# INVESTIGATION OF HYDROMETRIC NETWORK CHARACTERISTICS THROUGH THE USE OF SIMPLE STATISTICS

by

David A. Kiely

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Science
in
Civil Engineering

Winnipeg, Manitoba

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A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF SCIENCE

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## ABSTRACT

The recorded streamflow data consisting of typical streamflow parameters; annual mean flow, monthly mean flow and daily mean peak flows from the Pembina River basin, were analyzed with various statistical techniques including non-parametric analysis, simple statistics, regional regression and correlation analysis. The examination of the streamflow data attempted to identify any general relationships or anomalies in the streamflow parameters and the possible cause of the anomalies where appropriate.

It was found that nonparametric data screening is a good general tool for identifying anomalous station records. Plotting the sample statistics versus drainage area indicated that the mean, median, standard deviation, range, maximum and yield were well related to drainage area, and outlier detection techniques based on these relationships were used to identify anomalous station records. The correlation analysis identified station groupings which were hydrologically reasonable and determined the overlap of station records in the basin.

Minor problems with the hydrometric network of the basin were identified such as: no stations with drainage areas less than 50 $km^2$, overflow above Pembina River near Neche (05OC004) is unaccounted for, and several stations were located near to structures and the streamflow records at these stations are affected by these structures.

## TABLE OF CONTENTS


| | Page Number |
|---|---|
| 1. INTRODUCTION | 1 |
| 1.1 GENERAL DESCRIPTION | 1 |
| 1.2 NETWORK REVIEW IN CANADA | 2 |
| 2. PROBLEM EVALUATION | 6 |
| 2.1 SCOPE OF THIS STUDY | 6 |
| 2.2 STUDY AREA | 6 |
| 3. STATISTICAL TECHNIQUES | 13 |
| 3.1 BASIC PRINCIPLES | 13 |
| 3.2 NONPARAMETRIC STATISTICAL TESTS | 14 |
| 3.2.1 Description of Tests | 14 |
| 3.2.1.1 Independence | 16 |
| 3.2.1.2 Trend | 20 |
| 3.2.1.3 Homogeneity - Mann-Whitney Split Sample Test | 22 |
| 3.2.1.4 Homogeneity - Wald-Wolfowitz Split Sample Test | 25 |
| 3.2.1.5 Randomness | 29 |
| 3.2.2 Data Investigated | 32 |
| 3.2.3 Results of Nonparametric Tests | 34 |
| 3.2.4 Discussion of Nonparametric Test Results | 37 |
| 3.2.4.1 Independence | 38 |
| 3.2.4.2 Trend | 39 |
| 3.2.4.3 Homogeneity | 40 |
| 3.2.4.4 Randomness | 44 |
| 3.2.5 Implications of Nonparametric Tests on Data Screening | 44 |

3.3 SAMPLE STATISTICS . . . . . 46
3.3.1 Description of Sample Statistics . . . . . 46
3.3.2 Data Base . . . . . 51
3.3.2.1 Annual Mean Flows . . . . . 52
3.3.2.2 Maximum Daily Mean Peak Flows . . . . . 54
3.3.2.3 Monthly Mean Flows . . . . . 55
3.3.3 Investigation Procedure and Results . . . . . 55
3.3.3.1 Sample Statistics versus Drainage Areas . . 56
3.3.3.2 Linear Regression Data Screening . . . . . 61
3.3.4 General Summary and Discussion of Results . . 76
3.3.4.1 Simple Statistics Plotted Against Drainage Area . . . . . 77
3.3.4.2 Linear Regression Analysis . . . . . 80
3.3.4.3 Outlier Detection - Confidence Intervals . 83
3.3.4.4 Outlier Detection - Studentized Residual . 86
3.3.4.5 Outlier Detection - Cook's D . . . . . 90
3.3.5 Implications of Sample Statistics Data Screening . . . . . 90
3.4 REGIONAL CORRELATION ANALYSIS . . . . . 94
3.4.1 Description of Correlation and Cluster Analysis . . . . . 97
3.4.1.1 Interstation Correlation . . . . . 97
3.4.1.2 Cluster Analysis . . . . . 98
3.4.2 Data Investigated . . . . . 101
3.4.3 Results of Correlation and Cluster Analysis . 102
3.4.4 Discussion of the Correlation Analysis . . . 109
3.4.5 Implications of Correlation Analysis on Data Screening . . . . . 109
4. CONCLUSIONS AND NETWORK REVIEW . . . . . 111
5. RECOMMENDATIONS AND LIMITATIONS . . . . . 115
5.1 STREAMFLOW DATA . . . . . 115
5.2 STATISTICAL TECHNIQUES . . . . . 115

## LIST OF TABLES


| Table Number | | Page Number |
|---|---|---|
| 2.1 | Summary of Gauging Stations in Pembina River Basin . . . . . | 11 |
| 3.1 | Major Reservoirs in the Pembina River Basin . . . . . | 34 |
| 3.2 | Nonparametric Test Results - Median Period Split Data Stations Identified Significant at the 5% Level . . . . . | 35 |
| 3.3 | Nonparametric Test Results - Construction Time Split Data Station Data Sets Identified Significant at the 5% Level . . . . . | 37 |
| 3.4 | Adjusted $r^2$ Values for Regional Regression Equations Relating Sample Statistics to Gross Drainage Area . . . . . | 64 |
| 3.5 | Stations Whose Annual Mean Sample Statistics Fell Outside of the 95% Confidence Intervals . . . . . | 70 |
| 3.6 | Stations Whose Daily Peak Sample Statistics Fell Outside of the 95% Confidence Intervals . . . . . | 71 |
| 3.7 | Stations Whose Sample Statistics Have a $\lvert$Studentized Residual$\rvert$ Value > 1.5 . . | 73 |
| 3.8 | Stations Whose Sample Statistics Have a Cook's D Value > 0.164 . . . . . | 75 |
| 3.9 | Explanation of Anomalous Monthly Data Sets Based on the Prediction Confidence Interval . | 85 |
| 3.10 | Hypothetical Basin Correlation Coefficients to Illustrate McQuitty Procedure . . . . . | 100 |
| 3.11 | Pearson Correlation Coefficients for Pembina River Basin Period Mean Flows . . . . | 102 |
| 3.12 | Spearman Correlation Coefficients for Pembina River Basin Period Mean Flows . . . . | 103 |

APPENDIX A


| | | |
|---|---|---|
| A-1 | Listing of SIMPSTATS Program . . . . . | 122 |
| A-2 | Sample Statistics for Pembina River Basin Annual Mean Flows . . . . . | 128 |
| A-3 | Sample Statistics for Pembina River Basin Daily Mean Peak Flows . . . . . | 129 |
| A-4 | Sample Statistics for Pembina River Basin January Monthly Mean Flows . . . . . | 130 |
| A-5 | Sample Statistics for Pembina River Basin February Monthly Mean Flows . . . . . | 130 |
| A-6 | Sample Statistics for Pembina River Basin March Monthly Mean Flows . . . . . | 131 |
| A-7 | Sample Statistics for Pembina River Basin April Monthly Mean Flows . . . . . | 132 |
| A-8 | Sample Statistics for Pembina River Basin May Monthly Mean Flows . . . . . | 133 |
| A-9 | Sample Statistics for Pembina River Basin June Monthly Mean Flows . . . . . | 134 |
| A-10 | Sample Statistics for Pembina River Basin July Monthly Mean Flows . . . . . | 135 |
| A-11 | Sample Statistics for Pembina River Basin August Monthly Mean Flows . . . . . | 136 |
| A-12 | Sample Statistics for Pembina River Basin September Monthly Mean Flows . . . . . | 137 |
| A-13 | Sample Statistics for Pembina River Basin October Monthly Mean Flows . . . . . | 138 |
| A-14 | Sample Statistics for Pembina River Basin November Monthly Mean Flows . . . . . | 139 |
| A-15 | Sample Statistics for Pembina River Basin December Monthly Mean Flows . . . . . | 139 |

APPENDIX B


B-1 Example Output From SAS Regression Developed Using Sample Statistics Based on Annual Mean Flows . . . . . 165

B-2 Stations Whose Sample Statistics Fell Outside of the Prediction 95% Confidence Interval . . 168

B-3 Stations Whose Sample Statistics Have a |Studentized Residual| > 1.5 . . . . . 169

B-4 Stations Whose Sample Statistics Have a Cook's D Value > 0.164 . . . . . 170


APPENDIX C


C-1 Pearson Correlation Coefficients for Pembina River Basin Daily Mean Peak Flows . . 172

C-2 Spearman Correlation Coefficients for Pembina River Basin Daily Mean Peak Flows . . 173

C-3 Pearson Correlation Coefficients for Pembina River Basin March Monthly Mean Flows . . . . . 174

C-4 Spearman Correlation Coefficients for Pembina River Basin March Monthly Mean Flows . . . . . 175

C-5 Pearson Correlation Coefficients for Pembina River Basin April Monthly Mean Flows . . . . . 176

C-6 Spearman Correlation Coefficients for Pembina River Basin April Monthly Mean Flows . . . . . 177

C-7 Pearson Correlation Coefficients for Pembina River Basin May Monthly Mean Flows . . . . . 178

C-8 Spearman Correlation Coefficients for Pembina River Basin May Monthly Mean Flows . . . . . 179

C-9 Pearson Correlation Coefficients for Pembina River Basin June Monthly Mean Flows . . . . . 180

C-10 Spearman Correlation Coefficients for Pembina River Basin June Monthly Mean Flows . . . . . 181

C-11 Pearson Correlation Coefficients for Pembina River Basin July Monthly Mean Flows . . . . . 182

C-12 Spearman Correlation Coefficients for Pembina River Basin July Monthly Mean Flows . . . . . 183

C-13 Pearson Correlation Coefficients for Pembina River Basin August Monthly Mean Flows . . . . . 184

C-14 Spearman Correlation Coefficients for Pembina River Basin August Monthly Mean Flows . . . . . 185

C-15 Pearson Correlation Coefficients for Pembina River Basin September Monthly Mean Flows . . . . . 186

C-16 Spearman Correlation Coefficients for Pembina River Basin September Monthly Mean Flows . . . . . 187

C-17 Pearson Correlation Coefficients for Pembina River Basin October Monthly Mean Flows . . . . . 188

C-18 Spearman Correlation Coefficients for Pembina River Basin October Monthly Mean Flows . . . . . 189

## LIST OF FIGURES


| Figure Number | | Page Number |
|---|---|---|
| 2.1 | Pembina River Basin Location Map . . . . . | 7 |
| 3.1 | Sample Statistics Representation . . . . . | 50 |
| 3.2 | Schematic of Pembina River System Upstream of Swan Lake . . . . . | 79 |
| 3.3 | McQuitty Cluster Analysis Pearson Correlation Coefficients Based on Period Mean Flows . . . . . | 106 |
| 3.4 | McQuitty Cluster Analysis Spearman Correlation Coefficients Based on Period Mean Flows . . . . . | 107 |
| APPENDIX A | | |
| A-1 | Annual Mean Flows Sample Mean versus Gross Drainage Area . . . . | 140 |
| A-2 | Annual Mean Flows Sample Median versus Gross Drainage Area . . . | 140 |
| A-3 | Annual Mean Flows Sample Standard Deviation versus Gross Drainage Area . . . . . | 141 |
| A-4 | Annual Mean Flows Sample Coefficient of Variation versus Gross Drainage Area . . . . . | 141 |
| A-5 | Annual Mean Flows Sample Coefficient of Skew versus Gross Drainage Area . . . . . | 142 |
| A-6 | Annual Mean Flows Sample Coefficient of Excess versus Gross Drainage Area . . . . . | 142 |
| A-7 | Annual Mean Flows Sample Range versus Gross Drainage Area . . . | 143 |
| A-8 | Annual Mean Flows Sample Maximum versus Gross Drainage Area . . | 143 |

A-9 Annual Mean Flows
Sample Yield (Mean/Gross Drainage Area)
versus Gross Drainage Area . . . . . 144

A-10 Annual Mean Flows
Sample Maximum/Minimum
versus Gross Drainage Area . . . . . 144

