is beyond the scope of this discussion to consider each of these in detail. However, Table 3-1 has been compiled to synthesize some general background information concerning the distributions which are most often employed in hydrologic research. Further discussions and references are contained in Chow's discussion of frequency analysis (1964a) and in Riggs' review of frequency curves (1968).

3.2.4 Fitting Frequency Curves

Having made a basic assumption concerning the nature of the frequency distribution to which the population frequency curve is most likely to conform, the researcher faces the task of fitting this distribution to the sample data. The actual curve fitting may be by either mathematical or graphical methods.

3.2.4.1 Mathematical Methods of Curve Fitting

In mathematical curve fitting, the sample data series is employed to estimate the parameters of the assumed distribution. When a 2-parameter distribution is being utilized, it is necessary to estimate the population mean and standard deviation from the data. In the case of a 3-parameter distribution, an additional parameter, the skew coefficient, is required. Three methods employed in the estimation of distribution parameters are the method of moments, the method of maximum likelihood, and the method of least squares (Chow 1964a,p. 8-30; and

TABLE 3-1 - SUMMARY OF SOME THEORETICAL FREQUENCY DISTRIBUTIONS IN USE IN HYDROLOGIC FREQUENCY ANALYSIS

Distribution	Number of Parameters	General Comments	Selected References
Normal Distribution	2	i) Symmetrical distribution ii) Plots as straight line on normal probability graph paper iii) Gives rise to probabilities of Negative flows iv) Has been applied to annual yield data	Any basic statistical text (e.g. Keeping 1962) Leopold 1959
Lognormal Distribution	2	i) Skewed distribution (assumes fixed skew) ii) May be interpreted as Normal Distribution of the logarithms iii) Plots as straight line on log probability graph paper iv) Has been applied widely to various hydrologic data series including flood flows and annual yields (See modified lognormal distribution below)	Hazen 1930 Riggs 1968 Chow 1954
Type I Extremal Distribution (Gumbel)	2	i) Also known as the Gumbel Distribution ii) Skewed distribution (assumes fixed skew) iii) Based on theory of extreme values iv) Plots as straight line on Gumbel-Powell probability paper v) Has been widely applied to flood flows and other hydrologic series	Gumbel 1941, 1954, 1966 Powell 1943 Kendall 1959

Table 3-1, Continued

Distribution	Number of Parameters	General Comments	Selected References
Log-Gumbel Distribution	2	i) Same as above employing logarithms ii) Larger skew than above iii) Has been applied to flood data iv) Has advantages for comparing curves for different locations	Dalrymple 1960 See also references for Gumbel distribution above
Modified Lognormal Distribution	3	i) Also known as the 3 Parameter Lognormal Distribution ii) Skewed distribution which is a general form of the lognormal distribution iii) Has variable skew which must be calculated iv) Use of tables to estimate frequency curve v) Has 2 Parameter Lognormal and Gumbel Distributions as special cases vi) Has been applied to various hydrologic data series	Chow 1954 Brakensiek 1958 Sangal & Biswas 1970
Log-Pearson Type III Distribution	3	i) Flexible 3 parameter distribution ii) Variable skew iii) Recently recommended as base method for use in flood frequency studies by all United States Federal Agencies	United States Water Resources Council 1967 Benson 1968

Prasad 1970, p. 6). The estimated distribution parameters are employed to calculate the required frequency distribution according to the general formula for hydrologic frequency analyses:

$$X = \bar{X} + KS \tag{3-1}$$

where: X is a single value of the variate

$\bar{X}$ is the mean of the variates in the sample

S is the standard deviation of the variates in the sample

K is a frequency factor which is a function of the recurrence interval and the assumed theoretical distribution (Chow 1951, Chow 1964a,p. 23; and Riggs 1968, p. 5)

The values of the frequency factor,K,may be read from tables or graphs which have been prepared for the theoretical distributions in common usage (for references see Chow 1964a,pp. 4-23 to 4-26).

3.2.4.2 Graphical Methods of Curve Fitting

An alternative to the mathematical fitting of frequency curves is that of graphical fitting. In graphical fitting, each variate in the data sample is assigned a recurrence interval or probability of occurrence. The magnitudes of the variates are plotted against the assigned recurrence intervals or probabilities and a best fit line is drawn to describe the distribution (Riggs 1968, p. 7).

The probability or recurrence interval assigned to the individual variates is usually referred to as the plotting position. Several formulae are available for assigning plotting positions for use in hydrologic frequency analysis (Chow 1964a,p. 29; Langbein 1960; and Benson 1962a). One of the most widely accepted of these formulae is that originally proposed by Weibull and which has the form:

$$T = \frac{N + 1}{M} \tag{3-2}$$

where: T is the return period

N is the total number of variates in the sample

M is the order number assigned to the event by numbering consecutively beginning with the largest event equal to 1

(Benson 1962c)

Benson (1962c) examined several plotting position formulae from the point of view of their economic implications. He established that the above formula most closely approximates the expected probabilities. Therefore, this formula which is independent of the distribution considered, provides the best basis for planning decisions.

Having assigned plotting positions to the data sample being analysed, the next step is the graphical plotting of the data. This plotting is usually done on special probability graph paper with the magnitudes of the variate being plotted on the vertical, ordinate, axis and the return period or probabilities of occurrence being plotted on the horizontal, abscissa, axis. If arithmetic graph paper is employed, the resulting curves will usually be S-shaped (Riggs 1968, p. 7). In order to linearize the curves a special graph paper is used on which the abscissa scale is such that a particular distribution will plot as a straight line. Graph paper to linearize the 2-parameter Normal, Log-normal, and Gumbel distributions is readily obtainable. Three parameter distributions are not normally fitted graphically and plot as curved lines on the standard probability papers.

Once the data have been plotted, it is possible to fit a smooth curve to the points by eye. It is also possible when a straight line plot is desired to fit a least squares regression line to the data. One serious problem encountered in the use of calculated lines is the effect of anomalous data points or outliers, which do not fit the general pattern of the data. In graphical fitting such points may be ignored or adjusted for.

There has been considerable debate in the literature with regard to the relative merits of numerical and graphical fitting procedures. Riggs (1968, p. 11) has provided a useful comparison of the two approaches. Numerical fitting procedures have the advantages of producing identical results by different researchers, computer calculations, and a small number of parameters to define the distribution. They have the disadvantages of the arbitrary selection of the theoretical distribution, the tendency for characteristics of the data to be obscured, and the lack of a method of using historical or estimated data. Graphical methods have the advantages of their simplicity, no arbitrarily assumed distribution, visual presentation of the data, and a method for using historical or estimated data. The disadvantages of these procedures are the different results obtained by different researchers, and the inability to describe the distribution by a set of simple parameters. The method employed in the present study which is discussed in a later section of this chapter, combines both numerical and graphical techniques in an attempt to combine advantages of both methods while minimizing the disadvantages.

3.2.5 Reliability of Frequency Analysis Results

3.2.5.1 Single-Station Analysis

Once a sample series of hydrologic data has been analysed according to the techniques of frequency analysis, there is a temptation to interpret the resulting frequency curve as a true representation of the population distribution. However, the frequency relationship developed is only a statistical estimate of the long-term distribution. Even when the basic assumptions of time-stationarity, random events and homogeneous data have been satisfied, the estimated curve is subject to sampling errors. The relatively short hydrologic records on which frequency curves are based represent small samples taken from very large or infinite populations. On this basis, it must be recognized that any single-station frequency curve may deviate considerably from the true population curve (Benson 1962a,p. 15).

In a very revealing study, Benson (1960) examined the variability in short term records sampled from a theoretical 1000 flood record with known population parameters. From the 1000 year record, he draw one hundred 10 year records, forty 25 year records, twenty 50 year records and ten 100 year records. Upon plotting these samples on extreme value or Gumbel-Powell probability paper, he found that individual curves showed very large variations from the known population distribution. Benson also found that combining the curves for several of the short records resulted in a much closer approximation to the known long-term distribution. This variability in short-term records has led to the development of regional techniques of frequency analysis in which several short-term records are combined to estimate a regional frequency relationship.

3.2.5.2 Regional Analysis

Regional frequency analysis is aimed at improving the estimate of population frequency curves by reducing the effects of the sampling errors inherent in short-term single-station records. One method of regional analysis which has been successfully applied to rainfall data is the station year approach by which the short records at several stations are combined to provide one long record. This method is not suitable in analysing runoff data because of the lack of independence between stations (Dalrymple 1960, p. 26). While it is not feasible to combine records by adding them together, it is possible to average them and provide a better estimate of the true frequency relationships. There are two distinct approaches to the regional analysis of runoff patterns, the index-event method described for floods by Dalrymple (1960), and the multiple regression approach to regional analysis as employed by Benson (1962a, p. 20; 1962b; and 1964). These methods will be considered in detail in later chapters as they are applied in the present study.

The preceding major section of this chapter has included discussions of the basic principles and methods of frequency analysis techniques as they apply in hydrologic analysis. The following section entails a discussion of the data compilation and single-station frequency analyses of the annual yield and annual flood flow records of the study basins.

3.3 DATA COMPILATION AND SINGLE-STATION FREQUENCY ANALYSES FOR THE STUDY BASINS

A total of 161 hydrometric stations have been selected for inclusion in the present study. These stations include all those within the study area which meet the criteria relating to type of records, gross drainage area, length of record, and natural flow conditions, as outlined in Chapter 2, Section 2.4. For each of the selected hydrometric stations, the gross topographic drainage area upstream is assumed to delineate a study basin.

3.3.1 Location of the Hydrometric Stations

The selected hydrometric stations are located on the map, Figure 3-1, and are identified by a station number as assigned in the present analysis. Table 3-2 accompanies the map and provides a complete station identification including the Water Survey of Canada Hydrometric Station Number and the name of the stream.

3.3.2 Hydrometric Data Compilation

3.3.2.1 Data Sources Employed

One of the criteria applied in the selection of study basins was that within the 1940 to 1960 base period, a minimum of 5 years of daily discharge records for the open water season (March 1 to October 31) be available. The source of the hydrometric data employed in the present study is the records of the Water Survey of Canada, a branch of the Department of Energy, Mines and Resources. All available daily discharge data for the period prior to 1966 are stored on magnetic tapes prepared by the Water Survey of Canada, and copies of which are available in the Department of Geography at the University of Alberta. Daily discharge data for the study basins for the years 1967 and 1968 are available in published form in the annual data publications of the Water Survey of Canada for the Provinces of Alberta, Saskatchewan and

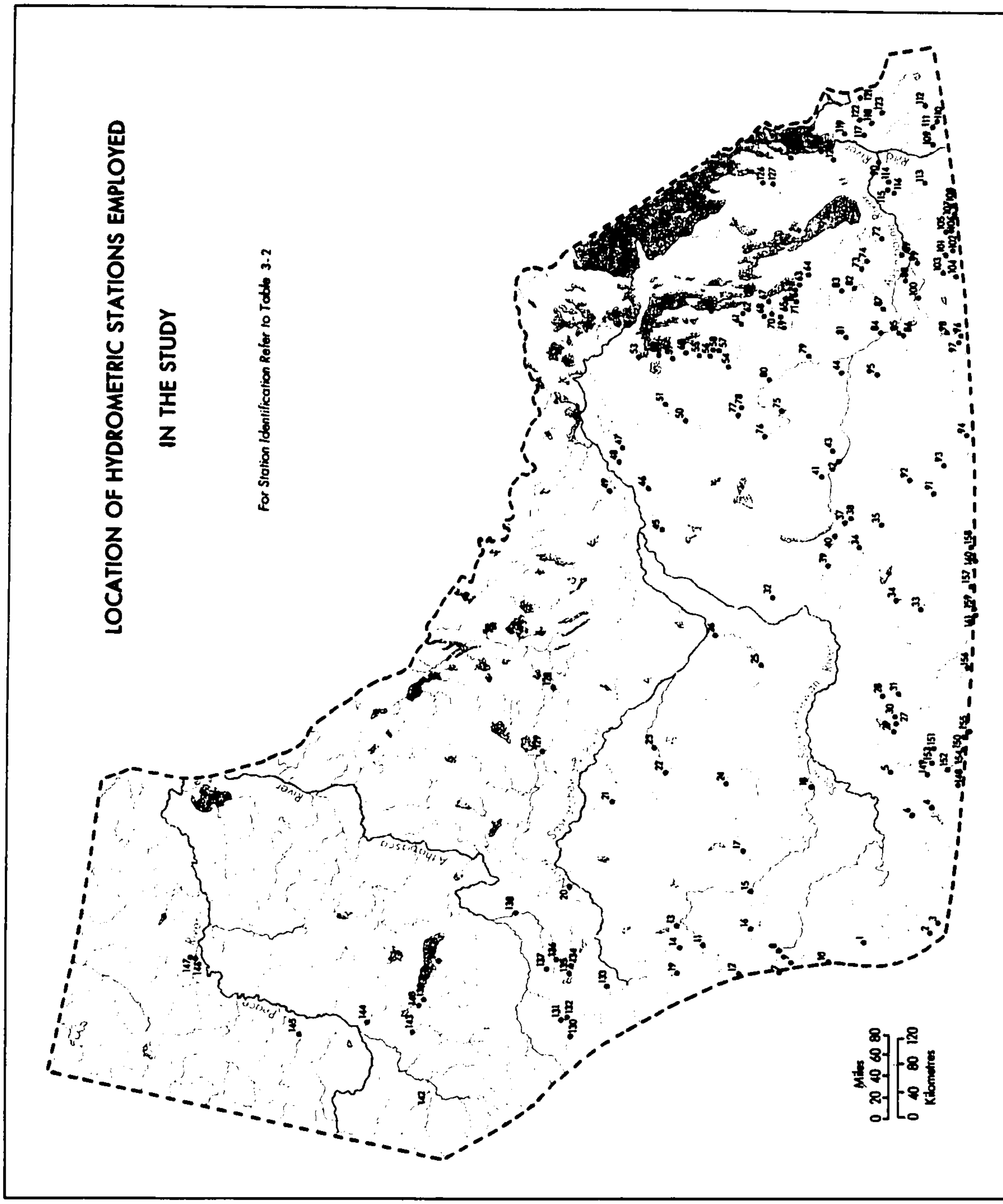

LOCATION OF HYDROMETRIC STATIONS EMPLOYED
IN THE STUDY
For Station Identification Refer to Table 3-2
Miles
0 20 40 60 80
0 40 80 120
Kilometres

Figure 3-1

TABLE 3-2

HYDROMETRIC STATION IDENTIFICATION

STATION NUMBER	WATER SURVEY STATION NUMBER	STATION NAME
1	05AB021	WILLOW CK
2	05AE002	LEE CK
3	05AE005	ROLPH CK
4	05AF010	MANYBERRIES CK
5	05AH002	MACKAY CK
6	05AH041	PEIGAN CK
7	05BJ004	ELBOW R
8	05BJ005	ELBOW R
9	05BK001	FISH CK
10	05BL007	STIMSON CK
11	05CB001	LITTLE RED DEER
12	05CB002	LITTLE RED DEER
13	05CC001	BLINDMAN R
14	05CC007	MEDICINE R
15	05CE002	KNEEHILLS CK
16	05CE006	ROSEBUD R
17	05CG002	BULLPOUND CK
18	05CK005	ALKALI CK
19	05DB002	PRAIRIE CK
20	05EA001	STURGEON R
21	05EE001	VERMILION R
22	05FD001	RIBSTONE CK
23	05FE001	BATTLE R
24	05GA003	MONITER CK
25	05GC005	EAGLE CK
26	05GC006	EAGLE CK
27	05HA003	BEAR CK
28	05HA015	BRIDGE CK
29	05HA062	PIAPOT CK
30	05HA075	SKULL CK
31	05HD036	SWIFTCURRENT CK
32	05HG002	BRIGHTWATER CK
33	05JA002	WOOD R
34	05JB003	NOTUKEU CK
35	05JE004	MOOSE JAW R
36	05JE006	MOOSE JAW R
37	05JF005	WASCANA CK
38	05JF006	BOGGY CK
39	05JG004	QU'APPELLE R
40	05JH001	ARM R
41	05JK004	JUMPING DEER CK
42	05JL002	INDIANHEAD CK
43	05JL005	PHEASANT CK
44	05JM015	CUTARM CK
45	05KA001	CARROT R
46	05KB003	CARROT R
47	05KC001	CARROT R
48	05KD002	PETAIGAN R
49	05KE002	TORCH R
50	05LB002	ETOMAMI R
51	05LC001	RED DEER R
52	05LC004	RED DEER R
53	05LD001	OVERFLOWING R
54	05LE001	SWAN R
55	05LE003	BIRCH R
56	05LE004	WOODY R
57	05LE005	ROARING R
58	05LE006	SWAN R
59	05LF001	STEEP ROCK R
60	05LF002	BELL R
61	05LG001	PINE R
62	05LG002	GARLAND R
63	05LJ005	OCHER R
64	05LJ007	TURTLE R
65	05LJ011	WILSON R
66	05LJ012	VERMILION R
67	05LJ015	FISHING R
68	05LJ016	FORK R
69	05LJ017	DRIFTING R
70	05LJ019	MINK R
71	05LJ022	EDWARDS CK
72	05LL007	PINE CK
73	05LL009	NEEPAWA CK
74	05LL013	WHITEMUD R
75	05MB001	YORKTON CK
76	05MB004	WHITESAND R
77	05MC001	ASSINIBOINE R
78	05MC002	STONY CK
79	05MD005	SHELL R
80	05MD006	LITTLE BOGGY CK
81	05ME003	BIRDTAIL CK
82	05MF001	MINNEDOSA R
83	05MF008	ROLLING R
84	05MG001	ARROW R
85	05MG002	BOSSHILL CK
86	05MG003	GOPHER CK
87	05MG004	OAK R
88	05MH006	LITTLE SOURIS R
89	05MH007	EPINETTE CK
90	05MJ004	STURGEON CK
91	05NA005	GIBSON CK
92	05NB011	YELLOWGRASS DITC
93	05NB014	JEWEL CK
94	05NB019	COULEE WEST
95	05NE003	PIPESTONE CK
96	05NF002	ANTLER R
97	05NF007	GAINSBOROUGH CK
98	05NF008	GRAHAM CK
99	05NG010	OAK CK
100	05NG012	ELGIN CK
101	05OA006	WHITEMUD CK
102	05OA007	BADGER CK
103	05OA008	PEMBINA
104	05OA009	WAKOPA
105	05OB006	CRYSTAL CK
106	05OB010	LONG R
107	05OB016	SNOWFLAKE CK
108	05OB021	MOWBRAY CK
109	05OD001	ROSEAU R
110	05OD004	ROSEAU R
111	05OD014	ROSEAU R
112	05OE004	RAT R
113	05OF015	SHANNON CK
114	05OG004	ELM CK 1
115	05OG005	ELM CK 2
116	05OG006	ELM CK 3
117	05OJ002	COOKS CK
118	05OJ006	COOKS CK
119	05OJ008	NETLEY CK
120	05OJ009	NETLEY CK
121	05PH003	WHITEMOUTH R
122	05SA002	BROKENHEAD R
123	05SA004	BROKENHEAD R
124	05SB002	OSIER CK
125	05SC002	ICELANDIC R
126	05SD003	FISHER R
127	05SD004	EAST FISHER R
128	06AD001	BEAVER R
129	06AD006	BEAVER R
130	07AF002	MCLEOD R
131	07AG001	MCLEOD R
132	07AG003	WOLF CK
133	07BA001	PEMBINA R
134	07BB002	PEMBINA R
135	07BB003	LOBSTICK R
136	07BB004	PADDLE R
137	07BB005	LITTLE PADDLE R
138	07BC002	PEMBINA R
139	07BF001	EAST PRAIRIE R
140	07BF002	WEST PRAIRIE R
141	07BJ001	SWAN R
142	07GE001	WAPITI R
143	07GH002	LITTLE SMOKY R
144	07HA003	HEART R
145	07HC001	NOTIKEWIN R
146	07JF002	BOYER R
147	07JF003	PONTON R
148	11AA026	SAGE CK
149	11AB009	MIDDLE CK
150	11AB075	LYONS CK
151	11AB076	BATTLE CK
152	11AB082	LODGE CK
153	11AB087	MIDDLE CK
154	11AB105	WOODPILE COULEE
155	11AB107	EAST BATTLE CK
156	11AD001	WHITEWATER CK
157	11AE002	POPLAR R W
158	11AE003	POPLAR R E
159	11AE005	ROCK CK
160	11AE008	POPLAR R M
161	11AE009	ROCK CK

Manitoba (Canada, Department of Energy, Mines and Resources 1967a, b and c; and 1968a, b and c). The daily discharge data for 1969 are not yet complete or published; however, those available were supplied in unpublished form by the Calgary and Winnipeg district offices of the Water Survey of Canada. Data for 1969 which were not available prior to May 1, 1970 have not been employed in the present study.

The actual data required in the present study have been compiled directly from the magnetic tapes for the period prior to 1966 and have been compiled from the printed records for later years.

3.3.2.2 Compilation of the "Annual" Yield Data Series

Daily discharge data for many small streams in the Prairie Provinces are not collected during the winter period from November 1 to the end of February. During this period the hydrometric stations are closed down in response to the severe winter conditions. Under normal conditions, there is little or no flow in these streams during the winter period. Since winter data are not available for many of the selected study basins, the period from March 1 to October 31 has been defined as the "annual" period applied to the present study. Therefore, throughout this project, the term "annual" as applied to streamflow data refers only to the March 1 to October 31 period. Undoubtedly, in some of the larger study basins, there is some significant discharge during the winter season; however, for the purposes of the present study this flow has not been measured, and the 8 month flow has been considered as representative of the annual flow, at least in relative if not in absolute magnitude. A study of both 8 month and 12 month annual flows for streams with year-round gauge operation might lead to a correction factor for the 8 month records; however, such a study has not been a part of the present research.

From the available records, the annual yield data for this study have been compiled for an 8 month, March to October, period. The daily discharge records for each of the study basins have been employed in this data compilation. The annual yield figures of each year have been arrived at by summing the daily discharges (in c.f.s.) for the 8 month period, and converting the sum to acre feet. In years for which entire months of daily discharge data were missing, no annual yield data were compiled. Where shorter periods of record were missing, the available daily data were examined and where possible the missing data were estimated by interpolation between preceding and succeeding measurements.

Table 3-3 has been prepared to indicate for each basin the years for which annual yield data have been compiled. The "X" symbols denote the years for which measured data are available, and the total years with measured data are listed in the column headed "ACTUAL YEARS."

3.3.2.3 Compilation of the "Annual" Flood Peak Data

In the compilation of any series of flood events, it is necessary to carefully define the term flood. In the literature on the subject, two different flood series, the annual series and the partial-duration series, have been proposed (Langbein 1949, and Chow 1950). The annual series is usually employed, since it is simpler to apply, and constitutes a complete series which is suitable for statistical treatment. The present research is concerned with the annual series which includes only the largest flood event of each year. The "annual" period em-

TABLE 3-3

ANNUAL YIELD RECORDS *

	STATION ID		YEARS 1940 — 1969	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
1	05AB021	WILLOW CK	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
2	05AE002	LEE CK	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX-	29	0	29
3	05AE005	ROLPH CK	XXXXXXXXXXXOXXXXXXXXXXXXXXXXX-	28	1	29
4	05AF010	MANYBERRIES CK	OO--O-OOOOOOOOOOOXXXXXXXXXXXXX	13	14	27
5	05AH002	MACKAY CK	OOOOOOOOOOOOOOOOXXXXOXXXXXXXXX	13	17	30
6	05AH041	PEIGAN CK	OOOOOOOOOOOOOOOOOOOOXXXXXXXXXX	10	20	30
7	05BJ004	ELBOW R	OOOOOOOOOOOOXXXXXXXXXXXXXXXXXX	18	12	30
8	05BJ005	ELBOW R	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	30	0	30
9	05BK001	FISH CK	OOOOOOOOOOOOOOOOXXXXXXXXXXXXXX	14	16	30
10	05BL007	STIMSON CK	X--XXXXXXXXXXXXOXXXXXXXXXXXXO-	25	2	27
11	05CB001	LITTLE RED DEER	OOOOOOOOOOOOOOOOOOOOOXXXXXXXXX	9	21	30
12	05CB002	LITTLE RED DEER	OOOOOOOOOOOOOOOOOOOOOOOOXXXXXX	6	24	30
13	05CC001	BLINDMAN R	OOOOOOOOOOOOOOOOOOOOOOOXXXXXXX	7	23	30
14	05CC0C7	MEDICINE R	OOOOOOOOOOOOOOOOOOOOOOOOXXXXXX	6	24	30
15	05CE002	KNEEHILLS CK	OOOOOOOOOOOOOOOOOOOXXXXXXXXXXX	11	19	30
16	05CE006	ROSEBUD R	OO--O-OOOOOOOOOOOOOXXXXXXXXXXX	11	16	27
17	05CG002	BULLPOUND CK	OOOOOOOOOOOOOOOOOOOOOOXXXXXXXX	8	22	30
18	05CK005	ALKALI CK	OOOOOOOOOOOOOOOOOOOOOOOXXXXXXX	7	23	30
19	05DB002	PRAIRIE CK	OOOOOOOOOOOOXXXXXXXXXXXXXXXXXX	18	12	30
20	05EA001	STURGEON R	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	30	0	30
21	05EE001	VERMILION R	----OOOOOOOOOOOOOOOXXXXXXXXXXX	11	15	26
22	05FD001	RIBSTONE CK	----OOOOOOOOOOOOOOOOOOXXXXXXXX	8	18	26
23	05FE001	BATTLE R	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
24	05GA003	MONITER CK	----OOOOOOOOOOXXXXXXXXXXXXXXXX	16	10	26
25	05GC005	EAGLE CK	----OOOOOOOOOOOOOOOOOOOXXXXXX-	6	19	25
26	05GC006	EAGLE CK	----OOOOOOOOOOOOOOOOOOOXXXXXX-	6	19	25
27	05HA003	BEAR CK	OOOOOOOOOOOOOOOOOOOOOOOXXXXXXX	7	23	30
28	05HA015	BRIDGE CK	OOOOOOOOOOOOOOOOOOOOOOOXXXXXX-	6	23	29
29	05HA062	PIAPOT CK	OOOOOOOOOOOOOOOOOOOOOOOXXXXXX-	6	23	29
30	05HA075	SKULL CK	OOOOOOOOOOOOOOOOOOOOOOOXXXXXXX	7	23	30
31	05HD036	SWIFTCURRENT CK	OOOOOOOOOOOOOOOXXXXXXXXXXXOXX-	13	16	29
32	05HG002	BRIGHTWATER CK	OOOOOOOOOOOOOOOOOOOOXOXXOXXXX-	7	22	29
33	05JA002	WOOD R	OOOO-OOOOOOOOOOOOXXXXXXXXXXXX-	12	16	28
34	05JB003	NOTUKEU CK	OOOO-OOOOOOOOOOOOXXXXXXXXXXXX-	12	16	28
35	05JE004	MOOSE JAW R	------OOOOOOOXXXXXXXXXXXXXXXX-	16	7	23
36	05JE006	MOOSE JAW R	------OOOOOOOXOXXXXXXXXXXXXXX-	15	8	23
37	05JF005	WASCANA CK	--OO--XXXXXOXXXXXXXXXXXXXXXXX-	22	3	25
38	05JF0C6	BOGGY CK	------OOOOXOOOOXXXXXXXXXXOOOX-	12	11	23
39	05JG004	QU'APPELLE R	----XXXXXXXXXXXXXXXXXXXXXXXXO-	24	1	25
40	05JH001	ARM R	------OOOOOOOOOXXXXXXXXXXXXXX-	14	9	23
41	05JK004	JUMPING DEER CK	-XXXXXXXXXXXXXXXXXXXXXXXXXXXX-	28	0	28
42	05JL002	INDIANHEAD CK	-OXXOOXXXXOXXXXXXXXXOXXXXXXXX-	23	5	28
43	C5JLCC5	PHEASANT CK	-OOOOOOXXXOXXXXXXXXXXXXXXXXXX-	21	7	28
44	05JM015	CUTARM CK	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
45	05KA001	CARROT R	-OOOOOOOOOOOOOOOOXXXXXXXXXXXXX	13	16	29
46	05KB003	CARROT R	-OOOOOOOOOOOOOOXXXXXXXXXXXXXXX	15	14	29
47	05KC001	CARROT R	-OOOOOOOOOOOOOOXXXXXXXXXXXXXXX	15	14	29
48	05KD002	PETAIGAN R	-OOOOOOOOOOOOOOXXXXXXXOOOOOOO-	7	21	28
49	05KE002	TORCH R	-OOOOOOOOOOOOXXXXXXXXXXXXXXXX-	16	12	28
50	05LB002	ETOMAMI R	-------OOOOOOOOOOXXXXXXXXOXXX-	11	11	22
51	05LC001	RED DEER R	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
52	05LC004	RED DEER R	-------OOOOOOOOOOXXXOXXXXXXXX-	11	11	22
53	05LD001	OVERFLOWING R	---------------OOXXXXXXXXXOXXO	11	4	15
54	05LE001	SWAN R	-------OOOOXXXXXXXXXOOOOOOOOO-	9	13	22
55	05LE003	BIRCH R	-------OOOOOOOOOXXXXXXXXXXOXX-	12	10	22
56	05LE004	WOODY R	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
57	05LE005	ROARING R	-------OOOOOOOOOOOOOXXXOXXXXX-	8	14	22
58	05LE006	SWAN R	-------OOOOOOOOOOOOOOXXXXXXXX-	8	14	22
59	C5LF001	STEEP ROCK R	-------OOOOOOOOOXXOXXXXXXXOXX-	11	11	22
60	05LF002	BELL R	-------OOOOOOOOOOXXXXXXXXOXXO-	10	12	22
61	05LG001	PINE R	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
62	05LGC02	GARLAND R	-------OOOOOOOOOXXXOXXOXXXXXX-	11	11	22
63	05LJ005	OCHER R	-------OOOOOOOOOXXXXXXXXXXXXX-	13	9	22
64	05LJ007	TURTLE R	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
65	05LJ011	WILSON R	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
66	05LJ012	VERMILION R	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
67	05LJ015	FISHING R	-------OOOOOOOOOOXXXOXXXXXXXX-	11	11	22
68	05LJ016	FORK R	-------OOOOOOOOOXXXXXXXXXXXXX-	13	9	22
69	05LJ017	DRIFTING R	--OO--OOOOOOOOOOXXXXXXXXXXXXX-	13	12	25
70	05LJ019	MINK R	-OOOOOOOOOOOOOOOXXXXXXXXXXXXX-	13	15	28
71	05LJ022	EDWARDS CK	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
72	05LL007	PINE CK	-O-OOO-----------OOXXXXXXXXXX-	10	6	16
73	05LLC09	NEEPAWA CK	-------OOOOOOOOOOOOXXXXXXXXXX-	10	12	22
74	05LL013	WHITEMUD R	---------OOOOOOOOOOOOXXXXXXXX-	8	12	20
75	05MB001	YORKTON CK	-X-XXX-OOOOOOOOOOXXXXXXXXXXXX-	16	10	26
76	05MB004	WHITESAND R	-------OOOOOOOOOOXXOXOXXOXXXX-	9	13	22
77	05MC001	ASSINIBOINE R	-------OOOOOOOOOOXXXXXXXOXXXX-	11	11	22
78	05MC002	STONY CK	--OO--OOOOOOOOOOOXXXXOXXXXXXX-	11	14	25
79	05MD005	SHELL R	-------OOOOOOOOOOXXXXXXOXXXXX-	11	11	22
80	05MD006	LITTLE BOGGY CK	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22
81	05ME003	BIRDTAIL CK	-------OOOOOOOOOOXXXXXXXXXXXX-	12	10	22

* THE SYMBOL X INDICATES YEARS WITH ACTUAL MEASURED RECORDS AND THE SYMBOL O INDICATES YEARS FOR WHICH RECORDS HAVE BEEN EXTENDED BY CORRELATION ANALYSIS

TABLE 3-3 CONTINUED

	STATION ID		YEARS (1940 – 1969)	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
82	05MF001	MINNEDOSA R	-------000000000000XXXXXXXXXX-	10	12	22
83	05MF008	ROLLING R	-------00000000000000XXXXXXXX-	8	14	22
84	05MG001	ARROW R	-------000000000000XXXXXXXXXX-	10	12	22
85	05MG002	BOSSHILL CK	-------000000000000XXXXXXXXXX-	10	12	22
86	05MG003	GOPHER CK	-------000000000000XXXXXXXXXX-	10	12	22
87	05MG004	OAK R	-------000000000000XXXXXXXXXX-	10	12	22
88	05MH006	LITTLE SOURIS R	-------------------00XXXXXXXX-	8	2	10
89	05MH007	EPINETTE CK	-------------------0000XXXXXX-	6	4	10
90	05MJ004	STURGEON CK	-------------------000XXXXXXX-	7	3	10
91	05NA005	GIBSON CK	-------000000000000XXXXXXXXXX-	10	12	22
92	05NB011	YELLOWGRASS DITC	-------0000000000XXXXXXXXXXXXX	13	10	23
93	05NB014	JEWEL CK	-------000000000000XX0XXXXXX0-	8	14	22
94	05NB019	COULEE WEST	-----------------000XXX00XXXX-	7	5	12
95	05NE003	PIPESTONE CK	-------0000000000000XXXXXXXXX-	9	13	22
96	05NF002	ANTLER R	-------000000000XXXXXX0XXXXXX-	12	10	22
97	05NF007	GAINSBOROUGH CK	----------------0XXXX000XXXXXX	10	4	14
98	05NF008	GRAHAM CK	----------------00XXX00XXXXXX0	9	5	14
99	05NG010	OAK CK	-------------------00XXXXXXXX-	8	2	10
100	05NG012	ELGIN CK	-------------------00XXXXXXX0-	7	3	10
101	05OA006	WHITEMUD CK	---------0000000000XXXXXXXXXX-	10	10	20
102	05OA007	BADGER CK	---------0000000000XXXXXXXXXX-	10	10	20
103	05OA008	PEMBINA	-------000000000000XXXXXXXXXX-	10	12	22
104	05OA009	WAKOPA	---------0000000000000XXXXXXX-	7	13	20
105	05OB006	CRYSTAL CK	-------------------XXXX0XXXXX-	9	1	10
106	05OB010	LONG R	-------000000000000XXXXXXXXXX-	10	12	22
107	05OB016	SNOWFLAKE CK	---------000000000000XXXXXXXX-	8	12	20
108	05OB021	MOWBRAY CK	---------0000000000000XXXXXXX-	7	13	20
109	05OD001	ROSEAU R	---------XXXXXXXXXXXXXXXXXXXX-	20	0	20
110	05OD004	ROSEAU R	---------00000000000000XXXXXX-	6	14	20
111	05OD014	ROSEAU R	---------0000000000000XXXXXXX-	7	13	20
112	05OE004	RAT R	---------00000000000XXXXXXXXX-	9	11	20
113	05OF015	SHANNON CK	---------00000000000XXXXXXXXX-	9	11	20
114	05OG004	ELM CK 1	-------------------0XXX0XXXXX-	8	2	10
115	C5CG005	ELM CK 2	-------------------0XXXXXXXXX-	9	1	10
116	05OG006	ELM CK 3	-------------------0XXX0XXXXX-	8	2	10
117	05OJ002	COOKS CK	---------000000000XXXXXXXXXXX-	11	9	20
118	05OJ006	COOKS CK	---------00000000000XXXXXXXXX-	9	11	20
119	05OJ008	NETLEY CK	----------------0000XXXXXXXXX-	9	4	13
120	05CJ009	NETLEY CK	-----------------000XXXX0XXXX-	8	4	12
121	05PH003	WHITEMOUTH R	---------0000000XXXXXXXXXXXXX-	13	7	20
122	05SA002	BROKENHEAD R	---------0000000XXXXXXXXXXXX0-	12	8	20
123	05SA004	BROKENHEAD R	---------000000000000XXXXXXXX-	8	12	20
124	05SB002	OSIER CK	-----------------000XXX000XXX-	6	6	12
125	05SC002	ICELANDIC R	-----------------00XXXXXXXXXX-	10	2	12
126	05SD003	FISHER R	-----------------0000XXXXXXXX-	8	4	12
127	05SD004	EAST FISHER R	-------------------0000XXXXXX-	6	4	10
128	06AD001	BEAVER R	----0000000000000000000XXXXXX-	6	19	25
129	06ADC06	BEAVER R	0000000000000000XXXXXXXXXXXXXX	14	16	30
130	07AF002	MCLEOD R	000000000000000XXXXXXXXXXXXXXX	15	15	30
131	07AG001	MCLEOD R	000000000000000000XXXXXXXXX000	9	21	30
132	07AGC03	WOLF CK	000000000000000XXXXXXXXXXXXXXX	15	15	30
133	07BA001	PEMBINA R	000000000000000000XXXXXXXXXX00	10	20	30
134	07BB002	PEMBINA R	000000000000000XXXXXXXXXXXXXXX	15	15	30
135	07BB003	LOBSTICK R	000000000000000XXXXXXXXXXXXXXX	15	15	30
136	07BB004	PADDLE R	00000000000000000000000XXXXXXX	7	23	30
137	07BB005	LITTLE PADDLE R	00000000000000000000000XXXXXXX	7	23	30
138	07BC002	PEMBINA R	000000000000000000XXXXXXXXXXXX	12	18	30
139	07BF001	EAST PRAIRIE R	0000000000000000000XXXXXXXXXXX	11	19	30
140	07BF002	WEST PRAIRIE R	0000000000000000000XXXXXXXXXXX	11	19	30
141	07BJ001	SWAN R	0000000000000000000000XX0XXXXX	7	23	30
142	07GE001	WAPITI R	---------------000000XXXXXXXXX	9	6	15
143	C7GH002	LITTLE SMOKY R	00000000000000000000XXX0XXXXXX	9	21	30
144	07HA003	HEART R	-------------------0000XXXXXXX	7	4	11
145	C7HC001	NOTIKEWIN R	----------------------XXXXXXX-	7	0	7
146	07JF002	BOYER R	-----------------------XXXXXXX	7	0	7
147	07JF003	PONTON R	-----------------------XXXXXXX	7	0	7
148	11AA026	SAGE CK	XX--X-XXXX00XXXXXXXXXXXXXXXXX-	24	2	26
149	11AB009	MIDDLE CK	0000000000XXXXXXXXXXXXXXXXXXX-	19	10	29
150	11AB075	LYONS CK	XXXXXXXX00XXX0XXXXXXXXXX0XXXX-	25	4	29
151	11ABC76	BATTLE CK	XXXXXXXXXXXXXXXXXXXXXXXXXXX00-	27	2	29
152	11ABC82	LODGE CK	00--0-00000XXXXXXXXX0XXXXXXXX-	17	9	26
153	11ABC87	MIDDLE CK	000000000000000000000XXXXXX0X-	7	22	29
154	11AB105	WOODPILE COULEE	XXXXXXXX00XXXXXXXXXXXXXX0XXXX-	26	3	29
155	11AB107	EAST BATTLE CK	XXXXXXXX00XXXXXXXXXXXXXX0XXXX-	26	3	29
156	11AD001	WHITEWATER CK	X-XXXXXXXXXXXXXXXXXXXXXXXXXXX-	28	0	28
157	11AE002	POPLAR R W	XXXXXXXXXXXXX0000000000000000-	13	16	29
158	11AE003	POPLAR R E	XXXX-XXXXXXXXXXXXXXXXXXXXXXXX-	28	0	28
159	11AE005	ROCK CK	XXXXXXXXXXXXXXXXXXXXXX0000X00-	23	6	29
160	11AE008	POPLAR R M	XXXXXXXXXX0XXXXXXXXXXXXXXXXXX-	28	1	29
161	11AE009	ROCK CK	00000000000000000XXXXXXXXX0XX-	11	18	29

ployed is the same 8 month, March to October, period adopted for the annual yield data. This 8 month period is acceptable for the compilation of flood data since no significant flood flows would be expected during the winter season. Since the available hydrometric records are in terms of daily discharges, it was necessary to further define an annual flood event as the highest daily discharge recorded during the annual period. For planning purposes, this value is not as useful as the maximum instantaneous flow. Unfortunately, this measure cannot be estimated from the available daily discharge data. It is possible, for stations with recording gauges, to estimate a correction factor to convert maximum daily discharges into instantaneous peaks; however, no such correction has been attempted in the present study.

From the available daily discharge records, the annual flood series for each of the study basins has been compiled. The highest daily discharge measured in c.f.s. has been recorded for each year of record. Where months or several days of record are missing, the available data have been examined; and where the missing data seem to constitute a low flow period, it has been assumed that the annual flood is contained in the existing record. Where the missing data seem to constitute a period of high flow, no annual flood has been recorded for that year.

Table 3-4 has been prepared to indicate for each study basin the years for which annual flood data have been compiled. The "X" symbols denote the years for which measured data are available; and the total years of measured data are listed in the column headed "ACTUAL YEARS."

TABLE 3-4

ANNUAL PEAK RECORDS *

	STATION ID		YEARS 1940 – 1969	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
1	05AB021	WILLOW CK	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
2	05AE002	LEE CK	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX-	29	0	29
3	C5AEC05	ROLPH CK	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX-	29	0	29
4	05AF010	MANYBERRIES CK	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	30	0	30
5	05AH002	MACKAY CK	0000000000000000XXXXX0XXXXXXXX	13	17	30
6	05AH041	PEIGAN CK	00000000000000000000XXXXXXXXXX	10	20	30
7	05BJ004	ELBOW R	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	30	0	30
8	05BJ005	ELBOW R	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	30	0	30
9	05BK001	FISH CK	0000000000000000XXXXXXXXXXXXXX	14	16	30
10	05BL007	STIMSON CK	XXXXXXXXXXXXXXXXXXXXXXXXXXXX0-	28	1	29
11	05CB001	LITTLE RED DEER	------------000000000XXXXXXXXX	9	9	18
12	05CB002	LITTLE RED DEER	000000000000000000000000XXXXXX	6	24	30
13	05CC001	BLINDMAN R	0000000000000000000000XXXXXXXX	8	22	30
14	05CCCC7	MEDICINE R	0000000000000000000000XXXXXXXX	8	22	30
15	05CE002	KNEEHILLS CK	0000000000000000000XXXXXXXXXXX	11	19	30
16	05CE006	ROSEBUD R	0000000000000000000XXXXXXXXXXX	11	19	30
17	05CG002	BULLPOUND CK	----000000000000000000XXXXXXXX	8	18	26
18	05CK005	ALKALI CK	00000000000000000000000XXXXXXX	7	23	30
19	05CB002	PRAIRIE CK	------------XXXXXXXXXXXXXXXXXX	18	0	18
20	05EA001	STURGEON R	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	30	0	30
21	05EE001	VERMILICN R	----000000000000000XXXXXXXXXXX	11	15	26
22	05FD001	RIBSTONE CK	----000000000000000000XXXXXXXX	8	18	26
23	05FE001	BATTLE R	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
24	05GA003	MONITER CK	----0000000000XXXXXXXXXXXXXXXX	16	10	26
25	C5GC005	EAGLE CK	----000000000000000000XXXXXXX-	7	18	25
26	05GC006	EAGLE CK	----0000000000000000000XXXXXX-	6	19	25
27	05HA003	BEAR CK	00000000000000000000000XXXXXXX	7	23	30
28	05HA015	BRIDGE CK	00000000000000000000000XXXXXX-	6	23	29
29	05HA062	PIAPOT CK	00000000000000000000000XXXXXX-	6	23	29
30	05HA075	SKULL CK	00000000000000000000000XXXXXXX	7	23	30
31	05HD036	SWIFTCURRENT CK	000000000000000XXXXXXXXXXX0XX-	13	16	29
32	05HG002	BRIGHTWATER CK	----0000000000000000X0XXXXXXX-	8	17	25
33	C5JAC02	WOOD R	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
34	05JB003	NOTUKEU CK	X---XXXXXXXXXXXXXXXXXXXXXXXXX-	26	0	26
35	05JE004	MOOSE JAW R	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
36	C5JE006	MOOSE JAW R	----XXXXXXXXXXXXXXXXXXXXXXXXX-	25	0	25
37	05JF005	WASCANA CK	-----XXXXXXXXXXXXXXXXXXXXXXXX-	24	0	24
38	05JF006	BOGGY CK	-----XXXXXX00XXXXXXXXXXXX000X-	19	5	24
39	05JC004	QU'APPELLE R	----XXXXXXXXXXXXXXXXXXXXXXXX0-	24	1	25
40	05JH001	ARM R	----000000000XXXXXXXXXXXXXXXX-	16	9	25
41	05JK0C4	JUMPING DEER CK	-XXXXXXXXXXXXXXXXXXXXXXXXXXXX-	28	0	28
42	C5JLC02	INDIANHEAD CK	-XXX00XXXX0XXXXXXXXXXX0XXXXXX-	24	4	28
43	05JL005	PHEASANT CK	-000000XXXXXXXXXXXXXXXXXXXXXX-	22	6	28
44	05JMC15	CUTARM CK	-000--0000000000XXXXXXXXXXXXX-	13	13	26
45	05KA001	CARROT R	-000000000000000XXXXXXXXXXXXXX	14	15	29
46	05KB003	CARROT R	-00000000000000XXXXXXXXXXXXXXX	15	14	29
47	C5KC001	CARROT R	-00000000000000XXXXXXXXXXXXXXX	15	14	29
48	C5KD002	PETAIGAN R	-000000000000000XXXXXXX000000-	7	21	28
49	C5KE002	TORCH R	----0000000XXXXXXXXXXXXXXXXXX-	18	7	25
50	C5LB002	ETOMAMI R	----00000000000XXXXXXXXXXXXXX-	14	11	25
51	05LC001	RED DEER R	----0000000000XXXXXXXXXXXXXXX-	15	10	25
52	C5LCC04	RED DEER R	----000000000000XXXXXXXXXXXXX-	13	12	25
53	05LD001	OVERFLOWING R	----000000000000XXXXXXXXXXXXX-	13	12	25
54	05LE001	SWAN R	----000000XXXXXXXXXX000000000-	10	15	25
55	C5LE003	BIRCH R	----0000000000XXXXXXXXXXXXXXX-	15	10	25
56	05LE004	WOODY R	----0000000000XXXXXXXXXXXXXXX-	15	10	25
57	C5LE005	ROARING R	-000000000000000000XXXXXXXXXX-	10	18	28
58	C5LE0C6	SWAN R	----00000000000000000XXXXXXXX-	8	17	25
59	05LF001	STEEP ROCK R	-0000000000000XXXXXXXXXXXX0XX-	14	14	28
60	C5LF002	BELL R	-0000000000000XXXXXXXXXXX0XXX-	14	14	28
61	C5LG001	PINE R	-0000000000000XXXXXXXXXXXXXXX-	15	13	28
62	05LG002	GARLAND R	-0000000000000XXXXXXXX0XXXXXX-	14	14	28
63	05LJCC5	OCHER R	-00000000XXXXXXXXXXXXXXXXXXXX-	20	8	28
64	05LJ007	TURTLE R	-00000000XXXXXXXXXXXXXXXXXXXX-	20	8	28
65	C5LJ011	WILSON R	-00000000XXXXXXXXXXXXXXXXXXXX-	20	8	28
66	05LJ012	VERMILION R	-0000000XXXXXXXXXXXXXXXXXXXXX-	21	7	28
67	05LJ015	FISHING R	----0000XXXXXXXXXXXXXX0XXXXXX-	20	5	25
68	C5LJ016	FORK R	-0000000000000XXXXXXXXXXXXXXX-	15	13	28
69	05LJ017	DRIFTING R	-0000000000000XXXXXXXXXXXXXXX-	15	13	28
70	05LJ019	MINK R	-000000000000000XXXXXXXXXXXXX-	13	15	28
71	C5LJ022	EDWARDS CK	-0000000000000000XXXXXXXXXXXX-	12	16	28
72	05LLCC7	PINE CK	-000000000000000000XXXXXXXXXX-	10	18	28
73	05LLC09	NEEPAWA CK	0000000000000000000XXXXXXXXXX-	10	19	29
74	05LL013	WHITEMUD R	000000000000000000000XXXXXXXX-	8	21	29
75	05MB001	YORKTON CK	-XXXXX0X0X0XXXXXXXXXXXXXXXXXX-	25	3	28
76	05MB004	WHITESAND R	-0000000000000000XX0X0XX0XXXX-	9	19	28
77	05MC001	ASSINIBOINE R	-000XXXXXXXXXXXXXXXXXXXX0XXXX-	24	4	29
78	05MC002	STONY CK	----0000000000000XXX0XXXXXXXX-	11	14	25
79	05MD005	SHELL R	-0000000XXXXXXXXXXXXXXX0XXXXX-	20	8	28
80	05MDC06	LITTLE BOGGY CK	-0000000000000000XXXXXXXXXXXX-	12	16	28
81	05MC003	BIRDTAIL CK	-0000000000000XXXXXXXXXXXXXXX-	15	13	28

* THE SYMBOL X INDICATES YEARS WITH ACTUAL MEASURED RECORDS AND THE SYMBOL 0 INDICATES YEARS FOR WHICH RECORDS HAVE BEEN EXTENDED BY CORRELATION ANALYSIS

TABLE 3-4 CONTINUED

	STATION ID		YEARS 1940 – 1969	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
82	05MFC01	MINNEDOSA R	----000000000000000XXXXXXXXXX-	10	15	25
83	05MF008	ROLLING R	----00000000000000000XXXXXXXX-	8	17	25
84	05MG001	ARROW R	---0000000000000000XXXXXXXXXX0	10	17	27
85	05MG002	BOSSHILL CK	---0000000000000000XXXXXXXXXX0	10	17	27
86	05MG003	GOPHER CK	----000000000000000XXXXXXXXXX-	10	15	25
87	05MG004	OAK R	----000000000000000XXXXXXXXXX-	10	15	25
88	05MH006	LITTLE SOURIS R	---000000000000000000XXXXXXXX-	8	18	26
89	05MH007	EPINETTE CK	000000000000000000000X0XXXXXX-	7	22	29
90	05PJ004	STURGEON CK	000000000000000000000XXXXXXXX-	8	21	29
91	05NA005	GIBSON CK	-000000000000000000XXXXXXXXXX-	10	18	28
92	05NBC11	YELLOWGRASS DITC	0000-000000000000XXXXXXXXXXXXX	13	16	29
93	05NB014	JEWEL CK	0000-00000000000000XX0XXXXXX0-	8	20	28
94	C5NB019	COULEE WEST	---00000000000000000XXX00XXXX-	7	19	26
95	05NE003	PIPESTONE CK	---00000000000000000XXXXXXXXX0	9	18	27
96	05NF002	ANTLER R	---XXXXXXXXXXXXXXXXXXX0XXXXXX-	25	1	26
97	C5NF007	GAINSBOROUGH CK	---0000000000000XXXX000XXXXXXX	11	16	27
98	05NF008	GRAHAM CK	---000000000000000XX00XXXXXXX0	9	18	27
99	05NG010	OAK CK	---000000000000000000XXXXXXXX-	8	18	26
100	05NG012	ELGIN CK	-00000000000000000000XXXXXXX0-	7	21	28
101	05OA006	WHITEMUD CK	---0000000000000000XXXXXXXXXX-	10	16	26
102	05CACC7	BADGER CK	---0000000000000000XXXXXXXXXX-	10	16	26
103	05OA008	PEMBINA	---0000000000000000XXXXXXXXXX0	10	17	27
104	05CA009	WAKOPA	---0000000000000000000XXXXXXX-	7	19	26
105	05OB006	CRYSTAL CK	---0000000000000000XXX0XXXXXX-	9	17	26
106	05OB010	LONG R	---0000000000000000XXXXXXXXXX0	10	17	27
107	05GB016	SNOWFLAKE CK	000000000000000000000XXXXXXXX-	8	21	29
108	C5CB021	MOWBRAY CK	0000000000000000000000XXXXXXX-	7	22	29
109	05OD001	ROSEAU R	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX-	29	0	29
110	05CD004	ROSEAU R	0000000000000000000000XXXXXXX-	7	22	29
111	05OD014	ROSEAU R	0000000000000000000000XXXXXXX-	7	22	29
112	05OEC04	RAT R	---00000000000000000XXXXXXXXX-	9	17	26
113	05CFC15	SHANNON CK	00000000000000000000XXXXXXXXX-	9	20	29
114	05OG004	ELM CK 1	00000000000000000000XXX0XXXXX-	8	21	29
115	05OG005	ELM CK 2	00000000000000000000XXXXXXXXX-	9	20	29
116	05OG006	ELM CK 3	00000000000000000000XXX0XXXXX-	8	21	29
117	05OJ0C2	COOKS CK	---00000000000000XXXXXXXXXXXX-	12	14	26
118	05OJ006	COOKS CK	---00000000000000000XXXXXXXXX-	9	17	26
119	05CJ008	NETLEY CK	---00000000000000000XXXXXXXXX-	9	17	26
120	05CJC09	NETLEY CK	---00000000000000000XXXXXXXXX-	9	17	26
121	05PH003	WHITEMOUTH R	---XXXXXXXXXXXXXXXXXXXXXXXXXX-	26	0	26
122	05SA002	BROKENHEAD R	---XXXXXXXXXXXXXXXXXXXXXXXXXX-	26	0	26
123	05SA004	BROKENHEAD R	---00000000000000000XXXXXXXXX-	9	17	26
124	05SB002	OSIER CK	---------00000000000XXXX0XXXX-	8	12	20
125	05SC002	ICELANDIC R	---0000000000000000XXXXXXXXXX-	10	16	26
126	05SD003	FISHER R	---000000000000000000XXXXXXXX-	8	18	26
127	05SDC04	EAST FISHER R	---------000000000000XXXXXXXX-	8	12	20
128	06AD001	BEAVER R	00000000000000000000XXXXXXXXX0	9	21	30
129	06AD006	BEAVER R	----000000000000XXXXXXXXXXXXXX	14	12	26
130	07AF002	MCLEOD R	------------000XXXXXXXXXXXXXXX	15	3	18
131	C7AG001	MCLEOD R	000000000000000000XXXXXXXXXX00	10	20	30
132	07AG003	WOLF CK	------------000XXXXXXXXXXXXXXX	15	3	18
133	C7BA001	PEMBINA R	------------0000XXXXXXXXXXXX00	12	6	18
134	07BB002	PEMBINA R	------------000XXXXXXXXXXXXXXX	15	3	18
135	07BB003	LOBSTICK R	000000000000000XXXXXXXXXXXXXXX	15	15	30
136	07BB004	PADDLE R	00000000000000000000000XXXXXXX	7	23	30
137	07BB005	LITTLE PADDLE R	00000000000000000000000XXXXXXX	7	23	30
138	07BC002	PEMBINA R	000000000000000000XXXXXXXXXXXX	12	18	30
139	07BF001	EAST PRAIRIE R	---------------0000XXXXXXXXXXX	11	4	15
140	07BF002	WEST PRAIRIE R	0000000000000000000XXXXXXXXXXX	11	19	30
141	07BJ001	SWAN R	----------------------XX-XXXXX	7	0	7
142	07GE001	WAPITI R	-------------------00XXXXXXXXX	9	2	11
143	C7GHC02	LITTLE SMOKY R	00000000000000000000XXX0XXXXXX	9	21	30
144	C7HA003	HEART R	-------------------0000XXXXXXX	7	4	11
145	C7HC001	NOTIKEWIN R	---------------------XXXXXXXXX	9	0	9
146	C7JFC02	BOYER R	----------------------XXXXXXXX	8	0	8
147	07JF003	PONTON R	-----------------------XXXXXXX	7	0	7
148	11AA026	SAGE CK	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX-	29	0	29
149	11AB009	MIDDLE CK	0000000000XXXXXXXXXXXXXXXXXXX-	19	10	29
150	11AB075	LYONS CK	XXXXXXX00XXX0XXXXXXXXXXX0XXXX-	25	4	29
151	11AB076	BATTLE CK	XXXXXXXXXXXXXXXXXXXXXXXXXXX00-	27	2	29
152	11ABC82	LODGE CK	00000000000XXXXXXXXXXXXXXXXXX-	18	11	29
153	11ABC87	MIDDLE CK	000000000000000000000XXXXXXXX-	8	21	29
154	11AB105	WOODPILE COULEE	XXXXXXX00XXXXXXXXXXXXXXX0XXXX-	26	3	29
155	11AB1C7	EAST BATTLE CK	XXXXXXX00XXXXXXXXXXXXXXX0XXXX-	26	3	29
156	11AD001	WHITEWATER CK	X-XXXXXXXXXXXXXXXXXXXXXXXXXXX-	28	0	28
157	11AE002	POPLAR R W	XXXXXXXXXXXXX0000000000000000-	13	16	29
158	11AE003	POPLAR R E	XXXX-XXXXXXXXXXXXXXXXXXXXXXXX-	28	0	28
159	11AE005	ROCK CK	XXXXXXXXXXXXXXXXXXXXXX0000X00-	23	6	29
160	11AE008	POPLAR R M	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX-	29	0	29
161	11AE009	ROCK CK	00000000000000000XXXXXXXXX0XX-	11	18	29

3.3.2.3.1 The Seasonal Distribution of Flood Flows. The seasonal distribution of flood flows was examined with the intention of considering the homogeneity of the flood series. In any frequency analysis, it is assumed that the data set being analysed is homogeneous, that is, it is representative of a single population. Previous work on prairie flood flow analysis has identified three distinct types of flood (Durrant 1954, p. 96). The three types are identified on the basis of causal factors, the first type being the result of snowmelt, the second type being the result of snowmelt and rainfall combined, and the third type being the result of rainfall. The examination of the seasonal distribution of flood flows was intended to provide a basis for some general conclusions regarding the relative importance of the three flood types.

For each of the 161 study basins, the flood flow data series was examined and a tally of the flood events occurring in each month was compiled. The pattern was generally consistent from basin to basin and may be illustrated by the combined tally for all basins as reproduced in Table 3-5. The data in the table indicate that approximately 90% of the peaks included in the annual flood series occurred during the spring months from March to June with a definite peak in April. These floods are most likely to be of the first two types resulting from snowmelt, and snowmelt in combination with rainfall. The remaining 10% of the annual peaks were recorded during the summer and fall season from July to October. These events are most likely of the third type resulting from rainfall.

In the present study, no attempt has been made to separate out the three types of flood events. The inclusion of Table 3-5 is intended

TABLE 3-5 - SEASONAL DISTRIBUTION OF RECORDED ANNUAL FLOOD FLOW COMBINING RECORDS FOR ALL STUDY BASINS

Month	Annual Flood Events Occurrences	% of Total
March	412	17.5
April	1033	44.0
May	388	16.5
June	284	12.1
July	138	5.9
August	63	2.7
September	22	0.9
October	8	0.3
TOTAL	2348	

only to provide some indication of the relative importance of summer and fall peaks. In the present analysis the records have been treated as if drawn from a single homogeneous population. Depending on the results of the present study, further research may be required into the frequency analysis of flood events for each of the three groupings.

3.3.2.4 Test of Serial Correlation in the Study Basin Data Series

One of the assumptions basic to any frequency analysis is that the sample data are a series of independent events. As discussed earlier in this Chapter, some hydrologic data series such as daily flows do not meet this assumption. However, other series in which the basic time interval is longer, as in the case of annual yields and annual flood peaks, are often assumed for analysis purposes to satisfy the assumption of independent events.

A simple measure of the degree of dependence between successive events in a sample data series is provided by serial correlation coefficients. In the present study serial correlation coefficients based on a lag of one year were computed for each of the 161 study basins for both the annual yield data series and the annual peak data series. The serial correlation coefficients calculated were then tested for significance on the basis of sample size "n" and their calculated "r" values. A table of critical values of the correlation coefficient "r" was employed (for an example of such a table see Crow, Davis and Maxfield 1960, p. 241). The results of the computations and significance tests are presented in summarized form in Table 3-6. In all cases, the serial correlation coefficients for a one year lag

TABLE 3-6 - SUMMARY OF THE RESULTS OF THE SERIAL CORRELATION ANALYSIS FOR THE ANNUAL YIELD AND ANNUAL FLOOD PEAK DATA SERIES
(Lag = 1 year)

Data Series	No. of Records Tested	Significance of Serial Correlation Coefficients (Lag = 1 year)	
		No. Significant at 5% Level	No. Significant at 1% Level
Annual Yield Data	161	5	3
Annual Flood Flow Data	161	5	2

were weak. Of the 161 annual yield data series tested, only five records resulted in a significant serial correlation coefficient at the 5% significance level and only 3 were significant at the 1% significance level. Of the 161 annual flood peak data series tested only 5 records resulted in a significant serial correlation coefficient at the 5% significance level and only 2 were significant at the 1% significance level. On the basis of these results, the assumption was confirmed that both the annual yield data series and the annual flood peak data series for the study basins approximate the assumption of independent events.

3.3.2.5 Extension of Available Records by Correlation and Regression

As discussed in earlier sections, the frequency analysis of any series of hydrologic data is based on the assumption that the past records represent a sample of random independent events drawn from a very large or infinite population. The available data series usually comprise relatively small samples; and the results of the analysis are sensitive to the chance inclusion in the sample of exceptionally large or exceptionally small events. The variability resulting from small samples has been well illustrated in the previously discussed theoretical flood frequency study by Benson (1960). The effects of small samples on the reliability of the estimate of the mean has been documented in articles by Matalas and Langbein (1955), and by Hidore (1963). Probably the best solution to this problem of variability in short records lies in the compilation of longer data series. However the time-consuming nature of hydrologic data collection usually precludes this solution. It remains for the individual researcher to make the most efficient use possible of the available data (Clark and Bruce 1966, p. 128; and Langbein and Hardison 1955, p. 1). One solution to the problem is the use of correlation and regression analysis to extend short records on the basis of their relationships to other nearby stations for which longer records are available. The resulting longer records are better bases for the estimation of population parameters (Searcy 1969, p. 69).

In regional frequency analyses, where frequency curves from several stations are being compared, there is the added consideration of the comparability of curves based on short records of variable length. When records are being combined, it is assumed that these sampled data series represent comparable sequences. If a common base period can be defined, the time variability can be minimized and the effects of other factors more easily analysed (Dalrymple 1960, p. 33). Dalrymple (1960) described the use of extended records in a regional analysis of flood frequencies. His method does not employ the extended data directly in the analysis, but rather, uses them to adjust the order numbers assigned to the measured peaks with respect to a selected base period. The base period chosen is normally as long as possible and an attempt is made to extend and fill in all records for the full period.

Langbein (1960, p. 28) suggests several alternative approaches to streamflow record extension by correlation and regression. The simplest approach is that discussed above in which a short-term record is extended by correlation with a long-term record from a nearby station. Other approaches include correlation with long-term precipitation records and multiple correlation with both long-term streamflow and precipitation records. In most cases a simple correlation with a single long-term hydrometric station provides satisfactory results.

The actual correlation and regression analysis may be carried out by either numerical or graphical techniques (Searcy 1960). The analysis may be of daily, monthly or annual data sets depending on the purpose of the extension. The actual variates may be employed in their arithmetic form, or in the case of skewed data, logarithmic transformations may improve the relationships.

3.3.2.5.1 Record Extension in the Present Study. In the present study, it is proposed to employ regional analysis techniques to investigate the relationships between streamflow characteristics and climatic and other physical geographic patterns. The streamflow characteristics are being estimated initially by the single-station frequency analyses of the available annual yield and annual flood flow data series. In order to facilitate the regional analyses of the streamflow characteristics derived from the single-station records, it is desirable to employ comparable data sets (Dalrymple 1960, p. 33). The actual data records available for the selected study basins are comparable neither in terms of length nor in terms of the time periods covered (see Tables 3-3 and 3-4 for available actual data records for annual yields and annual flood flows, respectively). In order to provide more comparable data series for the study basins, an attempt has been made to extend short records and fill in missing records by correlation with the available long-term stations. It was intended that these record extensions would result in a full 30 year record, 1940 to 1969, for both annual yields and annual flood flows, for each of the study basins. Unfortunately, the limited number of long-term (30 year) records available precluded this aim; and instead, each of the station records of both annual yields and annual flood flows has been extended as much as possible up to the full 30 year period. The extended data series provide the basic data sets employed in the frequency analyses for each of the study basins.

3.3.2.5.2 Methodology of Record Extension Employed. Record extension in this study has been accomplished by the use of simple linear regression analysis relating the short-term record or dependent variable, to the long-term record or independent variable. The regression equations calculated are based on either the original arithmetic data series or their logarithmic transformations, whichever provided the strongest relationship. The long-term station employed in each case has been chosen on the basis of proximity to the station for which the records are being extended, the length of record available, and the strength of the relationship as indicated by the significance level of the correlation coefficient.

Preparatory to selecting the station combinations to be employed in the record extensions, a map showing the locations of the study basins and the length of actual records for both annual yields and annual peaks was prepared. From this map the most likely station combinations for record extension were identified. In addition to the above map, correlation coefficients for all possible basin pair combinations were calculated for the relationships of both the available annual yield data series and the available flood flow data series. These correlation coefficients and their significance levels were calculated on IBM 360-67 computer* employing the Pearson Correlation Program of the "Statistical Package for the Social Sciences" (for program description see Nie, Bent and Hull 1969, p. XIII-7 ff.). The correlation

*Unless otherwise stated all calculations in this study have been made on the IBM 360-67 of the Computing Centre of the University of Alberta.

analyses were made on both the arithmetic data and the transformed logarithmic data. These analyses resulted in four separate 161 x 161 correlation matrices, two for the annual yield data and two for the annual flood flow data. For each of the data sets the first matrix was based on the arithmetic data and the second on the logarithmic data.

For each of the likely station combinations as identified above, the correlation coefficients and their significance levels were extracted from the correlation matrices. In each case, the nearby long-term station which provided the strongest arithmetic or logarithmic correlation was selected as the independent variable for the regression analysis. The regression equations calculated by the method of least squares were employed subsequently to extend and fill in the data series for the short-term station. These procedures were repeated for both the annual yield data and the annual flood flow data for each of the stations. In cases for which the actual data records were already complete or nearly complete, no record extension has been made. In other cases no nearby long-term stations showed significant correlations (at least at the 0.10 level) and no record extension was possible.

Tables 3-7 and 3-8 summarize the record extension by correlation and regression analysis for the annual yield data series and the annual flood flow data series, respectively. The information summarized in the tables is as follows:

Column 1 - Identification of study basin for which records are being extended
Column 2 - Identification of the long-term or base station employed as the independent variable in the regression analysis
Column 3 - Indicates whether the regression analysis was made on the logarithmically transformed data

TABLE 3-7

YIELD DATA RECORD EXTENSION BY CORRELATION AND REGRESSION

	DEPENDENT VARIABLE STATION I D		INDEPENDENT VARIABLE STATION I D		RESULTS OF CORRELATION AND REGRESSION LOG TRANS	R	N	SIG LEVEL	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
1	05AB021	WILLOW CK		NO RECORD EXTENSION					25	0	25
2	C5AE002	LEE CK		NO RECORD EXTENSION					29	0	29
3	05AE005	ROLPH CK	152	11AA025	NO	0.924	27	.001	28	1	29
4	05AF010	MANYBERRIES CK	148	11AA026	NO	0.940	12	.001	13	14	27
5	05AH002	MACKAY CK	151	11AB076	YES	0.730	12	.003	13	17	30
6	05AH041	PEIGAN CK	151	11AB076	YES	0.976	7	.001	10	20	30
7	C5BJ004	ELBOW R	8	05BJ005	YES	0.945	18	.001	18	12	30
8	05BJ005	ELBOW R		NO RECORD EXTENSION					30	0	30
9	C5BK001	FISH CK	8	05BJ005	YES	0.848	14	.001	14	16	30
10	05BL007	STIMSON CK	1	05AB021	YES	0.964	23	.001	25	2	27
11	05CB001	LITTLE RED DEER	8	05BJ005	YES	0.843	9	.002	9	21	30
12	05CB002	LITTLE RED DEER	8	05BJ005	YES	0.907	6	.006	6	24	30
13	05CC001	BLINDMAN R	20	05EA001	YES	0.966	7	.001	7	23	30
14	05CC007	MEDICINE R	20	05EA001	YES	0.976	6	.001	6	24	30
15	05CE002	KNEEHILLS CK	151	11AB076	YES	0.779	8	.011	11	19	30
16	C5CE006	ROSEBUD R	148	11AA026	YES	0.842	10	.001	11	16	26
17	05CG002	BULLPCUND CK	20	05EA001	NO	0.803	8	.008	8	22	30
18	C5CK005	ALKALI CK	151	11AB076	NO	0.975	4	.012	7	23	30
19	05CB002	PRAIRIE CK	8	05BJ005	NO	0.725	18	.001	18	12	30
20	05EA001	STURGEON R		NO RECORD EXTENSION					30	0	30
21	05EE001	VERMILION R	23	05FE001	NO	0.884	10	.001	11	15	26
22	05ED001	RIBSTONE CK	23	05FE001	YES	0.930	7	.001	8	18	26
23	05FE001	BATTLE R		NO RECORD EXTENSION					25	0	25
24	05GA003	MONITER CK	23	05FE001	NO	0.819	15	.001	16	10	26
25	05GC005	EAGLE CK	23	05FE001	YES	0.877	6	.011	6	19	25
26	C5GC006	EAGLE CK	23	05FE001	YES	0.866	6	.013	6	19	25
27	05HA003	BEAR CK	154	11AB105	YES	0.830	6	.015	7	23	30
28	05HA015	BRIDGE CK	150	11AB075	YES	0.970	6	.001	6	23	29
29	05HA062	PIAPOT CK	151	11AB076	YES	0.870	6	.013	6	23	29
30	05HAC75	SKULL CK	154	11AB105	NO	0.630	6	.079	7	23	30
31	05HD036	SWIFTCURRENT CK	154	11AB105	YES	0.890	13	.001	13	16	29
32	05HG002	BRIGHTWATER CK	151	11AB076	NO	0.890	5	.022	7	22	29
33	05JA002	WOOD R	158	11AE003	YES	0.839	12	.001	12	16	28
34	05JB003	NCTLKEU CK	158	11AE003	YES	0.738	12	.003	12	16	28
35	05JE004	MOOSE JAW R	37	05JF005	NO	0.825	16	.001	16	7	23
36	05JE006	MOOSE JAW R	37	05JF005	NO	0.897	15	.001	15	8	23
37	05JF005	WASCANA CK	42	05JL002	YES	0.831	20	.001	22	3	25
38	05JF006	BOGGY CK	37	05JF005	YES	0.984	12	.001	12	11	23
39	C5JG004	QU'APPELLE R	33	05JA002	YES	0.587	11	.029	24	1	25
40	05JH001	ARM R	37	05JF005	YES	0.899	14	.001	14	9	23
41	05JK004	JUMPING DEER CK		NO RECORD EXTENSION					28	0	28
42	05JL002	INDIANHEAD CK	41	05JK004	YES	0.771	23	.001	23	5	28
43	05JL005	PHEASANT CK	41	05JK004	YES	0.959	21	.001	21	7	28
44	05JM015	CUTARM CK	75	05MB001	YES	0.590	12	.022	12	4	16
45	C5KA001	CARROT R	41	05JK004	YES	0.883	12	.001	13	16	19
46	05KB003	CARROT R	41	05JK004	YES	0.949	14	.001	15	14	29
47	05KC001	CARROT R	41	05JK004	NO	0.865	14	.001	15	14	29
48	C5KD0C2	PETAIGAN R	41	05JK004	YES	0.997	7	.001	7	21	28
49	05KE002	TORCH R	41	05JK004	NO	0.727	16	.001	16	12	28
50	C5LB002	ETOMAMI R	43	05JL005	YES	0.692	11	.009	11	11	22
51	05LC001	RED DEER R	43	05JL005	NO	0.644	12	.012	12	10	22
52	05LC004	RED DEER R	43	05JL005	NO	0.649	11	.015	11	11	22
53	05LD001	OVERFLOWING R	47	05KC001	NO	0.571	11	.023	11	4	15
54	05LE001	SWAN R	43	05JL005	NO	0.722	9	.021	9	13	22
55	05LE003	BIRCH R	43	05JL005	NO	0.781	12	.001	12	10	22
56	C5LEC04	WOODY R	43	05JL005	NO	0.845	12	.001	12	10	22
57	C5LE005	ROARING R	43	05JL005	NO	0.878	8	.002	8	14	22
58	C5LE006	SWAN R	43	05JL005	NO	0.885	8	.002	8	14	22
59	05LF0C1	STEEP ROCK R	43	05JL005	NO	0.705	11	.008	11	11	22
60	05LF002	BELL R	43	05JL005	NO	0.755	10	.006	10	12	22
61	05LG001	PINE R	43	05JL005	NO	0.694	12	.006	12	10	22
62	05LG002	GARLAND R	43	05JL005	NO	0.649	11	.015	11	11	22
63	05LG005	OCHER R	43	05JL005	NO	0.728	13	.002	13	9	22
64	05LJ0C7	TURTLE R	43	05JL005	NO	0.776	12	.002	12	10	22
65	05LJ011	WILSON R	43	05JL005	NO	0.915	12	.001	12	10	22
66	05LJ012	VERMILION R	43	05JL005	NO	0.763	12	.002	12	10	22
67	C5LJ015	FISHING R	43	05JL005	YES	0.625	11	.020	11	11	22
68	05LJ016	FORK R	43	05JL005	NO	0.728	13	.002	13	9	22
69	C5LJ017	DRIFTING R	42	05JL002	YES	0.762	13	.002	13	12	25
70	05LJ019	MINK R	41	05JK004	NO	0.641	13	.009	13	15	28
71	05LJ022	EDWARDS CK	43	05JK005	NO	0.681	12	.007	12	10	22
72	05LL007	PINE CK	75	05MB001	YES	0.712	10	.011	10	6	16
73	05LL009	NEEPAWA CK	43	05JL005	NO	0.765	10	.005	10	12	22
74	C5LL013	WHITEMUD R	109	0500001	YES	0.590	8	.062	8	12	20
75	05MB001	YORKTON CK		NO RECORD EXTENSION					16	0	16
76	05MB004	WHITESAND R	43	05JL005	NO	0.845	9	.002	9	13	22
77	C5MC001	ASSINIBOINE R	43	05JL005	NO	0.770	12	.003	11	11	22
78	C5MC002	STONEY CK	42	05JL002	NO	0.747	11	.004	11	14	25
79	05MD005	SHELL R	43	05JL005	NO	0.646	11	.016	11	11	22
80	C5MD006	LITTLE BOGGY CK	43	05JL005	NO	0.648	12	.011	12	10	22
81	05ME003	BIRDTAIL CK	43	05JL005	YES	0.740	12	.003	12	10	22

TABLE 3-7 CONTINUED

CEPENDENT VARIABLE STATION I D	INDEPENDENT VARIABLE STATION I D	RESULTS OF CORRELATION AND REGRESSION LOG TRANS	R	N	SIG LEVEL	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
82 C5ME001 MINNEDOSA R	43 05JL005	NO	0.705	10	.011	10	12	22
83 05MF008 ROLLING	43 05JL005	NO	0.732	8	.020	8	14	22
84 05MG001 ARROW R	43 05JL005	NO	0.882	10	.001	10	12	22
85 05MG001 BOSSHILL CK	43 05JL005	NO	0.745	10	.007	10	12	22
86 05MG002 GOPHER CK	43 05JL005	NO	0.763	10	.005	10	12	22
87 C5MG0C4 CAK R	43 05JL005	NO	0.867	10	.001	10	12	22
88 05MH0C6 LITTLE SOURIS R	86 05MG003	YES	0.571	8	.070	8	2	10
89 05MH007 EPINETTE CK	101 050A006	YES	0.980	6	.001	6	4	10
90 05MJ004 STURGEON CK	125 05SC002	YES	0.757	7	.024	7	3	10
91 05NA005 GIBSON CK	43 05JL005	NO	0.915	10	.001	10	12	22
92 C5NB011 YELLOWGRASS DITC	43 05JL005	NO	0.873	12	.001	13	10	23
93 05NB014 JEWEL CK	43 05JL005	NO	0.809	8	.008	8	14	22
94 05NB019 COULEE WEST	92 05NB011	YES	0.831	7	.010	7	5	12
95 05NE002 PIPESTONE CK	43 05JL005	NO	0.819	9	.003	9	13	22
96 C5NF002 ANTLER R	95 05NE003	NO	0.919	8	.001	12	2	14
97 05NF007 GAINSBOROUGH CK	96 05NF002	NO	0.978	10	.001	10	3	13
98 C5NF008 GRAHAM CK	96 05NF002	NO	0.897	9	.001	9	4	13
99 05NG010 OAK CK	101 050A006	YES	0.751	8	.016	8	2	10
100 05NG012 ELGIN CK	102 050A007	YES	0.858	7	.007	7	3	10
101 050A006 WHITEMUD CK	109 050D001	NO	0.636	10	.024	10	10	20
102 05CA0C7 BADGER CK	109 050D001	NO	0.559	10	.046	10	10	20
103 C50A0C8 PEMBINA	43 05JL005	NO	0.620	10	.028	10	12	22
104 C50A009 WAKOPA	109 050D001	YES	0.634	7	.063	7	13	20
105 05CBC06 CRYSTAL CK	106 050B010	YES	0.643	9	.031	9	1	10
106 05CB010 LONG R	43 05JL005	NO	0.897	10	.001	10	12	22
107 050B016 SNOWFLAKE CK	109 050D001	NO	0.663	8	.037	8	12	20
108 05CB021 MOWBRAY CK	109 050D001	NO	0.655	7	.055	7	13	20
109 05CD001 ROSEAU R	NO RECORD EXTENSION					20	0	20
110 C5CD004 ROSEAU R	109 050D001	NO	0.983	6	.001	6	14	20
111 C5CD014 ROSEAU R	109 050D001	NO	0.981	7	.001	7	13	20
112 050E004 RAT R	109 050D001	NO	0.956	9	.001	9	11	20
113 05CF015 SHANNON CK	109 050D001	YES	0.580	9	.C51	9	11	20
114 05CG004 ELM CK 1	73 05LL009	NO	0.707	8	.025	8	2	10
115 050G005 ELM CK 2	73 05LL0C9	NO	0.707	9	.017	9	1	10
116 05CG006 ELM CK 3	73 05LL009	NO	0.666	8	.036	8	2	10
117 C5CJ002 COOKS CK	109 050D001	NO	0.635	11	.018	11	9	20
118 C5CJ006 COOKS CK	109 050D001	NO	0.621	9	.037	9	11	20
119 C5CJ008 NETLEY CK	122 05SA002	NO	0.659	8	.038	9	4	13
120 05CJ0C9 NETLEY CK	64 05LJ0C7	NO	0.663	8	.037	8	4	12
121 05PH003 WHITEMOUTH R	109 050D001	NO	0.863	13	.001	13	7	20
122 C5SA002 BROKENHEAD R	109 050D001	NO	0.774	20	.002	12	8	20
123 05SA0C4 BROKENHEAD R	109 050D001	NO	0.861	8	.003	8	12	20
124 C5SB002 CSIER CK	65 05LJ011	YES	0.787	6	.032	6	6	12
125 C5SC002 ICELANDIC R	64 05LJ007	YES	0.597	10	.034	10	2	12
126 C5SD003 FISHER R	64 05LJ007	NO	0.835	8	.005	8	4	12
127 05SD004 EAST FISHER R	125 05SC002	YES	0.930	6	.004	6	4	10
128 C6AD0C1 BEAVER R	23 05FE001	YES	0.927	6	.004	6	19	25
129 06AC006 BEAVER R	20 05EA001	NO	0.656	14	.005	14	16	30
130 C7AF0C2 MCLEOD R	8 05BJ005	YES	0.547	15	.017	15	15	30
131 C7AG001 MCLEOD R	20 05EA001	YES	0.764	9	.008	9	21	30
132 C7AG003 WOLF CK	20 05EA001	YES	0.552	15	.016	15	15	30
133 C7BA001 PEMBINA R	20 05EA001	YES	0.825	10	.002	10	20	30
134 C7B8002 PEMBINA R	20 05EA001	YES	0.599	15	.009	15	15	30
135 C7BB0C3 LOBSTICK R	20 05EA001	YFS	0.917	15	.001	15	15	30
136 C7BB0C4 PADDLE R	20 05EA001	YES	0.965	7	.001	7	23	30
137 C7BB0C5 LITTLE PADDLE R	20 05EA001	YES	0.976	7	.001	7	23	30
138 C7BC002 PEMBINA R	20 05FA001	YES	0.921	12	.001	12	18	30
139 C7BF0C1 EAST PRAIRIE R	20 05EA001	YES	0.687	11	.010	11	19	30
140 C7BF002 WEST PRAIRIE R	20 05EA001	YES	0.655	11	.014	21	9	30
141 C7BJ001 SWAN R	20 05EA001	YES	C.710	7	.037	7	23	30
142 07CE001 WAPITI R	132 07AG0C3	NO	0.720	9	.014	9	6	15
143 C7CH002 LITTLE SMOKY R	20 05EA001	YES	0.912	9	.001	9	21	30
144 07HA003 HEART R	140 07BF002	YES	0.775	7	.020	7	4	11
145 07HC001 NOTIKEWIN R	NO RECORD EXTENSION					7	0	7
146 07JF002 BOYER R	NO RECORD EXTENSION					7	0	7
147 C7JF003 PONTON R	NO RECORD EXTENSION					7	0	7
148 11AA026 SAGE CK	149 11AB009	YES	0.889	17	.001	24	2	26
149 11AB009 MIDDLE CK	151 11AB076	YES	0.918	17	.001	19	10	29
150 11ABC75 LYONS CK	151 11AB076	YES	0.803	23	.001	25	4	29
151 11AB076 BATTLE CK	150 11AB075	YES	0.803	23	.001	27	2	29
152 11AB082 LODGE CK	148 11AA027	NO	0.938	17	.001	17	9	26
153 11ABC87 MIDDLE CK	151 11AB076	YES	0.870	7	.012	7	22	29
154 11AB105 WOODPILE COULEE	156 11AD001	YES	0.699	25	.001	26	3	29
155 11AB107 EAST BATTLE CK	156 11AD001	YES	0.742	25	.001	26	3	29
156 11AD001 WHITEWATER CK	NO RECORD EXTENSION					28	0	28
157 11AE002 POPLAR R W	160 11AE008	YES	0.915	12	.001	13	16	29
158 11AE003 POPLAR R E	NO RECORD EXTENSION					28	0	28
159 11AE005 ROCK CK	158 11AE003	YES	0.836	22	.001	23	6	29
160 11AE008 POPLAR R M	157 11AE002	YES	0.915	12	.001	28	1	29
161 11AE0C9 ROCK CK	159 11AE005	YES	1.000	5	.001	11	18	29