A-11 Annual Mean Flows
Sample Maximum/Mean
versus Gross Drainage Area . . . . . 145

A-12 Annual Mean Flows
Sample Median/Mean
versus Gross Drainage Area . . . . . 145

A-13 Annual Mean Flows
Sample Mean versus Effective Drainage Area . 146

A-14 Annual Mean Flows
Sample Median
versus Effective Drainage Area . . . . . 146

A-15 Annual Mean Flows
Sample Standard Deviation
versus Effective Drainage Area . . . . . 147

A-16 Annual Mean Flows
Sample Coefficient of Variation
versus Effective Drainage Area . . . . . 147

A-17 Annual Mean Flows
Sample Coefficient of Skew
versus Effective Drainage Area . . . . . 148

A-18 Annual Mean Flows
Sample Coefficient of Excess
versus Effective Drainage Area . . . . . 148

A-19 Annual Mean Flows
Sample Range versus Effective Drainage Area . 149

A-20 Annual Mean Flows
Sample Maximum
versus Effective Drainage Area . . . . . 149

A-21 Annual Mean Flows
Sample Yield (Mean/Effective Drainage Area)
versus Effective Drainage Area . . . . . 150

A-22 Annual Mean Flows
Sample Maximum/Minimum
versus Effective Drainage Area . . . . . 150

A-23 Annual Mean Flows
Sample Maximum/Mean
versus Effective Drainage Area . . . . . 151

A-24 Annual Mean Flows
Sample Median/Mean
versus Effective Drainage Area . . . . . 151

A-25 Daily Mean Peak Flows
Sample Mean versus Gross Drainage Area . . . . 152

A-26 Daily Mean Peak Flows
Sample Median versus Gross Drainage Area . . . 152

A-27 Daily Mean Peak Flows
Sample Standard Deviation
versus Gross Drainage Area . . . . . 153

A-28 Daily Mean Peak Flows
Sample Coefficient of Variation
versus Gross Drainage Area . . . . . 153

A-29 Daily Mean Peak Flows
Sample Coefficient of Skew
versus Gross Drainage Area . . . . . 154

A-30 Daily Mean Peak Flows
Sample Coefficient of Excess
versus Gross Drainage Area . . . . . 154

A-31 Daily Mean Peak Flows
Sample Range versus Gross Drainage Area . . . 155

A-32 Daily Mean Peak Flows
Sample Maximum versus Gross Drainage Area . . 155

A-33 Daily Mean Peak Flows
Sample Yield (Mean/Gross Drainage Area)
versus Gross Drainage Area . . . . . 156

A-34 Daily Mean Peak Flows
Sample Maximum/Minimum
versus Gross Drainage Area . . . . . 156

A-35 Daily Mean Peak Flows
Sample Maximum/Mean
versus Gross Drainage Area . . . . . 157

A-36 Daily Mean Peak Flows
Sample Median/Mean
versus Gross Drainage Area . . . . . 157

A-37 Daily Mean Peak Flows
Sample Mean
versus Effective Drainage Area . . . . . 158

A-38 Daily Mean Peak Flows
Sample Median
versus Effective Drainage Area . . . . . 158

A-39 Daily Mean Peak Flows
Sample Standard Deviation
versus Effective Drainage Area . . . . . 159

A-40 Daily Mean Peak Flows
Sample Coefficient of Variation
versus Effective Drainage Area . . . . . 159

A-41 Daily Mean Peak Flows
Sample Coefficient of Skew
versus Effective Drainage Area . . . . . 160

A-42 Daily Mean Peak Flows
Sample Coefficient of Excess
versus Effective Drainage Area . . . . . 160

A-43 Daily Mean Peak Flows
Sample Range versus Effective Drainage Area . . 161

A-44 Daily Mean Peak Flows
Sample Maximum
versus Effective Drainage Area . . . . . 161

A-45 Daily Mean Peak Flows
Sample Yield (Mean/Effective Drainage Area)
versus Effective Drainage Area . . . . . 162

A-46 Daily Mean Peak Flows
Sample Maximum/Minimum
versus Effective Drainage Area . . . . . 162

A-47 Daily Mean Peak Flows
Sample Maximum/Mean
versus Effective Drainage Area . . . . . 163

A-48 Daily Mean Peak Flows
Sample Median/Mean
versus Effective Drainage Area . . . . . 163

APPENDIX C

C-1 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on Daily Mean Peak Flows . . . . . 190

C-2 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on Daily Mean Peak Flows . . . . . 190

C-3 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on March Mean Flows . . . . . 191

C-4 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on March Mean Flows . . . . . 191

C-5 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on April Mean Flows . . . . . 192

C-6 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on April Mean Flows . . . . . 192

C-7 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on May Mean Flows . . . . . 193

C-8 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on May Mean Flows . . . . . 193

C-9 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on June Mean Flows . . . . . 194

C-10 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on June Mean Flows . . . . . 194

C-11 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on July Mean Flows . . . . . 195

C-12 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on July Mean Flows . . . . . 196

C-13 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on August Mean Flows . . . . . 197

C-14 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on August Mean Flows . . . . . 197

C-15 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on September Mean Flows . . . . . 198

C-16 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on September Mean Flows . . . . . 199

C-17 McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on October Mean Flows . . . . . 199

C-18 McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on October Mean Flows . . . . . 200

# 1. INTRODUCTION

## 1.1 GENERAL DESCRIPTION

The increasing development of the water resources of the world has led to a need for accurate information to be supplied to planners, designers and ultimately, policy makers. Since accurate streamflow data is a fundamental tool for hydrologists and water resources planners, the availability and accuracy of this data is of vital importance. The conversion of streamflow data from detailed, raw measurements to the useful, refined discharge data needs to be completed precisely and efficiently. In order to be useful, the data must be presented in a manner such that it is accessible and beneficial to the user, while keeping the cost of processing data to a minimum.

The planning and implementation of water resources developments in Canada requires accurate information in order to make informed decisions. The hydrometric network system then plays an important role in the provision of such data. In Canada, the Water Resources Branch of Environment Canada designs, reviews and evaluates the hydrometric network and attempts to optimize the resources spent on monitoring streamflow. The Water Survey of Canada (WSC), a division of the Water Resources Branch of Environment Canada, has been given the responsibility of measuring, documenting and compiling streamflow data in Canada. Since 1908 various federal agencies have been providing hydrometric survey

services, and since 1975 cost-sharing agreements with the provinces have been established which support the operation of the network. Included as part of the hydrometric survey services is the production of streamflow data publications from which hydrologists and other data users may find flow information for streams and rivers in Canada.

Many authors, such as Rodda [1969], Moss [1979], Moss [1982] and Langbein [1979], have discussed the concept of hydrometric networks and have offered design philosophies. Other researchers, including Fiering [1965], Maddock [1974] and Switzer [1979], have introduced network design approaches based on information transfer techniques. Complex statistical tools, such as square-grid regionalization (Solomon [1972]), kriging techniques (Villeneuve et al. [1979], Bastin et al. [1984]) and Bayesian statistical approaches (Wood [1979], Gries and Wood [1981]) have also been proposed as possible network optimization techniques to be used in the data network design and review process. These researchers have treated the design of a hydrometric network as a problem of statistically sampling variations in a streamflow parameter, both in space and time.

## 1.2 Network Review in Canada

Hydrometric networks in Canada have been reviewed and evaluated in various studies over the past few years. Shawinigan [1970], on behalf of WSC, used square-grid regionalization to evaluate the hydrometric network for western and northern Canada. Both Environment Canada [1974]

and Acres [1977] studied the economic worth of hydrometric data collection and evaluated hydrometric networks based on this information. Kreuder [1979] described the work of WSC in the classification and evaluation of the hydrometric network in British Columbia.

The hydrometric network of Manitoba was reviewed in studies by Bowering and Bilozar [1972, 1980], which included data use surveys, instrumentation and structure requirement examinations, and interstation regression analyses. The data use surveys were used to identify stations which were installed for a specific purpose and then made redundant by the cancellation of that specific project. The interstation regression analyses were used to identify those stations for which operations could be suspended based on the predictive powers of the interstation regression equations.

For example, prior to 1977 the hydrometric station Shell River near Roblin (05MD007) recorded flow year-round. Based on the recommendations of Bowering and Bilozar [1972, 1980], the months of operation for this station were reduced in 1977 to cover the period March to June. This reduction in the months of operation was possible because an acceptable correlation was found with monthly mean flows recorded at Shell River near Inglis (05MD005).

Water Survey of Canada is in the process of reviewing the established hydrometric networks of Canada. An integral part of the review process is an evaluation phase to assess the information that is available in the collected data. The

main parts of the network evaluation include routine data reviews, procedural checks, data use surveys, error analysis, hydrologic analysis and research of any data anomalies.

The long-term objective of a planned group of studies, of which this study constitutes one part, will allow WSC to make reasonable design choices when the hydrometric networks of Manitoba are to be reviewed and upgraded. Future fiscal resources allotted to WSC are somewhat uncertain. Since the pressures of northern development continue to grow, decisions regarding redesign and expansion of Canadian hydrometric networks may soon be required. The long-term goals of the course of study being taken by WSC include reasonable criteria for station discontinuance in southern Canada, while also providing basic design objectives and guidelines for design of hydrometric networks in northern Canada.

This current study is a small component of the network evaluation process and involved the examination of the published streamflow data for a basin-wide hydrometric network. This examination used simple statistical techniques to identify generalizations and anomalies in the observed streamflow data. The statistical parameters of concern and anomalies discovered were then able to be investigated in more detail using conventional review procedures. The study was also concerned with the examination of the historical data using several statistical techniques as a component of network review and evaluation.

The principal direction of this study is that the investigation of basic relationships and anomalies that occur in the data of present networks in the south of Canada will help in the review and design of networks in both the southern and northern regions of Canada.