TABLE 3-8

PEAK DATA RECORD EXTENSION BY CORRELATION AND REGRESSION

	DEPENDENT VARIABLE		INDEPENDENT VARIABLE		RESULTS OF CORRELATION AND REGRESSION						
	STATION I D		STATION I D		LOG TRANS	R	N	SIG LEVEL	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
1	05AB021	WILLOW CK	NO RECORD EXTENSION						25	0	25
2	C5AE002	LEE CK	NO RECORD EXTENSION						29	0	29
3	C5AE005	ROLPH CK	NO RECORD EXTENSION						29	0	29
4	05AF010	MANYBERRIES CK	NO RECORD EXTENSION						30	0	30
5	05AH002	MACKAY CK	150	11AB075	NO	0.730	12	.005	13	17	30
6	05AH041	PEIGAN CK	151	11AB076	NO	0.960	7	.001	10	20	30
7	C5BJ004	ELBOW R	NO RECORD EXTENSION						30	0	30
8	C5BJ005	ELBOW R	NO RECORD EXTENSION						30	0	30
9	05BK001	FISH CK	8	05BJ005	YES	0.891	14	.001	14	16	30
10	05BL007	STIMSON CK	1	05AB021	NO	0.880	24	.001	28	1	29
11	C5CB001	LITTLE RED DEER	19	05DB002	NO	0.711	9	.016	9	9	18
12	05CB002	LITTLE RED DEER	7	05BJ004	YES	0.787	6	.032	6	24	30
13	05CC001	BLINDMAN R	20	05EA001	YES	0.719	8	.022	8	22	30
14	C5CC007	MEDICINE R	20	05EA001	YES	0.636	8	.045	8	22	30
15	05CE002	KNEEHILLS CK	20	05EA001	NO	0.624	11	.020	11	19	30
16	C5CE006	ROSEBUD R	20	05EA001	NO	0.575	11	.032	11	19	30
17	05CG002	BULLPOUND CK	23	05FE001	NO	0.881	7	.004	8	18	26
18	05CK005	ALKALI CK	151	11AB076	NO	0.994	4	.003	7	23	30
19	05DB002	PRAIRIE CK	9	05BK001	NO	0.664	14	.005	18	0	18
20	05EA001	STURGEON R	NO RECORD EXTENSION						30	0	30
21	05EE001	VERMILION R	23	05FE001	NO	0.909	10	.001	11	15	16
22	C5FD001	RIBSTONE CK	23	05FE001	YES	0.727	7	.032	8	18	26
23	05FE001	BATTLE R	NO RECORD EXTENSION						25	0	25
24	05GA003	MCNITER CK	23	05FE001	NO	0.872	15	.001	16	10	26
25	05GC005	EAGLE CK	23	05FE001	YES	0.948	7	.001	7	18	25
26	05GC006	EAGLE CK	39	C5JG004	NO	0.985	5	.001	6	19	25
27	05HA003	BEAR CK	150	11AB075	NO	0.800	6	.060	7	23	30
28	05HA015	BRIDGE CK	154	11AB105	YES	0.830	6	.040	6	23	29
29	05HA062	PIAPOT CK	154	11AB105	YES	0.988	6	.001	6	23	29
30	05HAC75	SKULL CK	155	11AB107	YES	0.721	6	.084	7	23	30
31	05HDC36	SWIFTCURRENT CK	150	11AB075	YES	0.900	13	.001	13	16	29
32	05HG002	BRIGHTWATER CK	39	05JG004	YES	0.956	7	.001	8	17	25
33	05JA002	WOOD R	NO RECORD EXTENSION						25	0	25
34	05JB003	NOTUKEU CK	NO RECORD EXTENSION						26	0	26
35	05JE004	MOOSE JAW CK	NO RECORD EXTENSION						25	0	25
36	05JE006	MOOSE JAW CK	NO RECORD EXTENSION						25	0	25
37	05JF005	WASCANA CK	NO RECORD EXTENSION						24	0	24
38	05JF006	BOGGY CK	37	05JF005	NO	0.879	19	.001	19	5	24
39	05JG004	QU'APPELLE R	37	05JF005	NO	0.695	23	.001	24	1	25
40	05JH001	ARM R	39	05JG004	YES	0.822	16	.001	16	9	25
41	C5JK004	JUMPING DEER CK	NO RECORD EXTENSION						28	0	28
42	05JL002	INDIANHEAD CK	41	05JK004	NO	0.629	24	.001	24	4	28
43	05JL005	PHEASANT CK	41	05JK004	NO	0.789	22	.001	22	6	28
44	05JM015	CUTARM CK	42	05JL002	YES	0.814	13	.001	13	13	26
45	05KA001	CARROT R	41	05JK004	YES	0.905	13	.001	14	15	29
46	C5KB0C3	CARROT R	41	05JK004	NO	0.817	14	.001	15	14	29
47	C5KC001	CARROT R	41	05JK004	NO	0.646	14	.006	15	14	29
48	05KD002	PETAIGAN R	41	05JK004	YES	0.869	7	.006	7	21	28
49	05KEC02	TORCH R	77	05MC001	YES	0.645	17	.003	18	7	25
50	05LB002	ETOMAMI R	77	05MC001	NO	0.847	14	.001	14	11	25
51	05LC001	RED DEER R	77	05MC001	YES	0.932	15	.001	15	10	25
52	05LC004	RED DEER R	77	05MC001	YES	0.888	13	.001	13	12	25
53	05LD001	OVERFLOWING R	77	05MC001	YES	0.664	12	.009	13	12	25
54	05LE001	SWAN R	77	05MC001	NO	0.864	10	.001	10	15	25
55	05LE003	BIRCH R	77	05MC001	NO	0.512	15	.031	15	10	25
56	05LE004	WOODY R	77	C5MC001	NO	0.866	15	.001	15	10	25
57	05LE005	ROARING R	75	05MB001	NO	0.941	10	.001	10	18	28
58	05LE006	SWAN R	77	05MC001	NO	0.868	8	.006	8	17	25
59	05LF001	STEEP ROCK R	41	05JK004	NO	0.367	14	.099	14	14	28
60	C5LF0C2	BELL R	41	05JK004	NO	0.671	14	.004	14	14	28
61	05LG001	PINE R	75	05MB001	NO	0.654	15	.004	15	13	28
62	05LG002	GARLAND R	75	05MB001	NO	0.531	14	.025	14	14	28
63	C5LJ0C5	OCHER R	75	05MB001	NO	0.738	20	.001	20	8	28
64	05LJ007	TURTLE R	75	05MB001	NO	0.748	20	.001	20	8	28
65	05LJ011	WILSON R	75	05MB001	NO	0.846	20	.001	20	8	28
66	05LJ012	VERMILION R	75	05MB001	NO	0.836	21	.001	21	7	28
67	05LJ015	FISHING R	77	05MC001	NO	0.720	20	.001	20	5	25
68	05LJ016	FORK R	75	05MB001	NO	0.872	15	.001	15	13	28
69	C5LJ017	DRIFTING R	75	05MB001	NO	0.790	15	.001	15	13	28
70	05LJ019	MINK R	75	05MB001	NO	0.832	13	.001	13	15	28
71	05LJ022	EDWARDS CK	75	05MB001	NO	0.731	12	.003	12	16	28
72	05LL007	PINE CK	75	05MB001	NO	0.766	10	.005	10	18	28
73	05LL009	NEEPAWA CK	109	05OD001	NO	0.885	10	.001	10	19	29
74	05LL013	WHITEMUD R	109	05OD001	NO	0.671	8	.034	8	21	29
75	C5MB001	YORKTON CK	77	05MC001	NO	0.750	24	.001	25	3	28
76	05MB004	WHITESAND R	75	05MB001	NO	0.702	9	.018	9	19	28
77	05MC001	ASSINIBOINE R	75	05MB001	NO	0.750	24	.001	24	4	28
78	05MC001	STONY CK	77	05MC002	NO	0.750	11	.005	11	14	25
79	05MD005	SHELL R	75	05MB001	NO	0.781	20	.001	20	8	28
80	05MD0C6	LITTLE BOGGY CK	75	05MB001	YES	0.925	12	.001	12	16	28
81	05ME003	BIRDTAIL CK	75	05MB001	NO	0.793	15	.001	15	13	28

TABLE 3-8 CONTINUED

DEPENDENT VARIABLE STATION I D	INDEPENDENT VARIABLE STATION I D	LOG TRANS	R	N	SIG LEVEL	ACTUAL YEARS	EXTENDED YEARS	TOTAL YEARS
		RESULTS OF CORRELATION AND REGRESSION						
82 05MF001 MINNEDOSA	77 05MC002	YES	0.790	10	.003	10	15	25
83 05MF008 ROLLING R	77 05MC002	YES	0.868	8	.006	8	17	25
84 05MG001 ARROW R	96 05NF002	NO	0.676	9	.023	10	17	27
85 05MG002 BOSSHILL CK	96 05NF002	NO	0.841	9	.002	10	17	27
86 C5MG003 GOPHER CK	77 05MC002	NO	0.869	10	.001	10	15	25
87 05MG004 OAK R	77 05MC002	NO	0.861	10	.001	10	15	25
88 05MH0C6 LITTLE SOURIS R	96 05NF002	YES	0.786	7	.018	8	18	26
89 05MH007 EPINETTE CK	109 050D001	YES	0.758	7	.024	7	22	29
90 05MJ004 STURGEON CK	109 050D001	NO	0.859	8	.003	8	21	29
91 05NA005 GIBSON CK	75 05MB001	YES	0.787	10	.003	10	18	28
92 05NB011 YELLOWGRASS DITC	158 11AE003	YES	0.913	12	.001	13	16	29
93 05NB014 JEWEL CK	158 11AE003	NO	0.915	8	.001	8	20	28
94 05NB019 CGULEE WEST	96 05NF002	YES	0.934	6	.003	7	19	26
95 05NE003 PIPESTONE CK	96 05NF002	NO	0.886	8	.002	9	18	27
96 C5NF002 ANTLER R	95 05NE003	NO	0.886	8	.002	25	2	27
97 05NF0C7 GAINSBOROUGH CK	96 05NF002	NO	0.911	11	.001	11	15	26
98 05NF008 GRAHAM CK	96 05NF002	NO	0.829	9	.003	9	17	26
99 05NG010 OAK CK	121 05PH003	YES	0.625	8	.049	8	18	26
100 05NG012 ELGIN CK	75 05MB001	YES	0.805	7	.014	7	21	28
101 05CA006 WHITEMUD CK	96 05NG002	NO	0.946	9	.001	10	16	26
102 C5CAC07 BADGER CK	96 05NF002	YES	0.989	9	.001	10	16	26
103 050A0C8 PEMBINA	96 05NF002	YES	0.833	9	.003	10	17	27
104 05CA009 WAKOPA	96 05NG002	NO	0.638	6	.086	7	19	26
105 050B0C6 CRYSTAL CK	96 05NF002	YES	0.830	8	.005	9	17	26
106 05CB010 LONG R	96 05NF002	YES	0.779	9	.007	10	17	27
107 05CB016 SNOWFLAKE CK	109 050D001	YES	0.868	8	.003	8	21	29
108 C50B021 MOWBRAY CK	109 050D001	YES	0.866	7	.006	7	22	29
109 C5CD001 ROSEAU R	NO RECORD EXTENSION					29	0	29
110 05CD004 ROSEAU R	109 050D001	NO	0.961	7	.001	7	22	29
111 050D014 ROSEAU R	109 050D001	NO	0.958	7	.001	7	22	29
112 050E004 RAT R	121 05PH003	NO	0.942	9	.001	9	17	26
113 05CF015 SHANNON CK	109 050D001	NO	0.683	9	.021	9	20	29
114 050G004 ELM CK 1	109 050D001	NO	0.713	8	.024	8	21	29
115 05CG005 ELM CK 2	109 050D001	NO	0.742	9	.011	9	20	29
116 C50GC06 ELM CK 3	109 050D001	NO	0.732	8	.019	8	21	29
117 05CJ002 COOKS CK	122 05SA002	NO	0.900	12	.001	12	14	26
118 05CJ006 CCOKS CK	122 05SA002	YES	0.874	9	.001	9	17	26
119 05CJ008 NETLEY CK	122 05SA002	NO	0.760	9	.009	9	17	26
120 05CJ009 NETLEY CK	121 05PH003	NO	0.640	9	.032	9	17	26
121 05PH003 WHITEMOUTH R	NO RECORD EXTENSION					26	0	26
122 C5SA002 BROKENHEAD R	NO RECORD EXTENSION					26	0	26
123 05SA004 BROKENHEAD R	122 C5SA002	NO	0.931	9	.001	9	17	26
124 C5SB002 OSIER CK	64 05LJ007	YES	0.713	8	.023	8	12	20
125 05SC002 ICELANDIC R	122 05SA002	YES	0.690	10	.014	10	16	26
126 05SD003 FISHER R	122 05SA002	NO	0.833	8	.C05	8	18	26
127 05SD004 EAST FISHER R	64 05LJ0C7	NO	0.823	8	.006	9	12	20
128 C6AD001 BEAVER R	20 C5EA001	NO	0.542	9	.066	9	21	30
129 C6AC006 BEAVER R	23 05FE001	NO	0.56[illegible]	13	.022	14	12	20
130 07AE002 MCLEOD R	19 05DB002	NO	0.595	15	.010	15	3	18
131 07AG001 MCLECD R	20 05EA001	YES	0.649	10	.021	10	20	30
132 C7AG003 WOLF CK	19 05DB002	NO	0.728	15	.001	15	3	18
133 C7BAOC1 PEMBINA R	19 05DB002	NO	0.750	12	.002	12	6	18
134 07BB002 PEMBINA R	19 05DB002	NO	0.746	15	.C01	15	3	18
135 07BB003 LCBSTICK R	20 05EA001	NO	0.570	15	.C13	15	15	30
136 07BB004 PADDLE R	20 05EA001	YES	C.630	7	.065	7	23	30
137 C7BB0C5 LITTLE PADDLE R	20 05EA001	NO	0.600	7	.078	7	23	30
138 C7BC002 PEMBINA R	20 05EA001	NO	0.501	12	.049	12	18	30
139 07BF001 EAST PRAIRIE R	135 07BB003	YES	0.677	11	.011	11	4	15
140 C7BF002 WEST PRAIRIE R	20 05EA001	YES	0.479	11	.069	22	8	30
141 C7BJ001 SWAN R	NO RECORD EXTENSION					7	0	7
142 C7GE001 WAPITI R	140 07BF002	YES	0.909	9	.001	9	2	11
143 07GH002 LITTLE SMOKY R	20 05EA001	YES	0.613	9	.C40	9	21	30
144 07HA003 HEART R	139 07BF001	YES	0.841	7	.C09	7	4	11
145 07HC001 NOTIKEWIN R	NO RECORD EXTENSION					9	0	9
146 C7JF002 BOYER R	NO RECORD EXTENSION					8	0	8
147 C7JF003 PONTON R	NO RECORD EXTENSION					7	0	7
148 11AA026 SAGE CK	NO RECORD EXTENSION					29	0	29
149 11AB009 MIDDLE CK	151 11AB076	YES	0.915	17	.001	19	10	29
150 11ABC75 LYCNS CK	151 11AB076	YES	0.726	23	.001	25	4	29
151 11ABC76 BATTLE CK	150 11AB075	YES	0.726	23	.001	27	2	29
152 11ABC82 LODGE CK	148 11AA026	NO	0.918	18	.001	18	11	29
153 11ABC87 MIDCLE CK	148 11AA026	YES	0.587	8	.063	8	21	29
154 11AB105 WOODPILE CCULEE	156 11AD001	YES	0.700	25	.C01	26	3	29
155 11AB107 EAST BATTLE CK	156 11AD001	YES	0.803	25	.C01	26	3	29
156 11AD001 WHITEWATER	NO RECORD EXTENSION					28	0	29
157 11AE002 POPLAR R W	156 11AD001	YES	0.884	12	.001	13	16	29
158 11AE003 PCPLAR R E	NO RECORD EXTENSION					28	0	28
159 11AE005 RCCK CK	156 11AD001	YES	0.848	22	.001	23	6	29
160 11AE008 POPLAR R M	NO RECORD EXTENSION					29	0	29
161 11AE009 ROCK CK	160 11AE008	YES	0.558	11	.037	11	18	29

(YES) or on the original arithmetic data (NO)
Column 4 - Value of the correlation coefficient calculated
Column 5 - Number of cases on which the correlation is based
Column 6 - Significance level of the correlation coefficient
Column 7 - Actual years of measured data available
Column 8 - Number of years for which records have been estimated by regression equations
Column 9 - Total years of record (sum of columns 7 and 8).

The years for which records have been extended and filled in are indicated by the "0" symbols on Tables 3-3 (p. 62) and 3-4 (p. 65).

The maps, Figures 3-2 and 3-3, illustrate visually the linkages which have formed the basis of the record extension calculations. These maps have been prepared to indicate the great distances over which correlations have been made. It is also obvious that only a very small number of stations have long enough original records to serve as base stations or independent variables. Both the long distances and small number of base stations would be expected to limit the validity of the data extensions. These limitations are recognized and the estimated data have not been employed directly in the frequency analyses which follow; rather the estimated events have served to allow some adjustment of the plotting positions of the actual data.

3.3.3 Choice of Curve Fitting Methods and Assumed Frequency Distributions

Two problems which must be resolved prior to the frequency analysis of any data set are the selection of the method of curve fitting and the choice of the assumed theoretical frequency distribution. There are two basic approaches to the problem of fitting a frequency curve to a sample data series, mathematical and graphical. As has been discussed earlier, each of these methods, mathematical and graphical, have rela-

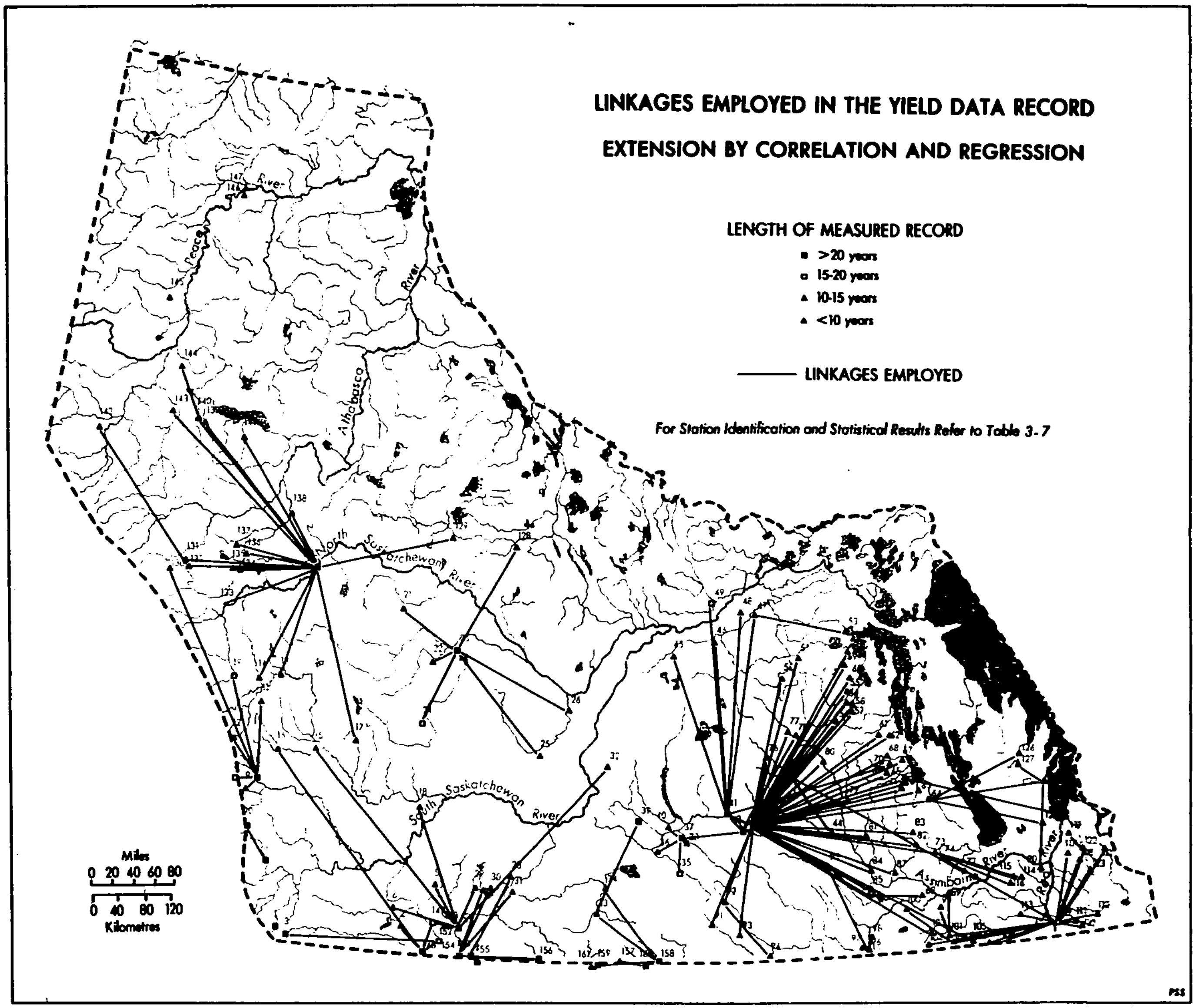

LINKAGES EMPLOYED IN THE YIELD DATA RECORD
EXTENSION BY CORRELATION AND REGRESSION
LENGTH OF MEASURED RECORD
>20 years
15-20 years
10-15 years
<10 years
LINKAGES EMPLOYED
For Station Identification and Statistical Results Refer to Table 3-7
Peace River
Athabasca River
North Saskatchewan River
South Saskatchewan River
Assiniboine River
Miles
0 20 40 60 80
0 40 80 120
Kilometres
PSS

Figure 3-2

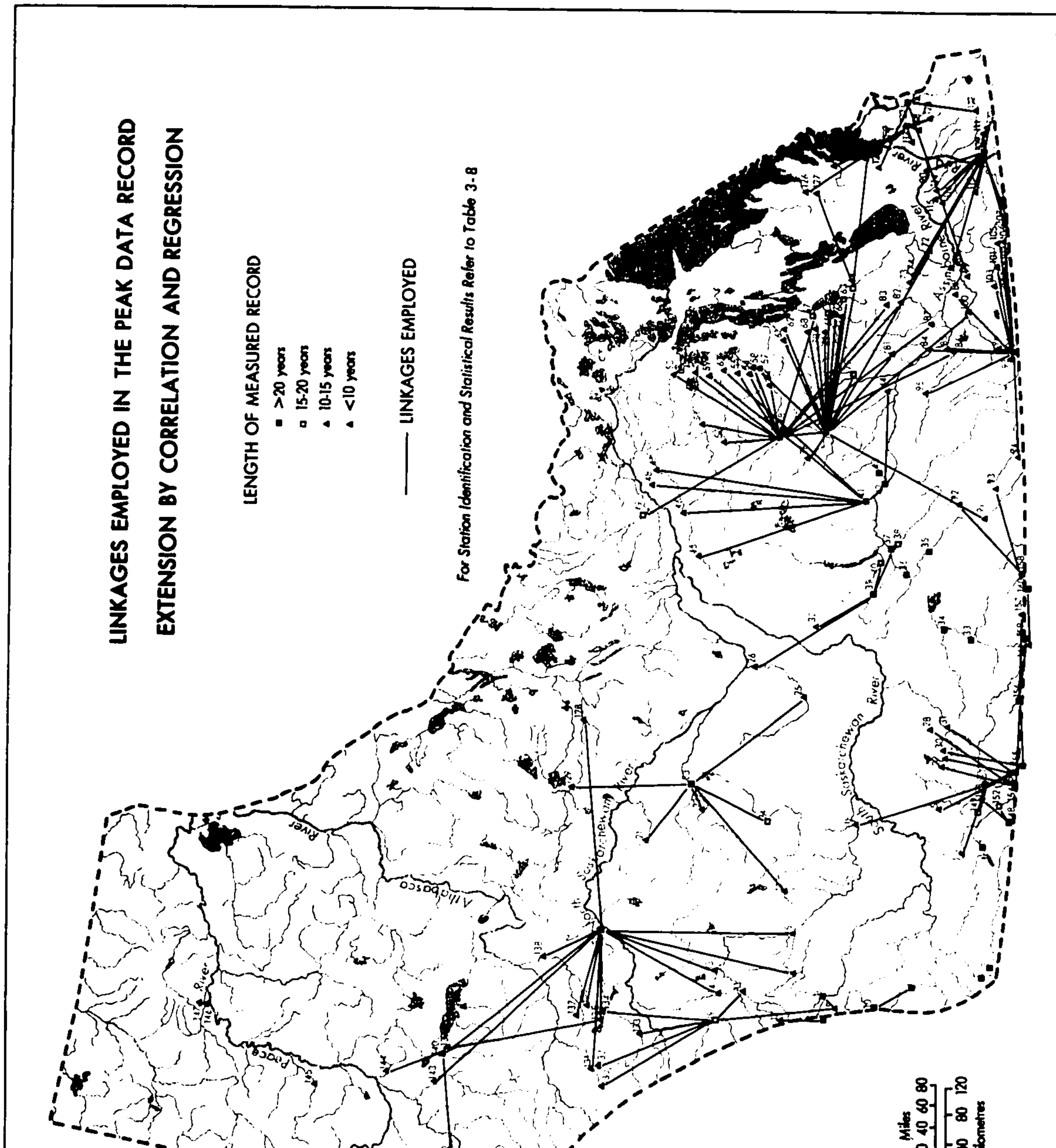

LINKAGES EMPLOYED IN THE PEAK DATA RECORD
EXTENSION BY CORRELATION AND REGRESSION
LENGTH OF MEASURED RECORD
>20 years
15-20 years
10-15 years
<10 years
LINKAGES EMPLOYED
For Station Identification and Statistical Results Refer to Table 3-8
Miles
0 20 40 60 80
0 40 80 120
Kilometres
Athabasca
River
Peace River
North Saskatchewan River
South Saskatchewan River
Assiniboine
River
PSS

Figure 3-3

tive advantages and disadvantages. The final choice of method rests with the individual researcher on the basis of the available data and the purpose of the investigation.

The second problem, that of selecting the most suitable theoretical frequency distribution, has no clear solution. Numerous distributions have been employed in hydrologic frequency analysis; however, no general agreement with respect to the best choice has evolved. The largest body of literature dealing with hydrologic frequency analysis is that dealing with flood frequency analysis. There has been no consistency in the choice of distribution for these studies, and numerous distributions have been employed with apparent success. In the past, government agencies in both Canada and the United States have tended to employ the Extreme Value Type I or Gumbel Distribution in flood frequency analysis (see for example Durrant and Blackwell 1959; Collier and Nix 1967; Coulson 1967a; Karuks 1963; Dalrymple 1960; and Benson 1962b and 1964). Other researchers such as Kuiper (1957) and Ansley (1959) have demonstrated the utility of the Lognormal distribution in analysing flood flows. Recently, the Log-Pearson Type III distribution has been recommended for use by all federal agencies in the United States (United States Water Resources Council 1967; and Benson 1968). The fact remains that no single distribution has been generally accepted for flood frequency work.

Although frequency analysis has not been as widely applied in the study of annual yield data, the same difficulty relating to choice of a theoretical distribution exists. Leopold (1959) demonstrated the utility of the Normal Distribution for annual yield analysis of Colorado River data. In Southern Ontario, Coulson (1967b) successfully employed the Log-Pearson Type III distribution. In an attempt to single out the best distribution for annual yield analysis, Markovic (1965) tested the fit of several distributions to over 400 runoff records from Western North America. He found that no single distribution consistently provided the best results.

The problems of choosing the method of frequency curve fitting and of selecting the most suitable theoretical distribution have no generally accepted solutions. It remains for each researcher, on the basis of the available data and the nature of the problem under study, to decide on the procedures which are best suited for a particular investigation.

3.3.3.1 Method of Curve Fitting for the Present Study

In the present study, many of the sample data series both for the annual yields and annual flood flows are of relatively short duration (see Tables 3-3 and 3-4). Whenever possible, these records have been extended and filled in by correlation and regression analysis with nearby long-term stations. These record extensions have been based on a small number of long-term records, and in many cases, the linkages employed (see Figures 3-2 and 3-3) have been over long distances. For these reasons, it would not be reasonable to employ the extended data directly in the frequency analysis. Alternatively, it is possible to employ the extended records in adjusting the plotting positions assigned to the actual measured data (Dalrymple 1960, p. 4). For example, if an actual record of 10 years is extended an additional 15 years by correlation, and if the largest flood in the actual measured data series is found to also be the largest flood in the extended series, the plotting position assigned to that flood based on the extended record would correspond to a return period of 26 years. If only the actual data were considered, the plotting position assigned to the same event would have corresponded to a return period of only 11 years. The use of extended records in this way serves both to assign more realistic plotting positions to events in short records, and to increase the comparability of the frequency plots of short-term records to available long-term records. It is not possible to employ extended records as described above if mathematical curve fitting methods are employed.

A second consideration with regard to the use of relatively short sample data series arises in the fitting of 3-parameter distributions. These distributions require the estimation of the skew coefficient for the data. This coefficient cannot normally be estimated with accuracy from a small sample (Riggs 1968, p. 5). For this reason, the data available for the present analysis would seem to be more amenable to the fitting of a 2-parameter distribution. This consideration is compatible with the above considered advantages of graphical fitting procedures, since 2-parameter distributions may be readily fitted by graphical methods while 3-parameter distributions may not. Therefore, in the present study, the decision was made to employ graphical techniques of curve fitting.

Frequency curve fitting by graphical procedures involves the plotting of the magnitudes of a series of events against their assigned return periods or probabilities of occurrence, and the fitting of a smooth curve to the resulting distribution. The first step in the procedure is the assigning of return periods or probabilities of occurrence to each of the events in the data series. The events in the series are arranged in order from the largest to the smallest, and each is assigned an order number beginning with the largest as 1. If extended records are being employed then these data are considered as part of the series. Plotting positions are then assigned to each of the actual measured events by means of one of the several available plotting position formulae. The formula employed in the present study is that of Equation 3-2 discussed previously (p. 53).

The second step in the fitting of frequency curves by graphical methods is the plotting of the data. The magnitudes of the events are normally plotted on the ordinate axis and the return period or probability of occurrence is plotted on the abscissa axis. If the data have been assumed to fit a particular 2-parameter distribution, then the data are plotted on special probability paper such that the theoretical distribution will plot as a straight line. A probability paper is a rectangular grid on which a variate "X" is plotted on one scale and a reduced variable "Y" is plotted on the other scale (Gumbel 1954, p. 13). In addition, the probabilities of occurrence and return periods are plotted on scales parallel to the "Y" scale. The values of the reduced variable "Y" corresponding to any probability of occurrence are calculated mathematically according to the theoretical distribution being considered.

In the present analysis four 2-parameter distributions were considered for possible use in the curve fitting procedures. The four distributions considered were the Normal, Lognormal, Gumbel and Log-

Gumbel distributions. Each of these distributions has a particular design of probability paper associated with it. The probability papers and their respective scales are summarized in Table 3-9.

TABLE 3-9 - THE 2-PARAMETER DISTRIBUTIONS CONSIDERED AND THEIR PROBABILITY PAPERS

Distribution	Probability Paper	Transformation on the Ordinate Scale, Dependent Variable, Magnitude of Event "X"	Transformation on the Abscissa Scale, Independent Variable, Probability of Occurrence "Y"
Normal	Normal Probability Paper	None	Normal Probability
Lognormal	Lognormal Probability Paper	Logarithmic Base 10	Normal Probability
Gumbel	Gumbel-Powell Probability Paper	None	Gumbel Probability
Log-Gumbel	Log-Gumbell-Powell Probability Paper	Logarithmic Base 10	Gumbel Probability

If the plotted data fit the theoretical distribution for which the probability paper is designed, the resulting frequency curve will be a straight line. In most cases where small data samples are plotted, the points will not fall directly along a straight line. This scatter of points may be the result of sampling error or may signify that the data do not fit the distribution assumed. If several probability papers are tested, the one on which a particular data set most nearly approximates a straight line represents the theoretical distribution to which the sample data series conforms most closely. These relationships are employed in the following section to choose the most suitable theoretical distributions for the present study.

In the preceding discussion of the use of graphical techniques in the fitting of frequency curves, it was assumed that the actual curve fitting was carried out by eye. However, in any large scale study the procedure of plotting the data points, and fitting the frequency curve by eye is extremely time-consuming. An alternative to this method is the fitting of a least squares regression line to the relationship between the variate "X" and the reduced variate "Y". The technique of least squares regression analysis results in the fitting of the regression line for which the standard error of the estimate is a minimum. (For further reference to the least squares method see Blalock 1960, p. 279 ff; and Ezekiel and Fox 1961, p. 61 ff.). The use of least squares techniques combines the advantages of rapid objective computer computations with the use of extended records when desired.

In fitting a frequency curve to a sample data series by least squares regression, it is not necessary to plot the data. Rather, the magnitude of the events, the dependent variable, and the probabilities of occurrence may be transformed to represent the coordinates of the required plotting paper. If either the Lognormal or Log-Gumbel distributions are being assumed, the magnitude of the events must be transformed by taking logarithms to the base 10. If the Normal or Gumbel distributions are assumed, then no transformation of the event magnitudes is necessary. In each case the probabilities of occurrence must be transformed into the reduced variable "Y" which corresponds to the to the assumed distribution. For the Gumbel or Log-Gumbel distributions, the value of the reduced variable "Y" is estimated by Equation 3-3 below:

$$Y = \log_e (-\log_e P) \qquad (3\text{-}3)$$

where: Y is the reduced variable

P is the probability of occurrence

(Gumbel 1953, p. 5)

For the Normal or Lognormal distributions, the reduced variable "Y" is estimated on the basis of the normal law of errors. In the present study the reduced variable "Y" corresponding to the normal probability scale has been calculated by a computer program function FNUPR written by Cooper and Howells (1969). By performing the necessary transformations, as listed in Table 3-9 for any assumed distribution, and applying the calculations of least squares regression analysis, it is possible to fit a straight line to correspond to the assumed theoretical distribution to any data series. The resulting regression equation is of the form of the equation of a straight line:

$$X = a + bY \qquad (3\text{-}4)$$

where: X is the dependent variable, the magnitude of event

Y is the independent variable, the reduced variable determined on the basis of the theoretical distribution

a and b are constants

3.3.3.2 <u>The Choice of Theoretical Frequency Distribution</u>

As discussed previously in this chapter, no theoretical frequency distribution has been generally accepted for application in the frequency analysis of various hydrologic data sets. The final choice of distribution in any investigation is the responsibility of the researcher. In most cases, the assumed distribution is chosen on the basis of empirical best fit.

In the present study, frequency curves were fitted to the sample data series by the techniques of least squares regression analysis. The methods employed are based on the principles of graphical curve fitting, and therefore, are well suited to the fitting of 2-parameter distributions. Four 2-parameter distributions which have been applied widely in the frequency analysis of hydrologic data have been considered. In order to select the most suitable distribution for the annual yield data series and for the annual flood flow data series, it was necessary to devise a method of examining the relative fit of the data to the four distributions.

According to the curve fitting procedures adopted in the present analysis, the fit of the available data series to the calculated best fit straight line is a measure of the suitability of a particular distribution. In calculating a least squares linear regression line, a measure of fit of the data to the line is given by the ratio of the variance in the dependent variable explained by the regression to the total variance of the dependent variable (Crow, Davis and Maxfield 1960, p. 157). This ratio is known as the correlation coefficient. When any sample data series is fitted by several frequency distributions, the highest correlation coefficient is provided by the distribution to which the data fits most closely. The choices of theoretical frequency distributions for the present study were made on the basis of a comparison of correlation coefficients. In another recent study, Prasad (1970) has employed similar methods in the empirical choice of a theoretical distribution to fit various hydrologic data series.

For each of the study basins, four separate data series were fitted by each of the four 2-parameter distributions being considered; and the correlation coefficient for each of the fits was recorded. The four data series fitted for each of the study basins were:

i) The annual yield data series of actual measured records only

ii) The annual yield data series including extended records

iii) The annual flood flow data series of actual measured records only

iv) The annual flood flow data series including extended records

It was not expected that the relatively small sample data series available in the present analysis would fit the theoretical distributions exactly. Each of the sample data series involved some measure of sampling error; however, this sampling error is constant regardless of which of the four distributions is being fitted. Therefore for each sample data series, the highest correlation coefficient recorded identified the theoretical distribution to which that particular sample conformed most closely. The results of the fitting of the four distributions to both the annual yield and annual flood flow data series are summarized in Table 3-10. Since the longer records provide the largest samples and therefore involve the smallest sampling errors, these records have been considered in selecting the theoretical distributions. The results of curve fitting to three groups of the longer records for

TABLE 3-10 - SUMMARY OF DISTRIBUTION FITTING BY CORRELATION

Sample Data Series		Frequency of Best Fit as Indicated by Highest "r"*				Total Number of Cases
		Normal Distribution	Lognormal Distribution	Gumbel Distribution	Log-Gumbel Distribution	
Actual Measured Data Series with 15 Years or More of Record	Annual Yields	0 (0)	23 (62)	9 (24)	5 (14)	37
	Annual Flood Flows	1 (2)	32 (54)	20 (34)	6 (10)	59
Extended Data Series with a Total of 20 Years or More of Record	Annual Yields	26 (19)	54 (39)	48 (35)	9 (6)	137
	Annual Flood Flows	7 (5)	73 (49)	56 (37)	14 (9)	150
Extended Data Series All Study Basins	Annual Yields	27 (17)	63 (39)	53 (33)	19 (22)	162**
	Annual Flood Flows	8 (5)	78 (48)	59 (36)	17 (10)	162**

*Figures in parentheses are % of the total
**162 cases include one tie case for which each distribution was credited with 1 occurrence.

both annual yields and annual flood flows have been summarized in the table. First, the actual data records for which 15 years or more of data were available were considered; second, the extended data records having a total length of 20 years or more were considered; and finally, the extended data records for all stations have been considered. The figures in the body of the table indicate the number of cases or frequencies in which each of the assumed distributions were the best fit to the sample data series. In all cases, regardless of the record lengths considered or whether the annual yield data or annual flood flow data were analysed, the Lognormal distribution resulted in the most cases of best fit. On the basis of these calculations and tabulations, the 2-parameter Lognormal distribution has been assumed as the theoretical distribution to which both the annual yield data and annual flood flow data series for the selected study basins conform most closely. This distribution has been employed throughout the frequency analyses which follow.

3.3.4 Single-Station Frequency Analysis.

In the preceding sections of this chapter, the techniques of frequency analysis as applied in hydrologic research have been introduced and considered in some detail. The sample data series of annual yields and annual flood flows have been compiled for each of the 161 study basins. These records have been extended to a 30 year base period whenever possible, and consideration has been given to the most suitable method of curve fitting and to the choice of the theoretical frequency distributions for the present study. This final section of Chapter 3 deals with the actual single-station frequency analyses of both the annual yield data and the annual flood flow data for each of the study basins.

The frequency analysis of the sample data series is intended to estimate the parameters of the distribtuions for the individual basin records. These parameters are employed in later chapters as dependent variables in the regional analyses of their relationships to climatic and other physical geographic patterns. The frequency analysis methods chosen for use in the present study employed least squares regression techniques in the fitting of the 2-parameter lognormal distribution to the sample data. Before applying the least squares calculations, the magnitudes of the events being considered are transformed by taking logarithms to the base 10, and the probabilities of occurrence are transformed into a rectangular scaled reduced variable "Y" corresponding to a normal probability scale. A partial table of the values of the reduced variable "Y" for a normal probability scale corresponding to the probability of occurrence has been included in Appendix A, Table A-1.

The equation resulting from the least squares regression analysis is of the form:

$$X = a + bY \tag{3-5}$$

where: X is the logarithm to the base 10 of the magnitude of event

Y is the reduced variable corresponding to the normal probability scale

a and b are constants

This equation may be employed to estimate the magnitude of an event with any given probability of occurrence. The given probability of occurrence is transformed into a reduced variable "Y", and the "Y" value is substituted in the above equation. (The transformation of the probability of occurrence into the reduced variable "Y" may be accomplished either mathematically or by reference to Table A-1 in Appendix A). The equation is then solved for "X", the logarithm of the event magnitude. The "X" value may be transformed to an arithmetic value by taking its antilog.

Since the frequency analysis is based on the assumption that the sample data fit the 2-parameter Lognormal distribution, it is only necessary to calculate 2 parameters in order to reproduce the distribution. This calculation normally involves the estimation of two points on the regression line. One of the characteristics of the Lognormal distribution is that the magnitude of the event with a probability of occurrence of 0.5 or a 2 year return period is the mean of the distribution. This value may be assumed to provide an estimate of the population mean. This graphical mean estimated from Equation 3-5 by the substitution of the "Y" value equal to 0.0 (see Table A-1 in Appendix A for "Y" corresponding to probability of occurrence of 0.5), is considered to be more stable and dependable than is the arithmetic mean (Benson 1960, p. 56). In the present study, the event corresponding to the probability of occurrence of 0.5 has been defined as the "mean annual yield" or the "mean annual flood flow." This parameter has been calculated for each of the data sets fitted with the Lognormal distribution. In order to fully specify the distribution for any given case, it is necessary to establish a second parameter. In the case of mathematical fitting this parameter would normally be the standard deviation; however, when graphic fitting is employed the usual procedure is to simply estimate a second index point of the graph. Such a point corresponds to the 10 year return period or 0.1 probability of occurrence. This index value was employed by Dalrymple (1960) and has been adopted in the present analysis. A third measure which has proved useful in previous regional hydrologic frequency analyses is the ratio of the 10 year event to the mean event. This measure has the advantage of providing a measure of the relative variation in the data without being affected by the absolute magnitudes involved. In the present analysis the values of the "mean annual event", the 10 year event, and of their ratios have been estimated for each of the records examined.

In the present study, a computer program was prepared to fit the 2-parameter Lognormal distribution to a sample data series, and to calculate the mean annual and 10 year events and their ratio. The major steps in the program are as follows:

i) A data set option is defined signifying whether calculations are to be based on the actual measured data only or whether the extended records are to be considered

ii) The period of years to be considered is defined

iii) The data set is read and sorted into descending order, each event being assigned an order number, the largest being 1

iv) Plotting positions are assigned to all the actual measured events by the formula:

$$T = (n + 1)/m$$

where: T is the return period
n is the total number of events in the series
m is the order number of the event

From "T" the probability of occurrence "P" is estimated by the formula:

$P = 1/T$

v) The magnitudes of the events are transformed by taking their logarithms to the base 10. The resulting values are the variates "X"

vi) The probabilities of occurrence "P" are transformed into values of the reduced variable "Y" corresponding to a normal probability scale

vii) The least squares regression equation is calculated for the regression of "Y" on "X". The resulting equation is of the form:

$$X = a + bY$$

viii) The regression equation is utilized in the estimation of the magnitudes of the "mean annual" and 10 year events; and the ratio of the 10 year event to the mean annual event is calculated

Tables 3-11 and 3-12 are examples of the computer output resulting from the processing of the annual yield data series for Basin Number 4, Manyberries Creek. Table 3-11 resulted from the processing of the actual measured data only, and Table 3-12 resulted from the processing of all the data,including the extended records. The first two columns of the tables list the years and their associated annual yields ordered from smallest to largest. The third column lists the order numbers assigned to the events with the largest being 1. The order numbers in Table 3-12 have been adjusted on the basis of the extended records and are different from those in Table 3-11. The last three columns of the tables list the calculated probabilities of occurrence, the return periods, and the reduced variables "Y", respectively, from left to right. Under the table, the value "N" refers to the number of actual measured data points on which the regression is based; and the value "TOTM" refers to the total number of years analysed including extended records. Note that the "TOTM" value in Table 3-12 is higher

TABLE 3-11

SAMPLE OUTPLT FOR FREQUENCY ANALYSIS EMPLOYING ACTUAL MEASURED DATA ONLY

4 05AF010 MANYBERRIES CK YIELD DATA LOG-NORMAL DISTN

YR	DATA	M	PRBOC	TR	YNORPROB
1961	456.0	13	0.071	1.08	-1.465
1968	786.0	12	0.143	1.17	-1.068
1962	1294.2	11	0.214	1.27	-0.792
1963	3153.7	10	0.286	1.40	-0.566
1964	3743.4	9	0.357	1.56	-0.366
1959	6850.1	8	0.429	1.75	-0.180
1966	8167.9	7	0.500	2.00	0.0
1969	8330.0	6	0.571	2.33	C.180
1960	8926.8	5	0.643	2.80	0.366
1957	9055.9	4	0.714	3.50	0.566
1958	10628.8	3	0.786	4.67	0.792
1967	12036.1	2	0.857	7.00	1.068
1965	17532.8	1	0.929	14.00	1.465

N = 13 TOTM = 13

LEAST SQUARES REGRESSION EQUATION TO FIT LOG-NORMAL PLOT IS

X = 3.6666+ 0.5368 Y

R = 0.9340 SEY = 0.1837 SEB = 0.0619

T = 8.667 F = 75.121

VY = 0.2423 VX = 0.7333

EVENT TR2 = 4640.5 EVENT TR10 = 22633.9 RATIO TR2/TR10 = 4.878

TABLE 3-12

SAMPLE OUTPUT FOR FREQUENCY ANALYSIS EMPLOYING ESTIMATED DATA

4 C5AF010 MANYBERRIES CK YIELD DATA LOG-NORMAL DISTN

YR	DATA	M	PRBOC	TR	YNORPROB
1961	456.0	27	0.036	1.04	-1.803
1968	786.0	26	0.071	1.08	-1.465
1962	1294.2	24	0.143	1.17	-1.068
1963	3153.7	22	0.214	1.27	-0.792
1964	3743.4	19	0.321	1.47	-0.464
1959	6850.1	14	0.500	2.00	C.0
1966	8167.9	12	0.571	2.33	C.180
1969	8330.0	11	0.607	2.55	0.272
1960	8926.8	9	0.679	3.11	0.464
1957	9055.9	8	0.714	3.50	0.566
1958	10628.8	5	0.821	5.60	0.921
1967	12036.1	4	0.857	7.00	1.068
1965	17532.8	1	0.964	28.00	1.803

N = 13 TOTM = 27

LEAST SQUARES REGRESSION EQUATION TO FIT LOG-NORMAL PLOT IS

X = 3.6775+ C.4482 Y

R = 0.9567 SEY = 0.1496 SEB = 0.0411

T = 10.903 F = 118.880

VY = 0.2423 VX = 1.1041

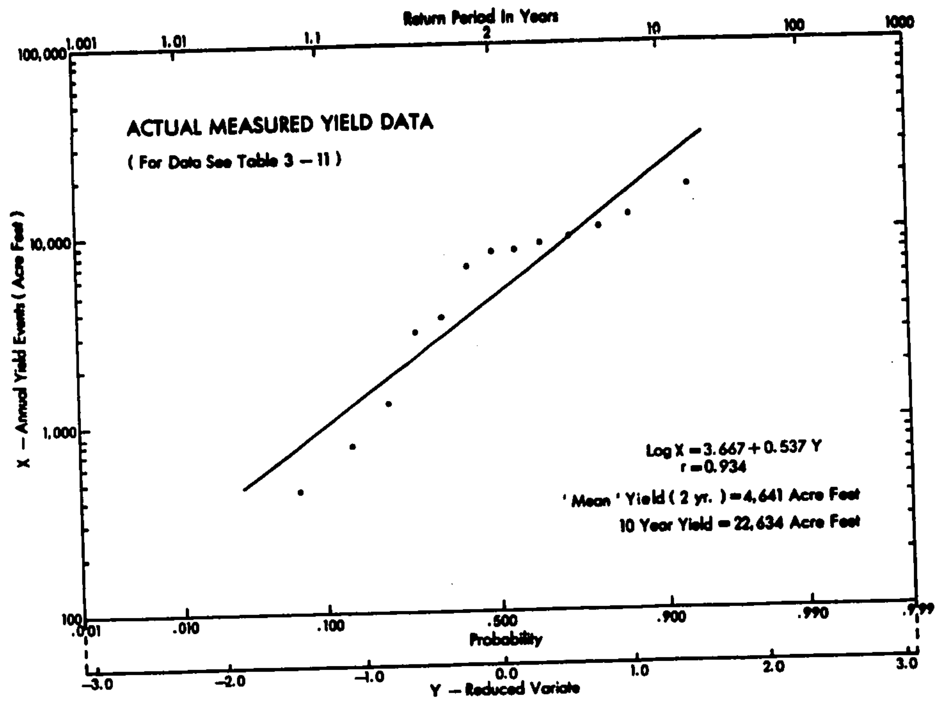
EVENT TR2 = 4759.2 EVENT TR10 = 17867.5 RATIO TR2/TR10 = 3.754

than "N" as a result of the inclusion of extended records. Beneath the values of "N" and "TOTM", the calculated regression equation and its statistics are presented, and the magnitudes of the mean annual and 10 year events are listed. In addition to the printed output, the program recorded the regression equation and the calculated event magnitudes on punch cards.

Figure 3-4 illustrates frequency plots of the annual yield data series for Study Basin Number 4, Manyberries Creek. The upper graph is an illustration of the frequency analysis of the actual measured data only, while the lower graph is an illustration of the analysis with plotting positions adjusted on the basis of extended records. The magnitudes of the events are plotted on the logarithmic ordinate scales; and the reduced variate, Y, is plotted on the abscissa scales. The abscissa scales are also graduated in terms of return period and probability. The linear regression for each of the plots has been estimated by the method of least squares on the transformed data. The adjustment of the probabilities of occurrence on the basis of extended records has resulted in a lowering of the slope of the regression relationship; and in an improved correlation coefficient. This use of extended data for Basin Number 4 provided a lower estimate of the 10 year annual yield and a slightly higher estimate of the mean annual yield.

In the present study, the relatively short actual measured data series for many of the basins did not provide a strong basis for frequency analyses. However, record extension by correlation and regression with nearby long-term stations, resulted in more complete data sets for most stations. For the purposes of the present research, these extended

EXAMPLE FREQUENCY PLOTS OF ANNUAL YIELD DATA FOR MANYBERRIES CREEK - STATION NO.4



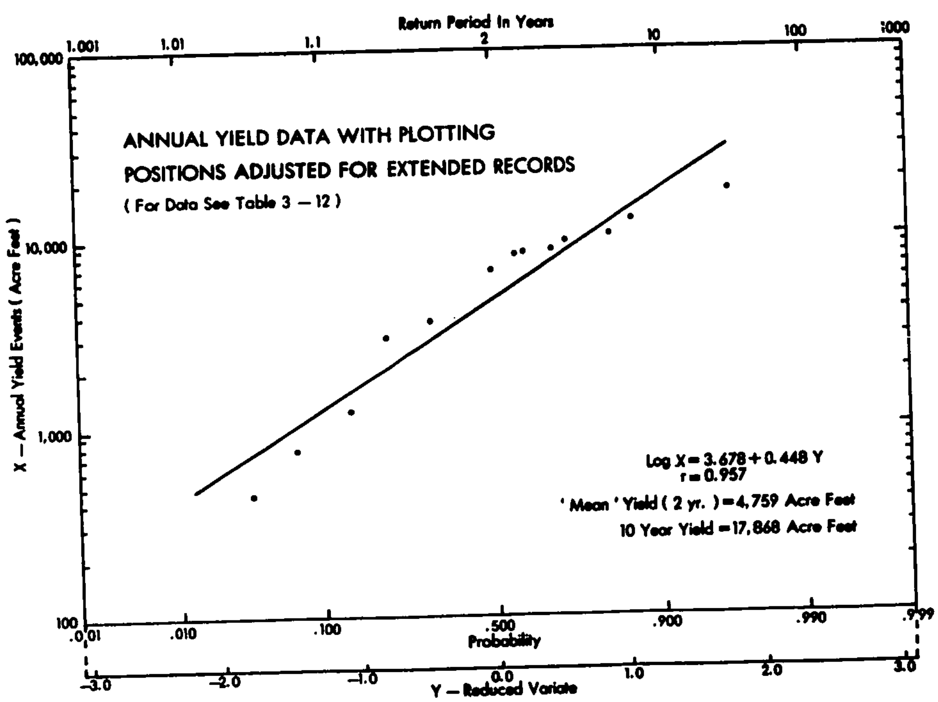


Figure 3-4

data series have been employed in the estimation of the dependent variables for each of the study basins. In all cases, extended data have been employed in adjusting the plotting positions of the actual measured events. However, only the actual measured events have been employed in the frequency analyses by least squares regression.

One of the difficulties inherent in the use of computerized calculations in the frequency analysis of hydrologic data series is that no visual presentation of the data is obtained. When no such visual plot of the data is obtained, it is difficult to identify anomalies in the data. In the present study, as a check for anomalies in the records, and in order to evaluate the curve fitting procedure, the Calcomp Plotter of the University of Alberta Computing Centre was utilized to plot frequency graphs for each of the data sets analysed. Each of the resulting graphs was examined with the aim of identifying anomalous values which obviously did not belong in the same sample as the other observations in the series. In the very few cases where such points existed, they were deleted from the data sets and the frequency analysis was repeated.

The estimated magnitudes of the dependent variables and the regression equations resulting from the frequency analyses for each of the study basins are listed in Tables A-2 and A-3 of Appendix A. Table A-2 contains the data from the frequency analyses of the annual yield data series, and Table A-3 contains the data from the frequency analyses of the annual flood flow data series.

3.4 SUMMARY

The first section of this chapter was devoted to a consideration of the techniques of frequency analysis as applied to hydrologic data series. Various techniques have been examined and examples of their applications have been cited. Throughout the discussion, it was noted that there is, to date, no generally accepted methodology of frequency analysis of hydrologic data. It remains for each researcher to select a methodology which is best suited to the data and problem at hand.

The second section of the chapter contained a description of the data compilation and single-station frequency analyses of the present study. For each of the 161 study basins, the daily discharge records were employed to calculate the annual yield and annual flood flow data series. Since many of the available data series were relatively short, record extension by correlations with nearby long-term stations was undertaken. On the basis of the available data, it was decided to employ a combination of graphical techniques and least squares regression analysis for curve fitting. The lognormal distribution was selected as the most suitable for the present analyses.

The final portion of the chapter was concerned with the actual single-station frequency analyses of the annual yield and annual flood flow data series. These analyses resulted in the estimation of the magnitudes of mean annual and 10 year events for both annual yields and annual flood flows for each of the study basins. These variables have been utilized as dependent variables in the analyses of Chapter 5.

CHAPTER 4

THE INDEPENDENT VARIABLES: MEASURES OF CLIMATIC AND OTHER PHYSICAL GEOGRAPHIC PATTERNS

4.1 INTRODUCTION

In this chapter, the selection and subsequent measurement of the independent variables is discussed. These variables, measures of climatic and other physical geographic patterns, are employed in the statistical analyses of the hypothetical model. These analyses are the subject of the succeeding chapter.

The hypothetical model for the present study, as introduced in Chapter 1, Section 1.2.1, is of the form:

$$\text{STREAMFLOW CHARACTERISTICS} = f\ (\text{CLIMATIC AND OTHER PHYSICAL GEOGRAPHIC PATTERNS}) \qquad (4\text{-}1)$$

Four streamflow characteristics were selected for analysis in the present study. These characteristics were the mean annual yield, the annual yield with a 10-year return period, the mean annual flood, and the annual flood with a 10-year return period. The magnitudes of these events were estimated for each of the 161 study basins by frequency analyses of the available streamflow data. The compilation of these data is the subject of Chapter 3. The proposed independent variables, whose selection and measurement are discussed in this chapter, were chosen to represent the prevailing climatic and other physical conditions which theoretically are expected to be related to the mean annual and 10-year streamflow events.

The proposed independent variables have been divided into two groups. This division is primarily for convenience of discussion, and is based on a consideration of both the theoretical relationships of the variables to streamflow and the available data sources. The first group of independent variables, the climatic measures, are closely related to the local moisture balance patterns and, therefore, represent factors which control the water supply available for streamflow. Climatic conditions are variable both spatially and temporally and measures must be estimated on the basis of available long-term climatic records. The second group of independent variables, the measures of other physical geographic patterns, is proposed to include measures of drainage area, basin topography, channel pattern, surficial deposits and vegetation. These variables control the efficiency with which the available moisture supply is collected in channels and conveyed from the basin as streamflow. In this manner, these variables are closely related to the timing and to a lesser extent to the amount of streamflow. While the variables included in this second grouping are not totally time invariant, they are considerably more so than are the climatic patterns considered above. For the purpose of the present study, it is assumed that the measures representative of this second group of independent variables are time invariant with reference to the relatively short periods of streamflow data being analysed. Under this assumption the data for this group of other physical geographic measures have been collected by measurement from available topographic maps.

Although for discussion purposes the independent variables have been separated into two groups, it is not intended that the interrelationships between the groups go unrecognized. As is the case with most hydrologic phenomena, the various possible measures of both climatic and other physical geographic patterns have a high degree of intercorrelation. For example, the relief and elevation of an area may influence the amount of precipitation; the efficiency of a channel network in collecting available moisture tends to reduce the evapotranspiration; and excessive precipitation events may result in major adjustments in the landforms, particularly the channel patterns, within a basin. These interrelationships will be considered further in later chapters with regard to the statistical analyses of the hypothetical model; meanwhile in the present chapter, the two groups of independent variables will be considered separately.

4.1.1 Criteria for the Selection of the Independent Variables

In the present study, two criteria have been employed in the selection of the independent variables. The first criterion was related to the theoretical relationships of the selected measures to the streamflow characteristics being studied. The proposed analyses of the hypothetical model (see Chapter 1, Section 1.3) relied heavily on the identification of statistical correlations. In order to avoid the development of spurious correlations, it was necessary to establish a theoretical justification for the inclusion of each of the independent variables. The second criterion on which the selection of the independent variables was based related to the available data sources. As mentioned in the preceding introductory discussion (Section 4.1), the climatic variables required had to be estimated on the basis of available long-term climatic records. The relatively short, two year, time span of the present research makes climatic data collection for this analysis impractical. With regard to the other physical geographic patterns, the scale of the study area and the large number of study basins being considered, made field collection of data impossible. Alternatively,the researcher has selected independent variables which may be estimated on the basis of available climatic data in the case of climatic measures, and on the basis of existing topographic maps in the case of other physical geographic measures.

In the following pages, each of the two groups of independent variables is discussed with regard to their theoretical relationships to the dependent variables, the available data sources, and the choice and measurement of the variables.

4.2 CLIMATIC PATTERNS

4.2.1 Theoretical Relationships of Climatic Patterns to Streamflow

Within the hydrologic cycle, there are three important processes which are closely related to climatic patterns. These processes are precipitation, snowmelt, and evapotranspiration. Each of these processes is discussed below in an attempt to identify possible climatic measures for inclusion in the analyses of the hypothetical model.

4.2.1.1 Precipitation

The precipitation process represents the major moisture input to the surface-division of the hydrologic cycle. As such, precipitation is the primary cause of all streamflow. The occurrence of precipitation involves both spatial and temporal variations in form, amount and intensity. This variability, which is an important factor in the determination of streamflow patterns, is discussed as a basis for the selection of precipitation variables.

Of the several forms of precipitation, rain and snow are the most significant from a hydrologic point of view. In the relatively dry study area, the Plains area of the Canadian Prairie Provinces, between 25 and 40 per cent of the mean annual precipitation is in the form of snow. This snowfall is extremely important in the production of streamflow; and estimates have been made that over 80 per cent of the plains' streamflow is the direct result of snow (McKay 1966, p. 2-23; and Gray 1968, p. 21). The effectiveness of snowfall in producing runoff results from the accumulation of moisture over winter in the snowpack, and its subsequent rapid release during the spring melt period. During the melt period, the available moisture supply exceeds the potential evapotranspiration and infiltration capacity of the soil resulting in runoff and streamflow; while during the summer season, the moisture supply from rainfall is either less than or more closely approximates the potential evapotranspiration and infiltration capacity resulting in little or no streamflow.

The amount of precipitation reaching the ground surface varies in both a spatial and temporal sense. The spatial variation in mean annual precipitation for the study area has been considered in Chapter

2 (Section 2.2.2.2 and Figure 2-3). The temporal variations in precipitation patterns relate both to seasonal and year-to-year variations. The seasonal variations are important hydrologically in the context of the effectiveness of snow in producing runoff. The year-to-year variations in precipitation patterns are important in their relationship to year-to-year variations in streamflow. It is expected that an above average precipitation year would be associated with above average streamflow yields and possibly that an above average winter precipitation would be associated with above average spring flood flows.

In employing the available measurements of precipitation, certain limitations in the data collection must be recognized. All precipitation measurements are point observations of a phenomenon which varies spatially. Care must always be taken in the interpolation of available point data to areal units such as drainage basins. In Canada, rainfall is measured in inches by the use of a standard Meteorological Service of Canada Raingauge. Snowfall has been measured most often with a ruler and the resulting depths converted to water equivalent by the application of an assumed conversion factor of 1 inch of snow having a water equivalent of 0.1 inches.* While the density of new snow varies considerably as the result of the size, shape, and type of snow

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*Since the winter of 1960-1961 the Nipher Snow Gauge has been the official instrument for measuring water equivalent of snowfall; however, the climatic data employed in the present study are normals for the 1931-1960 period and therefore are not affected by this instrument change (Canada, Department of Transport, Meteorological Branch, 1968b, p. v.)

crystals; air temperature; humidity; and wind; the assumed conversion factor, when employed on a daily basis, provides a reasonable approximation of water equivalent (U.S. Army Corps of Engineers 1956, p. 288).

On an areal basis, snowfall tends to be more uniform than rainfall; however, because of its relatively low specific gravity, snow is susceptible to redistribution by wind and the resulting snowpack is usually very heterogeneous in pattern of accumulation (McKay and Thompson 1967, p. 1; and Gray 1968, p. 1). In a plains area where wind speed tends to be relatively high, local variations in vegetation and topography result in major accumulations of snow in some locals while other areas are swept clean. The presence of shelter belts, crop stubble, ditches, or other topographic breaks, tend to result in accumulation of snow in drifts while open unprotected fields may be left bare of snowcover. Although the hydrologic importance of these drifting patterns is recognized, data are not normally available except on a local scale. Most researchers must rely on the available data on total snowfall for an estimate of the available moisture supply.

A third aspect of precipitation variability which is of significance in the production of streamflow is intensity of rainfall. This variability is important as related to the infiltration rates of the ground surface. In the plains area during intense summer storms, the soil moisture content is often below capacity; however when the intensity of rainfall exceeds the infiltration rate, runoff will result. Such conditions of intense local precipitation result in short-term fluctuations in streamflow and possible flooding. Unfortunately, data on rainfall intensity are limited and not generally available.

4.2.1.2 Snowmelt

The snowmelt process involves the ripening of snow and subsequent release of stored moisture from the snowpack. The processes by which the snowpack gains heat, increases in density, and finally releases water are extremely complex (U.S. Army Corps of Engineers 1956, p. 141). From a theoretical point of view, the best approach to this problem is through an analysis of the heat balance of the snowpack. A discussion of the various factors affecting this balance for a prairie environment has been provided by Gray (1968) and for a forest environment by Jeffrey (1968). Unfortunately, suitable data with respect to the radiation balance and the condition of the snowpack are not normally available; and the complete energy balance approach to the estimation of snowmelt is not possible. As an alternative, it is possible to employ the available air temperature and accumulated snowfall data to estimate various empirical indices of melt. Such an empirical approach to the estimation of a local snow budget has been employed by McKay (1962). Unfortunately in the present study, detailed data on the snowpack are not available, and it has been necessary to depend on air temperature for the calculation of melt indices.

4.2.1.3 Evapotranspiration

The third hydrologic process which is dependent on climatic conditions is evapotranspiration. Evapotranspiration is the process by which water in its liquid form is vapourized and lost to the atmosphere, either by direct evaporation as from the surface of lakes, streams, the soil and plants, or by transpiration by vegetation. This process results in a loss from the basic precipitation input to the hydrologic cycle. The actual amount of moisture lost by evapotranspiration varies as a function of several factors including the available moisture supply, air temperature, humidity, wind conditions, vegetation type, solar radiation and season. The multivariate nature of the relationships involved has resulted in the development of several methods for the empirical estimation of potential and actual evapotranspiration based on available data. These empirical methods range from the formulae developed by Penman (1963, p. 40) which require detailed data on radiation, wind and humidity, to the formulae developed by Turc (1953) and Thornthwaite (1948 and 1957) which are based on temperature and precipitation data only.

4.2.2 Available Climatic Data

The size of the study area and time span of the present research precluded the collection of climatic data specifically for this study; rather, it has been necessary to rely on available data for the estimation of climatic variables. The climatic data requirements for the study were for estimates of the normal climatic patterns, particularly for variables related to the precipitation, snowmelt and evapotranspiration processes.

In Canada, the task of climatic data collection and publication is the responsibility of the Meteorological Branch of the Canada , Department of Transport. The most recent set of climatic normal publications available, are based on the record period ending in 1960 (Canada, Department of Transport, Meteorological Branch 1968, a, b, c, d and e). The normal record period employed in the compilation of the normals is 30 years for precipitation and temperature, 20 years for hours of sunshine, cloud cover and thunderstorm days, and a lesser period for humidity and wind. A summary of the numbers of stations in the Canadian Prairie Provinces for which normals of the various elements have been published is provided in Table 4-1. From the table, it may be observed that for the elements hours of sunshine, cloud cover, thunderstorm days, humidity and wind, the reporting network is limited to 45 or fewer stations. For precipitation and temperature, the network is much more extensive with over 200 stations reporting.

In the present study, it was necessary to estimate the values of various climatic variables for each of the 161 study basins. The limited network of climatological stations reporting normal data other than for precipitation and temperature was not considered dense enough to allow realistic estimates of other climatic variables for each study basin. Therefore, the climatic data compilation for this research has been limited to those climatic variables based on the precipitation and temperature normals which are published for the more extensive network of over 200 stations.

Each of the over 200 climatological stations for which temperature and precipitation normals are available has been considered for possible use in the present study. Three criteria were employed in selecting the climatological stations to be included. These criteria were as follows:

TABLE 4-1 - SUMMARY OF THE PUBLISHED CLIMATIC NORMAL DATA FOR THE CANADIAN PRAIRIE PROVINCES**

Variable	Number of Stations by Province			Total Number of Stations
	Alberta	Saskatchewan	Manitoba	
Mean Daily Temperature	83	91	48	222
Mean Daily Maximum Temperature	83	91	48	222
Mean Daily Minimum Temperature	83	91	48	222
Mean Rainfall	105	92	42	239
Mean Snowfall	105	92	42	239
Mean Precipitation	105	92	42	239
Mean Hours of Sunshine	16	7	7	30
Cloud Cover	18	12	9	39
Number of Days with Thunder	21	11	13	45
Humidity	20	13	12	45
Wind	19	10	8	37

**The numbers of stations appearing in this table have been compiled from the climatic normal publications of the Canada, Department of Transport, Meteorological Branch (1968 a, b, c, d and e). These stations have data reported for the normal period ending in 1960.

1) The climatological station must be located within the defined study area;

2) The published climatological normals for the 1931 to 1960 period must include estimates of the monthly normal precipitation, the monthly normal snowfall, the monthly normal mean daily temperature, and the monthly normal daily maximum temperature;

3) The estimates of the climatic normals as described above must have a minimum level of accuracy as coded in the relevant climatic normal publications. The coding system employed by the Meteorological Branch of the Canada,Department of Transport for both precipitation and temperature normals has been reproduced in Table 4-2. In the present research all normals coded as 1, 2, 3, 6, or 7 have been considered acceptable for the purposes of the study and no further consideration of data accuracy has been made.

Of the over 200 climatological stations in the Prairie Provinces for which both precipitation and temperature normals are published, 174 met the above three criteria. These stations were employed in the compilation of the climatic variables for the study basins.

Since several of the study basins are located in close proximity to or partially outside the study area boundaries, it was necessary to consider the use of climatological stations which lie outside the study area but which qualify under the second and third criteria above. An examination of the locations of the study basins in relation to the study area boundary revealed that there was a need for climatological data outside the study area, particularly along the United States border and along the foothill boundary in Alberta. In each of these two areas additional climatological stations were examined and 22 stations were added to the 174 selected previously.

TABLE 4-2 - CODING SYSTEM FOR TYPES OF NORMAL AS APPLIED FOR MEAN TEMPERATURE AND PRECIPITATION NORMALS*

Code	Explanation
1	Normals were computed directly from a period of record of 25 to 30 years within the period 1931-1960. In most cases the record existed over the full 30 years.
2	Same as Code 1, but not as much confidence has been placed in the data. These data were considered suspect, but the overall values are mapable.
3	The data for these normals were from the full ten-year period 1951-1960 adjusted to the standard normal period 1931-1960.
4**	These averages are based on the complete ten years of record from 1951 to 1960. No adjustment factor was used.
5**	These averages were obtained by taking a ten-year period of record, ending in the early 1960s. No adjustment factor was used.
6	These averages are based on the period of record of 10 to 24 years during the period 1931 to 1960. No adjustment factor has been used.
7	At several locations the observing station was moved from the town or city to an airport during the 1930s. At many of these locations the records were kept separate, but at those locations indicated by Code 7, the airport and town data were considered homogeneous. The resulting normals are based on the full 30-year period, from 1931-1960.
8**	These data are based on the period of record of less than ten years.
9**	These data are based on a period of record of less than ten years, but adjustments have been made when an unusually warm or cold month unduly influenced the average values. (This last category does not apply to ppt. normals.)

* Source: Canada Department of Transport, Meteorological Branch. 1968a, p. 66 and 1968b, p. 110.

** Normals with these codes have not been employed in the current study. Normals with all other codes have been included without any further differentiation as to the accuracy of the estimates.

For the foothill and mountain region of Alberta a group of 9 climatological stations were included. These stations all qualified according to criteria 2 and 3 above.

In order to obtain the required climatic normal data for stations south of the United States-Canada border, letters of inquiry were sent to the State Climatologists for the states of Montana, North Dakota, and Minnesota. These gentlemen supplied the author with publications containing monthly normal precipitation and monthly normal mean daily temperatures for the 1931 to 1960 period for all climatological stations in the three states (United States Department of Commerce, Weather Bureau 1962, a, b and c). In the case of North Dakota, unpublished monthly normals of snowfall were also made available. Snowfall data were not available for either Montana or Minnesota. Monthly normal maximum daily temperatures were not generally available for the United States' stations considered.

After examining the climatic data available and the location of each of the climatological stations in the three border states, a group of 13 stations were selected for use in the present analysis. These stations are all located in relative proximity to the Canadian border. Of the United States' stations included, 6 were located in North Dakota and therefore had snowfall data available in addition to the precipitation and temperature data. The remaining 7 stations were located 3 in Minnesota and 4 in Montana, and had only precipitation and temperature data available.

The distribution by area of the 196 climatological stations employed is summarized in Table 4-3. These stations have been located

TABLE 4-3 - SUMMARY OF AREAL DISTRIBUTION OF CLIMATOLOGICAL STATIONS AND THE AVAILABLE NORMAL DATA EMPLOYED

Location	Number of Stations	Climatic Normal Data Employed
Within the Study Area	174	Monthly mean daily temperature Monthly mean daily maximum temperature Monthly mean snowfall Monthly mean precipitation
Foothills and Mountains of Alberta	9	Monthly mean daily temperature Monthly mean daily maximum temperature Monthly mean snowfall Monthly mean precipitation
Montana	4	Monthly mean daily temperature Monthly mean precipitation
North Dakota	6	Monthly mean daily temperature Monthly mean precipitation Monthly mean snowfall
Minnesota	3	Monthly mean daily temperature Monthly mean precipitation

on the map, Figure 4-1, and identified in the accompanying Table 4-4.

In addition to the climatic normal data compiled for each of the 196 selected climatological stations, precipitation frequency data were obtained for 10 of the Canadian stations.* These data provided a basis for the estimation of precipitation variability for the study area.

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*These data are unpublished and have been prepared by the Canada, Department of Transport, Meteorological Branch, for use in a forthcoming publication by R.W. Longley, The Climate of the Prairie Provinces. The data were supplied to the author by R.W. Longley.

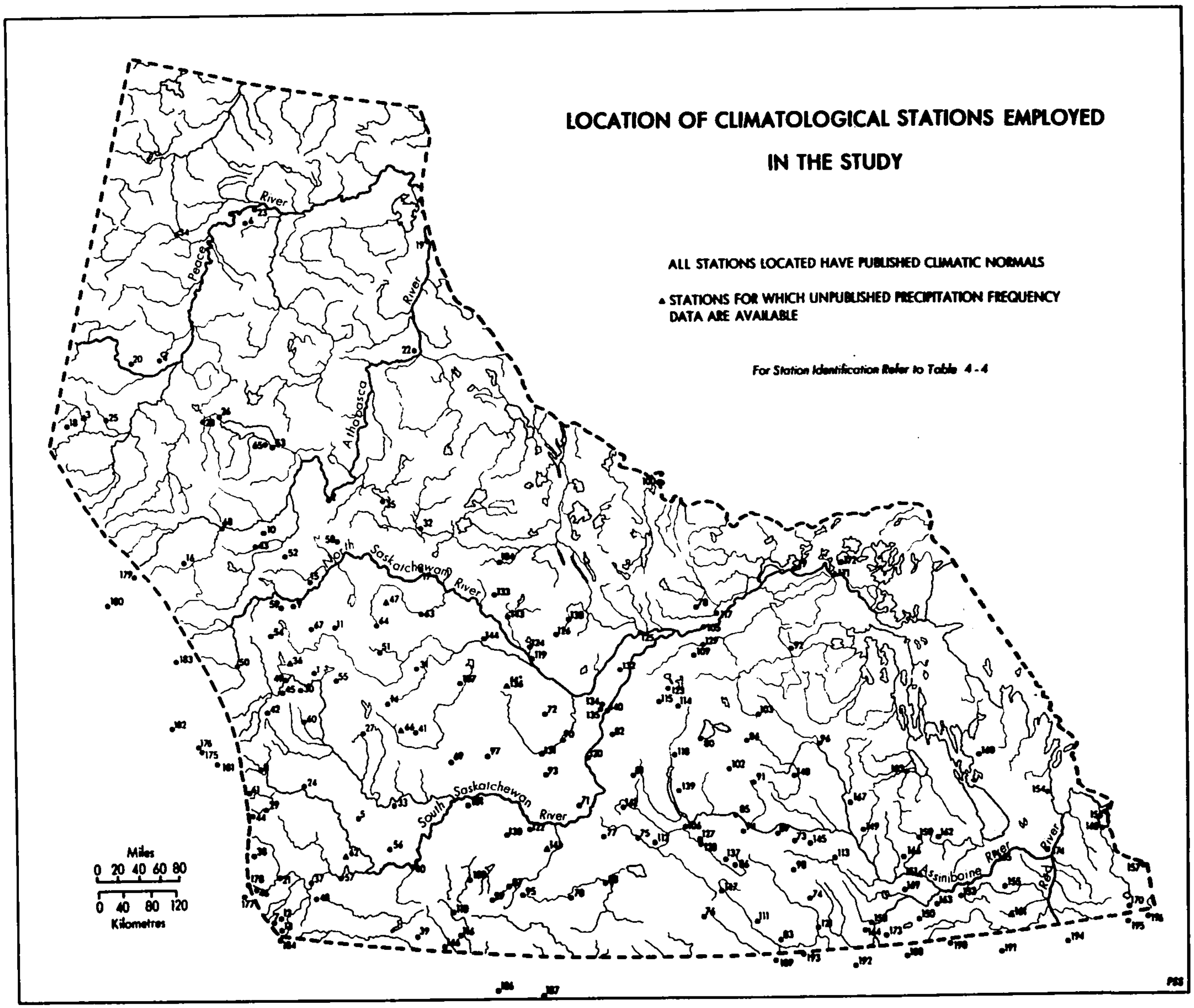

LOCATION OF CLIMATOLOGICAL STATIONS EMPLOYED
IN THE STUDY
ALL STATIONS LOCATED HAVE PUBLISHED CLIMATIC NORMALS
▲ STATIONS FOR WHICH UNPUBLISHED PRECIPITATION FREQUENCY DATA ARE AVAILABLE
For Station Identification Refer to Table 4-4
Peace River
Athabasca River
North Saskatchewan River
South Saskatchewan River
Assiniboine River
Red River
Miles
0 20 40 60 80
0 40 80 120
Kilometres

Figure 4-1

TABLE 4-4

CLIMATOLOGICAL STATION IDENTIFICATION *

STATION NUMBER	STATION NAME	STATION NUMBER	STATION NAME	STATION NUMBER	STATION NAME	STATION NUMBER	STATION NAME
1	ALIX	50	ROCKY MTN HOUSE	99	KLINTONEL	148	YORKTON A
2	ATHABASCA	51	SEDGEWICK	100	LAC LA RONGE	149	BIRTLE
3	BEAVERLODGE CDA	52	SION	101	LEADER	150	BOISSEVAIN 2
4	BERWYN	53	SLAVE LAKE	102	LEROSS	151	BRANDON CDA
5	BROCKS	54	SPRINGDALE	103	LINTLAW	152	CYPRESS RIVER
6	BUFFALO HEAD PRAIRIE	55	STETTLER	104	LOON LAKE CDA	153	DAUPHIN A
7	CALDWELL	56	SUFFIELD A	105	LOST RIVER	154	GIMLI A
8	CALGARY A	57	TABER	106	LUMSDEN	155	GRAYSVILLE
9	CALMAR	58	THORHILD	107	MACKLIN	156	GREAT FALLS
10	CAMPSIE	59	THORSBY	108	MAPLE CREEK	157	INDIAN BAY
11	CAMROSE	60	THREE HILLS	109	MELFORT	158	MELITA
12	CARDSTON	61	THRNER VALLEY	110	MERRYFLAT	159	MINNEDOSA
13	CARWAY	62	VAUXHALL	111	MIDALE	160	MOOSEHORN
14	CORCNATION	63	VERMILION A	112	MOOSE JAW A	161	MORDEN CDA
15	EDMCNTON INDUSTRIAL	64	VIKING	113	MOOSOMIN	162	NEPAWA A
16	EDSON	65	WAGNER	114	MUENSTER	163	NINETTE
17	ELK POINT	66	WASTINA HEMARUKA	115	MUSKIKE SPRINGS	164	PIERSON
18	ELMWORTH	67	WETASKIWIN	116	NASHLYN	165	PORTAGE LA PRAIRIE A
19	EMBARRAS A	68	WHITECOURT	117	NIPAWIN	166	RIVERS A
20	FAIRVIEW	69	ALSASK HARDENE	118	NOKOMIS	167	RUSSELL
21	FORT MACLEOD	70	ANEROID	119	NORTH BATTLEFORD A	168	SEVEN SISTERS FALLS
22	FORT MCMURRAY A	71	BEECHY	120	OUTLOOK	169	SOURIS
23	FORT VERMILION	72	BIGGAR	121	OXBOW	170	SPRAGUE
24	GLEICHEN	73	BROADVIEW A	122	PENNANT	171	THE PAS
25	GRAND PRAIRIE A	74	CARLYLE	123	PILGER	172	THE PAS A
26	GROUARD	75	CARON	124	PRINCE	173	WASKADA
27	HANNA	76	CEYLON	125	PRINCE ALBERT A	174	WINNIPEG A
28	HIGH PRAIRIE	77	CHAPLIN	126	RABBIT LAKE	175	ANTHRACITE
29	HIGH RIVER	78	CHOICELAND	127	REGINA A	176	BANFF
30	HILLSDOWN	79	CUMBERLAND HOUSE	128	REGINA CDA	177	BEAVER MINES
31	HUGHENDEN	80	DAFOE A	129	RIDGEDALE	178	COWLEY A
32	IRON RIVER	81	DAVIDSON	130	ROADENE	179	ENTRANCE
33	JENNER	82	DUNDURN	131	ROSETOWN	180	JASPER
34	KEG RIVER	83	ESTEVAN A	132	ROSTHERN	181	KANANASKIS
35	LAC LA BICHE	84	FOAM LAKE	133	ST WALBURG	182	LAKE LOUISE
36	LACOMBE	85	FORT QU'APPELLE	134	SASKATOON A	183	NORDEGG
37	LETHBRIDGE A	86	FRANCIS	135	SASKATOON U OF S	184	BABB
38	LUNDBRECK	87	GARDEN HEAD	136	SCOTT CDA	185	GLASGOW
39	MANNYBERRIES	88	GRAVELBOURG	137	SEDLEY	186	HARLEM
40	MEDICINE HAT	89	GRENFELL	138	SPIRITWOOD	187	MALTA
41	NACO	90	HARRIS	139	STRASBOURG	188	BOTTINEAU
42	OLDS	91	HUBBARD	140	SUTHERLAND	189	CROSBY
43	PEAVINE	92	HUDSON BAY	141	SWIFT CURRENT A	190	HANSBORO
44	PEKISKO	93	HUGHTON	142	TUGASKE	191	LANGDON
45	PENHOLD A	94	INDIAN HEAD	143	TURTLEFORD	192	MOHALL
46	PINCHER CREEK	95	INSTOW	144	WASECA	193	PORTAL
47	RANFURLY	96	KAMSACK	145	WHITEWOOD	194	HALLOCK
48	RAYMOND	97	KINDERSLEY	146	WILLOW CREEK	195	ROSEAU
49	RED DEER	98	KIPLING	147	YELLOW GRASS	196	WARROAD

* STATION NOS 1 TO 174 ARE LOCATED WITHIN THE STUDY AREA
STATION NOS 175 TO 183 ARE LOCATED OUTSIDE THE STUDY AREA IN THE FOOTHILLS AND MOUNTAINS OF ALBERTA
STATION NOS 184 TO 196 ARE LOCATED OUTSIDE THE STUDY AREA IN THE UNITED STATES
FOR EXACT STATION LOCATIONS SEE FIGURE 4-1

4.2.3 Interpolation of Climatic Data for the Study Basins

The climatic normal data selected for use in the present research are the result of measurements at point observation sites. The streamflow characteristics being examined have been estimated on a drainage basin basis. Before analysing the relationships between streamflow characteristics and various climatic measures, it is necessary to interpolate estimates of the climatic normals for each of the study basins. Several possible methods are available for such an estimation of areal data from a sample of point observations. Four of the more widely employed techniques are by the use of arithmetic averages, Thiessen polygons, isolines, and correlation and regression analysis. These techniques have been widely applied particularly with reference to the estimation of areal precipitation.

A general discussion of the use of arithmetic averages, Thiessen polygons, and isolines in the areal interpolation of precipitation patterns, is contained in most hydrologic textbooks (see for example Linsley, Kohler and Paulhus 1949, p. 77; and Bruce and Clark 1966, p. 167). The use of arithmetic averages is the simplest of these methods; however, where only a limited number of unevenly distributed climatological stations are available, or where station to station variations are high, the results may be subject to considerable error. The Thiessen polygon approach, the second method, takes account of the uneven distribution of observing stations through the introduction of weights in the calculation of areal averages. The third method, the isoline method, is more flexible; and when applied by an experienced analyst, probably results in more accurate estimates than either of the above methods. A fourth possible approach to the areal estimation of climatic data is through a correlation and regression analysis of the relationships between climatic patterns and various measures of topography and geographic location. Such an approach is most effective in areas of relatively high relief. Examples of this method applied to the areal estimation of precipitation are found in the work of Spreen (1947), Rodda (1962), and Solomon et al (1968). In the latter work correlation and regression techniques were employed in the interpolation of both precipitation and temperature patterns.

In the present research, the Thiessen polygon method has been utilized in the estimation of climatic data for each of the study basins. The limited number and uneven distribution of climatological stations precluded the use of either the arithmetic average or isoline methods. The correlation and regression approach was not employed because the necessary topographic measures were being employed elsewhere in the analysis of streamflow patterns; and their use in the estimation of climatic data would have introduced undesirable intercorrelations into the subsequent analyses of streamflow characteristics. The Thiessen polygon method provided an objective method for interpolating areal estimates of the required climatic normals from the data available for the selected climatological stations.

4.2.3.1 Climatic Normal Interpolation for the Study Basins by Thiessen Weights

The Thiessen polygon method for estimating areal climatic data on the basis of point observations was developed by A.H. Thiessen (1911). This method involves the calculation of a weighted arithmetic average of the available point data. The weight for each climatological station is derived such that the station is considered to be representative of a proportion of the total area, dependent on the spacing of the observation points. The calculation of the weights involves the construction on a map of a polygon network. The network is composed of the right bisectors of the lines joining the observation points. The boundary of the drainage basin or other areal unit under consideration forms the outer edge of the polygons. The area of each polygon is measured and expressed as a proportion of the total area. These proportions are the weighting factors employed in the estimation of the weighted average for the areal unit. This method of climatic data interpolation for areal units has the advantage of providing an objective method of accounting for the non-uniform distribution of observation points.

In the present research, Thiessen polygons were employed in the estimation of monthly mean daily temperatures, monthly mean daily maximum temperatures, mean monthly precipitation and mean monthly snowfall for each of the study basins. The analysis procedures employed in the estimation of the above climatic data for the study basins were as follows:

1) The 196 selected climatological stations (see Section 4.2.2 above) and the 161 selected hydrometric stations (see Chapter 3 Section 3.3.1) were located on 1:250,000 scale topographic maps of the study area and environs.

2) The drainage basin area upstream from each of the hydrometric stations was outlined on the 1:250,000 scale topographic maps. The drainage area delimited was that of gross drainage area as defined by the topographic

divide between adjacent basins. Wherever map coverage was available, the topographic divide was first located on 1:50,000 scale topographic maps and then transferred to the smaller scale 1:250,000 scale maps.

3) For each of the drainage basins delimited, the polygons were constructed for the climatological stations located within and adjacent to the basins. The polygons were drawn by joining the climatological stations with straight lines and constructing the right bisectors of these lines. The drainage basin boundaries formed the outer edge of the polygons for a particular basin.

4) The area within each of the polygons was measured in square inches using a Bruning Areagraph Chart.* The areas of all the polygons included in a given basin were summed to give the topographic drainage area of the basin. As a check on the polygon area measurements, the topographic drainage area was measured separately and the results compared. Where discrepancies between the two measures existed, the measurements were repeated until corresponding values were obtained.

5) The polygon areas corresponding to each of the climatological stations located within and adjacent to a study basin were expressed as proportions of the topographic drainage area for that basin. These proportions are the Thiessen Weights for use in the estimation of basin climatic data.

6) The Thiessen weights corresponding to the relevant climatological stations were employed in the estimation of climatic normals for the drainage basin. The general formula for the calculation of basin climatic normals is of the form:

$$BCN = (W_1 \times D_1) + (W_2 \times D_2) + \dots\dots\dots(W_n \times D_n) \quad (4\text{-}2)$$

---

*The Bruning Areagraph Charts were employed for all area measurements in the present research. The Areagraph charts used were of a random dot type with dot densities of 100 per square inch and 30 per square inch.

where: BCN - basin climatic normal

W_1 - Thiessen weights associated with the relevant climatological station 1, 2, ...n

D_1 - published climatic normals for the climatological stations 1, 2, ...n.

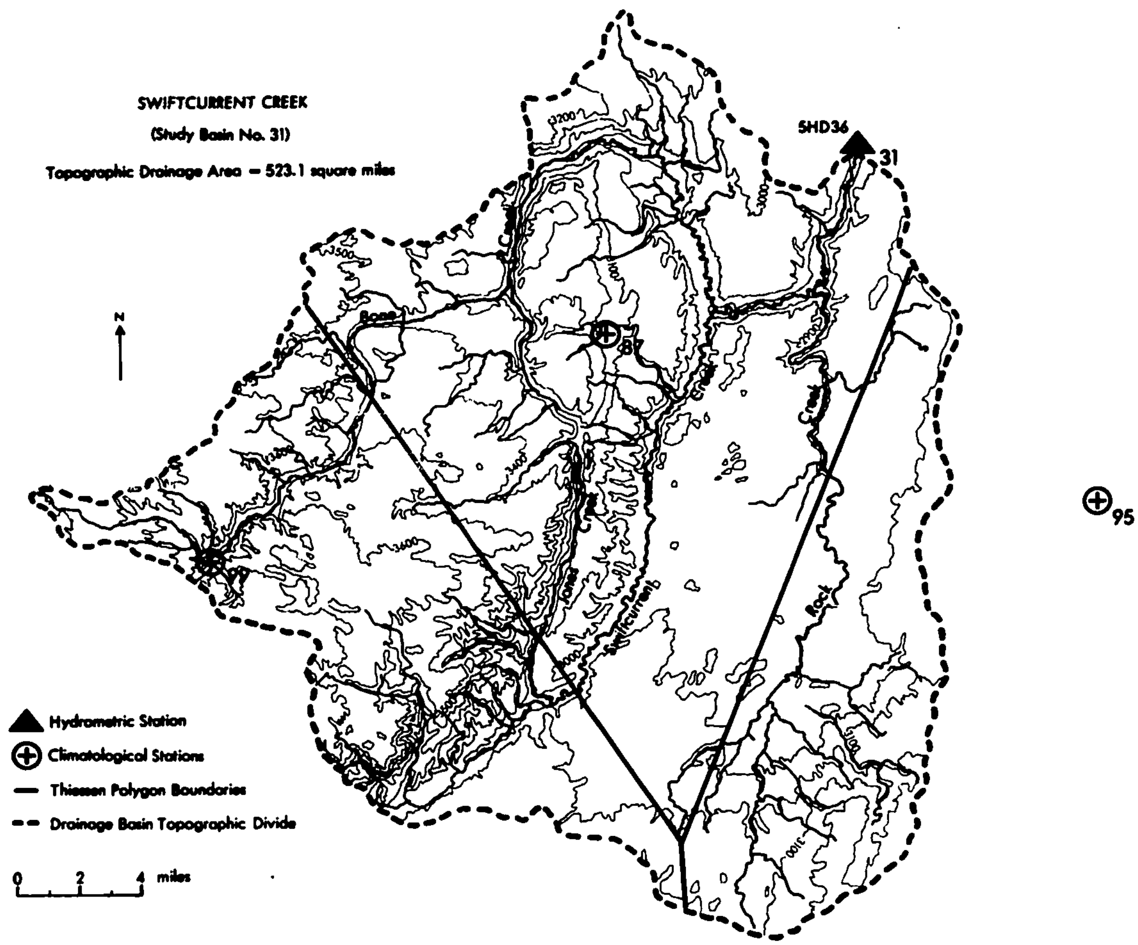
The above procedures were employed for the estimation of monthly normals of mean daily temperature, maximum daily temperature, monthly precipitation, and monthly snowfall, for each of the 161 study basins. The resulting climatic normal data sets for each of the study basins formed the basis for the estimation of climatic variables (see Section 4.2.4 following).

Figure 4-2 presents an example of Thiessen polygons applied to one of the study basins, Swiftcurrent Creek basin number 31. In this example, three climatological stations have been considered, two located within the basin and one adjacent to it. Other climatological stations in the area are too far distant to be included in the Thiessen calculations. The calculations of the Thiessen weights for the three climatological stations are summarized in the table which forms the lower portion of the figure. The weights as calculated in the last column of the table were employed in an equation of the form of the equation 4-2 above.

Table 4-5 lists the climatological stations which were employed in the Thiessen weight calculations for each of the study basins.

The application of Thiessen weight calculations in the estimation of climatic data for the study basins involved a straightforward procedure with the exception of those basins for which American climatological stations were included. In these cases, special methods

EXAMPLE THIESSEN POLYGON WEIGHT CALCULATION



CALCULATION OF THIESSEN WEIGHTS

Meteorological Station Identification		Polygon Area (sq. mi.)	Weight = Polygon Area / Topographic Basin Area
Number	Name		
87	Garden Head	281.8	0.539
95	Instow	100.7	0.192
99	Klintonel	140.6	0.269
TOTAL		523.1	1.000

PSS.

Figure 4-2

TABLE 4-5

CLIMATOLOGICAL STATIONS EMPLOYED IN THE THIESSEN WEIGHT CALCULATIONS FOR EACH OF THE STUDY BASINS

BASIN IDENTIFICATION NUMBER	BASIN IDENTIFICATION NAME	CLIMATOLOGICAL STATIONS EMPLOYED NUMBER OF STATIONS	LIST OF STATIONS									
1	WILLOW CK	3	29	38	44							
2	LEE CK	3	7	12	13							
3	ROLPH CK	2	12	13								
4	MANYBERRIES CK	2	39	110								
5	MACKAY CK	3	40	108	110							
6	PEIGAN CK	3	39	40	110							
7	ELBOW R	3	44	61	181							
8	ELBOW R	4	8	44	61	181						
9	FISH CK	1	61									
10	STIMSON CK	2	29	44								
11	LITTLE RED DEER	2	42	181								
12	LITTLE RED DEER	2	42	181								
13	BLINDMAN R	3	36	49	54							
14	MEDICINE R	3	49	50	54							
15	KNEEHILLS CK	3	30	42	60							
16	ROSEBUD R	2	8	42								
17	BULLPOUND CK	1	27									
18	ALKALI CK	3	33	66	69							
19	PRAIRIE CK	1	50									
20	STURGEON R	4	15	43	52	59						
21	VERMILION R	5	11	17	47	63	64					
22	RIBSTONE CK	3	14	31	41							
23	BATTLE R	17	1	9	11	14	31	36	41	49	51	54
			55	59	63	64	67	107	144			
24	MONITER CK	3	14	41	66							
25	EAGLE CK	4	72	97	131	136						
26	EAGLE CK	7	72	90	97	119	131	134	136			
27	BEAR CK	2	99	108								
28	BRIDGE CK	2	87	99								
29	PIAPOT CK	2	99	108								
30	SKULL CK	2	87	99								
31	SWIFTCURRENT CK	3	87	95	99							
32	BRIGHTWATER CK	3	81	82	120							
33	WOOD R	2	70	88								
34	NOTUKEU CK	4	70	88	95	141						
35	MOOSE JAW R	4	76	112	128	147						
36	MOOSE JAW CK	9	71	75	76	77	112	127	128	142	147	
37	WASCANA CK	7	86	94	106	112	127	128	137			
38	BOGGY CK	3	106	127	128							
39	QU'APPELLE R	4	75	77	81	142						
40	ARM R	5	75	81	106	139	142					
41	JUMPING DEER CK	3	85	91	102							
42	INDIANHEAD CK	1	94									
43	PHEASANT CK	4	85	89	91	94						
44	CUTARM CK	3	145	148	167							
45	CARROT R	3	109	123	125							
46	CARROT R	6	105	109	117	123	125	129				
47	CARROT R	7	92	105	109	117	123	125	129			
48	PETAIGAN R	1	117									
49	TORCH R	2	78	125								
50	ETOMAMI R	2	92	103								
51	RED DEER R	5	92	103	109	114	129					
52	RED DEER R	5	92	103	109	114	129					
53	OVERFLOWING R	2	92	171								
54	SWAN R	3	92	96	103							
55	BIRCH R	1	92									
56	WOODY R	2	92	96								
57	ROARING R	1	96									
58	SWAN R	3	92	96	103							
59	STEEP ROCK R	1	92									
60	BELL R	1	92									
61	PINE R	2	96	153								
62	GARLAND R	2	96	153								
63	OCHER R	2	153	159								
64	TURTLE R	3	153	159	162							
65	WILSON R	2	153	167								
66	VERMILION R	1	153									
67	FISHING R	1	153									
68	FORK R	1	153									
69	DRIFTING R	1	153									
70	MINK R	1	153									
71	EDWARDS CK	1	153									
72	PINE CK	2	152	162								
73	NEEPAWA CK	2	159	162								
74	WHITEMUD R	2	151	162								
75	YORKTON CK	2	91	148								
76	WHITESAND R	2	84	103								
77	ASSINIBOINE R	1	103									
78	STONY CK	2	96	103								
79	SHELL R	2	96	167								
80	LITTLE BOGGY CK	1	96									
81	BIRDTAIL CK	3	149	153	167							

TABLE 4-5 CONTINUED

BASIN IDENTIFICATION NUMBER	NAME	CLIMATOLOGICAL STATIONS EMPLOYED: NUMBER OF STATIONS	LIST OF STATIONS
82	MINNEDOSA R	4	149 153 159 162
83	ROLLING R	3	153 159 162
84	ARROW R	1	149
85	BOSSHILL CK	2	113 166
86	GOPHER CK	3	113 158 166
87	OAK R	3	149 159 166
88	LITTLE SOURIS R	2	151 169
89	EPINETTE CK	4	151 152 159 162
90	STURGEON CK	1	174
91	GIBSON CK	1	76
92	YELLOWGRASS DITC	3	86 137 147
93	JEWEL CK	3	76 111 147
94	COULEE WEST	1	83
95	PIPESTONE CK	6	73 74 89 98 113 145
96	ANTLER R	4	74 121 164 173
97	GAINSBOROUGH CK	4	74 113 121 164
98	GRAHAM CK	3	113 158 164
99	OAK CK	2	152 163
100	ELGIN CK	2	150 169
101	WHITEMUD CK	2	150 163
102	BADGER CK	3	150 161 163
103	PEMBINA R	1	150
104	WAKOPA CK	1	150
105	CRYSTAL CK	2	161 163
106	LONG R	2	161 163
107	SNOWFLAKE CK	1	161
108	MOWBRAY CK	1	161
109	ROSEAU R	2	170 174
110	ROSEAU R	1	170
111	ROSEAU R	1	170
112	RAT R	1	170
113	SHANNON CK	1	161
114	ELM CK 1	2	155 165
115	ELM CK 2	2	155 165
116	ELM CK 3	2	155 165
117	COOKS CK	2	168 174
118	COOKS CK	2	168 174
119	NETLEY CK	1	154
120	NETLEY CK	1	154
121	WHITEMOUTH R	3	157 168 170
122	BROKENHEAD R	1	168
123	BROKENHEAD R	1	168
124	OSIER CK	1	154
125	ICELANDIC R	1	154
126	FISHER R	1	154
127	FAST FISHER R	1	154
128	BEAVER R	7	2 17 32 35 58 104 133
129	BEAVER R	5	2 17 32 35 58
130	MCLEOD R	2	16 179
131	MCLEOD R	2	16 179
132	WOLF CK	1	16
133	PEMBINA R	3	16 179 183
134	PEMBINA R	5	16 43 59 179 183
135	LOBSTICK R	3	16 43 68
136	PADDLE R	2	43 68
137	LITTLE PADDLE R	2	43 68
138	PEMBINA R	10	2 10 16 43 52 58 59 68 179 183
139	EAST PRAIRIE R	3	26 28 68
140	WEST PRAIRIE R	1	28
141	SWAN R	3	53 65 68
142	WAPITI R	3	3 18 25
143	LITTLE SMOKY R	3	25 28 68
144	HEART R	3	4 26 28
145	NOTIKEWIN R	3	4 20 34
146	BOYER R	3	6 23 34
147	PONTON R	1	23
148	SAGE CK	1	39
149	MIDDLE CK	1	110
150	LYONS CK	1	116
151	BATTLE CK	1	110
152	LODGE CK	2	39 110
153	MIDDLE CK	1	110
154	WOODPILE COULEE	2	116 146
155	EAST BATTLE CK	1	116
156	WHITEWATER CK	1	95
157	POPLAR R W	1	88
158	POPLAR R E	2	76 88
159	ROCK CK	2	70 88
160	POPLAR R M	2	76 88
161	ROCK CK	2	70 88

TABLE 4-5 CONTINUED *

BASIN IDENTIFICATION		CLIMATOLOGICAL STATIONS EMPLOYED				
NUMBER	NAME	NUMBER OF STATIONS	LIST OF STATIONS			
2	LEE CK	4	7	12	13	184
3	ROLPH CK	2	12	184		
94	COULEE WEST	2	83	189		
101	WHITEMUD CK	3	150	163	190	
102	BADGER CK	1	190			
105	CRYSTAL CK	2	190	191		
106	LONG R	2	190	191		
107	SNOWFLAKE CK	2	190	191		
108	MOWBRAY CK	1	191			
109	ROSEAU R	4	170	194	195	196
110	ROSEAU R	4	170	194	195	196
111	ROSEAU R	4	170	194	195	196
156	WHITEWATER CK	3	95	186	187	
157	POPLAR R W	2	88	185		
159	ROCK CK	3	70	88	185	
161	ROCK CK	3	70	88	185	

* BASINS LISTED ON THIS PAGE INCLUDE U.S.STATIONS EMPLOYED IN THE ESTIMATION OF CLIMATIC NORMALS

were necessary as a result of the lack of maximum temperature and snowfall normals for the American stations. The calculations for these basins involved the estimation of two sets of Thiessen weights, the first based only on Canadian climatological stations and the second based on both American and Canadian climatological stations. The monthly mean daily temperatures and the mean precipitation normals were estimated employing the weights calculated with both the American and Canadian stations included. In cases where the American stations did not have snowfall normals, the weights based only on the Canadian stations were employed; and where the American stations did have snowfall normals, the weights based on both American and Canadian stations were utilized. In estimating the maximum temperature normals, the difference between the monthly mean daily temperature and maximum daily temperature based on the Canadian stations only was added to the monthly mean daily temperatures calculated on the basis of both American and Canadian stations. In this manner, the available climatic normals for the American stations were employed in combination with the normals for the Canadian stations to provide the best possible estimates of the basin data.

The end result of the Thiessen weight calculations for all study basins was to produce for each basin monthly estimates of the normal mean daily temperatures, maximum daily temperatures, total precipitation and snowfall. This basic set of climatic normals has been employed to estimate climatic variables for each of the study basins. The climatic normal estimates for each of the basins have been included in Appendix B, Table B-1 of this thesis.

4.2.4 The Selection and Measurement of Climatic Variables

In the preceding sections, the compilation of a basic set of climatic normal data for each of the study basins has been discussed. In this section, the selection and estimation of climatic variables for these basins are considered. The two criteria which have been established as a basis for the selection of these variables relate to the available data and the theoretical relationships of the measures to the streamflow characteristics being studied. The three hydrologic processes which are dependent on climatic conditions and which are closely related to streamflow are precipitation, snowmelt, and evapotranspiration. The available climatic data sets for the study basins include monthly normals of daily mean temperatures, daily maximum temperatures, monthly precipitation and monthly snowfall. For the purposes of discussion the selection and measurement of climatic variables is considered under three divisions, precipitation based variables, temperature based variables and composite variables.

4.2.4.1 Precipitation Based Variables

A summary of the selected precipitation based climatic variables and their methods of calculation is contained in Table 4-6. Precipitation is the primary cause of all streamflow. The selected variables are intended to provide indices of the variations in precipitation patterns with respect to amount, form, and seasonal pattern. A brief statement of the theoretical reasoning underlying the choice of the selected variables follows.

TABLE 4-6 - SELECTED PRECIPITATION BASED CLIMATIC VARIABLES
(All Units are Inches)

Variable Abbreviation	Variable Name	Calculation
MAP	Mean Annual Precipitation	Sum of the Basin Mean Monthly Precipitation totals for 12 months
MAS	Mean Annual Snowfall	Sum of the Basin Mean Monthly Snowfall totals for 12 months
MASP	Percentage of MAP as Snowfall	MAS water equivalent expressed as a % of MAP
MWP	Mean Winter Precipitation	Sum of the Basin Mean Monthly Precipitation totals for the 5 months, November to March inclusive
MSP	Mean Spring Precipitation	Sum of the Basin Mean Monthly Precipitation totals for the 3 months, April to June inclusive
MWSP	Mean Winter and Spring Precipitation	Sum of MWP and MSP
A10YP	Annual 10 year Precipitation	Established ratio of 10 year to the mean 300 day from November 1 precipitation for nearest index station. Multiplied the above ratio by the sum of the 10 Monthly Precipitation figures November to August and added September to October normals
W10YP	Winter 10 year Precipitation	Established ratio of 10 year to the mean 160 day precipitation from November. Multiply ratio by MWP

The Mean Annual Precipitation, MAP, was selected as an index of the total water supply available annually within a basin. This variable is logically related to the annual yield of streamflow from an area. It might also be expected that this variable may represent a general index of climate and total water supply as related to the potential magnitude of annual flood events.

The Mean Annual Snowfall, MAS, was selected on the basis of the fact that most streamflow on the plains is the result of snowmelt. Ideally, this measure requires the estimation of the water equivalent of the snowpack at the end of winter. Such data are not readily available and in the present analysis it has been necessary to assume a constant conversion factor of 0.1 to estimate the water equivalent of the annual snowfall. These data have been expressed as two variables, first the Mean Annual Snowfall in inches, and secondly, the MAS water equivalent as a percentage of the mean annual precipitation. This second snowfall measure has been abbreviated, MASP, for Mean Annual Snowfall as a Percentage of MAP.

Another measure of seasonal precipitation is that of the Mean Winter Precipitation, MWP. This variable compiled for the five month period from November to March is based on the consideration that the total winter precipitation becomes stored in a frozen state to await the spring melt period.

The Mean Spring Precipitation, MSP, was estimated for the three months April to June. This variable was selected as an index of the amount of moisture which is available in spring to supplement the snowmelt runoff. This additional moisture is an important factor during the spring period of high streamflow.

The preceding two variables have been combined to estimate another variable, the Mean Winter-Spring Precipitation, MWSP. This variable is an index of the total moisture input to a basin during the season of high flows.

In addition to the above measures of precipitation amount and seasonal distribution, two variables intended to provide measures of the year-to-year variability of precipitation patterns have been included. The first of these, the Annual 10 Year Precipitation, A10YP, is included to provide an index of the variability of the available moisture supply. Such a variable might be related both to the above average annual yields and the above average flood flows. The estimation of this variable has been based on the limited number of precipitation frequency data which are available for only 10 climatological stations within the study area. The records for these index stations have been assumed to provide the best estimate of precipitation variability over the study basins. The index station closest to the study basin has been used in the precipitation frequency calculations for that basin. In the estimation of the A10YP, the ratio of the 10 year to the mean 300 day precipitation from November 1 for the selected index station has been employed to estimate the basin A10YP from the available monthly normals of precipitation. The actual calculations involved multiplying the normal 10 month, from November 1, total basin precipitation by the ratio calculated from the index station records, and then adding the normal precipitation for September and October. This rather circuitous method of calculation resulted from the fact that the precipitation frequency data for the index stations are not available for a 360 day period but rather only for 300 days.

The second measure of precipitation variability was the Winter 10 Year Precipitation, W10YP. The estimation of this variable involved similar calculations to those employed in the estimation of the A10YP above. The ratio of the 10 year to the mean 160 day from November 1 precipitation for the nearest index station was employed. This ratio was multiplied by the normal winter precipitation (November to March) for the study basin.

4.2.4.2 Temperature Based Variables

A summary of the selected temperature based climatic variables and their methods of calculation is contained in Table 4-7. Temperature patterns and their seasonal variations are primary controls over the processes of snowmelt and evapotranspiration. It is in this context that temperature based variables have been included in the present study. A brief statement of the theoretical considerations underlying the choice of the temperature variables follows.

The first of the temperature based variables is the Mean Annual Temperature Range, MATR. This measure is intended as a general index of continentality and therefore of basin location. The higher the value of the annual temperature range the greater the seasonal contrast in temperature. This seasonal contrast in temperature represents a factor related to the winter snowfall accumulation and the summer rate of evapotranspiration.

The next two variables, the Mean Winter Temperature, MWT, and the Mean January Temperature, MJANT, are proposed as measures of the

TABLE 4-7 - SELECTED TEMPERATURE BASED CLIMATIC VARIABLES
(All Units are Degrees Fahrenheit)

Variable Abbreviation	Variable Name	Calculation
MATR	Mean Annual Temperature Range	Basin Mean Monthly Temperature for warmest month minus the Basin Mean Monthly Temperature for the coldest month
MWT	Mean Winter Temperature	Mean of the Basin Mean Monthly Temperatures for the 5 months November to March inclusive
MJANT	Mean January Temperature Below 32° F.	Basin Mean January Temperature subtracted from 32° F.
MST	Mean Spring Temperature	Mean of the Basin Mean Monthly Temperatures for the 3 months April to June inclusive
MJUNT	Mean June Temperature	Basin Mean June Temperature
WMXT	Mean Winter Maximum Temperature	Mean of the Basin Mean Monthly Maximum temperatures for the 5 months November to March inclusive
JAMXT	Mean January Maximum Temperature Below 32° F.	Basin Mean Monthly Maximum Temperature for January subtracted from 32° F.

intensity of winter and therefore of the permanency of the snowpack. The colder the winter temperatures, the more permanent the snowpack is likely to be, and the greater the potential for spring runoff. The second of these measures, the Mean January Temperature, has been included to overcome the limitations of the Mean Winter Temperature, the value of which is affected by the uneven length of the winter season over the study area. In order to avoid the inclusion of zeros and negative numbers in the data, the MJANT has been subtracted from 32.0° F.

The climatic variables, Mean Spring Temperature, MST, and Mean June Temperature, MJUNT, were included to provide indices of the rapidity of the spring warming trend. Spring temperatures are expected to relate both to the rate of spring runoff from snowmelt and to the increase in evapotranspiration. The Mean June Temperature measure was proposed to overcome the season length variations which might affect the Mean Spring Temperature Measure.

The final two temperature based measures are the Winter Maximum Temperature, WMXT, and the January Maximum Temperature, JAMXT. These variables provide further measures of the intensity of winter conditions. The maximum temperatures are particularly important in controlling the snowmelt process. A higher winter maximum temperature indicates a greater potential for melt to occur during winter. In the southwestern portion of the study area, a higher winter maximum might be associated with the occurrence of "chinook" conditions, which may result in the rapid sublimation or melt of a snowpack. The Mean January Maximum Temperature is again intended to overcome the limitations imposed by variable season lengths. This variable has been calculated by subtracting the Mean January Maximum Temperature from 32.0° F. in order to avoid zeros and negative numbers in the data.

4.2.4.3 Composite Variables Based on Both Temperature and Precipitation Data

A third group of climatic variables for the study basins was derived by combining the available temperature and precipitation data. These composite variables were based on water balance calculations and include estimates of potential evapotranspiration, actual evapotranspiration, and annual water surplus. The estimation of these variables in the present research has been accomplished by the application of empirical formulae developed by Thornthwaite (1948) and Turc (1953). These two procedures are by no means the only available methods for estimation of water balance patterns; however, they have the advantage of entailing relatively simple calculations based on only temperature and precipitation data. The selected composite variables are summarized in Table 4-8.

The Potential Evapotranspiration by Thornthwaite procedures, PE, is introduced as an index of general climatic conditions particularly summer temperature and sunshine patterns. It also represents the potential water loss from the basin by evapotranspiration where water supply is not limited.

Two estimates of Actual Evapotranspiration have been included in the present study. The first such measure, THAET, was calculated according to Thornthwaite (1948) procedures. This method employs the mean monthly temperature and precipitation data and the station lati-

TABLE 4-8 - SELECTED COMPOSITE CLIMATIC VARIABLES BASED ON BOTH PRECIPITATION AND TEMPERATURE DATA
(All final units are Inches)

Variable Abbreviation	Variable Name	Calculation
PE	Potential Evapotranspiration	Potential Evapotranspiration calculated by Thornthwaite (1948) procedures based on Basin Monthly Temperature Normals
THAET	Thornthwaite Actual Evapotranspiration	Actual Evapotranspiration calculated by Thornthwaite (1948) procedures based on Basin Monthly Temperature and Precipitation Normals
TUAET	Turc Actual Evapotranspiration	Actual Evapotranspiration according to Turc's formula (1953): $TUAET = (P/\sqrt{0.9 + (P/L)^2})/25.4$ $L = 300 + 25t + 0.05t^3$ where: P is mean annual ppt. in millimeters t is mean annual temp. in °C.
THSUR	Thornthwaite Surplus	THAET subtracted from MAP
TUSUR	Turc Surplus	TUAET subtracted from MAP

tude, and entails the calculation of a monthly water budget including estimates of precipitation, storage and potential evapotranspiration. A more recent modification of these procedures (Thornthwaite 1957) has not been employed in the present study. This modified method involves provisions for water use at less than potential rates; however for prairie conditions it has been demonstrated by Holmes and Robertson (1959) that current precipitation from summer storms is used at or near potential rates. Also, the 1948 procedures have been successfully employed for the study area by Laycock (1967). The Thornthwaite calculations in the present analysis have been made employing a modification of a computer program written by Black (1966). A second estimate of actual evapotranspiration, TUAET, was made employing procedures developed by Turc (1962). These procedures are simpler than for the Thornthwaite method and use only mean annual temperature and mean annual precipitation data. These two estimates of actual evapotranspiration were introduced in the present study as measures of the water loss by the evapotranspiration process.

The final pair of climatic variables are estimates of annual moisture surplus based on the actual evapotranspiration estimates discussed above and the mean annual precipitation. The first of these measures, the Mean Annual Water Surplus by Thornthwaite, THSUR, was estimated by subtracting the actual evapotranspiration estimate by Thornthwaite procedures, THAET, from the Mean Annual Precipitation, MAP. The second water surplus variable, the Mean Annual Water Surplus by Turc, TUSUR, was calculated in the identical manner employing the actual evapotranspiration estimated by Turc's procedures, TUAET, and the MAP. Both of these annual surplus measures are proposed as indices of the total available water supply.

4.2.4.4. Summary of Selected Climatic Variables and Data

A summary of the selected climatic variables and their methods of calculation is presented in Tables 4-6, 4-7 and 4-8. The complete climatic variable data set compiled for each of the 161 study basins is listed in Appendix B, Table B-2.

4.3 OTHER PHYSICAL GEOGRAPHIC PATTERNS

The second major group of independent variables included in the present research has been classified under the general heading "Other Physical Geographic Patterns." This grouping includes measures of the physical characteristics of the study basins with the exception of the climatic variables. The two criteria on which the variable selection is based are the same as those employed in the choice of the climatic variables. The first of these criteria concerns the theoretical relationships of the variables to streamflow, and the second is related to the available data sources. The discussion which follows is divided into four sections dealing with the theoretical relationships of the variables to streamflow, the available data sources, the basic data compilation, and the selection and estimation of variables.

4.3.1 Theoretical Relationships to Streamflow Characteristics

The physical geographic characteristics of a watershed, with the exception of the climatic patterns, control the efficiency with which the available moisture supply is collected in channels and conveyed from the basin as streamflow. In particular, the physical characteristics are related to the timing of streamflow and have a less well-defined influence on the total volume of streamflow, which is more directly the result of the climatic parameters. For the purpose of discussion of the theoretical relationships of the physical characteristics to streamflow, the physical patterns have been considered under three headings: drainage area; topographic patterns; and surficial geology, soil, vegetation and landuse.

4.3.1.1 Drainage Area

Drainage area is a measure which is of the utmost importance in any study of streamflow characteristics. The importance of this variable has been confirmed in numerous such studies (see for example Thomas and Benson 1969, and Karuks 1963). The drainage area is a variable which exerts a basic control over the amount of streamflow. All other factors being held constant, it is to be expected that a greater volume of streamflow will be derived from a large drainage basin than from a smaller one. In any study of the relationships of physical geographic patterns to streamflow, it is imperative that the effect of drainage basin size be accounted for before considering other factors. One of the most straightforward approaches to this problem is to divide the streamflow volume by the drainage area, thus converting the volume measure to an estimate of depth over the basin. Unfortunately in many areas, particularly in a semi-arid glaciated plains region such as the present study area, it is not possible to accurately delimit the drainage area contributing to streamflow.

The problem of defining drainage area as a hydrologic variable in the glaciated Canadian prairies has been discussed in some detail by Stichling and Blackwell (1958) and by Laycock (1959). Drainage in this region is characterized by large areas of internal drainage. This drainage is directed into local depressions which contain swamps or sloughs. The pattern is particularly pronounced in areas of hummocky dead ice morainic deposits. Many of the local depressions have no outlet except by evaporation, while others overflow and contribute to streamflow in some years. The net result of these patterns is that the drainage area contributing to streamflow is extremely variable both seasonally and from year to year as a function of the moisture supply conditions.

Stichling and Blackwell (1958, p. 366-367) have summarized the likely effects of variable drainage area on both streamflow volumes and flood flows. While the areas of local drainage vary from time to time, the general effect of such patterns within a basin is to reduce the volume of streamflow. Some of this loss from streamflow may be offset where local groundwater systems are well developed. Flood flows will in general be reduced by the presence of local depressional storage; however, this effect may be countered in part where local groundwater systems are such that water from the depressions provides a significant base flow in the streams. It is also recognized that in the case of rare flood events, a much larger proportion or all of a drainage basin may contribute directly to streamflow.

Unfortunately, most of what has been written concerning the hydrologic importance of internal drainage in the plains area has been of a general qualitative nature. One exception to this trend is the continuing work of the United States Geological Survey and other agencies which are studying the hydrology of prairie potholes in North Dakota. Examples of some recent publications resulting from this work includes those by Shjeflo and others (1962), Shjeflo (1968), Eisenlohr and Sloan (1968), and Sloan (1970). The general conclusion emanating from this research is a confirmation of the complex, multivariate nature of the hydrologic processes involved in the water balance of prairie potholes.

There is no simple method of evaluating the area of a drainage basin which contributes to streamflow under given conditions. The best solution probably is the detailed field study of local patterns under varying conditions of moisture supply. Such an approach is impossible for a project such as the present study which involves a large number of basins over a large study area. Durrant and Blackwell (1959, p. 107) in their study of flood flows in the southern Canadian prairies prepared detailed drainage maps at a relatively large scale from aerial photographs. These maps were employed as a basis for estimating the drainage area contributing to the mean annual floods. A similar approach has been taken in the present study, and a measure of non-contributing drainage area has been included.

4.3.1.2 Topographic Patterns

Topographic characteristics of drainage basins are related to the efficiency with which the available moisture is collected in channels and conveyed as streamflow from the basin (Langbein and others 1947, p. 128). In this context, topographic patterns are closely related to the concentration and timing of streamflow, and indirectly related to the total volume of streamflow. Where topography is such that the movement of available moisture toward channels is retarded, the result may be an increase in the infiltration and in the actual evapotranspiration. These additional losses from the available moisture supply result in a lower volume of streamflow.

The influence of topographic patterns on streamflow characteristics has been given general consideration in the discussion of streamflow in the context of the hydrologic cycle as contained in Chapter 1, Section 1.2.1. Many hydrologic textbooks contain a general discussion of the influence of topographic patterns on both the timing and volume of runoff (see for example Ward 1967, p. 324 and 330 ff; and Wilson 1969, p. 84). Laycock (1959) has provided a qualitative discussion of the effects of local topographic patterns on available water supplies in the Canadian prairies. In this work, variations in slope, infiltration capacity, and internal drainage patterns have been discussed in relation to the prevailing landform types.

While the importance of landform and topographic patterns in the determination of the characteristics of streamflow is widely recognized, any analysis of these relationships requires the quantitative measurement of these patterns. A large number of quantitative measures of landform patterns have been devised during recent decades. The pioneering work in this field was published by Horton in 1945. More recently, Strahler (1964) published a comprehensive review of the various measures. Most of the quantitative geomorphic measures have been devised for use in relatively small basins and many involve time-consuming measurements from topographic maps. In a study on the scale of the present research in which basin sizes range from 50 to 10,000 square miles, it is imperative that straightforward, readily measured indices of topographic conditions be employed. Many such measures have been devised and are in evidence in the work of Benson (1962b and 1964), Karuks (1962), Thomas and Benson (1969) and many others.

Some topographic elements which are of particular interest in an analysis of streamflow variations include measures of elevation, slope, basin shape, channel development and storage potential. Measures of basin elevation and relief are related to the available moisture supply in that in many areas orographic effects result in higher precipitation at higher elevations. In the plains region, high values for basin relief usually indicate the presence of a significant topographic relief feature. The effect of local relief features in increasing precipitation may be observed in the areas of the Cypress Hills and the Manitoba Escarpment as illustrated on the map of Mean Annual Precipitation for the Study Area, Figure 2-3 (Section 2.2.2.2).

Measures of basin relief are closely related to various slope measures. Slope variables are of particular importance in relation to the rate at which available moisture moves toward stream channels and then flows downstream and out of the basin. Slope measures are also related to the total volume of streamflow; since in areas with a low degree of slope, the runoff will take place at a slower rate resulting in greater infiltration and evapotranspiration.

Basin shape is recognized as a factor which in part governs the timing of streamflow. A given precipitation input spread evenly over an elongated basin tends to produce a lower peak in the hydrograph than would an identical precipitation input over a basin with a more rotund shape. This pattern is related to the tendency for runoff from a rotund basin to converge downstream at a point in time while runoff from an elongated basin tends not to converge but to be strung out over time.

The degree to which the channel network is developed is another factor which influences the volume of streamflow. One of the most useful methods of considering this association is through the concept of drainage density (Horton 1945, p. 285). Drainage density is a measure of the number of streams occurring per square mile. Where drainage density is higher, the efficiency with which available moisture is collected in channels as streamflow is greater, and the runoff is greater than for a similar basin in which the drainage density is lower.

A further topographic pattern of significance in a consideration of streamflow characteristics is the amount of natural storage within the basin. Natural storage, as defined here, includes areas of swamp, lakes and sloughs which are capable of absorbing available moisture and thereby retarding the flow of available moisture. The amount of streamflow is also affected by increased infiltration and evapotranspiration which results from the slower movement of the available moisture.

In the present study of plains streamflow patterns, independent variables have been selected, such that one or more measures of each of the above aspects of topographic pattern are included.

4.3.1.3 Surficial Geology, Soil, Vegetation and Landuse

The four sets of basin conditions considered in this section: the surficial geology, the soils, the vegetation and the landuse pattern, share a common influence on the production of streamflow. All of these factors are associated with variations in the infiltration capacity of the land surface. Surficial geology and soils are closely linked variables in that the available parent material, which is the product of the surficial geology, is one of the important factors governing the texture of the soil profile. The infiltration rate of a given surface is allied to the texture of the soil. In a study of streamflow patterns in relation to surficial geology in Southern Ontario, Ayers and Ding (1967) have demonstrated a definite correlation between the soil texture of various deposits and the concentration of streamflow during the spring period. Coarse textured deposits were associated with lower spring flows and more reliable summer flows while finer textured deposits with lower permeabilities were associated with high spring and low summer flows. Laycock (1959) has discussed the effects of various landform and soil texture associations with respect to available water supplies in the Prairie Provinces. Unfortunately, in the present study, it is not possible because of a lack of available data to directly evaluate the relationships of surficial geology and soil textures to the selected streamflow characteristics. There are no available sources from which detailed data on surficial geology and soil textures may be extracted for the study area. Alternatively, it was expected that several of the measures of topographic patterns would be indirectly related to and reflect the variations in both surficial geology and soil textures.

Vegetative cover patterns also play an important role in governing the amount and rate of runoff by effecting variations in the infiltration capacities of the land surface. The presence of vegetation tends to maintain the infiltration capacity of a soil; while in a non-vegetated state, the soil surface is susceptible to compaction and surface sealing and will have a lower infiltration rate. The effect of a vegetative cover on infiltration and subsequent runoff production is most vividly observed in the increased runoff which occurs following the harvesting of a forest cover (Slaymaker and Jeffrey 1969, p. 176). Any decrease in the infiltration capacity of the surface will result in an increase in both the amount and rate of runoff. Vegetative conditions within a particular watershed are not time invariant; but rather, as a vegetative cover matures, its effect on the runoff process changes. Such temporal variations make the inclusion of measures of vegetative cover in a study of streamflow patterns difficult. There is also a definite lack of detailed data on local vegetation patterns. In the present study the use of vegetation variables has been limited to a single measure of the percentage of a basin under forest vegetation as measured from topographic maps.

Landuse patterns, like vegetative patterns, are variable over time; and therefore, difficult to employ in a study on the scale of the present research. However, the effects of landuse on both the amount and rate of runoff are recognized. Cultivated land is likely to have a different infiltration capacity than non-cultivated land. Another significant landuse from a hydrologic point of view is urban development. Such development involves the paving of large areas and the introduction of artificial drainage through sewer systems; the net effect is a large reduction in infiltration capacity and a marked increase in both the amount and rate of runoff. In the present study no attempt has been made at the evaluation of the effects of landuse changes on streamflow. The areas of urban development within the study basins are of limited extent; and the changes in agricultural landuse can much better be evaluated in a study of streamflow on a more local scale.

4.3.2 Available Data Sources

The theoretical relationships between the physical characteristics of streamflow have been discussed. The types of variables which are likely to be most closely linked to the streamflow characteristics being analysed in the present study include measures of basin drainage areas, topography, surficial geology and soils, and prevailing vegetation and landuse patterns. While none of these conditions are completely time invariant, the assumption of time invariance has been made for the time span of the present research. This time span has a maximum limit of 30 years corresponding to the maximum period of hydrometric data compilation. This assumption was required so that estimates of physical characteristics could be made from available data sources and in particular from topographic maps which have been compiled at different times for different sections of the study area.

Several possible sources for physical data exist on a local scale; however in the present research, it was considered desirable to employ a data source which provided consistent data over the entire study area. Such a data set exists in the form of the National Topographic Series of Maps. The topographic maps of this series have been used exclusively for the compilation of physical data within the study area.

The available topographic map coverage for the study area at scales of 1:50,000 and 1:250,000 is illustrated in Figure 4-3. The entire study area has been mapped at a scale of 1:250,000. The contour interval for these maps is 100 feet over most of the study area with a larger interval of up to 500 feet for areas in close proximity to the foothills and mountains. For most of the southern part of the study area, topographic map coverage is also available at a scale of 1:50,000. These maps have a contour interval of 25 feet over most of the area, with a 50 foot interval in areas of more extensive local relief. Some of the study basins extend south of the United States-Canada border, and topographic map coverage for these areas is available at a scale of 1:250,000. Larger scale 1:63,360 topographic maps for the border areas of the United States do not yet provide complete coverage nor were they available for the present research.

Since 1:250,000 scale topographic maps were available for the entire study area and bordering regions, this scale of maps was chosen as the basic data source to be employed in the compilation of the physical variables. One of the major disadvantages of employing these

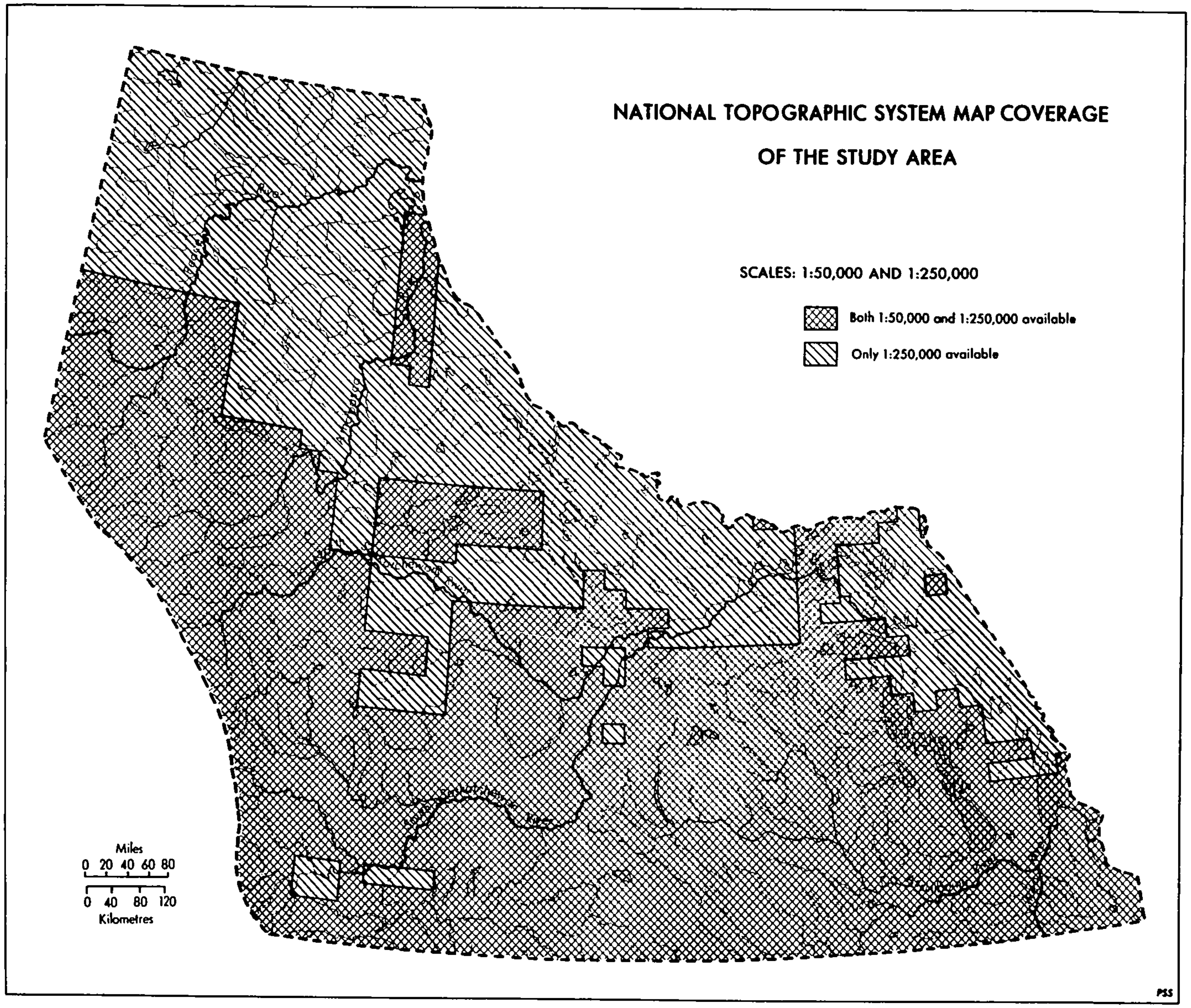

NATIONAL TOPOGRAPHIC SYSTEM MAP COVERAGE
OF THE STUDY AREA
SCALES: 1:50,000 AND 1:250,000
Both 1:50,000 and 1:250,000 available
Only 1:250,000 available
Miles
0 20 40 60 80
0 40 80 120
Kilometres
PSS

Figure 4-3

maps was related to the evaluation of measures which were dependent on the interpolation of elevations from the contour lines. The relatively large contour interval of 100 feet made such measures difficult to evaluate. As a partial solution to this problem, it was decided to employ 1:50,000 scale topographic maps, wherever available, to increase the accuracy with which elevations could be estimated. Although the incomplete coverage of the study area at a map scale of 1:50,000 precluded the adoption of this scale as the basic data source for the study, it was recognized that these larger scale maps included considerably more detail than did the 1:250,000 maps. To evaluate the effect of this greater detail on the evaluation of basin physical data, it was proposed to compile physical data from maps at both the 1:50,000 and 1:250,000 scales for a sample of basins and to compare the results. Therefore although the 1:250,000 scale maps have been adopted as the basic data source in the present study, a preliminary examination of the effect of adopting maps of larger scale was undertaken.

Table C-1 in Appendix C lists the identification numbers of the 1:250,000 scale map sheets which provide complete coverage of the drainage basins associated with each of the 161 study basins.

4.3.3 The Selection and Compilation of Other Physical Variables

The selection of the other physical geographic variables to be included in the analyses of the present project was made on the basis of a consideration of their theoretical relationships to the streamflow characteristics under study, a review of the relevant literature concerning other similar studies, and a recognition of some of the practical problems of data compilation on the scale of the present investigation. The consideration of the theoretical relationships of physical geographic patterns to the streamflow characteristics being studied identified three main groups of variables for inclusion in the analyses. These groups of variables were measures of drainage basin area with particular reference to the contributing portion of the basin; measures of topographic factors including slopes, elevations, basin shape, channel network and natural storage; and finally measures of surficial geology, soils, vegetation and landuse patterns.

A review was made of the relevant literature concerning similar studies in other areas and the problems associated with the quantitative measurement of physical geographic patterns.* This literature review introduced the author to the great number of different measurements of physical geographic patterns which have been employed with varying degrees of success in other similar studies. The experience of other researchers, the theoretical relationships to streamflow characteristics, and some consideration of the practical limitations of data collection from the available maps and on the scale of the present study, provided a basis for the selection of a set of physical geographic variables.

*The literature review of other similar studies examined a large number of publications including: Benson (1959, 1962a and b, and 1964); Cole (1966); Collier and Nix (1967); Coulson and Gross (1967); Durrant and Blackwell (1959); Golding and Low (1960); Horton (1945); Howe, Slaymaker and Harding (1967); Karuks (1964); Kennard and Bass (1963); Lull and Anderson (1967); Lull and Sopper (1966); Morisawa (1954 a and b); Nash and Shaw (1966); Schneider (1965); Slaymaker and Jeffrey (1969); Solomon et al (1968); Strahler (1964); Thomas and Benson (1969); and others.

4.3.3.1 The Compilation of the Basic Physical Data from Topographic Maps

A set of basic physical geographic data was compiled for each of the 161 study basins. These data were obtained by measurements from the 1:250,000 scale topographic maps of the study basins. In addition to the measurements from the 1:250,000 scale maps, similar measurements were compiled from 1:50,000 scale maps for a sample of basins. Initially a random sample of 50 basins was selected from the total list of 161. Of these 50 basins, 31 had complete map coverage at the 1:50,000 scale, and this group formed the sample for the evaluation of the effect of map scale on the physical measurements.

The measures of physical geographic patterns, which were included in the basic physical data set for each basin, are listed in Table 4-9. The table summarizes the abbreviations attached to the measures, the measure names, and the methods of measurement as applied both to the 1:50,000 scale maps for the sample basins, and to the 1:250,000 scale maps for all basins.

The first pair of physical measures relate to the drainage basin area. The Topographic Drainage Area, TDA, is defined as the area enclosed within the topographic divide of the drainage basin. This is the same measurement as was employed in the estimation of the Thiessen weights for the interpolation of basin climatic normals (Section 4.2.3.1). The second measure associated with drainage area is the Non-Contributing Drainage Area, NCDA. This measure was defined as the total area within a basin, which on the 1:250,000 scale maps had internal drainage to swamp or sloughs without any surface connection to

TABLE 4-9 - BASIC PHYSICAL DATA COMPILED FROM TOPOGRAPHIC MAPS OF THE STUDY BASINS

Abbreviation for Measure	Name of Measure	Evaluation of Measurement	
		1:50,000 Scale - Sample Basins	1:250,000 Scale - All Study Basins
TDA	Topographic Drainage Area***	Measured on 1:250,000 scale maps only	Topographic drainage area was outlined and measured in the calculation of Thiessen weights for climatic data interpolation (see Section 4.2.3.1). Whenever 1:50,000 scale maps were available, the divide was located on the larger scale maps and transferred to 1:250,000 scale
NCDA	Non-contributing Drainage Area***	Measured on 1:250,000 scale maps only	Non-contributing drainage area was delimited on 1:250,000 scale maps to include all areas of internal drainage not contributing surface runoff to the stream under normal conditions. Such areas include swamp, lake and slough drainage not connected to the main stream
MCL	Main Channel Length*	Measured length of longest channel from hydrometric station site to end of tributary	Same as for 1:50,000 scale sample
MCLD	Mean Channel Length to the Divide*	Same as MCL above but extended upstream to the topographic basin divide	Same as for 1:50,000 scale sample

Table 4-9, Continued

Abbreviation for Measure	Name of Measure	Evaluation of Measurement: 1:50,000 Scale - Sample Basins	Evaluation of Measurement: 1:250,000 Scale - All Study Area
TL	Total Tributary Length*	Measured total length of all tributaries (including intermittent streams) with connections to main channel	Same as for 1:50,000 scale sample
ELG	Elevation of Gauge** (Hydrometric Station)	Elevation of gauge interpolated between nearest contour lines	Same as for 1:50,000 scale sample. Whenever 1:50,000 maps are available, this measure has been made on those larger scale maps
ELD	Elevation of Main Channel intersection with Divide**	Elevation of main channel intersection with divide interpolated between nearest contour lines	Same as for 1:50,000 scale sample. Whenever 1:50,000 scale maps are available, this measure has been made on those larger scale maps
ELMX	Maximum Elevation within the Drainage Basin**	Elevation of highest point in the basin	Same as for 1:50,000 scale sample. Whenever 1:50,000 scale maps are available, this measure has been made on those larger scale maps
EL10	Elevation of point on Main Channel located 10% of MCLD above gauge**	Elevation of point 10% of length up Main Channel interpolated between nearest contour lines	Same as for 1:50,000 scale sample. Whenever 1:50,000 scale maps are available, this measure has been made on those larger scale maps

Table 4-9, Continued

Abbreviation for Measure	Name of Measure	Evaluation of Measurement 1:50,000 Scale - Sample Basins	1:250,000 Scale - All Study Basins
EL85	Elevation of point on Main Channel located 85% of MCLD above gauge**	Elevation of point 85% of length up Main Channel interpolated between nearest contour lines	Same as for 1:50,000 scale sample. Whenever 1:50,000 scale maps are available, this measure has been made on those larger scale maps
ALOS	Surface Area of Lakes on the Stream***	Surface area of lakes located on streams and therefore a part of the stream network	Same as for 1:50,000 scale sample
ASOS	Surface Area of Swamps Adjacent to Streams***	Surface area of swamps located on or immediately adjacent to the streams and therefore part of the stream network	Same as for 1:50,000 scale sample
AF	Area of Forest Cover within the Topographic Drainage Area***	Total area of forest cover in the basin	Same as for 1:50,000 scale sample

*All length measurements were made in inches with an opsometer. These measurements were subsequently converted to miles.

** All elevation measurements were made in feet by interpolation between contour lines. 1:50,000 scale maps were employed wherever such coverage was available.

*** All area measurements were made in square inches with "Bruning" Areagraph Charts. These measurements were subsequently converted to square miles.

the stream network.

The second group of physical measures, summarized in Table 4-9, includes three measures of channel length. The Main Channel Length, MCL, is the length of the longest channel measured from the hydrometric station to the end of the farthest distant finger tributary in the basin. The second measure, the Main Channel Length to the Divide, MCLD, is the same as the MCL above except that the finger tributary has been assumed to extend to the topographic divide of the basin. The final measure of channel length is the Total Tributary Length, TL, which is the total length of all tributaries including intermittent streams.

The third group of physical measures are a series of reference elevations for particular locations within a basin. The elevations recorded for each basin were the Elevation of the Hydrometric Station, ELG; the Elevation of the Divide, where the extension of the main channel would end, ELD; the Highest Point in the Basin, ELMX; the Elevation of the Point on the Main Channel 10% of MCL Upstream from the Gauge, EL10; and the Elevation of the Point on the Main Channel 85% of MCL Upstream from the Gauge, EL85. In all cases where map coverage at the 1:50,000 scale was available these elevation measurements were made on the 1:50,000 scale maps. Where only 1:250,000 scale maps were available, it was necessary to estimate the elevations from these smaller scale maps.

The next pair of physical measures were estimates of the natural storage on the stream in the form of lakes and swamps. The Area of Lakes on the Stream, ALOS, was estimated by measuring the total surface area of lakes which were joined to the stream network. The Area of

Swamps Adjacent to Streams, ASOS, was estimated by measuring the total surface area of swamps located adjacent to the streams.

The final measure of physical pattern was the Area of Forest in each of the study basins, AF. This measure was made by measuring the total extent of the forest area as shown on the topographic maps.

These thirteen physical geographic measures which have been discussed above and which are summarized in Table 4-9 form the basic physical data set as compiled from the 1:250,000 scale maps for each of the 161 study basins. A set of these data was compiled from the available 1:50,000 scale maps for each of the 31 basins selected in the sample. The basic physical data sets for each of the basins and for the sample basins are listed in Appendix C. Table C-2 lists the basic physical geographic data collected for each of the 161 basins; and, Table C-3 lists the data compiled from the larger scale maps for the sample of 31 basins.

In the following sections of this chapter, the effect of map scale on the compilation of the physical geographic data is considered (Section 4.3.3.2), and the estimation of the selected physical variables from the basic data sets is described.

4.3.3.2 The Effect of Map Scale on the Measurement of the Basic Physical Data

In the present study the basic physical data have been compiled for all basins from 1:250,000 scale topographic maps and for a sample of 31 basins from 1:50,000 scale topographic maps. The reason for collecting the sample data from larger scale maps was to provide a basis for a comparison of data compiled at the two scales. The 1:50,000 scale maps obviously represent a basis for the compilation of more exact measurements. These larger scale maps have a smaller contour interval and cover a much smaller area with sixteen 1:50,000 scale sheets being required to cover the same area as one 1:250,000 scale sheet. On this basis, the larger scale maps would definitely provide a basis for more detailed measures.

The present study is aimed at an analysis by statistical correlation of the relationships between various physical geographic measures and streamflow characteristics. In such an analysis emphasis is on the relative rather than the absolute differences between basins, and the less detailed measures taken from smaller scale maps may not represent a serious problem provided they are representative of the relative differences between basins.

In the compilation of the basic physical geographic data from the topographic maps several of the measures, such as the Drainage Area and Elevations, were based on the use of both 1:50,000 and 1:250,000 scale maps. These measures do not provide a basis for a consideration of the effect of map scale on the measurements. However, other measures, such as the channel lengths and the areas of lakes, swamps and forests, were based only on the use of a single scale of maps. These measures, which were compiled from 1:50,000 scale maps for the sample basins and from 1:250,000 scale maps for all basins, may be considered in an evaluation of the effect of map scale.

In order to examine the relative variations in the measurements related to map scale, linear correlations between data collected at the two scales were calculated for six physical geographic measures. The resulting correlations are summarized in Table 4-10. In all cases, the

TABLE 4-10 - COMPARISON BY CORRELATION OF PHYSICAL DATA COMPILED FROM 1:50,000 AND 1:250,000 SCALE TOPOGRAPHIC MAPS FOR A SAMPLE OF STUDY BASINS
(Sample Size Equals 31)

Physical Measure (for method of measurement see Table 4-7)	Correlation Coefficients* Between Data Compiled from 1:50,000 and 1:250,000 Scale Maps
MCL Mean Channel Length	0.982
MCLD Mean Channel Length to the Divide	0.981
TL Total Tributary Length	0.957
ALOS Surface Area of Lakes on the Stream	0.967
ASOS Surface Area of Swamps Adjacent to the Stream	0.940
AF Area of Forest within the Topographic Drainage Area	0.997

* All correlation coefficients are significant at the 1% level.

correlations between measures compiled from 1:50,000 scale maps and the same measures compiled from 1:250,000 scale maps are highly significant at above the 1% level. On this basis, it seems reasonable to suggest that for the physical measures being employed in the present study the relative differences between basins would not be greatly changed by the use of larger scale maps if these were available. It is important to realize that this does not mean that larger scale maps would not be of value in a similar study, for such maps would provide a basis for more detailed measurements; however, for the measures being employed in the present analysis, the use of larger scale maps does not seem to result in changes in the relative measures being compiled.

4.3.3.3 The Final Calculation of the Physical Variables

The physical geographic variables for inclusion in the analysis of streamflow characteristics were calculated from the basic physical data sets, which were compiled for each of the study basins from the 1:250,000 scale topographic maps. A summary of the variable abbreviations, the variable names and their methods of calculation is contained in Table 4-11. A brief consideration of the reasons for the selection of these measures is presented in the following pages.

The first group of physical variables relate to the measurement of drainage basin area. The Topographic Drainage Area, TDA, is the simplest such measure and was compiled directly from the topographic maps. The Non-Contributing Drainage Area as a % of TDA, NCDA, represents an attempt to introduce a measure of the relative area within a basin which is subject to internal drainage and does not normally contribute directly to streamflow. A variation on this variable is the Contributing Drainage Area, CDA, which is the difference between the TDA and the NCDA measures. This CDA measure is proposed as a substitute for TDA particularly when mean streamflow events are being analysed. The CDA variable is similar to the "effective drainage area" measure employed by Durrant and Blackwell (1959, p. 107) in their analysis of floods in the southern prairies.

TABLE 4-11 - SUMMARY OF SELECTED INDEPENDENT VARIABLE MEASURES OF OTHER PHYSICAL GEOGRAPHIC PATTERNS

Variable Abbre-viation	Variable Name	Calculation of Variable (For explanation of variable abbre-viation see Table 4-7 and column 1 of this table)
TDA	Topographic Drainage Area	Topographic Drainage Area expressed in square miles
NCDA	Non-contributing Drainage Area as % of TDA	NCDA = ((NCDA/TDA) x 100.0) + 1.0
CDA	Contributing Drainage Area	CDA = TDA - NCDA
BL	Basin Length	Equivalent to the Main Channel Length to the Divide, MCLD
BS	Basin Shape	BS = BL^2/TDA
MCS	Main Channel Slope	Estimated as slope of the channel between points located 10% and 85% of total BL measured upstream from the hydrometric station MCS = (EL85-EL10)/(BL x 0.75)
BEL	Basin Elevation	Mean of the elevations at 10% and 85% of the total BL measured from the hydrometric station BEL = (EL85-EL10)/2.0
BR	Basin Relief	Total Basin Relief, the difference between the highest elevation and the elevation of the hydrometric station BR = ELMX - ELG
DDTDA	Drainage Density based on TDA	DDTDA = (MCL + TL)/TDA
DDCDA	Drainage Density based on CDA	DDCDA = (MCL + TL)/CDA

Table 4-11, Continued

Variable Abbre-viation	Variable Name	Calculation of Variable (For explanation of variable abbre-viation see Table 4-7 and column 1 of this table)
OFTDA	Average Length of Overland Flow based on TDA	OFTDA = 1.0/(2.0 x DDTDA)
OFCDA	Average Length of Overland Flow based on CDA	OFCDA = 1.0/(2.0 x DDCDA)
ALTDA	Surface Area of Lakes on Stream as % of TDA	ALTDA = ((ALOS/TDA) x 100.0) + 1.0
ALCDA	Surface Area of Lakes on Stream as % of CDA	ALCDA = ((ALOS/CDA) x 100.0) + 1.0
STDA	Surface Area of Swamp on Stream as % TDA	STDA = ((ASOS/TDA) x 100.0) + 1.0
SCDA	Surface Area of Swamp on Stream as % CDA	SCDA = ((ASOS/CDA) x 100.0) + 1.0
SLTDA	Surface Area of Lakes and Swamp on Stream as % TDA	SLTDA = ((ALOS + ASOS)/TDA) x 100.0) + 1.0
SLCDA	Surface Area of Lakes and Swamp on Stream as % CDA	SLCDA = (((ALOS + ASOS)/TDA) x 100.0) + 1.0
FTDA	Area of Forest as % TDA	FTDA = (AF/TDA) x 100.0) + 1.0

The second group of physical variables includes a large number of measures of basin topography. The selected variables include measures of basin shape, channel slope, basin elevation and relief, channel development, and natural storage. The first of the topographic variables is the Basin Length, BL, which is defined as the main channel length extended to the divide. This variable represents a very general measure of drainage area, a measure which is not affected by non-contributing sections of the basin. The BL variable is combined with the TDA variable to estimate an index of Basin Shape, BS. There are several possible indices of basin shape referred to in the literature; however, the measure selected for the present study was chosen on the basis of its simple calculation and use of available data. The shape of a basin is theoretically related to the timing of streamflow.

There are several possible methods for the evaluation of slope within a basin. In the present study the estimation of an average basin slope was ruled out because of the time-consuming measurements which would have been required. As an index of slope within a basin, a measure of the Main Channel Slope, MCS, as developed by Benson (1959) has been adopted in the present study. This measure is expected to be closely related to the timing of runoff and thus to the magnitudes of flood flows.

Two simple measures of basin elevation and relief have been included in the analyses. Basin Elevation, BEL, has been estimated by assuming the mean of the elevations as 10% and 85% of the channel length (the same points as employed in the estimate of channel slope) and provides an approximation to the mean elevation of the basin.

This relatively crude index has been proposed as an alternative to the task of actually measuring the area-elevation relationship for the entire basin. The proposed basin elevation index, BEL, was expected to relate in a general way to the precipitation patterns within the study area. Another measure, Basin Relief, BR, was proposed to account for local orographic effects on the precipitation pattern. This measure was estimated as the difference in elevation between the hydrometric station and the highest point in the basin.

The degree to which the channel network is developed within a basin is related to the efficiency with which the available moisture is collected in streams. In the present analyses, two measures of network development have been investigated, the drainage density and the length of overland flow. The Drainage Density which is the mean number of streams occurring per square mile has been calculated both for the topographic drainage area and for the contributing drainage area. The Average Length of Overland Flow is estimated to be equal to one half of the average distance between streams. This measure has also been estimated both for the TDA and for the CDA.

The final variables relating to basin topography are measures of the natural storage on or adjacent to the streams. These measures include the Percentage Area of Lakes, the Percentage Area of Swamps, and the Percentage Area of Lakes and Swamps. In each case, these measures have been expressed as percentages of both the topographic and the contributing drainage area. A constant value of 1.0 has been added to all percentages to avoid the inclusion of zeros in the data set. The measures of natural storage within a basin are particularly important as a result of their dampening effect on peak discharges.

In addition to the physical variables relating to drainage area and topographic patterns, it was desirable to include some measures of surficial geology, soils, vegetation, and landuse patterns. Unfortunately, data on these patterns are not readily available on the scale of the present study. A further problem relates to the quantitative measurement of these conditions. For these reasons no attempt has been made to include measures of surficial geology and soils in the present analysis. Landuse and vegetation data are also difficult to obtain on the scale of the present study, and only one such variable has been included, the Percentage Forest Area in a Basin. This variable has been estimated for the topographic drainage area, and a constant of 1.0 has been added to all percentages to avoid the inclusion of zeros in the data set. The forest area variable was proposed on the basis of the effect forest cover has on reducing the seasonal peaks in streamflow by increasing the infiltration capacity of a watershed.

In all, data for 19 physical variables have been compiled for each of the 161 study basins. These variables have been employed as independent variables in the analyses of the regional streamflow characteristics. A complete listing of the physical variable data for all of the study basins is contained in Table C-4 of Appendix C.

4.4 SUMMARY

This chapter has considered the selection and measurement of the independent variables. The variables have been selected on the basis of their likely theoretical relationships to the streamflow characteristics under study and on the basis of available data sources. For the purposes of discussion, the independent variables have been considered in two groups, climatic measures and measures of other physical geographic variables. The latter group included various elements of drainage basin area, topography, and surficial geology, soils, vegetation, and landuse. In all, 39 independent variables, 20 climatic measures, and 19 measures of other physical geographic patterns, have been estimated for each of the 161 study basins. These data are employed in the analyses of Chapter 5.

CHAPTER 5

THE ANALYSES OF THE RELATIONSHIPS OF THE SELECTED STREAMFLOW CHARACTERISTICS TO THE INDEPENDENT VARIABLES

5.1 INTRODUCTION

In this chapter, the statistical analyses of the relationships of the selected streamflow characteristics to the measures of climatic and other physical geographic patterns are described. The analyses have been undertaken from the approach of hydrologic system investigation utilizing the multivariate statistical techniques of multiple regression and factor analysis. The data set utilized included 4 dependent and 39 independent variables compiled for each of the 161 study basins. A complete list of all the variables and their abbreviations is presented in Table 5-1. These abbreviations are used interchangeably with the variable names in the discussion of the analyses which follows.

5.2 METHODOLOGY OF ANALYSIS

Statistical methods are widely used in hydrologic research in an attempt to synthesize the information contained in a mass of data, and to make the best use of past records in the understanding and prediction of future events (Slivitzky 1966, p. 184). The complex nature of the interrelationships linking streamflow characteristics and the various measures of climatic and other physical geographic patterns are well suited to analysis by multivariate statistical techniques. The basic

TABLE 5-1 - ALPHABETICAL LISTING OF VARIABLE ABBREVIATIONS AND NAMES AS EMPLOYED IN THE ANALYSES

Variable Abbreviation*	Variable Name
ALCDA	Area of Lakes % CDA
ALTDA	Area of Lakes % TDA
A10YP	Annual Precipitation 10 Year Return Period
BEL	Basin Elevation
BL	Basin Length
BR	Basin Relief
BS	Basin Shape
CDA	Contributing Drainage Area
DDCDA	Drainage Density Based on CDA
DDTDA	Drainage Density Based on TDA
FR	Flood Index-Ratio 10 Year to the Mean
FTDA	Area of Forest as % of TDA
JAMXT	Mean January Maximum Temperature below 32°F
MAP	Mean Annual Precipitation
MAS	Mean Annual Snowfall
MASP	Mean Annual Snowfall as % of MAP
MATR	Mean Annual Temperature Range
MCS	Main Channel Slope
MF	Mean Annual Flood
MJANT	Mean January Temperature below 32°F
MJUNT	Mean June Temperature
MSP	Mean Spring Precipitation
MST	Mean Spring Temperature
MWP	Mean Winter Precipitation
MWSP	Mean Winter Spring Precipitation
MWT	Mean Winter Temperature
MY	Mean Annual Yield
M10YF	Annual Flood with 10 Year Return Period
M10YY	Annual Yield with 10 Year Return Period
NCDA	Non-contributing Drainage Area % of TDA
OFCDA	Length of Overland Flow Based on CDA
OFTDA	Length of Overland Flow Based on TDA
PE	Potential Evapotranspiration
SCDA	Area of Swamps as % of CDA
STDA	Area of Swamps as % of TDA
SLCDA	Area of Swamps and Lakes as % CDA
SLTDA	Area of Swamps and Lakes as % TDA
TDA	Topographic Drainage Area
THAET	Actual Evapotranspiration by Thornthwaite
THSUR	Annual Water Surplus by Thornthwaite
TUAET	Actual Evapotranspiration by Turc
TUSUR	Annual Water Surplus by Turc
WMXT	Mean Winter Maximum Temperature
W10YP	Winter Precipitation with 10 Year Return Period
YR	Yield Index-Ratio 10 Year to the Mean

*The prefix L added to any of these variable abbreviations as employed in the text indicates a transformation to a logarithm with base 10 has been made.

technique employed in the present analysis is multiple linear regression.