# 2. PROBLEM EVALUATION

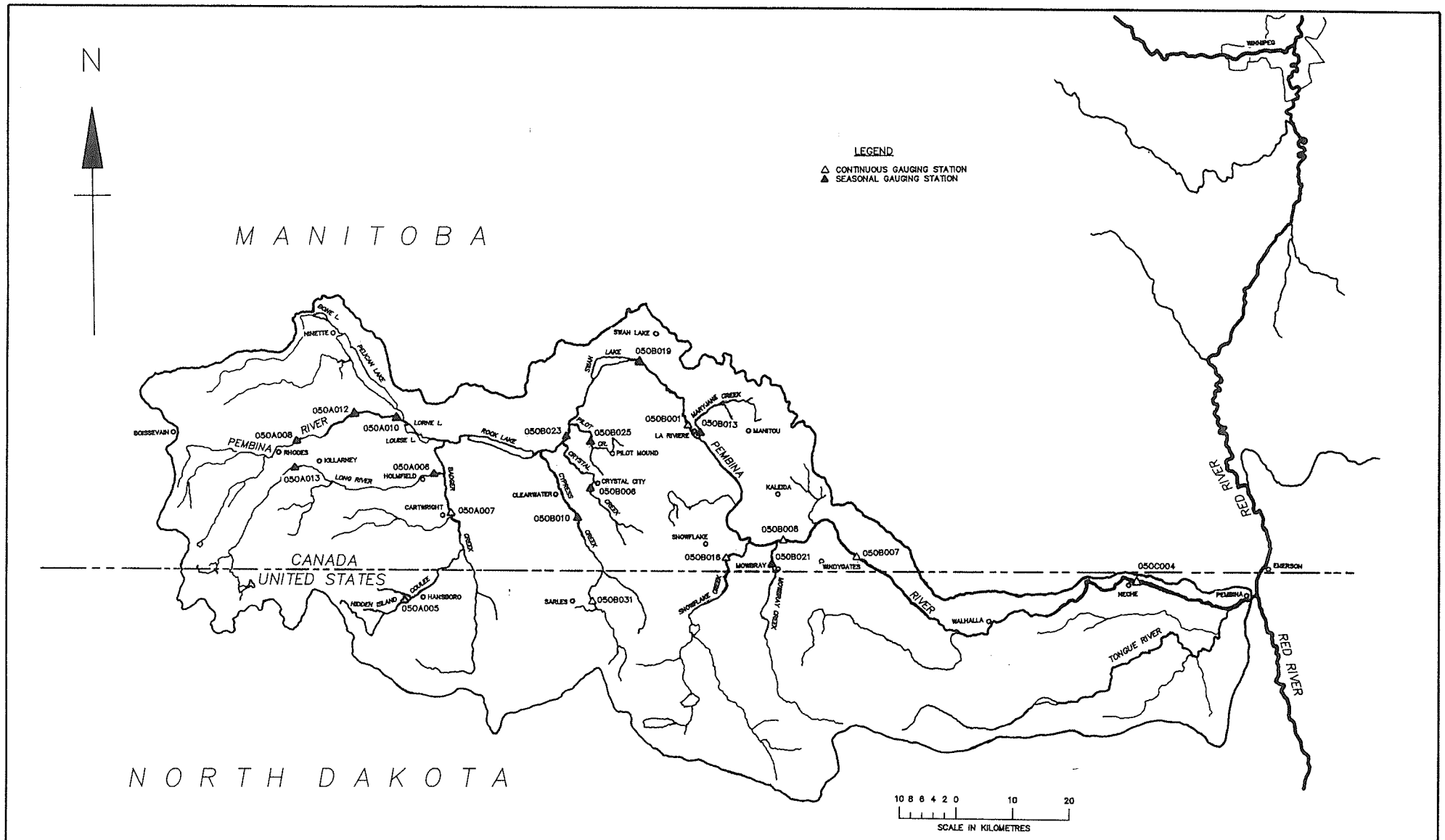
## 2.1 SCOPE OF THIS STUDY

Streamflow data consisting of typical streamflow parameters; annual mean flow, monthly mean flow and annual daily mean peak flows from a study basin, were analyzed with various statistical techniques including nonparametric analysis, simple statistics, regional regression and correlation analysis. This investigation attempts to address two distinct issues:

1. To identify any general relationships in the streamflow parameters as well as any anomalies in the data.
2. To investigate anomalies for possible causes where appropriate.

## 2.2 STUDY AREA

The area chosen for the investigation was the Pembina River basin, which lies in the south-central portion of Manitoba in Canada, and in the northeastern portion of North Dakota in the United States (see Figure 2.1). The western boundary of the basin is in the Turtle Mountain district on the international boundary. The outlet of the Pembina River is the Red River. The confluence of these two rivers is at Pembina, North Dakota, approximately two kilometres south of Emerson, Manitoba and the U.S./Canada boundary.




NOTE: Taken from International Pembina River Engineering Board (1964) Report to the International Joint Commission.

FIGURE 2.1
PEMBINA RIVER BASIN
LOCATION MAP

The basin is approximately 210 km in length on an east-west axis. Its width varies from a minimum of about 30 km in the east to a maximum of approximately 60 km in the western portion of the basin. The total gross drainage area of the Pembina River at Neche, as delineated by PFRA [1983], is 8 474 $km^2$, of which 50.3 percent is in Canada and 49.7 percent is in the United States.

The Pembina River region is part of the Interior Plains of North America and is composed of three geographic subdivisions. The most westerly region is the Drift Prairie Plateau. This plateau is intersected by the Pembina Escarpment area, which represents the second geographic region. The eastern geographic region, the Red River Valley, is the floor of the glacial Lake Agassiz and has a very gentle slope towards the present location of the Red River. The Pembina River in this eastern region is a flat, meandering river which includes gentle slopes, cutoffs and meander loops.

The Pembina Escarpment is part of the Pembina Mountains, which are the deltaic deposits of the prehistoric Souris River, where it emptied into Lake Agassiz. At the escarpment, there is a sudden rise of 180 metres in the level of the land, and the Pembina River has produced a young valley here with a steep V-shaped cut. The Drift Prairie Plateau or Uplands area above and to the west of the Escarpment is a collection of rolling plain and flat areas, interrupted by a small collection of shale mounds which include Pilot Mound

and Neboqwawin butte. The areas around Killarney and Holmfield include irregular hills and depressions which are characteristic of 'pothole' country. These poorly-drained local basins have resulted in small sloughs and alkali swamps such as described by Eisenlohr [1972].

The Pembina River itself originates at an elevation of about 600 m above mean sea level in the northeastern part of the Turtle Mountain region approximately 20 km south of Boissevain, Manitoba. The river is about 500 km in length and discharges into the Red River at an elevation of approximately 230 m. The river follows a winding course from its source until it reaches the Pembina Valley Lake area, which is bounded at the upstream end by the eastern end of Pelican Lake and at the downstream end by the outlet of Swan Lake. The valley is very wide through this area, and deep ancient coulees have deposited fan debris to form natural dams. The collection of water behind these dams of sediment and alluvium have produced a collection of valley lakes; Bone, Pelican, Lorne, Louise, Rock and Swan Lakes.

Downstream of Swan Lake the river valley is 1000 m wide and 60 m deep and becomes progressively wider and deeper until the valley is 2500 m wide and 140 m deep upstream of Walhalla. At Walhalla itself, the valley breaks out of the escarpment onto the flat plain. At this point the river grade flattens out, and the river becomes slow and meandering. As shown in Figure 2.1, the main tributaries in the Pembina River basin are Badger Creek, Long River and Tongue

River. The minor tributaries are Snowflake Creek, Cypress Creek, Mowbray Creek and Crystal Creek.

Table 2.1 lists the twenty hydrometric gauging stations in the Pembina River basin that are included in this study. As can be seen in Table 2.1, the stations chosen all have at least ten years of record, while the majority have approximately twenty years of record. The station Pembina River at Neche (05OC004) is a long-term station with 73 years of record beginning in 1903.

Twelve stations are seasonal gauging stations, which are operated only in the open-water season and are not monitored year-round. The streamflow data available for these seasonal stations generally covers the months of March to October, and the four missing months (November to February) are not included in the Historic Streamflow Summary published by Environment Canada [1983]. This particular set of twenty stations was chosen because the clustering of the records, both in terms of length and coincident period, was seen to provide a good data base for the statistical methods that were to be applied.

# Table 2.1

## Summary of Gauging Stations in Pembina River Basin

| Station Number | Station Name | No. of Years of Record | Period of Record | Drainage Area ($km^2$) | |
|---|---|---|---|---|---|
| | | | | Gross | Effective |
| 05OC004 | Pembina River near Neche | 73 | 1903-1980[1] | 8470 | 5366 |
| 05OB007 | Pembina River near Windygates | 19 | 1962-1980 | 7510 | 4462 |
| 05OB008 | Pembina River near Kaleida | 13 | 1957-1969 | 7120 | 4172 |
| 05OB001 | Pembina River near La Riviere | 15 | 1963-1977 | 5310 | 3351 |
| 05OB019 | Pembina River near Swan Lake | 10 | 1962-1972(S) | 4970 | 3110 |
| 05OB023 | Pembina River below Crystal Creek | 18 | 1962-1980(S) | 4480 | 2714 |
| 05OA007 | Badger Creek near Cartwright | 10 | 1959-1980 | 1520 | 735 |
| 05OB016 | Snowflake Creek near Snowflake | 20 | 1961-1980 | 979 | 245 |
| 05OA006 | Long River near Holmfield | 22 | 1959-1980(S) | 578 | 489 |
| 05OA010 | Pembina River above Lorne Lake | 19 | 1962-1980(S) | 544 | 360 |
| 05OA012 | Pembina River above Diversion | 14 | 1963-1976(S) | 487 | 328 |
| 05OB010 | Cypress Creek near Clearwater | 22 | 1959-1980(S) | 389 | 282 |
| 05OA008 | Pembina River near Killarney | 22 | 1959-1980(S) | 355 | 279 |
| 05OB021 | Mowbray Creek near Mowbray | 19 | 1962-1980(S) | 262 | 168 |
| 05OA013 | Long River near Killarney | 10 | 1967-1976(S) | 209 | 180 |
| 05OB031 | Cypress Creek near Sarles | 19 | 1961-1980 | 184 | 143 |
| 05OB006 | Crystal Creek near Crystal City | 21 | 1959-1980(S) | 153 | 88 |
| 05OB025 | Pilot Creek near Pilot Mound | 18 | 1963-1980(S) | 147 | 102 |
| 05OB013 | Mary Jane Creek at La Riviere | 21 | 1960-1980(S) | 135 | 111 |
| 05OA005 | Hidden Island Coulee near Hansboro | 9 | 1962-1980 | 68.1 | 61.8 |

(S) seasonal gauging station

1 small number of years missing from record

The drainage areas for the stations in the Pembina River basin shown in Table 2.1 were delineated by the Hydrology Division of the Prairie Farm Rehabilitation Administration (PFRA) [1983]. The gross drainage area is the physical drainage area of the basin, while the effective drainage area has been defined by PFRA as that area which contributes to the median return period runoff event. The determination of the effective drainage area developed by PFRA was created to account for the small depressional storage in a basin that does not contribute to streamflow in the drier years. In certain cases, the difference between gross and effective drainage areas is significant. For example, Snowflake Creek near Snowflake (05OB016) has an effective drainage area of only thirty percent of the gross drainage area.

Overall, the Pembina River Basin is representative of a typical small prairie watershed in Manitoba and the results obtained from this study should be applicable to other watersheds in the province. Due to the quality of the streamflow data in the basin relative to other small river basins in the Prairies, both in terms of the temporal and the spatial distribution, the use of the Pembina River basin will permit a relatively rigorous statistical analysis. These two features of the data are the primary reasons for the choice of the Pembina River basin for this study.

# 3. STATISTICAL TECHNIQUES

## 3.1 BASIC PRINCIPLES

The statistical techniques used in this study were chosen to screen the published historical streamflow data for the hydrometric stations in the Pembina River basin and to look for gaps, anomalies and general relationships in the data. The use of simple statistical techniques in screening the historical hydrometric data allows a large number of stations to be investigated quickly while identifying those stations or areas that require a more intensive examination.

The first set of statistical techniques used to screen the streamflow data were nonparametric tests for independence, trend, homogeneity and randomness. These tests were originally intended to screen data samples which were to be subjected to frequency analysis but have been used in this study as a general tool for examining streamflow data sets.

The second set of screening techniques used simple sample statistics to examine the station streamflow data for general relationships, gaps and anomalies. The mean, standard deviation, skew, kurtosis and other similar simple statistics for the sample were chosen to be examined. A method of converting seasonal monthly data (March to October flows) to annual mean flows was developed in order that the statistical parameters could be compared for both seasonal and year-round hydrometric stations.

Certain sample statistics were used to create regional regression equations based on drainage area. The statistical characteristics of these regional regressional equations were used to identify anomalous data sets, which were subsequently probed for possible hydrologic explanation.

The final set of screening techniques applied to the streamflow data involved the correlations between the stations in the basin. The interstation correlation matrices for each data type were separated into groups using cluster analysis. The groupings were examined for reasonableness based on knowledge of the basin.

## 3.2 NONPARAMETRIC STATISTICAL TESTS

### 3.2.1 Description of Tests

The first set of statistical techniques used to screen the flow data from the Pembina River basin was a set of non-parametric tests for independence, trend, homogeneity and randomness. The package of statistical tests used was developed by Shiau and Condie [1980] for the Water Resources Branch of Environment Canada and released as a computer program (NONPARA).

The NONPARA program was developed in order to screen streamflow data before it was subjected to a flood frequency analysis using the Flood Damage Reduction Flood Frequency Analysis (FDRFFA) program developed by Condie and Nix [1978]. The assumption that the sample is random, homogeneous, independent and contains no trend component is essential to the

correct application of flood frequency theory. The non-parametric tests were not used in such a rigorous fashion in this study but were rather used as screening tools to identify stations and samples of data for which anomalies may be present.

The use of nonparametric tests to substantiate the basic assumptions of a random, homogeneous, independent data sample containing no trend component lifted the constraint of assuming or finding a distribution that the data samples fit. The nature of these tests also permits the use of fewer data than would be needed if parametric tests were to be used. The extra statistical power gained by using parametric tests to check for independence, trend, homogeneity and randomness is offset by the assumption of a parent distribution to which the data sample holds. Most of these parametric tests require twenty or more observations or members in a sample in order to draw firm conclusions. Many of the streamflow records on the prairies are composed of less than twenty years of record. The nonparametric tests were used, however, because they do not assume an underlying distribution and hence are often more applicable to short hydrologic records.