In the present study, two approaches to the analysis by multiple linear regression techniques have been proposed. In the first approach, stepwise multiple linear regression analysis was utilized to relate each of the dependent variables to the full set of 39 independent variables. In the second approach, factor analytic methods were employed in the screening of the independent variables prior to the application of stepwise multiple linear regression. This screening procedure was necessary in order to eliminate redundant independent variables, and results in simpler, more easily interpreted regression models. In the following sections a brief discussion of the techniques of multiple regression and factor analysis is presented.

5.2.1 Stepwise Multiple Linear Regression

Stepwise multiple linear regression is a special case of multiple linear regression analysis. The basic regression model on which the technique is based entails the calculation of a prediction equation relating a dependent random variable to one or more independent deterministic variables (Stammers 1966, p. 256). The resulting equation is of the general form

$$Y = a + b_1X_1 + b_2X_2 + \ldots\ldots\ldots + b_nX_n \qquad (5\text{-}1)$$

where Y is the dependent variable

$X_1, X_2 \ldots X_n$ are the independent variables

$b_1, b_2 \ldots b_n$ are the regression coefficients corresponding to the independent variables $X_1, X_2 \ldots X_n$, respectively

a is a constant

In addition to the regression equation, the analysis results in two measures of the strength of the relationship, the coefficient of multiple correlation and the standard error of the estimate. The former measure provides an indication of the relative strength of the relationship, while the latter measure indicates the absolute scatter of the observations about the regression line. The importance of these measures and their related significance tests will be discussed further in a later section of this chapter. The theoretical considerations and mathematical calculations which underlie regression analyses are beyond the scope of the present discussion; however, the reader is referred to the work of Ezekiel and Fox (1959) and Solomon (1966) for a complete discussion of these aspects of the technique.

The interpretation of a regression analysis for any data set is based on several assumptions regarding the nature of the input data. The most important of these assumptions relate to the sampling procedures and frequency distributions of the variables examined. In most regression analyses the aim is to develop relationships which are applicable beyond the confines of the data sample analysed. In order to ensure the applicability of the results to a particular population of events, it is necessary to ensure that the data analysed represent a random sample of observations drawn from the population of interest. When the observations fail to meet this requirement of random sampling, it is not reasonable to expect the results of the analysis to have general application to the overall population. The second assumption relating to the nature of the basic data requires that the frequency distributions of the variables included approximate the normal distribution. The significance tests which are available to test the reliability of a regression analysis are based on this assumption. When the condition of normality is not met, the use of the standard significance tests is in jeopardy.

Two further problems which are closely related to the selection of input data for a regression analysis are those of spurious correlations and multicollinearity among the independent variables. Both of these problems are closely related to the interpretation of the regression results. A spurious correlation is said to exist when a statistical correlation is found between two variables which are theoretically unrelated. It must be recognized that while the existence of such a relationship is indicative of a statistical covariation between the variables, it in no way indicates a physical or causal relationship. Benson (1965) has discussed the problem of spurious correlation in hydrologic research with particular reference to the use of composite variables, which are products sums or ratios based on several measures which may be common to more than one variable. In order to avoid the misinterpretation of spurious correlations, it is imperative that the input variables are selected on the basis of theoretical or intuitive relationships; otherwise, it is not possible to interpret the physical significance of any relationships which may result.

The existence of multicollinearity among the independent variables in a regression analysis may lead to serious difficulties in the interpretation of the regression results. Multicollinearity is the presence of linear interrelationships among variables in the independent variable set. When such intercorrelations exist, certain elements of information have been measured by more than one variable (Tennessee Valley Authority 1966, p. 134). This problem of multicollinearity is common in hydrologic analysis because of the multivariate nature of the relationships involved. The intercorrelations among independent variables tend to result in unstable regression coefficients which make the interpretation of the functional relationships between the variables most difficult.

In any research project utilizing statistical methods, it is imperative that the researcher carefully evaluates the merits of his data with reference to the assumptions and limitations of the techniques employed. In the case of regression analysis, the implications of the assumptions of random sampling and normal data, and the limitations with respect to spurious correlations and multicollinearity are of particular relevance. The random sampling assumption must be accounted for in the original research design. The problem of normally distributed variables may be attacked by the use of transformations. Many hydrologic variables have right skewed distributions that are limited to positive values. If the data for such variables are transformed to logarithms, the resulting frequency distributions will more closely approximate normality. The spurious correlation problem can best be approached through a theoretical formulation of the hypothetical model and a careful choice of input variables. The final problem, that of multicollinearity, requires the careful selection and screening of independent variables. In the present analysis the technique of factor analysis has been employed for the purpose of identifying the independent elements of information contained in the independent variable set.

In the present research, the multiple regression analysis has been executed, utilizing the Stepwise Multiple Linear Regression Computer Program, BMD02R, of the Biomedical Computer Program of the University of California (for program documentation refer to Dixon 1970, pp. 233-257). This program computes a sequence of least squares multiple linear regression equations in a stepwise fashion, one variable being added at each step. The variable added at each step is the one which makes the greatest reduction in the error sum of the squares of the relationship, that is the variable which has the highest partial correlation with the dependent variable partialed on the variables already entered in the equation.

5.2.2 Factor Analysis

The second multivariate statistical technique employed in the present research is factor analysis. Factor analysis is a technique which provides a means of collapsing a set of intercorrelated variables into a smaller number of independent dimensions or factors (King 1969, p. 165). In general terms, factor analysis begins with an n x n matrix of the simple correlations between variables. From this matrix is calculated an n x m factor loading matrix, with m being the number of independent factors or dimensions. The factor loadings are the correlations between the original variables and the identified factors. In order to simplify the interpretation of the factor loading matrix, a process of rotation is undertaken such as to maximize the difference between factors and result in a rotated factor matrix. It is beyond the scope of this discussion to consider the theoretical background and calculations involved in factor analysis; however, the reader is referred to the work of King (1969, pp. 165-193); Harmon (1967); and the Tennessee Valley Authority (1966, pp. 151-156) for a discussion of the mathematical methodologies involved.

Factor analytic techniques have been employed for two rather different purposes (Tennessee Valley Authority 1966, p. 151). In the first case, the aim is to discover the underlying factors which operate in determining the measurements of the variables and possibly to test hypotheses related to these underlying factors. The ultimate aim in this application is to group variables and identify the underlying dimensions. The second purpose for which factor analysis is employed is in the screening of an intercorrelated variable set in an effort to identify the independent components of that set; and ultimately, to reduce the dimensionality of the variable set to a few components which may be represented by individual variables. The first approach has been employed widely in human geography in the building of descriptive models, as in the work of Romsa et al (1969) and Simmons et al (1970). The second approach is more amenable to the building of predictive models in that the variables selected by the screening process represent an economy of explanation. Examples of this approach are included in the work of the Tennessee Valley Authority (1966), Wallis (1965) and Wong (1963). The variable screening approach has been employed in the present research in an attempt to identify the variables which most closely represent independent measures of the basic dimensions of the original set of climatic and physical measures. These variables were subsequently employed in the stepwise regression analyses of the streamflow characteristics.

In the present study the factor analyses have been executed utilizing the Factor Analysis Computer Program, BMDX72, of the Biomedical Computer Programs of the University of California (for program documentation see Dixon 1970a,pp. 90-103).

The analyses undertaken have utilized a principal component solution and a varimax factor rotation. This method results in a stable factor structure, which is characterized by a strong correspondence between factor dimensions and variables, leading to relatively easy factor identification (Wallis 1965, p. 453; and Tennessee Valley Authority 1966, pp. 155-156).

5.2.3 The Structure of the Analysis

The analyses of the present study have been structured in two stages. The first stage entailed the analysis of the relationships of streamflow characteristics and climatic and other physical geographic patterns at the scale of the entire study area. In this first stage, two approaches to the analysis have been undertaken, firstly a stepwise multiple regression analysis based on all of the independent variables; and secondly, a stepwise multiple regression analysis based on the independent variables as selected by the screening technique of factor analysis.

On the basis of the results of the first stage of the analysis, a second stage, in which the study area was divided into hydrologic regions, was undertaken. In this analysis, the stepwise multiple regression technique in combination with factor analytic variable screening was employed for each of the hydrologic regions. This second stage of the analysis was attempted in an effort to improve the relationships developed in the first stage and to evaluate the regional differences, if any, in the relationships.

5.3 DATA PREPARATION

Prior to the commencement of the analyses of the data compiled for the 161 study basins, consideration was given to the relationships of these data to the assumptions underlying the techniques to be employed. In particular, the random sampling and normal distribution assumptions were considered.

5.3.1 Sampling Limitation in the Present Study

In order to ensure the applicability of the results of a statistical analysis, it is necessary to assume that the basic data set represents a random sample drawn from the population in question. The selection of study basins in the present research has been discussed in Chapter 2 (Section 2.4). The population of basins which has been considered in this study includes all basins located within the study area, having a drainage area of between 50 and 10,000 square miles, and having natural streamflow conditions. Unfortunately, it was not possible to draw a random sample from all the basins which met the above three criteria. Rather it was also necessary to impose the criterion of available hydrometric records. The basins which were selected for analysis were all those which met the above criteria with respect to location, drainage area, and flow conditions, and for which a minimum of 5 years of streamflow records were available. Prairie basins for which streamflow data have been collected are not randomly located throughout the study area; but rather, their distribution is closely related to settlement patterns with a much denser coverage in the southern areas. This means that the distribution of study basins available in the present research is also concentrated in the southern regions of the study area, and their selection for analysis cannot be assumed to represent a random sample drawn from the study area. Unfortunately, there is no method to select a random sample in that streamflow data are non-existent in many basins. Therefore, the interpretation of the results of the ensuing analyses and their application in the prediction of streamflow characteristics for ungauged areas must remain in doubt. The results must be interpreted carefully with regard to the distribution of the study basins as illustrated in Figure 3-1.

5.3.2 Non-normality and Transformations of the Variables

Significance tests utilized in evaluating the results of a multiple regression analysis are based on the assumption that the input data are normally distributed. Many of the variables employed in the present analysis have a limit and their distributions are skewed. Previous research of a similar nature has led to the conclusion that hydrologic data can be made to approximate normality by means of a logarithmic transformation (Benson 1962b,1964 and 1969; and Karuks 1963).

In the present study, histograms were plotted of the frequency distributions of each of the independent variables. The climatic variables with the exception of the Annual Surplus calculated by Thornthwaite procedures, THSUR, were found to approximate a normal distribution. The histograms of the measures of the other physical geographic patterns and the THSUR variable exhibited a right skewness and in most cases were limited to the left. These variables were transformed by taking their logarithms to the base 10. A similar transformation was applied to each of the dependent variables. These transformed variables replaced their corresponding original measures in all of the subsequent analyses.

5.3.3 Selection of Comparative Test Sample

The limitations of the basic data set with respect to random sampling and non-normality may introduce some bias into the significance tests of the results of the regression analysis. As a check on the predictive strength of the relationships resulting from the analyses, it was decided to retain a test sample from the original 161 study basins for use in evaluating the relationships. A random sample of 15 basins was selected from the original list of 161 study basins. The test sample was selected on the basis of random numbers with the proviso that no two spatially adjacent basins would be included in the sample. The 15 basins included in this test sample are listed in Table 5-2.

TABLE 5-2 - BASINS IN TEST SAMPLE FOR COMPARISON OF ANALYSIS RESULTS (Not Employed in the Analyses)

Basin Number	Basin Name	Basin Number	Basin Name
4	Manyberries Ck	78	Stony Ck
7	Elbow R	82	Minnedosa R
15	Kneehills Ck	108	Mowbray Ck
25	Eagle Ck	118	Cooks Ck
30	Skull Ck	133	Pembina R
37	Wascana Ck	139	East Prairie R
44	Cutarm Ck	159	Rock Ck
52	Red Deer R		

The data compiled for these 15 basins were not employed in the subsequent analysis, but rather were retained as an independent sample for the testing of the relationships developed in the analyses.

5.4 ANALYSIS STAGE 1: COMPLETE STUDY AREA

In this initial stage of the analysis, the relationships of the selected streamflow characteristics to the various measures of climatic and other physical geographic patterns were examined on the scale of the complete study area. Two approaches to the building of statistical models were utilized, first, a stepwise multiple regression analysis including all of the independent variables, and secondly, a stepwise multiple regression analysis including only those independent variables selected after screening by factor analytic techniques. In the following sections, each of these approaches is discussed and a comparative summary of the resulting relationships is presented.

5.4.1 Stepwise Multiple Regression Analyses: All Variables

The first approach to the analysis of the data for the entire study area utilized the stepwise multiple linear regression technique to estimate a multiple regression equation for each of the four dependent variables. In each case the full set of 39 independent variables for the 146 study basins was entered in the analysis. The regression relationships were built up in a stepwise fashion, with the variable added at each step being that one which has the highest partial correlation with the dependent variable after the effects of variables already in the model have been accounted for.

Table 5-3 is the simple correlation matrix for all of the vari-

TABLE 5-3

ALL VARIABLE CORRELATION MATRIX FOR THE FULL STUDY AREA

(N=146)

VARIABLE	1	2	3	4	5	6	7	8	9	10	11
1 LMY	1.000	0.918	0.922	0.671	0.669	-0.310	0.729	-0.090	0.005	0.481	0.634
2 LMIOYY		1.000	0.849	0.761	0.751	-0.267	0.811	-0.146	0.059	0.472	0.723
3 LMF			1.000	0.818	0.666	-0.265	0.716	-0.157	0.007	0.434	0.612
4 LMIOYF				1.000	0.690	-0.127	0.719	-0.200	0.153	0.415	0.637
5 LTDA					1.000	0.172	0.980	-0.473	0.033	0.286	0.930
6 LNCDA						1.000	0.019	-0.413	-0.156	-0.368	0.071
7 LCDA							1.000	-0.413	0.048	0.343	0.926
8 LMCS								1.000	0.526	0.558	-0.359
9 LBEL									1.000	0.632	0.098
10 LBR										1.000	0.386
11 LBL											1.000

VARIABLE	12	13	14	15	16	17	18	19	20	21	22
1 LMY	0.212	0.186	0.120	0.633	0.622	0.614	0.584	0.069	-0.069	-0.093	0.061
2 LMIOYY	0.266	0.226	0.159	0.631	0.619	0.615	0.584	0.072	-0.063	-0.096	0.058
3 LMF	0.160	0.115	0.059	0.521	0.505	0.496	0.466	0.087	-0.023	-0.109	0.019
4 LMIOYF	0.175	0.097	0.056	0.358	0.341	0.342	0.316	0.122	0.066	-0.138	-0.060
5 LTDA	0.270	0.231	0.227	0.463	0.475	0.460	0.470	-0.183	-0.167	0.170	0.183
6 LNCDA	-0.186	0.123	0.247	-0.275	-0.238	-0.237	-0.158	-0.380	-0.086	0.406	0.108
7 LCDA	0.302	0.227	0.192	0.500	0.505	0.492	0.484	-0.104	-0.166	0.086	0.177
8 LMCS	0.083	0.032	-0.006	-0.156	-0.176	-0.122	-0.149	0.609	0.533	-0.611	-0.553
9 LBEL	0.185	0.078	0.067	-0.124	-0.127	-0.099	-0.106	0.598	0.623	-0.604	-0.627
10 LBR	0.392	0.201	0.147	0.172	0.157	0.199	0.171	0.576	0.506	-0.588	-0.502
11 LBL	0.605	0.243	0.234	0.461	0.469	0.458	0.464	-0.039	-0.040	0.025	0.056
12 LBS	1.000	0.136	0.122	0.204	0.199	0.203	0.198	0.294	0.257	-0.301	-0.249
13 LALTDA		1.000	0.979	0.227	0.233	0.403	0.420	0.132	0.143	-0.129	-0.149
14 LALCDA			1.000	0.182	0.195	0.363	0.401	0.082	0.157	-0.076	-0.160
15 LSTDA				1.000	0.997	0.972	0.958	-0.068	-0.169	0.049	0.157
16 LSCDA					1.000	0.969	0.962	-0.087	-0.175	0.070	0.164
17 LSLTDA						1.000	0.993	-0.030	-0.119	0.016	0.108
18 LSLCDA							1.000	-0.062	-0.114	0.050	0.105
19 LDDTDA								1.000	0.902	-0.986	-0.912
20 LDDCDA									1.000	-0.895	-0.987
21 LOFTDA										1.000	0.913
22 LOFCDA											1.000

VARIABLE	23	24	25	26	27	28	29	30	31	32	33
1 LMY	0.643	0.349	0.365	0.218	0.364	0.086	0.236	0.291	0.302	-0.104	0.081
2 LMIOYY	0.539	0.211	0.275	0.216	0.256	-0.034	0.107	0.151	0.203	-0.114	0.085
3 LMF	0.511	0.272	0.293	0.187	0.293	0.050	0.179	0.222	0.233	-0.076	0.062
4 LMIOYF	0.219	-0.004	0.109	0.171	0.046	-0.133	-0.060	-0.035	0.003	-0.003	-0.015
5 LTDA	0.185	-0.077	-0.050	0.023	-0.062	-0.256	-0.192	-0.125	-0.097	-0.183	0.160
6 LNCDA	-0.338	-0.181	-0.301	-0.279	-0.291	-0.132	-0.229	-0.191	-0.262	-0.183	0.204
7 LCDA	0.245	-0.046	0.002	0.074	-0.010	-0.235	-0.153	-0.095	-0.045	-0.160	0.135
8 LMCS	0.161	-0.006	0.330	0.483	0.188	0.144	0.185	0.074	0.244	0.329	-0.369
9 LBEL	-0.224	-0.282	0.226	0.563	-0.165	0.013	-0.074	-0.216	-0.147	0.727	-0.775
10 LBR	0.290	-0.013	0.410	0.607	0.200	0.050	0.132	0.031	0.238	0.323	-0.374
11 LBL	0.190	-0.070	-0.007	0.078	-0.027	-0.241	-0.165	-0.106	-0.050	-0.162	0.139
12 LBS	0.096	-0.017	0.088	0.152	0.065	-0.078	-0.016	-0.005	0.079	-0.030	0.017
13 LALTDA	0.207	-0.186	-0.076	0.091	-0.123	-0.275	-0.234	-0.237	-0.066	-0.321	0.280
14 LALCDA	0.153	-0.199	-0.105	0.048	-0.152	-0.263	-0.242	-0.233	-0.097	-0.326	0.290
15 LSTDA	0.691	0.281	0.160	-0.003	0.217	-0.049	0.078	0.212	0.130	-0.249	0.236
16 LSCDA	0.586	0.268	0.144	-0.013	0.200	-0.063	0.061	0.198	0.112	-0.247	0.241
17 LSLTDA	0.593	0.218	0.118	0.000	0.158	-0.099	0.017	0.148	0.086	-0.279	0.265
18 LSLCDA	0.568	0.207	0.096	-0.022	0.134	-0.109	-0.001	0.137	0.063	-0.293	0.281
19 LDDTDA	-0.027	-0.191	0.170	0.431	-0.019	-0.051	-0.042	-0.136	0.011	0.384	-0.415
20 LDDCDA	-0.167	-0.277	0.069	0.353	-0.134	-0.098	-0.128	-0.212	-0.098	0.376	-0.404
21 LOFTDA	0.022	0.177	-0.184	-0.439	0.005	0.039	0.027	0.124	-0.022	-0.396	0.429
22 LOFCDA	0.170	0.272	-0.071	-0.353	0.133	0.089	0.123	0.210	0.100	-0.384	0.413
23 LFTDA	1.000	0.617	0.526	0.193	0.629	0.295	0.500	0.569	0.597	-0.307	0.285
24 MAP		1.000	0.725	0.071	0.804	0.832	0.925	0.971	0.735	0.021	-0.005
25 MAS			1.000	0.730	0.833	0.700	0.857	0.760	0.816	0.304	-0.333
26 MASP				1.000	0.454	0.148	0.321	0.152	0.491	0.376	-0.433
27 MWP					1.000	0.563	0.855	0.838	0.969	-0.016	0.012
28 MSP						1.000	0.910	0.827	0.545	0.356	-0.347
29 MWSP							1.000	0.939	0.828	0.216	-0.212
30 AIOYP								1.000	0.770	0.071	-0.059
31 WIOYP									1.000	-0.063	0.052
32 MWT										1.000	-0.991
33 MJANT											1.000

VARIABLE	34	35	36	37	38	39	40	41	42	43
1 LMY	-0.488	-0.392	-0.032	0.034	-0.522	0.342	0.099	0.301	0.421	-0.157
2 LMIOYY	-0.463	-0.408	-0.026	0.026	-0.523	0.203	-0.034	0.206	0.292	-0.154
3 LMF	-0.419	-0.343	-0.012	0.022	-0.458	0.260	0.056	0.259	0.236	-0.148
4 LMIOYF	-0.339	-0.359	0.072	-0.062	-0.409	-0.014	-0.150	0.051	0.056	-0.193
5 LTDA	-0.264	-0.259	-0.116	0.111	-0.361	-0.037	-0.234	-0.144	-0.006	-0.022
6 LNCDA	0.229	0.223	-0.243	0.239	0.207	-0.134	-0.130	-0.281	-0.186	0.258
7 LCDA	-0.302	-0.292	-0.083	0.079	-0.394	-0.013	-0.213	-0.100	0.026	-0.056
8 LMCS	-0.269	-0.346	0.351	-0.373	-0.228	-0.060	0.043	0.123	-0.025	-0.394
9 LBEL	-0.415	-0.730	0.784	-0.800	-0.444	-0.302	-0.092	-0.232	-0.334	-0.855
10 LBR	-0.534	-0.645	0.392	-0.406	-0.554	-0.049	-0.048	0.073	0.002	-0.548
11 LBL	-0.281	-0.293	-0.092	0.089	-0.381	-0.028	-0.229	-0.139	-0.002	-0.050
12 LBS	-0.164	-0.207	0.009	-0.006	-0.218	0.006	-0.078	-0.046	0.009	-0.082
13 LALTDA	-0.240	-0.183	-0.269	0.244	-0.325	-0.157	-0.387	-0.180	-0.088	0.126
14 LALCDA	-0.194	-0.144	-0.287	0.262	-0.278	-0.153	-0.372	-0.208	-0.098	0.151
15 LSTDA	-0.386	-0.264	-0.173	0.195	-0.444	0.296	-0.016	0.208	0.377	0.009
16 LSCDA	-0.379	-0.258	-0.180	0.202	-0.437	0.285	-0.024	0.192	0.364	0.017
17 LSLTDA	-0.395	-0.271	-0.204	0.219	-0.460	0.242	-0.087	0.143	0.323	0.032
18 LSLCDA	-0.378	-0.255	-0.224	0.238	-0.445	0.235	-0.094	0.119	0.311	0.051
19 LDDTDA	-0.218	-0.396	0.425	-0.431	-0.255	-0.213	-0.103	-0.088	-0.210	-0.462
20 LDDCDA	-0.149	-0.357	0.397	-0.405	-0.197	-0.283	-0.153	-0.206	-0.303	-0.434
21 LOFTDA	0.229	0.406	-0.442	0.449	0.264	0.198	0.091	0.085	0.197	0.478
22 LOFCDA	0.146	0.352	-0.408	0.417	0.192	0.281	0.146	0.198	0.300	0.438
23 LFTDA	-0.502	-0.274	-0.267	0.260	-0.480	0.585	0.247	0.577	0.713	0.049
24 MAP	-0.273	-0.111	-0.031	0.033	-0.158	0.974	0.843	0.776	0.976	-0.091
25 MAS	-0.610	-0.564	0.297	-0.320	-0.517	0.610	0.607	0.602	0.710	-0.497
26 MASP	-0.613	-0.688	0.416	-0.450	-0.600	-0.065	0.034	0.409	0.080	-0.592
27 MWP	-0.374	-0.226	-0.049	0.044	-0.294	0.699	0.605	0.894	0.815	-0.115
28 MSP	-0.200	-0.153	0.293	-0.306	-0.038	0.806	0.881	0.586	0.738	-0.327
29 MWSP	-0.313	-0.209	0.160	-0.170	-0.171	0.857	0.856	0.816	0.872	-0.263
30 AIOYP	-0.262	-0.122	0.014	-0.016	-0.147	0.930	0.847	0.791	0.936	-0.133
31 WIOYP	-0.374	-0.214	-0.092	0.081	-0.289	0.630	0.533	0.850	0.753	-0.067
32 MWT	-0.073	-0.412	0.980	-0.969	-0.007	-0.005	0.415	-0.023	-0.142	-0.886
33 MJANT	0.154	0.484	-0.983	0.986	0.090	0.027	-0.372	0.018	0.144	0.920
34 MST	1.000	0.897	-0.154	0.192	0.970	-0.204	0.033	-0.363	-0.374	0.495
35 MJUNT		1.000	-0.495	0.520	0.903	-0.056	0.021	-0.178	-0.155	0.778
36 WMXT			1.000	-0.992	-0.105	-0.064	0.316	-0.039	-0.170	-0.916
37 JAMXT				1.000	0.139	0.072	-0.303	0.030	0.167	0.925
38 PE					1.000	-0.101	0.173	-0.262	-0.278	0.460
39 THAET						1.000	0.865	0.621	0.960	-0.049
40 TUAET							1.000	0.547	0.705	-0.290
41 LTHSUR								1.000	0.801	-0.083
42 TUSUR									1.000	-0.002
43 MATR										1.000

ables. This 43 x 43 matrix is the starting point for the calculation of the regression equations. The regression equations which resulted from the stepwise regression analyses for each of the dependent variables are summarized in Tables 5-4, 5-5, 5-6 and 5-7. Table 5-4 is discussed in detail below as an example of the format employed throughout this study in displaying the results of the stepwise regression analyses.

5.4.1.1 Format of Regression Results

All of the stepwise regression results in the present research are reported in a tabular form similar to Table 5-4. Each table is comprised of 7 columns containing the following information:

Column (1) The step number in the regression analysis
Column (2) The regression equation resulting at the given analysis step
Column (3) The multiple correlation coefficient, R, corresponding to the regression equation at the given analysis step
Column (4) The coefficient of multiple determination, R^2, corresponding to the regression equation at the given analysis step
Column (5) The value of the analysis of variance F statistic for the regression equation at the given analysis step
Column (6) The standard error of the estimate associated with the given analysis step
Column (7) The standard error of the estimate expressed as a percentage of the mean of the dependent variable.

In Table 5-4 the dependent variable is the LMY. The first row of the table contains entries in columns 2, 6 and 7 only. The entry in column 2 reports the mean value of the dependent variable, while the entries in columns 6 and 7 report the standard deviation and the standard deviation expressed as a percentage of the mean, respectively. These values are included for comparison with the standard errors

TABLE 5-4 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA
ALL VARIABLE ANALYSIS OF LMY
(N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMY}$ (7)
	$\overline{LMY}$ = 4.14614				.87969	21.2
1	LMY = 1.269 +1.159 LCDA (.09)	.729	.532	163.6	.6040	14.6
2	LMY = 1.074 +0.967 LCDA +0.571 LFTDA (.07) (.05)	.872	.761	227.6	.4331	10.4
3	LMY = 1.316 +0.998 LCDA +0.496 LFTDA -0.291 LNCDA (.06) (.05) (.07)	.888	.788	176.2	.4091	9.9
4	LMY = -0.106 +1.054 LCDA +0.453 LFTDA -0.287 LNCDA +0.122 TUAET (.06) (.05) (.07) (.04)	.895	.801	141.7	.3982	9.6
5	LMY = -0.538 +1.091 LCDA +0.475 LFTDA -0.248 LNCDA +0.145 TUAET -0.484 LOFCDA (.06) (.05) (.06) (.04) (.14) (5-2)	.904	.817	125.3	.3827	9.2

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

TABLE 5-5 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA
ALL VARIABLE ANALYSIS OF LM10YY
(N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LM10YY}$ (7)
	$\overline{LM10YY}$ = 4.73958				.67723	14.3
1	LM10YY = 2.276 +0.993 LCDA (.06)	.811	.658	276.9	.3975	8.4
2	LM10YY = 2.166 +0.884 LCDA +0.323 LFTDA (.05) (.04)	.884	.782	255.9	.3187	6.7
3	LM10YY = 2.357 +0.908 LCDA +0.264 LFTDA -0.230 LNCDA (.05) (.04) (.05)	.900	.810	202.2	.2980	6.3
4	LM10YY = 2.254 +0.925 LCDA +0.284 LFTDA -0.205 LNCDA -0.310 LOFCDA (.05) (.04) (.05) (.10) (5-3)	.907	.822	162.9	.2897	6.1

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

resulting for the regression steps. The second and subsequent rows of the table contain entries in all columns and include a complete set of statistics for each step in the regression analysis.

The statistics reported for each step are the multiple correlation coefficient, R; the coefficient of determination, R^2; the analysis of variance F statistic and the standard error both in absolute terms and as a percentage. The R value is a measure of the relative strength of the relationship and ranges in value from 0 for no correlation to 1 for a perfect correlation. The square of this statistic, R^2, provides a measure of the proportion of the total variance in the dependent variable which is explained statistically by the regression. The F statistic is employed to evaluate the significance of the R value for the relationship. The standard error of estimate is a measure of the scatter of the observed values of the dependent variable about the regression line. It is analogous to the standard deviation and is interpreted accordingly. In order to provide a more easily interpreted statistic, the standard error has been expressed as a percentage of the mean of the dependent variable. In addition to the above statistics which have been compiled for each of the regression equations, a t test was employed to test the significance of each of the regression coefficients. The results of this test are indicated by asterisks as explained in the table footnotes.

In the tables of results, each step of the stepwise regression analysis has been reported until the addition of a variable fails to add at least 1% to the R^2 value. Further steps in the analysis contribute little to the explained variance and often involve regression coefficients which are not significantly different from 0. For reference purposes the regression equation from the final step in each of the regression analyses has been assigned an equation number.

In the interpretation of the results of the regression analyses, it is imperative that consideration be given to the underlying theoretical relationships. In these discussions, references to physical significance suggest only that the signs of the regression coefficients correspond to physical expectations, rather than implying functional relationships.

5.4.1.2 Summary of Results for the Dependent Variable LMY

The results of the all variable stepwise regression analysis for the dependent variable LMY are summarized in Table 5-4. The first independent variable to enter the regression was LCDA and this measure accounts for 53% of the total variance in the dependent variable. In subsequent steps, an additional four independent variables were added to the regression equation (5-2). These variables contributed an additional 29% to the explained variance.

All of the regression coefficients of the final equation (5-2) are significant at the 1% level; however, the signs of some of these coefficients seem to contradict physical theory. The positive coefficient associated with the LCDA term is as expected with larger drainage areas being related to larger mean annual yields. The positive coefficient associated with the LFTDA is not as easily explained. On the basis of physical theory, a negative relationship between percentage of forest area and mean annual yield would be expected. The positive relationship in the present analysis is hypothesized to be a somewhat spurious relationship reflecting the geographic distribution of forest within the study area. Forested area is more prevalent in the north and east of the study area in regions which have a greater moisture supply. Therefore in the present analysis, LFTDA may be entering the regression as a substitute for a moisture supply index and does not represent a moisture retention index as might be expected. The third term in the equation, LNCDA, has a negative coefficient which seems to reflect a physical relationship in that the non-contributing drainage area reflects a reduction in runoff. The positive coefficient associated with the fourth term, TUAET, seems to represent a spurious relationship. The actual evapotranspiration is a loss from available moisture and therefore is expected to be negatively related to annual yield. However, in the relatively dry study area the precipitation total is closely related to the evapotranspiration, and TUAET is higher in the areas with higher precipitation. Thus, TUAET may be representing an index of moisture supply in the present equation. The final term in the equation is LOFCDA and has a negative coefficient. This relationship corresponds to physical theory in that greater distance of overland flow is associated with lower yields.

The F statistic from the analysis of variance for the final equation (5-2) indicates that the total regression is highly significant; however, the standard error is relatively large, 9.2% of the mean. This relatively large standard error and the difficulties related to physical interpretation indicate that this equation (5-2) is of only limited theoretical and predictive value.

5.4.1.3 Summary of Results for the Dependent Variable LM10YY

The results of the all variable stepwise regression analysis of the dependent variable LM10YY are summarized in Table 5-5. The first variable to enter the regression is again LCDA which accounts for 66% of the total variance in the dependent variable. Three further variables were added and contributed an additional 16% to the explained variance.

All of the regression coefficients in the equation 5-3 are significant at the 1% level. The positive sign associated with the LCDA term and the negative signs associated with the LNCDA and LOFCDA terms correspond to those in equation 5-2, and have the same physical basis as discussed in the preceding section (5.4.1.2). The positive sign of the LFTDA is contrary to the expected relationship and this anomaly is hypothesized to be the result of a spurious correlation similar to that discussed in the previous section (5.4.1.2).

The F statistic for the final equation in Table 5-5 is highly significant; however, the standard error of the estimate is again large, 6.1% of the mean. This equation, 5-3, has the same limitations with regard to physical interpretation and predictive power as were associated with equation 5-2.

5.4.1.4 Summary of Results for the Dependent Variable LMF

The results of the all variable stepwise regression analysis of the dependent variable LMF are summarized in Table 5-6. The first variable to enter the regression is again LCDA. This measure accounts for 51% of the total variance in LMF. The further addition of five other independent variables provided an additional 20% explanation.

The regression coefficients associated with the first five terms of the final equation (5-4) are significant at the 1% level, while the coefficient of the sixth term, MASP, is significant at the 5% level. The positive sign of the LCDA term is as expected on a physical basis, indicating larger flood volumes eminate from larger drainage areas. The positive coefficient associated with the LFTDA is again contrary to physical theory. It is recognized that the presence of a forest cover tends to reduce the magnitudes of peak flow. The relationship in the present analysis does not support this fact. Therefore it must be assumed that the relationship is spurious and possibly associated with the geographic distribution pattern of forest as discussed previously in Section 5.4.1.2. The signs of the regression coefficients for the LOFTDA, LTHSUR, and LBS terms correspond to the relationships anticipated on the basis of theory. The negative effect of the LOFTDA term indicates higher flood flows are associated with more closely spaced drainage networks. The positive relationship of LTHSUR is predictable since for basins with a greater available moisture surplus the flood potential would be higher. The LBS term has a negative coefficient which implies basins with a higher shape index, indicating a more elongated basin, have lower flood peaks. This conforms with the expected pattern of flood flows. The negative coefficient of the final variable, MASP, does not correspond to the expected relationship. It was anticipated that

TABLE 5-6 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA
ALL VARIABLE ANALYSIS OF LMF
(N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMF}$ (7)
	$\overline{LMF}$ = 2.66213				.62776	23.6
1	LMF = 0.648 +0.812 LCDA (.07)	.716	.512	151.1	.4400	16.5
2	LMF = 0.547 +0.713 LCDA +0.295 LFTDA (.06) (.04)	.795	.632	122.7	.3835	14.4
3	LMF = 0.509 +0.729 LCDA +0.295 LFTDA -0.405 LOFTDA (.06) (.04) (.12)	.813	.661	92.4	.3692	13.9
4	LMF = 0.341 +0.796 LCDA +0.184 LFTDA -0.451 LOFTDA +0.742 LTHSUR (.06) (.05) (.11) (.21)	.829	.688	77.6	.3558	13.4
5	LMF = 0.473 +0.852 LCDA +0.187 LFTDA -0.567 LOFTDA +0.741 LTHSUR -0.375 LBS (.06) (.05) (.12) (.21) (.13)	.840	.706	67.2	.3466	13.0
6	LMF = 0.963 +0.891 LCDA +0.164 LFTDA -0.748 LOFTDA +1.047 LTHSUR -0.385 LBS -0.021* MASP (.06) (.05) (.14) (.24) (.13) (.01) (5-4)	.848	.718	59.1	.3403	12.8

[1] A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

TABLE 5-7 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA
ALL VARIABLE ANALYSIS OF LM10YF
(N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LM10YF}$ (7)
	$\overline{LM10YF}$ = 3.29262				.53375	16.2
1	LM10YF = 1.571 +0.694 LCDA (.06)	.719	.517	154.5	.3721	11.3
2	LM10YF = 1.533 +0.711 LCDA -0.403 LOFTDA (.05) (.11)	.747	.557	90.1	.3575	10.8
3	LM10YF = 1.417 +0.727 LCDA -0.429 LOFTDA +0.417* LTHSUR (.05) (.11) (.17)	.759	.577	64.5	.3509	10.7
4	LM10YF = 2.163 +0.744 LCDA -0.496 LOFTDA +1.291 LTHSUR -0.148 W10YP (.05) (.11) (.31) (.04) (5-5)	.779	.607	54.4	.3393	10.3

[1] A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1 % level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

basins having a high percentage of their annual precipitation as snow would have a higher flood potential. This negative relationship may be spurious resulting from the multicollinearity among the independent variables.

The F statistic indicates that the equation (5-4) is highly significant; however, the explained variance of 72%, the relatively high standard error of the estimate, 12.8%, and the spurious relationships of the LFTDA and MASP terms, limit the usefulness of the equation.

5.4.1.5 Summary of Results for the Dependent Variable LM10YF

The results of the all variable stepwise multiple regression analysis of the dependent variable, LM10YF, are summarized in Table 5-7. Once again, the first independent variable to enter the regression is LCDA,which in this case accounts for 52% of the original variance in the dependent variable. An additional three variables account for only 16% more of this variance.

All of the regression coefficients are significant at the 1% level, and the signs associated with the LCDA, LOFTDA and LTHSUR are in agreement with anticipated physical relationships. These relationships are similar to those considered above (Section 5.4.1.4) with respect to the analysis of LMF. The negative coefficient of the fourth term, W10YP, does not conform to the expected physical relationship. It is logical that the ten year flood is linked to the ten year winter precipitation; however the negative sign is contrary to that anticipated. There would seem to be no physical basis for the relationship as developed here; and it must be considered to be spurious resulting from the multicollinearity among the independent variables.

The F test of the significance of the regression equation is significant at the 1% level; however the total explained variance as indicated by R^2 is only 61%, the standard error is 10% of the mean, and several of the regression coefficients have signs which contradict physical theory. The equation 5-5 is therefore of only limited use either as a physical model or for prediction.

5.4.1.6 Summary of the All Variable Stepwise Regression Analyses

The preceding four sections of this chapter have contained the results of the all variable stepwise regression analyses for each of the dependent variables. The relationships resulting from these analyses were subject to two limitations, spurious correlations and high standard errors. The spurious relationships limit the usefulness of the regression equations as physical models; and the relatively high standard errors limit their application in predicting streamflow characteristics for ungauged basins.

The spurious nature of some of the relationships identified in these analyses have been attributed to the multicollinearity among the independent variables. In an effort to overcome this problem, the technique of factor analysis was proposed for the screening of the independent variables. This second approach to the analysis for the full study region is discussed below in Section 5.4.3.

The problem of the relatively high standard errors of the estimates has no immediate solution. However, it would seem that these errors must be attributed either to the original sample data or to some independent variables which have been omitted from the present analyses. This difficulty will be considered further in Section 5.5.

5.4.2 Drainage Area Measures as Independent Variables

The theoretical physical importance of drainage area in controlling the magnitude of both annual yields and flood flows has been discussed in Chapter 4 (Section 4.3.1.1). The results of the all variable stepwise multiple regression analysis for each of the dependent variables, as reported in the preceding sections, have confirmed the importance of this variable in the present research.

Unfortunately, there is no completely satisfactory method for the accurate delimitation of drainage area, particularly in glaciated plains of relatively low relief, such as the present study area. The major problem involved relates to the placement of basin divides in areas of internal or non-contributing drainage. In an effort to account for this difficulty, at least partially, three drainage area measures, calculated from available topographic maps, have been employed in the present study. The first of these is the topographic drainage area. In many cases the exact delimitation of this area was hampered by the presence of areas of non-contributing drainage. In an effort to remove some of the subjectivity involved in this measure, a second variable, the non-contributing drainage area, was defined. This measure included all areas within the topographic drainage divides which were obviously not contributing to streamflow under normal conditions. By subtracting this non-contributing drainage area from the measured topographic drainage area, the third measure, the contributing drainage area, was estimated. Prior to the analysis, the data for these measures were transformed to logarithms in an effort to normalize their distributions.

Table 5-8 summarizes the simple correlations between the three

TABLE 5-8 - CORRELATIONS OF THE DRAINAGE AREA MEASURES TO THE DEPENDENT VARIABLES (N=146)

Variables	Variables 5 LTDA	6 LNCDA	7 LCDA
1 LMY	0.669 *	-0.310 *	0.729 *
2 LM10YY	0.751 *	-0.267 *	0.811 *
3 LMF	0.666 *	-0.265 *	0.716 *
4 LM10YF	0.690 *	-0.127	0.719 *
5 LTDA	1.000	0.172	0.980 *
6 LNCDA		1.000	0.019
7 LCDA			1.000

* Indicates a correlation coefficient, r, which is significant at the 1% level.

drainage area measures and the four dependent variables. The correlations provide a basis for some generalizations regarding the importance of the drainage area measures in relation to the selected streamflow characteristics. A highly significant positive correlation exists between both the LTDA and LCDA measures and each of the four dependent variables. In each case the LCDA measure has a slightly higher correlation than the LTDA measure. This difference is least in the case of the LM10YF. This observation may be explained in that the extreme flood events might be expected to receive runoff contributions from a larger than normal portion of the drainage basin. On the basis of the higher correlations and on the author's belief that greater confidence could be placed in the accuracy of the CDA measure than in the TDA measure, subsequent analyses have employed CDA based measures over TDA based measures, whenever a subjective choice has been required.

The third drainage basin area measure is the NCDA which is expressed as a percentage of the TDA. This measure is negatively correlated with each of the four dependent variables. The correlations with the LMY, LM10YY and LMF are significant at the 1% level; however, the correlation with the LM10YF was not significant. The lack of a significant correlation with the LM10YF may be related to the fact that for extreme flood events much of that area normally non-contributing may be contributing to flood flows. The negative sign associated with the correlations of the LNCDA variable is logical, since the larger the area of a basin which is non-contributing the smaller the annual yields and floods which would be expected.

The importance of the relationships between drainage area measures and streamflow characteristics has been confirmed for the study area. In view of the relatively simple measures which have been utilized, it may be anticipated that the compilation of more accurate measurements for these variables might result in even stronger correlations with the selected dependent variables.

5.4.3 Stepwise Multiple Regression Analysis in Combination with Factor Analytic Screening of Variables

The second approach to the full study area analysis of the relationships between the selected streamflow characteristics and the independent variables employed the stepwise multiple regression technique in combination with factor analytic screening of the independent variables. The relationships developed in the first approach to this analysis contained several spurious relationships as a result of the multicollinearity among the independent variables. This second approach to the analysis was undertaken with the aim of overcoming the multicollinearity problem and developing more meaningful models of the relationships.

The actual methodology employed in this approach is patterned after that utilized by the Tennessee Valley Authority (1966) and by Wallis (1965). The steps in the analysis are as follows:

1) Make a principal component factor analysis with varimax rotation on the complete set of 39 independent variables as compiled for the full sample of 146 basins

2) Examine the rotated factor matrix which resulted from step 1; and select two defining variables for each factor which contributes a minimum of 1% to the cumulative proportion of the total variance explained by the analysis. Generally, only variables with loadings greater than 0.900 are considered in the selection of defining variables; however, when no such loadings exist the highest available are selected

3) Make a second principal components analysis with varimax rotation on the set of defining variables selected in step 2 above

4) Examine the rotated factor matrix which resulted from step 3; and select one defining variable for each factor which contributes at least 1% to the cumulative proportion of the total variance explained by the analysis

5) Employ the variables selected in step 4, as independent variables in a stepwise multiple regression analysis for each of the four dependent variables.

The results of these analyses applied to the data for the full study area are reported below.

5.4.3.1 Screening of the Independent Variables by Factor Analytic Techniques

A factor analysis by principal component solution with a varimax factor rotation was made on the full set of 39 independent variables for the 146 study basins. The initial correlation matrix for this analysis is the same as that of Table 5-3 with the omission of the first four variables, the dependent measures. The rotated factor matrix which resulted from this analysis has been reproduced as Table 5-9. Only those factors which add at least 1% to the cumulative proportion of the total variance have been included. The 11 factors included account for a total of 97% of the total variance in the original independent variable set.

The choice of defining variables for each of the factors has been made on the basis of two considerations. First, the magnitudes of the factor loadings have been considered; and second, the problems of data compilation and the ultimate use of the variables have been considered. As pointed out in the Tennessee Valley Authority report (1966) cited earlier, a factor analysis does not intrinsically select the reduced set of orthogonal variables that can replace the original data set. Rather, factor analysis indicates if redundant variables are present, the number of dimensions, and the grouping of the variables. The final selection of variables must be made on the basis of a full consideration of the limitations of the data and their intended use. For this reason, some degree of subjectivity has been utilized along with the factor loadings in the ultimate selection of defining variables.

In the first stage of the variable selection process the highest loadings on each factor were identified. In Table 5-9 all loadings above 0.900 have been underlined; and in the cases of factors for which no loadings of this strength existed, the highest loadings have been indicated. Having identified these highest loadings, one or two defining variables were selected for each factor. The defining

TABLE 5-9

ROTATED FACTOR MATRIX RESULTING FROM THE FACTOR ANALYSIS OF ALL INDEPENDENT VARIABLES FOR THE FULL STUDY AREA

(N=146)

VARIABLE	FACTOR 1	2	3	4	5	6	7	8	9	10	11
1 LTDA	-0.11709	-0.03183	0.28428	-0.13421	-0.14265	0.91782◄	0.06821	-0.10875	0.00058	0.01797	-0.05265
2 LNCDA	-0.16048	-0.14951	-0.22284	-0.18298	0.08466	0.10464	0.15021	-0.89192◄	0.06626	-0.07971	-0.08594
3 LCDA	-0.08541	-0.01760	0.30265	-0.09802	-0.15253	0.92599◄	0.05665	0.04895	-0.02132	0.02152	-0.03926
4 LMCS	0.08215	0.22815	-0.08148	0.47057	-0.19895	-0.38083	0.03787	0.19358	-0.12949	0.03836	0.67251◄
5 LBEL	-0.20974	0.73751	-0.07041	0.37473	-0.38311	0.05234	0.09046	-0.02063	-0.04592	0.07680	0.21393
6 LBR	0.06600	0.31037	0.08843	0.44816	-0.34033	0.33241	0.10655	0.18816	-0.15639	0.13176	0.32565
7 LBL	-0.09255	-0.03348	0.27709	-0.01587	-0.14060	0.86577	0.07015	-0.05854	-0.00688	0.36286	-0.03383
8 LBS	0.01166	-0.01919	0.10950	0.24963	-0.05895	0.27959	0.03579	0.08113	-0.01891	0.91308◄	0.02472
9 LALTDA	-0.16328	-0.17863	0.20068	0.11625	-0.14938	0.08968	0.92171◄	-0.00237	-0.02636	0.01643	0.01533
10 LALCDA	-0.16239	-0.18597	0.17729	0.10658	-0.12017	0.07452	0.92224◄	-0.13916	-0.00443	0.02656	0.01059
11 LSTDA	0.13451	-0.09793	0.94515	-0.04668	-0.13409	0.20674	0.00573	0.08734	0.00076	0.03930	-0.01845
12 LSCDA	0.12004	-0.09821	0.94771◄	-0.06003	-0.13032	0.21067	0.01147	0.05127	-0.00015	0.03983	-0.02363
13 LSLTDA	0.08420	-0.11549	0.93621	-0.01435	-0.13637	0.18970	0.18704	0.07907	0.01202	0.02917	0.00138
14 LSLCDA	0.07329	-0.12475	0.93506◄	-0.02486	-0.12661	0.18505	0.21000	-0.00404	0.01896	0.03572	-0.00202
15 LDDTDA	-0.07835	0.25062	-0.01650	0.91577	-0.10937	-0.04921	0.04586	0.20422	-0.06387	0.06392	0.05186
16 LDDCDA	-0.15306	0.24538	-0.07209	0.92014◄	-0.09735	-0.07917	0.06882	-0.12002	-0.01112	0.07182	0.01765
17 LOFTDA	0.06576	-0.26641	0.00361	-0.91149	0.10887	0.03453	-0.04453	-0.22668	0.06380	-0.06500	-0.05513
18 LOFCDA	0.14987	-0.25573	0.05612	-0.92441◄	0.08546	0.09297	-0.07707	0.09830	0.01004	-0.06235	-0.03746
19 LFTDA	0.55286	-0.26216	0.44783	0.00692	-0.26637	0.10182	0.10558	0.17274	-0.04824	-0.03424	0.17283
20 MAP	0.97070◄	-0.01886	0.14990	-0.11725	-0.03873	-0.02580	-0.05304	0.01355	0.09211	-0.00694	-0.03235
21 MAS	0.77952	0.25170	0.03105	0.09753	-0.37033	0.00717	0.01202	0.05393	-0.40444	0.02167	0.03881
22 MASP	0.17529	0.33964	-0.06483	0.25875	-0.48372	0.05056	0.07183	0.08859	-0.71719◄	0.03368	0.10034
23 MWP	0.85149	-0.08622	0.06254	0.01394	-0.14574	0.01494	-0.05185	0.10915	-0.35166	0.01565	0.06170
24 MSP	0.86128	0.28130	-0.11616	-0.05410	-0.00702	-0.12934	-0.04140	-0.02227	0.11190	-0.01745	0.00649
25 MWSP	0.96766	0.13340	-0.04165	-0.02702	-0.07775	-0.07398	-0.05198	0.04081	-0.10614	-0.00306	0.03506
26 A10YP	0.97000◄	0.01053	0.09350	-0.06763	-0.03482	-0.04800	-0.09447	-0.00129	0.01933	0.00652	0.02429
27 W10YP	0.81083	-0.14548	-0.02973	0.04225	-0.16900	-0.00224	0.00198	0.10901	-0.40446	0.03103	0.10782
28 MWT	0.07668	0.95712	-0.13776	0.16487	0.03942	-0.07388	-0.12746	0.00816	-0.02658	-0.01380	-0.01276
29 MJANT	-0.06470	-0.95715◄	0.14390	-0.18434	0.04412	0.05798	0.10136	-0.02555	0.03576	0.01793	-0.01166
30 MST	-0.24401	-0.12738	-0.23388	-0.10035	0.89359◄	-0.12641	-0.10218	-0.05001	0.08513	-0.01442	-0.04062
31 MJUNT	-0.10987	-0.46561	-0.17036	-0.21110	0.80123	-0.16045	-0.09419	-0.01055	0.08234	-0.04771	-0.03806
32 WMXT	0.01411	0.96491	-0.08093	0.18250	-0.03946	-0.02758	-0.11183	0.06471	-0.02267	-0.00694	0.01148
33 JAMXT	-0.01890	-0.95850◄	0.11110	-0.18574	0.07942	0.01872	0.08629	-0.06633	0.03573	0.01477	-0.03145
34 PE	-0.12330	-0.08384	-0.29146	-0.14834	0.89053◄	-0.19973	-0.13958	-0.04035	0.09686	-0.03241	-0.03169
35 THAET	0.93076	-0.03526	0.17319	-0.12006	0.02003	0.00869	-0.02768	-0.00994	0.22417	0.01216	-0.03251
36 TUAET	0.86034	0.33268	-0.04632	-0.08526	0.26082	-0.08834	-0.12990	-0.02894	0.08713	-0.00639	-0.04787
37 LTHSUR	0.78976	-0.07840	0.08404	-0.06897	-0.16706	-0.10284	-0.10473	0.10768	-0.33412	-0.04207	-0.02611
38 TUSUR	0.93012	-0.16024	0.21689	-0.12012	-0.15717	0.00210	-0.01716	0.02966	0.08625	-0.00684	-0.02314
39 MATR	-0.12593	-0.88941	-0.01159	-0.22505	0.35994	-0.05004	0.03863	-0.02702	0.04351	-0.00325	-0.01500
CUMULATIVE PROPORTION OF TOTAL VARIANCE	0.27171	0.50758	0.68937	0.77035	0.82277	0.86637	0.90586	0.92722	0.94554	0.96101	0.97289

◄ DEFINING VARIABLES SELECTED FOR FURTHER ANALYSIS

variables selected for each factor are listed in Table 5-10. Wherever

TABLE 5-10 - DEFINING VARIABLES SELECTED FOR FURTHER ANALYSIS ON THE BASIS OF THE ROTATED FACTOR MATRIX (TABLE 5-9)

Factor Number	Selected Defining Variables	
1	MAP	A10YP
2	MJANT	JAMXT
3	LSCDA	LSLCDA
4	LOFCDA	LDDCDA
5	ST	PE
6	LCDA	LTDA
7	LALCDA	LALTDA
8	LNCDA	
9	MASP	
10	LBS	
11	LMCS	

more than two high loadings were present on a single factor, the author selected the defining variables on the added consideration of the available data and the expected relationships to the dependent variables. For the first factor, MAP was selected because of its high loading and simplicity of measurement, and A10YP was selected on the basis of its anticipated relationship to the 10 year hydrologic events. For the second factor, MJANT and JAMXT were chosen over MWT and WMXT on the basis of the consideration that the former pair of variables are not affected by season length and therefore have more general application over the study area. In the case of the third factor, LSCDA and LSLCDA were selected over their TDA based counterparts on the basis of the greater confidence the writer has in the CDA based measures. Similar considerations led to the selection of defining variables for each factor.

The third step in the variable screening process was to make a second factor analysis of the defining variables selected on the basis of Table 5-9. The rotated factor matrix resulting from this analysis is reproduced as Table 5-11. This second factor analysis was employed to examine the stability of the factor structure before selecting the final set of variables for inclusion in the regression analyses.

The highest factor loadings for each factor have been identified by underlining in Table 5-11. The actual selection of the final set of independent variables was made on the basis of considerations similar to those employed in the selection of defining variables from Table 5-9. For example, the MAP was selected over M10YP in factor 3, on the basis of its ease of measurement; LALCDA was selected over LALTDA in factor 4, on the basis of the author's expressed confidence in the CDA based measure; and LSLCDA was selected over LSCDA in factor 5 on the basis of its possible wider application under more varied lake and swamp conditions in future studies. A list of the final selection of independent variables is presented in Table 5-12.

TABLE 5-12 - FINAL SELECTION OF INDEPENDENT VARIABLES BASED ON FACTOR ANALYSIS SCREENING

Factor Number	Selected Variable	Factor Number	Selected Variable
1	LCDA	7	ST
2	LDDCDA	8	LNCDA
3	MAP	9	JAMXT
4	LALCDA	10	MASP
5	LSLCDA	11	LMCS
6	LBS		

The independent variables selected by the screening for multicollinearity by factor analysis will not be totally independent of each

TABLE 5-11

ROTATED FACTOR MATRIX RESULTING FROM THE FACTOR ANALYSIS OF THE SELECTED DEFINING VARIABLES

(N=146)

VARIABLE	FACTOR 1	2	3	4	5	6	7	8	9	10	11
1 LTDA	0.92727	0.09777	-0.08019	0.09267	0.22407	-0.10192	0.15001	0.12477	-0.04108	-0.00046	-0.10767
2 LNCDA	0.08205	0.04016	-0.09530	0.13257	-0.15257	0.09600	-0.11944	0.93970◄	-0.12399	0.06901	-0.12078
3 LCDA	0.93346◄	0.10502	-0.06137	0.08376	0.22841	-0.11815	0.16901	-0.02675	-0.02635	-0.02036	-0.08405
4 LMCS	-0.36151	-0.37511	0.02520	0.03464	-0.07949	-0.03750	0.20122	-0.24528	0.19429	-0.15351	0.74633◄
5 LBS	0.18133	-0.17664	0.00440	0.05342	0.08592	-0.95400◄	0.07283	-0.09144	-0.02367	-0.03011	0.01963
6 LALTDA	0.08919	-0.07438	-0.12513	0.95118	0.13862	-0.03195	0.13969	0.00733	-0.13848	-0.02328	0.01746
7 LALCDA	0.07172	-0.09880	-0.11060	0.94791◄	0.13107	-0.03242	0.10358	0.13655	-0.14554	-0.00839	0.00201
8 LSCDA	0.25868	0.08328	0.13531	0.06401	0.90932	-0.06140	0.19218	-0.11885	-0.11510	0.02173	-0.03957
9 LSLCDA	0.23370	0.04062	0.10527	0.26451	0.89285◄	-0.05320	0.18104	-0.06442	-0.13047	0.03688	-0.01690
10 LDDCDA	-0.09218	-0.93769◄	-0.13900	0.08653	-0.06265	-0.10790	0.09330	-0.01332	0.20604	-0.06498	0.09068
11 LOFCDA	0.10628	0.93293	0.13814	-0.09472	0.04671	0.09985	-0.08519	0.03238	-0.21940	0.06203	-0.10695
12 MAP	-0.04893	0.14854	0.96180◄	-0.08842	0.12323	0.00480	0.11625	-0.05576	-0.00304	0.02048	-0.01727
13 MASP	0.02671	-0.19271	0.07231	0.04774	-0.08037	-0.05434	0.48979	-0.12257	0.29167	-0.76473◄	0.14230
14 A10YP	-0.07321	0.09633	0.96649	-0.13239	0.07281	-0.00834	0.10298	-0.04639	0.01681	-0.06449	0.03289
15 MJANT	0.05722	0.21229	-0.03127	0.15927	0.11992	-0.01742	-0.06730	0.05201	-0.94196	0.09013	-0.05482
16 ST	-0.12330	0.06203	-0.17572	-0.10869	-0.16471	0.03523	-0.93254◄	0.06923	-0.10642	0.11092	-0.06919
17 JAMXT	0.01605	0.20469	0.01602	0.13903	0.09453	-0.00975	-0.10220	0.09062	-0.94554◄	0.08566	-0.06548
18 PE	-0.20172	0.11692	-0.07044	-0.15927	-0.21700	0.05950	-0.91159	0.06895	-0.05136	0.12705	-0.04644

CUMULATIVE PROPORTION OF TOTAL VARIANCE

	1	2	3	4	5	6	7	8	9	10	11
	0.24282	0.46959	0.62705	0.72677	0.79578	0.84957	0.89984	0.93791	0.96158	0.97959	0.99496

◄ DEFINING VARIABLES SELECTED FOR INCLUSION IN THE MULTIPLE REGRESSION ANALYSES other. However, it is assumed that they approximate independence and represent the best possible selection of independent variables for inclusion in the stepwise multiple regression analyses of the dependent variables.

5.4.3.2 Stepwise Multiple Regression Analysis After Variable Screening

The factor analytic screening of the original set of 39 independent variables resulted in the identification of 11 orthogonal factors, and the subsequent selection of a set of 11 independent variables. While these variables are not totally free of multicollinearity since their factor loadings were all somewhat less than 1.0, they do represent a set of variables which approximate the assumption of independence among the independent variables. These eleven variables were employed in a stepwise multiple regression analysis of each of the four dependent variables.

The basic 15 x 15 simple correlation matrix has been reproduced in Table 5-13. The results of the regression analysis for each of the dependent variables are summarized in the following sections.

5.4.3.2.1 Summary of the Stepwise Regression Analysis, After Variable Screening, for LMY. A summary of the results of the stepwise multiple regression analysis, after variable screening by factor analysis, for the dependent variable LMY is presented in Table 5-14. The first variable to enter the regression was LCDA which accounts for 53% of the total variance in the dependent variables. The subsequent addition of four other independent variables accounted for an additional 25% of the variance.

TABLE 5-13

CORRELATION MATRIX FOR DEPENDENT VARIABLES AND SELECTED INDEPENDENT MEASURES FOR THE FULL STUDY AREA

(N=146)

VARIABLE	1	2	3	4	5	6	7	8
1 LMY	1.000	0.918	0.922	0.671	-0.310	0.729	-0.090	0.212
2 LM10YY		1.000	0.849	0.761	-0.267	0.811	-0.146	0.266
3 LMF			1.000	0.818	-0.265	0.716	-0.157	0.160
4 LM10YF				1.000	-0.127	0.719	-0.200	0.175
5 LNCDA					1.000	0.019	-0.413	-0.186
6 LCDA						1.000	-0.413	0.302
7 LMCS							1.000	0.083
8 LBS								1.000

VARIABLE	9	10	11	12	13	14	15
1 LMY	0.120	0.584	-0.069	0.349	0.218	-0.488	0.034
2 LM10YY	0.159	0.584	-0.063	0.211	0.216	-0.463	0.026
3 LMF	0.059	0.466	-0.023	0.272	0.187	-0.419	0.022
4 LM10YF	0.056	0.316	0.066	-0.004	0.171	-0.339	-0.062
5 LNCDA	0.247	-0.158	-0.086	-0.181	-0.279	0.229	0.239
6 LCDA	0.192	0.484	-0.166	-0.046	0.074	-0.302	0.079
7 LMCS	-0.006	-0.149	0.533	-0.006	0.483	-0.269	-0.373
8 LBS	0.122	0.198	0.257	-0.017	0.152	-0.164	-0.006
9 LALCDA	1.000	0.401	0.157	-0.189	0.048	-0.194	0.262
10 LSLCDA		1.000	-0.114	0.207	-0.022	-0.378	0.238
11 LDDCDA			1.000	-0.277	0.353	-0.149	-0.405
12 MAP				1.000	0.071	-0.273	0.033
13 MASP					1.000	-0.613	-0.450
14 ST						1.000	0.192
15 JAMXT							1.000

TABLE 5-14 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA
ANALYSIS OF LMY AFTER INDEPENDENT VARIABLE SCREENING
(N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMY}$ (7)
	$\overline{LMY}$ = 4.14614				.87969	21.2
1	LMY = 1.269 +1.159 LCDA (.09)	.729	.532	163.6	.6040	14.6
2	LMY = -0.874 +1.187 LCDA +0.119 MAP (.08) (.01)	.824	.679	151.1	.5020	12.1
3	LMY = -0.285 +1.192 LCDA +0.104 MAP -0.433 LNCDA (.07) (.01) (.07)	.864	.746	138.9	.4482	10.8
4	LMY = -1.080 +1.304 LCDA +0.110 MAP -0.313 LNCDA +0.330 LMCS (.07) (.01) (.08) (.10)	.875	.765	114.9	.4322	10.4
5	LMY = -0.780 +1.180 LCDA +0.100 MAP -0.280 LNCDA +0.329 LMCS +0.250 LSLCDA (.08) (.01) (.07) (.09) (.08) (5-6)	.885	.782	100.7	.4176	10.1

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

TABLE 5-15 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA
ANALYSIS OF LM1OYY AFTER INDEPENDENT VARIABLE SCREENING
(N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E. % of $\overline{LM1OYY}$ (7)
	$\overline{LM1OYY}$ = 4.73958				.67723	14.3
1	LM1OYY = 2.276 +0.993 LCDA (.06)	.811	.658	276.9	.3975	8.4
2	LM1OYY = 2.544 +0.999 LCDA -0.359 LNCDA (.05) (.05)	.859	.738	201.4	.3491	7.4
3	LM1OYY = 1.631 +1.010 LCDA -0.312 LNCDA +0.048 MAP (.05) (.05) (.01)	.882	.778	166.1	.3223	6.8
4	LM1OYY = 1.848 +0.919 LCDA -0.287 LNCDA +0.041 MAP +0.183 LLSCDA (.05) (.05) (.01) (.06)	.891	.794	135.7	.3119	6.6
5	LM1OYY = 1.337 +0.992 LCDA -0.210 LNCDA +0.045 MAP +0.182 LSLCDA +0.212 LMCS (.06) (.05) (.01) (.05) (.07) (5-7)	.899	.807	117.3	.3026	6.4

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

All of the regression coefficients in the final equation (5-6) are significant at the 1% level, and their signs seem to correspond to physical theory. The LCDA variable has a positive sign as anticipated in that larger drainage areas are associated with larger annual yields. The positive coefficient of the MAP term is in accordance with that variable's role as an index of available moisture supply. The negative effect of LNCDA is in accordance with the expected relationship. The LMCS has a positive coefficient which is indicative of the greater efficiency in the collection and transport of runoff in basins with higher slopes. The final term in the equation, LSLCDA, has a positive coefficient which demands some further explanation. The possibility of a spurious relationship is evident in that the area of lakes and swamps represents a measure of moisture storage, and therefore, might be expected to have a negative effect on runoff volume. However, this measure as defined in the present study included only those lakes and swamps adjacent to and part of the drainage network. In this respect these areas may indicate areas of highly efficient runoff collection in that moisture available in these areas is in fact already in the drainage network. On this basis it may be suggested that the positive relationship of LSLCDA to the LMY may have a physical basis and is not a spurious correlation.

The statistical significance of the multiple regression relationship is confirmed by the highly significant F statistic. The R^2 statistic indicates that 78% of the total variance in LMY is accounted for by the regression. This is only slightly less than the 82% accounted for by the corresponding equation 5-2 in the all variable analysis. The equation 5-6 resulting after the variable screening process has the great advantage that the signs of the regression coefficients conform to physical expectations.

5.4.3.2.2 Summary of the Stepwise Regression Analysis, After Variable Screening, for LM10YY. A summary of the results of the stepwise multiple regression analysis, after variable screening by factor analysis, for the dependent variable LM10YY is presented in Table 5-15. The first variable to enter the regression is again LCDA, which in this case, accounts for 66% of the variance in the dependent variable. The next four variables contribute an additional 15% to this explained variance.

All of the regression coefficients are significant at the 1% level. The independent variables and the signs of their coefficients correspond with those of equation 5-6 as discussed in the preceding section (5.4.1.1). The physical bases for these relationships are similar to those discussed with respect to the LMY analysis in the preceding section.

The regression equation is highly significant on the F test of an analysis of variance. The R^2 value of .807 indicates that 81% of the total variance in the dependent variable has been explained by the regression. This figure is only slightly lower than the 82% explained by the corresponding multiple regression equation (5-3) as calculated without variable screening. The equation (5-7) developed in this section has the advantage of conforming to physical theory.

5.4.3.2.3 Summary of the Stepwise Regression Analysis, After Variable Screening, for LMF.

Table 5-16 contains the results of the stepwise multiple regression analysis, after variable screening, for the dependent variable LMF. The first variable to enter the regression is the LCDA which explains 51% of the total variance in the dependent variable. The subsequent entry of five additional variables contributes a further 21% to this explained variance.

The regression coefficients for the first five dependent variables are significant at the 1% level, while that of the sixth variable, the JAMXT, is significant at the 5% level. The signs associated with each of these coefficients correspond to the relationships anticipated on the basis of physical theory. The LCDA and LNCDA terms with their positive and negative coefficients, respectively, indicate the relationship of drainage area to flood magnitude. The MAP term provides an index of moisture supply and is therefore positively related to the LMF. The LDDCDA is positively related to LMF, indicating that a denser drainage network has a greater flood potential. The LBS index has a negative coefficient which indicates that basins with an elongated shape have lower flood flows than do basins with more rotund shapes. The final variable in the equation, JAMXT, has a positive coefficient. This relationship might be anticipated in that the higher values of JAMXT, which is estimated in degrees below freezing, are related to areas with a more permanent snowpack. This more permanent snowpack provides a basis for larger spring floods.

The analysis of variance F statistic indicates that the re-

TABLE 5-16 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA ANALYSIS OF LMF AFTER INDEPENDENT VARIABLE SCREENING (N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E. % of $\overline{LMF}$ (7)
	$\overline{LMF}$ = 2.66213				.62776	23.6
1	LMF = 0.648 +0.812 LCDA (.07)	.716	.512	151.1	.4400	16.5
2	LMF = -0.568 +0.828 LCDA +0.068 MAP (.06) (.01)	.778	.605	109.5	.3973	14.9
3	LMF = -0.198 +0.830 LCDA +0.058 MAP -0.272 LNCDA (.06) (.01) (.06)	.810	.657	90.6	.3716	14.0
4	LMF = -0.407 +0.866 LCDA +0.070 MAP -0.244 LNCDA +0.437 LDDCDA (.05) (.01) (.06) (.13)	.827	.683	76.0	.3583	13.5
5	LMF = -0.235 +0.943 LCDA +0.073 MAP -0.278 LNCDA +0.591 LDDCDA -0.476 LBS (.06) (.01) (.06) (.13) (.13)	.844	.712	69.1	.3431	12.9
6	LMF = -0.435 +0.951 LCDA +0.074 MAP -0.311 LNCDA +0.733 LDDCDA -0.528 LBS +0.013* JAMXT (.06) (.01) (.06) (.14) (.13) (.01) (5-8)	.851	.724	60.7	.3370	12.7

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

TABLE 5-17 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE FULL STUDY AREA ANALYSIS OF LM10YF AFTER INDEPENDENT VARIABLE SCREENING (N=146)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LM10YF}$ (7)
	$\overline{LM10YF}$ = 3.29262				.53375	16.2
1	LM10YF = 1.571 +0.694 LCDA (.06)	.719	.517	154.4	.3721	11.3
2	LM10YF = 1.596 +0.724 LCDA +0.407 LDDCDA (.05) (.12)	.743	.553	88.3	.3595	10.9
3	LM10YF = 1.688 +0.725 LCDA +0.384 LDDCDA -0.125* LNCDA (.05) (.12) (.05)	.754	.568	62.3	.3544	10.8
4	LM10YF = 1.840 +0.778 LCDA +0.484 LDDCDA -0.151 LNCDA -0.330* LBS (.06) (.12) (.06) (.13) (5-9)	.766	.587	50.1	.3478	10.6

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

gression equation is highly significant. Unfortunately, the coefficient of multiple determination, R^2, is 0.72 indicating that only 72% of the total variance of the dependent variable is accounted for by the regression. The standard error of the estimate is correspondingly large being 12.7% of the mean. In summary, the relationship expressed in equation 5-8 conforms to theoretical expectations; however, its predictive value is limited by the low value of R^2 and the high standard error of the estimate.

5.4.3.2.4 Summary of Stepwise Regression Analysis, After Variable Screening, for LM10YF. Table 5-17 summarizes the results of the stepwise multiple regression analysis, after variable screening by factor analysis, for the dependent variable LM10YF. The LCDA variable is again dominant, and is first to enter the regression explaining 52% of the total variance in the LM10YF. The addition of three more variables contributed a further 7% to this explained variance.

The first three regression coefficients in equation 5-9 are significant at the 1% level, while the fourth, which is associated with the LBS measure, is significant at the 5% level. The signs of all the coefficients conform to anticipated relationships which are the same as discussed for equation 5-8 in the preceding section (5.4.3.2.3).

The analysis of variance F statistic confirms the significance of the regression equation at the 1% level. However, the low R^2 value indicates the limited usefulness of the relationship for predictive purposes.

5.4.4 Summary of Results for the Full Study Area Analysis

Two approaches to the analysis of the relationships of the selected streamflow characteristics to the various measures of climatic and other physical geographic patterns for the entire study area, have been discussed in the preceding section of this chapter. The first approach involved the utilization of stepwise multiple regression analysis to examine the relationships of each of the dependent variables to the full set of independent measures; while the second approach employed factor analytic techniques in the screening of the independent variables prior to a regression analysis for each of the dependent variables. In order to facilitate a comparative summary of these two approaches to the analysis, Table 5-18 has been compiled, summarizing the results from the two sets of analyses.

Several comparative observations may be made based on the data in the table. In the case of the all variable regression approach, there is a tendency for spurious relationships to be developed as indicated when regression coefficients have the opposite sign to that expected on the basis of physical theory. In the case of regression analysis after variable screening, the signs of the regression coefficients corresponded to those expected on the basis of physical theory. The R^2 values, indicating the proportion of the total variance in the dependent variable,explained by the selected independent variables, were observed to be slightly higher for relationships developed by the first approach. The standard errors of the estimates were similar for the two approaches with those of the first approach being slightly lower in three out of the four cases examined.

The stated aims of the present study are twofold; first, to examine some of the physical relationships which underlie prairie streamflow patterns, and second, to develop statistical relationships for the pre-

TABLE 5-18 - COMPARATIVE SUMMARY OF ANALYSIS RESULTS FOR THE FULL STUDY AREA (N=146)

Dependent Variable	Approach I: Stepwise Multiple Regression All Variables					Approach II: Stepwise Multiple Regression After Factor Analytic Variable Screening				
	Equat No.	No. of Steps	Reg. Coef. Conform to Theory	R^2	S.E. % Mean	Equat No.	No. of Steps	Reg. Coef. Conform to Theory	R^2	S.E. % Mean
LMY	5-2	5	No	.82	9.2	5-6	5	Yes	.78	10.1
LM10YY	5-3	4	No	.82	6.1	5-7	5	Yes	.81	6.4
LMF	5-4	6	No	.72	12.8	5-8	6	Yes	.72	12.7
LM10YF	5-5	4	No	.61	10.3	5-9	4	Yes	.59	10.6

diction of streamflow characteristics for ungauged streams. On the basis of the data in Table 5-18, it seems that the first aim is best served by the second approach to the analysis in that the relationships derived in this manner corresponded more closely to physical expectations. The second aim, that of prediction, is slightly better served by the first approach to the analysis; however, this slight advantage is offset by the possibility of spurious relationships. The relatively large standard errors and low values for R^2 derived from all of the analyses limit the possible use of the regression equations for prediction purposes. This is particularly true when it is recognized that the dependent variables have been transformed to logarithmic units, and the process of converting these measures back to arithmetic values results in considerably larger percentage standard errors than are indicated by the logarithmic measures in the table.

The limitations of the regression equations for predictive purposes must initially be attributed to either errors in variable measurements or to variables which have not been considered in the analysis. Several groups of possible variables including measures of precipitation intensity, soil infiltration rates, and landuse patterns, have not been included in the present analysis because of a lack of available data. While it was not considered feasible to add measures of these variables at this stage of the study, an alternative approach for increasing the strength of the regression relationships was proposed. This proposal involved the division of the study area into regions of hydrologic similarity and the subsequent repetition of the multiple regression analyses on a regional basis. The division of the study area into hydrologic regions and the subsequent regression analyses are discussed in the following sections of this chapter.

5.5 ANALYSIS STAGE II: HYDROLOGIC REGIONS

In an effort to improve the predictive value of the regression equations resulting from the analyses, it was proposed to divide the study region into hydrologically similar regions. Such a division of the study area in order to improve the strength of relationships has been employed with some success in several similar studies in other areas. Examples of such an approach are included in the work of Durrant and Blackwell (1959), Dalrymple (1960), Benson (1964), Coulson (1967), Solomon et al (1968), and Canada, Department of Energy, Mines and Resources (1970).

Regions of hydrologic similarity are delimited for the purpose of accounting for some of the regional variations in the relationships of streamflow characteristics to physical geographic patterns. There are several possible methods for the delimitation of such regions. Two such methods which have been employed in other studies are regionalization on the basis of residual plots, and regionalization on the basis of index-ratios of selected hydrologic events. A third alternative approach involves the use of multivariate techniques to delimit regions of similarity. Each of these three methods has been considered and tested in the present study.

5.5.1 Regional Subdivision on the Basis of Residual Plots

The residuals which result from the estimation of a regression equation for a given set of data may indicate some geographical pattern to these errors. Several other researchers working in different study areas have successfully employed the spatial distribution of residual errors as a basis for the subdivision of their study areas. Benson (1964), in his flood frequency study of the Southwest,found that mapped residuals indicated a twofold subdivision of the study area. Solomon et al (1968) found a similar twofold subdivision for their study area, the Island of Newfoundland. In a recent study of hydrologic patterns throughout Western Canada, including the northern territories and British Columbia, a similar technique was employed to subdivide the study region (Canada, Department of Energy, Mines and Resources 1970).

In the present study, the residuals which resulted from the stepwise multiple regression analyses after variable screening were considered as a possible basis for the subdivision of the study area. For each of the four dependent variables, a map was plotted to show the spatial distribution of the residuals from the regression analysis. The residuals plotted were expressed as percentages of the observed values of the dependent variables. The map which resulted from the plotting of the residuals for the LMY relationship (equation 5-5), has been reproduced as Figure 5-1. The pattern of residuals on this map is similar to those obtained for the regression relationships of the other three dependent variables.

The pattern of the residuals as plotted on Figure 5-1 does not reveal any obvious regional divisions. The only residual groupings which are observed are local clusters of only a few basins. These local patterns were considered to represent divisions on too small a scale for use in the present research. Such small divisions include so few of the study basins that meaningful statistical analyses would be impossible without the addition of more basins. On the basis of the residual plots for the four

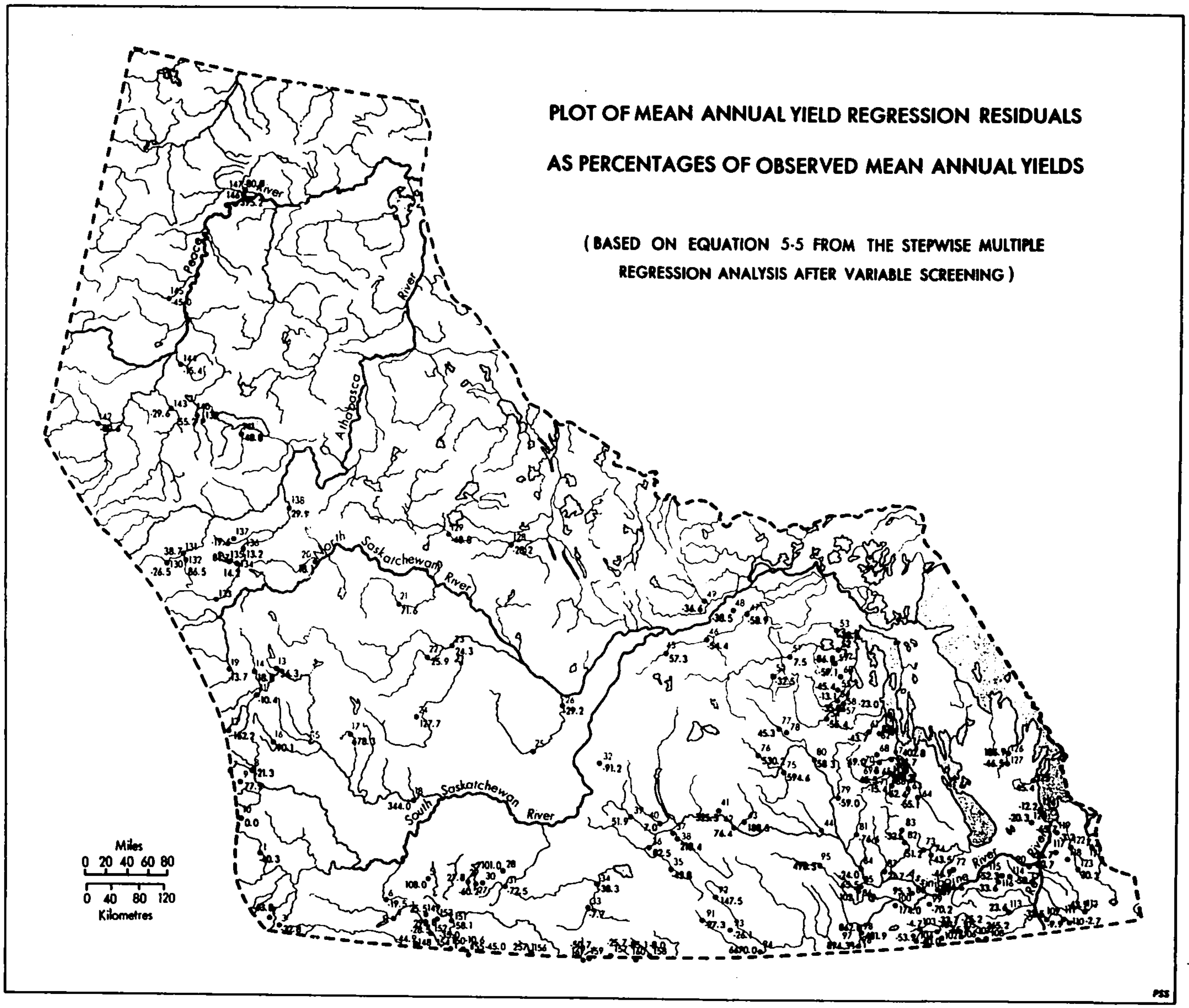

PLOT OF MEAN ANNUAL YIELD REGRESSION RESIDUALS
AS PERCENTAGES OF OBSERVED MEAN ANNUAL YIELDS
(BASED ON EQUATION 5-5 FROM THE STEPWISE MULTIPLE
REGRESSION ANALYSIS AFTER VARIABLE SCREENING)
Peace River
Athabasca River
North Saskatchewan River
South Saskatchewan River
Saskatchewan River
Miles
0 20 40 60 80
0 40 80 120
Kilometres
PSS

Figure 5-1

regression relationships which resulted from the stepwise multiple regression analyses after variable screening, the use of residual plots for the subdivision of the study area was ruled out.

5.5.2 Regional Subdivision on the Basis of Index-Event Ratios

The index-event method of regional subdivision has been widely employed in flood frequency studies by the United States Geological Survey; and the method has been outlined in detail by Dalrymple (1960). A similar method was employed by Blackwell and Durrant (1959) in their flood frequency study for the southern prairies. In this method, regional subdivision is based on the ratio of some index-event to the mean event. The index-event is usually an event with a return period of 10 years. The index-ratio is a measure of the year to year variability in the magnitudes of the particular event being analysed. If the spatial distribution of index-ratios is such as to indicate regions of hydrologic similarity, the analyses for each area can be concentrated on explaining the mean magnitudes of events in terms of the physical basin characteristics. The estimated mean events in combination with regional index-ratios provide a basis for the estimation of the magnitudes of events with any required return period.

In the present study, the ratios of the 10 year to the mean events were estimated for both annual yields and annual flood flows for each of the study basins. These ratios were then plotted on maps of the study area. The map of the index-ratios for the annual yield events has been reproduced as Figure 5-2. A similar pattern resulted from the plot of the index-ratios for annual flood flow events.

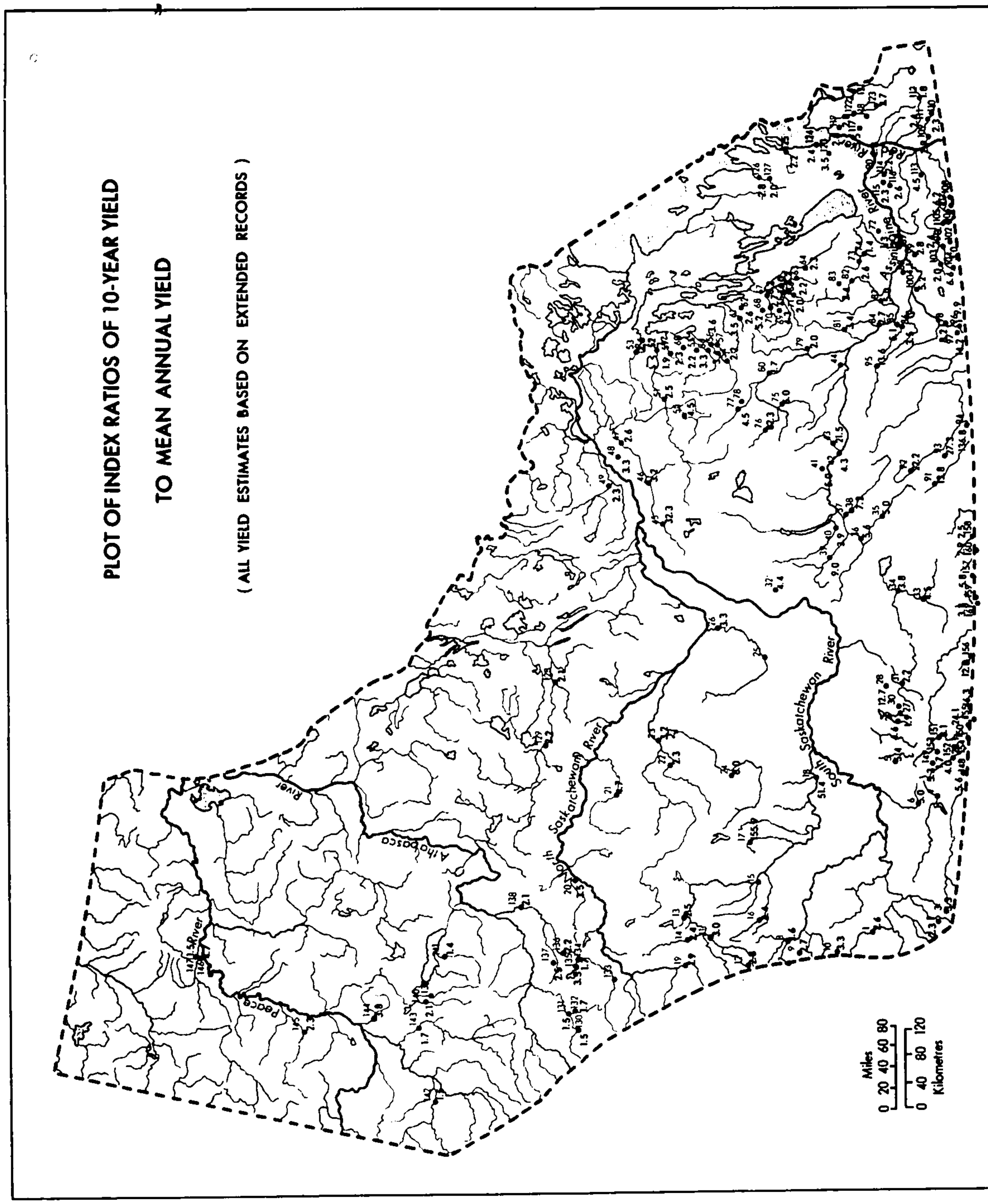

PLOT OF INDEX RATIOS OF 10-YEAR YIELD
TO MEAN ANNUAL YIELD
(ALL YIELD ESTIMATES BASED ON EXTENDED RECORDS)
Peace River
Athabasca River
North Saskatchewan River
South Saskatchewan River
Miles
0 20 40 60 80
0 40 80 120
Kilometres

Figure 5-2

On the basis of these maps, it was observed that the spatial pattern of index-ratios as plotted for the study basins did not lend itself to regional grouping except on a local scale. Such local scale groupings are not suited to the type of statistical analyses utilized in the present study. On the basis of the above considerations, regional subdivision based on index-ratios was ruled out for the present research.

5.5.3 Regional Subdivision by Multivariate Grouping Techniques

In view of the failure of the residual plots and index-ratio plots to provide a basis for a meaningful subdivision of the study area, it was proposed to employ a multivariate technique to subdivide the study area according to indices of climatic and hydrologic variability. As discussed in a previous section (4.1), the large scale regional variations in streamflow patterns tend to be closely related to climatic conditions which govern the available moisture supply, while smaller scale local variations in streamflow are more closely related to variations in other physical geographic patterns. Building on this premise, it was proposed to approach the regional subdivision problem from the point of view of the large scale climatic patterns which control the available moisture supply.

The multivariate grouping technique utilized in the present study employed factor analytic methods in conjunction with an optimal grouping algorithm. A factor analysis with a principal components solution and varimax rotation was used in the identification of the most significant dimensions underlying the set of climatic and hydrologic variables as compiled for the study basins. Factor scores were calculated for each observation on three factors. These factor scores were then employed as input to an optimal grouping computer program as developed by Semple et al (n.d.). This grouping program has recently been employed in a study of microclimatic zonation in Northern Alberta (MacIver 1970).

The initial set of variables employed in the grouping analysis included all of the 20 climatic measures, and the index-event ratios for annual yields and annual flood flows as compiled for each of the study basins. All of the climatic measures were originally selected on the basis of their theoretical relationships to streamflow, and therefore, were considered to be potentially useful in the regional subdivision problem. The index-event ratios for the annual yields and annual flood flows are measures of the year to year variability in streamflow patterns, and therefore, were considered for inclusion in the grouping analysis of the study basins.

The first step in the grouping procedure was to execute a factor analysis on the 22 selected variables as compiled for the 146 study basins. The principal components solution with varimax rotation resulted in the rotated factor matrix which has been reproduced as Table 5-19. Only the first four factors have been reproduced in the table. The use of factor analytic techniques in this section of the study has been with the ultimate aim of identifying the main dimensions underlying the climatic and hydrologic measures for the study basins. This application is in contrast to the use of factor analysis in other sections of the study, where the ultimate aim has been to screen the independent variables for multicollinearity.

TABLE 5-19

ROTATED FACTOR MATRIX FROM THE FACTOR ANALYSIS OF THE CLIMATIC VARIABLES AND HYDROLOGIC INDEX EVENT RATIOS

(N=146)

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
1 LYR	-0.27546	-0.02521	0.18370	0.85435
2 LFR	-0.33616	-0.12292	0.10643	0.81333
3 MAP	0.94427	0.00780	-0.01139	-0.26472
4 MAS	0.77806	-0.25243	-0.53428	-0.02732
5 MASP	0.20104	-0.32233	-0.77741	0.20141
6 MWP	0.87893	0.10123	-0.32611	-0.03114
7 MSP	0.83273	-0.35328	0.08532	-0.12922
8 MWSP	0.96352	-0.17102	-0.11021	-0.09668
9 A10YP	0.95616	-0.03363	-0.03332	-0.19055
10 W10YP	0.84298	0.14730	-0.35348	0.03566
11 MWT	0.05767	-0.98876	-0.02008	0.05985
12 MJANT	-0.04030	0.98681	0.10524	-0.06300
13 MST	-0.17764	0.07635	0.90669	0.19970
14 MJUNT	-0.03493	0.41826	0.86094	0.11045
15 WMXT	-0.01039	-0.98157	-0.11705	0.04003
16 JAMXT	0.00781	0.97717	0.15449	-0.05215
17 PE	-0.04979	0.01648	0.93952	0.19753
18 THAET	0.87871	0.01553	0.09153	-0.33981
19 TUAET	0.84284	-0.38643	0.28569	-0.16368
20 LTHSUR	0.84937	0.10192	-0.29741	0.02062
21 TUSUR	0.90234	0.16760	-0.13122	-0.28301
22 MATR	-0.07010	0.88645	0.43708	0.04208

CUMULATIVE PROPORTION OF TOTAL VARIANCE

0.45531	0.71513	0.85424	0.91671

From the rotated factor matrix, Table 5-19, the four factors may be identified in terms of their highest loadings. The highest loadings on the first factor are positive for the variables MAP, MWSP, A10YP and TUSUR. From these loadings, it is evident that this factor is an index of moisture availability. The second factor has high positive loadings for the variables MJANT and JAMXT, and high negative loadings for MWT and WMXT. This factor is therefore an index of the intensity of winter temperatures. The highest loadings on the third factor are positive for the variables MST and PE. This factor is an index of spring and summer temperature conditions. The fourth factor has high positive loadings for the two hydrologic index-ratios LYR and LFR, and is therefore an index of the year to year variability in streamflow.

In preparation for basin grouping, the factor analytic procedure was extended a further step and factor scores were calculated for each observation on each of the first four factors. The individual factor scores for each observation and dimension were estimated by summing the products of the normalized raw input data and factor loadings for each variable. The factor scores as calculated for each of the study basins are listed in Table 5-20.

The optimal grouping algorithm employed in the present analysis utilizes the three sets of factor scores as a basis for the grouping of the observations into a set of optimal groups. This method employs the three factor scores for each observation to fix its location in three dimensional space. The distance between pairs of observations is then employed to estimate group centroids in a stepwise fashion.

TABLE 5-20

FACTOR SCORES RESULTING FROM FACTOR ANALYSIS OF THE CLIMATIC VARIABLES AND HYDROLOGIC INDEX EVENT RATIOS

(N=146)

BASIN NO.	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
1	1.35650	-2.08699	-2.22653	0.59846
2	2.28512	-2.43207	-1.33024	1.35388
3	1.12878	-2.79941	-1.22787	0.83033
5	-1.25255	-1.35288	-0.23772	-0.11667
6	-0.69237	-1.61579	1.11490	0.77896
8	1.66278	-2.10829	-1.61127	-0.46227
9	1.80452	-2.08366	-1.76565	0.02424
10	2.41931	-1.99794	-2.27155	0.94244
11	0.42246	-1.84715	-0.55916	-0.66929
12	2.50041	-1.97922	-2.06030	0.30717
13	0.22754	-0.88037	-0.56463	-1.12027
14	0.74120	-1.21907	-0.68011	-0.73835
16	-0.27138	-1.79261	-0.07112	-0.70516
17	-0.55791	-0.45036	-0.04134	4.41812
18	-1.23969	-0.23745	0.12660	3.87796
19	0.93755	-1.45303	-0.53736	-0.83347
20	0.18601	-0.51214	-0.19032	-0.25460
21	-0.58788	0.02406	-0.29419	-0.37196
22	-1.47020	-0.16643	-0.28986	-1.24496
23	-1.09420	-0.30009	-0.26451	-0.86266
24	-1.43241	-0.06218	-0.59454	0.47403
26	-1.33113	0.41583	0.01384	0.97200
27	-0.67580	-1.37069	-0.88700	-1.15936
28	-0.75454	-0.75151	-0.48137	1.21357
29	-0.95832	-1.83848	1.01931	0.06637
31	-0.98202	-1.04561	-0.39810	-0.92636
32	-1.44836	0.14701	0.59349	0.09231
33	-1.35107	-0.96679	0.78776	-0.05177
34	-1.31371	-1.14344	0.64627	-0.19577
35	-0.71050	-0.14362	0.72275	-0.05968
36	-0.61459	-0.44054	0.98092	0.37739
38	-0.65235	0.28259	0.50377	0.67272
39	-0.49412	0.13651	0.26299	0.80141
40	-1.16192	0.20637	0.46841	-0.22062
41	0.54793	0.74629	-0.86071	0.90198
42	-0.17582	0.35982	0.10380	0.24994
43	0.34915	0.85756	-0.91874	2.14299
45	-0.00151	1.25896	-0.81767	2.41777
46	-0.41812	1.20003	-0.75280	-0.11091
47	-0.33401	1.29842	-0.75173	-0.39794
48	-0.32905	1.42679	-0.46827	-0.12810
49	-0.24755	1.29669	-0.73207	-0.50712
50	-0.22123	1.37784	-1.27263	0.07328
51	-0.26732	1.33207	-1.13985	-0.32774
53	0.09910	1.66676	-1.36407	-0.19330
54	-0.60022	1.13739	-0.52558	-0.73894
55	-0.00437	1.41220	-1.24519	-0.14212
56	-0.41331	1.20159	-0.63007	-0.21709
57	-0.78387	1.03283	-0.13431	-0.49741

BASIN NO.	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
58	-0.51651	1.15407	-0.51973	-0.05789
59	-0.02131	1.40713	-1.24497	-0.25440
60	0.00574	1.41393	-1.24699	-0.06601
61	-0.40474	0.90226	0.04354	-0.36921
62	0.87992	0.54242	0.48073	-0.11880
63	1.00312	0.49524	0.52568	-0.10574
64	0.84086	0.52632	0.49526	-0.26562
65	0.98148	0.58819	0.49403	1.20549
66	1.06024	0.51097	0.52609	0.23795
67	1.21619	0.54887	0.51280	1.33302
68	1.15655	0.53269	0.51559	0.92687
69	1.11859	0.52399	0.51962	0.65596
70	1.04584	0.50587	0.52524	0.14834
71	0.99223	0.49370	0.53092	-0.23425
72	0.50966	0.43541	0.71293	-0.81212
73	0.16726	0.39287	0.46026	-0.52461
74	0.52198	0.58002	0.42585	-0.74067
75	0.25411	0.97164	-1.00049	0.93272
76	0.38265	0.88656	-0.70712	2.26376
77	-0.45906	1.33272	-1.30328	-0.00029
79	-0.99151	0.96556	-0.02793	-1.17535
80	-0.82098	0.99559	-0.09995	-0.96409
81	-0.97551	0.77566	0.29136	-1.38701
83	-0.10285	0.24608	0.49481	-0.96785
84	-0.16127	0.67251	0.35266	-0.87549
85	1.09725	0.40846	0.15260	1.15208
86	0.96639	0.36897	0.23848	0.31603
87	0.09383	0.64101	0.46610	-0.40079
88	0.50919	0.25976	1.21066	0.45377
89	0.33662	0.31486	1.01808	-0.68090
90	1.09555	0.59234	1.23741	-0.40479
91	-0.67761	-0.32428	0.69423	0.48682
92	-0.92008	0.21494	0.55987	1.21674
93	-0.35599	-0.21666	0.84427	1.11104
94	-0.47765	-0.56109	1.54484	2.86026
95	0.50294	0.33769	-0.04729	1.94736
96	-0.55958	0.34600	0.39559	0.70969
97	0.37700	0.41378	0.51745	1.76068
98	0.28452	0.35436	0.93505	0.55285
99	0.88895	0.12545	1.11480	-0.08340
100	1.04051	-0.03264	1.17031	0.55752
101	0.29663	-0.19902	1.20229	-0.80177
102	-1.13995	-0.38786	1.45702	-0.99363
103	1.53270	-0.07048	0.91776	0.10810
104	1.63791	-0.03448	0.92225	0.77294
105	-1.05614	-0.29841	1.46826	-0.98422
106	-0.86770	-0.26188	1.51491	-0.81178
107	0.08920	0.04996	1.70547	-0.16561
109	0.57532	-0.14745	1.73677	-0.96031

BASIN NO.	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
110	0.54911	-0.15174	1.73281	-1.23457
111	0.54914	-0.15444	1.74273	-1.20854
112	1.11477	0.51182	0.74758	-0.82211
113	1.43062	0.11560	1.65081	0.54523
114	1.45126	0.14081	1.26126	-0.41760
115	1.53200	0.12540	1.26611	-0.32491
116	1.37643	0.17686	1.24799	-0.14361
117	0.93494	0.55898	1.22497	0.02630
119	1.09619	0.91622	0.55900	-0.31900
120	1.13115	0.92482	0.55617	-0.07431
121	1.27230	0.60787	0.63748	-0.30692
122	-0.09022	0.33547	1.25192	-1.06990
123	-0.09050	0.33441	1.25067	-1.06491
124	1.10278	0.91441	0.55404	-0.24851
125	1.07693	0.90928	0.55773	-0.43819
126	1.24575	0.96282	0.51424	0.08385
127	1.18367	0.94842	0.52040	-0.35685
128	-1.04413	0.47592	-0.81864	-1.04420
129	-1.02481	0.45737	-0.76550	-1.12861
130	0.28491	-1.70369	-0.71221	-1.52618
131	0.41647	-1.31323	-0.81276	-1.54910
132	0.59391	-0.95136	-0.91981	-1.09451
134	0.41887	-1.00227	-0.95036	-1.30482
135	0.36826	-0.72256	-0.46176	-0.70191
136	0.21578	-0.59245	-0.32687	-0.88355
137	0.16794	-0.65586	-0.17488	-0.95733
138	0.15891	-0.64876	-0.59830	-1.15096
140	0.16742	0.22433	-0.90364	-0.33484
141	-0.38056	0.17664	-1.64897	-1.13178
142	0.04034	-0.09827	-2.02535	-0.01051
143	0.31503	0.11265	-1.13792	-0.65101
144	0.07041	0.94448	-1.97393	0.72549
145	-0.01942	1.17671	-2.28661	0.33633
146	-0.91312	2.12391	-2.26008	0.25293
147	-1.20912	2.71490	-2.64737	-0.57834
148	-1.52186	-1.38291	0.53889	0.52981
149	-1.37581	-1.11643	-0.96753	0.18088
150	-2.43976	-0.73874	0.11108	1.26022
151	-1.47888	-1.12821	-0.97866	-0.50378
152	-1.49498	-1.24863	-0.31691	-0.11448
153	-1.56811	-1.16326	-0.95128	-1.16865
154	-2.00247	-0.82895	0.49872	1.88896
155	-2.47496	-0.75056	0.10986	1.03623
156	-1.06568	-1.46662	0.91357	1.79678
157	-1.18881	-0.95183	0.98893	0.27173
158	-1.02833	-0.55187	0.69281	-0.69859
160	-0.95886	-0.48527	0.68682	-0.64727
161	-1.50351	-1.11785	0.98616	-0.56593

The optimal grouping is controlled by two criteria, the first defining the minimum explained variance to be associated with an acceptable group and the second defining the maximum total explained variance for all groups. The grouping calculations in the present study were made utilizing a computer program prepared by Semple et al (n.d.) and modified by MacIver (1970).

The optimal grouping algorithm was applied to the factor scores of the first three dimensions of the rotated factor matrix, Table 5-19. The limiting criteria were set at 1% for the minimum variance explained by an acceptable group and at 95% for the maximum variance explained by all groups. The calculations resulted in the identification of two groups which accounted for a total of only 19% of the total variance. Although the total variance explained by these groups is low, when they were plotted on a map of the study area, two well defined areal groupings were observed.

The first group of basins included those in the eastern part of the study area and those in northern Alberta. This group included 83 basins. The centroid of the group had factor scores of 0.35, 0.65 and 0.15 for the first, second and third dimensions respectively. These factor scores may be interpreted to characterize the first group of basins has having above average moisture supply, relatively extreme winter conditions, and warmer spring and summer temperatures with higher PE.

The second group of basins included those in the southwestern portion of the study area. This group included 63 basins. The centroid of this second group had factor scores of -0.45, -0.88 and -0.19 for the three dimensions. Interpreting these scores the area might be characterized as having below average moisture supply, less extreme winter conditions and slightly less extreme summer temperatures. The third factor, which relates to spring and summer temperatures, shows a much less pronounced differentiation between groups than do the first two.

The map, Figure 5-3, was prepared to illustrate the grouping of the study basins. Each hydrometric station has been plotted to indicate the group to which it has been assigned and its distance from the group centroid. This distance is the distance relative to the three dimensional plots employed in the grouping procedure. The general pattern of basin grouping as illustrated on the map is contradicted in three areas by seemingly anomalous stations. In order to smooth the tentative regional boundary each of the anomalous areas was examined in detail with the aim of explaining the assignment of basins to a particular group.

The first anomaly to the basin grouping is in south central Manitoba where basins 102, 105 and 106 were assigned to Group 2, while all of the surrounding basins were assigned to Group 1. An examination of the climatic data for stations in this area revealed that this anomalous grouping resulted from lower precipitation estimates for these basins. These lower estimates were the result of a particular climatological station, Hansboro, North Dakota, Number 190, being included in the Thiessen calculations for the basins. This climatological station which is located in an area of lower precipitation to the southeast of Turtle Mountain, has a mean annual precipitation of 15.6 inches compared to over 18 inches for most of the surrounding stations. It is not

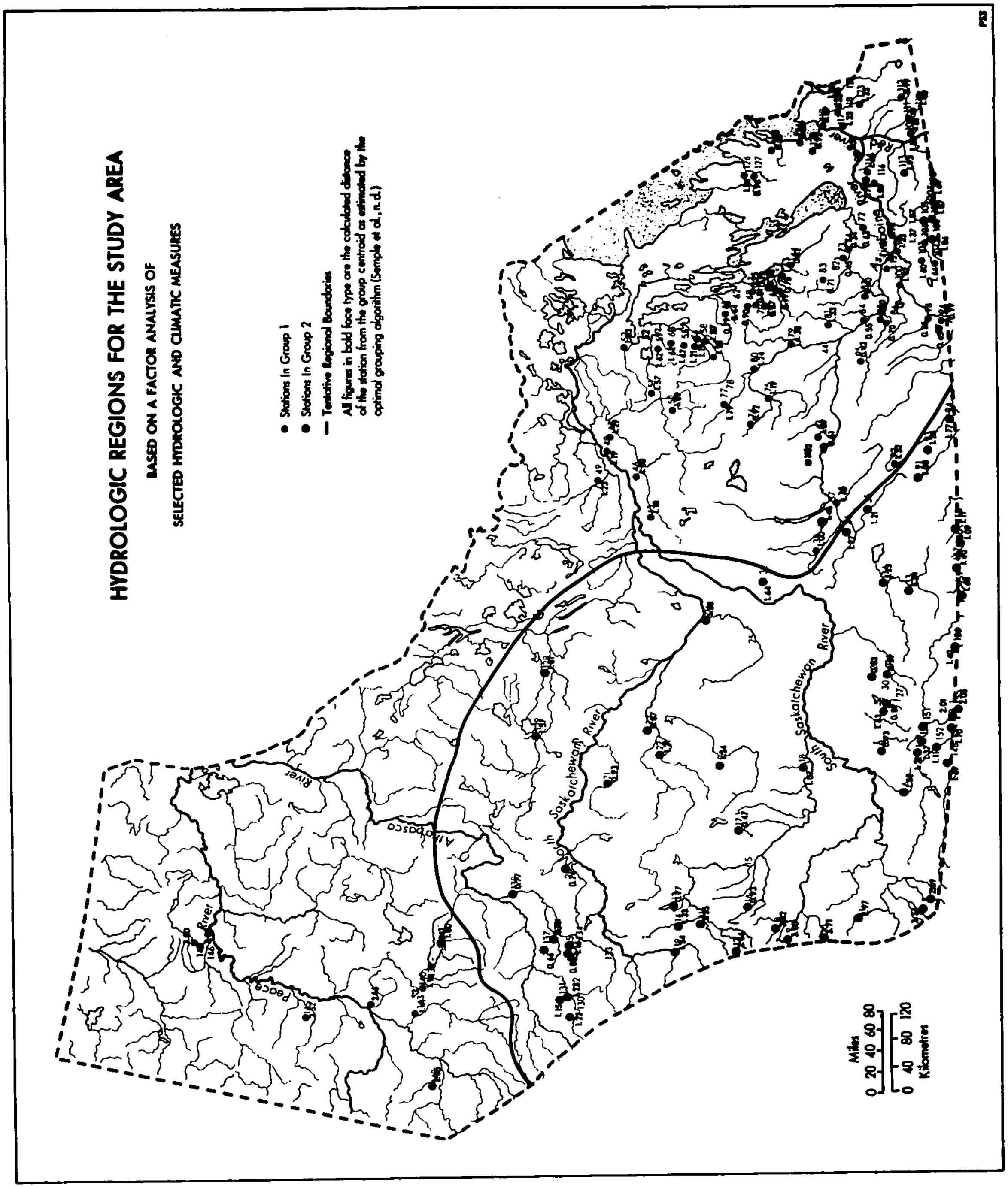

HYDROLOGIC REGIONS FOR THE STUDY AREA
BASED ON A FACTOR ANALYSIS OF
SELECTED HYDROLOGIC AND CLIMATIC MEASURES
Stations In Group 1
Stations In Group 2
Tentative Regional Boundaries
All figures in bold face type are the calculated distance of the station from the group centroid as estimated by the optimal grouping algorithm (Semple et al., n.d.)
Miles
0 20 40 60 80
0 40 80 120
Kilometres
Peace River
Athabasca River
North Saskatchewan River
South Saskatchewan River

Figure 5-3

possible on the basis of available data to indicate the true effect of this area of lower precipitation on the basins in question. However, having explained the reasons for the anomaly, and recognizing that these three basins are not closely linked to the centroid of Group 2 as indicated by their distance statistics of over 1.8 (see Figure 5-3), it was decided to assign these basins to Group 1 for the purposes of analysis.

The second anomaly to the grouping pattern is in south central Saskatchewan where basin 40 was assigned to Group 2 while nearby basins 38 and 39 were assigned to Group 1. An examination of the basic climatic data for these stations revealed that the precipitation estimates for basin 40 were lower than for either 38 or 39. This lower precipitation can be attributed to the influence of a particular climatological station, Davidson, Saskatchewan, No. 81. This climatological station is located in a drier area to the northwest of basin 40. After examining the distance statistics from the centroids of their respective groups, 1.46 for basin 40, 1.13 for basin 38, and 1.00 for basin 39, and on the basis of the single climatological station involved, it was decided to assign basin 40 to Group 1 for the purposes of analysis.

A third anomalous area in the grouping pattern occurred in northern Alberta where basins 141 and 142 were assigned to Group 1. On examination of the climatic data for these basins it was found that basins 141 and 142 were somewhat drier than were basins 140 and 143. After considering the distance statistics, 1.80 and 2.05 for basins 141 and 142 respectively and 1.16 and 1.41 for basins 140 and 143 respectively, it was decided to assign basins 141 and 142 to Group 1 for the purposes of analysis.

Having examined the anomalies in the spatial distribution of the basin grouping, a tentative boundary was drawn for the regions of hydrologic similarity (Figure 5-3). The first group, the eastern region, included 89 study basins; and the second group, the western region, included 57 basins. Although the grouping analysis accounted for only 19% of the total variance in the factor scores for the three climatic factors, the regional grouping has been utilized as a basis for further analyses of the relationships between streamflow characteristics and the various measures of physical geographic patterns. These relationships were analysed for each of the two regions employing the techniques of variable screening by factor analysis and stepwise multiple regression.

5.5.4 Analysis for the Eastern Region

The analysis of the relationships of each of the dependent variables to the various measures of climatic and other physical geographic patterns for the 89 study basins in the eastern region employed the same methods as were utilized in the full study area analysis of Section 5.4.3. The full set of independent variables was screened for multicollinearity by factor analytic techniques; and the resulting selection of independent variables was employed in the stepwise multiple regression analysis for each of the dependent variables.

5.5.4.1 Screening of the Independent Variables by Factor Analysis

The full set of 39 independent variables for each of the 89 study basins in the eastern region was factor analysed according to the principal component method with varimax factor rotation. The resulting rotated factor matrix is presented in Table 5-21. The highest loadings on each factor have been underlined and the variables selected for further analysis have been indicated. The actual selection of variables for further analysis was based both on the strength of factor loadings and on a consideration of the data compilation problems and ultimate use of the variables. Eighteen defining variables from Table 5-21 were selected for further analysis.

The 18 defining variables were factor analysed a second time, and the resulting rotated factor matrix is reproduced as Table 5-22. This table served as the basis for the ultimate selection of a set of 10 independent variables for the eastern region. These 10 variables were then employed in a stepwise multiple regression analysis for each of the four dependent variables.

5.5.4.2 Stepwise Multiple Regression Analyses after Variable Screening for the Eastern Region

The initial correlation matrix for all of the variables employed in the eastern region multiple regression analyses is reproduced in Table 5-23. For each of the four dependent variables the set of 10 independent variables was entered in the analysis. The resulting relationships are summarized in Tables 5-24 to 5-27 inclusive. These tables employ the same format as that used in previous sections and as explained in Section 5.4.1.1. A brief discussion of the results is contained in the following section.

5.5.4.2.1 Summary of the Results of the Eastern Region Regression Analyses. The results of the eastern region regression analysis for the dependent variable LMY are presented in Table 5-24. The final

TABLE 5-21

ROTATED FACTOR MATRIX RESULTING FROM THE FACTOR ANALYSIS OF ALL INDEPENDENT VARIABLES FOR THE EASTERN REGION

(N=89)

VARIABLE	FACTOR 1	2	3	4	5	6	7	8	9	10	11
1 LTDA	0.30554	-0.14427	0.09468	-0.01483	0.29859	0.01407	-0.87725◄	-0.06862	0.01846	-0.09358	-0.01157
2 LNCDA	-0.25243	-0.16988	0.06229	-0.04234	-0.03960	-0.18352	-0.05839	-0.06510	-0.11055	-0.91364◄	0.01544
3 LCDA	0.32484	-0.11808	0.08427	0.00544	0.30511	0.04730	-0.87584◄	-0.06015	0.02545	0.04952	-0.01584
4 LMCS	-0.06169	0.11450	-0.50766	0.01055	0.15399	-0.08473	0.35219	0.71028◄	0.10316	0.14397	-0.01493
5 LBEL	-0.10533	-0.25214	-0.40869	-0.34389	0.54613	-0.23689	-0.09808	0.40089	0.15220	-0.10026	-0.06361
6 LBR	0.10101	0.04241	-0.52169	-0.00313	0.36678	-0.17308	-0.27821	0.33493	0.16318	0.15399	-0.04911
7 LBL	0.26536	-0.12142	-0.05458	0.02125	0.27150	0.01779	-0.81627	-0.02268	0.40786	-0.02423	-0.01159
8 LBS	0.04050	-0.01068	-0.30250	0.08055	0.06725	0.01438	-0.24078	0.07333	0.90299◄	0.11762	-0.00528
9 LALTDA	0.15892	-0.16627	-0.26562	0.28266	0.26677	-0.84261◄	0.02873	0.04926	-0.01251	-0.04842	-0.01136
10 LALCDA	0.13419	-0.18552	-0.26444	0.23773	0.23060	-0.84805◄	0.06311	0.04179	-0.00704	-0.18943	-0.01481
11 LSTDA	0.95636	0.05863	0.04649	0.10495	0.11189	0.03351	-0.19449	-0.01737	0.02566	0.10464	0.00210
12 LSCDA	0.95838◄	0.04684	0.05233	0.10841	0.10367	0.02112	-0.19920	-0.02411	0.02121	0.07644	0.00712
13 LSLTDA	0.95405	-0.00681	-0.01133	0.13163	0.14143	-0.13083	-0.14587	-0.00110	0.01343	0.07497	-0.00287
14 LSLCDA	0.95551◄	-0.02116	-0.01494	0.12529	0.13003	-0.16443	-0.13233	-0.00466	0.01333	-0.00709	-0.00132
15 LDDTDA	-0.00096	0.02033	-0.95853	-0.00922	0.15418	-0.06512	0.01045	0.05561	0.06105	0.14143	-0.02061
16 LDDCDA	-0.06233	-0.02035	-0.95545◄	-0.06294	0.13114	-0.12312	0.04992	0.02571	0.06456	-0.12577	0.00389
17 LOFTDA	-0.02719	-0.02830	0.96390	0.01072	-0.14100	0.05701	0.00127	-0.05400	-0.07456	-0.15494	0.02003
18 LOFCDA	0.03150	0.01859	0.96078◄	0.05262	-0.10928	0.14116	-0.05149	-0.05260	-0.06253	0.12554	0.01436
19 LFTDA	0.44288	0.42454	-0.10378	0.29215	0.10554	-0.07473	-0.05300	0.13415	-0.10281	0.21027	0.01828
20 MAP	0.05603	0.70600	0.13721	-0.17064	-0.57676	0.12071	0.13486	-0.09109	-0.05128	-0.03596	0.18824
21 MAS	0.03311	0.90004	-0.22047	-0.06953	0.20619	-0.02688	-0.02153	0.02710	-0.00110	0.05863	-0.26341
22 MASP	0.02904	0.39440	-0.33077	0.10543	0.69086	-0.10730	-0.14781	0.09673	0.07769	0.09523	-0.42786◄
23 MWP	0.00415	0.97148◄	-0.03209	-0.04598	0.07080	0.08294	0.02732	0.03606	0.02543	0.09620	-0.03055
24 MSP	-0.22030	0.27005	0.07527	-0.24120	-0.78263	0.03595	0.22059	0.04619	-0.06415	-0.12888	0.07034
25 MWSP	-0.14581	0.79643	0.03067	-0.19172	-0.48095	0.07646	0.16642	0.05418	-0.02698	-0.02571	0.02774
26 A10YP	0.02002	0.72534	0.04648	-0.31358	-0.46266	0.18387	0.14285	0.01425	-0.01008	-0.04409	0.15774
27 W10YP	-0.09666	0.93738◄	-0.07295	0.07054	0.11878	-0.02671	0.02137	0.12311	0.05140	0.09250	-0.06790
28 MWT	-0.19648	0.08914	0.01679	-0.86555	-0.38466	0.13487	0.11999	-0.04034	-0.03627	-0.05130	-0.00541
29 MJANT	0.20587	-0.07371	0.0[illegible]178	0.90324◄	0.30276	-0.10672	-0.08566	-0.00445	0.04111	0.05649	-0.00683
30 MST	-0.25565	-0.10279	0.12434	-0.33240	-0.83355	0.12186	0.15694	-0.02734	0.00818	0.02556	-0.14153
31 MJUNT	-0.15223	-0.02152	0.23823	-0.06532	-0.90452◄	0.14187	0.21550	-0.04458	-0.03984	0.02985	-0.06878
32 WMXT	-0.07490	0.03157	0.00333	-0.93856	-0.26254	0.11864	-0.01166	-0.00228	-0.00063	0.05054	0.00345
33 JAMXT	0.10311	-0.00112	0.01583	0.94199◄	0.24753	-0.08158	0.04950	-0.04137	0.00950	-0.01116	-0.00337
34 PE	-0.25776	-0.03845	0.18086	-0.30046	-0.85319◄	0.12034	0.21631	-0.02292	-0.01378	0.01421	-0.04306
35 THAET	0.02424	0.52822	0.12242	-0.21670	-0.70428	0.10550	0.12610	-0.07306	-0.04321	-0.05378	0.20953
36 TUAET	-0.12104	0.38626	0.12551	-0.45588	-0.73523	0.14040	0.18167	-0.06387	-0.03886	-0.02558	0.06016
37 LTHSUR	0.12641	0.90575	0.09445	0.03546	0.02345	0.10611	0.08643	-0.08729	-0.04644	0.06371	-0.00280
38 TUSUR	0.15797	0.80638	0.12614	0.02836	-0.40010	0.09185	0.08732	-0.09564	-0.05203	-0.03740	0.24109
39 MATR	-0.00341	-0.11238	0.22089	0.85273	-0.41269	-0.03407	0.12037	-0.00919	0.02529	0.04740	-0.02180

CUMULATIVE PROPORTION OF TOTAL VARIANCE

1	2	3	4	5	6	7	8	9	10	11
0.32622	0.50091	0.65627	0.75944	0.82683	0.87044	0.90714	0.93007	0.94611	0.96050	0.97088

◄ DEFINING VARIABLES SELECTED FOR FURTHER ANALYSIS

TABLE 5-22

ROTATED FACTOR MATRIX RESULTING FROM THE FACTOR ANALYSIS OF THE SELECTED DEFINING VARIABLES FOR THE EASTERN REGION

(N=89)

VARIABLE	FACTOR 1	2	3	4	5	6	7	8	9	10
1 LTDA	-0.91129	0.06563	-0.09759	-0.02708	-0.24692	-0.09134	0.09137	-0.00316	-0.12225	0.24308
2 LNCDA	-0.03582	-0.04798	-0.16785	0.05396	0.19226	0.12066	0.93577◄	-0.15804	-0.10435	-0.03716
3 LCDA	-0.91294◄	0.08453	-0.06924	-0.04766	-0.25426	-0.10420	-0.05051	0.02237	-0.10117	0.24750
4 LMCS	0.31265	-0.39401	0.16110	0.00065	0.05390	-0.11363	-0.16802	-0.14109	0.79460◄	0.15694
5 LBS	-0.15369	-0.21895	0.03644	-0.06814	-0.03383	-0.94769◄	-0.11621	-0.00999	0.06912	0.06858
6 LALTDA	-0.01127	-0.19789	-0.08290	-0.24055	-0.12139	-0.01049	0.02925	-0.91001	0.07052	0.19973
7 LALCDA	0.03118	-0.23344	-0.11005	-0.19441	-0.11441	-0.00577	0.16633	-0.90284◄	0.04536	0.17375
8 LSCDA	-0.26002	0.07369	0.02267	-0.13094	-0.93279	-0.02779	-0.14291	-0.01630	-0.03448	0.09860
9 LSLCDA	-0.20157	0.00195	-0.03487	-0.13591	-0.93206◄	-0.01343	-0.06927	-0.21029	-0.00485	0.12359
10 LDDCDA	0.06044	-0.94934◄	0.02081	0.05035	0.05377	-0.11864	0.02860	-0.17736	0.10668	0.15778
11 LOFCDA	-0.06447	0.94753	-0.01859	-0.04449	-0.02113	0.11972	-0.03097	0.19480	-0.12806	-0.13359
12 MASP	-0.17945	-0.26469	0.46678	-0.14916	-0.00605	-0.05631	-0.11261	-0.15683	0.11809	0.62228
13 MWP	0.08114	-0.00471	0.96858◄	0.05454	-0.05032	0.00181	-0.09081	0.15279	-0.00028	0.05758
14 WIOYP	0.07180	-0.01976	0.97408	-0.04485	0.06253	-0.03726	-0.07144	0.02126	0.09896	0.09038
15 MJANT	-0.11137	0.06356	-0.02891	-0.91920	-0.17054	-0.06242	-0.06791	-0.20591	0.01533	0.20203
16 MJUNT	0.28059	0.19583	-0.07368	0.14295	0.10856	0.06128	0.00319	0.21426	-0.07296	-0.88562◄
17 JAMXT	0.03532	0.03780	0.02851	-0.96029◄	-0.08555	-0.01873	0.00269	-0.17067	-0.01282	0.14870
18 PE	0.27847	0.13781	-0.07580	0.37232	0.21498	0.03614	0.02372	0.20463	-0.04589	-0.81233

CUMULATIVE PROPORTION OF TOTAL VARIANCE

0.29724	0.48767	0.63224	0.73602	0.81323	0.87489	0.91560	0.94813	0.96911	0.98486

◄ DEFINING VARIABLES SELECTED FOR INCLUSION IN THE MULTIPLE REGRESSION ANALYSES FOR THE EASTERN REGION.

TABLE 5-23

CORRELATION MATRIX FOR DEPENDENT VARIABLES AND SELECTED INDEPENDENT VARIABLES FOR THE EASTERN REGION

(N=89)

VARIABLE	1	2	3	4	5	6	7
1 LMY	1.000	0.916	0.908	0.715	-0.324	0.718	-0.110
2 LM10YY		1.000	0.837	0.768	-0.284	0.829	-0.151
3 LMF			1.000	0.894	-0.239	0.708	-0.202
4 LM10YF				1.000	-0.157	0.744	-0.209
5 LNCDA					1.000	-0.073	-0.247
6 LCDA						1.000	-0.367
7 LMCS							1.000

VARIABLE	8	9	10	11	12	13	14
1 LMY	0.152	0.053	0.612	0.039	0.159	-0.390	0.125
2 LM10YY	0.203	0.103	0.605	0.001	0.095	-0.474	0.110
3 LMF	0.082	-0.029	0.422	0.072	0.145	-0.382	0.077
4 LM10YF	0.105	-0.025	0.295	0.071	0.023	-0.459	0.013
5 LNCDA	-0.232	0.281	-0.212	0.076	-0.283	0.038	-0.055
6 LCDA	0.246	0.006	0.460	-0.117	-0.109	-0.482	0.073
7 LMCS	0.237	0.242	-0.062	0.543	0.185	-0.229	0.036
8 LBS	1.000	0.070	0.101	0.323	0.034	-0.228	0.084
9 LALCDA		1.000	0.332	0.403	-0.249	-0.419	0.367
10 LSLCDA			1.000	-0.015	-0.031	-0.330	0.255
11 LDDCDA				1.000	0.006	-0.350	-0.031
12 MWP					1.000	-0.062	-0.036
13 MJUNT						1.000	-0.302
14 JAMXT							1.000

TABLE 5-24 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE EASTERN REGION
ANALYSIS OF LMY AFTER INDEPENDENT VARIABLE SCREENING
(N=89)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMY}$ (7)
	$\overline{LMY}$ = 4.18352				.76360	18.3
1	LMY = 1.604 +1.049 LCDA (.11)	.718	.516	92.8	.5342	12.8
2	LMY = 1.857 +0.810 LCDA +0.494 LSLCDA (.11) (.10	.785	.617	69.1	.4783	11.4
3	LMY = 0.661 +0.851 LCDA +0.486 LSLCDA +0.256 MWP (.10) (.10) (.07)	.819	.670	57.6	.4460	10.7
4	LMY = 1.110 +0.850 LCDA +0.437 LSLCDA +0.204 MWP -0.234* LNCDA (.10) (.10) (.07) (.09)	.833	.693	47.4	.4329	10.3
5	LMY = 1.198 +0.876 LCDA +0.425 LSLCDA +0.202 MWP -0.250 LNCDA +0.364* LDDCDA (.10) (.09) (.07) (.09) (.17)	.842	.709	40.4	.4243	10.1
6	LMY = 1.453 +0.944 LCDA +0.406 LSLCDA +0.200 MWP -0.307 LNCDA +0.529 LDDCDA -0.423* LBS (.10) (.09) (.07) (.09) (.18) (.19) (5-10)	.852	.726	36.2	.4142	9.9

[1] A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

TABLE 5-25 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE EASTERN REGION
ANALYSIS OF LM10YY AFTER INDEPENDENT VARIABLE SCREENING
(N=89)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LM10YY}$ (7)
	$\overline{LM10YY}$ = 4.73699				.65213	13.8
1	LM10YY = 2.197 +1.033 LCDA (.07)	.829	.686	190.5	.3673	7.8
2	LM10YY = 2.368 +0.870 LCDA +0.336 LSLCDA (.08) (.07)	.866	.750	129.1	.3297	7.0
3	LM10YY = 1.574 +0.898 LCDA +0.331 LSLCDA +0.170 MWP (.07) (.07) (.05)	.885	.783	102.1	.3093	6.5
4	LM10YY = 1.903 +0.897 LCDA +0.295 LSLCDA +0.132 MWP -0.172 LNCDA (.07) (.07) (.05) (.06)	.894	.800	83.7	.2989	6.3
5	LM10YY = 1.740 +0.932 LCDA +0.220 LSLCDA +0.152 MWP -0.223 LNCDA +0.322* LALCDA (.07) (.07) (.05) (.07) (.14) (5-11)	.901	.811	71.3	.2918	6.2

[1] A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

equation (5-9) contains six independent variables which combine to explain 73% of the total variance in the dependent variables. The regression coefficients for the first five terms are significant at the 1% level and that of the sixth term is significant at the 5% level. The signs of the regression coefficients correspond to those anticipated on the basis of physical theory. The regression equation is significant at the 1% level for an analysis of variance F test; and the standard error of the estimate is 9.9% of the mean.

The results of the eastern region analysis for the dependent variable LM10YY are presented in Table 5-25. The final regression equation includes five independent variables which combine to explain 81% of the total variance in the dependent variable. The regression coefficients associated with the first four variables conform to physical theory; however, the positive coefficient of the sixth term, the LALCDA, requires an explanation. This coefficient indicates that in basins with a higher percentage area of lakes, the 10 year yield tends to be higher. This relationship may indicate that in high flow years some of the additional water may be derived from lake storage. The effect would be particularly pronounced if two or more years of relatively high flows occurred in succession. The analysis of variance confirmed the significance of the regression equation (5-11) at the 1% level, and the standard error of the estimate is 6.2% of the mean.

The results of the eastern region regression analysis for the dependent variable LMF are displayed in Table 5-26. The resulting regression equation contains six independent variables and has an R^2 value of 0.66. The regression coefficients for the first five terms

TABLE 5-26 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE EASTERN REGION
ANALYSIS OF LMF AFTER INDEPENDENT VARIABLE SCREENING
(N=89)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMF}$ (7)
	$\overline{LMF}$ = 2.67960				.58804	21.9
1	LMF = 0.722 +0.796 LCDA (.09)	.708	.501	87.4	.4177	15.6
2	LMF = 0.160 +0.824 LCDA +0.189 MWP (.08) (.06)	.742	.551	52.8	.3986	14.9
3	LMF = 0.099 +0.845 LCDA +0.190 MWP +0.354 LDDCDA (.08) (.06) (.16)	.759	.576	38.5	.3896	14.5
4	LMF = 0.052 +0.911 LCDA +0.201 MWP +0.513*LDDCDA -0.431 LBS (.08) (.06) (.16) (.16)	.780	.608	32.6	.3767	14.1
5	LMF = 0.577 +0.907 LCDA +0.152 MWP +0.589 LDDCDA -0.553 LBS -0.234 LNCDA (.08) (.06) (.16) (.16) (.08)	.803	.645	30.2	.3606	13.5
6	LMF = 0.927 +0.850 LCDA +0.160 MWP +0.747 LDDCDA -0.522 LBS -0.277 LNCDA -0.194**LMCS (.09) (.06) (.19) (.16) (.08) (.13) (5-12)	.810	.656	26.1	.3573	13.3

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5 % level.

*** All F statistics are significant at the 1% level.

TABLE 5-27 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE EASTERN REGION
ANALYSIS OF LM10YF AFTER INDEPENDENT VARIABLE SCREENING
(N=89)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LM10YF}$ (7)
	$\overline{LM10YF}$ = 3.23827				.54429	16.8
1	LM10YF = 1.335 +0.774 LCDA (.07)	.744	.553	107.7	.3660	11.3
2	LM10YF = 1.396 +0.794 LCDA +0.331* LDDCDA (.07) (.15)	.761	.579	59.0	.3575	11.0
3	LM10YF = 1.550 +0.843 LCDA +0.452 LDDCDA -0.330* LBS (.08) (.15) (.15)	.775	.601	42.6	.3500	10.8
4	LM10YF = 1.773 +0.847 LCDA +0.511 LDDCDA -0.428 LBS -0.172* LNCDA (.07) (.15) (.15) (.07)	.791	.626	35.2	.3406	10.5
5	LM10YF = 1.750 +0.906 LCDA +0.533 LDDCDA -0.450 LBS -0.197 LNCDA -0.118** LSLCDA (.08) (.15) (.15) (.07) (.08) (5-13)	.798	.637	29.1	.3377	10.4

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

are significant at the 1% level and have signs which conform to theoretical expectations. The sixth variable, LMCS, has a coefficient which is not significant at the 5% level and which has a negative sign. This negative relationship is contrary to physical theory; however, in view of the lack of significance of the regression coefficient, it is not possible to give further consideration to the role of LMCS on the basis of the present data. The analysis of variance for equation 5-11 confirmed the significance of the relationship at the 1% level. The standard error of the estimate is 13% of the mean.

The results for the analysis of the LM10YF are contained in Table 5-27. The final equation (5-13) contains five independent variables and has an R^2 value of 0.637. The regression coefficients for the first four terms are significant at the 1% level and conform to physical theory. The regression coefficient of the fifth term, LSLCDA, is not significant at the 5% level. The sign of this coefficient does conform with flood theory in that swamp and lake storage have a dampening effect on the peaks. The final regression equation is significant at the 1% level according to an analysis of variance; and the standard error of the estimate is 10.4% of the mean.

5.5.5 Analysis for the Western Region

The methods employed in these analyses for the western region are the same as those utilized for the eastern region (Section 5.5.4) and for the full study area (Section 5.4.3). The first step in the analysis involved the screening of the independent variables by factor analytic techniques. The independent variables selected by this screening procedure were then employed in the stepwise multiple regression analysis for each of the four dependent variables.

5.5.5.1 Screening of the Independent Variables by Factor Analysis

The factor analysis of the full set of 39 independent variables for each of the 57 study basins in the western region resulted in the rotated factor matrix, Table 5-28. The highest loadings on all factors have been underlined; and the defining variables which were selected for further analysis have been indicated. A second factor analysis on the set of 17 defining variables resulted in the rotated factor matrix, Table 5-29.

The factor loadings of Table 5-29 provided a basis for the selection of the final set of independent variables for the western region. The final decisions were again based on consideration both of the strength of the factor loadings and of the data compilation and ultimate use of the measures. A set of 8 independent variables was selected. No defining variables were selected for factor 9, since the highest loadings on this factor, 0.45 for MAP and A10YP, were lower than the loadings for the same variables on factor 2 for which a defining variable, MST, had already been selected.

The 8 independent variables selected as the result of the screening of the independent variables were subsequently employed in a stepwise multiple regression analysis for each of the four dependent variables. The results of these analyses are discussed in the following section.

5.5.5.2 Stepwise Multiple Regression Analyses After Variable Screening for the Western Region

Table 5-30 is the initial correlation matrix for the regression

TABLE 5-28

ROTATED FACTOR MATRIX RESULTING FROM THE FACTOR ANALYSIS OF ALL INDEPENDENT VARIABLES FOR THE WESTERN REGION

(N=57)

VARIABLE	FACTOR 1	2	3	4	5	6	7	8	9	10
1 LTDA	-0.03416	-0.26533	0.29606	-0.87019◄	0.16076	0.02444	-0.21047	-0.04854	0.02506	0.07064
2 LNCDA	0.24438	0.18780	0.50417	-0.10774	-0.00193	-0.05626	-0.42096	-0.00898	-0.10386	0.65158◄
3 LCDA	-0.07625	-0.28221	0.19343	-0.90044◄	0.19339	0.02825	-0.13048	-0.05050	-0.01413	-0.04601
4 LMCS	-0.16725	0.06917	-0.40222	0.38703	-0.07870	0.17074	0.58826	0.16492	0.39207	-0.10187
5 LBEL	-0.38586	0.01577	-0.32856	0.12633	-0.07930	0.25950	0.76312	0.02766	0.11635	-0.14711
6 LBR	-C.40171	-0.13587	-0.19678	-0.44483	-0.08494	0.13761	0.49309	-0.06935	0.49384◄	-0.19915
7 LBL	-C.06055	-0.30452	0.20988	-0.83306	0.16639	0.02651	-0.18057	-0.31177	0.01988	0.05941
8 LBS	-0.10384	-0.26104	-0.13363	-0.31475	0.09702	0.01906	-0.00605	-0.89067◄	-0.00117	-0.00029
9 LALTDA	0.08759	-0.26493	0.12563	-0.19991	0.91991◄	0.02084	-0.11160	-0.03544	-0.01266	-0.03353
10 LALCDA	0.11289	-0.24983	0.16972	-0.21162	0.90243◄	0.01884	-0.16557	-0.06775	-0.01224	0.03896
11 LSTDA	-0.28606	-0.91889	0.03392	-0.18131	0.06823	0.06163	-0.13194	-0.07181	-0.00880	-0.04491
12 LSCDA	-0.25971	-0.92363◄	0.07107	-0.18476	0.05759	0.07075	-0.13941	-0.07707	-0.01279	-0.01539
13 LSLTDA	-0.22275	-0.90340	0.02663	-0.20535	0.25071	0.06598	-0.10518	-0.06868	0.01819	-0.04200
14 LSLCDA	-0.19181	-0.90326◄	0.07299	-0.20961	0.24323	0.07147	-0.13151	-0.08748	0.01614	0.00885
15 LDDTDA	-0.03554	0.01130	-0.88885	0.09893	-0.04107	-0.00408	0.33678	-0.04182	-0.06509	-0.20858
16 LDDCDA	0.11108	0.08070	-0.91393◄	0.19539	-0.15771	-0.00285	0.13914	-0.05119	0.08446	0.14824
17 LOFTDA	C.06046	-0.02399	0.89307	-0.06798	0.00790	-0.01111	-0.32459	0.02400	0.05493	0.23103
18 LOFCDA	-0.09045	-0.10257	0.92907◄	-0.20953	0.12745	-0.00294	-0.13613	0.02392	-0.08090	-0.09508
19 LFTDA	-0.63580	-0.53724	0.02152	-0.17451	0.07047	0.16788	0.10528	-0.03489	0.15317	-0.04476
20 MAP	-0.93851◄	-0.27991	0.03638	-0.05843	-0.02642	0.08282	0.11407	-0.02709	0.00312	-0.04796
21 MAS	-C.88720	-0.02510	-0.00026	0.01106	-0.00764	0.12035	0.38536	-0.03082	0.01603	0.00411
22 MASP	-0.54353	0.21770	-0.04563	0.06033	0.04402	0.13476	0.61731	-0.03875	0.06128	0.05754
23 MWP	-C.91323	-0.14276	-0.05021	-0.06690	0.00620	-0.00802	0.24781	-0.00938	0.12111	-0.01275
24 MSP	-0.91577	0.00844	0.00446	0.02597	-0.09201	0.09414	0.30216	-0.00643	-0.07899	-0.07148
25 MWSP	-0.94748	-0.05358	-0.01804	-0.01124	-0.05479	0.05544	0.28974	-0.00792	0.00142	-0.04999
26 A10YP	-0.95768◄	-0.19436	0.01546	-0.01289	-0.02695	0.08934	0.15109	-0.02453	0.01033	-0.03805
27 W10YP	-0.90512	-0.05075	-0.07053	-0.05755	-0.02225	-0.03862	0.25952	-0.00065	0.12102	-0.00209
28 MWT	-0.41122	0.16602	-0.23052	0.15097	-0.15151	-0.10927	0.82143◄	-0.02134	-0.00117	0.00763
29 MJANT	0.44053	-0.20023	0.24978	-0.13711	0.10419	-0.01327	-0.81212	0.00132	-0.02934	0.01680
30 MST	0.68719	0.24219	0.00880	0.06666	-0.02616	-0.63809◄	-0.20493	0.01626	-0.04433	0.02832
31 MJUNT	C.72400	0.28401	0.02824	0.04579	-0.02174	-0.53208	-0.31287	0.03439	-0.03816	0.00217
32 WMXT	-0.37608	0.12814	-0.26701	0.12870	-0.11755	-0.01659	0.84770◄	0.00559	-0.04875	-0.05710
33 JAMXT	0.39149	-0.20130	0.26310	-0.11017	0.06601	-0.06965	-0.83349	-0.02136	0.02012	0.06188
34 PE	C.65617	0.35712	0.00032	0.09957	-0.08969	-0.63344◄	-0.11639	0.02248	-0.04592	0.04107
35 THAET	-0.88082	-0.36883	0.04740	-0.10353	-0.01065	0.06912	0.03529	-0.05246	0.00969	-0.03913
36 TUAET	-0.91924	-0.07676	-0.00286	-0.01884	-0.08907	-0.13658	0.25734	-0.05367	0.03040	0.03484
37 LTHSUR	-C.85094	-0.02007	-0.02876	0.07143	-0.05536	0.09002	0.33513	0.01434	-0.01618	-0.04607
38 TUSUR	-0.90681	-0.34173	0.04889	-0.07043	-0.00302	0.15822	0.05767	-0.01591	-0.00682	-0.07580
39 MATR	0.68512	0.08938	0.17027	-0.04026	0.03920	-0.25213	-0.64488	0.01931	-0.03780	0.01920

CUMULATIVE PROPORTION OF TOTAL VARIANCE

0.44955	0.70128	0.79232	0.84357	0.88149	0.90836	0.93017	0.94765	0.96071	0.97131

◄ DEFINING VARIABLES SELECTED FOR FURTHER ANALYSIS

TABLE 5-29

ROTATED FACTOR MATRIX RESULTING FROM THE FACTOR ANALYSIS OF THE SELECTED DEFINING VARIABLES FOR THE WESTERN REGION

(N=57)

VARIABLE	FACTOR 1	2	3	4	5	6	7	8	9
1 LTDA	-0.20751	0.07233	0.27262	0.86403	-0.21172	0.13983	0.12880	-0.20161	0.00560
2 LNCDA	0.10704	-0.23893	0.31116	0.10843	-0.01858	-0.02400	0.82691◄	-0.35344	-0.02589
3 LCDA	-0.20941	0.10635	0.23007	0.88780◄	-0.23950	0.15907	-0.00719	-0.11563	0.01138
4 LBR	-0.06233	C.40723	-0.11957	0.37691	0.07337	0.12717	-0.27740	0.43298	0.01248
5 LBS	-0.19500	0.10925	-0.08285	0.21648	-0.12416	0.93716◄	-0.01978	0.01463	0.01580
6 LALTDA	-0.16233	0.00620	0.13653	0.17020	-0.94989	0.05755	-0.02758	-0.12482	-0.01355
7 LALCDA	-0.15716	-0.01636	0.15371	0.18282	-0.93402◄	0.08529	0.05838	-0.17600	-0.01581
8 LSCDA	-0.87500	0.34035	0.09461	0.21138	-0.12874	0.14038	-0.06584	-0.12782	0.04653
9 LSLCDA	-0.84088◄	0.29366	0.08320	0.22383	-0.31709	0.14752	-0.04035	-0.13241	0.02638
10 LDDCDA	0.06001	-0.08248	-0.94259◄	-0.18605	0.15705	0.05550	-0.09145	0.14623	-0.02841
11 LOFCDA	-0.08725	0.06591	0.93851	0.19784	-0.13391	-0.03143	0.14367	-0.14398	0.00886
12 MAP	-0.24643	0.79354	0.12177	0.07399	0.07022	0.06567	-0.07899	0.25889	0.45069
13 A10YP	-0.16467	0.80511	0.09991	0.02145	0.08076	0.05572	-0.06434	0.29743	0.45585
14 MWT	0.13867	0.22477	-0.15634	-0.17007	0.19894	0.01148	-0.11766	0.89251◄	0.08953
15 MST	0.12424	-0.95934◄	-0.01756	-0.05457	0.00979	-0.04172	0.07563	-0.15976	0.13518
16 WMXT	C.12312	0.26558	-0.18991	-0.14544	0.15814	-0.00973	-0.18752	0.88436	-0.00231
17 PE	C.22784	-0.94502	-0.02725	-0.09264	0.08522	-0.05607	0.09378	-0.06362	0.11918

CUMULATIVE PROPORTION OF TOTAL VARIANCE

0.32916	0.62870	0.73394	0.80592	0.87118	0.90928	0.94486	0.96804	0.98591

◄ DEFINING VARIABLES SELECTED FOR INCLUSION IN THE MULTIPLE REGRESSION ANALYSES FOR THE WESTERN REGION

TABLE 5-30

CORRELATION MATRIX FOR DEPENDENT VARIABLES AND SELECTED INDEPENDENT VARIABLES FOR THE WESTERN REGION

(N=57)

VARIABLE	1	2	3	4	5	6
1 LMY	1.000	0.933	0.941	0.675	-0.311	0.755
2 LM10YF		1.000	0.865	0.771	-0.246	0.792
3 LMF			1.000	0.749	-0.308	0.732
4 LM10YF				1.000	-0.057	0.693
5 LNCDA					1.000	0.149
6 LCDA						1.000

VARIABLE	7	8	9	10	11	12
1 LMY	0.327	0.201	0.564	-0.240	0.050	-0.552
2 LM10YF	0.387	0.248	0.566	-0.258	-0.056	-0.458
3 LMF	0.304	0.184	0.527	-0.196	0.025	-0.466
4 LM10YF	0.308	0.229	0.403	-0.146	-0.167	-0.235
5 LNCDA	-0.096	0.183	-0.099	-0.423	-0.535	0.357
6 LCDA	0.406	0.484	0.542	-0.448	-0.333	-0.175
7 LBS	1.000	0.247	0.416	0.054	-0.020	-0.185
8 LALCDA		1.000	0.511	-0.360	-0.433	0.003
9 LSLCDA			1.000	-0.251	-0.271	-0.391
10 LDDCDA				1.000	0.342	0.076
11 MWT					1.000	-0.333
12 MST						1.000

analyses for the western region. For each of the four dependent variables, the 8 independent variables, selected by the factor analytic variable screening procedure, have been entered in a stepwise regression analysis. The results of these analyses are summarized in Tables 5-31 to 5-34 inclusive and discussed in the following section. The regression results are displayed in the standard format as explained in Section 5.4.1.1.

5.5.5.2.1 Summary of the Results of the Western Region Regression Analyses. The results of the western region regression analysis for the dependent variable LMY are displayed in Table 5-31. The final equation in this table (equation 5-14) has four independent variables which combine to account for 85% of the total variance in the dependent variable. The first three regression coefficients are significant at the 1% level while the fourth is significant at the 5% level. The signs of the regression coefficients correspond to expectations based on physical theory. The positive coefficient of the LCDA and the negative coefficient of the LNCDA are consistent with previous results. The negative coefficient associated with MST indicates that areas with warm spring temperatures and therefore higher PE tend to have less streamflow. It is important to note that the MST variable was selected as a defining variable for factor 2 in Table 5-29. This factor also had significant positive loadings for the variables MAP and A10YP, while the selected MST variable had a negative loading. This would indicate that an inverse correlation exists between the precipitation variables and the MST. This relationship while without a physical basis indicates a strong spatial covariance between MST and the precipitation variables. The MST term in equation 5-14 therefore tends to represent the inverse

TABLE 5-31 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE WESTERN REGION
ANALYSIS OF LMY AFTER INDEPENDENT VARIABLE SCREENING
(N=57)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMY}$ (7)
	$\overline{LMY}$ = 4.08794				1.04009	25.4
1	LMY = 0.795 +1.307 LCDA (.15)	.755	.570	73.1	.6877	16.8
2	LMY = 1.125 +1.419 LCDA -0.822 LNCDA (.12) (.13)	.869	.755	83.0	.5248	12.8
3	LMY = 9.258 +1.294 LCDA -0.592 LNCDA -0.165 MST (.12) (.12) (.03)	.913	.833	88.2	.4367	10.7
4	LMY = 8.902 +1.407 LCDA -0.569 LNCDA -0.161 MST -0.592* LALCDA (.11) (.11) (.03) (.27) (5-14)	.920	.847	72.0	.4220	10.3

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5 % level.

*** All F statistics are significant at the 1% level.

TABLE 5-32 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE WESTERN REGION
ANALYSIS OF LM10YY AFTER INDEPENDENT VARIABLE SCREENING
(N=57)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E. % of $\overline{LM10YY}$ (7)
	$\overline{LM10YY}$ = 4.74375				.72058	15.2
1	LM10YY = 2.352 +0.950 LCDA (.10)	.792	.627	92.6	.4439	9.4
2	LM10YY = 2.548 +1.016 LCDA -0.490 LNCDA (.08) (.09)	.874	.763	86.9	.3572	7.5
3	LM10YY = 6.469 +0.956 LCDA -0.379 LNCDA -0.079 MST (.08) (.09) (.02) (5-15)	.895	.801	71.2	.3303	7.0

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the * indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

of a moisture availability measure. The negative regression coefficient associated with the LALCDA is in accordance with physical theory in that the presence of lakes on a water course represents storage capacity which results in higher evaporation losses and lower streamflow. The F test of an analysis of variance indicated that the regression is significant at the 1% level, while the standard error of the estimate is 10.3% of the mean.

The regression results for the western region analysis of the dependent variable LM10YY are presented in Table 5-32. The final equation in this table (equation 5-15) contains three independent variables which combine to explain 80% of the variance in the dependent variable. All of the regression coefficients are significant at the 1% level and their signs correspond to physical theory. The physical basis for the three independent variables LCDA, LNCDA, and MST corresponds to those considered in the preceding paragraph. The F statistic confirms the significance of the regression at the 1% level and the standard error of the estimate is 7.0% of the mean.

The regression results for the western region analysis of the dependent variable LMF are presented in Table 5-33. The final equation (5-16) contains four independent variables, which combine to explain 77% of the total variance in the dependent variable. The first three regression coefficients are significant at the 1% level while the fourth, that associated with the LALCDA term is not significant at the 5% level. The signs of all the coefficients correspond to those expected on the basis of physical theory. The regression is significant at the 1% level for the F test and the standard error of the estimate is 10.3%

TABLE 5-33 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE WESTERN REGION
ANALYSIS OF LMF AFTER INDEPENDENT VARIABLE SCREENING
(N=57)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LMF}$ (7)
	$\overline{LMF}$ = 2.63495				.68975	26.2
1	LMF = 0.519 +0.840 LCDA (.11)	.732	.536	63.4	.4743	18.0
2	LMF = 0.734 +0.913 LCDA -0.536 LNCDA (.08) (.09)	.845	.713	67.2	.3761	14.3
3	LMF = 4.440 +0.856 LCDA -0.431 LNCDA -0.075 MST (.08) (.09) (.03)	.866	.750	53.1	.3543	13.4
4	LMF = 4.179 +0.939 LCDA -0.414 LNCDA -0.072 MST -0.434** LALCDA (.09) (.09) (.03) (.22) (5-16)	.876	.767	42.9	.3452	13.1

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

TABLE 5-34 - SUMMARY OF STEPWISE MULTIPLE REGRESSION RESULTS FOR THE WESTERN REGION
ANALYSIS OF LM10YF AFTER INDEPENDENT VARIABLE SCREENING
(N=57)

Step Number (1)	Regression Equations[1] (2)	R (3)	R^2 (4)	F*** (5)	S.E. (6)	S.E.% of $\overline{LM10YF}$ (7)
	$\overline{LM10YF}$ = 3.37760				.50997	15.1
1	LM10YF = 1.897 +0.588 LCDA (.08)	.693	.480	50.7	.3711	11.0
2	LM10YF = 1.781 +0.666 LCDA +0.673** LDDCDA (.09) (.35)	.717	.514	28.5	.3621	10.7
3	LM10YF = 3.302 +0.649 LCDA +0.672** LDDCDA -0.030** MST (.09) (.35) (.03) (5-17)	.726	.527	19.7	.3605	10.7

[1]A t test has been employed to test the significance of each of the regression coefficients. All regression coefficients are significant at the 1% level except where noted by * or **. The * indicates the coefficient is significant at the 5% level only; and the ** indicates the coefficient is not significant at the 5% level.

*** All F statistics are significant at the 1% level.

of the mean.

The results of the western region regression analysis for the dependent variable LM10YF are summarized in Table 5-34. The final equation (5-17) contains three independent variables which explain only 53% of the total variance in the dependent variable. The LDDCDA and MST terms have regression coefficients which are not significant at the 5% level. This regression analysis for the LM10YF indicates that it is not possible to develop a meaningful equation for this variable in the western region on the basis of the available independent variables.

5.6 COMPARISON OF REGRESSION RESULTS FOR THE FULL STUDY AREA AND BY REGION

The results of the multiple regression analyses after variable screening, for the full study area and for the eastern and western regions, have been summarized in Table 5-35. In this table, the regression results for each of the dependent variables have been summarized in the presentation of data on the number of steps in the analyses, the R^2 value, and the standard error of the estimate in log units expressed as a percentage of the mean. These data have been listed for the full study area as well as the eastern and western regions.

On the basis of the data summarized in this table, it must be concluded that the twofold subdivision of the study area by multivariate grouping has not resulted either in substantially increased values of R^2, or in a reduction in the standard errors of the estimates. From these observations, it is suggested that the regional grouping at the present scale has not been successful in improving the predictive value of the regression relationships. The relatively large errors must therefore

TABLE 5-35 - COMPARATIVE SUMMARY OF MULTIPLE REGRESSION RESULTS AFTER VARIABLE SCREENING FOR THE FULL STUDY AREA AND FOR THE EASTERN AND WESTERN REGIONS

Dependent Variable	Region	Equat No.	No.of Steps	R^2	S.E. as % of Mean Log Units
LMY	Full study area	5-6	5	0.782	10.1
	Eastern Region	5-10	6	0.726	9.9
	Western Region	5-14	4	0.847	10.3
LM10YY	Full study area	5-7	5	0.807	6.4
	Eastern Region	5-11	5	0.811	6.2
	Western Region	5-15	3	0.801	7.0
LMF	Full study area	5-8	6	0.724	12.7
	Eastern Region	5-12	6	0.656	13.1
	Western Region	5-16	4	0.767	13.1
LM10YF	Full study area	5-9	4	0.587	10.6
	Eastern Region	5-13	5	0.637	10.4
	Western Region	5-17	3	0.527	10.7

be attributed to factors which are operative on a more local scale than the twofold regional division which has been employed in the present analyses. In an effort to further account for some of these local variations, it was proposed to attempt to further subdivide the study area.

5.7 FURTHER ATTEMPTS TO SUBDIVIDE THE STUDY AREA

Three further attempts were made to establish subdivisions of the full study area such that the predictive power of the regression relationships would be improved. The first method employed utilized the multivariate grouping technique as described in Section 5.5.3 in an attempt to further subdivide both the eastern and western regions. These analyses involved a factor analysis and subsequent optimal grouping analysis for each of the regions. In each case two further groups were identified; however when mapped, these groups did not have spatial continuity and it was not possible to establish meaningful subdivisions for either the eastern or western regions.

A second attempt to improve the regression relationships for each region involved the subjective modification of the regional boundaries. The ten study basins in Northern Alberta which were grouped in the eastern region were deleted from that region. In the western region, seven study basins in southwestern Alberta which drained areas of foothills and mountains were removed from the grouping. These modified groups were then subjected to a full analysis by factor analytic and multiple regression techniques. The resulting relationships were not appreciably improved over those of the previous analyses.

A third attempt at the establishment of more meaningful regional subdivisions involved a complete regrouping of the full set of study basins. This regrouping was based on a re-examination of the original multivariate grouping analysis, as described in Section 5.5.3. A further consideration of the original factor matrix, Table 5-19, led to a proposal to repeat the grouping analysis on the basis of the first two and fourth factors, rather than the first three factors as had been previously employed. The fourth factor represented a measure of hydrologic variability, and, it was expected, might lead to a better grouping for analysis purposes. The application of the optimal grouping algorithm resulted in the definition of two groups which when plotted grouped spatially, but were not very different from the original eastern and western regions. The groups resulting from this analysis were not employed in further regression analyses.

All attempts to further subdivide the study area into meaningful hydrologic regions were unsuccessful. This difficulty in regional delimitation led to a general conclusion with regard to variations in prairie hydrologic patterns. On the basis of the data employed in the present study, it would seem that local variations are dominant in the definition of prairie hydrologic patterns. It has not been possible to improve the relationships on the basis of regional subdivision. Seemingly, the alternatives to this approach must involve a more detailed examination of local patterns.

5.8 TEST OF REGRESSION RELATIONSHIPS FOR THE COMPARATIVE TEST SAMPLE

Earlier in this chapter (Section 5.5.3), the selection of a random sample of 15 study basins was discussed. These basins were not included in the analysis, and therefore represent an independent sample for the testing of the regression results. Such an independent sample for testing the regression results was considered useful, in that the significance tests which are normally employed with regression analysis are based on the assumptions of random sampling and normally distributed variates. Although logarithmic transformations were applied to several of the variables (Section 5.3.2), it was not expected that the normality assumption would be totally satisfied. It was also recognized that the random sampling assumption had not been met by the input data (Section 5.3.1). Therefore as a check on the stability of the regression relationships, it was proposed to test the performance of these relationships on a sample of data for which the dependent variables had been previously measured.

Three regression relationships for each of the dependent variables were considered. These relationships resulted from the full study area analyses by multiple regression after variable screening, the western region analyses and the eastern region analyses. For each of the dependent variables the regression equations were employed to estimate the value of the dependent variables for basins in the sample. In the case of the relationships from the full study area analyses, all of the 15 study basins in the sample were considered, while for the eastern and western regions, only those basins lying within each area as delimited on Figure 5-3 were considered. The residuals for each application of the equations have been expressed as percentages of the observed values. These data are reported in Table 5-36 and provide a basis for a further consideration of the predictive value of the relationships.

The percentage residuals from the test sample applications of the regression equations are listed in Table 5-36. Each column of the table contains the results for a particular equation. The figures which have been entered in the table for each of the test basins for each equation are the percentage residuals estimated in arithmetic units and the percentage residuals estimated in logarithmic units. The latter group of figures have been enclosed in parentheses in the table. The last four rows in the table contain the means and standard deviations of the percentage residuals for each of the equations.

On the basis of the results summarized in Table 5-36, it is possible to make several observations and to draw conclusions regarding the validity of the regression equations developed in the present research. On comparison of the percentage residuals for the test sample based on logarithmic units with the standard errors of the estimates

TABLE 5-36 - PERCENTAGE RESIDUALS RESULTING FROM APPLICATION OF REGRESSION EQUATIONS TO COMPARATIVE TEST SAMPLE OF BASINS*

Basin No.	Dependent Variable LMY			Dependent Variable LM10YY			Dependent Variable LMF			Dependent Variable LM10YF		
	Equat 5-6 Full Study Area (10.1)**	Equat 5-10 E. Region (9.9)**	Equat 5-14 W.Region (10.3)**	Equat 5-7 Full Study Area (6.4)**	Equat 5-11 E.Region (6.2)**	Equat 5-15 W.Region (7.0)**	Equat 5-8 Full Study Area (12.7)**	Equat 5-12 E.Region (13.1)**	Equat 5-16 W.Region (13.1)**	Equat 5-9 Full Study Area (10.6)**	Equat 5-13 E.Region (10.4)**	Equat 5-17 W.Region (10.7)**
4	-50.1 (-8.2)		-24.4 (-3.3)	+ 3.2 (+0.3)		+36.8 (+3.2)	-57.6 (-14.7)		-24.5 (-4.8)	+15.9 (+2.0)		-16.2 (-2.4)
7	- 0.5 (-0.0)		-10.9 (-1.0)	-18.7 (-1.7)		-23.9 (-2.2)	+27.8 (+3.2)		+ 3.2 (+0.4)	-33.9 (-4.8)		-37.3 (-5.5)
15	+57.5 (+4.6)		+162.8 (+9.7)	+70.1 (+4.8)		+109.3 (-6.6)	+ 4.2 (-0.6)		+41.7 (+5.2)	-27.7 (-3.7)		-30.2 (-4.1)
25	-37.6 (-5.1)		-29.1 (-3.7)	+16.9 (+1.7)		+39.8 (+3.2)	-15.4 (-2.7)		-33.3 (-6.6)	-47.4 (-7.3)		-35.3 (-4.9)
30	-46.4 (-7.8)		-62.1 (-12.2)	+91.9 (+7.7)		+74.9 (+6.6)	-84.3 (-33.3)		-71.5 (-22.5)	-52.5 (-10.9)		- 8.2 (-1.3)
37	-12.4 (-1.3)	-52.9 (-7.5)		+57.6 (+4.1)	+34.2 (+2.6)		+ 8.3 (+1.3)	+39.6 (+5.5)		+61.5 (+6.3)	+116.4 (+10.1)	
44	-38.4 (-5.5)	-19.8 (-2.5)		+88.8 (+6.8)	+70.7 (+5.7)		+34.2 (+5.6)	+49.5 (+7.6)		+195.2 (+17.4)	+229.9 (+19.2)	
52	+ 7.2 (+0.5)	-11.3 (-0.9)		+ 5.5 (+0.4)	+55.3 (+3.2)		+99.1 (+8.7)	+78.4 (+7.3)		+75.9 (+6.3)	+99.0 (+7.7)	
78	-17.2 (-2.5)	+31.3 (+3.6)		-27.6 (-3.4)	-15.8 (-1.8)		+133.3 (+21.9)	+180.0 (+26.6)		+88.0 (+10.7)	+74.0 (+9.6)	
82	-47.1 (5.8)	-41.8 (-4.9)		-27.8 (-2.8)	+17.9 (+1.4)		+37.7 (+5.0)	+43.8 (+5.7)		+93.7 (+9.0)	+80.8 (+8.0)	
108	+269.8 (+20.2)	+207.5 (+17.3)		+30.3 (+2.9)	- 5.9 (-0.6)		+186.1 (+27.5)	+184.6 (+27.4)		+83.1 (+10.3)	+78.5 (+9.8)	
118	-21.6 (-2.5)	-17.3 (-1.9)		+ 3.3 (+0.3)	- 3.3 (-0.3)		-15.7 (-2.5)	-17.5 (-2.8)		-41.6 (-6.8)	-31.3 (-4.8)	
133	+ 8.9 (+0.7)		+ 9.4 (+0.7)	- 0.6 (+0.0)		-19.3 (-1.6)	-39.2 (-5.9)		-23.8 (-3.2)	-48.0 (-7.0)		-30.7 (-3.9)
139	-60.1 (-7.7)	-53.2 (-6.4)		-37.6 (-3.8)	-42.2 (-4.4)		-43.6 (-7.4)	-32.3 (-5.0)		-22.4 (-3.0)	-18.8 (-4.4)	
159	-51.3 (-7.8)		- 5.1 (-0.6)	+32.2 (+2.8)		+95.1 (+6.6)	-29.8 (-5.7)		- 5.6 (-0.9)	+63.0 (+6.5)		+19.7 (+2.4)
Mean % Arithmetic	-2.6	+5.4	+5.8	+19.2	+13.9	+44.7	+16.3	+65.8	-16.3	+26.9	+78.6	-19.7
S.D.	81.5	86.2	72.8	41.9	38.0	52.5	74.1	80.5	34.9	73.6	81.4	20.3
Mean % Log	-1.9	-0.4	-1.5	+1.3	+0.7	+1.3	+0.1	+9.0	-4.6	+1.7	+6.9	-2.8
S.D.	7.2	8.0	6.5	3.5	3.2	4.9	14.2	12.0	8.8	8.5	8.0	2.7

*Figures in the body of the table are the percentage differences between the observed and predicted magnitudes of the dependent variables. These differences have been expressed as percentages of the observed magnitudes. The percentages in parentheses are based on logarithmic units, while those without parentheses are based on arithmetic units.