As was noted above, the tests developed by Shiau and Condie are able to utilize the available data without having to assume a statistical distribution for the sample. The independence of each sample was investigated using rank serial correlation. The rank correlation within each sample was also used to distinguish any trends that may have been

present in the streamflow data. Homogeneity in the streamflow data was checked through the investigation of patterns in the ranking of the data and of clustering within the data. Randomness was checked by examining the streamflow data for patterns and clustering. The tests used checked the structure of the data and were able to identify significant anomalies and aberrations within the data at specified confidence levels.

#### 3.2.1.1 Independence

The assumed independence of a sample is important when conducting a frequency analysis on streamflow. Non-independence in the sample would indicate that the magnitude of one flow is influenced by the previous flow. An example could be illustrated by considering two flood flows on a stream in one year. In a partial duration flood frequency analysis, any flood above a threshold is considered part of the flood sample if the floods are independent. If, however, the second flood in the year is actually caused by conditions that make it dependent upon the first flood (i.e. large storage in the basin or a rainstorm that is broken by a period of light precipitation), the second flow value should not be included in the flood series. In this study, nonindependence in a series may indicate anomalous data that should be checked for physical reasons as to why the streamflow data is nonindependent, e.g. large upstream storage or flow regulation.

In order to check a sample of a certain size N for internal independence, the test must be able to decide whether, within the sample, the probability of occurrence of one event is influenced by the occurrence of another event. The test chosen to perform this task was developed by Glasser and Winter [1961] and measures the internal independence in a time series through the checking of the significance level of the Spearman rank correlation coefficient between the ith and the (i+1)th observation throughout the N-1 pairs of the series.

The actual procedure for use of the Spearman correlation coefficient to test two samples for independence, as is the case in this study, was developed by Daniels [1950]. If the Spearman rank correlation coefficient in this test is not shown to be significantly larger than zero, independence is assumed. In a strict mathematical sense, however, this condition does not define independence but was assumed by Shiau and Condie [1980] to be practically correct in this situation.

The null hypothesis of the test is that there is a tendency for the larger values in each of the samples to be paired together. In this application of the test, the independence of the sample is assumed correct when, in the time series, the larger values do not follow the larger values That is, the next year's flow is not dependent upon the previous year's flow. The parametric counterpart to the Spearman rank correlation coefficient is the Pearson

correlation coefficient, assuming a normal underlying distribution, which could be used in a similar testing procedure.

The procedure used to determine the levels and significance of the Spearman rank correlation coefficient in this test of independence is as follows:

The time series $Q_i$, with i ranging from 1 to the sample size N, has ranks assigned starting from the smallest observation to the largest. Using the rankings of the **Q** series, two other series are created, **b** and **c**, which are denoted as:

$Q_1, Q_2, Q_3 \cdot \cdot Q_i \cdot \cdot Q_{N-1}$ with $b_i$ representing the rank of $Q_i$

and

$Q_2, Q_3, Q_4 \cdot \cdot Q_i \cdot \cdot Q_N$ with $c_i$ representing the rank of $Q_i$

This **b** and **c** are, respectively, the rankings of the time series $Q_i$, with the largest value $Q_N$ omitted and the ranking of the $Q_i$ series offset by one, with the $Q_1$ value missing. In both cases the size of the time series is N-1 as opposed to N in the original series.

The Spearman rank order correlation is then calculated by:

$$S = 1/2(\Sigma b_i^2 + \Sigma c_i^2 - \Sigma d_i^2)(\Sigma b_i^2 * \Sigma c_i^2)^{-1/2} \qquad (3.1)$$

$$\text{where: } \Sigma b_i^2 = \frac{(m^3 - m)}{12} - \Sigma T_b \qquad (3.1a)$$

$$\Sigma c_i^2 = \frac{(m^3 - m)}{12} - \Sigma T_c \qquad (3.1b)$$

$d_i$ = the difference in rank between $b_i$ and $c_i$

$m$ = N-1

the summations are over the m pairs of $b_i$ and $c_i$

The terms in $T_b$ and $T_c$ adjust the coefficient for tied ranks and are computed as in the following manner:

If two observations in the **b** series were tied for the ranks of 20 and 21, both observations are ranked at 20.5. If three observations are tied, all three observations receive the middle ranking.

Then, for each tied set, $T_b$ or $T_c$ is computed from:

$$T_b \text{ or } T_c = \frac{(p^3 - p)}{12} \qquad (3.1c)$$

where p = the number of observations tied at a given rank.

Ignoring the tied terms, Equation 3.1 becomes

$$S = 1 - \frac{(6 \ \Sigma d_i^2)}{(m^3 - m)} \qquad (3.2)$$

which is the more familiar form of the Spearman rank correlation coefficient.

As reported by Stuart [1956], the asymptotic relative efficiency (ARE) of the nonparametric Spearman rank correlation coefficient relative to the parametric regression test is 0.98 if the underlying distribution is truly a normal distribution. This measure of the power of the statistic gives a compact indication of the relative efficiency between two tests.

For N greater than 10, the distribution of the value

$$t = S\left[\frac{m-2}{1-S^2}\right]^{1\backslash 2} \qquad (3.3)$$

is similar to the Student's t-distribution with m-2 degrees of freedom. For a given significant level $\alpha$ a one-tail test of significance was used. Statistical tables outlining the t-distribution can be found in texts such as Haan [1977] and Kennedy and Neville [1976].

For N less than 10 and certain significant levels $\alpha$, tables are available (see Conover [1971] p 390 or Gibbons [1976] p 417) to define the region of rejection for a computed S value. The program package supplied by Shiau and Condie [1980] incorporates this table and internally checks the significance of the Spearman rank correlation coefficient at the 0.05 and 0.01 probability levels.

### 3.2.1.2 Trend

A simple method for testing a time series Q for the presence of trend was accomplished by examining another application of the Spearman rank order correlation coefficient. Due to the possibility of gradually changing conditions within the basin, there may be an observable trend in the time series data. If a trend were identified in a flood frequency analysis sample, its trend component could be extracted from the flood series. An example of this case would be an increasing diversion into a stream upstream of

the station under study. This increasing diversion could then be calculated and subtracted from the flood series in order to detrend the sample.

The nonparametric test, which was used in this study, checks for significant trend within the data using the following procedure:

The time series $Q_i$, with i increasing from 1 to N, has ranks assigned to each $Q_i$. From this ranking is created the series z, which is denoted as:

$Q_1, Q_2 \ldots Q_i \ldots Q_N$ with $z_i$ representing the rank of $Q_i$

and also the series

1, 2 . . . i . . . N
with $t_i$ representing the chronological position of $Q_i$

The Spearman rank order correlation coefficient S is then calculated as in Equation 3.1, except for this set m=N, $T_t$=0, and the summations are over the N pairs of $t_i, z_i$. This leads to:

$$S = 1/2\ (\Sigma t_i^2 + \Sigma z_i^2 - \Sigma d_i^2)(\Sigma t_i^2 * \Sigma z_i^2)^{-1/2} \qquad (3.4)$$

where: $$\Sigma t_i^2 = \frac{(N^3 - N)}{12} \qquad (3.4a)$$

$$\Sigma z_i^2 = \frac{(N^3 - N)}{12} - \Sigma T_z \qquad (3.4b)$$

$d_i$ = the difference in rank between $t_i$ and $z_i$ for that i.

A slight change in Equation 3.3 for this test yields the function

$$t = S\left[\frac{N-2}{1-S^2}\right]^{1\backslash 2} \qquad (3.5)$$

which has a distribution similar to Student's t with N-2 degrees of freedom. Since the null hypothesis is that there is neither any upward or downward trend with time, a two-tailed test was used with the chosen level of significance $\alpha$. Again, for N greater than 10 the above function holds, while for N less than 10 the same tables used previously to test independence were applied to define the rejection region for a specified level of significance $\alpha$.

### 3.2.1.3 Homogeneity - Mann-Whitney Split Sample Test

Homogeneity within a sample in terms of the mean assumes that no jump or abrupt change occurs during the sampling period that would unduly influence the mean of the sample. An example in basin hydrology would be the creation of a large reservoir that intercepts a large portion of the streamflow. If the sample is internally homogeneous with respect to the mean, splitting the sample would yield two subsamples having no discernible difference in their means. If an abrupt change did occur during the period of record, the data sample would be inhomogeneous if a significant difference was discernible in the means of the subsamples taken before and after the change.

The parametric test that could be applied to the subsamples in order to test for homogeneity in the means is the Student's t-test. However, the use of the t-test would require that the underlying distribution of the sample is normal. Stolte and Dumontier [1977] have shown that the parent distribution of flood flows for prairie streams is rarely normal. The probability theory of ranks is, however, relatively simple in comparison to that for unknown or difficult distributions. Consequently, the Mann-Whitney nonparametric test, a 'ranks' test developed by Wilcoxon [1945] and revised and extended by Mann and Whitney [1947], is useful in testing the means of subsamples for the purpose of identifying nonhomogeneity within the data. This procedure can test subsamples of varying and unequal sizes, an attribute which is particularly useful when known changes have occurred on the stream. The test checks the significance of the Mann-Whitney U statistic as follows:

The data series has ranks assigned following the rules for ties described previously. The series is then split into the two ranking subseries **r1** and **r2** denoted as:

$Q_1, Q_2 \ldots Qn_1$
with $r1_i$, the ranks of $Q_i$ in subsample of size $n_1$

and

$Qn_{1+1}, Qn_{1+2} \ldots Q_N$
with $r2_i$, the ranks of $Q_i$ in subsample of size $n_2$

Parameters $U_1$, $U_2$ and **U** are then defined as follows:

$$U_1 = n_1 * n_2 + \frac{n_1(n_1+ 1)}{2} - Sr_1 \qquad (3.6)$$

$$U_2 = n_1 * n_2 - U_1 \qquad (3.7)$$

where $Sr_1 = \sum_{i=1}^{n_1} r1_i$ (the sum of ranks in subsample 1)

then

$$U = \min(U_1, U_2) \qquad (3.8)$$

The Mann-Whitney U statistic is therefore a function of the sizes of the subsamples and their sum of ranks. The distribution of the Mann-Whitney U is known, and critical values have been tabulated. If both $n_1$ and $n_2$ are less than 21, the region of rejection for U has been tabulated as in Conover [1971] pp 384-388. The distribution of U rapidly approaches normality for $n_1$ greater than 4 and $n_2$ greater than 20. The standardized variable z is then represented by:

$$z = \frac{U - \frac{n_1 n_2}{2}}{\left[\left(\frac{n_1 n_2}{N(N-1)}\right)\left(\frac{N^3 - N}{12} - \Sigma T\right)\right]^{1\backslash 2}} \qquad (3.9)$$

with $T = \frac{(p^3 - p)}{12}$ summed over all groups of tied observations in both r1 and r2

and where p = the number of observations tied at a given rank

Since z is a normal variate with mean of zero and a standard deviation of one, the region of rejection for a given significance level $\alpha$ can be found in tables outlining the standard normal density, such as in Haan [1977] and Kennedy and Neville [1976]. This test is a one-tail test and so for example:

$\alpha$ = 0.05, the region of rejection is $z < -1.645$

and

$\alpha$ = 0.01, the region of rejection is $z < -2.326$

As shown by Hodges and Lehmann [1956], the Mann-Whitney test is almost as powerful as the t-test. If the underlying distribution is normal, the resulting asymptotic relative efficiency (ARE) is 0.955. If the underlying distribution is not normal, Hodges and Lehmann [1956] have also shown that the worst that the ARE can be is 0.864, which provides the user with a powerful statistical tool, even when the distribution is unusual or unknown.