** Standard Error of Estimate of the regression equation expressed as a percentage of the mean value of the dependent variables.

for the regression equations, it may be concluded that the regression relationships are stable. That is, the errors which resulted from the application of the equations to the independent test sample of basins were similar in magnitude to those expected on the basis of the standard errors of estimate which resulted from the analyses for the full set of 146 study basins. This stability of the relationships lends credibility to the statistical significance of the regression equations.

The percentage residuals based on arithmetic units have been included in the table to illustrate the magnitudes of residual errors which are involved in the prediction of the actual magnitudes of streamflow events. The skewed nature of the distribution of these errors is evident in the larger magnitudes associated with the positive residuals than with the negative residuals. While the percentage errors are somewhat larger than might be considered desirable for prediction purposes, the regression relationships developed in this research are useful models for the estimation of streamflow characteristics on a regional basis. The relationships are stable, conform to physical theory, and are based on readily available data.

The earlier conclusion, that the division of the study area into hydrologic regions did not result in a significant improvement in the predictive strength of the regression relationships, is confirmed on the basis of the results summarized in Table 5-36.

5.9 SUMMARY

This chapter has included a discussion of the analyses of the relationships between each of the selected streamflow characteristics, the dependent variables, and the various measures of climatic and other physical geographic patterns, the independent variables. Four dependent variables: the mean annual yield, the mean 10 year yield, the mean annual flood and the mean 10 year flood, have been considered. The independent variable set included 39 variables, 20 measures of climatic and 19 msasures of other physical geographic patterns.

The first stage of the analysis involved the processing of data for the entire study area. Two approaches to these analyses were employed. The first involved a stepwise multiple regression analysis for each of the dependent variables which employed the full set of 39 independent variables. The second approach to the analysis involved the use of factor analytic techniques to screen the independent variables prior to regression analysis. The second approach proved to be more useful in that the resulting relationships were less susceptible to spurious correlations and were more easily interpreted in terms of physical theory. This second approach resulted in only slightly lower coefficients of determination than did the first method.

The second stage of the analysis involved an attempt to improve on the strength of the relationships from the first stage by subdividing the study area into regions of hydrologic similarity. Attempts to subdivide the study area on the basis of residual plots and on the basis of index-ratio plots were unsuccessful. A multivariate grouping method resulted in the delimitation of two regions, an eastern region including 89 study basins and a western region including 57 study basins. Multiple regression analyses on a regional basis, after factor analytic screening of the independent variables, failed to improve on the predictive strength

CHAPTER 6

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

6.1 INTRODUCTION

In this final chapter, the methodology and findings of the present research are summarized. Conclusions are drawn, and several suggestions for future research are introduced.

6.2 SUMMARY OF THE PRESENT RESEARCH

In recent years, the needs for planning and management of water resources have grown rapidly. Many more streamflow data are required; and it is to this need that the present study has been directed. The present research is an examination of the relationships of streamflow characteristics to climatic and other physical geographic patterns for the plains region of the Canadian Prairie Provinces. The ultimate aim of these analyses has been to develop predictive relationships for the estimation of streamflow characteristics for ungauged basins in the plains. A second aim of the study has been to add to our understanding of plains' hydrologic patterns through the identification of climatic and other physical geographic variables which are related to streamflow characteristics.

The multivariate nature of the relationships involved, as exemplified in the hydrologic cycle, led to the adoption of a systems approach to the present study. The multivariate statistical techniques of multiple correlation and regression analysis and factor analysis have been employed in the regional analyses of the hypothetical model which is of the form:

$$\text{STREAMFLOW CHARACTERISTICS} = f\ (\text{CLIMATIC AND OTHER PHYSICAL GEOGRAPHIC PATTERNS}) \quad (6\text{-}1)$$

The study area was delimited as that area of Alberta, Saskatchewan and Manitoba which lies east of the Rocky Mountain Foothills and south and west of the margin of the Canadian Shield. The topography of the study area is relatively flat with a low local relief provided by pre-glacial erosional remnants and a diversity of glacial drift deposits. The climate of the area is continental with annual precipitation ranging from less than 12 inches in the drier areas of southeastern Alberta and southwestern Saskatchewan to over 20 inches in parts of northern and western Alberta and southern Manitoba. Evapotranspiration rates in summer are relatively high and the water surpluses are limited. Much of the streamflow in the area occurs in spring as the direct result of snowmelt.

A group of 161 study basins was selected for analysis. Each of these basins met defined criteria with regard to basin location, size of drainage area, available streamflow data, and natural flow conditions (Section 2.4). The criteria relating to available streamflow data resulted in the selected basins being concentrated in the southern, more populous areas of the region, since very few streamflow records have been collected in the more remote areas.

It was beyond the scope of the present research to analyse all possible streamflow characteristics; rather four characteristics, the mean annual yield, the mean 10 year yield, the mean annual flood, and the mean 10 year flood were selected for analysis. These characteristics were chosen because of their potential usefulness in the planning process.

The actual estimation of the dependent variables for each of the study basins was based upon frequency analyses of the available annual yield and annual flood flow data series. The annual period employed for the hydrologic data compilation was actually the 8 month period from March 1 to October 31. This period was necessary in that many prairie hydrometric stations are closed down during the winter season because of the difficulties of measurement, and for many streams, the negligible flow. The data series for each basin were compiled on the basis of all available streamflow records for the period 1940-1969. Wherever possible these streamflow data series were extended by correlation and regression analysis with data from nearby longer-term stations.

The frequency analyses of the annual yield and annual flood flow data series for each of the study basins involved the fitting of a least squares regression line to the data series as plotted on lognormal probability paper. The lognormal distribution was selected over the normal, Gumbel and log-Gumbel distributions on the basis of an empirical test of the best fit for both the yield and flood data series from the study basins. The actual method of fitting the curves by least squares allowed the use of extended streamflow data in the adjustment of the plotting positions for the actual measured data. The equations for the fit of the least squares regression line to the lognormal data provided a basis for the estimation of the mean annual (2 year return period), and 10 year annual yield and flood flow events for each basin. These data were subsequently employed as the dependent variables in the analyses of the hypothetical model.

A group of 39 independent variables, various measures of climatic and other physical geographic patterns, was compiled for each of the study basins. Each variable was selected on the basis of two considerations. The first consideration related to its theoretical relationships to the dependent variables, and the second related to the available data sources and the problems of data compilation.

The first group of independent variables included 20 measures of climatic patterns. Each of these measures was related to one of the three most important climate controlled processes in the hydrologic cycle, precipitation, snowmelt and evapotranspiration. For the purposes of the present study, the basic climatic data set was comprised of published climatic normals based on the 30 year period 1930-1960. Four sets of monthly normals, the monthly mean daily temperatures, the monthly mean maximum daily temperatures,the mean monthly precipitation, and the mean monthly snowfall were considered for each of the 196 climatological stations used in the analyses. The climatic normals for these climatological stations formed the basis for the estimation, by Thiessen weight procedures, of a set of monthly climatic normals for mean daily temperatures, mean daily maximum temperatures, mean precipitation and mean snowfall, for each of the 161 study basins. These data for each of the basins were employed as bases for estimating climatic variables for use in the analyses of the hypothetical model. Of the 20 climatic variables employed in the analyses, 8 were based on precipitation data, 7 were based on temperature data, and 5 were composite variables based on both precipitation and temperature data.

The second group of independent variables included 19 measures of other physical geographic patterns. Each of these measures was related to one of three hydrologically significant groups of variables which were classified as measures of drainage area, measures of basin topography, and measures of surficial geology, soils, vegetation and landuse. All of the chosen variables were measured from 1:250,000 scale topographic maps of the study basins. The data compiled from these maps were compared to similar data compiled from 1:50,000 scale maps for a sample of basins. The results of this comparison indicated that for the data compiled for the present study, the use of 1:250,000 scale maps resulted in the same relative variations from basin to basin as for data compiled from the larger scale maps. The actual independent variable measures of other physical geographic patterns compiled for each of the study basins included 3 measures of drainage basin area, 15 measures of basin topography and 1 measure of vegetation patterns.

The full set of 4 dependent variables and 39 independent variables was compiled for each of the 161 study basins. These data were subsequently employed in the statistical analyses of the hypothetical model. In preparation for the statistical analyses, logarithmic transformations were made on several of the variables in an effort to normalize their distributions. Also prior to the analyses, a comparative test sample of 15 basins was withdrawn from the data set for later use in testing the predictive performance of the regression equations resulting from the analyses.

The statistical analyses of the hypothetical model involved two stages, the first entailing an examination of the model for the entire study area, and the second involving its examination on the scale of hydrologic regions. In the first stage of the analyses two approaches were utilized for the estimation of statistical models. The first method involved the use of stepwise multiple regression techniques in the analyses of the relationships of each of the dependent variables to the full set of 39 independent variables. The second method utilized the technique of factor analysis to screen the independent variable set for multicollinearities, as a basis for the selection of a set of independent variables for inclusion in the stepwise multiple regression analysis for each of the dependent variables.

The all variable stepwise multiple regression analyses of the data for the full study area resulted in statistically significant multiple regression equations. However, several of the regression coefficients had signs which contradicted the relationships expected on the basis of physical theory. These results were attributed to the presence of multicollinearities among the independent variables.

The second approach to the full study area analysis utilized factor analysis in the screening of the independent variables. This technique enabled the researcher to select a set of independent variables which approximated the assumption of independence among the independent variables. When these variables were entered in the stepwise regression analyses, the resulting equations were again statistically significant, and in addition, the signs of the regression coefficients conformed to physical theory. The coefficients of determination of this second set of equations were only slightly lower than for the equations from the previous approach. Although a very slight loss in explanatory power was observed, the gain in physical significance resulted in this second group of relationships being judged to be superior in the context of the present study.

All of the relationships resulting from the full study area stage of the analyses had relatively large standard errors of estimates. The magnitudes of these errors, particularly in view of the fact that they were measured in logarithmic units, limited the usefulness of the relationships for predictive purposes. In an attempt to improve the predictive power of the relationships, the second stage of the analyses was undertaken. This stage entailed the subdivision of the study area into regions of hydrologic similarity in order to account for some of the regional variations in streamflow patterns and to improve on the predictive strength of the equations resulting from the analyses. Attempts to subdivide the study area, on the basis of plots of regression residuals and on the basis of plots of hydrologic index-event ratios, were not successful as local variations dominated and obscured any possible regional divisions. The use of a multivariate optimal grouping technique based on factor scores resulting from a factor analysis of the climatic variables and the hydrologic index-ratios, provided a twofold grouping of the study basins. Although the grouping accounted for only a small percentage, 19%, of the total variance in the input data, the grouping resulted in a well-defined spatial division of the study area. This grouping identified an eastern and a western region which were employed as a basis for further analyses of the hypothetical model.

The analyses of the hypothetical model for the two subregions of the study area employed the technique of stepwise multiple regression after factor analytic screening of the independent variables. The resulting regression equations, while conforming to physical theory, did not result in any appreciable improvement in the predictive potential of the relationships. Further attempts at subdividing the study area to improve the regression relationships were also unsuccessful. Throughout these attempts at regional subdivision the importance of local anomalies was dominant.

The predictive performance of the regression equations was tested by their application to data for the test sample of 15 basins. On the basis of these calculations, it was concluded that the regression relationships were stable and applied equally as well to the test sample as to the original data.

6.3 CONCLUSIONS

The twofold aims of the present research were firstly, to develop predictive relationships for the estimation of streamflow characteristics in ungauged areas of the prairie, and secondly, to add to our overall knowledge of prairie hydrologic patterns through the identification of climatic and other physical geographic patterns which are closely related to streamflow characteristics. With respect to the first of these aims, a limited degree of success has been achieved in the present study. The stability of the relationships has been demonstrated by their application to the independent test sample of 15 basins. However, the standard errors of the estimates associated with the regression equations are relatively large. It is suggested that care must be taken in the use of these relationships for the prediction of streamflow characteristics for ungauged basins within the study area. With the aim of improving the predictive strength of the regression relationships, it is possible to suggest several extensions of the present research. These suggestions for further research are outlined in the following section of this chapter.

The present analyses have been successful with respect to the second aim of the study, to add to our overall knowledge of prairie hydrologic patterns through the identification of climatic and other physical geographic patterns which are closely related to streamflow characteristics. In order to illustrate this conclusion, the results of the full study area stepwise multiple regression analyses, after factor analytic screening of the independent variables, are considered.

The use of factor analytic techniques in the screening of the independent variable sets led to the development of more meaningful regression equations. In the case of the full study area analyses by these techniques (Section 5.4.3), the original set of 39 independent variables was collapsed to a group of 9 variables which were relatively free of multicollinearity, and therefore, approximated the assumption of independence. The stepwise multiple regression analysis for each of the dependent variables,employing this set of 9 independent variables, resulted in significant regression equations in which the signs of the regression coefficients conformed to physical theory. Their relationships were found to be stable when applied to an independent test sample of 15 basins.

Of particular interest, in the present study, is the consistently strong influence of the drainage area measures in the regression models. In all cases, the single most important variable is the LCDA measure. This is, of course, not unexpected in that larger contributing drainage areas are expected to produce larger streamflow events. However, a second drainage area measure, the LNCDA, was also found to be significant in the regression models. This variable exhibited a negative effect on the magnitudes of streamflow events. Although this variable is a measure of the difference between the TDA and the CDA measures, its significance in the equations would suggest that it provides an index of the non-contributing area which may have been included in the CDA measure as a result of measurement errors. It is suggested that the true meaning of this variable may be that in cases where some non-contributing drainage areas have been delimited by the relatively crude measures of the present study, there may be further non-contributing areas which are in proportion to the measured NCDA percentage. At any rate, the importance of drainage area measures has been confirmed, and it would seem that a possible direction for further investigations has been established.

Another observation of particular significance in the present study related to the spatial distribution of residuals from the regression analysis. When the residuals from the various multiple regression analyses were mapped, the resulting patterns were local in nature and did not reveal any large scale regional patterns. This observation leads the author to suggest that local variations in prairie hydrologic patterns are the dominant factor in limiting the predictive value of the regression relationships. The importance of these local variations has been confirmed by the failure of the regional subdivision of the second stage of the analysis to result in significant improvements in the predictive strength of the regression relationships.

In addition to establishing statistical relationships, two methodological conclusions have been reached. The first conclusion is that the lognormal distribution is the most appropriate 2-parameter distribution for use in the frequency analyses of both the annual yield and annual flood flow data series for prairie streams. The lognormal distribution was selected over the normal, Gumbel and log-Gumbel distributions on the basis of its empirical fit to the available data series. This conclusion is an empirical confirmation of the use of this distribution which previously has been widely employed in engineering hydrology for plains' streams (for examples of the use of the lognormal distribution in hydrological studies for the plains see Ansley 1959; and Neill 1970).

The second methodological conclusion is that factor analytic screening of the independent variables prior to regression analysis results in more meaningful regression models. The models developed by this technique conform to physical theory while sacrificing only a small degree of explanation relative to the all variable regression approach.

6.4 SUGGESTIONS FOR FURTHER RESEARCH

In the present analyses, only a limited degree of success has been achieved in the development of statistical models for the prediction of streamflow characteristics for ungauged plains' basins. On the basis of these results it is possible to make several suggestions for the extension of the present research with the aim of improving the relationships. Of particular relevance to further research is the observed importance of local deviations as exemplified in the results of the regression analyses of the present study. It is proposed that extensions to the present research should concentrate on an examination of local scale patterns which may be related to these local anomalies.

The dependent variables in the present research, the selected streamflow characteristics, have been estimated by frequency analyses of the available streamflow data series. The number of streamflow data available can only be increased by continued data collection over time. Therefore with respect to the dependent variables, it is not possible to rely on further data collection at this time; but rather, efforts to improve the relationships must concentrate on making better use of the available records. In this regard, it is suggested that a review of the reliability of the available streamflow data be considered. In the present research the published streamflow data and gauging station descriptions have been accepted as a basis for basin selection. In view of the numerous local anomalies which have been noted in the analyses, it is suggested that the streamflow data for such anomalous basins be reviewed with the aim of detecting any inconsistencies or human influences such as diversions or storage developments which have not been previously identified. Such unrecognized limitations in the original data set may have resulted in some of the prediction errors in the present analyses.

The first group of independent variables employed in the study, the climatic measures, were based on 30 year climatic normals of temperature and precipitation. These data were employed for ease of data compilation and on the assumption that the year to year variations in hydrologic conditions would be accounted for in the frequency analyses of the streamflow data. In view of the limited success of the present analysis, it is proposed that consideration should be given to the year to year variations in climatic patterns. Such considerations might be based on frequency analyses of several years of climatic data. This approach to developing climatic variables may be of particular relevance in the semi-arid sections of the study area in which the annual variations in water balance patterns are relatively pronounced.

The second group of independent variables, the measures of other physical geographic patterns, should also be re-examined with a view to explaining some of the local hydrologic anomalies. The drainage area measures employed in the present study are far from ideal, in that a high degree of subjectivity exists in their measurement. However, these measures have proven to be highly significant in the present study and it would seem reasonable to suggest that further refinement in the methods of drainage area delimitation might result in a reduction of the errors in the analyses. Another group of physical measures which may hold the key to some of the local anomalies includes measures of surficial geology, soils, and landuse patterns. All of these variables which are operative on a local scale have been omitted from the present study because of a lack of suitable data sources. However, any extension to the present study should include efforts to provide at least some crude indices for these factors which are closely related to infiltration rates and capacities.

The present study has resulted in the successful development of meaningful models of prairie hydrologic patterns. The relationships are statistically significant, stable when applied to independent data, and in agreement with physical theory. Unfortunately, the magnitudes of the standard errors of estimates associated with the regression equations are relatively large and limit the predictive usefulness of the models. Several extensions to the present research have been proposed with the aim of improving the predictive strength of these relationships. At the present time, the relationships developed in this study provide a basis for the preliminary estimation of streamflow patterns for ungauged areas. Care must be exercised in the interpretation of these estimates and it is anticipated that further research along the lines suggested above will result in more accurate and useful relationships.

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APPENDIX A

RESULTS OF THE FREQUENCY ANALYSES OF THE DEPENDENT VARIABLES FOR THE STUDY BASINS

TABLE A-1 - VALUES OF THE REDUCED VARIATE Y FOR THE NORMAL PROBABILITY SCALE CORRESPONDING TO SELECTED RETURN PERIODS

TR *	PRBOC **	Y ***
1.1	0.100	- 1.28
1.4	0.300	- 0.52
2.0	0.500	0.00
5.0	0.800	+ 0.84
10.0	0.900	+ 1.28
15.0	0.933	+ 1.50
25.0	0.960	+ 1.75
35.0	0.971	+ 1.90
50.0	0.980	+ 2.05
75.0	0.987	+ 2.23
100.0	0.990	+ 2.33
1000.0	0.999	+ 3.09

* Return Period in Years

** Probability of Non-occurrence - to convert to a probability of occurrence subtract PRBOC from 1.0.

*** Reduced variate Y corresponding to the normal probability scale.

TABLE A-2

SUMMARY OF THE RESULTS OF THE FREQUENCY ANALYSES OF THE ANNUAL YIELD DATA SERIES

STUDY BASIN I D NUMBER	NAME	LEAST SQUARES REGRESSION FOR LOGNORMAL FREQUENCY CURVE *	R	N**	M***	ESTIMATES OF DEPENDENT VARIABLES MY	M10YY
1	WILLOW CK	X = 4.830 + 0.325 Y	0.989	25	25	67559.9	176590.8
2	LEE CK	X = 4.590 + 0.280 Y	0.993	29	29	38882.0	88817.9
3	ROLPH CK	X = 3.729 + 0.409 Y	0.984	28	29	5362.6	17955.5
4	MANYBERRIES CK	X = 3.678 + 0.448 Y	0.957	13	27	4759.2	17867.5
5	MACKAY CK	X = 3.629 + 0.569 Y	0.964	13	30	4251.8	22822.2
6	PEIGAN CK	X = 3.787 + 0.544 Y	0.924	10	30	6121.9	30469.7
7	ELBOW R	X = 5.280 + 0.128 Y	0.989	18	30	190475.2	277883.4
8	ELBOW R	X = 5.329 + 0.158 Y	0.991	30	30	213496.3	340668.6
9	FISH CK	X = 4.317 + 0.331 Y	0.994	14	30	20740.8	55161.5
10	STIMSON CK	X = 4.105 + 0.407 Y	0.978	25	27	12746.2	42390.3
11	LITTLE RED DEER	X = 5.030 + 0.367 Y	0.981	9	30	107141.7	316348.4
12	LITTLE RED DEER	X = 4.636 + 0.343 Y	0.998	6	30	43215.7	118897.6
13	BLINDMAN R	X = 4.695 + 0.317 Y	0.992	7	30	49553.1	126218.1
14	MEDICINE R	X = 4.989 + 0.294 Y	0.999	6	30	97498.8	232317.4
15	KNEEHILLS CK	X = 4.312 + 0.419 Y	0.995	11	30	20504.4	70575.2
16	ROSEBUD R	X = 3.824 + 0.414 Y	0.985	11	27	6669.9	22655.2
17	BULLPOUND CK	X = 2.256 + 1.710 Y	0.995	8	30	180.4	28122.7
18	ALKALI CK	X = 2.409 + 1.335 Y	0.998	7	30	256.4	13186.6
19	PRAIRIE CK	X = 4.963 + 0.219 Y	0.994	18	30	91758.5	175348.5
20	STURGEON R	X = 4.666 + 0.422 Y	0.988	30	30	46354.8	161031.8
21	VERMILION R	X = 4.547 + 0.526 Y	0.995	11	26	35238.2	166337.1
22	RIBSTONE CK	X = 3.860 + 0.288 Y	0.993	8	26	7238.8	16960.4
23	BATTLE R	X = 5.177 + 0.390 Y	0.994	25	25	150306.8	475281.7
24	MONITER CK	X = 3.120 + 0.705 Y	0.991	16	26	1319.6	10571.4
25	EAGLE CK	X = 4.036 + 0.453 Y	0.999	6	25	10871.0	41443.3
26	EAGLE CK	X = 4.194 + 0.400 Y	0.996	6	25	15646.9	50921.2
27	BEAR CK	X = 3.952 + 0.213 Y	0.997	7	30	8947.0	16801.1
28	BRIDGE CK	X = 3.120 + 0.862 Y	0.963	6	29	1319.5	16806.3
29	PIAPOT CK	X = 3.098 + 0.516 Y	0.981	6	29	1253.5	5743.7
30	SKULL CK	X = 3.461 + 0.161 Y	0.971	7	30	2887.7	4650.9
31	SWIFTCURRENT CK	X = 4.441 + 0.264 Y	0.988	13	29	27587.4	60153.2
32	BRIGHTWATER CK	X = 3.153 + 0.498 Y	0.982	7	29	1421.6	6187.1
33	WOOD R	X = 4.454 + 0.509 Y	0.971	12	28	28441.9	127678.5
34	NOTUKEU CK	X = 4.359 + 0.454 Y	0.969	12	28	22850.0	87275.3
35	MOOSE JAW R	X = 4.257 + 0.543 Y	0.983	16	23	18087.3	89920.3
36	MOOSE JAW R	X = 4.400 + 0.584 Y	0.987	15	23	25098.6	140787.6
37	WASCANA CK	X = 4.379 + 0.364 Y	0.993	22	25	23943.0	70135.0
38	BOGGY CK	X = 3.188 + 0.671 Y	0.972	12	23	1541.6	11166.2
39	QU'APPELLE R	X = 3.928 + 0.743 Y	0.834	24	25	8463.5	75983.1
40	ARM R	X = 3.652 + 0.463 Y	0.986	14	23	4487.2	17606.8
41	JUMPING DEER CK	X = 3.064 + 0.547 Y	0.995	28	28	1158.9	5823.2
42	INDIANHEAD CK	X = 3.236 + 0.497 Y	0.960	23	28	1721.4	7469.2
43	PHEASANT CK	X = 3.246 + 1.039 Y	0.855	21	28	1760.6	37854.4
44	CUTARM CK	X = 3.818 + 0.210 Y	0.991	12	22	6580.2	12237.8
45	CARROT R	X = 3.618 + 1.177 Y	0.964	13	29	4145.0	133716.9
46	CARROT R	X = 4.791 + 0.392 Y	0.969	15	29	61796.7	196682.0
47	CARROT R	X = 5.351 + 0.320 Y	0.989	15	29	224296.8	577204.1
48	PETAIGAN R	X = 3.919 + 0.403 Y	0.982	7	28	8292.3	27243.4
49	TORCH R	X = 5.144 + 0.287 Y	0.994	16	28	139442.4	325798.3
50	ETOMAMI R	X = 4.850 + 0.513 Y	0.983	11	22	70825.9	321776.7
51	RED DEER R	X = 5.392 + 0.304 Y	0.976	12	22	246619.7	605833.0
52	RED DEER R	X = 5.597 + 0.290 Y	0.957	11	22	395252.6	931307.4
53	OVERFLOWING R	X = 5.249 + 0.318 Y	0.943	11	15	177365.7	452839.7
54	SWAN R	X = 5.191 + 0.260 Y	0.956	9	22	155104.7	334048.9
55	BIRCH R	X = 4.097 + 0.272 Y	0.905	12	22	12510.2	27898.1
56	WOODY R	X = 4.854 + 0.403 Y	0.927	12	22	71396.9	234783.9
57	ROARING R	X = 4.509 + 0.430 Y	0.939	8	22	32274.3	114875.4
58	SWAN R	X = 4.958 + 0.436 Y	0.929	8	22	90706.5	328386.1
59	STEEP ROCK R	X = 4.567 + 0.220 Y	0.938	11	22	36907.5	70581.9
60	BELL R	X = 4.272 + 0.279 Y	0.880	10	22	18705.4	42588.1
61	PINE R	X = 4.173 + 0.426 Y	0.939	12	22	14879.7	52258.2
62	GARLAND R	X = 4.041 + 0.329 Y	0.979	11	22	10989.1	29012.3
63	OCHER R	X = 4.457 + 0.260 Y	0.933	13	22	28658.4	61766.9
64	TURTLE R	X = 4.546 + 0.276 Y	0.939	12	22	35187.1	79403.9
65	WILSON R	X = 4.417 + 0.894 Y	0.903	12	22	26126.0	366175.9
66	VERMILION R	X = 4.433 + 0.395 Y	0.952	12	22	27098.7	87004.4
67	FISHING R	X = 3.395 + 0.713 Y	0.992	11	22	2485.0	20375.6
68	FORK R	X = 3.680 + 0.558 Y	0.921	13	22	4785.1	24870.1
69	DRIFTING R	X = 3.647 + 0.493 Y	0.953	13	25	4435.9	18983.4
70	MINK R	X = 3.621 + 0.336 Y	0.985	13	28	4175.2	11257.5
71	EDWARDS CK	X = 4.046 + 0.243 Y	0.949	12	22	11111.3	22751.4
72	PINE CK	X = 4.287 + 0.090 Y	0.915	10	16	19368.0	25292.2
73	NEEPAWA CK	X = 3.777 + 0.326 Y	0.945	10	22	5979.7	15666.9
74	WHITEMUD R	X = 3.826 + 0.102 Y	0.979	8	20	6694.1	9035.4
75	YORKTON CK	X = 3.544 + 0.606 Y	0.941	16	26	3496.7	20933.7
76	WHITESAND R	X = 3.261 + 1.494 Y	0.968	9	22	1823.7	150140.6
77	ASSINIBOINE R	X = 4.274 + 0.511 Y	0.961	11	22	18805.1	85005.9
78	STONY CK	X = 3.342 + 0.662 Y	0.980	11	25	2196.6	15485.0
79	SHELL R	X = 4.598 + 0.239 Y	0.962	11	22	39594.4	80257.1
80	LITTLE BOGGY CK	X = 3.729 + 0.185 Y	0.941	12	22	5352.0	9250.9

* IN THE EQUATION X IS THE MAGNITUDE OF THE EVENT AND Y IS THE REDUCED VARIATE CORRESPONDING TO THE PLOTTING POSITIONS

** N IS THE NUMBER OF YEARS OF ACTUAL MEASURED DATA ON WHICH THE REGRESSION IS BASED

*** M IS THE TOTAL NUMBER OF YEARS IN THE DATA SERIES INCLUDING EXTENDED RECORDS

TABLE A-2 CONTINUED

STUDY BASIN I D NUMBER	NAME	LEAST SQUARES REGRESSION FOR LOGNORMAL FREQUENCY CURVE *	R	N**	M***	ESTIMATES OF DEPENDENT VARIABLES MY	M10YY
81	BIRDTAIL CK	X = 4.374 + 0.413 Y	0.988	12	22	23671.8	80077.8
82	MINNEDOSA R	X = 4.769 + 0.306 Y	0.926	10	22	58688.3	144891.5
83	ROLLING R	X = 4.448 + 0.294 Y	0.919	8	22	28061.3	66925.5
84	ARROW R	X = 3.565 + 0.338 Y	0.916	10	22	3673.9	9971.8
85	BOSSHILL CK	X = 3.257 + 0.554 Y	0.943	10	22	1807.0	9264.5
86	GOPHER CK	X = 3.385 + 0.423 Y	0.913	10	22	2427.6	8452.6
87	OAK R	X = 3.609 + 0.548 Y	0.885	10	22	4064.2	20484.6
88	LITTLE SOURIS R	X = 3.541 + 0.477 Y	0.983	8	10	3475.8	14208.9
89	EPINETTE CK	X = 3.540 + 0.411 Y	0.950	6	10	3471.0	11693.5
90	STURGEON CK	X = 4.333 + 0.284 Y	0.983	7	10	21534.5	49795.0
91	GIBSON CK	X = 3.206 + 0.888 Y	0.909	10	22	1608.7	22145.0
92	YELLOWGRASS DITC	X = 3.125 + 1.050 Y	0.924	13	23	1332.7	29553.5
93	JEWEL CK	X = 3.385 + 1.121 Y	0.894	8	22	2425.1	66305.3
94	COULEE WEST	X = 0.148 + 1.666 Y	0.982	7	12	1.4	192.3
95	PIPESTONE CK	X = 3.595 + 0.885 Y	0.923	9	22	3932.2	53594.3
96	ANTLER R	X = 3.607 + 0.777 Y	0.902	12	22	4049.3	40081.3
97	GAINSBOROUGH CK	X = 3.274 + 0.898 Y	0.984	10	14	1880.0	26620.9
98	GRAHAM CK	X = 3.004 + 0.712 Y	0.962	9	14	1008.3	8252.1
99	OAK CK	X = 3.928 + 0.348 Y	0.972	8	10	8469.5	23654.2
100	ELGIN CK	X = 3.382 + 0.560 Y	0.976	7	10	2407.9	12578.2
101	WHITEMUD CK	X = 3.833 + 0.298 Y	0.990	10	20	6807.0	16396.6
102	BADGER CK	X = 3.868 + 0.374 Y	0.996	10	20	7374.3	22232.2
103	PEMBINA	X = 3.848 + 0.234 Y	0.968	10	22	7045.1	14038.2
104	WAKOPA	X = 3.124 + 0.641 Y	0.913	7	20	1329.0	8825.0
105	CRYSTAL CK	X = 3.205 + 0.386 Y	0.995	9	10	1603.9	5019.3
106	LONG R	X = 3.781 + 0.499 Y	0.920	10	22	6038.1	26351.1
107	SNOWFLAKE CK	X = 3.081 + 0.620 Y	0.979	8	20	1205.0	7512.7
108	MOWBRAY CK	X = 2.819 + 0.908 Y	0.944	7	20	659.3	9631.1
109	ROSEAU R	X = 5.366 + 0.360 Y	0.976	20	20	232347.1	673352.9
110	ROSEAU R	X = 5.351 + 0.288 Y	0.971	6	20	224265.4	524218.8
111	ROSEAU R	X = 5.385 + 0.294 Y	0.954	7	20	242934.9	578607.3
112	RAT R	X = 4.531 + 0.200 Y	0.983	9	20	33926.7	61253.4
113	SHANNON CK	X = 3.523 + 0.512 Y	0.990	9	20	3332.2	15090.7
114	ELM CK 1	X = 4.183 + 0.273 Y	0.983	8	10	15229.7	34046.2
115	ELM CK 2	X = 3.855 + 0.287 Y	0.977	9	10	7154.7	16707.1
116	ELM CK 3	X = 3.567 + 0.328 Y	0.975	8	10	3688.2	9724.5
117	COOKS CK	X = 4.368 + 0.422 Y	0.972	11	20	23343.0	81189.3
118	COOKS CK	X = 4.298 + 0.300 Y	0.989	9	20	19408.3	47021.5
119	NETLEY CK	X = 4.122 + 0.349 Y	0.983	9	13	13248.1	37077.3
120	NETLEY CK	X = 3.528 + 0.422 Y	0.953	8	12	3374.1	11725.1
121	WHITEMOUTH R	X = 5.446 + 0.299 Y	0.974	13	20	278998.2	674575.4
122	BROKENHEAD R	X = 4.914 + 0.350 Y	0.981	12	20	81977.1	230505.3
123	BROKENHEAD R	X = 4.457 + 0.331 Y	0.991	8	20	28617.7	76136.4
124	OSIER CK	X = 3.657 + 0.299 Y	0.989	6	12	4535.7	10958.8
125	ICELANDIC R	X = 4.597 + 0.268 Y	0.973	10	12	39511.9	87052.7
126	FISHER R	X = 4.446 + 0.345 Y	0.982	8	12	27943.7	77256.4
127	EAST FISHER R	X = 4.172 + 0.231 Y	0.901	6	10	14857.1	29354.7
128	BEAVER R	X = 5.694 + 0.256 Y	0.992	6	25	494344.4	1052958.0
129	BEAVER R	X = 5.685 + 0.267 Y	0.996	14	30	484647.0	1066960.0
130	MCLEOD R	X = 5.692 + 0.143 Y	0.993	15	30	491490.1	749482.1
131	MCLEOD R	X = 5.973 + 0.135 Y	0.987	9	30	940307.8	1400357.0
132	WOLF CK	X = 4.872 + 0.187 Y	0.988	15	30	74483.1	129500.4
133	PEMBINA R	X = 5.534 + 0.163 Y	0.956	10	30	342171.0	554362.8
134	PEMBINA R	X = 5.632 + 0.179 Y	0.968	15	30	428494.4	727734.9
135	LOBSTICK R	X = 4.752 + 0.422 Y	0.988	15	30	56471.3	196150.2
136	PADDLE R	X = 4.534 + 0.270 Y	0.989	7	30	34183.2	75860.1
137	LITTLE PADDLE R	X = 4.176 + 0.309 Y	0.992	7	30	14989.1	37350.7
138	PEMBINA R	X = 5.814 + 0.251 Y	0.988	12	30	651096.2	1364373.0
139	EAST PRAIRIE R	X = 5.151 + 0.194 Y	0.992	11	30	141599.9	250757.9
140	WEST PRAIRIE R	X = 4.990 + 0.248 Y	0.985	11	30	97789.6	203549.9
141	SWAN R	X = 5.451 + 0.125 Y	0.989	7	30	282404.3	409030.9
142	WAPITI R	X = 6.395 + 0.145 Y	0.977	9	15	2483825.0	3806115.0
143	LITTLE SMOKY R	X = 6.043 + 0.188 Y	0.968	9	30	1104990.0	1922128.0
144	HEART R	X = 4.803 + 0.453 Y	0.985	7	11	63502.3	241595.4
145	NOTIKEWIN R	X = 5.530 + 0.282 Y	0.954	7	7	338969.5	779524.7
146	BOYER R	X = 4.706 + 0.523 Y	0.976	7	7	50808.4	238056.5
147	PONTON R	X = 5.421 + 0.129 Y	0.955	7	7	263913.7	386288.5
148	SAGE CK	X = 3.683 + 0.582 Y	0.956	24	26	4822.8	26844.2
149	MIDDLE CK	X = 3.450 + 0.565 Y	0.973	19	29	2817.5	14933.9
150	LYONS CK	X = 2.820 + 1.079 Y	0.699	25	29	660.5	15949.9
151	BATTLE CK	X = 4.142 + 0.379 Y	0.993	27	29	13881.3	42541.1
152	LODGE CK	X = 4.088 + 0.471 Y	0.993	17	26	12241.8	49233.3
153	MIDDLE CK	X = 3.089 + 0.171 Y	0.996	7	29	1226.1	2033.8
154	WOODPILE COULEE	X = 2.851 + 1.130 Y	0.752	26	29	709.5	19951.1
155	EAST BATTLE CK	X = 2.964 + 0.946 Y	0.697	26	29	920.0	15030.8
156	WHITEWATER CK	X = 3.012 + 0.865 Y	0.975	28	28	1028.7	13204.9
157	POPLAR R W	X = 3.351 + 0.593 Y	0.985	13	29	2243.4	12934.6
158	POPLAR R E	X = 3.987 + 0.317 Y	0.991	28	28	9705.8	24733.2
159	ROCK CK	X = 3.987 + 0.307 Y	0.982	23	29	9706.9	24018.5
160	POPLAR R M	X = 4.018 + 0.363 Y	0.994	28	29	10428.5	30465.3
161	ROCK CK	X = 4.082 + 0.402 Y	0.984	11	29	12068.9	39580.4

TABLE A-3

SUMMARY OF THE RESULTS OF THE FREQUENCY ANALYSES OF THE ANNUAL FLOOD FLOW DATA SERIES

STUDY BASIN I D NUMBER	STUDY BASIN I D NAME	LEAST SQUARES REGRESSION FOR LOGNORMAL FREQUENCY CURVE *	R	N**	M***	ESTIMATES OF DEPENDENT VARIABLES MF	ESTIMATES OF DEPENDENT VARIABLES M10YF
1	WILLOW CK	X = 3.041 + 0.450 Y	0.982	25	25	1099.8	4156.4
2	LEE CK	X = 2.804 + 0.450 Y	0.959	29	29	636.5	2403.5
3	ROLPH CK	X = 2.071 + 0.543 Y	0.985	29	29	117.8	385.6
4	MANYBERRIES CK	X = 2.535 + 0.481 Y	0.963	30	30	343.1	1418.2
5	MACKAY CK	X = 2.468 + 0.401 Y	0.952	13	30	293.9	960.0
6	PEIGAN CK	X = 2.575 + 0.565 Y	0.958	10	30	375.6	1989.6
7	ELBOW R	X = 3.291 + 0.330 Y	0.978	30	30	1954.9	5180.1
8	ELBOW R	X = 3.304 + 0.283 Y	0.980	30	30	2012.5	4641.0
9	FISH CK	X = 2.744 + 0.425 Y	0.994	14	30	555.0	1945.9
10	STIMSON CK	X = 2.516 + 0.470 Y	0.988	28	29	328.4	1316.6
11	LITTLE RED DEER	X = 3.195 + 0.484 Y	0.977	9	18	1566.2	6539.4
12	LITTLE RED DEER	X = 2.938 + 0.253 Y	0.984	6	30	868.0	1829.7
13	BLINDMAN R	X = 3.241 + 0.401 Y	0.989	8	30	1741.4	5685.5
14	MEDICINE R	X = 3.313 + 0.442 Y	0.980	8	30	2055.2	7586.1
15	KNEEHILLS CK	X = 2.907 + 0.681 Y	0.987	11	30	807.2	6027.8
16	ROSEBUD R	X = 2.320 + 0.658 Y	0.984	11	30	209.1	1457.4
17	BULLPOUND CK	X = 0.874 + 1.927 Y	0.989	8	26	7.5	2211.7
18	ALKALI CK	X = 1.086 + 1.958 Y	0.996	7	30	12.2	3944.8
19	PRAIRIE CK	X = 3.040 + 0.355 Y	0.983	18	18	1095.2	3126.0
20	STURGEON R	X = 2.837 + 0.343 Y	0.993	30	30	687.3	1893.5
21	VERMILION R	X = 2.588 + 0.456 Y	0.992	11	26	387.2	1489.4
22	RIBSTONE CK	X = 1.824 + 0.253 Y	0.978	8	26	66.8	140.8
23	BATTLE R	X = 3.245 + 0.464 Y	0.992	25	25	1756.1	6900.7
24	MONITER CK	X = 1.898 + 0.712 Y	0.984	16	26	79.1	646.4
25	EAGLE CK	X = 2.670 + 0.896 Y	0.985	7	25	468.1	6588.4
26	EAGLE CK	X = 2.971 + 1.309 Y	0.979	6	25	934.8	44536.7
27	BEAR CK	X = 2.400 + 0.260 Y	0.930	7	30	251.3	542.2
28	BRIDGE CK	X = 2.250 + 0.908 Y	0.966	6	29	177.8	2596.1
29	PIAPOT CK	X = 1.862 + 0.451 Y	0.985	6	29	72.8	275.4
30	SKULL CK	X = 2.416 + 0.436 Y	0.983	7	30	260.6	942.7
31	SWIFTCURRENT CK	X = 2.982 + 0.378 Y	0.991	13	29	960.3	2928.6
32	BRIGHTWATER CK	X = 2.159 + 0.793 Y	0.822	8	25	144.1	1497.3
33	WOOD R	X = 3.159 + 0.530 Y	0.980	25	25	1442.6	6898.9
34	NOTUKEU CK	X = 2.961 + 0.534 Y	0.978	26	26	913.2	4412.8
35	MOOSE JAW R	X = 2.817 + 0.571 Y	0.988	25	25	656.5	3540.9
36	MOOSE JAW R	X = 2.874 + 0.632 Y	0.925	25	25	747.9	4832.5
37	WASCANA CK	X = 2.633 + 0.538 Y	0.975	24	24	430.0	2107.4
38	BOGGY CK	X = 1.917 + 0.814 Y	0.983	19	24	82.6	914.4
39	QU'APPELLE R	X = 2.414 + 0.663 Y	0.857	24	25	259.2	1835.0
40	ARM R	X = 2.236 + 0.639 Y	0.945	16	25	172.3	1135.4
41	JUMPING DEER CK	X = 1.834 + 0.564 Y	0.966	28	28	68.3	361.4
42	INDIANHEAD CK	X = 2.215 + 0.478 Y	0.930	24	28	164.1	673.4
43	PHEASANT CK	X = 2.204 + 0.876 Y	0.857	22	28	159.8	2122.8
44	CUTARM CK	X = 2.300 + 0.312 Y	0.955	13	26	199.6	501.3
45	CARROT R	X = 2.133 + 0.938 Y	0.882	14	29	135.7	2165.7
46	CARROT R	X = 3.389 + 0.390 Y	0.985	15	29	2451.5	7750.0
47	CARROT R	X = 3.891 + 0.264 Y	0.991	15	29	7778.8	16973.2
48	PETAIGAN R	X = 3.039 + 0.298 Y	0.998	7	28	1094.3	2636.5
49	TORCH R	X = 3.208 + 0.302 Y	0.960	18	25	1615.9	3942.0
50	ETOMAMI R	X = 3.112 + 0.441 Y	0.962	14	25	1292.8	4756.2
51	RED DEER R	X = 3.698 + 0.393 Y	0.983	15	25	4989.5	15897.3
52	RED DEER R	X = 3.437 + 0.366 Y	0.988	13	25	2734.2	8062.8
53	OVERFLOWING R	X = 3.271 + 0.226 Y	0.994	13	25	1867.9	3642.1
54	SWAN R	X = 3.283 + 0.312 Y	0.976	10	25	1918.6	4817.3
55	BIRCH R	X = 2.344 + 0.380 Y	0.918	15	25	220.8	678.5
56	WOODY R	X = 3.001 + 0.393 Y	0.926	15	25	1001.3	3189.9
57	ROARING R	X = 2.755 + 0.349 Y	0.938	10	28	569.5	1595.0
58	SWAN R	X = 3.120 + 0.522 Y	0.971	8	25	1318.6	6151.5
59	STEEP ROCK R	X = 3.029 + 0.371 Y	0.987	14	28	1069.9	3197.1
60	BELL R	X = 2.435 + 0.416 Y	0.968	14	28	272.2	930.2
61	PINE R	X = 2.413 + 0.384 Y	0.903	15	28	258.6	803.3
62	GARLAND R	X = 2.447 + 0.286 Y	0.935	14	28	280.1	651.5
63	OCHER R	X = 2.926 + 0.337 Y	0.981	20	28	842.9	2282.7
64	TURTLE R	X = 3.059 + 0.281 Y	0.985	20	28	1146.7	2628.7
65	WILSON R	X = 2.693 + 0.513 Y	0.879	20	28	781.4	3553.7
66	VERMILION R	X = 2.971 + 0.388 Y	0.961	21	28	936.3	2940.7
67	FISHING R	X = 2.013 + 0.679 Y	0.993	20	25	103.1	766.5
68	FORK R	X = 2.120 + 0.610 Y	0.912	15	28	132.0	797.9
69	DRIFTING R	X = 2.188 + 0.524 Y	0.971	15	28	154.3	724.6
70	MINK R	X = 2.003 + 0.399 Y	0.973	13	28	100.6	326.2
71	EDWARDS CK	X = 2.488 + 0.278 Y	0.974	12	28	307.4	698.5
72	PINE CK	X = 2.650 + 0.281 Y	0.995	10	28	446.4	1023.1
73	NEEPAWA CK	X = 2.321 + 0.421 Y	0.997	10	29	209.6	727.1
74	WHITEMUD R	X = 1.964 + 0.269 Y	0.983	8	29	92.0	203.7
75	YORKTON CK	X = 2.375 + 0.617 Y	0.936	25	28	237.3	1468.1
76	WHITESAND R	X = 1.593 + 0.640 Y	0.986	9	28	39.2	259.0
77	ASSINIBOINE R	X = 2.762 + 0.568 Y	0.968	24	28	577.7	3091.0
78	STONY CK	X = 1.681 + 0.680 Y	0.979	11	25	47.9	356.3
79	SHELL R	X = 2.721 + 0.292 Y	0.977	20	28	525.8	1245.9
80	LITTLE BOGGY CK	X = 2.090 + 0.359 Y	0.978	12	28	122.9	354.3

* IN THE EQUATION X IS THE MAGNITUDE OF THE EVENT AND Y IS THE REDUCED VARIATE CORRESPONDING TO THE PLOTTING POSITIONS

** N IS THE NUMBER OF YEARS OF ACTUAL MEASURED DATA ON WHICH THE REGRESSION IS BASED

*** M IS THE TOTAL NUMBER OF YEARS IN THE DATA SERIES INCLUDING EXTENDED RECORDS

TABLE A-3 CONTINUED

STUDY BASIN I D NUMBER	NAME	LEAST SQUARES REGRESSION FOR LOGNORMAL FREQUENCY CURVE *	R	N**	M***	ESTIMATES OF DEPENDENT VARIABLES MY	M10YY
81	BIRDTAIL CK	X = 2.638 + 0.225 Y	0.980	15	28	434.6	843.5
82	MINNEDOSA R	X = 2.767 + 0.337 Y	0.996	10	25	585.1	1582.7
83	ROLLING R	X = 2.523 + 0.346 Y	0.993	8	25	333.1	925.0
84	ARROW R	X = 2.417 + 0.492 Y	0.914	10	27	261.1	1114.3
85	BOSSHILL CK	X = 2.209 + 0.683 Y	0.964	10	27	161.9	1214.8
86	GOPHER CK	X = 1.986 + 0.374 Y	0.966	10	25	96.8	292.0
87	OAK R	X = 2.336 + 0.421 Y	0.952	10	25	216.9	751.4
88	LITTLE SOURIS R	X = 3.104 + 0.835 Y	0.986	8	26	1269.9	14934.9
89	EPINETTE CK	X = 1.666 + 0.231 Y	0.983	7	29	46.4	91.6
90	STURGEON CK	X = 2.719 + 0.181 Y	0.984	8	29	523.8	892.5
91	GIBSON CK	X = 2.189 + 0.681 Y	0.873	10	28	154.6	1155.5
92	YELLOWGRASS DITC	X = 1.798 + 0.875 Y	0.931	13	29	62.8	831.3
93	JEWEL CK	X = 1.857 + 0.586 Y	0.954	8	28	71.9	405.2
94	COULEE WEST	X = 0.912 + 1.120 Y	0.992	7	26	8.2	222.5
95	PIPESTONE CK	X = 2.949 + 1.239 Y	0.932	9	27	889.0	39919.7
96	ANTLER R	X = 2.450 + 0.810 Y	0.936	25	26	281.9	3083.8
97	GAINSBOROUGH CK	X = 2.147 + 1.007 Y	0.949	11	27	140.4	2743.3
98	GRAHAM CK	X = 1.729 + 0.523 Y	0.992	9	27	53.6	250.9
99	OAK CK	X = 2.335 + 0.434 Y	0.985	8	26	216.4	779.7
100	ELGIN CK	X = 2.214 + 0.551 Y	0.984	7	28	163.6	832.6
101	WHITEMUD CK	X = 2.428 + 0.320 Y	0.916	10	26	267.9	688.8
102	BADGER CK	X = 2.911 + 0.596 Y	0.996	10	26	815.5	4731.5
103	PEMBINA	X = 2.587 + 0.381 Y	0.985	10	27	386.0	1189.2
104	WAKOPA	X = 1.977 + 0.334 Y	0.945	7	26	94.7	253.9
105	CRYSTAL CK	X = 2.380 + 0.570 Y	0.990	9	26	240.0	1290.8
106	LONG R	X = 2.785 + 0.520 Y	0.953	10	27	609.3	2829.9
107	SNOWFLAKE CK	X = 1.643 + 0.587 Y	0.996	8	29	44.0	248.9
108	MOWBRAY CK	X = 1.660 + 0.689 Y	0.991	7	29	45.7	349.6
109	ROSEAU R	X = 3.297 + 0.256 Y	0.984	29	29	1982.9	4227.4
110	ROSEAU R	X = 3.270 + 0.173 Y	0.996	7	29	1863.8	3107.1
111	ROSEAU R	X = 3.299 + 0.183 Y	0.992	7	29	1991.0	3416.8
112	RAT R	X = 2.707 + 0.275 Y	0.990	9	26	509.9	1147.1
113	SHANNON CK	X = 2.616 + 0.316 Y	0.956	9	29	413.2	1051.1
114	ELM CK 1	X = 2.949 + 0.209 Y	0.978	8	29	890.0	1649.4
115	ELM CK 2	X = 2.615 + 0.245 Y	0.986	9	29	411.9	850.2
116	ELM CK 3	X = 2.311 + 0.310 Y	0.991	8	29	204.5	510.7
117	COOKS CK	X = 3.051 + 0.403 Y	0.983	12	26	1123.6	3686.8
118	COOKS CK	X = 2.928 + 0.393 Y	0.989	9	26	846.6	2701.2
119	NETLEY CK	X = 2.731 + 0.293 Y	0.991	9	26	538.0	1276.9
120	NETLEY CK	X = 1.862 + 0.356 Y	0.986	9	26	72.7	207.8
121	WHITEMOUTH R	X = 3.419 + 0.309 Y	0.947	26	26	2622.6	6521.6
122	BROKENHEAD R	X = 3.015 + 0.350 Y	0.970	26	26	1034.2	2906.0
123	BROKENHEAD R	X = 2.557 + 0.372 Y	0.991	9	26	360.6	1082.7
124	OSIER CK	X = 2.304 + 0.385 Y	0.983	8	20	201.5	627.8
125	ICELANDIC R	X = 3.059 + 0.310 Y	0.990	10	26	1146.2	2858.6
126	FISHER R	X = 2.929 + 0.470 Y	0.995	8	26	849.8	3401.6
127	EAST FISHER R	X = 2.673 + 0.338 Y	0.980	8	20	470.6	1275.9
128	BEAVER R	X = 3.718 + 0.408 Y	0.995	9	30	5224.2	17424.4
129	BEAVER R	X = 3.647 + 0.299 Y	0.983	14	26	4439.0	10735.8
130	MCLEOD R	X = 3.871 + 0.325 Y	0.980	15	18	7429.8	19395.0
131	MCLEOD R	X = 4.084 + 0.255 Y	0.989	10	30	12139.3	25793.0
132	WOLF CK	X = 3.126 + 0.401 Y	0.994	15	18	1337.7	4368.3
133	PEMBINA R	X = 3.673 + 0.291 Y	0.994	12	18	4714.4	11130.0
134	PEMBINA R	X = 3.772 + 0.303 Y	0.992	15	18	5909.5	14458.5
135	LOBSTICK R	X = 2.680 + 0.379 Y	0.978	15	30	478.9	1466.3
136	PADDLE R	X = 3.040 + 0.423 Y	0.995	7	30	1096.4	3823.4
137	LITTLE PADDLE R	X = 2.704 + 0.363 Y	0.998	7	30	506.2	1477.2
138	PEMBINA R	X = 3.793 + 0.256 Y	0.993	12	30	6215.5	13251.2
139	EAST PRAIRIE R	X = 3.371 + 0.251 Y	0.952	11	15	2351.7	4931.9
140	WEST PRAIRIE R	X = 3.316 + 0.380 Y	0.927	11	30	2069.2	6361.3
141	SWAN R	X = 3.674 + 0.182 Y	0.910	7	7	4724.3	8082.4
142	WAPITI R	X = 4.407 + 0.349 Y	0.970	9	11	25533.9	71443.1
143	LITTLE SMOKY R	X = 4.274 + 0.227 Y	0.990	9	30	18785.3	36700.0
144	HEART R	X = 3.196 + 0.460 Y	0.983	7	11	1571.8	6106.7
145	NOTIKEWIN R	X = 3.851 + 0.326 Y	0.969	9	9	7102.7	18606.5
146	BOYER R	X = 3.105 + 0.420 Y	0.961	8	8	1274.4	4405.1
147	PONTON R	X = 3.539 + 0.148 Y	0.965	7	7	3456.1	5356.6
148	SAGE CK	X = 2.496 + 0.603 Y	0.968	29	29	313.6	1857.8
149	MIDDLE CK	X = 2.243 + 0.673 Y	0.940	19	29	175.0	1277.1
150	LYONS CK	X = 1.935 + 0.914 Y	0.756	25	29	86.1	1276.8
151	BATTLE CK	X = 2.590 + 0.462 Y	0.985	27	29	389.0	1520.5
152	LODGE CK	X = 2.785 + 0.497 Y	0.991	18	29	610.2	2648.6
153	MIDDLE CK	X = 1.930 + 0.316 Y	0.925	8	29	85.1	216.2
154	WOODPILE COULEE	X = 1.978 + 1.131 Y	0.820	26	29	95.0	2673.8
155	EAST BATTLE CK	X = 2.021 + 0.924 Y	0.759	26	29	105.0	1606.7
156	WHITEWATER CK	X = 1.894 + 1.150 Y	0.973	28	28	78.3	2335.9
157	POPLAR R W	X = 2.357 + 0.531 Y	0.985	13	29	227.5	1092.4
158	POPLAR R E	X = 2.735 + 0.472 Y	0.963	28	28	542.7	2186.3
159	ROCK CK	X = 2.724 + 0.403 Y	0.988	23	29	530.0	1742.8
160	POPLAR R M	X = 2.724 + 0.503 Y	0.985	29	29	529.1	2334.2
161	ROCK CK	X = 2.750 + 0.387 Y	0.959	11	29	561.8	1758.6

APPENDIX B

CLIMATIC DATA FOR THE STUDY BASINS

TABLE B-1

MONTHLY CLIMATIC NORMALS FOR STUDY BASINS ESTIMATED BY THIESSEN WEIGHTS

	J	F	M	A	M	J	J	A	S	O	N	D	YR
BASIN NUMBER 1													
MT	15.9	17.3	23.6	36.4	46.5	52.1	59.4	56.8	49.5	40.7	28.1	21.2	37.3
MP	0.84	1.17	1.43	1.63	2.24	3.71	1.95	2.03	1.72	1.21	1.02	1.08	20.05
MS	8.3	11.7	14.3	12.5	3.9	0.6	0.0	0.2	3.8	8.3	9.8	10.7	83.9
PXT	28.4	30.3	36.0	49.6	61.0	66.0	77.1	74.7	65.6	54.8	40.4	32.6	51.4
BASIN NUMBER 2													
MT	18.9	20.5	26.4	38.8	49.1	54.8	62.5	59.8	51.7	43.0	30.9	24.2	40.0
MP	1.19	1.24	1.42	1.85	2.56	3.82	1.59	1.59	1.85	1.47	1.22	1.18	21.00
MS	10.7	12.8	14.1	14.0	4.9	1.1	0.0	0.0	3.9	9.6	11.7	11.8	94.8
PXT	27.8	29.4	35.7	49.2	60.7	66.3	76.3	73.3	63.7	53.8	39.9	32.9	50.8
BASIN NUMBER 3													
MT	19.3	20.7	27.0	38.9	48.5	54.2	61.4	59.3	51.4	43.1	31.3	24.9	40.0
MP	0.78	0.91	1.08	1.51	2.52	3.91	1.63	1.67	1.91	1.24	1.02	0.91	19.10
MS	9.8	12.1	13.4	12.7	4.7	1.0	0.1	0.1	3.4	8.9	10.3	10.4	86.8
MXT	28.5	29.7	36.3	48.9	59.7	65.3	74.8	72.2	63.2	53.9	40.6	34.0	50.6
BASIN NUMBER 4													
MT	11.1	13.4	23.7	41.1	52.5	59.4	67.9	65.3	55.1	43.7	27.1	18.1	39.8
MP	0.64	0.66	0.77	0.98	1.34	2.47	1.33	1.08	0.96	0.65	0.62	0.52	11.95
MS	4.1	5.9	7.1	4.2	0.4	0.2	0.0	0.0	1.1	2.9	5.8	5.1	38.8
MXT	21.2	23.4	33.8	53.4	65.6	71.5	82.6	79.8	68.7	56.7	37.7	27.9	51.8
BASIN NUMBER 5													
MT	11.2	12.7	22.9	38.7	50.2	57.4	65.1	62.0	52.4	41.5	25.9	17.8	38.1
MP	0.73	0.78	0.76	1.20	1.41	2.40	1.58	1.88	1.02	0.57	0.68	0.53	13.53
MS	7.3	7.8	7.2	6.1	0.5	0.0	0.0	0.0	0.8	2.8	5.8	4.9	43.1
MXT	21.9	23.2	33.1	50.4	63.4	69.9	79.7	76.4	66.0	54.6	36.8	28.3	50.3
BASIN NUMBER 6													
MT	11.8	14.5	25.6	42.6	54.0	60.6	68.7	65.7	55.8	45.0	28.7	19.4	41.0
MP	0.80	0.76	0.93	0.99	1.57	2.35	1.36	1.45	1.36	0.77	0.73	0.69	13.77
MS	7.9	7.5	8.6	4.5	0.4	0.0	0.0	0.0	1.1	3.6	6.2	6.7	46.5
MXT	22.1	24.6	35.3	54.5	66.6	72.5	82.9	79.8	68.8	57.4	38.9	29.1	52.7
BASIN NUMBER 7													
MT	14.9	17.2	23.5	35.9	46.0	51.6	58.0	55.2	48.4	40.0	28.0	20.8	36.6
MP	0.93	1.35	1.31	2.40	2.86	4.30	2.70	3.07	1.86	1.29	1.02	1.03	24.14
MS	9.0	13.5	13.0	19.8	8.1	2.3	0.0	0.1	2.1	8.8	9.4	10.2	96.3
MXT	27.4	29.4	35.6	47.0	58.2	63.1	71.5	68.0	61.1	52.1	39.5	32.5	48.8
BASIN NUMBER 8													
MT	14.6	16.8	23.5	36.5	47.0	52.5	59.0	56.2	49.2	40.4	27.9	20.5	37.0
MP	0.65	1.20	1.21	2.17	2.61	4.09	2.62	2.93	1.71	1.17	0.90	0.92	22.40
MS	8.3	12.0	11.9	17.6	6.9	2.0	0.0	0.1	2.2	7.9	8.4	9.1	86.4
MXT	26.7	28.7	35.1	47.6	59.0	63.9	72.3	69.0	61.6	52.4	39.1	32.0	48.9
BASIN NUMBER 9													
MT	14.1	16.0	22.1	35.8	46.7	52.1	58.5	55.7	48.3	39.9	27.2	19.4	36.3
MP	0.77	1.18	0.99	2.59	2.42	4.22	2.90	3.40	1.51	1.04	0.78	0.93	22.73
MS	7.4	11.7	9.8	21.6	8.1	2.7	0.0	0.0	2.4	7.4	7.5	9.1	87.7
MXT	27.9	29.5	34.8	47.3	59.4	63.4	71.3	68.2	61.2	53.0	40.0	33.0	49.0
BASIN NUMBER 10													
MT	15.7	17.0	23.3	36.0	46.1	51.5	58.0	55.5	48.8	40.4	28.1	21.2	36.8
MP	0.97	1.33	1.52	2.13	2.69	4.19	2.09	2.48	2.02	1.39	1.08	1.14	23.03
MS	9.4	13.2	14.9	15.9	4.6	1.1	0.0	0.1	3.5	9.4	10.1	11.3	93.5
MXT	27.4	29.4	35.1	48.5	59.6	64.5	73.8	71.2	63.3	53.8	39.6	32.4	49.9
BASIN NUMBER 11													
MT	12.7	15.3	23.1	37.7	48.5	54.1	60.2	57.6	50.3	40.9	27.0	19.0	37.2
MP	0.74	0.84	1.09	1.41	2.31	3.74	2.70	2.79	1.94	1.13	0.77	0.67	19.73
PS	7.3	8.2	10.6	9.7	2.8	0.4	0.0	0.1	1.2	6.8	7.1	6.9	60.7
MXT	23.4	26.3	33.5	48.8	60.8	65.6	73.3	70.3	62.7	53.3	37.5	29.1	48.7
BASIN NUMBER 12													
MT	14.9	17.5	24.2	36.2	46.1	51.7	58.0	55.3	48.8	40.1	28.3	21.3	36.9
MP	0.99	1.37	1.46	2.14	3.01	4.26	2.59	2.85	2.00	1.40	1.11	1.03	24.20
MS	9.6	13.6	14.4	17.1	7.2	1.7	0.0	0.2	1.7	9.3	10.1	10.2	95.2
MXT	26.5	28.8	35.7	47.1	58.6	63.4	72.0	68.2	61.3	51.7	38.8	31.7	48.6
BASIN NUMBER 13													
MT	6.6	10.7	21.1	37.1	49.0	54.4	60.0	57.0	48.8	39.0	23.6	11.9	35.0
MP	0.89	0.79	0.91	1.41	2.22	3.54	3.17	2.76	1.76	0.97	0.72	0.70	19.84
MS	8.7	7.8	8.6	7.8	1.2	0.0	0.0	0.1	1.3	5.5	6.3	6.7	53.9
MXT	18.8	23.5	33.1	49.7	62.4	67.4	74.0	71.1	62.7	52.9	34.8	23.2	47.8
BASIN NUMBER 14													
MT	9.1	14.2	23.0	37.6	48.6	54.2	59.8	56.8	49.3	40.1	25.5	15.6	36.1
MP	0.89	0.88	1.00	1.47	2.24	3.64	3.30	2.91	1.91	0.98	0.77	0.87	20.86
MS	8.8	8.6	9.6	10.1	2.6	0.0	0.0	0.2	1.8	6.3	6.7	8.3	63.0
MXT	19.3	25.6	33.7	49.0	61.2	65.9	72.5	69.2	61.8	52.5	35.1	25.8	47.6
BASIN NUMBER 15													
MT	8.4	11.6	21.6	38.3	49.8	55.7	61.7	58.6	50.5	39.9	24.7	15.3	36.3
MP	0.57	0.62	0.83	1.11	1.88	3.20	2.44	2.56	1.33	0.94	0.59	0.50	16.71
MS	5.7	6.1	7.7	5.2	0.4	0.0	0.0	0.0	0.7	5.5	5.5	4.8	42.0
MXT	19.8	23.5	32.7	51.0	63.4	68.7	76.2	73.0	64.4	53.9	36.0	26.3	49.1
BASIN NUMBER 16													
MT	12.0	14.6	22.8	38.2	49.3	54.9	61.1	58.4	50.8	41.1	26.7	18.3	37.4
MP	0.65	0.67	0.97	1.18	2.07	3.55	2.71	2.74	1.38	1.02	0.66	0.55	18.17
MS	6.5	6.5	9.3	7.4	1.4	0.0	0.0	0.1	1.1	5.9	6.1	5.2	49.5
MXT	22.5	25.5	32.8	49.4	61.6	66.4	73.8	71.1	63.2	53.8	37.1	28.3	48.7
BASIN NUMBER 17													
MT	7.0	10.1	20.6	39.0	51.6	57.6	64.9	61.2	51.7	40.8	24.6	13.0	36.8
MP	0.64	0.75	0.81	0.96	1.24	2.49	2.27	2.15	1.14	0.91	0.56	0.53	14.39
MS	6.4	7.5	8.0	4.3	0.2	0.0	0.0	0.0	1.0	4.0	5.0	5.1	41.5
MXT	15.9	19.3	29.2	50.0	63.7	69.0	77.8	74.3	64.3	52.7	34.1	22.1	47.7
BASIN NUMBER 18													
MT	4.5	8.0	20.7	39.4	52.6	58.7	65.3	62.3	53.0	41.4	24.1	12.5	36.9
MP	0.62	0.53	0.74	0.74	1.40	2.01	1.60	1.59	1.08	0.82	0.61	0.51	12.26
MS	6.1	5.3	7.0	2.4	0.1	0.0	0.0	0.0	0.4	3.3	4.7	4.9	34.2
MXT	15.5	19.1	31.5	51.9	66.3	72.4	81.6	78.1	67.8	55.1	35.2	23.1	49.8
BASIN NUMBER 19													
MT	10.5	16.2	24.1	35.1	45.8	54.6	60.3	57.2	50.1	41.0	26.8	17.9	37.1
MP	0.87	0.93	1.06	1.48	2.23	3.69	3.32	2.97	1.94	0.98	0.78	0.95	21.20
MS	8.7	9.1	10.1	11.2	3.3	0.0	0.0	0.2	1.9	6.6	6.8	9.0	66.9
MXT	19.6	26.9	34.2	49.0	60.9	65.6	72.2	68.8	61.8	52.6	35.5	27.6	47.9
BASIN NUMBER 20													
MT	5.6	10.6	22.0	38.9	51.7	56.9	62.2	58.8	50.9	40.4	24.7	12.7	36.3
MP	1.01	0.89	0.79	0.98	1.71	3.03	3.38	2.43	1.34	0.84	0.88	0.95	18.22
PS	10.1	8.8	7.6	5.6	1.3	0.0	0.0	0.0	0.7	4.9	7.7	8.9	55.6
MXT	15.5	21.4	32.2	50.5	64.6	69.8	75.3	71.7	63.2	52.0	33.6	21.8	47.6
BASIN NUMBER 21													
PT	2.9	7.4	18.4	38.0	51.1	56.8	62.8	59.6	50.5	39.7	22.1	10.1	35.0
MP	0.78	0.57	0.79	0.94	1.46	2.64	2.81	2.77	1.64	0.78	0.84	0.82	16.85
MS	7.6	5.7	7.8	5.4	1.1	0.0	0.0	0.0	0.7	4.0	7.4	7.8	47.6
MXT	12.5	17.5	29.1	49.3	64.1	69.2	75.7	72.5	62.5	51.1	30.7	19.0	46.2
BASIN NUMBER 22													
PT	3.8	8.1	19.8	37.7	51.0	57.0	64.0	60.4	51.4	40.5	23.6	12.1	35.8
MP	0.76	0.65	0.71	0.94	1.16	2.35	2.50	2.32	1.31	0.74	0.57	0.63	14.64
MS	7.4	6.5	6.9	4.1	0.6	0.0	0.0	0.0	0.9	3.3	5.1	5.9	40.7
MXT	12.9	18.3	29.6	49.4	64.1	69.3	77.6	73.4	63.9	52.7	33.1	21.1	47.2
BASIN NUMBER 23													
MT	4.6	8.1	19.7	37.9	50.6	56.4	62.6	59.3	50.5	39.9	22.9	11.3	35.4
MP	0.73	0.61	0.74	0.98	1.42	2.68	2.65	2.39	1.37	0.78	0.63	0.65	15.63
MS	7.1	6.1	7.2	4.5	0.7	0.0	0.0	0.0	0.6	3.4	5.4	6.2	41.2
MXT	14.0	18.8	30.1	49.6	63.6	68.7	76.0	72.4	63.1	52.7	32.2	20.3	46.8
BASIN NUMBER 24													
MT	3.8	7.0	18.7	37.8	50.9	56.8	64.0	60.6	51.1	40.0	22.9	11.4	35.5
MP	0.66	0.59	0.87	0.90	1.07	2.34	2.13	1.90	1.15	0.77	0.56	0.55	13.50
MS	6.5	5.9	8.4	4.6	0.4	0.0	0.0	0.0	0.9	3.4	5.2	5.4	40.6
MXT	13.8	17.4	28.9	49.9	64.6	69.8	78.6	75.2	64.6	53.1	33.0	21.2	47.5
BASIN NUMBER 25													
MT	1.0	4.4	17.4	37.5	51.3	58.3	65.0	62.0	52.0	40.0	21.4	8.4	34.9
MP	0.63	0.53	0.60	0.85	1.36	2.36	2.16	1.77	1.24	0.75	0.63	0.67	13.54
MS	6.2	5.2	5.8	3.1	0.1	0.0	0.0	0.0	0.6	2.7	5.5	6.3	35.9
MXT	10.3	14.6	27.3	49.3	65.0	71.5	79.2	76.4	65.3	52.6	30.4	17.3	46.6
BASIN NUMBER 26													
MT	1.0	4.6	17.6	37.8	51.7	58.8	65.7	62.6	52.3	40.4	21.3	8.6	35.2
MP	0.61	0.57	0.66	0.82	1.36	2.42	2.04	1.74	1.27	0.69	0.57	0.65	13.41
MS	6.0	5.6	6.4	3.0	0.1	0.0	0.0	0.0	0.6	2.6	4.8	6.2	35.3
MXT	10.6	15.0	27.8	49.7	65.4	72.1	80.2	77.3	65.8	52.9	30.5	17.5	47.1
BASIN NUMBER 27													
MT	10.9	13.0	22.0	37.1	48.3	54.9	62.0	59.2	50.5	41.0	25.9	17.8	36.9
MP	0.84	0.75	0.86	1.05	1.79	3.22	1.95	1.78	1.49	0.80	0.82	0.67	16.01
MS	8.2	7.6	8.3	6.1	0.8	0.2	0.0	0.0	1.9	3.9	7.7	6.3	50.9
MXT	21.3	23.3	32.6	49.8	62.4	68.4	77.8	75.5	65.1	54.5	36.3	27.7	49.6
BASIN NUMBER 28													
MT	6.5	13.2	21.9	36.4	49.5	56.9	63.8	62.1	52.7	41.9	27.2	18.0	37.5
MP	0.75	0.72	0.76	1.04	1.60	2.98	1.84	1.61	1.21	0.72	0.71	0.61	14.55
MS	7.3	7.2	7.2	5.5	0.3	0.1	0.0	0.0	1.1	4.0	6.4	5.7	44.8
MXT	15.6	22.7	31.2	47.4	62.5	69.3	77.3	76.4	66.5	54.5	36.9	27.4	49.0
BASIN NUMBER 29													
MT	12.7	15.1	26.1	41.3	53.1	59.9	67.3	64.1	54.3	44.1	28.5	19.8	40.5
MP	0.80	0.82	0.62	0.92	1.47	2.61	1.67	1.49	1.31	0.73	0.79	0.63	13.87
MS	7.9	8.2	5.5	3.5	0.2	0.0	0.0	0.0	0.7	1.9	6.7	6.0	40.7
MXT	24.2	26.6	36.9	53.5	66.6	72.6	81.9	78.8	67.9	56.7	39.3	31.2	53.0
BASIN NUMBER 30													
MT	10.2	12.1	21.7	36.8	48.1	54.8	61.9	59.2	50.5	40.9	25.9	17.6	36.7
MP	0.83	0.75	0.86	1.06	1.78	3.23	1.95	1.77	1.46	0.80	0.80	0.66	15.96
MS	8.1	7.5	8.3	6.2	0.7	0.2	0.0	0.0	1.9	4.1	7.6	6.2	50.8
MXT	20.4	23.0	32.1	49.2	62.1	68.3	77.5	75.4	65.1	54.3	36.2	27.4	49.3
BASIN NUMBER 31													
MT	8.1	13.0	22.1	37.3	49.5	56.6	63.8	61.5	52.3	42.0	26.5	18.2	37.6
MP	0.77	0.72	0.78	1.01	1.61	3.06	1.87	1.67	1.25	0.71	0.71	0.61	14.77
MS	7.5	7.2	7.4	5.5	0.5	0.1	0.0	0.0	1.2	3.8	6.5	5.7	45.4
PXT	17.8	22.9	32.0	48.8	42.9	67.4	78.2	76.6	66.5	55.0	36.5	27.7	49.6
BASIN NUMBER 32													
MT	2.1	5.7	18.3	38.5	52.4	59.6	66.3	63.5	53.0	41.1	22.2	9.5	36.0
PP	0.51	0.56	0.64	0.77	1.42	2.82	2.00	1.48	1.27	0.67	0.52	0.58	13.26
MS	5.0	5.4	5.6	2.8	0.7	0.0	0.0	0.0	0.4	2.4	4.4	5.4	31.6
MXT	11.2	15.4	27.8	49.7	65.5	72.1	79.9	77.4	65.9	53.0	31.0	18.4	47.2
BASIN NUMBER 33													
MT	7.9	11.1	22.5	39.9	52.4	59.9	67.1	64.2	54.1	42.3	25.5	15.3	38.5
MP	0.76	0.63	0.63	0.83	1.48	2.65	1.73	1.66	0.97	0.54	0.57	0.59	13.05
MS	7.2	6.1	5.2	3.1	0.5	0.0	0.0	0.0	0.3	2.3	4.9	5.6	35.2
MXT	18.9	22.4	33.1	52.4	66.5	73.1	82.4	80.0	69.0	56.1	36.2	25.9	51.3
BASIN NUMBER 34													
MT	8.9	11.9	23.2	39.9	52.0	59.1	66.8	63.7	53.8	42.9	25.6	17.1	38.8
MP	0.75	0.63	0.69	0.90	1.42	2.79	1.82	1.64	1.01	0.57	0.57	0.53	13.33
MS	7.0	6.2	6.1	3.8	0.4	0.0	0.0	0.0	0.5	2.6	5.0	5.0	36.8
MXT	19.5	22.6	33.4	52.0	65.5	71.9	81.7	79.2	68.3	56.4	36.0	27.2	51.1
BASIN NUMBER 35													
MT	3.3	7.1	19.0	38.5	51.7	59.5	66.6	63.9	53.5	41.4	23.1	11.8	36.6
MP	0.65	0.61	0.76	0.89	1.60	3.15	2.34	1.90	1.31	0.71	0.67	0.66	15.30
MS	6.8	5.9	6.7	3.3	0.4	0.0	0.0	0.0	0.6	2.4	5.9	6.4	38.6
MXT	12.8	17.1	28.6	50.2	65.0	72.1	80.7	78.3	67.0	53.9	32.5	21.3	48.3
BASIN NUMBER 36													
MT	5.0	8.9	20.7	39.6	52.7	60.2	67.6	64.7	54.3	42.5	24.4	13.0	37.8
MP	0.75	0.61	0.75	0.86	1.67	3.03	2.09	1.85	1.23	0.65	0.70	0.74	14.94
MS	7.4	6.0	6.6	3.2	0.5	0.0	0.0	0.0	0.6	2.6	6.2	7.1	40.1
MXT	14.6	18.5	30.1	51.2	65.9	72.6	81.4	78.7	67.5	54.8	33.6	22.2	49.3
BASIN NUMBER 37													
MT	0.7	5.1	17.4	38.1	51.7	59.1	66.0	63.6	53.0	40.7	21.8	9.3	35.9
MP	0.64	0.63	0.70	0.77	1.50	3.18	2.19	1.95	1.32	0.66	0.69	0.53	14.77
MS	6.4	6.1	6.0	2.8	0.5	0.0	0.0	0.0	0.4	1.8	6.1	5.1	35.5
MXT	10.0	14.6	27.0	49.5	65.6	72.0	80.1	77.9	66.7	53.6	30.9	18.0	47.1
BASIN NUMBER 38													
MT	1.2	5.2	17.6	38.1	52.1	59.4	66.4	63.8	53.1	40.3	21.9	9.6	35.7
MP	0.68	0.63	0.74	0.84	1.59	3.17	2.19	1.94	1.33	0.67	0.72	0.62	15.14
MS	6.7	6.1	6.6	3.3	0.6	0.0	0.0	0.0	0.9	2.5	6.5	6.0	39.2
MXT	10.7	14.8	27.1	49.8	65.9	72.1	80.4	77.9	66.5	52.7	30.8	18.6	47.2
BASIN NUMBER 39													
MT	2.7	6.4	18.4	38.3	51.7	59.1	66.0	63.4	53.1	41.3	22.7	10.6	36.1
MP	0.79	0.64	0.93	0.89	1.59	3.10	2.06	1.71	1.33	0.67	0.63	0.81	15.14
MS	7.7	6.2	8.3	3.8	0.7	0.0	0.0	0.0	0.7	2.9	5.2	7.6	43.1
MXT	11.3	15.7	27.8	49.9	65.2	71.7	80.2	78.0	66.6	53.7	31.5	18.9	47.5
BASIN NUMBER 40													
MT	1.6	5.3	17.8	38.1	51.9	59.1	65.7	63.1	52.8	40.7	21.9	9.1	35.6
MP	0.53	0.57	0.74	0.84	1.57	3.02	2.07	1.64	1.30	0.71	0.59	0.61	14.20
PS	5.3	5.5	6.5	3.1	0.3	0.0	0.0	0.0	0.6	2.6	5.1	5.5	34.5
MXT	10.9	15.1	27.3	49.3	65.1	71.6	79.3	77.1	65.8	52.8	30.6	18.0	46.8
BASIN NUMBER 41													
MT	0.6	4.6	16.2	36.1	50.3	57.4	64.4	61.5	51.2	40.2	21.0	7.4	34.2
MP	0.99	0.83	1.07	1.09	1.71	3.03	2.25	2.43	1.59	0.99	1.09	0.90	17.96
MS	9.9	8.1	9.7	4.6	0.6	0.0	0.0	0.0	1.2	4.5	9.5	8.5	56.6
MXT	10.4	15.2	26.8	47.3	63.2	69.7	77.5	75.0	63.8	51.7	29.6	16.7	45.5
BASIN NUMBER 42													
MT	1.4	5.5	17.4	37.5	51.4	59.3	66.2	63.5	52.9	41.2	21.9	9.4	35.6
MP	0.62	0.70	0.93	0.83	1.57	3.26	1.95	2.15	1.38	0.83	0.96	0.78	16.16
MS	8.2	6.9	8.1	3.6	1.1	0.0	0.0	0.0	1.0	2.9	8.8	7.4	48.0
MXT	10.9	15.5	27.4	49.1	64.9	71.3	79.6	77.0	65.6	52.9	30.5	18.1	46.9

TABLE 8-1 CONTINUED

	J	F	M	A	M	J	J	A	S	O	N	D	YR
BASIN NUMBER 43													
MT	0.2	3.6	15.8	35.2	50.1	57.8	64.3	61.1	50.8	39.9	20.5	8.4	34.0
MP	0.52	0.83	0.93	1.00	1.51	3.24	2.04	2.36	1.53	C.91	0.88	0.89	17.05
MS	9.2	8.3	9.1	5.4	0.7	0.0	0.0	0.0	1.0	3.7	8.4	8.7	54.5
MXT	9.3	13.7	25.5	45.6	62.8	69.9	77.6	74.6	63.1	51.1	28.7	17.2	44.9
BASIN NUMBER 44													
MT	-1.5	3.0	15.1	35.8	50.5	58.6	65.3	62.7	51.6	40.0	20.9	7.3	34.1
MP	0.67	0.55	0.89	0.80	1.53	3.21	2.41	2.30	1.58	0.75	0.80	0.66	16.16
MS	6.6	5.5	8.1	3.2	0.7	0.0	0.0	0.0	0.5	2.2	7.1	6.5	40.4
MXT	7.3	12.6	24.8	46.0	62.5	69.9	77.3	74.7	62.6	50.5	28.6	15.8	44.4
BASIN NUMBER 45													
MT	-2.5	3.0	15.0	35.3	50.9	58.3	64.7	61.8	51.3	39.0	19.3	5.2	33.5
MP	0.79	0.67	0.93	1.02	1.44	2.72	2.30	1.88	1.62	0.99	1.04	0.74	16.13
MS	7.8	6.6	9.2	4.6	0.8	0.0	0.0	0.0	0.3	3.7	9.2	7.3	49.5
MXT	7.2	13.3	25.6	46.0	63.9	70.6	77.8	74.8	63.5	49.8	27.4	14.2	44.5
BASIN NUMBER 46													
MT	-2.8	2.9	14.8	35.2	50.8	58.2	64.7	61.6	51.2	38.9	19.1	4.9	33.3
MP	C.76	0.63	0.91	0.98	1.46	2.77	2.41	1.90	1.64	1.02	1.04	0.73	16.25
MS	7.5	6.3	9.0	4.2	0.8	0.0	0.0	0.0	0.4	3.6	9.2	7.2	48.1
MXT	7.0	13.4	26.0	46.3	64.0	70.8	78.0	74.9	63.6	49.9	27.2	14.0	44.6
BASIN NUMBER 47													
MT	-3.5	2.6	14.7	35.3	50.6	58.3	64.8	61.6	51.3	39.0	18.8	4.4	33.2
MP	0.73	0.59	0.96	1.03	1.50	2.83	2.42	1.97	1.63	1.02	1.06	0.80	16.55
MS	7.2	5.9	9.5	4.8	0.8	0.0	0.0	C.0	0.4	3.4	9.6	8.0	49.5
MXT	6.0	13.4	26.4	46.8	64.3	71.2	78.2	75.0	63.6	50.2	27.1	13.5	44.7
BASIN NUMBER 48													
MT	-4.5	2.3	14.5	35.8	51.1	59.2	66.0	62.5	51.8	39.3	18.7	4.1	33.4
MP	0.63	0.45	0.98	1.02	1.58	2.72	2.25	2.13	1.54	1.00	1.19	0.81	16.30
MS	6.2	4.5	9.6	5.4	1.2	0.0	0.0	0.0	0.2	3.0	10.9	8.1	49.1
MXT	4.5	13.2	26.6	47.3	64.7	71.9	78.6	75.1	63.4	50.0	26.8	13.4	44.6
BASIN NUMBER 49													
MT	-4.1	1.7	14.5	35.7	51.5	57.3	64.0	60.6	50.3	38.9	19.3	5.3	32.9
MP	0.65	0.65	0.94	C.99	1.77	2.54	2.94	2.51	1.52	0.98	1.08	0.83	17.40
MS	6.5	6.5	9.1	4.5	0.9	0.0	0.0	0.0	0.4	4.4	9.3	8.2	49.8
MXT	5.9	13.5	26.4	46.5	64.8	70.1	77.2	73.9	62.5	50.2	27.3	13.9	44.4
BASIN NUMBER 50													
MT	-3.3	2.5	13.9	34.2	49.4	56.8	63.2	60.4	50.0	38.4	18.5	3.1	32.3
MP	0.75	0.58	0.88	1.09	1.57	3.01	2.57	2.17	1.69	0.91	1.10	0.74	17.09
MS	7.4	5.8	8.5	6.1	1.1	0.2	0.0	0.0	0.8	3.5	10.2	7.4	51.0
MXT	6.1	13.7	25.2	45.C	61.7	68.7	75.4	72.6	61.2	48.9	26.3	10.6	43.0
BASIN NUMBER 51													
MT	-3.3	2.6	14.2	34.5	49.7	57.2	63.6	60.8	50.4	38.6	18.6	3.6	32.6
MP	0.76	0.59	0.90	1.06	1.54	2.95	2.59	2.14	1.60	0.92	1.12	0.76	17.03
MS	7.8	5.8	8.8	5.9	1.1	0.1	0.0	0.0	0.7	3.4	10.2	7.5	51.1
MXT	6.1	13.8	25.6	45.4	62.2	69.3	76.0	73.2	61.7	49.2	26.8	11.6	43.4
BASIN NUMBER 52													
MT	-3.4	2.7	14.3	34.5	49.7	57.2	63.6	60.8	50.3	38.6	18.6	3.7	32.6
MP	0.77	0.59	0.92	1.06	1.54	2.93	2.65	2.17	1.69	0.90	1.15	0.76	17.13
MS	7.7	5.9	9.0	6.1	1.1	0.1	0.0	0.0	0.8	3.4	10.6	7.5	52.1
MXT	6.C	13.9	25.8	45.5	62.2	69.3	75.9	73.1	61.5	49.2	26.5	11.9	43.4
BASIN NUMBER 53													
MT	-4.6	1.9	14.0	34.1	49.4	57.6	64.2	61.4	50.5	38.5	18.1	3.3	32.4
MP	0.84	0.63	0.98	1.06	1.54	2.72	2.77	2.29	1.83	0.95	1.29	0.86	17.78
MS	8.4	6.3	9.5	6.4	1.2	0.0	0.0	0.0	0.7	3.2	11.8	8.6	56.2
MXT	4.5	13.1	25.7	45.1	61.5	69.3	76.0	72.9	61.0	48.5	25.8	11.9	43.0
BASIN NUMBER 54													
MT	-3.3	2.1	14.7	35.6	50.6	58.3	64.6	62.5	51.4	39.5	19.2	4.6	33.3
MP	0.80	0.55	0.81	0.93	1.41	3.01	2.44	2.18	1.65	0.80	0.93	0.76	16.28
MS	8.C	5.5	7.7	5.1	0.9	0.0	0.0	0.0	0.8	2.7	8.5	7.5	46.8
MXT	6.8	13.6	26.0	46.4	63.2	70.3	77.5	76.2	63.2	50.4	27.2	13.6	44.6
BASIN NUMBER 55													
MT	-3.6	2.9	14.5	34.6	49.7	57.4	63.7	61.2	50.4	38.6	18.6	4.1	32.7
MP	0.82	0.60	0.98	1.07	1.52	2.85	2.83	2.27	1.70	0.85	1.27	0.77	17.53
MS	8.2	6.0	9.6	6.8	1.3	0.0	0.0	0.0	0.9	3.1	11.7	7.7	55.3
MXT	5.5	14.4	26.4	45.7	62.1	69.5	75.9	73.1	61.2	49.2	26.5	12.9	43.6
BASIN NUMBER 56													
MT	-3.4	2.2	14.7	35.5	50.5	58.2	64.6	62.5	51.3	39.4	19.1	4.7	33.3
MP	0.81	0.56	0.84	0.95	1.42	2.96	2.53	2.21	1.66	0.80	1.00	0.76	16.52
MS	8.1	5.6	8.1	5.4	1.0	0.0	0.0	0.0	0.8	2.7	9.2	7.6	48.6
MXT	6.5	13.9	26.2	46.4	63.1	70.3	77.4	75.8	63.0	50.3	27.2	13.8	44.5
BASIN NUMBER 57													
MT	-3.2	1.7	14.9	36.3	51.2	58.9	65.3	63.5	52.0	40.0	19.6	5.2	33.8
MP	0.81	0.53	0.73	0.85	1.33	3.06	2.28	2.16	1.63	0.76	0.78	0.76	15.68
MS	8.1	5.3	6.9	4.3	0.7	0.0	0.0	0.0	0.8	2.3	7.1	7.5	43.0
MXT	7.4	13.4	26.1	47.0	63.9	71.0	78.6	78.1	64.4	51.2	27.7	14.5	45.3
BASIN NUMBER 58													
MT	-3.3	2.1	14.7	35.6	50.6	58.3	64.7	62.6	51.4	39.5	19.2	4.7	33.4
MP	0.80	0.55	0.80	0.93	1.40	3.01	2.43	2.18	1.65	0.80	0.93	0.76	16.26
MS	8.0	5.5	7.7	5.1	0.9	0.0	0.0	0.0	0.8	2.6	8.5	7.5	46.7
MXT	6.8	13.6	26.0	46.4	63.2	70.4	77.6	76.3	63.3	50.5	27.2	13.6	44.6
BASIN NUMBER 59													
MT	-3.6	2.9	14.5	34.6	49.7	57.4	63.7	61.2	50.4	38.6	18.6	4.1	32.7
MP	0.82	0.60	0.98	1.07	1.52	2.85	2.83	2.27	1.70	0.85	1.27	0.77	17.53
MS	8.2	6.0	9.6	6.8	1.3	0.0	0.0	0.0	0.9	3.1	11.7	7.7	55.3
MXT	5.5	14.4	26.4	45.7	62.1	69.5	75.9	73.1	61.2	49.2	26.5	12.9	43.6
BASIN NUMBER 60													
MT	-3.6	2.9	14.5	34.6	49.7	57.4	63.7	61.2	50.4	38.6	18.6	4.1	32.7
MP	0.82	0.60	0.98	1.07	1.52	2.85	2.83	2.27	1.70	0.85	1.27	0.77	17.53
MS	8.2	6.0	5.6	6.8	1.3	0.0	0.0	0.0	0.9	3.1	11.7	7.7	55.3
MXT	5.5	14.4	26.4	45.7	62.1	69.5	75.9	73.1	61.2	49.2	26.5	12.9	43.6
BASIN NUMBER 61													
MT	-2.4	2.4	15.4	36.5	51.2	59.2	65.7	63.6	52.4	40.6	20.2	5.9	34.2
MP	0.85	0.57	0.82	0.89	1.45	3.21	2.32	2.22	1.67	0.82	0.83	0.79	16.44
MS	8.4	5.7	7.5	4.4	0.9	0.0	0.0	0.0	0.7	2.5	7.4	7.8	45.4
MXT	7.8	13.7	26.3	47.1	63.8	71.1	78.7	77.7	64.5	51.5	28.2	15.C	45.5
BASIN NUMBER 62													
MT	0.7	4.9	17.2	37.0	51.4	60.1	67.0	64.1	53.7	42.6	22.5	8.4	35.8
MP	0.98	0.73	1.14	1.02	1.87	3.75	2.47	2.43	1.80	1.05	1.02	0.90	19.16
MS	9.7	7.2	9.5	4.9	1.5	0.0	0.0	0.0	0.4	3.2	8.5	8.8	53.8
MXT	9.2	14.8	27.0	47.3	63.5	71.5	79.0	76.3	64.6	52.7	29.9	16.8	46.0
BASIN NUMBER 63													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.45
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.6
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1

	J	F	M	A	M	J	J	A	S	O	N	D	YR
BASIN NUMBER 64													
MT	0.7	4.9	17.3	37.0	51.2	60.3	66.8	64.2	53.7	42.4	22.7	8.7	35.9
MP	0.96	0.70	1.09	1.00	1.90	3.62	2.62	2.49	1.74	1.15	1.05	0.92	19.26
MS	9.6	6.9	9.6	4.6	1.5	0.0	0.0	0.0	0.3	3.7	8.8	9.1	54.0
MXT	9.2	14.6	26.9	47.1	63.2	71.3	78.6	75.9	64.6	52.4	30.2	17.0	45.9
BASIN NUMBER 65													
MT	0.7	4.9	17.1	36.9	51.3	60.0	66.9	64.0	53.5	42.5	22.5	8.5	35.8
MP	0.94	0.72	1.12	1.01	1.88	3.75	2.47	2.43	1.78	1.04	0.99	0.86	19.01
MS	9.3	7.1	9.3	4.8	1.5	0.0	0.0	0.0	0.4	3.1	8.2	8.5	52.2
MXT	9.1	14.6	26.8	47.2	63.4	71.4	78.8	76.0	64.6	52.6	29.9	16.9	45.9
BASIN NUMBER 66													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.46
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.7
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1
BASIN NUMBER 67													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.46
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.7
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1
BASIN NUMBER 68													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.46
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.7
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1
BASIN NUMBER 69													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.46
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.7
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1
BASIN NUMBER 70													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.46
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.7
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1
BASIN NUMBER 71													
MT	1.0	5.2	17.4	37.1	51.4	60.2	67.1	64.2	53.8	42.8	22.7	8.7	36.0
MP	0.99	0.75	1.17	1.04	1.92	3.81	2.49	2.45	1.81	1.08	1.04	0.91	19.46
MS	9.8	7.4	9.7	5.0	1.6	0.0	0.0	0.0	0.4	3.3	8.6	8.9	54.7
MXT	9.4	14.9	27.1	47.3	63.5	71.5	79.0	76.2	64.8	52.8	30.1	17.0	46.1
BASIN NUMBER 72													
MT	0.8	4.4	17.5	37.3	51.4	60.7	66.9	64.7	53.8	41.8	22.8	9.2	36.0
MP	0.94	0.61	0.95	0.98	1.85	3.36	2.81	2.54	1.66	1.23	1.02	0.91	18.86
MS	9.4	5.8	9.3	3.7	1.0	0.0	0.0	0.0	0.1	3.9	8.3	9.1	50.6
MXT	9.7	14.3	27.1	47.6	63.3	71.3	78.5	76.1	64.4	52.1	30.7	17.7	46.2
BASIN NUMBER 73													
MT	0.9	4.2	17.2	37.3	50.7	59.8	66.0	63.3	52.9	41.2	22.3	8.8	35.3
MP	0.80	0.66	0.99	0.87	1.94	3.28	2.90	2.47	1.57	1.14	0.87	0.79	18.27
MS	8.0	6.5	9.0	3.2	1.2	0.0	0.0	0.0	0.3	4.4	7.3	7.9	47.9
MXT	10.2	14.2	26.8	47.2	63.C	70.6	78.1	75.4	64.3	51.7	30.2	17.4	45.8
BASIN NUMBER 74													
MT	0.2	4.3	17.2	36.8	50.9	60.4	66.3	64.1	53.6	41.8	22.6	8.7	35.6
MP	0.92	0.61	0.94	0.93	1.86	3.26	2.85	2.58	1.63	1.28	1.08	0.95	18.91
MS	9.2	5.9	9.3	3.9	1.4	0.0	0.0	0.0	0.1	4.5	9.1	9.5	52.8
MXT	8.9	14.0	26.5	46.7	62.7	71.0	77.9	75.4	64.1	51.8	30.4	17.1	45.6
BASIN NUMBER 75													
MT	-0.6	3.2	15.2	34.9	50.0	57.7	64.2	61.2	50.7	39.7	20.5	7.9	33.7
MP	0.92	0.82	0.99	1.01	1.52	3.25	2.15	2.37	1.58	C.90	0.89	0.90	17.29
MS	9.2	8.2	9.8	5.4	0.7	0.0	0.0	0.0	1.0	3.6	8.5	8.9	55.3
MXT	8.2	13.1	24.7	44.9	62.2	69.5	76.9	74.1	62.3	50.4	28.3	16.5	44.2
BASIN NUMBER 76													
MT	0.0	3.1	15.2	36.3	50.1	57.3	64.3	61.3	51.1	40.3	20.2	6.4	33.8
MP	0.81	0.63	0.93	1.02	1.71	2.94	2.16	2.22	1.57	0.85	1.04	0.75	16.63
MS	8.0	6.3	8.7	4.5	1.1	0.1	0.0	0.0	C.3	3.1	9.5	7.3	49.0
MXT	9.3	13.5	25.6	47.0	62.4	69.4	77.0	74.0	62.9	51.2	28.4	14.5	44.7
BASIN NUMBER 77													
MT	-3.1	2.1	13.4	33.8	49.1	56.3	62.7	59.7	49.7	38.3	18.4	2.2	31.9
MP	0.68	0.56	0.80	1.10	1.62	3.15	2.34	2.08	1.68	0.97	0.96	0.76	16.70
MS	6.7	5.6	7.5	5.5	1.0	0.3	0.0	C.0	0.7	3.9	8.8	7.2	47.2
MXT	6.7	13.0	24.2	44.4	61.4	68.0	75.0	72.2	61.2	48.7	26.1	8.5	42.5
BASIN NUMBER 78													
MT	-3.2	1.9	14.2	35.2	50.3	57.8	64.2	61.8	51.0	39.3	19.1	3.9	33.0
MP	0.75	0.54	0.76	0.96	1.46	3.10	2.31	2.13	1.65	0.85	0.86	0.76	16.12
MS	7.5	5.4	7.2	4.8	0.8	0.1	0.0	0.0	0.8	3.0	7.8	7.4	44.8
MXT	7.1	13.2	25.3	45.9	62.8	69.7	77.0	75.5	63.0	50.1	27.0	11.9	44.1
BASIN NUMBER 79													
MT	-3.0	1.8	14.7	36.1	51.0	58.8	65.2	63.2	51.8	40.0	19.8	5.6	33.8
MP	0.74	0.52	0.72	0.81	1.36	3.09	2.28	2.18	1.61	0.74	0.72	0.68	15.45
MS	7.3	5.2	6.7	3.9	0.6	0.0	0.0	0.0	0.6	2.1	6.5	6.7	39.6
MXT	7.2	13.1	25.7	46.8	63.6	70.8	78.3	77.3	64.0	51.2	27.8	14.8	45.1
BASIN NUMBER 80													
MT	-3.2	1.7	14.9	36.3	51.2	58.9	65.3	63.5	52.0	40.0	19.6	5.2	33.8
MP	0.81	0.53	0.73	0.85	1.33	3.06	2.28	2.16	1.63	0.76	0.78	0.76	15.68
MS	8.1	5.3	6.9	4.3	0.7	0.0	0.0	0.0	0.8	2.3	7.1	7.5	43.0
MXT	7.4	13.4	26.1	47.C	63.9	71.0	78.6	78.1	64.4	51.2	27.7	14.5	45.3
BASIN NUMBER 81													
MT	-1.7	2.9	15.0	35.8	50.4	58.6	65.2	62.4	51.6	40.3	20.8	7.0	34.1
MP	0.59	0.51	0.76	0.78	1.57	3.34	2.49	2.35	1.59	0.77	0.67	0.54	15.97
MS	5.8	5.1	6.6	3.0	0.7	0.0	0.0	0.0	0.1	2.0	5.7	5.3	34.3
MXT	7.0	12.7	25.1	46.4	62.9	70.2	77.6	74.9	63.3	51.4	28.5	15.5	44.7
BASIN NUMBER 82													
MT	1.1	4.4	17.1	37.3	50.8	59.0	66.0	63.1	52.6	41.2	22.1	8.3	35.3
MP	0.78	0.70	1.05	0.89	1.96	3.49	2.82	2.42	1.61	1.02	0.80	0.74	18.27
MS	7.8	6.9	8.9	3.5	1.2	0.0	0.0	0.0	0.4	3.9	6.8	7.3	46.8
MXT	10.2	14.4	27.0	47.3	63.3	70.5	78.3	75.6	64.5	51.9	29.9	17.0	45.8
BASIN NUMBER 83													
MT	1.5	4.3	17.2	37.6	50.7	58.8	65.9	62.8	52.4	40.9	22.1	8.4	35.2
MP	0.73	0.70	1.04	0.85	2.00	3.35	2.89	2.38	1.54	1.02	0.71	0.69	17.91
MS	7.3	7.0	8.9	2.9	1.1	0.0	0.0	0.0	0.5	4.3	6.1	6.8	44.9
MXT	11.0	14.4	27.1	47.5	63.3	70.4	78.4	75.5	64.5	51.7	30.1	17.5	46.0
BASIN NUMBER 84													
MT	-0.9	3.7	16.2	36.2	50.7	58.4	65.0	62.7	52.0	40.5	20.9	6.8	34.4
MP	0.70	0.54	0.81	0.89	1.75	3.64	3.09	2.63	1.60	0.92	0.88	0.69	18.14
MS	6.9	5.3	7.5	3.7	1.0	0.0	0.0	0.0	0.2	3.3	7.5	6.8	42.2
MXT	7.1	13.3	26.2	46.5	63.0	70.0	77.4	75.3	64.0	51.5	28.3	14.4	44.8

TABLE B-1 CONTINUED

	J	F	M	A	M	J	J	A	S	O	N	D	YR
BASIN NUMBER 85													
MT	1.7	6.0	17.6	37.6	51.5	59.1	66.8	63.5	52.5	41.8	22.4	10.3	35.9
MP	1.04	0.69	1.36	0.83	1.72	3.86	2.81	2.46	1.47	0.81	1.01	1.00	19.07
MS	10.3	6.8	13.3	3.0	1.3	0.0	0.0	0.0	0.0	2.3	9.1	10.0	56.2
MXT	11.2	16.0	28.1	47.7	63.3	69.8	78.7	75.3	64.3	52.7	30.6	19.5	46.4
BASIN NUMBER 86													
MT	1.7	5.9	17.6	37.7	51.5	59.1	66.8	63.6	52.6	41.9	22.4	10.3	35.9
MP	1.02	0.69	1.34	0.85	1.74	3.87	2.80	2.48	1.47	0.83	1.00	0.98	19.09
MS	10.1	6.8	13.0	3.1	1.3	0.0	0.0	0.0	0.0	2.4	9.0	9.8	55.5
MXT	11.2	15.9	28.1	47.8	63.4	70.0	78.7	75.5	64.5	52.9	30.7	19.5	46.5
BASIN NUMBER 87													
MT	-0.5	3.8	16.6	36.6	51.0	58.9	65.6	63.2	52.5	40.8	21.2	7.2	34.8
MP	0.73	0.62	0.86	0.88	1.79	3.67	3.05	2.52	1.58	0.92	0.92	0.75	18.30
MS	7.2	6.1	7.9	3.5	1.0	0.0	0.0	0.0	0.2	3.2	7.9	7.4	44.4
MXT	7.6	13.3	26.4	46.7	63.0	70.1	77.6	75.3	64.0	51.4	28.6	14.9	44.9
BASIN NUMBER 88													
MT	1.0	4.9	18.2	38.1	52.3	60.9	67.4	64.5	53.6	41.6	22.6	8.2	36.1
MP	0.76	0.55	1.05	1.05	1.97	3.58	2.90	2.51	1.60	1.06	0.82	0.81	18.67
MS	7.6	5.5	9.0	3.9	0.8	0.0	0.0	0.0	0.3	3.5	6.9	8.0	45.6
MXT	10.2	15.6	28.5	49.4	65.3	72.9	80.6	77.6	66.2	53.4	30.9	17.3	47.3
BASIN NUMBER 89													
MT	0.9	4.3	17.7	37.9	51.8	60.5	67.1	64.4	53.6	41.6	22.5	8.5	35.9
MP	0.82	0.59	1.00	1.01	1.95	3.48	2.87	2.53	1.62	1.07	0.86	0.80	19.61
MS	8.2	5.8	9.0	3.8	0.8	0.0	0.0	0.0	0.2	3.7	7.1	8.0	46.5
MXT	10.1	14.7	27.7	48.7	64.4	72.0	79.7	77.1	65.6	52.9	30.7	17.5	46.8
BASIN NUMBER 90													
MT	0.1	4.1	17.7	38.0	52.4	61.7	68.3	66.0	55.1	43.2	23.3	8.7	36.5
MP	1.03	0.82	1.08	1.17	1.97	3.19	2.71	2.76	2.16	1.44	1.14	0.88	20.35
MS	10.2	7.9	8.1	3.9	1.0	0.0	0.0	0.0	0.2	2.7	8.8	8.5	51.3
MXT	8.8	13.5	26.7	47.5	64.1	72.6	79.7	77.5	65.6	52.6	30.3	16.1	46.2
BASIN NUMBER 91													
MT	4.9	8.0	19.6	38.2	51.3	58.6	65.9	63.6	53.3	41.3	22.6	13.5	36.7
MP	0.66	0.56	0.74	0.97	1.65	3.28	2.24	2.02	1.37	0.73	0.60	0.63	15.45
MS	6.4	5.5	6.4	3.4	0.3	0.0	0.0	0.0	0.6	2.1	4.9	6.2	35.8
MXT	13.2	17.0	28.4	49.4	64.2	71.0	80.1	77.7	66.2	53.6	32.3	22.7	47.9
BASIN NUMBER 92													
MT	1.6	5.6	17.9	38.1	51.4	59.2	66.1	63.4	53.1	41.0	22.1	10.0	35.8
MP	0.63	0.59	0.68	0.79	1.46	3.14	2.32	1.93	1.28	0.69	0.64	0.56	14.74
MS	6.3	5.8	6.0	2.8	0.3	0.0	0.0	0.0	0.5	1.8	5.8	5.4	34.8
MXT	11.2	15.8	27.9	49.8	65.1	72.2	80.5	78.2	67.3	54.3	31.6	19.2	47.8
BASIN NUMBER 93													
MT	4.0	7.7	19.8	38.9	52.2	59.7	66.9	64.4	53.9	42.0	23.3	12.2	37.1
MP	0.74	0.64	0.84	0.87	1.60	3.20	2.21	2.16	1.21	0.85	0.71	0.64	15.69
MS	7.3	6.3	7.5	3.5	0.5	0.0	0.0	0.0	0.5	2.5	6.0	6.3	40.4
MXT	13.6	17.6	29.4	50.5	65.5	72.2	81.2	78.8	67.6	54.9	33.2	22.0	48.9
BASIN NUMBER 94													
MT	5.7	9.5	21.5	39.8	53.3	60.9	68.5	66.0	55.1	43.8	25.6	14.2	38.7
MP	0.49	0.48	0.67	0.83	1.59	3.28	2.11	1.86	1.30	0.91	0.65	0.54	14.71
MS	5.5	5.2	5.6	3.3	0.6	0.0	0.0	0.0	0.2	3.3	5.9	5.9	35.7
MXT	14.5	18.4	30.3	50.5	65.3	72.2	81.2	78.6	66.9	55.2	34.3	22.8	49.2
BASIN NUMBER 95													
MT	1.6	5.3	17.0	36.4	50.2	57.9	65.2	62.2	51.5	40.1	21.8	9.5	34.9
MP	0.78	0.63	0.96	0.91	1.73	3.92	2.35	2.54	1.72	1.02	0.98	0.73	18.26
MS	7.8	6.2	8.9	4.2	1.1	0.0	0.0	0.0	0.8	4.1	8.9	7.0	49.2
MXT	11.1	15.6	27.4	47.1	62.7	69.4	77.7	74.7	63.3	51.2	30.3	18.5	45.8
BASIN NUMBER 96													
MT	0.6	5.3	17.7	37.6	51.4	58.9	66.0	63.5	52.8	41.2	22.2	8.9	35.5
MP	0.66	0.56	0.74	0.82	1.65	3.26	2.15	2.39	1.10	0.92	0.79	0.61	15.66
MS	6.6	5.6	6.4	3.9	0.5	0.0	0.0	0.0	0.3	2.7	7.3	6.0	39.7
MXT	9.9	15.0	27.5	48.7	64.6	70.7	79.5	77.1	65.9	53.3	31.3	17.9	46.8
BASIN NUMBER 97													
MT	0.7	5.0	17.7	37.4	51.9	59.6	66.8	64.0	53.3	41.5	22.2	9.5	35.8
MP	0.86	0.70	1.00	0.90	1.82	3.44	2.53	2.38	1.22	0.78	0.84	0.80	17.27
MS	8.5	6.9	9.0	3.5	0.7	0.0	0.0	0.0	0.2	2.0	7.4	8.0	46.3
MXT	10.4	15.1	27.9	48.5	64.7	71.3	79.5	77.0	66.3	53.5	31.2	18.6	47.1
BASIN NUMBER 98													
MT	0.3	4.4	17.9	38.5	52.4	60.4	67.1	64.7	54.1	41.8	22.4	9.5	36.1
MP	0.85	0.78	0.94	1.01	2.01	3.36	2.51	2.39	1.17	0.78	0.79	0.78	17.36
MS	8.4	7.7	7.8	3.9	0.5	0.0	0.0	0.0	0.2	1.6	6.7	7.7	44.5
MXT	10.4	14.8	28.1	50.0	65.7	72.7	80.4	78.3	67.9	54.4	31.8	18.9	47.8
BASIN NUMBER 99													
MT	1.8	6.3	19.2	38.0	52.3	60.6	67.4	65.2	54.1	42.6	23.7	10.6	36.8
MP	0.90	0.66	1.11	1.13	2.04	3.66	2.58	2.72	1.63	1.07	0.94	0.90	19.37
MS	8.9	6.5	9.9	4.1	0.6	0.0	0.0	0.0	0.2	3.0	7.1	8.7	49.2
MXT	11.1	16.7	29.5	49.2	64.9	72.1	79.5	77.6	65.8	53.5	31.7	19.2	47.6
BASIN NUMBER 1CC													
MT	3.1	7.0	19.4	38.5	52.6	60.9	67.5	64.5	53.8	42.4	23.8	10.6	37.0
MP	0.97	0.53	1.17	1.03	2.09	3.92	2.80	2.60	1.56	1.23	0.94	0.89	19.45
MS	9.7	5.1	10.2	4.2	2.4	0.0	0.0	0.0	0.4	3.6	7.7	8.8	52.0
MXT	12.0	16.7	29.2	49.4	65.3	72.6	80.1	77.1	65.7	53.2	31.8	19.3	47.7
BASIN NUMBER 1C1													
MT	3.0	7.3	19.7	38.4	52.2	60.4	67.2	64.5	54.4	43.2	24.2	11.5	37.2
MP	0.83	0.45	0.97	0.98	2.11	3.81	2.33	2.82	1.46	1.12	0.88	0.71	18.48
MS	9.7	5.1	8.9	4.4	2.1	0.0	0.0	0.0	0.4	3.6	7.4	7.7	49.5
MXT	11.9	13.3	29.0	49.1	64.5	71.7	79.4	77.1	66.0	53.7	31.9	19.7	47.5
BASIN NUMBER 102													
MT	3.0	7.3	20.0	38.5	51.9	60.5	67.2	64.9	54.7	43.2	23.9	11.1	37.2
MP	0.39	0.24	0.60	0.85	1.82	3.44	2.52	2.68	1.32	0.87	0.54	0.34	15.61
MS	7.7	4.4	5.6	3.1	0.5	0.0	0.0	0.0	0.3	2.9	5.3	5.2	35.1
MXT	12.2	17.3	30.0	49.6	64.5	72.0	79.4	77.5	66.6	54.0	31.8	19.5	47.8
BASIN NUMBER 1C3													
MT	3.4	7.5	19.6	38.6	52.5	60.5	67.3	64.7	54.4	43.4	24.6	12.1	37.4
MP	1.18	0.53	1.22	1.03	2.36	4.18	2.11	2.96	1.52	1.35	1.15	0.94	20.53
MS	11.8	5.0	11.3	5.6	4.0	0.0	0.0	0.0	0.6	4.5	9.3	9.3	61.4
MXT	12.1	15.8	28.3	49.0	64.6	71.6	79.5	76.8	65.8	53.7	32.1	20.2	47.5
BASIN NUMBER 104													
MT	3.4	7.5	19.6	38.6	52.5	60.5	67.3	64.7	54.4	43.4	24.6	12.1	37.4
MP	1.18	0.53	1.22	1.03	2.36	4.18	2.11	2.96	1.52	1.35	1.15	0.94	20.53
MS	11.8	5.0	11.3	5.6	4.0	0.0	0.0	0.0	0.6	4.5	9.3	9.3	61.4
MXT	12.1	15.8	28.3	49.0	64.6	71.6	79.5	76.8	65.8	53.7	32.1	20.2	47.5
BASIN NUMBER 1C5													
MT	2.9	7.2	20.0	38.5	51.9	60.6	67.2	65.0	54.7	43.2	23.8	11.0	37.2
MP	0.42	0.26	0.62	0.87	1.83	3.41	2.53	2.69	1.36	0.89	0.56	0.36	15.81
MS	7.7	4.5	5.7	3.1	0.5	0.0	0.0	0.0	0.3	2.9	5.4	5.2	35.4
MXT	11.2	16.1	23.9	48.9	64.4	72.1	79.6	77.3	66.2	53.4	31.0	18.7	47.3

	J	F	M	A	M	J	J	A	S	O	N	D	YR
BASIN NUMBER 106													
MT	2.8	7.1	19.9	38.5	52.0	60.7	67.3	65.1	54.8	43.1	23.7	10.8	37.2
MP	0.47	0.31	0.66	0.92	1.85	3.36	2.55	2.71	1.45	0.94	0.60	0.39	16.22
MS	7.8	4.7	6.0	3.2	0.5	0.0	0.0	0.0	0.3	2.8	5.5	5.2	36.0
MXT	11.3	16.3	29.2	49.1	64.5	72.2	79.7	77.5	66.4	53.5	31.0	18.7	47.4
BASIN NUMBER 1C7													
MT	1.9	6.2	19.7	38.4	52.5	61.3	67.8	65.9	55.3	42.9	22.9	9.6	37.0
MP	0.76	0.55	0.90	1.20	1.97	3.07	2.65	2.84	1.91	1.21	0.84	0.57	18.45
MS	8.0	5.6	7.4	3.7	0.7	0.0	0.0	0.0	0.2	2.2	6.2	5.4	39.4
MXT	10.1	15.0	28.5	48.7	64.9	72.8	80.2	78.2	66.7	53.1	30.0	17.3	47.1
BASIN NUMBER 108													
MT	1.9	6.2	19.7	38.4	52.5	61.3	67.8	65.9	55.3	42.9	22.9	9.6	37.0
MP	0.76	0.55	0.90	1.20	1.97	3.07	2.65	2.84	1.92	1.21	0.84	0.57	18.48
MS	8.0	5.6	7.4	3.7	0.7	0.0	0.0	0.0	0.2	2.2	6.2	5.4	39.5
MXT	1C.1	15.0	25.5	48.7	64.9	72.8	80.2	78.2	66.7	53.1	30.0	17.3	47.1
BASIN NUMBER 109													
MT	1.9	6.1	19.2	38.6	52.5	61.8	67.6	65.1	54.8	43.6	24.4	9.2	37.1
MP	0.68	0.57	0.96	1.37	2.11	3.05	3.00	3.16	2.41	1.40	0.97	0.64	20.32
MS	9.7	7.7	9.3	4.2	0.7	0.0	0.0	0.0	0.0	1.4	7.2	8.0	48.3
MXT	12.9	17.8	31.2	49.8	65.5	74.2	81.1	78.6	67.0	54.7	32.6	18.7	48.7
BASIN NUMBER 110													
MT	1.9	6.1	19.1	38.5	52.4	61.8	67.6	65.1	54.8	43.6	24.4	9.2	37.0
MP	0.68	0.57	0.97	1.37	2.11	3.06	3.01	3.18	2.39	1.40	0.98	0.64	20.35
MS	9.7	7.7	9.3	4.2	0.7	0.0	0.0	0.0	0.0	1.4	7.2	8.0	48.2
MXT	12.9	17.9	31.2	49.8	65.5	74.3	81.1	78.6	67.0	54.8	32.7	18.7	48.7
BASIN NUMBER 111													
MT	1.9	6.1	19.1	38.6	52.5	61.8	67.7	65.1	54.8	43.6	24.4	9.2	37.1
MP	0.68	0.57	0.96	1.37	2.11	3.06	3.01	3.17	2.40	1.40	0.97	0.64	20.35
MS	9.7	7.7	9.3	4.2	0.7	0.0	0.0	0.0	0.0	1.4	7.2	8.0	48.2
MXT	12.9	17.9	31.2	49.9	65.6	74.3	81.2	78.6	67.0	54.8	32.7	18.7	48.8
BASIN NUMBER 112													
MT	0.1	4.4	17.3	37.3	30.7	60.0	65.8	63.0	52.9	41.7	22.9	7.7	35.3
MP	0.98	0.81	1.11	1.37	2.02	3.06	2.92	3.51	2.28	1.44	1.19	0.86	21.55
MS	9.7	7.7	9.3	4.2	0.7	0.0	0.0	0.0	0.0	1.4	7.2	8.0	48.2
MXT	11.1	16.2	29.4	48.6	63.8	72.5	79.3	76.5	65.1	52.9	31.2	17.2	47.0
BASIN NUMBER 113													
MT	2.9	7.7	20.6	39.0	53.3	62.8	69.5	66.9	56.4	44.3	24.8	10.9	38.3
MP	1.C9	0.82	1.29	1.28	2.12	3.04	2.76	2.67	1.79	1.30	1.14	0.92	20.22
MS	10.9	7.5	10.3	4.3	0.5	0.0	0.0	0.0	0.3	2.3	8.2	8.8	53.1
MXT	11.1	16.5	29.4	49.3	65.7	74.3	81.9	79.2	67.8	54.5	31.9	18.6	48.4
BASIN NUMBER 114													
MT	2.6	7.2	19.0	38.0	51.4	61.3	68.1	65.6	54.1	44.1	24.8	11.3	37.3
MP	0.98	0.73	1.39	1.11	2.28	3.66	2.78	2.67	2.31	1.33	1.30	0.74	21.29
MS	9.7	7.1	11.5	4.2	1.2	0.0	0.0	0.0	0.3	2.8	10.4	7.3	54.6
MXT	10.4	16.2	27.9	47.5	62.9	72.2	79.6	77.0	64.7	53.9	31.4	19.0	46.9
BASIN NUMBER 115													
MT	2.7	7.3	19.0	38.0	51.4	61.3	68.0	65.6	54.0	44.3	24.9	11.4	37.4
MP	0.98	0.74	1.41	1.11	2.32	3.69	2.81	2.71	2.33	1.33	1.32	0.74	21.50
MS	9.7	7.2	11.7	4.3	1.3	0.0	0.0	0.0	0.3	2.9	10.6	7.2	55.0
MXT	10.5	16.3	27.9	47.5	62.7	72.0	79.5	77.0	64.6	54.0	31.4	19.1	46.9
BASIN NUMBER 116													
MT	2.4	7.1	19.1	38.1	51.6	61.4	68.1	65.6	54.1	44.0	24.7	11.1	37.3
MP	0.99	0.72	1.37	1.11	2.22	3.60	2.73	2.61	2.27	1.31	1.26	0.75	20.94
MS	9.7	7.0	11.3	4.2	1.2	0.0	0.0	0.0	0.2	2.7	10.1	7.3	53.8
MXT	10.2	16.0	27.9	47.7	63.2	72.4	79.8	77.1	65.0	53.8	31.3	18.7	46.9
BASIN NUMBER 117													
MT	0.1	4.1	17.6	37.7	52.0	61.5	68.2	65.9	54.9	43.1	23.3	8.5	36.4
MP	0.96	0.78	1.06	1.20	1.99	3.14	2.70	2.68	2.13	1.42	1.04	0.81	19.92
MS	9.5	7.6	8.0	4.1	0.8	0.0	0.0	0.0	0.2	2.2	8.3	7.7	48.4
MXT	9.1	13.9	27.2	47.3	63.7	72.3	79.5	77.2	65.3	52.5	30.4	16.1	46.2
BASIN NUMBER 118													
MT	0.1	4.1	17.5	37.6	52.0	61.5	68.2	65.9	54.9	43.1	23.3	8.5	36.4
MP	0.95	0.78	1.06	1.20	1.99	3.13	2.69	2.66	2.13	1.42	1.02	0.80	19.84
MS	9.4	7.6	8.0	4.1	0.8	0.0	0.0	0.0	0.1	2.1	8.2	7.5	47.8
MXT	9.1	14.0	27.3	47.2	63.6	72.3	79.4	77.1	65.2	52.4	30.5	16.1	46.1
BASIN NUMBER 119													
MT	-1.1	3.4	16.2	36.3	50.3	60.3	67.0	64.1	53.8	42.2	23.0	7.2	35.2
MP	0.94	0.72	0.86	0.99	2.00	3.32	2.92	2.86	2.27	1.73	1.40	0.99	21.00
MS	9.4	6.6	6.6	4.2	1.4	0.0	0.0	0.0	0.0	2.4	11.1	9.7	51.4
MXT	7.3	12.7	25.9	45.2	60.9	70.1	77.3	74.0	62.6	50.4	29.5	15.1	44.2
BASIN NUMBER 120													
MT	-1.1	3.4	16.2	36.3	50.3	60.3	67.0	64.1	53.8	42.2	23.0	7.2	35.2
MP	0.94	0.72	0.86	0.99	2.00	3.32	2.92	2.86	2.27	1.73	1.40	0.99	21.00
MS	9.4	6.6	6.6	4.2	1.4	0.0	0.0	0.0	0.0	2.4	11.1	9.7	51.4
MXT	7.3	12.7	25.9	45.2	60.9	70.1	77.3	74.0	62.6	50.4	29.5	15.1	44.2
BASIN NUMBER 121													
MT	-0.2	4.0	16.9	36.4	50.5	60.4	66.7	64.0	53.5	42.2	23.1	7.5	35.5
MP	1.C6	0.89	1.14	1.32	2.02	3.08	3.07	3.04	2.26	1.45	1.18	0.92	21.40
MS	10.6	8.2	9.4	4.8	0.5	0.0	0.0	0.0	0.0	1.1	8.3	8.7	51.7
MXT	11.2	16.7	29.6	47.3	62.5	71.7	78.5	75.7	64.1	52.1	30.9	16.9	46.4
BASIN NUMBER 122													
MT	0.0	4.3	17.0	36.4	50.6	60.9	67.8	65.0	54.3	42.8	23.5	7.9	35.9
MP	0.70	0.65	0.99	1.30	2.06	2.96	2.65	2.36	2.02	1.36	0.67	0.56	18.28
MS	7.0	6.5	7.7	4.7	0.0	0.1	0.0	0.0	0.0	0.2	6.5	4.6	37.3
MXT	10.1	15.6	29.0	46.4	62.2	71.2	78.6	75.9	64.0	51.9	31.0	16.2	46.0
BASIN NUMBER 123													
MT	0.0	4.3	17.0	36.4	50.6	60.9	67.8	65.0	54.3	42.8	23.5	7.9	35.9
MP	0.70	0.65	0.99	1.30	2.06	2.96	2.65	2.36	2.02	1.36	0.67	0.56	18.28
MS	7.0	6.5	7.7	4.7	0.0	0.1	0.0	0.0	0.0	0.2	6.5	4.6	37.3
MXT	10.1	15.6	29.0	46.4	62.2	71.2	78.6	75.9	64.0	51.9	31.0	16.2	46.0
BASIN NUMBER 124													
MT	-1.1	3.4	16.2	36.3	50.3	60.3	67.0	64.1	53.8	42.2	23.0	7.2	35.2
MP	0.94	0.72	0.86	0.99	2.C0	3.32	2.92	2.86	2.27	1.73	1.40	0.99	21.00
MS	9.4	6.6	6.6	4.2	1.4	0.0	0.0	0.0	0.0	2.4	11.1	9.7	51.4
MXT	7.3	12.7	25.9	45.2	60.9	70.1	77.3	74.0	62.6	50.4	29.5	15.1	44.2
BASIN NUMBER 125													
MT	-1.1	3.4	16.2	36.3	50.3	60.3	67.0	64.1	53.8	42.2	23.0	7.2	35.2
MP	0.94	0.72	0.86	0.99	2.00	3.32	2.92	2.86	2.27	1.73	1.40	0.99	21.00
MS	9.4	6.6	6.6	4.2	1.4	0.0	0.0	0.0	0.0	2.4	11.1	9.7	51.4
MXT	7.3	12.7	25.9	45.2	60.9	70.1	77.3	74.0	62.6	50.4	29.5	15.1	44.2
BASIN NUMBER 126													
MT	-1.1	3.4	16.2	36.3	50.3	60.3	67.0	64.1	53.8	42.2	23.0	7.2	35.2
MP	0.94	0.72	0.86	0.99	2.00	3.32	2.92	2.86	2.27	1.73	1.40	0.99	21.00
MS	9.4	6.6	6.6	4.2	1.4	0.0	0.0	0.0	0.0	2.4	11.1	9.7	51.4
MXT	7.3	12.7	25.9	45.2	60.9	70.1	77.3	74.0	62.6	50.4	29.5	15.1	44.2

TABLE 8-1 CONTINUED

	J	F	M	A	M	J	J	A	S	O	N	D	YR
BASIN NUMBER 127													
MT	-1.1	3.4	16.2	36.3	50.3	60.3	67.0	64.1	53.8	42.2	23.0	7.2	35.2
MP	0.94	0.72	0.86	0.99	2.00	3.32	2.92	2.86	2.27	1.73	1.40	0.99	21.00
MS	9.4	6.6	6.6	4.2	1.4	0.0	0.0	0.0	0.0	2.4	11.1	9.7	51.4
MXT	7.3	12.7	25.9	45.2	60.9	70.1	77.3	74.0	62.6	50.4	29.5	15.1	44.2
BASIN NUMBER 128													
MT	0.4	5.5	17.2	36.3	49.8	56.5	61.9	58.6	49.0	38.8	19.8	6.6	33.3
MP	0.68	0.54	0.71	0.83	1.42	2.71	2.57	2.40	1.57	0.78	0.87	0.80	15.89
MS	6.7	5.4	6.7	4.7	1.1	0.0	0.0	0.0	0.6	3.9	7.9	7.8	44.7
MXT	10.5	17.1	28.7	47.9	63.1	69.7	74.9	71.6	61.3	49.8	28.4	16.1	44.9
BASIN NUMBER 129													
MT	0.5	5.5	17.4	36.3	50.0	57.1	61.9	58.7	49.3	38.9	20.5	7.2	33.6
MP	0.69	0.57	0.69	0.85	1.40	2.72	2.50	2.41	1.55	0.73	0.90	0.80	15.82
MS	6.8	5.6	6.6	5.0	1.2	0.0	0.0	0.0	0.5	4.0	8.1	7.8	45.7
MXT	10.3	16.9	28.7	47.6	62.8	70.0	74.4	71.1	61.2	49.4	28.7	16.3	44.8
BASIN NUMBER 130													
MT	11.8	16.1	24.7	37.6	47.9	53.6	58.7	56.0	49.2	40.0	26.2	15.9	36.4
MP	0.84	0.73	0.97	1.19	2.09	3.59	2.89	3.11	1.78	1.09	0.96	0.89	20.14
MS	8.1	7.3	9.1	7.5	1.0	0.0	0.0	0.0	1.3	5.4	8.4	8.2	56.2
MXT	23.0	29.0	36.9	51.0	62.5	67.3	73.4	71.0	63.6	52.8	36.8	26.5	49.5
BASIN NUMBER 131													
MT	10.0	14.9	24.1	37.4	48.0	53.7	58.7	56.1	48.9	39.2	24.8	14.1	35.8
MP	0.93	0.74	0.96	1.12	2.07	3.59	3.30	3.14	1.70	1.03	1.00	0.94	20.51
MS	9.0	7.3	9.0	7.1	0.9	0.0	0.0	0.0	1.4	5.8	8.5	8.6	57.5
MXT	20.7	27.4	36.4	50.6	62.4	67.4	73.4	70.8	63.1	52.0	35.0	23.8	48.6
BASIN NUMBER 132													
MT	8.4	13.8	23.6	37.2	48.2	53.9	58.7	56.2	48.7	38.4	23.5	12.5	35.3
MP	1.00	0.75	0.95	1.06	2.05	3.59	3.66	3.16	1.63	0.98	1.03	0.99	20.85
MS	9.8	7.3	8.8	6.8	0.8	0.0	0.0	0.0	1.5	6.1	8.6	9.0	58.7
MXT	18.7	26.1	35.9	50.2	62.3	67.5	73.0	70.6	62.6	51.2	33.4	21.5	47.8
BASIN NUMBER 133													
MT	9.2	14.3	23.3	36.4	47.2	52.9	57.8	55.2	48.0	38.3	24.0	13.4	35.0
MP	0.59	0.79	1.02	1.13	2.13	3.72	3.49	3.12	1.63	0.99	1.01	0.94	20.97
MS	9.7	7.8	9.7	8.0	2.4	0.2	0.1	0.1	2.0	6.7	8.8	8.6	64.2
MXT	19.3	26.2	35.4	49.1	60.8	66.2	72.1	69.4	61.8	50.7	33.8	22.4	47.3
BASIN NUMBER 134													
MT	8.6	13.6	23.2	37.1	48.2	53.5	58.5	56.2	48.8	38.9	24.1	13.2	35.4
MP	0.59	0.77	0.95	1.10	2.05	3.60	3.53	3.05	1.57	0.96	0.94	0.90	20.38
MS	9.7	7.5	8.9	6.8	2.0	0.2	0.0	0.1	1.5	6.2	8.0	8.2	59.2
MXT	18.5	25.2	34.9	49.5	61.4	67.3	72.4	70.1	62.2	51.3	33.8	22.2	47.5
BASIN NUMBER 135													
MT	7.1	12.5	23.2	38.2	49.5	55.0	60.2	57.4	49.7	39.6	23.8	12.0	35.7
MP	1.07	0.84	0.86	0.96	1.90	3.30	3.72	3.20	1.41	0.93	0.80	0.93	19.92
MS	10.7	8.1	8.1	5.0	1.1	0.0	0.0	0.0	0.7	5.9	6.5	8.3	54.4
MXT	16.3	23.8	34.7	50.8	61.8	67.6	73.9	70.3	62.7	52.0	33.4	20.9	47.6
BASIN NUMBER 136													
MT	6.4	11.8	22.7	35.5	50.0	55.5	60.8	57.9	50.0	40.0	23.8	11.5	35.8
MP	1.11	0.89	0.81	0.94	1.83	3.14	3.76	3.23	1.30	0.92	0.70	0.91	19.54
MS	11.1	8.6	7.7	4.5	1.2	0.0	0.0	0.0	0.4	5.8	5.6	8.1	53.0
MXT	15.0	22.7	34.0	50.9	61.6	70.2	74.2	70.8	62.5	52.1	33.2	20.4	47.3
BASIN NUMBER 137													
MT	6.6	12.0	23.1	38.8	50.3	55.6	60.9	58.1	50.2	40.3	24.1	12.0	36.0
MP	1.11	0.87	0.81	0.89	1.82	3.18	3.74	3.21	1.30	0.89	0.67	0.89	19.41
MS	11.1	8.4	7.7	4.0	1.2	0.0	0.0	0.0	0.3	5.7	9.4	7.9	51.8
MXT	15.0	22.6	34.1	51.2	61.6	70.8	74.4	71.0	62.8	52.5	33.4	20.1	47.5
BASIN NUMBER 138													
MT	6.4	11.6	22.3	37.9	49.5	55.1	60.2	57.3	49.5	39.4	23.8	11.8	35.4
MP	1.02	0.84	0.85	0.97	1.88	3.26	3.58	2.89	1.41	0.88	0.85	0.90	19.32
MS	10.1	8.2	8.1	5.3	1.4	0.1	0.0	0.0	0.8	5.5	7.3	8.3	55.0
MXT	16.3	23.2	33.9	50.4	62.6	69.1	74.1	71.0	62.8	51.8	33.4	21.0	47.5
BASIN NUMBER 139													
MT	2.7	8.4	20.6	37.4	50.1	56.3	60.9	57.9	49.5	39.3	21.7	9.0	34.4
MP	1.00	0.87	0.82	0.92	1.54	2.76	2.92	2.36	1.45	1.23	1.14	1.08	18.09
MS	9.5	8.4	7.4	4.5	0.3	0.0	0.0	0.3	0.7	5.5	8.9	9.8	55.3
MXT	12.3	19.4	32.4	49.8	63.4	69.3	74.0	71.1	62.0	50.6	30.5	17.9	46.1
BASIN NUMBER 140													
MT	2.5	8.5	20.7	37.4	50.2	56.4	61.0	57.9	49.6	39.3	21.7	9.3	34.5
MP	0.97	0.87	0.82	0.93	1.51	2.73	2.91	2.34	1.46	1.23	1.14	1.09	18.00
MS	9.1	8.4	7.3	4.4	0.3	0.0	0.0	0.4	0.7	5.6	8.7	9.8	54.7
MXT	12.0	19.3	32.5	49.8	63.5	69.4	74.1	71.1	62.1	50.6	30.4	18.2	46.1
BASIN NUMBER 141													
MT	3.0	8.6	19.7	35.8	48.2	54.6	60.4	57.4	49.0	38.8	22.9	9.3	34.0
MP	0.90	0.92	0.65	0.88	1.59	2.33	2.72	2.54	1.50	0.95	1.05	1.12	17.17
MS	8.8	9.1	6.1	5.6	0.8	0.0	0.0	0.0	0.6	5.1	9.8	10.4	55.2
MXT	11.9	19.2	36.4	46.8	60.5	65.4	71.3	68.2	59.1	48.3	31.1	18.0	44.7
BASIN NUMBER 142													
MT	5.5	10.1	21.2	36.7	49.3	55.0	59.0	56.7	49.7	38.5	21.8	9.0	34.3
MP	1.19	1.10	1.09	0.83	1.33	2.02	2.57	2.07	1.67	1.08	1.13	0.98	17.12
MS	11.7	11.0	10.4	5.2	0.3	0.0	0.0	0.3	2.0	4.5	9.2	9.2	63.7
MXT	17.4	22.3	34.6	49.2	63.7	69.1	73.5	71.6	63.8	50.5	31.6	19.8	47.2
BASIN NUMBER 143													
MT	3.4	9.1	20.8	37.2	49.6	55.8	60.5	57.7	49.4	38.7	22.1	9.2	34.4
MP	1.09	0.98	0.82	0.97	1.63	2.73	3.10	2.58	1.37	1.16	1.04	1.13	18.59
MS	10.6	9.5	7.5	5.3	0.6	0.0	0.0	0.3	0.7	5.8	8.1	10.2	58.8
MXT	12.9	20.3	32.3	49.1	62.7	68.2	73.3	70.3	61.6	50.0	31.2	18.4	45.9
BASIN NUMBER 144													
MT	-0.8	6.2	17.6	36.2	50.4	55.2	60.0	57.5	49.3	37.7	21.7	6.9	33.2
MP	1.13	0.84	0.97	0.64	1.37	2.55	2.69	1.93	1.26	0.95	1.11	1.23	16.69
MS	11.0	8.3	9.3	3.8	0.3	0.0	0.0	0.4	1.5	4.2	9.7	11.6	60.2
MXT	8.7	16.9	29.0	48.1	63.4	69.0	73.4	71.0	62.2	48.7	30.4	16.0	44.7
BASIN NUMBER 145													
MT	-1.2	4.9	16.7	35.3	49.8	55.6	60.2	57.5	49.1	37.5	19.3	5.6	32.5
MP	1.05	0.96	0.95	0.76	1.43	2.23	2.57	1.96	1.34	0.95	1.13	1.22	16.57
MS	10.4	9.5	9.3	5.2	0.3	0.0	0.0	0.2	1.7	5.0	10.0	11.8	63.5
MXT	8.1	15.0	27.6	46.4	62.8	68.3	73.0	70.3	61.2	47.7	27.6	14.3	43.5
BASIN NUMBER 146													
MT	-6.8	-0.7	13.1	33.7	49.3	56.3	61.0	57.8	47.9	35.9	14.8	-1.2	30.1
MP	0.75	0.74	0.81	0.66	1.49	1.97	2.37	1.90	1.36	0.86	0.96	0.97	14.85
MS	7.5	7.4	7.8	4.2	0.3	0.0	0.0	0.0	0.7	4.3	8.6	9.6	50.3
MXT	3.0	10.6	25.7	45.6	62.9	69.5	74.2	71.0	60.3	46.2	23.2	7.5	41.6
BASIN NUMBER 147													
MT	-9.5	-2.9	11.7	33.1	49.7	57.0	61.7	58.2	47.4	34.2	12.5	-4.2	29.1
MP	0.84	0.75	0.84	0.55	1.34	1.83	2.21	1.69	1.17	0.76	0.89	1.02	13.92
MS	8.3	7.8	9.1	3.4	0.8	0.0	0.0	0.0	0.2	4.1	8.1	10.1	50.9
MXT	0.0	8.4	24.5	44.8	62.0	70.0	74.7	71.3	59.7	43.9	20.2	4.2	40.3
BASIN NUMBER 148													
MT	11.1	13.4	23.8	41.2	52.6	59.5	68.0	65.4	55.2	43.8	27.2	18.1	39.9
MP	0.44	0.60	0.77	0.97	1.34	2.47	1.32	1.06	0.96	0.65	0.62	0.52	11.92
MS	6.1	5.9	7.1	4.1	0.4	0.2	0.0	0.0	1.1	2.9	5.8	5.1	38.7
MXT	21.2	23.4	33.9	53.5	65.7	71.6	82.7	79.9	68.8	56.8	37.7	27.9	51.9
BASIN NUMBER 149													
MT	10.5	11.6	21.3	37.1	48.5	56.0	63.7	60.7	51.1	40.1	24.5	16.8	36.8
MP	0.70	0.76	0.79	1.32	1.37	2.36	1.59	2.06	0.87	0.49	0.63	0.48	13.42
MS	7.0	7.6	7.6	7.2	0.7	0.0	0.0	0.0	0.9	3.0	5.4	4.3	43.7
MXT	21.0	21.8	31.3	48.7	61.8	68.5	78.4	75.1	64.9	53.4	35.5	27.1	48.9
BASIN NUMBER 150													
MT	7.1	10.2	21.7	39.8	51.5	58.5	66.2	63.2	52.8	41.5	24.3	13.9	37.6
MP	0.49	0.43	0.47	0.70	1.08	2.32	1.32	1.20	0.78	0.45	0.40	0.36	10.00
MS	4.9	4.3	3.9	2.7	0.2	0.2	0.0	0.0	0.7	1.9	3.7	3.3	25.8
MXT	19.2	22.8	33.6	53.3	66.5	72.5	83.3	80.6	69.4	56.8	36.7	25.7	51.7
BASIN NUMBER 151													
MT	10.5	11.6	21.3	37.1	48.5	56.0	63.7	60.7	51.1	40.1	24.5	16.8	36.8
MP	0.70	0.76	0.79	1.32	1.37	2.36	1.59	2.06	0.87	0.49	0.63	0.48	13.42
MS	7.0	7.6	7.6	7.2	0.7	0.0	0.0	0.0	0.9	3.0	5.4	4.3	43.7
MXT	21.0	21.8	31.3	48.7	61.8	68.5	78.4	75.1	64.9	53.4	35.5	27.1	48.9
BASIN NUMBER 152													
MT	10.8	12.4	22.4	38.8	50.2	57.5	65.5	62.7	52.8	41.7	25.6	17.3	38.1
MP	0.67	0.64	0.78	1.17	1.36	2.41	1.48	1.64	0.91	0.56	0.63	0.50	12.78
MS	6.6	6.9	7.4	5.9	0.6	0.1	0.0	0.0	1.0	3.0	5.6	4.6	41.6
MXT	21.1	22.5	32.4	50.7	63.4	69.8	80.2	77.1	66.5	54.8	36.4	27.4	50.2
BASIN NUMBER 153													
MT	10.5	11.6	21.3	37.1	48.5	56.0	63.7	60.7	51.1	40.1	24.5	16.8	36.8
MP	0.70	0.76	0.79	1.32	1.37	2.36	1.59	2.06	0.87	0.49	0.63	0.48	13.42
MS	7.0	7.6	7.6	7.2	0.7	0.0	0.0	0.0	0.9	3.0	5.4	4.3	43.7
MXT	21.0	21.8	31.3	48.7	61.8	68.5	78.4	75.1	64.9	53.4	35.5	27.1	48.9
BASIN NUMBER 154													
MT	7.4	10.6	22.5	40.7	52.3	59.3	67.0	63.9	53.3	42.1	24.7	14.4	38.2
MP	0.51	0.50	0.53	0.71	1.14	2.41	1.61	1.10	0.90	0.54	0.46	0.39	10.81
MS	5.0	5.0	4.0	3.0	0.3	0.1	0.0	0.0	0.6	2.3	4.3	3.7	28.3
MXT	19.4	22.9	34.3	54.3	67.4	73.4	84.0	81.2	69.5	57.4	36.8	25.9	52.2
BASIN NUMBER 155													
MT	7.1	10.2	21.7	39.8	51.5	58.5	66.2	63.2	52.8	41.5	24.3	13.9	37.6
MP	0.49	0.43	0.47	0.70	1.08	2.32	1.32	1.20	0.78	0.45	0.40	0.36	10.00
MS	4.9	4.3	3.9	2.7	0.2	0.2	0.0	0.0	0.7	1.9	3.7	3.3	25.8
MXT	19.2	22.8	33.6	53.3	66.5	72.5	83.3	80.6	69.4	56.8	36.7	25.7	51.7
BASIN NUMBER 156													
MT	10.6	13.6	25.2	41.6	52.9	59.6	67.8	64.6	54.7	44.4	27.0	19.4	40.1
MP	0.66	0.61	0.68	0.81	1.44	3.03	1.68	1.49	1.01	0.61	0.54	0.48	13.04
MS	7.2	7.0	6.8	4.3	0.4	0.0	0.0	0.0	0.7	2.8	5.3	4.8	39.3
MXT	20.9	24.3	35.2	53.5	66.3	72.5	82.8	80.3	69.3	58.1	37.2	29.0	52.4
BASIN NUMBER 157													
MT	7.5	11.1	23.0	40.5	53.0	60.7	68.0	65.2	54.9	42.6	25.7	15.2	38.9
MP	0.74	0.64	0.54	0.73	1.86	2.83	1.59	1.70	1.00	0.54	0.61	0.67	13.14
MS	7.9	6.9	4.4	2.6	0.6	0.0	0.0	0.0	0.1	2.5	5.4	7.0	37.4
MXT	18.6	22.5	33.6	53.2	67.5	74.4	83.3	80.7	69.7	56.3	36.4	25.6	51.8
BASIN NUMBER 158													
MT	5.7	9.0	20.6	33.8	51.7	59.3	66.5	63.9	53.7	41.5	23.6	13.9	37.3
MP	0.73	0.62	0.65	0.83	1.62	3.07	1.99	1.91	1.22	0.64	0.62	0.68	14.58
MS	7.0	6.1	5.5	3.1	0.4	0.0	0.0	0.0	0.4	2.3	5.1	6.5	36.5
MXT	15.2	19.1	30.2	50.6	65.3	72.2	81.1	78.6	67.4	54.4	33.8	23.6	49.3
BASIN NUMBER 159													
MT	8.3	11.6	23.3	40.5	52.9	60.2	67.8	64.8	54.6	42.9	26.0	15.8	39.1
MP	0.71	0.58	0.63	0.88	1.47	2.70	1.67	1.61	0.96	0.56	0.54	0.55	12.87
MS	7.1	5.9	5.4	3.2	0.5	0.0	0.0	0.0	0.4	2.3	4.8	5.3	34.7
MXT	19.4	22.9	33.9	53.0	66.8	73.4	83.0	80.6	69.4	56.7	36.7	26.5	51.8
BASIN NUMBER 160													
MT	5.4	8.7	20.2	39.4	51.6	59.0	66.3	63.8	53.6	41.4	23.3	13.7	37.1
MP	0.70	0.60	0.68	0.88	1.63	3.14	2.08	1.95	1.27	0.67	0.61	0.66	14.89
MS	6.8	5.9	5.9	3.2	0.4	0.0	0.0	0.0	0.5	2.2	5.0	6.4	36.2
MXT	14.5	18.3	29.5	50.2	64.9	71.8	80.8	78.3	67.0	54.1	33.2	23.3	48.8
BASIN NUMBER 161													
MT	8.4	11.6	23.2	40.4	52.8	60.1	67.6	64.7	54.4	42.9	25.9	15.9	39.0
MP	0.71	0.57	0.65	0.91	1.46	2.66	1.69	1.60	0.96	0.56	0.54	0.53	12.84
MS	6.8	5.6	5.7	3.3	0.4	0.0	0.0	0.0	0.5	2.2	4.6	4.7	33.8
MXT	19.4	22.8	33.8	52.9	66.6	73.1	82.8	80.5	69.3	56.6	36.7	26.6	51.7

TABLE B-2

CLIMATIC VARIABLES BY BASIN *

BASNO	MAP	MAS	ASPCT	MWP	MSP	MWSP	A10YP	W10YP	MWT	MJANT	MST	MJUNT	MWMXT	JAMXT	ATRG	PE	THAET	TUAET	THSUR	TUSUR
1	20.0	83.9	41.8	5.5	7.6	13.1	27.5	8.7	21.2	16.1	45.0	52.1	33.6	3.6	20.2	17.8	12.1	3.2	7.9	43.5
2	21.0	94.8	45.1	6.3	8.2	14.5	28.7	9.8	24.2	13.1	47.6	54.8	33.1	4.2	21.2	18.0	13.2	4.0	7.8	43.6
3	19.1	86.8	45.4	4.7	7.9	12.6	26.1	7.4	24.6	12.7	47.2	54.2	33.8	3.5	21.1	18.1	12.7	2.0	6.4	42.2
4	11.9	38.8	32.5	3.1	4.8	7.9	16.5	4.9	18.7	20.9	51.0	59.4	28.8	10.8	22.8	11.9	10.0	1.0	2.0	56.8
5	13.5	43.1	31.9	3.5	5.0	8.5	18.8	5.5	18.1	20.8	48.8	57.4	28.7	10.1	21.7	13.5	10.4	1.0	3.1	53.9
6	13.8	46.5	33.8	3.9	4.9	8.8	18.9	6.1	20.0	20.1	52.4	60.6	30.0	9.9	23.5	13.8	11.0	1.0	2.7	56.9
7	24.1	96.3	39.9	5.6	9.6	15.2	30.5	8.4	20.9	17.1	44.5	51.5	32.9	4.6	19.8	19.8	12.5	5.3	11.6	43.1
8	22.4	86.4	38.6	5.1	8.9	14.0	28.3	7.6	20.7	17.4	45.3	52.5	32.3	5.3	20.2	20.1	12.4	3.3	10.0	44.3
9	22.7	87.7	38.6	4.6	9.2	13.9	31.5	7.3	19.8	17.9	44.9	52.1	33.0	4.1	19.9	19.7	12.2	4.0	10.5	44.4
10	23.0	93.5	40.6	6.0	9.0	15.0	31.6	9.5	21.1	16.3	44.5	51.5	32.8	4.5	19.9	19.4	12.4	4.7	10.6	42.2
11	19.7	60.7	30.8	4.1	7.5	11.6	24.9	6.1	19.4	19.3	46.8	54.1	29.9	8.6	20.7	19.3	12.0	1.4	7.7	47.6
12	24.2	95.2	39.3	6.0	9.4	15.4	30.5	8.9	21.3	17.0	44.6	51.7	32.3	5.5	19.9	19.9	12.6	5.3	11.6	43.1
13	19.8	53.9	27.2	4.0	7.2	11.2	25.0	6.0	14.8	25.4	46.8	54.4	26.7	13.2	20.5	19.4	11.3	1.4	8.5	53.4
14	20.9	63.0	30.2	4.4	7.3	11.8	26.3	6.6	17.5	22.9	46.8	54.2	27.9	12.7	20.6	20.1	11.9	1.8	9.0	50.7
15	16.7	42.0	25.1	3.1	6.3	9.4	23.3	4.6	16.3	23.6	47.9	55.7	27.6	12.2	21.0	16.7	11.1	1.0	5.6	53.3
16	18.2	49.5	27.3	3.5	6.8	10.3	23.0	5.2	18.9	20.0	47.5	54.9	29.2	9.5	21.0	18.2	11.7	1.0	6.5	49.0
17	14.4	41.5	28.8	3.3	4.6	7.9	20.0	4.9	15.1	25.0	49.4	57.6	24.1	16.1	21.8	14.4	10.5	1.0	3.9	57.9
18	12.3	34.2	27.9	3.0	4.1	7.2	17.0	4.5	14.0	27.5	50.2	58.6	24.9	16.5	22.2	12.3	9.7	1.0	2.6	61.3
19	21.2	66.9	31.6	4.6	7.4	12.0	26.8	6.8	19.1	21.5	47.2	54.6	28.8	12.4	20.8	20.3	12.3	1.9	8.9	49.8
20	19.2	55.6	30.5	4.5	5.7	10.2	23.4	6.8	15.1	26.4	49.2	56.9	24.9	16.5	21.4	17.7	11.4	1.5	6.8	56.6
21	16.8	47.6	28.2	3.9	5.0	8.9	21.5	5.7	12.3	29.1	48.6	56.8	21.9	19.5	21.3	16.8	10.7	1.0	6.1	59.9
22	14.6	40.7	27.8	3.3	4.4	7.8	18.7	5.0	13.5	28.2	48.6	57.0	23.0	19.1	21.4	14.6	10.3	1.0	4.3	60.2
23	15.6	41.2	26.3	3.4	5.1	8.4	20.0	5.0	13.3	27.4	48.3	56.4	23.1	18.0	21.2	15.6	10.5	1.0	5.1	58.1
24	13.5	40.6	30.1	3.2	4.3	7.5	18.8	4.8	12.8	28.2	48.5	56.8	22.8	18.2	21.4	13.5	9.9	1.0	3.6	60.2
25	13.5	35.5	26.2	3.1	4.6	7.6	17.5	5.1	10.5	31.0	49.1	58.3	20.0	21.7	21.6	13.5	9.8	1.0	3.8	64.0
26	13.4	35.3	26.3	3.1	4.6	7.7	17.4	5.1	10.6	31.0	49.4	58.8	20.3	21.4	21.9	13.4	9.8	1.0	3.6	64.8
27	16.0	50.9	31.8	3.9	6.1	10.0	21.2	6.4	17.9	21.1	46.8	54.9	28.3	10.7	20.8	16.0	11.0	1.0	5.0	51.1
28	14.5	44.8	30.8	3.5	5.6	9.2	19.3	5.8	17.3	25.5	47.6	56.8	26.8	16.4	21.4	14.5	10.7	1.0	3.9	57.3
29	13.9	40.7	29.3	3.7	5.0	8.7	18.3	5.9	20.4	19.3	51.4	59.9	31.6	7.8	22.9	13.9	11.0	1.0	2.9	54.6
30	16.0	50.8	31.8	3.9	6.1	10.0	21.1	6.3	17.7	21.8	46.6	54.8	27.8	11.6	20.8	15.9	10.9	1.1	5.0	51.7
31	14.8	45.4	30.8	3.6	5.7	9.3	19.6	5.8	17.6	23.9	47.8	56.6	27.4	14.2	21.4	14.8	10.8	1.0	4.0	55.7
32	13.3	31.6	23.8	2.8	5.0	7.8	17.5	4.6	11.6	29.9	50.1	59.6	20.8	20.8	22.2	13.3	9.9	1.0	3.4	64.2
33	13.0	35.2	27.0	3.2	5.0	8.1	17.4	5.2	16.4	24.1	50.7	59.9	27.3	13.1	22.6	13.0	10.3	1.0	2.8	59.3
34	13.3	36.8	27.6	3.2	5.1	8.3	17.8	5.1	17.3	23.1	50.3	59.0	27.8	12.5	22.5	13.3	10.4	1.0	2.9	57.9
35	15.3	38.6	25.2	3.4	5.6	9.0	20.3	5.5	12.9	28.7	49.9	59.5	22.5	19.2	22.2	15.3	10.7	1.0	4.6	63.3
36	14.9	40.1	26.8	3.5	5.6	9.1	19.9	5.8	14.4	26.9	50.8	60.2	23.8	17.3	22.7	14.9	10.9	1.0	4.1	62.5
37	14.8	35.5	24.0	3.2	5.5	8.7	19.6	5.7	10.8	31.3	49.6	59.1	20.1	22.0	22.0	14.8	10.3	1.0	4.5	65.3
38	15.1	39.2	25.9	3.4	5.6	9.0	20.1	5.5	11.1	30.8	49.9	59.4	20.4	21.3	22.1	15.1	10.5	1.0	4.7	65.2
39	15.1	43.1	28.5	3.8	5.6	9.4	20.1	6.1	12.2	29.3	49.7	59.1	21.0	20.8	22.1	15.1	10.6	1.0	4.6	63.3
40	14.2	34.5	24.3	3.0	5.4	8.5	18.8	4.9	11.1	30.4	49.7	59.1	20.4	21.1	22.0	14.2	10.1	1.0	4.1	64.2
41	18.0	56.6	31.5	4.9	5.8	10.7	23.8	7.9	10.0	31.4	47.9	57.4	19.7	21.6	21.3	16.7	10.7	2.3	7.2	63.7
42	16.2	48.0	29.7	4.2	5.7	9.8	21.8	6.7	11.1	30.6	49.4	59.3	20.5	21.1	22.0	16.0	10.7	1.2	5.4	64.8
43	17.0	54.5	32.0	4.4	5.8	10.2	22.9	7.1	9.7	31.8	47.7	57.8	18.9	22.7	21.1	16.2	10.5	1.9	6.6	64.1
44	16.2	40.4	25.0	3.6	5.5	9.1	21.7	5.7	9.0	33.5	48.3	58.6	17.8	24.7	21.4	16.2	10.3	1.0	5.8	66.7
45	16.1	49.5	30.7	4.2	5.2	9.3	20.8	6.9	8.0	34.5	48.2	58.3	17.5	24.8	21.2	15.4	10.1	1.7	6.0	67.2
46	16.3	48.1	29.6	4.1	5.2	9.3	19.9	6.8	7.8	34.8	48.1	58.2	17.5	25.0	21.2	15.6	10.1	1.6	6.1	67.5
47	16.5	49.5	29.9	4.1	5.4	9.5	20.3	6.9	7.4	35.5	48.1	58.3	17.3	26.0	21.2	15.9	10.1	1.7	6.4	68.4
48	16.3	49.1	30.1	4.1	5.3	9.4	20.0	6.8	7.0	36.5	48.7	59.2	16.9	27.5	21.5	15.7	10.1	1.6	6.1	70.5
49	17.4	49.8	28.6	4.1	5.3	9.4	21.4	6.9	7.3	36.1	48.2	57.3	17.4	26.1	21.1	16.9	10.2	1.5	7.2	68.1
50	17.1	51.0	29.8	4.1	5.7	9.8	21.0	6.8	6.9	35.3	46.8	56.8	16.4	25.9	20.6	16.4	10.0	1.7	7.1	66.5
51	17.0	51.1	30.0	4.1	5.6	9.7	20.9	6.9	7.1	35.3	47.1	57.2	16.7	25.9	20.7	16.3	10.0	1.7	7.0	66.9
52	17.1	52.1	30.4	4.2	5.5	9.7	21.1	7.0	7.2	35.4	47.1	57.2	16.8	26.0	20.7	16.3	10.1	1.8	7.1	66.9
53	17.8	56.2	31.6	4.6	5.3	9.9	21.8	7.7	6.5	36.6	47.0	57.6	16.2	27.5	20.7	16.4	10.1	2.3	7.7	68.7
54	16.3	46.8	28.7	3.9	5.3	9.2	20.0	6.4	7.5	35.3	48.2	58.3	17.5	25.2	21.3	16.1	10.1	1.2	6.2	67.9
55	17.5	55.3	31.5	4.4	5.4	9.9	21.6	7.4	7.3	35.6	47.2	57.4	17.1	26.5	20.8	16.5	10.2	2.0	7.4	67.3
56	16.5	48.6	29.4	4.0	5.3	9.3	20.3	6.6	7.5	35.4	48.1	58.2	17.5	25.5	21.3	16.2	10.2	1.3	6.4	68.0
57	15.7	43.0	27.4	3.6	5.2	8.8	19.3	6.0	7.6	35.2	48.8	58.9	17.8	24.6	21.6	15.7	10.1	1.0	5.6	68.5
58	16.3	46.7	28.7	3.8	5.3	9.2	20.0	6.4	7.5	35.3	48.2	58.3	17.5	25.2	21.3	16.1	10.1	1.2	6.1	68.0
59	17.5	55.3	31.5	4.4	5.4	9.9	21.6	7.4	7.3	35.6	47.2	57.4	17.1	26.5	20.8	16.5	10.2	2.0	7.4	67.3
60	17.5	55.3	31.5	4.4	5.4	9.9	21.6	7.4	7.3	35.6	47.2	57.4	17.1	26.5	20.8	16.5	10.2	2.0	7.4	67.3
61	16.4	45.3	27.6	3.9	5.5	9.4	22.0	6.1	8.3	34.4	48.9	59.2	18.2	24.2	21.8	16.4	10.4	1.1	6.0	68.0
62	19.2	53.8	28.1	4.8	6.6	11.4	25.7	7.6	10.7	31.3	49.5	60.1	19.5	22.8	22.2	18.1	11.4	2.1	7.7	66.3
63	19.4	54.6	28.1	4.8	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
64	19.3	54.0	28.0	4.7	6.5	11.2	25.8	7.5	10.9	31.3	49.5	60.3	19.6	22.8	22.2	18.3	11.5	2.0	7.8	66.1
65	19.0	52.2	27.5	4.6	6.6	11.3	25.5	7.4	10.7	31.3	49.4	60.0	19.5	22.9	22.2	18.1	11.4	1.9	7.6	66.2
66	19.5	54.7	28.1	4.9	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
67	19.5	54.7	28.1	4.9	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
68	19.5	54.7	28.1	4.9	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
69	19.5	54.7	28.1	4.9	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
70	19.5	54.7	28.1	4.9	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
71	19.5	54.7	28.1	4.9	6.8	11.6	26.1	7.7	11.0	31.0	49.6	60.2	19.7	22.6	22.3	18.3	11.6	2.2	7.9	66.1
72	18.9	50.6	26.8	4.4	6.2	10.6	25.3	7.1	10.9	31.2	49.8	60.7	19.9	22.3	22.3	18.1	11.4	1.8	7.4	66.1
73	18.3	47.9	26.2	4.1	6.1	10.2	24.5	6.5	10.6	31.1	49.2	59.5	19.8	21.8	21.9	18.0	11.1	1.2	7.1	65.1
74	18.9	52.8	27.9	4.5	6.1	10.6	25.3	7.2	10.6	31.8	49.4	60.4	19.4	23.1	22.1	18.0	11.3	1.9	7.6	66.1
75	17.3	55.3	32.0	4.5	5.8	10.3	23.2	7.2	9.2	32.6	47.5	57.7	18.1	23.8	21.0	16.3	10.4	2.0	6.8	64.8
76	16.6	49.0	29.5	4.2	5.7	9.8	20.5	6.9	9.0	32.0	47.9	57.3	18.3	22.7	21.3	16.2	10.3	1.4	6.3	64.2
77	16.7	47.2	28.3	3.8	5.9	9.6	20.5	6.3	6.6	35.1	46.4	56.3	15.7	25.3	20.4	16.2	9.8	1.5	6.9	65.8
78	16.1	44.8	27.8	3.7	5.5	9.2	19.8	6.1	7.2	35.2	47.8	57.8	16.9	24.9	21.1	16.1	10.0	1.1	6.1	67.3
79	15.4	39.6	25.6	3.4	5.3	8.6	20.7	5.4	7.8	35.0	48.6	58.8	17.7	24.8	21.5	15.4	10.0	1.0	5.4	68.2
80	15.7	43.0	27.4	3.6	5.2	8.8	21.0	5.7	7.6	35.2	48.8	58.9	17.8	24.6	21.6	15.7	10.1	1.0	5.6	68.5
81	16.0	34.3	21.5	3.1	5.7	8.8	21.4	4.9	8.8	33.7	48.3	58.6	17.8	25.0	21.4	16.0	10.3	1.0	5.7	66.9
82	18.3	46.8	25.6	4.1	6.3	10.4	24.5	6.5	10.6	30.9	49.0	59.0	19.7	21.8	21.8	18.1	11.1	1.1	7.2	64.9
83	17.9	44.8	25.0	3.9	6.2	10.1	24.1	6.2	10.7	30.5	49.0	58.8	20.0	21.0	21.8	17.9	11.0	1.0	6.9	64.4
84	18.1	42.2	23.3	3.6	6.2	9.9	24.4	5.8	9.3	32.9	48.4	58.4	17.9	24.9	21.5	18.1	10.8	1.0	7.3	65.9
85	19.1	56.2	29.4	5.1	6.4	11.5	25.8	8.1	11.6	30.3	49.4	59.1	21.1	20.8	22.0	18.0	11.5	2.1	7.6	65.1
86	19.1	55.5	29.1	5.0	6.5	11.5	25.8	8.0	11.6	30.3	49.4	59.1	21.1	20.8	22.1	18.0	11.5	2.1	7.6	65.1
87	18.3	44.3	24.2	3.9	6.3	10.2	24.6	6.2	9.7	32.5	48.8	58.9	18.2	24.4	21.7	18.3	11.0	1.0	7.3	66.1
88	18.7	45.5	24.4	4.0	6.6	10.6	25.1	6.4	11.0	31.0	50.4	60.9	20.5	21.8	22.4	18.5	11.4	1.2	7.2	66.3
89	18.6	46.5	25.0	4.1	6.4	10.5	25.0	6.5	10.8	31.1	50.1	60.5	20.1	21.9	22.3	18.4	11.4	1.3	7.2	66.3
90	20.0	51.3	25.7	4.9	6.3	11.3	25.9	7.1	10.8	31.9	50.7	61.7	19.1	23.2	22.8	18.8	11.9	2.6	8.4	68.2