#### 3.2.1.4 Homogeneity - Wald-Wolfowitz Split Sample Test

Unfortunately, the Mann-Whitney test is constrained to testing the homogeneity of a sample in terms of its mean only. The Wald-Wolfowitz test is less powerful statistically, but is general enough to test for significant differences in the variance, skewness, kurtosis and mean between the subsamples. By investigating the number of runs Rw, as described later, within the data, the Wald-Wolfowitz test (Wald and Wolfowitz, 1940) is able to detect clustering in the data. A theoretical homogeneous sample will exhibit a large number of runs in the data, while inhomogeneity will be indicated by a lowered number of runs.

The runs in the data samples were computed as follows. The original time series $Q_1$, $Q_2$ . . . $Q_N$ is split into two subsamples on the basis of time. Subsample 1 is comprised of $n_1$ values of $Q_1$, $Q_2$ . . . $Qn_1$, while subsample 2 is composed of $n_2$ values of $Qn_{1+1}$, $Qn_{1+2}$ . . . $Q_N$ where $n_1 + n_2 = N$. The entire sample is ordered in descending order, and a run is then defined as a sequence of flows (or a lone flow) from the same subsample in the ordered set. For example:

consider the time series of Q's with $n_1 = n_2 = 5$ is

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 13 | 16 | 20 | 11 | 26 | 17 | 18 | 19 | 23 |
| subsample 1 | | | | | subsample 2 | | | | |

with $n_1 = n_2 = 5$

The corresponding ordered set and subsample membership are

| Q | 26 | 23 | 20 | 19 | 18 | 17 | 16 | 15 | 13 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| subsample | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 1 |
| | run | | run | run | | | run | | | |

Rw = number of runs = 4

Ties pose a problem with this nonarametric test. Ideally, no ties should occur because, in the derivation of the Wald-Wolfowitz testing procedure, the assumption was made that the subsamples have continuous populations. This does not hold for hydrologic data since measurements follow round-off rules, and thus the sample distribution is discrete

instead of being continuous. Practically, ties become a problem only when ties are split between subsamples. If members of one subsample are tied with members of the other subsample (a group k), there cannot be a single way of ordering the members, and hence this means that there is not a single Rw value. For each group k of ties across subsamples, where there are f sets of r1's and g sets of r2's of equal value with $f \geq 1$ and $g \geq 1$, then there are $\binom{f+g}{f}$ ways to break the ties. So, if there are **k** groups of ties across the subsamples, then the total number of ways **d** to resolve the ties are:

$$d = \prod_{i=1}^{k} \binom{f_i + g_i}{f_i} \qquad (3.10)$$

Of these **d** ways to break the ties, one single combination has the largest computed number of runs. As is mentioned below, due to the nature of the test, this largest value would be less likely to be rejected by the Wald-Wolfowitz test, and hence is the most conservative of all the ways to break the ties. Unfortunately, for a large number of ties and groups of ties, the calculation of **d** runs becomes prohibitive, and in the case of the NONPARA program supplied by Shiau and Condie [1980], the Wald-Wolfowitz test is not run on data that has ties between subsamples.

Like the Mann-Whitney test, if both $n_1$ and $n_2$ are less than 21, tables have been computed that define the region of rejection given a significance level $\alpha$ (see Conover

[1971] p 414). If the number of runs, Rw, is less than this critical value, the sample is said to be inhomogeneous at the significance level being used. For $n_1>4$ and $n_2>20$, the sampling distribution for Rw approaches normality, with the standardized variable z being represented by:

$$z = \frac{\left| Rw - \left[ 1 + \frac{2\, n_1 * n_2}{n_1+n_2} \right] - 0.5 \right|}{\left[ \frac{2n_1n_2(2n_1n_2-n_1-n_2)}{(n_1+n_2)^2 * (n_1+n_2-1)} \right]^{1\backslash 2}} \qquad (3.11)$$

Since z is a normal variate with mean of zero and a standard deviation of one, the region of rejection for a given significance level $\alpha$ is easily found in any table outlining the standard normal density function (as with the Mann-Whitney test). This test is a one-tail test and so, for given levels of significance, such as:

$\alpha = 0.05$, the region of rejection is $z > 1.645$

and for

$\alpha = 0.01$, the region of rejection is $z > 2.326$

The Wald-Wolfowitz test is a very general test, and it is this generality which affects the power of the test. The test is unable to differentiate between nonhomogeneity in the mean (location difference), variance (scale difference) or skewness (direction difference). Asymptotic relative

efficiency can be calculated only for specific alternatives, e.g., differences in a sample with respect to the mean or with respect to the variance. Since this test is not specific about where the nonhomogeneity originates, power comparisons for this test are not truly representative of the Wald-Wolfowitz's performance.

Although the type of inhomogeneity (i.e. with respect to the mean, variance or skew) is not indicated by the Wald-Wolfowitz test, if the Wald-Wolfowitz test in this package is run parallel to the Mann-Whitney test, a hypothesis of inhomogeneity with respect to the mean is strengthened through the use of the Mann-Whitney test. If the Mann-Whitney test does not show inhomogeneity in the mean and the Wald-Wolfowitz test shows that inhomogeneity is present, the inhomogeneity is most likely to be in the variance or skew of the sample.

#### 3.2.1.5 Randomness

Flood frequency analysis theory dictates that a flood series be random since, if there is a cyclic pattern in the data or an abrupt change in the mean of the sample, the probability distribution of future events would be difficult to predict based on the overall 'nonrandom' sample. The testing of randomness by the Runs Test investigates clustering in the data by counting the runs above and below the median. It is similar to the Wald-Wolfowitz test in that the sample is divided in two by choosing a group in which to

put each observation. While the Wald-Wolfowitz test used a time split sample to divide the sample, the Runs Test uses a pivot point to divide the sample. By choosing the median as the pivot point, the probability of exceeding the median is always 0.5, regardless of the underlying distribution.

The sample median is calculated as the middle observation when the sample is ranked in order of magnitude. The series is then placed in chronological order, and the value of the observed flow is compared to the median. A run in this test is defined as a sequence of flows (or a lone flow) that are all from the same side of the focal point, in this case the median. For example:

Consider the time series of Q's chronologically ordered as:

Q = 15 13 16 20 11 26 17 18 19 23

with a median of 17.5.

If "A" represents an observation being above the median and "B" represents the observation being below the median, we get (median = 17.5).

| Q | 15 | 13 | 16 | 20 | 11 | 26 | 17 | 18 | 19 | 29 |
|---|---|---|---|---|---|---|---|---|---|---|
| symbol | B | B | B | A | B | A | B | A | A | A |
| | | run | | run | run | run | run | | run | |

Rm = number of runs = 6

$n_1 = 5$, $n_2 = 5$

If the median is an observed value, this value is ignored in the calculation of the runs.

The sampling distribution of Rm is known and can be found in tabular form in Gibbons [1976] pp 424-428. This test involves the use of a two-tail probability, and so upper and lower critical values are available for varying significance levels. If the number of runs is above the upper critical level, it indicates a cyclic pattern is present. If the number of runs is below the lower critical level, an abrupt change in the sample is indicated.

For $n_1$ and $n_2$ greater than 20, the sampling distribution of Rm tends to normality, and so a N(0,1) variate z can be formed by:

$$Z = \frac{\left| Rm - \left[ 1 + \frac{2\, n_2 * n_2}{n_1 + n_2} \right] \right|}{\left[ \frac{2n_1n_2(2n_1n_2 - n_1 - n_2)}{(n_1+n_2)^2 \; * \; (n_1+n_2-1)} \right]^{1/2}} \qquad (3.12)$$

This is the right tail variate value and, since the test is a two-tail test of significance, the region of rejection is defined as:

$z > 1.970$ for $\alpha = 0.05$

$z > 2.326$ for $\alpha = 0.01$

The Wald-Wolfowitz runs test is derived from this general runs test, and the similarity can be seen in Equations 3.11

and 3.12, except that the general runs test does not adjust the computed runs for discretization. The overall power of the runs test lies in its simplicity and ease of use.

### 3.2.2 Data Investigated

The nonparametric statistical tests described above were used to screen streamflow data recorded at the twenty hydrometric stations under study in the Pembina River basin. The data to which these tests were applied were extracted from the Historical Streamflow Summary for Manitoba published by Environment Canada [1983]. The two particular flow parameters that were investigated using these tests were the maximum daily means (daily peaks) and the "period means." The maximum daily mean is defined as the maximum calendar-day mean streamflow in each year. The "period mean" is the average streamflow for those months in a year for which records are complete. In the study basin, twelve seasonal gauging stations measure streamflow during the period March to October. This period generally covers the open-water season. For these seasonal stations, the period means are the average streamflow for the months March to October. The remaining eight stations in the basin measure streamflow year-round, and thus the period mean for these stations is the average annual streamflow.

Two study periods were chosen for these tests. One series examined all years of data that were available for the stations, e.g. 1903 to 1980 in the case of station 05OC004. The second series represented a standard period which covered

the year 1960 to 1980 and was chosen because thirteen of the twenty stations were established on or after 1960. For all stations, at least 10 years of record are available in this standard period.

The two nonparametric tests for homogeneity and randomness utilize split sample testing. In the initial data screening, the default option of the program was used, which arbitrarily divides each period of record into halves (median period splitting). If a data screening process to investigate a large number of stations in a basin or group of basins were to be instituted, this automatic method of splitting the periods would most likely be used to quickly assess the data. The second screening technique used in this study accounted for any development directly above or below the hydrometric stations. In this second case, the streamflow data for the affected stations was split into predevelopment and postdevelopment data sets.

Table 3.1 shows the location, capacity and year of development of major reservoirs in the Pembina River basin. This information was provided by the Water Resources Branch of the Manitoba Department of Natural Resources. It was hypothesized that for data screening purposes, the construction of these projects may jeopardize the homogeneity and randomness of the streamflow data sets affected by the projects. Thus, using an option in the NONPARA program, the streamflow data sets for gauging stations affected by reservoir sites were split into predevelopment and postdevelopment data sets

where possible, with each set being tested for homogeneity and randomness

Table 3.1

Major Reservoirs in the Pembina River Basin

| Impounding Structure | Location | Year of Development | Reservoir Capacity (dam3) | Stream Affected | Affected Hydrometric Stations |
|---|---|---|---|---|---|
| CPR Project | NE05-01-09-W1 | 1919,1969[1] | 39 | Snowflake Creek | 05OB016,05OB008 05OB007,05OC004 |
| Crystal City Dam | NW24-02-12-W1 | 1962 | 148 | Crystal Creek | 05OB006,05OB023 05OB109,05OB001 05OB008,05OB007 05OC004 |
| Killarney Dam | NE33-02-17-W1 | 1956 | 990 | Long River | 05OA006,05OB023 05OB019,05OB001 05OB008,05OB007 05OC004 |
| Manitou Dam | SW09-04-09-W1 | 1959 | 1 420 | Mary Jane Creek | 05OB013,05OB008 05OB007,05OC004 |
| Pelican Lake Control Structure | NW32-03-15-W1 | 1919,1966,[1] 1976 | 96 000 | Pembina River | 05OA012,05OA010 05OB023,05OB019 05OB001,05OB008 05OB007,05OC004 |
| Pilot Mound Dam | SW18-03-11-W1 | 1966 | 555 | Pilot Creek | 05OB025,05OB023 05OB019,05OB001 05OB008,05OB007 05OC004 |
| Rock Lake Dam | NE07-03-12-W1 | 1940 | 56 000 | Pembina River | 05OB023,05OB019 05OB001,05OB008 05OB007,05OC004 |

1 Multiple dates indicate that a series of works were performed at the site following the initial facility construction in the year of the first date on the list.

### 3.2.3 Results of Nonparametric Tests

The tests for independence, trend, homogeneity and randomness were applied to the initial screening of Pembina River streamflow data which used the automatic time split (median period) option from the program. Data screening in this manner showed that both the period mean and daily mean peak data for most of the Pembina River stations did not exhibit incongruities with respect to independence, trend, homogeneity and randomness. Almost all of the stations passed these nonparametric tests at the 5% significance level. The stations for which the median period split data did not pass the statistical tests at the 5% significance level are presented in Table 3.2.