* FOR VARIABLE IDENTIFICATION AND METHODS OF CALCULATION SEE TABLE 4-6

TABLE B-2 CONTINUED

BASNO	MAP	MAS	ASPCT	MWP	MSP	MWSP	A10YP	W10YP	MWT	MJANT	MST	MJUNT	MWMXT	JANXT	ATRG	PE	THAET	TUAET	THSUR	TUSUR
91	15.4	35.8	23.2	3.2	5.9	9.1	20.5	5.2	13.7	27.1	49.4	58.6	22.7	18.8	22.0	15.4	10.8	1.0	4.6	61.0
92	14.7	34.8	23.6	3.1	5.4	8.5	19.6	5.0	11.4	30.4	49.5	59.2	21.2	20.8	22.0	14.7	10.4	1.0	4.4	64.6
93	15.7	40.4	25.8	3.6	5.7	9.3	21.1	5.7	13.4	28.0	50.3	59.7	23.2	18.4	22.3	15.7	11.0	1.0	4.7	62.9
94	14.7	35.7	24.3	2.8	5.7	8.5	19.7	4.5	15.3	26.3	51.3	60.9	24.1	17.5	23.1	14.7	11.0	1.0	3.7	62.8
95	18.3	49.2	27.0	4.1	6.6	10.6	24.5	6.5	11.1	30.4	48.2	57.9	20.6	20.9	21.4	18.0	11.0	1.3	7.3	63.6
96	15.7	39.7	25.3	3.4	5.7	9.1	21.1	5.3	10.9	31.4	49.3	58.9	20.3	22.1	21.9	15.7	10.6	1.0	5.1	65.4
97	17.3	46.3	26.8	4.2	6.2	10.4	23.4	6.7	11.0	31.3	49.8	59.6	20.6	21.6	22.1	17.0	11.1	1.3	6.2	66.1
98	17.4	44.5	25.6	4.1	6.4	10.5	23.5	6.6	10.9	31.7	50.4	60.4	20.8	21.6	22.4	17.1	11.2	1.3	6.2	67.0
99	19.4	49.2	25.4	4.5	6.8	11.4	26.0	7.2	12.3	30.2	50.3	60.6	21.6	20.9	22.5	18.5	11.8	1.8	7.5	65.6
100	19.4	51.9	26.7	4.5	7.0	11.5	26.1	7.2	12.8	28.9	50.6	60.9	21.8	20.0	22.6	18.7	11.9	1.7	7.6	64.3
101	18.5	49.4	26.7	3.8	6.9	10.8	24.9	6.1	13.1	29.0	50.3	60.4	21.2	20.1	22.5	18.5	11.7	1.0	6.8	64.2
102	15.6	35.0	22.4	2.1	6.1	8.2	20.0	3.0	13.1	29.0	50.3	60.5	22.1	19.8	22.5	15.6	11.0	1.0	4.6	64.2
103	20.5	61.4	29.9	5.0	7.6	12.6	27.6	8.0	13.4	28.6	50.5	60.5	21.7	19.9	22.5	19.3	12.2	2.2	8.3	63.9
104	20.5	61.4	29.9	5.0	7.6	12.6	27.6	8.0	13.4	28.6	50.5	60.5	21.7	19.9	22.5	19.3	12.2	2.2	8.3	63.9
105	15.8	35.3	22.3	2.2	6.1	8.3	20.3	3.2	13.0	29.1	50.3	60.5	21.2	20.8	22.5	15.8	11.0	1.0	4.8	64.3
106	16.2	35.9	22.1	2.4	6.1	8.6	20.8	3.5	12.8	29.2	50.4	60.7	21.3	20.7	22.5	16.2	11.1	1.0	5.1	64.6
107	18.4	39.3	21.3	3.6	6.2	9.8	23.5	5.2	12.1	30.1	50.7	61.3	20.2	21.9	22.7	18.4	11.7	1.0	6.8	65.9
108	18.5	39.4	21.3	3.6	6.2	9.9	23.5	5.2	12.1	30.1	50.7	61.3	19.6	21.9	22.7	18.5	11.7	1.0	6.8	65.9
109	20.3	48.3	23.7	3.8	6.5	10.3	25.8	5.5	12.2	30.0	50.9	61.8	22.7	19.1	22.7	19.8	12.1	1.5	8.3	65.7
110	20.3	48.2	23.7	3.8	6.5	10.4	25.8	5.5	12.1	30.1	50.9	61.8	22.7	19.1	22.7	19.9	12.1	1.5	8.3	65.7
111	20.3	48.2	23.7	3.8	6.5	10.4	25.8	5.5	12.2	30.1	50.9	61.8	22.7	19.1	22.7	19.9	12.1	1.5	8.3	65.7
112	21.5	48.2	22.4	4.9	6.4	11.4	27.4	7.1	10.5	31.9	49.3	60.0	21.0	20.9	21.8	19.7	11.7	2.8	9.9	65.7
113	20.2	53.1	26.3	5.3	6.4	11.7	25.9	7.6	13.4	29.1	51.7	62.8	21.5	20.9	23.3	18.5	12.4	2.7	7.8	66.6
114	21.3	54.6	25.6	5.1	7.0	12.2	27.1	7.4	13.0	29.4	50.3	61.3	21.0	21.6	22.7	19.8	12.3	2.5	9.0	65.5
115	21.5	55.0	25.6	5.2	7.1	12.3	27.4	7.5	13.1	29.3	50.2	61.3	21.1	21.5	22.7	20.0	12.4	2.5	9.1	65.3
116	20.9	53.8	25.7	5.1	6.9	12.0	26.6	7.3	12.9	29.6	50.3	61.4	20.8	21.8	22.7	19.5	12.3	2.4	8.7	65.7
117	19.9	48.4	24.3	4.7	6.3	11.0	25.3	6.7	10.7	31.9	50.4	61.5	19.3	22.9	22.7	18.6	11.8	2.3	8.1	68.1
118	19.8	47.8	24.1	4.6	6.3	10.9	25.2	6.6	10.7	31.9	50.3	61.5	19.4	22.9	22.7	18.5	11.8	2.3	8.1	68.1
119	21.0	51.4	24.5	4.9	6.3	11.2	26.6	7.1	9.7	33.1	49.0	60.3	18.1	24.7	22.0	19.2	11.6	2.8	9.4	68.1
120	21.0	51.4	24.5	4.9	6.3	11.2	26.6	7.1	9.7	33.1	49.0	60.3	18.1	24.7	22.0	19.2	11.6	2.8	9.4	68.1
121	21.4	51.7	24.2	5.2	6.4	11.6	27.2	7.4	10.3	32.2	49.1	60.4	21.0	20.8	22.0	19.3	11.7	3.1	9.7	66.9
122	18.3	37.3	20.4	3.6	6.3	9.9	23.2	5.2	10.5	32.0	49.3	60.9	20.4	21.9	22.3	17.9	11.3	1.4	7.0	67.8
123	18.3	37.3	20.4	3.6	6.3	9.9	23.2	5.2	10.5	32.0	49.3	60.9	20.4	21.9	22.3	17.9	11.3	1.4	7.0	67.8
124	21.0	51.4	24.5	4.9	6.3	11.2	26.6	7.1	9.7	33.1	49.0	60.3	18.1	24.7	22.0	19.2	11.6	2.8	9.4	68.1
125	21.0	51.4	24.5	4.9	6.3	11.2	26.6	7.1	9.7	33.1	49.0	60.3	18.1	24.7	22.0	19.2	11.6	2.8	9.4	68.1
126	21.0	51.4	24.5	4.9	6.3	11.2	27.8	7.8	9.7	33.1	49.0	60.3	18.1	24.7	22.0	19.2	11.6	2.8	9.4	68.1
127	21.0	51.4	24.5	4.9	6.3	11.2	27.8	7.8	9.7	33.1	49.0	60.3	18.1	24.7	22.0	19.2	11.6	2.8	9.4	68.1
128	15.9	44.7	28.1	3.6	5.0	8.6	20.3	5.4	9.9	31.6	47.6	56.5	20.2	21.5	20.7	15.9	10.0	1.0	5.8	61.5
129	15.8	45.7	28.9	3.6	5.0	8.6	20.2	5.5	10.2	31.5	47.8	57.0	20.2	21.7	20.8	15.8	10.1	1.0	5.7	61.4
130	20.1	56.2	27.9	4.4	6.9	11.3	25.4	6.6	18.9	20.2	46.3	53.6	30.4	9.0	20.4	19.7	11.8	1.5	8.3	46.9
131	20.5	57.5	28.0	4.6	6.8	11.3	25.9	6.8	17.6	22.0	46.4	53.8	28.7	11.3	20.3	19.9	11.7	1.6	8.8	48.7
132	20.8	58.7	28.1	4.7	6.7	11.4	26.4	7.0	16.4	23.6	46.4	53.9	27.1	13.3	20.3	20.1	11.6	1.7	9.3	50.3
133	21.0	64.2	30.6	4.8	7.0	11.7	26.5	7.1	16.8	22.8	45.5	52.9	27.4	12.7	19.9	19.9	11.5	2.1	9.5	48.7
134	20.4	59.3	29.1	4.5	6.7	11.3	25.8	6.8	16.5	23.4	46.4	53.8	26.9	13.5	20.3	19.8	11.5	1.6	8.8	50.2
135	19.9	54.4	27.3	4.5	6.2	10.7	25.3	6.7	15.8	24.9	47.6	55.0	25.8	15.8	20.8	19.4	11.6	1.5	8.4	53.0
136	19.5	53.0	27.1	4.4	5.9	10.3	24.8	6.6	15.3	25.6	48.0	55.5	25.0	17.0	21.0	19.1	11.5	1.4	8.0	54.4
137	19.4	51.8	26.7	4.4	5.9	10.3	24.6	6.5	15.5	25.4	48.3	55.6	25.2	16.9	21.1	19.0	11.6	1.4	7.8	54.4
138	19.3	55.0	28.5	4.4	6.1	10.6	24.5	6.6	15.2	25.6	47.5	55.1	25.6	15.7	20.8	18.9	11.4	1.4	8.0	53.8
139	18.1	55.3	30.6	4.9	5.2	10.1	25.5	7.1	12.5	29.3	47.9	56.3	22.5	19.7	20.8	17.0	10.8	2.1	7.3	58.2
140	18.0	54.7	30.4	4.9	5.2	10.1	25.4	7.1	12.5	29.5	48.0	56.4	22.5	20.0	20.9	16.9	10.8	2.1	7.2	58.5
141	17.2	55.2	32.1	4.6	4.8	9.4	24.3	6.8	12.7	29.0	46.2	54.6	23.3	20.1	20.3	16.4	10.5	1.7	6.7	57.4
142	17.1	63.7	37.2	5.5	4.2	9.7	24.0	8.0	13.5	26.5	47.0	55.0	25.1	14.6	20.4	15.5	10.6	2.6	6.5	53.5
143	18.6	58.8	31.6	5.0	5.3	10.4	26.3	7.3	12.9	28.6	47.5	55.8	23.0	19.1	20.7	17.4	10.9	2.2	7.7	57.1
144	16.7	60.2	36.0	5.3	4.6	9.8	23.7	7.7	10.3	32.8	47.3	55.2	20.2	23.3	20.4	15.3	10.2	2.3	6.5	60.8
145	16.6	63.5	38.3	5.3	4.4	9.8	23.4	7.7	9.1	33.3	46.9	55.6	18.5	23.9	20.3	15.1	9.9	2.5	6.6	61.5
146	14.8	50.3	33.9	4.2	4.1	8.3	20.9	6.2	3.8	38.8	46.4	56.3	14.0	29.0	19.9	14.2	8.9	1.7	6.0	67.8
147	13.9	50.9	36.6	4.4	3.7	8.1	19.7	6.4	1.5	41.5	46.6	57.0	11.5	32.0	19.7	12.9	8.4	2.0	5.5	71.2
148	11.9	38.7	32.5	3.1	4.8	7.9	16.4	4.9	18.7	20.9	51.1	59.5	28.8	10.8	22.9	11.9	10.0	1.0	2.0	56.9
149	13.4	43.7	32.6	3.4	5.0	8.4	18.7	5.3	16.9	21.5	47.2	56.0	27.3	11.0	20.9	13.4	10.1	1.0	3.3	53.2
150	10.0	25.8	25.8	2.1	4.1	6.3	13.3	3.5	15.4	24.9	49.9	58.5	27.6	12.8	22.1	10.0	8.6	1.0	1.4	59.1
151	13.4	43.7	32.6	3.4	5.0	8.4	18.0	5.5	16.9	21.5	47.2	56.0	27.3	11.0	20.9	13.4	10.1	1.0	3.3	53.2
152	12.8	41.6	32.5	3.3	4.9	8.2	17.7	5.1	17.7	21.3	48.8	57.5	28.0	10.9	21.8	12.8	10.1	1.0	2.7	54.8
153	13.4	43.7	32.6	3.4	5.0	8.4	18.7	5.3	16.9	21.5	47.2	56.0	27.3	11.0	20.9	13.4	10.1	1.0	3.3	53.2
154	10.8	28.3	26.2	2.4	4.3	6.6	14.4	3.9	15.9	24.6	50.8	59.3	27.9	12.6	22.4	10.8	9.1	1.0	1.7	59.6
155	10.0	25.8	25.8	2.1	4.1	6.3	13.3	3.5	15.4	24.9	49.9	58.5	27.6	12.8	22.1	10.0	8.6	1.0	1.4	59.1
156	13.0	39.3	30.1	3.0	5.3	8.2	17.4	4.8	19.1	21.4	51.4	59.6	29.3	11.0	22.9	13.0	10.5	1.0	2.5	57.2
157	13.1	37.4	28.4	3.2	5.1	8.3	17.5	5.2	16.5	24.5	51.4	60.7	27.4	13.4	22.8	13.1	10.4	1.0	2.8	60.5
158	14.6	36.5	25.0	3.3	5.5	8.8	19.4	5.4	14.6	26.3	49.9	59.3	24.3	16.8	22.1	14.6	10.7	1.0	3.9	60.7
159	12.9	34.7	26.9	3.0	5.1	8.1	17.2	4.9	17.0	23.7	51.2	60.2	27.9	12.6	22.7	12.9	10.3	1.0	2.6	59.4
160	14.9	36.2	24.3	3.3	5.6	8.9	19.8	5.3	14.3	26.6	49.7	59.0	23.8	17.5	22.1	14.9	10.7	1.0	4.2	60.8
161	12.8	33.8	26.3	3.0	5.0	8.0	17.1	4.9	17.0	23.6	51.1	60.1	27.9	12.6	22.7	12.8	10.3	1.0	2.6	59.2

APPENDIX C

DATA ON OTHER PHYSICAL GEOGRAPHIC PATTERNS FOR THE STUDY BASINS

TABLE C-1

LISTING OF 1:250,000 SCALE TOPOGRAPHIC MAP SHEETS FOR THE STUDY BASINS

STATION NUMBER	STATION NAME	TOPOGRAPHIC MAP COVERAGE 1:250,000 Scale*
1	Willow Ck	82I, 82J
2	Lee Ck	82H, NM12-10
3	Rolph Ck	82H, NM12-10
4	Manyberries Ck	72E
5	Mackay Ck	72E, 72F
6	Peigan Ck	72E
7	Elbow R	82J
8	Elbow R	82O, 82J
9	Fish Ck	82J
10	Stimson Ck	82J
11	Little Red Deer R	83B, 82O, 82P
12	Little Red Deer R	82O
13	Blindman R	83A, 83B
14	Medicine R	83B
15	Kneehills Ck	82P, 82O, 83A
16	Rosebud R	82P, 82O
17	Bullpound Ck	82P
18	Aldali Ck	72L, 72M
19	Prairie Ck	83B
20	Sturgeon R	83H, 83G
21	Vermilion R	73E, 73O, 83A, 83H
22	Ribstone Ck	73D
23	Battle R	73C, 73D, 73E, 83A, 73F, 83B, 83G, 83H
24	Moniter Ck	72M, 73D
25	Eagle Ck	72N, 72O, 73C
26	Eagle Ck	73B, 72O, 72N, 73C
27	Bear Ck	72F
28	Bridge Ck	72K, 72F
29	Piapot Ck	72F
30	Skull Ck	72F
31	Swiftcurrent Ck	72F
32	Brightwater Ck	72O
33	Wood R	72G, 72H
34	Notukeu Ck	72G, 72J, 72F
35	Moose Jaw R	72I, 72H
36	Moose Jaw R	72I, 72H, 72J
37	Wascana Ck	72I, 62L, 62E
38	Boggy Ck	72I
39	Qu'Appelle R	72I, 72J, 72O, 72P
40	Arm R	72I, 72O, 72P
41	Jumping Deer Ck	62L, 62M, 72P
42	Indianhead Ck	62L
43	Pheasant Ck	62L, 62M
44	Cutarm Ck	62K, 62L, 62M
45	Carrot R	73A
46	Carrot R	73H, 73A
47	Carrot R	63E, 73H, 73A, 63D
48	Petaigan R	63E
49	Torch R	73H, 73I
50	Etomami R	63D
51	Red Deer R	63D, 73A, 63E
52	Red Deer R	63C, 63F, 63D, 63E, 73A
53	Overflowing R	63F, 63E, 63D
54	Swan R	63C, 63D, 62M, 62N
55	Birch R	63C
56	Woody R	63C, 62N
57	Roaring R	63C, 62N
58	Swan R	63C
59	Steep Rock R	63C
60	Bell R	63C
61	Pine R	62N
62	Garland R	62N
63	Ocher R	62O, 62J, 62K
64	Turtle R	62J
65	Wilson R	62N, 62K
66	Vermilion R	62N, 62K
67	Fishing R	62N
68	Fork R	62N
69	Drifting R	62N
70	Mink R	62N
71	Edwards Ck	62N, 62K
72	Pine Ck	62J, 62G
73	Neepawa Ck	62J
74	Whitemud R	62J, 62G
75	Yorkton Ck	62M, 62L
76	Whitesand R	62M, 63D
77	Assiniboine R	62M, 63D
78	Stony Ck	62M, 63D
79	Shell R	62K, 62N
80	Little Boggy Ck	62N
81	Birdtail Ck	62K, 62N
82	Minnedosa R	62J, 62K
83	Rolling R	62J, 62K
84	Arrow R	62K
85	Bosshill Ck	62F, 62K
86	Gopher Ck	62F, 62K
87	Oak R	62K
88	Little Souris R	62G, 62F
89	Epinette Ck	62G, 62J
90	Sturgeon Ck	62H, 62J
91	Gibson Ck	72H
92	Yellowgrass Ditch	72H, 72I, 62E, 62L
93	Jewel Ck	62E, 72H
94	Coulee West	62E
95	Pipestone Ck	62K, 62L, 62E
96	Antler R	62F, 62E, NM14-10
97	Gainsborough Ck	62F
98	Graham Ck	62F
99	Oak Ck	62G
100	Elgin Ck	62F
101	Whitemud Ck	62G, NM14-11
102	Badger Ck	62G, NM14-11
103	Pembina R	62G, 62F
104	Wakopa R	62G, NM14-11
105	Crystal Ck	62G
106	Long R	62G, NM14-11
107	Snowflake Ck	62G, NM14-11
108	Mowbray Ck	62G, NM14-11
109	Roseau R	62H, 52E, NM14-12, NM15-10
110	Roseau R	62H, 52E, NM14-12, NM15-10
111	Roseau R	62H, 52E, NM14-12, NM15-10
112	Rat R	62H, 52E
113	Shannon Ck	62H, 62G
114	Elm Ck 1	62H, 62G
115	Elm Ck 2	62H, 62G
116	Elm Ck 3	62H, 62G
117	Cooks Ck	62I
118	Cooks Ck	62I, 62H
119	Netley Ck	62I
120	Netley Ck	62I
121	Whitemouth R	52E, 62H
122	Brokenhead R	62I, 62H, 52E
123	Brokenhead R	62H
124	Osier Ck	62I
125	Icelandic R	62I, 62P
126	Fisher R	62P, 62I
127	East Fisher R	62P
128	Beaver R	73K, 73L, 73E, 73F
129	Beaver R	73L, 83I, 73E, 73M
130	McLeod R	83F, 83C
131	McLeod R	83F, 83C
132	Wolf Ck	83F, 83G
133	Pembina R	83G, 83F, 83C, 83B
134	Pembina R	83G, 83B, 83C, 83F
135	Lobstick R	83G
136	Paddle R	83G
137	Little Paddle R	83G, 83J
138	Pembina R	83I, 83J, 83G, 83H
139	East Prairie R	83N, 83O, 83K, 83J
140	West Prairie R	83N, 83K
141	Swan R	83O, 83J
142	Wapiti R	83M, 83L, 93P, 93I
143	Little Smoky R	83N, 83K, 83J, 83L, 83E
144	Heart R	84C, 83N
145	Notikewin R	84C, 84D, 84E, 84F
146	Boyer R	84K, 84L
147	Ponton R	84K, 84J, 84O, 84N
148	Sage Ck	72E
149	Middle Ck	72E
150	Lyons Ck	72F
151	Battle Ck	72F, 72E
152	Lodge Ck	72F, 72E
153	Middle Ck	72F, 72E
154	Woodpile Coulee	72F, NM12-12
155	East Battle Ck	72F, NM12-12
156	Whitewater Ck	72G, 72F, NM13-10, NM12-12
157	Poplar R W	72G, NM13-10
158	Poplar R E	72H, 72G
159	Rock Ck	72G, NM13-10
160	Poplar R M	72H, NM13-11
161	Rock Ck	72H, NM13-11

* Listed map numbers refer to Canadian N.T.S. maps with the exception of the NM Series which are United States Geological Survey Maps covering the southern border region of the study area.

TABLE C-2

LISTING OF BASIC PHYSICAL DATA FROM 1-250000 SCALE MAPS *

BASNO	TDA	NCDA	MCL	MCLD	TL	EL10	EL85	ELG	ELD	ELMX	ALOS	ASOS	AF
1	447.3	28.5	49.7	50.1	360.6	3330.	4650.	2280.	6100.	6700.	1.2	0.0	211.7
2	120.0	0.3	29.2	30.8	113.6	3780.	5100.	3710.	8050.	9066.	0.3	0.0	54.5
3	79.2	4.4	22.1	23.3	45.8	3948.	4260.	3862.	4600.	4700.	0.3	0.0	0.0
4	129.1	0.6	21.7	22.1	77.7	2990.	3628.	2840.	3670.	4085.	0.0	0.0	0.0
5	171.4	0.5	24.9	25.6	121.9	2540.	3850.	2463.	5100.	5120.	6.7	0.0	6.2
6	173.9	1.9	28.4	28.8	117.6	2773.	3575.	2705.	4075.	5010.	0.6	0.0	0.0
7	301.6	0.0	33.5	33.5	210.3	4390.	6240.	4250.	6900.	10560.	0.0	4.8	168.1
8	457.2	0.3	57.6	57.6	308.2	3572.	5760.	3524.	6900.	10560.	0.3	5.0	242.9
9	100.6	0.0	22.5	22.5	48.9	3843.	4680.	3797.	6050.	6050.	0.0	3.4	82.5
10	95.4	5.3	19.7	20.1	45.4	3960.	4500.	3910.	5150.	6000.	0.0	0.0	52.9
11	976.6	41.6	85.6	85.6	467.6	3080.	4120.	2995.	5450.	6241.	2.3	11.2	515.3
12	190.4	0.0	22.1	22.1	98.2	3960.	4750.	3888.	5500.	6241.	0.2	6.5	182.2
13	688.6	22.9	61.6	62.3	235.2	2783.	3120.	2759.	3400.	3420.	34.9	28.6	291.1
14	718.8	27.9	51.3	51.7	299.9	3010.	3143.	3002.	3350.	3460.	2.6	71.6	398.6
15	931.0	57.6	71.8	73.4	438.4	2377.	2985.	2177.	3275.	3325.	4.0	0.0	9.3
16	292.2	16.5	40.2	41.0	136.5	3078.	3415.	3038.	3625.	3800.	3.0	0.0	3.1
17	86.3	6.7	16.2	16.2	48.9	2693.	3037.	2670.	3510.	3535.	0.3	0.0	0.0
18	242.9	66.5	41.8	40.2	133.0	2251.	2480.	2055.	2625.	2625.	1.9	0.0	0.0
19	334.6	3.9	37.9	38.3	179.9	3390.	4470.	3247.	5500.	6590.	0.8	11.8	330.1
20	1212.9	167.4	106.1	108.9	400.1	2125.	2400.	2000.	2800.	2850.	56.0	87.2	409.5
21	2237.2	401.7	121.5	122.7	1445.7	1930.	2250.	1905.	2350.	2350.	43.6	63.8	281.8
22	1138.1	654.3	86.8	88.8	86.8	2102.	2390.	2065.	2610.	2620.	2.5	182.9	200.8
23	10147.0	2918.5	354.3	360.6	4047.9	1840.	2548.	1748.	3010.	3125.	96.5	359.6	2022.4
24	513.8	238.7	41.0	43.0	150.7	2236.	2553.	2210.	2600.	2600.	3.9	7.3	0.0
25	1598.9	741.1	92.3	97.5	484.1	1875.	2070.	1860.	2150.	2325.	17.6	0.0	0.0
26	3747.4	2252.8	175.2	176.4	690.5	1710.	2012.	1545.	2150.	2500.	31.9	0.0	52.9
27	99.0	6.1	17.8	17.8	88.4	2590.	3874.	2572.	4050.	4050.	0.0	0.0	15.6
28	157.3	17.1	39.1	39.5	98.2	2593.	2845.	2567.	3512.	3610.	0.6	8.3	1.6
29	54.6	0.5	15.4	15.4	49.7	2587.	3573.	2550.	3965.	3975.	0.0	0.0	14.0
30	60.9	11.8	19.9	19.3	18.5	2703.	3605.	2643.	3690.	3850.	0.0	1.6	4.7
31	523.1	56.2	47.3	47.3	135.7	2775.	3053.	2757.	3725.	3800.	0.0	2.3	3.1
32	244.6	201.3	15.8	21.3	8.7	1820.	1870.	1810.	1925.	2100.	0.0	0.0	0.0
33	1925.8	211.4	72.2	73.0	1274.1	2363.	2860.	2351.	3350.	3350.	15.9	0.0	0.0
34	1770.6	350.9	119.2	119.2	963.5	2280.	2700.	2240.	3400.	3400.	4.7	0.0	0.0
35	1053.8	110.2	67.1	67.5	563.1	1850.	1895.	1847.	2050.	2885.	2.2	5.3	0.0
36	4187.6	527.5	123.1	123.5	962.4	1795.	1890.	1740.	2050.	2885.	18.2	10.1	0.0
37	1733.4	198.7	105.4	112.1	212.7	1790.	2050.	1625.	2200.	2200.	2.0	0.0	0.0
38	168.5	1.7	31.2	32.7	28.0	1798.	2170.	1755.	2300.	2300.	0.6	0.0	4.7
39	969.9	227.8	49.7	51.3	296.3	1690.	1950.	1680.	2100.	2100.	6.1	6.2	24.9
40	644.5	149.0	74.6	80.9	90.4	1660.	1950.	1633.	2125.	2250.	1.7	0.0	0.0
41	273.3	161.9	37.1	39.9	60.8	1880.	2125.	1843.	2200.	2400.	3.1	0.0	40.5
42	119.9	12.3	18.2	18.9	39.1	1660.	2012.	1590.	2062.	2250.	1.4	0.0	3.1
43	383.3	121.3	50.5	50.9	93.5	1855.	2163.	1830.	2225.	2250.	1.7	0.0	28.0
44	311.7	76.1	29.2	30.4	83.6	1487.	1675.	1457.	1725.	1750.	1.9	0.0	51.4
45	209.9	11.1	26.8	27.2	13.8	1482.	1628.	1476.	1655.	1910.	9.3	3.1	60.7
46	1360.7	187.9	91.5	91.9	340.5	1190.	1515.	1150.	1655.	1910.	13.1	3.1	163.5
47	3393.6	315.9	161.0	161.0	1249.6	1040.	1485.	1025.	1655.	1910.	15.7	14.5	884.3
48	208.9	0.0	11.0	16.6	13.0	1080.	1110.	1070.	1200.	1250.	0.0	0.0	28.0
49	1823.1	176.1	97.9	98.2	402.9	1335.	1698.	1210.	1830.	2291.	77.7	82.7	1332.7
50	800.8	33.2	54.5	56.0	439.2	1340.	1715.	1318.	1950.	2125.	7.0	54.0	582.3
51	4018.6	284.7	161.4	164.9	1980.7	1195.	1722.	1035.	1875.	2125.	72.2	720.8	1953.9
52	5239.1	305.3	224.1	227.7	2594.7	870.	1700.	843.	1875.	2125.	195.7	910.8	3054.6
53	1139.6	60.3	96.7	97.5	234.0	865.	1280.	845.	2100.	2400.	26.0	719.3	1105.4
54	1543.3	115.4	112.8	116.8	943.0	1163.	1710.	1080.	2010.	2250.	20.4	144.5	862.5
55	55.6	1.2	22.9	24.1	22.9	1200.	2350.	1036.	2525.	2550.	0.9	14.6	52.9
56	829.3	25.8	77.7	78.5	472.7	1025.	2285.	990.	2600.	2600.	19.6	40.5	639.9
57	329.6	4.8	55.2	55.6	245.0	1030.	2258.	943.	2375.	2550.	9.5	7.5	244.4
58	1602.2	120.0	129.8	133.8	947.8	1062.	1648.	910.	2010.	2250.	20.4	144.5	965.6
59	116.3	1.9	23.3	24.1	75.8	930.	974.	924.	2250.	2375.	10.4	3.9	104.3
60	69.9	1.4	19.3	19.7	35.5	1175.	2325.	1040.	2500.	2525.	3.4	3.6	68.5
61	109.4	0.8	19.3	19.7	58.8	1165.	2320.	1130.	2550.	2550.	1.7	0.0	99.6
62	160.7	3.7	33.1	33.5	88.8	992.	2000.	967.	2350.	2550.	1.7	6.9	121.4
63	144.2	11.8	29.6	30.4	77.3	962.	2110.	912.	2300.	2300.	1.4	0.0	133.9
64	425.5	41.3	21.7	21.7	69.4	930.	974.	924.	2250.	2375.	0.0	12.1	205.5
65	353.6	10.1	43.4	45.8	193.7	942.	1462.	905.	1940.	2110.	1.6	6.5	172.8
66	256.6	2.6	35.1	35.5	99.4	952.	1852.	915.	2000.	2225.	0.8	2.5	143.2
67	109.9	0.3	34.3	34.3	26.8	917.	1745.	882.	2450.	2727.	0.0	0.0	51.4
68	117.4	0.6	20.5	20.9	62.7	1133.	2277.	1118.	2475.	2727.	0.9	6.7	81.0
69	65.5	0.8	21.3	22.1	24.1	1125.	1817.	1118.	2425.	2727.	0.6	0.0	29.6
70	58.4	0.8	22.9	23.7	27.2	1198.	2075.	1128.	2500.	2727.	0.3	1.6	34.3
71	66.3	0.0	15.8	17.4	22.5	1010.	1710.	968.	2250.	2250.	0.9	0.0	49.8
72	152.3	0.9	29.6	30.0	16.6	990.	1240.	942.	1275.	1275.	0.0	1.4	59.2
73	70.1	4.7	24.1	24.1	46.6	1400.	2042.	1300.	2325.	2350.	0.2	0.0	10.9
74	75.7	0.3	15.0	16.2	0.0	1187.	1263.	1190.	1275.	1300.	0.3	0.0	66.9
75	680.7	241.8	67.5	68.3	217.0	1587.	1875.	1575.	1990.	2200.	22.1	66.3	93.4
76	376.8	44.5	45.8	47.0	112.8	1700.	1950.	1680.	1980.	2000.	17.9	8.3	40.5
77	749.3	62.1	47.3	49.3	344.5	1663.	1980.	1638.	2112.	2150.	11.7	14.0	479.5
78	86.3	6.4	18.9	19.3	20.5	1645.	1787.	1640.	1850.	1850.	1.6	0.0	3.1
79	779.4	131.6	104.2	105.0	338.1	1530.	2090.	1395.	2300.	2500.	23.7	11.8	504.4
80	99.2	15.6	18.9	20.1	46.6	1480.	2074.	1457.	2175.	2275.	1.6	0.0	63.8
81	468.1	164.9	48.1	48.9	119.2	1623.	1815.	1590.	2175.	2225.	8.9	7.9	267.8
82	943.0	242.4	80.5	80.9	408.4	1740.	2000.	1713.	2275.	2400.	51.4	32.8	524.7
83	282.4	12.9	24.1	24.9	168.5	2002.	2178.	1993.	2365.	2450.	14.0	23.4	186.8
84	299.9	171.1	54.5	55.2	59.6	1545.	1850.	1257.	1935.	2025.	3.3	0.0	7.8
85	95.3	10.0	36.7	37.5	24.1	1485.	1780.	1440.	1855.	1855.	0.3	0.0	3.1
86	120.3	5.1	39.9	41.4	45.0	1485.	1865.	1445.	1875.	1875.	0.0	0.0	4.7
87	480.6	273.4	60.0	62.3	59.2	1580.	1878.	1505.	1887.	2125.	5.8	0.0	10.9
88	187.0	7.3	24.1	24.5	58.0	1265.	1380.	1243.	1455.	1600.	0.3	0.0	21.8
89	276.0	7.3	34.3	43.0	6.7	1178.	1342.	1155.	1575.	1750.	0.9	36.0	88.7
90	161.4	1.1	34.3	35.5	50.1	775.	810.	757.	837.	845.	0.0	2.5	4.7

* FOR VARIABLE IDENTIFICATION AND METHODS OF MEASURMENT SEE TABLE 4-7

TABLE C-2 CONTINUED

BASNO	TDA	NCDA	MCL	MCLD	TL	EL10	EL85	ELG	ELD	ELMX	ALOS	ASOS	AF
91	160.8	61.5	20.1	20.1	51.7	2087.	2332.	2072.	2420.	2480.	0.0	0.0	0.0
92	598.0	167.1	39.9	41.4	41.0	1863.	1935.	1858.	1975.	2155.	0.6	0.0	0.0
93	91.7	1.1	31.6	32.0	39.5	1920.	2065.	1880.	2115.	2115.	0.0	0.0	0.0
94	44.8	23.7	16.2	18.2	0.0	1860.	1899.	1848.	1912.	1912.	0.2	0.0	0.0
95	1014.6	212.2	55.2	56.8	226.5	1825.	2047.	1800.	2100.	2250.	3.7	0.0	116.8
96	1227.9	101.4	141.7	142.0	309.3	1492.	2107.	1467.	2537.	2585.	0.8	0.0	56.0
97	508.0	7.2	90.4	92.7	87.2	1510.	1915.	1477.	2040.	2150.	0.0	0.0	10.9
98	287.7	6.2	55.6	58.0	5.9	1443.	1770.	1410.	1905.	1905.	0.0	0.0	1.6
99	153.4	67.9	16.6	18.2	57.6	1208.	1360.	1205.	1425.	1575.	1.1	0.0	4.7
100	164.1	10.1	32.4	32.7	35.5	1417.	1630.	1395.	1640.	1650.	0.2	0.0	0.0
101	180.0	42.0	27.2	27.6	111.7	1532.	1855.	1488.	1990.	2200.	1.1	0.0	21.8
102	600.5	191.3	32.4	33.9	251.3	1497.	1530.	1476.	1540.	2120.	6.9	9.5	3.1
103	206.3	49.8	26.8	28.0	131.8	1623.	1810.	1580.	2250.	2350.	0.9	0.0	43.6
104	44.1	29.9	11.4	11.8	5.1	1870.	2150.	1810.	2220.	2310.	0.6	0.0	24.9
105	47.6	14.5	10.3	11.0	17.4	1498.	1558.	1493.	1590.	1600.	0.9	0.0	0.0
106	213.8	61.8	22.9	23.7	39.9	1487.	1600.	1470.	1620.	1700.	0.9	0.0	0.0
107	381.0	213.3	36.3	36.7	52.5	1510.	1590.	1500.	1600.	1650.	4.2	20.6	0.0
108	112.7	12.6	24.1	24.1	11.4	1520.	1600.	1510.	1610.	1665.	0.0	0.6	0.0
109	1177.0	47.6	113.6	123.5	464.0	895.	1160.	793.	1210.	1275.	0.0	400.6	703.7
110	1658.1	45.9	94.7	104.6	451.4	992.	1170.	968.	1210.	1275.	0.0	383.5	647.7
111	1691.8	47.6	99.4	109.3	451.4	985.	1165.	924.	1210.	1275.	0.0	383.5	661.7
112	160.4	6.1	14.6	15.4	59.6	1063.	1125.	1047.	1250.	1250.	0.0	18.5	137.0
113	59.2	0.0	18.9	21.3	14.2	835.	955.	828.	1100.	1275.	0.0	0.0	1.6
114	212.2	29.0	18.9	20.9	38.7	788.	822.	780.	850.	960.	0.0	0.0	54.5
115	152.3	29.0	10.3	12.2	24.5	810.	825.	805.	850.	960.	0.0	0.0	54.5
116	103.2	29.0	16.6	17.4	5.5	825.	920.	820.	950.	960.	0.0	0.0	34.3
117	231.7	0.0	37.1	37.9	32.0	740.	825.	726.	880.	910.	0.0	2.8	90.3
118	192.6	0.0	24.1	24.9	28.8	773.	840.	767.	885.	910.	0.0	2.8	82.5
119	199.8	23.2	22.5	25.6	22.1	748.	767.	737.	873.	905.	0.0	0.0	60.7
120	97.3	23.2	9.9	13.0	0.0	782.	862.	773.	885.	905.	0.0	0.0	45.1
121	1359.1	39.2	84.8	86.4	102.6	958.	1130.	885.	1200.	1275.	23.7	912.3	1253.3
122	511.6	0.0	42.6	42.6	32.0	785.	922.	767.	948.	1005.	0.0	324.3	406.3
123	265.2	0.0	22.1	29.6	0.0	863.	958.	858.	1090.	1100.	0.0	182.2	224.2
124	31.9	0.0	11.0	13.4	2.0	726.	835.	720.	865.	865.	0.0	1.2	18.7
125	508.7	171.7	33.5	47.3	41.4	728.	851.	723.	885.	917.	0.0	45.6	213.3
126	666.9	53.4	38.3	40.6	65.5	748.	868.	740.	912.	917.	0.0	185.4	425.0
127	206.0	32.1	22.5	30.4	13.8	785.	875.	780.	925.	937.	0.0	2.2	91.9
128	8042.7	890.5	241.9	243.5	2373.3	1550.	2095.	1530.	2300.	2500.	369.4	1264.2	7030.8
129	5427.2	669.9	155.5	157.0	1739.7	1674.	2170.	1640.	2300.	2500.	298.9	1060.2	4697.0
130	576.2	0.0	89.6	89.6	937.5	3143.	4800.	3010.	8100.	9040.	4.4	219.5	935.7
131	2385.6	0.0	128.6	128.6	2739.1	2825.	4580.	2747.	8100.	9040.	13.5	1477.5	2338.4
132	322.7	0.0	45.0	46.[illegible]	440.7	2920.	3430.	2860.	3700.	3700.	4.5	317.6	322.3
133	1017.7	8.1	118.4	118.4	928.4	2820.	4430.	2780.	7852.	7852.	3.7	284.3	965.3
134	1610.4	8.1	196.5	196.5	1224.4	2505.	4150.	2349.	7852.	7852.	4.8	422.5	1499.3
135	611.7	10.0	62.7	63.1	195.3	2552.	2830.	2510.	3425.	3475.	29.0	180.1	398.6
136	236.2	6.9	32.4	33.5	92.7	2275.	2725.	2198.	3130.	3300.	0.0	25.8	161.9
137	104.3	3.6	18.2	18.9	69.0	2293.	2650.	2265.	2850.	3275.	0.0	12.6	77.8
138	4876.9	130.8	372.5	372.5	3132.5	2010.	3653.	1973.	7852.	7852.	64.9	1062.6	3115.3
139	552.7	4.5	85.2	85.6	495.6	1975.	2770.	1940.	4475.	4475.	0.0	30.4	543.3
140	456.2	6.2	60.8	60.8	368.5	1975.	2575.	1940.	3425.	3425.	1.1	33.6	448.4
141	731.7	0.8	63.5	63.5	864.9	1965.	3610.	1935.	4400.	4400.	2.5	182.9	200.8
142	4351.4	69.9	132.6	132.6	2694.1	1800.	3775.	1695.	6750.	8162.	15.3	129.2	2501.9
143	4296.9	30.5	264.0	264.8	2598.6	1851.	3647.	1645.	4890.	5300.	68.3	475.9	4191.1
144	749.9	29.3	56.8	58.4	282.9	1865.	2275.	1820.	2400.	2500.	6.2	163.5	669.4
145	1830.9	16.7	152.7	153.5	1073.2	1630.	2580.	1493.	3520.	3575.	3.6	355.0	1815.3
146	2378.9	0.0	100.2	100.6	1782.3	910.	1260.	890.	1500.	1573.	8.4	2304.2	2375.8
147	1001.1	74.0	101.0	102.2	663.7	1000.	2775.	880.	3100.	3300.	53.7	331.6	974.6
148	176.7	2.8	30.4	31.2	116.0	2873.	3430.	2857.	4000.	4000.	0.6	0.0	0.0
149	116.8	0.0	18.5	20.9	90.8	3423.	4000.	3401.	4730.	4730.	0.5	0.0	0.0
150	65.7	1.2	16.6	17.4	46.2	2840.	3245.	2818.	3500.	3525.	0.5	0.0	0.0
151	255.3	4.5	39.9	41.8	203.6	3270.	4080.	3229.	4700.	4720.	0.9	0.0	62.3
152	364.3	5.9	39.5	39.5	253.7	3060.	4080.	2975.	4700.	4807.	1.7	0.0	14.0
153	160.4	0.5	29.2	31.6	119.2	3310.	3900.	3274.	4730.	4730.	2.2	0.0	0.0
154	56.2	2.2	19.7	20.1	31.2	2810.	3035.	2780.	3160.	3160.	0.6	0.6	0.0
155	71.3	0.5	17.4	17.4	82.9	2850.	3000.	2840.	3112.	3325.	0.2	0.0	0.0
156	504.0	118.8	47.0	48.9	255.7	2570.	2930.	2520.	3180.	3250.	2.8	0.0	0.0
157	153.7	11.1	20.1	20.1	97.5	2863.	3105.	2853.	3225.	3300.	0.2	0.0	0.0
158	541.5	50.4	51.3	51.7	414.7	2465.	2680.	2425.	2925.	3075.	13.4	0.0	0.0
159	224.7	0.0	34.3	34.3	222.5	2598.	3000.	2590.	3250.	3285.	0.0	0.0	0.0
160	80.0	0.9	20.9	20.9	92.7	2500.	2673.	2495.	3005.	3035.	0.0	0.0	0.0
161	304.4	0.6	34.3	34.3	325.9	2575.	2890.	2565.	3280.	3285.	0.3	0.0	0.0

TABLE C-4
LISTING OF PHYSICAL VARIABLES FOR THE STUDY BASINS *

BASNO	TDA	NCDA	CDA	MCS	EL	TOTR	MCL	BS	ALTDA	ALCDA	ASTDA	ASCDA	LSTDA	LSCDA	DDTDA	DDCDA	LOTDA	LOCDA	AFTDA
1	447.3	7.4	418.8	35.1	3990.	4420.	50.1	5.6	1.3	1.3	1.0	1.0	1.3	1.3	0.9	1.0	0.5	0.5	48.3
2	120.0	1.3	119.7	57.2	4440.	5356.	30.8	7.9	1.3	1.3	1.0	1.0	1.3	1.3	1.2	1.2	0.4	0.4	46.4
3	79.2	6.5	74.9	17.9	4104.	838.	23.3	6.8	1.4	1.4	1.0	1.0	1.4	1.4	0.9	0.9	0.6	0.6	1.0
4	129.1	1.5	128.4	38.5	3309.	1245.	22.1	3.8	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.6	0.6	1.0
5	171.4	1.3	170.9	68.1	3195.	2657.	25.6	3.8	4.9	4.9	1.0	1.0	4.9	4.9	0.9	0.9	0.6	0.6	4.6
6	173.9	2.1	172.0	37.1	3174.	2305.	28.8	4.8	1.4	1.4	1.0	1.0	1.4	1.4	0.8	0.8	0.6	0.6	1.0
7	301.6	1.0	301.6	73.5	5315.	6310.	33.5	3.7	1.0	1.0	2.6	2.6	2.6	2.6	0.8	0.8	0.6	0.6	56.8
8	457.2	1.1	456.9	50.6	4666.	7036.	57.6	7.3	1.1	1.1	2.1	2.1	2.2	2.2	0.8	0.8	0.6	0.6	54.1
9	100.6	1.0	100.6	49.6	4262.	2253.	22.5	5.0	1.0	1.0	4.4	4.4	4.4	4.4	0.7	0.7	0.7	0.7	83.0
10	95.4	6.5	90.1	35.8	4230.	2090.	20.1	4.2	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.7	0.7	56.5
11	976.6	5.3	935.0	16.2	3600.	3246.	85.6	7.5	1.2	1.2	2.1	2.2	2.4	2.4	0.6	0.6	0.9	0.8	53.8
12	190.4	1.0	190.4	47.7	4355.	2353.	22.1	2.6	1.1	1.1	4.4	4.4	4.5	4.5	0.6	0.6	0.8	0.8	96.7
13	688.6	4.3	665.7	7.2	2952.	661.	62.3	5.6	6.1	6.2	5.2	5.3	10.2	10.5	0.4	0.4	1.2	1.1	43.3
14	718.8	4.9	690.9	3.4	3077.	458.	51.7	3.7	1.4	1.4	11.0	11.4	11.3	11.7	0.5	0.5	1.0	1.0	56.4
15	931.0	7.2	873.4	11.0	2681.	1148.	73.4	5.8	1.4	1.5	1.0	1.0	1.4	1.5	0.5	0.6	0.9	0.9	2.0
16	292.2	6.6	275.7	10.9	3247.	762.	41.0	5.8	2.0	2.1	1.0	1.0	2.0	2.1	0.6	0.6	0.8	0.8	2.1
17	86.3	8.8	79.6	28.4	2865.	865.	16.2	3.0	1.4	1.4	1.0	1.0	1.4	1.4	0.8	0.8	0.7	0.6	1.0
18	242.9	28.4	176.4	7.6	2366.	570.	40.2	6.7	1.8	2.1	1.0	1.0	1.8	2.1	0.7	1.0	0.7	0.5	1.0
19	334.6	2.2	330.7	37.6	3930.	3343.	38.3	4.4	1.2	1.2	4.5	4.6	4.8	4.8	0.7	0.7	0.8	0.8	99.7
20	1212.9	14.8	1045.6	3.4	2263.	850.	108.9	9.8	5.6	6.4	8.2	9.3	12.8	14.7	0.4	0.5	1.2	1.0	34.8
21	2237.2	19.0	1835.5	3.5	2090.	445.	122.7	6.7	2.9	3.4	3.9	4.5	5.8	6.9	0.7	0.9	0.7	0.6	13.6
22	1138.1	58.5	483.7	4.3	2246.	555.	88.8	6.9	1.2	1.5	17.1	38.8	17.3	39.3	0.2	0.4	3.3	1.4	18.6
23	10147.0	25.8	7228.5	2.6	2194.	1377.	360.6	12.8	2.0	2.3	4.5	6.0	5.5	7.3	0.4	0.6	1.2	0.8	20.9
24	513.8	47.5	275.1	9.8	2395.	390.	43.0	3.6	1.8	2.4	2.4	3.7	3.2	5.1	0.4	0.7	1.3	0.7	1.0
25	1598.9	47.3	857.8	2.7	1973.	465.	97.5	5.9	2.1	3.1	1.0	1.0	2.1	3.1	0.4	0.7	1.4	0.7	1.0
26	3747.4	61.1	1494.6	2.3	1861.	955.	176.4	8.3	1.9	3.1	1.0	1.0	1.9	3.1	0.2	0.6	2.2	0.9	2.4
27	99.0	7.1	92.9	96.4	3232.	1478.	17.8	3.2	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	0.5	0.4	16.7
28	157.3	11.9	140.1	8.5	2719.	1043.	39.5	9.9	1.4	1.4	6.2	6.9	6.6	7.3	0.9	1.0	0.6	0.5	2.0
29	54.6	1.9	54.2	85.4	3080.	1425.	15.4	4.3	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.2	0.4	0.4	26.6
30	60.9	20.4	49.0	62.2	3154.	1207.	19.3	6.1	1.0	1.0	3.6	4.2	3.6	4.2	0.6	0.8	0.8	0.7	8.7
31	523.1	11.7	466.3	7.8	2914.	1043.	47.3	4.2	1.0	1.0	1.4	1.5	1.4	1.5	0.3	0.4	1.4	1.3	1.6
32	244.6	83.3	43.3	3.1	1845.	290.	21.3	1.9	1.0	1.0	1.0	1.0	1.0	1.0	0.1	0.6	5.0	0.9	1.0
33	1925.8	12.0	1714.4	9.1	2612.	999.	73.0	2.8	1.8	1.9	1.0	1.0	1.8	1.9	0.7	0.8	0.7	0.6	1.0
34	1770.6	20.8	1419.7	4.7	2490.	1160.	119.2	8.0	1.3	1.3	1.0	1.0	1.3	1.3	0.6	0.8	0.8	0.7	1.0
35	1053.8	11.5	943.6	0.9	1873.	1038.	67.5	4.3	1.2	1.2	1.5	1.6	1.7	1.8	0.6	0.7	0.8	0.7	1.0
36	4187.6	13.6	3660.2	1.0	1843.	1145.	123.5	3.6	1.4	1.5	1.2	1.3	1.7	1.8	0.3	0.3	1.9	1.7	1.0
37	1733.4	12.5	1534.8	3.1	1920.	575.	112.1	7.2	1.1	1.1	1.0	1.0	1.1	1.1	0.2	0.2	2.7	2.4	1.0
38	168.5	2.0	166.7	15.1	1984.	545.	32.7	6.4	1.4	1.4	1.0	1.0	1.4	1.4	0.4	0.4	1.4	1.4	3.8
39	969.9	24.5	742.2	6.8	1820.	420.	51.3	2.7	1.6	1.8	1.6	1.8	2.3	2.7	0.4	0.5	1.4	1.1	3.6
40	644.5	24.1	455.5	4.8	1805.	617.	80.9	10.2	1.3	1.3	1.0	1.0	1.3	1.3	0.3	0.3	2.0	1.5	1.0
41	373.3	44.4	211.4	8.2	2003.	557.	39.9	4.3	1.8	2.5	1.0	1.0	1.8	2.5	0.3	0.5	1.9	1.1	11.8
42	119.5	11.3	107.6	24.8	1836.	660.	18.9	3.0	2.2	2.3	1.0	1.0	2.2	2.3	0.5	0.5	1.0	0.9	3.6
43	383.3	32.6	262.0	8.1	2009.	420.	50.9	6.8	1.4	1.7	1.0	1.0	1.4	1.7	0.4	0.5	1.3	0.9	8.3
44	311.7	25.4	235.6	8.3	1581.	293.	30.4	3.0	1.6	1.8	1.0	1.0	1.6	1.8	0.4	0.5	1.4	1.0	17.5
45	209.9	6.3	198.8	7.2	1555.	434.	27.2	3.5	5.5	5.7	2.5	2.6	6.9	7.3	0.2	0.2	2.6	2.4	29.9
46	1360.7	14.8	1172.3	4.7	1353.	760.	91.9	6.2	2.0	2.1	1.2	1.3	2.2	2.4	0.3	0.4	1.6	1.4	13.0
47	3393.6	10.3	3077.8	3.7	1263.	885.	161.0	7.6	1.5	1.5	1.4	1.5	1.9	2.0	0.4	0.5	1.2	1.1	27.1
48	208.9	1.0	208.9	2.4	1095.	180.	16.6	1.3	1.0	1.0	1.0	1.0	1.0	1.0	0.1	0.1	4.3	4.3	14.4
49	1823.1	10.7	1647.0	4.9	1517.	1081.	98.2	5.3	5.3	5.7	5.5	6.0	9.8	10.7	0.3	0.3	1.8	1.6	74.1
50	800.8	5.1	767.7	8.9	1528.	807.	56.0	3.9	1.9	1.9	7.7	8.0	8.6	8.9	0.6	0.6	0.8	0.8	73.7
51	4018.6	8.1	3733.8	4.3	1459.	1090.	164.9	6.8	2.8	2.9	18.9	20.3	20.7	22.2	0.5	0.6	0.9	0.9	49.6
52	5239.1	6.8	4933.8	4.9	1285.	1282.	227.7	9.9	4.7	5.0	18.4	19.5	22.1	23.4	0.5	0.6	0.9	0.9	59.3
53	1139.6	6.3	1079.4	5.7	1073.	1555.	97.5	8.3	3.3	3.4	64.1	67.6	66.4	70.0	0.3	0.3	1.7	1.6	98.0
54	1543.3	8.5	1428.0	6.2	1437.	1170.	116.8	8.8	2.3	2.4	10.4	11.1	11.7	12.5	0.7	0.7	0.7	0.7	56.9
55	55.6	3.2	54.3	63.7	1775.	1514.	24.1	10.4	2.7	2.7	27.3	27.9	29.0	29.7	0.8	0.8	0.6	0.6	96.2
56	829.3	4.1	803.5	21.4	1655.	1610.	78.5	7.4	3.4	3.4	5.9	6.0	8.2	8.5	0.7	0.7	0.8	0.7	78.2
57	329.6	2.5	324.8	29.4	1644.	1607.	55.6	9.4	3.9	3.9	3.3	3.3	6.1	6.2	0.9	0.9	0.5	0.5	75.2
58	1602.2	8.5	1482.1	5.8	1355.	1340.	133.8	11.2	2.3	2.4	10.0	10.7	11.3	12.1	0.7	0.7	0.7	0.7	55.0
59	116.3	2.6	114.4	2.4	952.	1451.	24.1	5.0	10.0	10.1	4.3	4.4	13.3	13.5	0.9	0.9	0.6	0.6	90.7
60	69.9	3.0	68.5	77.7	1750.	1485.	19.7	5.6	5.9	6.0	6.1	6.2	11.0	11.2	0.8	0.8	0.6	0.6	99.0
61	109.4	1.7	108.7	78.1	1743.	1420.	19.7	3.6	2.6	2.6	1.0	1.0	2.6	2.6	0.7	0.7	0.7	0.7	92.0
62	160.7	3.3	156.9	40.1	1496.	1583.	33.5	7.0	2.1	2.1	5.3	5.4	6.3	6.5	0.8	0.8	0.7	0.6	76.6
63	144.2	9.2	132.3	50.4	1536.	1386.	30.4	6.4	2.0	2.1	1.0	1.0	2.0	2.1	0.7	0.8	0.7	0.6	93.9
64	425.5	10.7	384.2	2.7	952.	1451.	21.7	1.1	1.0	1.0	3.9	4.2	3.9	4.2	0.2	0.2	2.3	2.1	49.3
65	353.6	3.9	343.4	15.1	1202.	1205.	45.8	5.9	1.4	1.5	2.8	2.9	3.3	3.4	0.7	0.7	0.7	0.7	49.9
66	255.6	2.0	253.9	33.8	1402.	1310.	35.5	4.9	1.3	1.3	2.0	2.0	2.3	2.3	0.5	0.5	1.0	0.9	56.8
67	109.9	1.3	109.6	32.2	1331.	1845.	34.3	10.7	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.9	0.9	47.7
68	117.4	1.5	116.8	72.9	1705.	1609.	20.9	3.7	1.8	1.8	6.7	6.7	7.5	7.5	0.7	0.7	0.7	0.7	70.0
69	65.5	2.2	64.8	41.8	1471.	1609.	22.1	7.4	2.0	2.0	1.0	1.0	2.0	2.0	0.7	0.7	0.7	0.7	46.1
70	58.4	2.3	57.6	49.4	1637.	1599.	23.7	9.6	1.5	1.5	3.7	3.7	4.2	4.2	0.9	0.9	0.6	0.6	59.7
71	66.3	1.0	66.3	53.8	1360.	1282.	17.4	4.5	2.4	2.4	1.0	1.0	2.4	2.4	0.6	0.6	0.9	0.9	76.1
72	152.3	1.6	151.3	11.1	1115.	333.	30.0	5.9	1.0	1.0	1.9	1.9	1.9	1.9	0.3	0.3	1.6	1.6	39.9
73	70.1	7.7	65.4	35.6	1721.	1050.	24.1	8.3	1.2	1.2	1.0	1.0	1.2	1.2	1.0	1.1	0.5	0.5	16.6
74	75.7	1.4	75.4	6.3	1225.	120.	16.2	3.5	1.4	1.4	1.0	1.0	1.4	1.4	0.2	0.2	2.5	2.5	89.5
75	880.7	23.5	638.9	5.6	1731.	625.	68.3	5.3	3.5	4.5	8.5	11.4	11.0	14.8	0.3	0.4	1.5	1.1	11.6
76	376.8	12.8	332.2	7.1	1825.	320.	47.0	5.9	5.8	6.4	3.2	3.5	7.9	8.9	0.4	0.5	1.2	1.0	11.7
77	749.3	9.3	687.2	8.6	1822.	512.	49.3	3.2	2.6	2.7	2.9	3.0	4.4	4.7	0.5	0.6	1.0	0.9	65.0
78	86.3	8.4	79.9	9.8	1716.	210.	19.3	4.3	2.8	2.9	1.0	1.0	2.8	2.9	0.5	0.5	1.1	1.0	4.6
79	779.4	17.9	647.8	7.1	1810.	1105.	105.0	14.1	4.0	4.7	2.5	2.8	5.6	6.5	0.6	0.7	0.9	0.7	65.7
80	99.2	16.7	83.6	39.4	1777.	818.	20.1	4.1	2.6	2.9	1.0	1.0	2.6	2.9	0.7	0.8	0.8	0.6	65.4
81	468.1	36.2	303.3	5.2	1719.	635.	48.9	5.1	2.9	3.9	2.7	3.6	4.6	6.5	0.4	0.6	1.4	0.9	58.2
82	943.0	20.7	700.6	4.3	1870.	687.	80.9	6.9	6.4	8.3	4.5	5.7	9.9	13.0	0.5	0.7	1.0	0.7	56.6
83	282.4	5.6	269.5	9.4	2090.	457.	24.9	2.2	6.0	6.2	9.3	9.7	14.2	14.9	0.7	0.7	0.7	0.7	67.2
84	299.9	58.1	128.8	7.4	1698.	768.	55.2	10.2	2.1	3.5	1.0	1.0	2.1	3.5	0.4	0.9	1.3	0.6	3.6
85	95.3	11.5	85.3	10.5	1633.	415.	37.5	14.7	1.3	1.4	1.0	1.0	1.3	1.4	0.6	0.7	0.8	0.7	4.3
86	120.3	6.0	114.3	12.2	1675.	430.	41.4	14.3	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.7	0.7	4.9
87	480.6	57.9	207.2	6.4	1729.	620.	62.3	8.1	2.2	3.8	1.0	1.0	2.2	3.8	0.2	0.6	2.0	0.9	3.3
88	187.0	4.9	179.7	6.3	1323.	357.	24.5	3.2	1.2	1.2	1.0	1.0	1.2	1.2	0.4	0.5	1.1	1.1	12.7
89	276.0	3.7	268.7	5.1	1260.	595.	43.0	6.7	1.3	1.3	14.0	14.4	14.4	14.7	0.1	0.2	3.4	3.3	33.1
90	161.4	1.7	160.4	1.3	793.	88.	35.5	7.8	1.0	1.0	2.5	2.6	2.5	2.6	0.5	0.5	1.0	0.9	3.9

* FOR VARIABLE IDENTIFICATION AND METHODS OF CALCULATION SEE TABLE 4-9

TABLE C-4 CONTINUED

BASNO	TDA	NCDA	CDA	MCS	EL	TOTR	MCL	BS	ALTDA	ALCDA	ASTDA	ASCDA	LSTDA	LSCDA	DDTDA	DDCDA	LOTDA	LOCDA	AFTDA
91	160.8	39.2	99.3	16.2	2210.	408.	20.1	2.5	1.0	1.0	1.0	1.C	1.0	1.0	0.4	0.7	1.1	0.7	1.0
92	598.0	28.9	430.9	2.3	1899.	297.	41.4	2.9	1.1	1.1	1.0	1.0	1.1	1.1	0.1	0.2	3.7	2.7	1.0
93	91.7	2.2	90.6	6.0	1993.	235.	32.0	11.1	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8	0.6	0.6	1.0
94	44.8	53.8	21.2	2.9	1880.	64.	18.2	7.3	1.3	1.7	1.0	1.0	1.3	1.7	0.4	0.8	1.4	0.7	1.0
95	1014.6	21.9	802.4	5.2	1936.	450.	56.8	3.2	1.4	1.5	1.0	1.0	1.4	1.5	0.3	0.4	1.8	1.4	12.5
96	1227.9	9.3	1126.5	5.8	1800.	1118.	142.0	16.4	1.1	1.1	1.0	1.0	1.1	1.1	0.4	0.4	1.4	1.2	5.6
97	508.0	2.4	500.8	5.8	1713.	673.	92.7	16.9	1.0	1.0	1.0	1.0	1.0	1.0	0.3	0.4	1.4	1.4	3.1
98	287.7	3.2	281.5	7.5	1607.	495.	58.0	11.7	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.2	2.3	2.3	1.5
99	153.4	45.3	85.5	11.2	1284.	370.	18.2	2.1	1.7	2.3	1.0	1.0	1.7	2.3	0.5	0.9	1.0	0.6	4.0
100	164.1	7.2	154.0	8.7	1524.	255.	32.7	6.5	1.1	1.1	1.0	1.0	1.1	1.1	0.4	0.4	1.2	1.1	1.0
101	180.0	24.4	137.9	15.6	1694.	712.	27.6	4.2	1.6	1.8	1.0	1.0	1.6	1.8	0.8	1.0	0.6	0.5	13.1
102	600.5	32.9	409.1	1.3	1514.	644.	33.9	1.9	2.1	2.7	2.6	3.3	3.7	5.0	0.5	0.7	1.1	0.7	1.5
103	206.3	25.2	156.5	8.9	1717.	770.	28.0	3.8	1.5	1.6	1.0	1.0	1.5	1.6	0.8	1.0	0.7	0.5	22.1
104	44.1	68.8	14.2	31.5	2010.	500.	11.8	3.2	2.4	5.4	1.0	1.0	2.4	5.4	0.4	1.2	1.3	0.4	57.5
105	47.6	31.4	33.2	7.2	1528.	107.	11.0	2.6	3.0	3.8	1.0	1.0	3.0	3.8	0.6	0.8	0.9	0.6	1.0
106	213.8	29.9	151.9	6.4	1544.	230.	23.7	2.6	1.4	1.6	1.0	1.0	1.4	1.6	0.3	0.4	1.7	1.2	1.0
107	381.0	57.0	167.7	2.9	1550.	150.	36.7	3.5	2.1	3.5	6.4	13.3	7.5	15.8	0.2	0.5	2.1	0.9	1.0
108	112.7	12.2	100.1	4.4	1560.	155.	24.1	5.1	1.0	1.0	1.6	1.6	1.6	1.6	0.3	0.4	1.6	1.4	1.0
109	1177.0	5.0	1129.4	2.9	1028.	482.	123.5	13.0	1.0	1.0	35.0	36.5	35.0	36.5	0.5	0.5	1.0	1.0	60.8
110	1658.1	3.8	1612.1	2.3	1081.	307.	104.6	6.6	1.0	1.0	24.1	24.8	24.1	24.8	0.3	0.3	1.5	1.5	40.1
111	1691.8	3.8	1644.2	2.2	1075.	351.	109.3	7.1	1.0	1.0	23.7	24.3	23.7	24.3	0.3	0.3	1.5	1.5	40.1
112	160.4	4.8	154.3	5.4	1094.	203.	15.4	1.5	1.0	1.0	12.6	13.0	12.6	13.0	0.5	0.5	1.1	1.0	86.4
113	59.2	1.0	59.2	7.5	895.	447.	21.3	7.7	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.6	0.9	0.9	3.6
114	212.2	14.6	183.2	2.2	805.	180.	20.9	2.1	1.0	1.0	1.0	1.0	1.0	1.0	0.3	0.3	1.8	1.6	26.7
115	152.3	20.0	123.3	1.6	818.	155.	12.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.3	2.2	1.8	36.8
116	103.2	29.1	74.3	7.3	873.	140.	17.4	2.9	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.3	2.3	1.7	34.2
117	231.7	1.0	231.7	3.0	783.	184.	37.9	6.2	1.0	1.0	2.2	2.2	2.2	2.2	0.3	0.3	1.7	1.7	40.0
118	192.6	1.0	192.6	3.6	807.	143.	24.9	3.2	1.0	1.0	2.5	2.5	2.5	2.5	0.3	0.3	1.8	1.8	43.8
119	199.8	12.6	176.6	1.0	758.	168.	25.6	3.3	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.3	2.2	2.0	31.4
120	97.3	24.8	74.1	8.2	822.	132.	13.0	1.7	1.0	1.0	1.0	1.0	1.0	1.0	0.1	0.1	4.9	3.8	47.4
121	1359.1	3.9	1319.9	2.7	1044.	390.	86.4	5.5	2.7	2.8	68.1	70.1	69.9	71.9	0.1	0.1	3.6	3.5	93.2
122	511.6	1.0	511.6	4.3	854.	238.	42.6	3.5	1.0	1.0	64.4	64.4	64.4	64.4	0.1	0.1	3.4	3.4	80.4
123	265.2	1.0	265.2	4.3	911.	242.	29.6	3.3	1.0	1.0	69.7	69.7	69.7	69.7	0.1	0.1	6.0	6.0	85.5
124	31.9	1.0	31.9	10.8	781.	145.	13.4	5.6	1.0	1.0	4.9	4.9	4.9	4.9	0.4	0.4	1.2	1.2	59.5
125	508.7	34.8	337.0	3.5	790.	194.	47.3	4.4	1.0	1.0	10.0	14.5	10.0	14.5	0.1	0.2	3.4	2.2	42.9
126	666.9	9.0	613.5	3.9	808.	177.	40.6	2.5	1.0	1.0	28.8	31.2	28.8	31.2	0.2	0.2	3.2	3.0	64.7
127	206.0	16.6	173.9	3.9	830.	157.	30.4	4.5	1.0	1.0	2.1	2.3	2.1	2.3	0.2	0.2	2.8	2.4	45.6
128	8042.7	12.1	7152.2	3.0	1823.	970.	243.5	7.4	5.6	6.2	16.7	18.7	21.3	23.8	0.3	0.4	1.5	1.4	88.4
129	5427.2	13.3	4757.3	4.2	1922.	860.	157.0	4.5	6.5	7.3	20.5	23.3	26.0	29.6	0.3	0.4	1.4	1.3	87.5
130	976.2	1.0	976.2	24.7	3972.	6030.	89.6	8.2	1.4	1.4	23.5	23.5	23.9	23.9	1.1	1.1	0.5	0.5	96.9
131	2385.6	1.0	2385.6	18.2	3703.	6293.	128.6	6.9	1.6	1.6	62.9	62.9	63.5	63.5	1.2	1.2	0.4	0.4	99.0
132	322.7	1.0	322.7	14.6	3175.	840.	46.6	6.7	2.4	2.4	99.4	99.4	100.8	100.8	1.5	1.5	0.3	0.3	100.9
133	1017.7	1.8	1009.6	18.1	3629.	5072.	118.4	13.8	1.4	1.4	28.9	29.2	29.3	29.5	1.0	1.0	0.5	0.5	95.8
134	1610.4	1.5	1602.3	11.2	3328.	5503.	196.5	24.0	1.3	1.3	27.2	27.4	27.5	27.7	0.9	0.9	0.6	0.6	94.1
135	611.7	2.6	601.7	5.9	2691.	965.	63.1	6.5	5.7	5.8	30.4	30.9	35.2	35.7	0.4	0.4	1.2	1.2	66.2
136	236.2	3.9	229.3	17.9	2500.	1102.	33.5	4.8	1.0	1.0	11.9	12.3	11.9	12.3	0.5	0.5	0.9	0.9	69.6
137	104.3	4.4	100.7	25.1	2472.	1010.	18.9	3.4	1.0	1.0	13.1	13.5	13.1	13.5	0.8	0.9	0.6	0.6	75.7
138	4876.9	3.7	4746.1	5.9	2832.	5879.	372.5	28.4	2.3	2.4	22.8	23.4	24.1	24.8	0.7	0.7	0.7	0.7	64.9
139	552.7	1.8	548.2	12.4	2373.	2535.	85.6	13.3	1.0	1.0	6.5	6.5	6.5	6.5	1.1	1.1	0.5	0.5	99.3
140	456.2	2.4	449.9	13.2	2275.	1485.	60.8	8.1	1.2	1.2	8.4	8.5	8.6	9.7	0.9	1.0	0.5	0.5	99.3
141	731.7	1.1	730.9	34.5	2788.	2465.	63.5	5.5	1.3	1.3	26.0	26.0	26.3	26.4	1.3	1.3	0.4	0.4	28.4
142	4351.4	2.6	4281.5	19.9	2788.	6467.	132.6	4.0	1.4	1.4	4.0	4.0	4.3	4.4	0.6	0.7	0.8	0.8	58.5
143	4296.9	1.7	4246.4	9.0	2749.	3655.	264.8	16.3	2.6	2.6	12.1	12.2	13.7	13.8	0.7	0.7	0.8	0.7	98.5
144	749.9	4.9	720.7	9.4	2070.	680.	58.4	4.5	1.8	1.9	22.8	23.7	23.6	24.5	0.5	0.5	1.1	1.1	90.3
145	1830.9	1.9	1814.2	8.3	2105.	2082.	153.5	12.9	1.2	1.2	20.4	20.6	20.6	20.8	0.7	0.7	0.7	0.7	100.1
146	2378.9	1.0	2378.9	4.6	1085.	683.	100.6	4.3	1.4	1.4	97.9	97.9	98.2	98.2	0.8	0.8	0.6	0.6	100.9
147	1001.1	8.4	927.1	23.2	1888.	2420.	102.2	10.4	6.4	6.8	34.1	36.8	39.5	42.6	0.8	0.8	0.7	0.6	98.4
148	176.7	2.6	173.9	23.8	3152.	1143.	31.2	5.5	1.4	1.4	1.0	1.0	1.4	1.4	0.8	0.8	0.6	0.6	1.0
149	116.8	1.0	116.8	36.8	3712.	1329.	20.9	3.7	1.4	1.4	1.0	1.0	1.4	1.4	0.9	0.9	0.5	0.5	1.0
150	65.7	2.9	64.5	31.1	3043.	707.	17.4	4.6	1.7	1.7	1.0	1.0	1.7	1.7	1.0	1.0	0.5	0.5	1.0
151	255.3	2.8	250.8	25.8	3675.	1491.	41.8	6.9	1.4	1.4	1.0	1.0	1.4	1.4	1.0	1.0	0.5	0.5	25.4
152	364.3	2.6	358.4	34.5	3570.	1832.	39.5	4.3	1.5	1.5	1.0	1.0	1.5	1.5	0.8	0.8	0.6	0.6	4.8
153	160.4	1.3	159.9	24.9	3605.	1456.	31.6	6.2	2.4	2.4	1.0	1.0	2.4	2.4	0.9	0.9	0.5	0.5	1.0
154	56.2	4.9	54.0	14.9	2923.	380.	20.1	7.2	2.1	2.2	2.1	2.2	3.2	3.3	0.9	0.9	0.6	0.5	1.0
155	71.3	1.7	70.8	11.5	2925.	485.	17.4	4.2	1.2	1.2	1.0	1.0	1.2	1.2	1.4	1.4	0.4	0.4	1.0
156	504.0	24.6	385.2	9.8	2750.	730.	49.9	4.8	1.6	1.7	1.0	1.0	1.6	1.7	0.6	0.8	0.8	0.6	1.0
157	153.7	8.2	142.6	16.0	2984.	447.	20.1	2.6	1.1	1.1	1.0	1.0	1.1	1.1	0.8	0.8	0.7	0.6	1.0
158	541.5	10.3	491.0	5.5	2573.	650.	51.7	4.9	3.5	3.7	1.0	1.0	3.5	3.7	0.9	0.9	0.6	0.5	1.0
159	224.7	1.0	224.7	15.6	2799.	695.	34.3	5.2	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	0.4	0.4	1.0
160	80.0	2.2	79.1	11.0	2587.	540.	20.9	5.5	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.4	0.4	0.3	1.0
161	304.4	1.2	303.7	12.2	2733.	720.	34.3	3.9	1.1	1.1	1.0	1.0	1.1	1.1	1.2	1.2	0.4	0.4	1.0