Table 3.2

Nonparametric Test Results - Median Period Split Data
Station Data Sets Identified Significant at the 5% Level

| Nonparametric Test | Period Mean Flows | | Mean Daily Peaks | |
|---|---|---|---|---|
| | Full Period | 1960-80 | Full Period | 1960-80 |
| Independence | 05OC004 | - | - | - |
| Trend | - | - | - | - |
| Mann-Whitney Homogeneity | 05OA012<br>05OB010<br>05OC004 | 05OA012<br>05OB008 | 05OA012<br>05OB019 | 05OA012<br>05OB019 |
| Wald-Wolfowitz Homogeneity | - | - | - | - |
| Randomness | 05OB013 | 05OB013 | - | - |

The station histories from WSC files for each of the failing hydrometric stations were scrutinized for any problems in metering or disruptions to the stream regime that were noted by WSC personnel.

Two stations (05OB019 and 05OA012) were identified as having specific problems which could have led to the nonhomogeneity or nonrandomness in the data and for which known dates of intervention were available. For the gauging station Pembina River near Outlet of Swan Lake (05OB019), metering problems were encountered in most years of the short period of record (1962-72). A shifting shale bottom and downstream beaver dams affected streamflow measurements at the station. A large beaver dam was reported in 1965, and so a development time split covering this year was used for 05OB019 in the second screening of the data.

For the gauging station Pembina River above Pembina River Diversion (05OA012), the gauge was moved in 1965 because a new bridge was put in. Since the gauge was installed in 1963, this would have led to a time split of three years (i.e. 1963-65, 1966-76). However, the statistical tests have a minimum sample size of four, and thus the data for 05OA012 could not be split at 1965. The station history also indicated that in 1968 a local farmer built an unlicensed dam just downstream of the gauging station. This dam may have affected the measurements. The data sets for 05OA012 and downstream stations were then split at the year 1968 where possible on the basis of minimum sample size requirements.

The consideration of appropriate additional development and disruption time splits in the data, which differed from the median period time splits, yielded some supplementary information. Table 3.3 presents the results of the nonparametric tests for homogeneity and randomness and identifies those stations (and their corresponding development year) whose data failed the tests at the 5% significance level. As can be seen in Table 3.3, only a few new sets of data were identified as being inhomogeneous with the differing time splits.

Table 3.3

Nonparametric Test Results - Construction Time Split Data
Station Data Sets Identified Significant at the 5% Level

| Nonparametric Test | Period Mean Flows | | Mean Daily Peaks | |
|---|---|---|---|---|
| | Full Period | 1960-80 | Full Period | 1960-80 |
| Mann-Whitney Homogeneity | 050A012(1968)<br>050B019(1965)<br>050C004(1940) | 050A012(1968)<br>050B019(1965) | 050A012(1968)<br>050B019(1965) | 050A012(1968)<br>050B019(1965) |
| Wald-Wolfowitz Homogeneity | 050B001(1968) | 050B001(1968) | - | - |
| Randomness | - | - | - | - |

Note: The number in parentheses alongside each station number is the year of the split in data for which the station failed that test.

### 3.2.4 Discussion of Nonparametric Test Results

As can be seen in Tables 3.2 and 3.3, very few of the data sets tested failed the nonparametric tests for independence, trend, homogeneity and randomness at the 5%

significance level. For some tests, only one station data set out of twenty failed the test. This result then may be due to chance considering that the 5% significance level was used. Nevertheless, all data sets which failed and the information available on the corresponding stations were given a cursory examination for possible explanations or rationales for the inability of the data sets to pass the nonparametric tests.

#### 3.2.4.1 Independence

The annual mean streamflow for Pembina River near Neche (05OC004) for the full period of record (1903-80) was the only data set to fail the nonparametric test for independence. In this case the Spearman rank order serial correlation coefficient for independence (S) had a value of 0.211, which from Equation 3.3 produced a Student's t value of 1.808. This value is larger than the critical Student's t value at the 5% significance level of 1.669 , which indicates that there may be internal dependence between annual means for this data set. The implication of this data set exhibiting internal dependence is that it is more likely that a high flow volume year will follow another high flow volume year at the station.

The internal dependence of this data set is possibly caused by the presence of large, regulated, upstream storage projects, natural lakes and the large number of potholes and sloughs in the basin. The resulting storage and regulation

in the basin may cause a carryover from year to year which would affect the independence of the annual mean flow data series. The fact that there was recorded streamflow during the winter months at 050C004 in 70 of the 73 years of record supported this hypothesis. The contribution of the storage in the basin to a winter base flow may be another indication of significant carryover in the basin.

The test was unable to identify this internal dependence in the annual mean flows for 050C004 for the shorter standard period 1960-80. The Spearman rank order serial correlation coefficient for independence was calculated to be -0.157. The negative sign indicated no internal dependence in the data set and may be interpreted (if the value were significant) to mean that in this data set, a year with a large annual flow volume is more likely to be followed by a year with a small annual flow volume. The daily mean peak data sets for 050C004 also exhibited no sign of internal dependence. This could be expected since the peak flow values are less likely to be influenced by storage carryover than the annual flow volumes.

None of the other stations in the basin examined had significant internal dependence, a result which may be due to the shorter periods of record. Recall that no internal dependence was found for 050C004 for the shorter period either. Another explanation could be that for the other stations in the headwaters and on small tributaries, any

carryover effects that do exist are less than that for the downstream stations on the main stem of the basin.

#### 3.2.4.2 Trend

None of the data sets tested were identified as having a significant trend component through the Spearman rank correlation test for trend. On the prairies, it is likely that only the development of extensive drainage systems or major clearcutting would influence the basin hydrologic regime enough to exhibit trend in the data.

#### 3.2.4.3 Homogeneity

The homogeneity of the data sets was tested using the Mann-Whitney and Wald-Wolfowitz split-sample nonparametric tests. Only one data set was identified as being inhomogeneous using the Wald-Wolfowitz test. As was indicated in Table 3.3, the annual mean flows for Pembina River near La Riviere (05OB001), when split at the year 1968, did not pass the Wald-Wolfowitz test. The period of record for this station is 1963-77; thus the full period of record lies within the standard period of record 1960-80.

For this development split of the data set, the number of runs $R_W$ were calculated to be 3, which was less than the critical $R_W$ of 5 specified by the program. This low value for $R_W$ indicated that there was clustering of high values with high values and low values with low values within the data. An inspection of this data set supported this

statistical observation. With the data split at the year 1968, it appears that the first subsample covering the years 1963-68 is lower in variability when compared to the second subsample (1969-77). This is further supported by the fact that this area of the prairies experienced an extended period of low flows in the early 1960's. This extended 'dry' period would cause low variability for that portion of the overall record. For the second subsample, 1974 was the largest flow year on record for all stations in the Pembina River basin. The presence of this high flow would cause high variability in this part of the sample. The Mann-Whitney test on this data did not indicate inhomogeneity in the means, which supports the hypothesis that the inhomogeneity is in the variance or skew of the two subsamples.

For Pembina River above Pembina River Diversion (05OA012), both the period means and the mean daily peaks did not pass the Mann-Whitney split sample test for either split choice. The program automatically split the data at the year 1969 for the median period split testing. The time split of 1968, which corresponded to the construction of a small structure just downstream of the station was also used. Since the difference in the sample splits was only one year, it is possible that the construction of the small structure caused the data sets to fail the Mann-Whitney test for both the time splits.

Another possible explanation for the inhomogeneity with respect to the sample mean for 05OA012 may be related to the

period of record (1963-76) for the station. The low runoff years in the early 1960's would make up the first subsample. The mean of this first subsample would be lower than the high flow years of the early 1970's which followed.

For most prairie streams, the majority of the annual runoff occurs during the spring as a result of snowmelt. It is then not surprising that the daily mean peaks for this station follow the same pattern as the period means and are also inhomogenous.

The daily mean peaks and the period mean data for Pembina River near Outlet of Swan Lake (05OB019) fail the tests in the same manner as station 05OA012. It therefore seems that the period of record (1962-72) for 05OB019 may be responsible for the inhomogeneity in the data. Another possible explanation for the inhomogeneity at 05OB019 may, however, be the previously-noted metering problems encountered at the station.

The period mean data for Cypress Creek near Clearwater (05OB010) also failed the Mann-Whitney test. A close examination of the data and the station history yielded no explanation as to why this period mean data set did not pass the test. This failure may be due only to chance, since there is a 5% chance that the nonhomogeneity identified on the test is due only to normal fluctuations.

The annual mean data for Pembina River at Neche (05OC004) for the full period of record (1903-80) did not pass the Mann-Whitney split sample test for homogeneity. The data was

split at 1943 for the automatic median period split. This split was fairly close to the year of construction for the Rock Lake Dam, which was completed in 1940. The Mann-Whitney test also found the annual mean data to be inhomogeneous when split at 1940. The construction of the project may have influenced the runoff recorded at the station.

Another explanation of the inhomogeneity in the data could be due to the period of record. The first subsample of the median period split covered the years 1903-43, which included the low runoff years of the 1930's. The second subsample covered the years 1944-80, which included nine of the top ten runoff years in the 73 years of record. These high flow years may have influenced the mean of the second subsample enough that the Mann-Whitney test identified significant inhomogeneity between the means of the first and second subsamples. None of the other construction splits of this data indicated a failure through the Mann-Whitney test. The influence of these minor upstream projects on the annual runoff recorded at 05OC004 therefore appears to have been rather limited.

In summary, it appears that the inhomogeneity found in the data for stations 05OB001, 05OA012 and 05OB019, all of which have relatively short records, may have been due primarily to the period of record these stations covered. When the data was split for testing, the low flow years of the early 1960's were grouped in one subsample and the high flow years of the early 1970's in the other subsample. This

decrease in variability and lowering of the mean due to the low flow years caused the data to fail the tests for homogeneity. However, the station histories indicated that problems in streamflow gauging due to shifting controls and dam construction were encountered at stations 05OA012 and 05OB019. Both conditions may have helped in creating inhomogeneity in the samples.

#### 3.2.4.4 Randomness

The period mean streamflow data for Mary Jane Creek at La Riviere (05OB013) was identified as being nonrandom. According to the runs test, the data was identified as having 16 runs above and below the median. This number of runs was larger than the critical value of 15 and, hence the data failed the test. With this large number of runs it seemed that there was a cyclic pattern in the data where each high streamflow year was followed by a low streamflow year.

An examination of the period means showed that this cyclic pattern was evident in the data. The Manitou Dam is located above the station and may have substantially affected the flow in the creek. The reservoir is unregulated, with the only releases being those spills which occur once the reservoir level exceeds full supply level. The streamflow at the station is then made up of local inflow from the area below the dam and any spills from the reservoir. In low flow years the reservoir would not spill, which would cause the flow at the station to be lower than it would have been naturally. It seems that the regulation of the streamflow

has imposed a cyclic pattern on the recorded period mean flow data at 05OB013.

### 3.2.5 Implications of Nonparametric Tests on Data Screening

For the Pembina River basin certain stations were identified as having data which failed the nonparametric tests for independence, homogeneity and randomness. Further examination of the streamflow data and gauging histories for these stations usually suggested a possible explanation or rationale for the problem. In future data screening, this set of nonparametric tests will be able to detect data samples which are not independent, homogenous and random.

When these tests are applied against the streamflow records for gauging stations in a region, they will aid in identifying those stations which require a closer, more detailed examination. In the Pembina River study basin, some of the stations failing the nonparametric tests had gauging problems or anomalies in the period of record. Problems like these would be of interest if a review were being made of a network. A station identified as being internally dependent may indicate large upstream storage. If a trend component is identified, this may indicate a change in the streamflow regime due to changes in land use through extensive drainage or clearcutting. A data sample being identified as being inhomogeneous may indicate an abrupt change in the runoff from a basin. A nonrandom data set may indicate extensive streamflow regulation causing a cyclic pattern to be imposed on the runoff. These nonparametric tests will flag those

stations for which further examination by the network reviewer may be appropriate to see if conditions such as those suggested above caused the changes or if the characteristics of the gauging station itself changed, e.g., gauging problems due to physical changes in the stream near the station.

## 3.3 SAMPLE STATISTICS

### 3.3.1 Description of Sample Statistics

The streamflow past a point (station) is the measurable result of the runoff from the basin, which is a random process and if all possible values of streamflow are gathered together, this collection is called a population. However, only a small portion of the population is collected at a station (i.e. a sample). From this sample, inferences about the behavior of the entire population (the population probability distribution) are to be made. In order to obtain such inferences, the characteristics of the population must be described with quantities called population parameters. Since only a sample of the population is available, the sample statistics are used to estimate the population parameters and thus the probability distribution.

The simple sample statistics that were considered in this study were the mean, median, standard deviation, skew, kurtosis, coefficient of variation, coefficient of skew, range and maximum. Several composite statistics, which included yield, maximum flow value divided by the mean,

median divided by mean and maximum flow value divided by minimum flow value, were also examined.

1. Mean - The sample arithmetic mean (X) is calculated as follows:

$$\bar{X} = \frac{\Sigma X_i}{N} \qquad (3.13)$$

where: $X_i$ = value of ith member of sample
$N$ = sample size (number of members in sample)

The arithmetic mean is a measure of the central tendency of a sample, and as such defines the most likely value of a probability distribution and describes the relative location of the probability distribution. The mean is also analogous to the centre of gravity of the probability distribution and is the first moment of the sample about the origin.

2. Median - The sample median (Md) is another measure of central tendency and is the middle observation when the observations are ranked in order of magnitude. Thus, the median is the observation such that half of the values lie on either side of the median. If the number of values in a sample is even, the median is taken as one-half the sum of the two middle values.

3. Standard Deviation - The sample standard deviation (s) is an estimate of the dispersion of a population and is the square root of the variance. The standard deviation is calculated as:

$$s = \left[ \frac{\Sigma (X_i - \bar{X})^2}{(N-1)} \right]^{1/2} \qquad (3.14)$$

4. Coefficient of Variation - The sample coefficient of variation (Cv) is a dimensionless measure of dispersion which is based on the standard deviation and is calculated as:

$$Cv = \frac{s}{\bar{X}} \qquad (3.15)$$

5. Coefficient of Skew - The sample coefficient of skew (Cs) is a dimensionless measure of symmetry and is based on the sample skew (g), which is calculated as:

$$g = \frac{N^2 \ \Sigma \ (X_i - \bar{X})^3}{(N-1)(N-2)} \qquad (3.16)$$

which leads the coefficient of skew, calculated as:

$$Cs = \frac{g}{s^3} \qquad (3.17)$$

6. Coefficient of Excess - The sample coefficient of excess (Ce) is a measure of peakedness of a probability distribution in comparison with the normal probability distribution and is based on the sample kurtosis calculated as:

$$k = \frac{N^3 \ \Sigma \ (X_i - \bar{X})^4}{(N-1)(N-2)(N-3)s^4} \qquad (3.18)$$

from which the coefficient of excess is determined as:

$$Ce = k-3 \qquad (3.19)$$

7. Range - The sample range (R) is another measure of dispersion and is calculated as the difference between the maximum (Mx) and minimum (Mn) sample values. The Range gives the spread of the recorded data.
8. Maximum - The maximum (Mx) is the largest recorded value in the sample and was felt to give another measure of the dispersion.

Figure 3.1 illustrates these sample statistics using hypothetical probability distributions.

The above sample statistics are used in many applications (not just water resources) to describe observed data. The following composite statistics were examined as it was felt that they may carry additional information related to hydrometric data and the hydrology of a basin.

1. Yield - The sample yield (Yd) is the mean divided by the drainage area (DA).

$$Yd = \frac{\overline{X}}{DA} \qquad (3.20)$$

2. Maximum divided by Mean (MXMN) - This parameter provides another measure of the dispersion of the sample.

$$MXMN = \frac{Mx}{\overline{X}} \qquad (3.21)$$

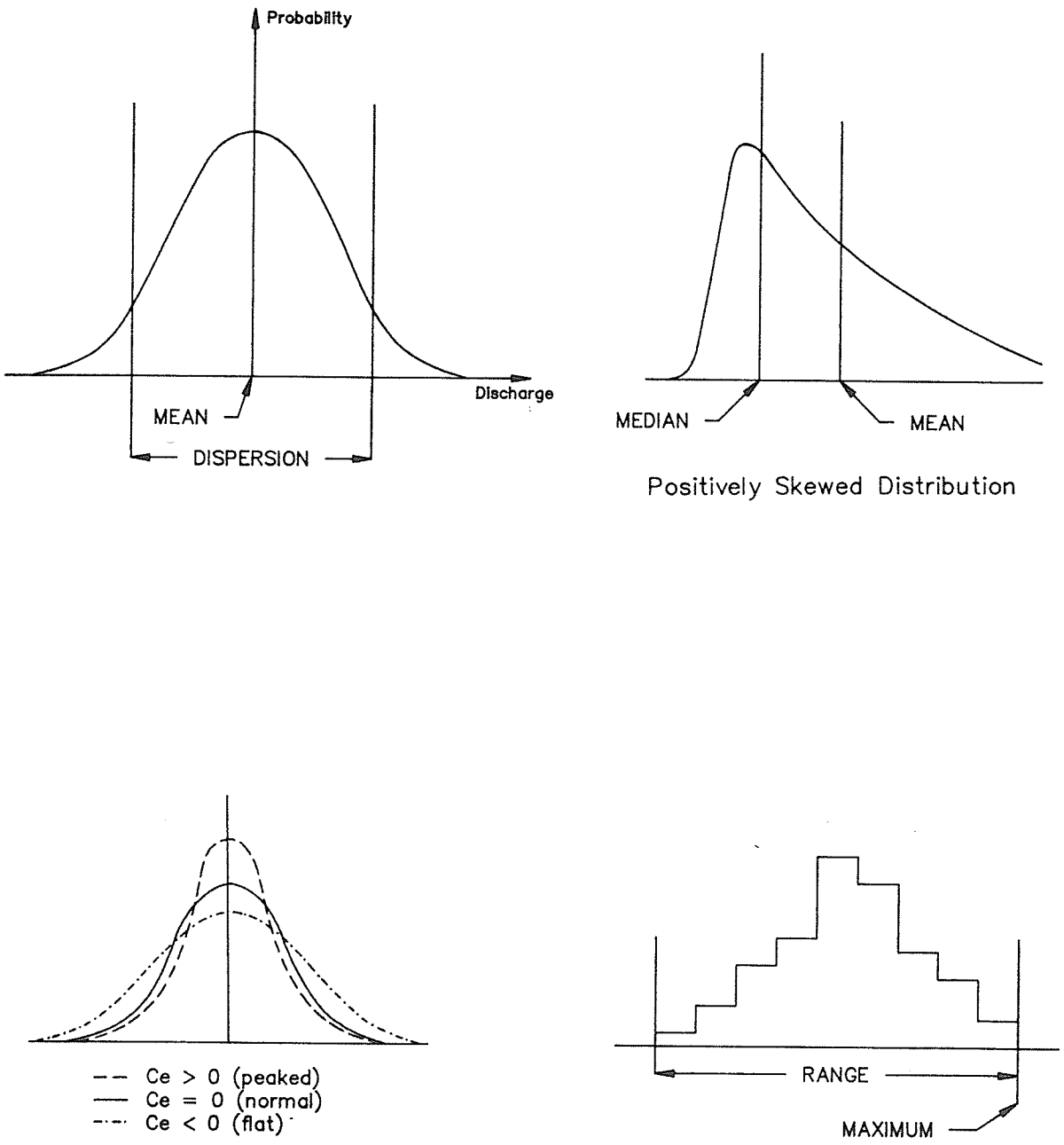



Figure 3.1

Sample Statistics Representation

3. Median divided by Mean (MDMN) - This parameter provides another measure of the skewness of the sample.

$$MDMN = \frac{Md}{\bar{X}} \qquad (3.22)$$

4. Maximum divided by Minimum - This parameter provides another measure of the dispersion of the sample.

$$MXMI = \frac{Mx}{Mn} \qquad (3.23)$$

### 3.3.2 Data Base

The sample statistics were derived for three types of streamflow data from the twenty stations in the Pembina River basin. The data types investigated were the annual mean flows, the daily mean peak flows and the monthly mean flows. The data utilized in the investigation was taken from the standard (1960-80) period of record only. Not all station records span the entire standard period; however, rarely will all stations in a basin cover the same period. It is assumed that the sample statistics derived truly represent the population parameters, even though they are based on samples of various sizes. The implications of this assumption are discussed in the interpretation of the results of the investigation.

### 3.3.2.1 Annual Mean Flows

The annual mean flows, rather than the period mean flows, were chosen for investigation in order that all stations in the basin would have a common measure. The nonparametric testing investigated the period mean flow data for each station because the data checking was internal to each station and did not involve other stations. In such internal checking, it does not matter that some stations were operated year-round and others were operated seasonally. However, in order to investigate the relationships between the sample statistics and drainage areas in the basin, the annual mean flows were felt to be more appropriate than the open water (March to October) mean flows. It was feared that some information may be lost by ignoring the winter flows.

As can be seen in Table 2.1, eight of the twenty stations considered in this study recorded streamflow year-round. The annual mean flows for these stations were presented in the Historical Streamflow Summary [Environment Canada, 1983]. The remaining twelve stations reported monthly streamflow for the period March to October only. In order to estimate the annual mean flows for these stations, the available seasonal data was extended by estimating the flow data for the missing winter months (November to February).

The winter monthly mean flow data for the seasonal stations could have been estimated by using recorded data from the year-round metering stations in the basin and nearby basins in a regression analysis or transfer technique.

However, relationships in the flow data between stations were to be investigated, and it was felt that using other stations in the basin or nearby basins to estimate the winter data for the seasonal stations may bias or otherwise unduly affect any relationships for the annual mean data among the various stations.

The volume of runoff during the winter months is quite small in comparison to the total annual volume for most prairie streams. The majority of the annual runoff volume is due to spring snowmelt runoff and is sometimes augmented by rainfall runoff during the year. Thus winter months add little to the annual flow volume unless unusually warm conditions occurring during the winter cause melting of the snowpack. In fact, only an average of 6% of the annual flow volume has been recorded for the combined winter months of November to February at the eight year-round stations in the Pembina River basin. This recorded winter flow volume varied from 1% of the annual flow for the smaller tributaries to a high of 13% recorded at station 05OB008, which is located at the downstream end of the Pembina River.

The missing winter mean flow data for each seasonal station was estimated using an interpolation technique based on logarithmic flow recession. A paper by Kiely and Goulter [1986] provides a full description of the interpolation technique used in this study. Kiely and Goulter [1986] also provide the results of the testing of this technique using

the recorded winter data collected at the eight year-round stations of the Pembina River basin.

Since the contribution of the flow in the unrecorded winter months to the mean annual flow is small, any errors in annual volume as a result of the logartihmic flow recession procedure should also be small. Testing of the procedure, as explained by Kiely and Goulter [1986], confirmed this assumption. The eight year-round stations in the study basin were tested for the difference between the annual mean flows determined from recorded data and those using the logarithmic recession procedure. The average absolute difference between the recorded and estimated annual flows (excluding 05OB008, which was influenced by one anomalously high winter flow volume) was 2%, which was deemed acceptable for this study.

#### 3.3.2.2 Maximum Daily Mean Peak Flows

The maximum daily mean peak flow, i.e. maximum "daily peak" is the largest daily discharge recorded in the year. The daily peak values are published in the Historical Streamflow Summary [Environment Canada, 1983]. It should be noted that the daily peak flood series in this study included both spring snowmelt runoff peaks and summer rainfall runoff peaks. The Historical Streamflow Summary does not differentiate between the runoff producing mechanisms when compiling the maximum daily mean peak series. For this data screening study, the difference between the two populations

of floods is unimportant but in flood frequency analysis this difference may be of interest.

The Historical Streamflow Summary also includes maximum instantaneous discharges for some stations. However, since not all stations record these values and since most stations that have recorded instantaneous peaks for only a few years, this data type was not included in the study.

#### 3.3.2.3 Monthly Mean Flows

The monthly mean flow is the average streamflow recorded in a month. The monthly mean flows for each month of the year were investigated separately in this study and are those published in the Historical Streamflow Summary. The estimated winter monthly mean flows for the seasonal stations were not included in the analysis. The analysis used recorded monthly flow values for the summer period only.

### 3.3.3 Investigation Procedure and Results

A FORTRAN computer program was written to extract the required data from the WSC format streamflow data files (see Environment Canada [1980]), which are used in the publication of the Historical Streamflow Summary. This program calculated the sample statistics from the data thus extracted. The simple statistics (SIMPSTATS) program, which performed the analysis of the sample statistics described previously, also included a subroutine for estimating the winter monthly flows and hence the annual flows for the seasonal stations.

A listing of the SIMPSTATS program is presented in Table A-1 of Appendix A.

The annual mean daily peak and monthly mean flow data were passed through SIMPSTATS, producing values for the sample statistics described in Section 3.3.1 for each data set. These resulting sample statistics for the annual mean and daily mean peak flow data are presented in Appendix A, Tables A-2 and A-3, respectively. The sample statistics for each of the months January to December are presented in Appendix A, Tables A-4 to A-15.

#### 3.3.3.1 Sample Statistics versus Drainage Areas

Confronted with this large volume of statistical results, a methodology for screening these results for anomalies and relationships was required. A visual inspection of the tabled statistical results suggested a strong relationship between the drainage area of the station and certain statistics. Such a relationship has been documented in previous studies and is also intuitively reasonable. For this reason, the effective and gross drainage areas were chosen in order to relate a physical basin characteristic to the sample statistics.

The relationship between drainage area and stream flow has been mentioned by many authors. Durrant and Blackwell [1961] developed regional curves for the three prairie provinces which related the mean annual flood (MAF) to the effective drainage area. The MAF in this instance is defined as

that flood which has a probability of occurrence of 0.5 in any one year (a return period of 2.0). A power function involving the effective drainage area (EDA) was developed to estimate MAF and is of the form:

$$MAF = f(EDA^n) \qquad (3.24)$$

where: n is the power function value which was found to have a value of 0.675 near Winnipeg and to increase in a westerly direction, reaching a value of 0.90 near the Rocky Mountains.

This concept of relating flood flows to drainage areas was used by Scott [1983] to investigate the impact of agricultural drainage on flood flows. Riggs [1973] developed a method of regional flood analysis based on the relationship between flood peaks and drainage area. The influence of the drainage area on the annual volume of runoff was reported by Mowchenko [1978], in which unit runoff (or yield) on the prairies was examined. Dunne and Leopold [1978] reported on the relationship between drainage area and average discharge for various regions in the United States.

As discussed in Chapter 2 and presented in Table 2.1, the drainage areas of the stations under study were delineated following the concepts of gross and effective drainage areas developed by PFRA and subsequently accepted and approved by the three prairie provinces and the Prairie Provinces Water Board. The gross drainage area is the total physical area that would contribute to the flow at a station under extreme runoff conditions. The gross drainage area is delimited by

the height of land defining direction of flow. The concept of an effective drainage area was described in a paper by Godwin and Martin [1975] as follows:

> "The effective or dry drainage area is that portion of a drainage basin which might be expected to entirely contribute runoff to the main stream during a flood with a return period of two years. This area excludes marsh and slough areas and other natural storage areas which would prevent runoff from reaching the main stream in a year of average runoff."

It was felt that the annual mean flow (annual volume) would be more closely related to the effective drainage area since the annual mean flow is less dependent on high runoff producing events. Conversely, the daily mean peak flows should then be more closely related to the gross drainage area to account for the larger area contributing to the higher runoff-producing events.

The sample statistics for the three types of data (annual mean flow, daily peak flow and monthly mean flow) were plotted against the logarithms of the gross and effective drainage areas and the graphs evaluated for any obvious anomalies or relationships. The linear plots for the annual mean flows are presented in Appendix A, Figures A-1 to A-24. The linear plots for the daily mean peak flows are presented in Appendix A, Figures A-25 to A-48.

The plots of the sample statistics for the annual mean flows against the logarithms of the drainage area revealed various interesting tendencies in the sample statistics and data.

1. Two distinct regions can be identified in the plots of mean, median, standard deviation, range and maximum (Figures A-1 to A-3, A-7 and A-8, respectively). For gross drainage areas less than 1500 $km^2$ (720 $km^2$ for effective drainage areas), there appears to be one linear relationship, while for those gross drainage areas greater than 4300 $km^2$ (2600 $km^2$ for effective drainage areas), there appears to be another distinct linear relationship.
2. The plots indicate the lack of gauging stations for drainage areas between the two threshold levels of 1500 and 6300 $km^2$ for gross drainage area and 720 and 2600 $km^2$ for effective drainage areas and for small agricultural drainage areas, i.e. gross drainage area less than 50 $km^2$.
3 The shape of the linear plots of mean, median, standard deviation, range and maximum also suggest that the relationship between these statistics and drainage area is log-log, rather than linear-log.
4. For the annual mean flows the ratio of maximum to minimum, when plotted against gross and effective drainage area, showed that there is apparently no relationship involved. (see Figures A-10 and A-22). However, certain stations have values for maximum divided by minimum, which were so anomously large that they warranted closer examination.

These stations (05OB025, 05OB006, 05OB023) are downstream of structures which control the flow. A possible explanation for the large maximum divided by minimum values may be found in the operation of these reservoirs. During high runoff years, the reservoirs quickly fill and spill, and the effect on recorded downstream flows is nominal. The reservoir regulation can, however, substantially reduce downstream flows in low runoff years and extended dry periods. This reduction in the minimum flow year is attributed to the storage of the majority of the runoff in the reservoir to supply consumptive uses.

5. The mean value for station 05OB016, when plotted against gross drainage area, seems low. However, when plotted against effective drainage area the mean for this station is not anomalously low. This is due to the relatively large difference in the effective and gross drainage areas for this station (245 vs 980 $km^2$). The drainage area to 05OB016 is poorly drained and thus the ratio of gross to effective drainage area is 4.0, which is substantially different than the average value of 1.4 for the remainder of the stations in the basin.
6. None of the other sample statistics seemed to be related to drainage area, and the values extracted from the data and plotted did not show any pattern or anomalous points.

The plots of the sample statistics for the daily mean peak flows against the logarithms of the drainage area

revealed the same general relationships as the annual mean statistics. However, due to the large variability in the daily peak flows these relationships were not as well defined and the statistics revealed more scatter. The values of maximum divided by minimum were extreme for more stations and seemed to be related more to the vagaries of flood conditions than to regulation. The high values for the ratio are believed to be related more to high maximum values associated with extreme floods than to low values associated with flow regulation. Plotting the logarithms of the sample statistics versus the drainage area confirmed the existence of a linear relationship for certain statistics. The scatter for the other statistics remained wide in these plots, and no obvious relationships with drainage area were revealed.

#### 3.3.3.2 Linear Regression Data Screening

Since there seemed to be a log-log relationship between certain sample statistics and the drainage area of the station, the logarithms of the sample statistics were linearly regressed with the logarithms of the drainage area. It should be noted that although the station data sets had varying record lengths, the regression analysis did not correct for record length. From this linear regression it was felt that the strength of this relationship could be gauged and any anomalous stations would be identified as outliers from the regression.

The sample statistics and drainage area for each station were entered into the SAS [1982a] program for simple linear regression. The program transformed the statistics and drainage areas into their logarithms, which were used to develop simple linear regression models. Each log statistic was regressed against the logarithm of the gross drainage area using the regression (REG) procedure available in the SAS program. A residual analysis was not performed for these simple linear regression models.

Example output from the REG procedure using the annual mean sample statistics is presented in Appendix B, Table B-1. This output includes the results of the linear regression, statistical information concerning the regressions and line-printer plots of the relationships. The relationships between the statistics and drainage area previously observed in the linear plots were supported by the regression results. The mean (X), median (Md), standard deviation (s), range (R) and maximum (Mx) sample statistics, when transformed to logarithms, relate well to the logarithm of the drainage area. The yield (Yd) was also found to be related to the drainage area. The remainder of the sample statistics showed no relationship or dependence on drainage area. Some sample statistics, like the coefficient of variation (Cv) and coefficient of skew (Cs), have relatively constant values for the Pembina River basin.

The measure used to evaluate the relationship between the drainage area and the sample statistics was the adjusted

coefficient of determination ($r^2$). The $r^2$ value was used in this study as a measure of ability of the regression line to explain variation in the dependent variable (i.e. the sample statistic). First, the coefficient of determination ($r^2$) was calculated from:

$$r^2 = \frac{\text{sum of squares due to regression model}}{\text{total sum of squares}} = \frac{\Sigma (\hat{y}_i - \bar{y})^2}{\Sigma (y_i - \bar{y})^2} \qquad (3.25)$$

where: $y_i$ are the dependent (y) values which, in this application, are the logarithms of a certain sample statistic.

$\hat{y}_i$ is the value of the dependent variable predicted by the regression model.

$\bar{y}$ is the mean of the dependent variable.

The $r^2$ value was then adjusted for the degrees of freedom with:

$$r^2 = 1 - \frac{(1-r^2)(n-1)}{(n-2)} \qquad (3.26)$$

where: n is the number of values in the regression analysis.

The adjusted $r^2$ values were used to compare the relationships between the drainage area and the sample statistics. The adjusted $r^2$ values calculated in the SAS program for sample statistics based on the annual mean flows, daily peak flows and the open-water (March to November) monthly flows are presented in Table 3.4.

The results indicated that certain statistics had similar degrees of relationship with drainage area. The standard

deviation, range and maximum had similar $r^2$ values for the different data samples. This similarity in relationship strength is not that surprising since these statistics all describe the degree of dispersion of the data sample. The range and maximum value are similar because the smallest value of most samples is zero or near to zero for streamflow, which causes these two statistics to have very similar values.

The two measures of central tendency did not seem to be related to the drainage area in the same way. The mean had the most stable relationship with the drainage area in terms of the data samples studied. The $r^2$ values describing this relationship between mean and drainage area were high. The median did not enjoy the same strength of relationship as the mean nor the same pattern of $r^2$ values as the mean.

Table 3.4

Adjusted $r^2$ Values for Regional Regression Equations Relating Sample Statistics to Gross Drainage Area

| Sample Statistic | Annual Means | Daily Peaks | Monthly Mean Flows | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. |
| Mean ($\bar{X}$) | 0.96 | 0.76 | 0.76 | 0.95 | 0.93 | 0.90 | 0.83 | 0.90 | 0.88 | 0.77 |
| Median (Md) | 0.91 | 0.69 | 0.63[1] | 0.90 | 0.87 | 0.78 | 0.79[1] | 0.81[1] | 0.80[1] | 0.56[1] |
| Standard Deviation (s) | 0.98 | 0.70 | 0.67 | 0.95 | 0.95 | 0.89 | 0.81 | 0.78 | 0.83 | 0.83 |
| Range (R) | 0.98 | 0.67 | 0.60 | 0.95 | 0.95 | 0.86 | 0.80 | 0.72 | 0.82 | 0.85 |
| Maximum (Mx) | 0.98 | 0.70 | 0.60 | 0.95 | 0.95 | 0.87 | 0.80 | 0.72 | 0.82 | 0.85 |
| Yield (Yd) | 0.26 | 0.74 | 0.73 | 0.69 | 0.06 | 0.09 | 0.02 | 0.02 | 0.05 | 0.15 |

1. The median data set for these months included stations whose sample medians were zero and hence were not included in the regional logarithmic regression analysis.

The yield related well to the drainage area only for the daily peak flow data and for the March and April monthly mean flows. Most of the daily peak flows were recorded during the spring runoff event, the majority of which occur during April in this basin. The April spring flood event provides a large volume of flow during the month and hence a connection between the April mean flows and daily peak flows is understandable.

An explanation of the strength of the relationship between March monthly yields and drainage area is less obvious. The nature of March flows in the Pembina river basin is dependent on early snowmelt events and winter base flow. The base flow for most of the tributaries and headwater stations is low but increases as the distance travelled downstream from the headwaters increases. March spring snowmelt events are more likely to encounter a more uniformly-distributed snowpack as compared to the possibly depleted snowpack in a May snowmelt event. Because of the low and limited base flow, the values of the mean, yield and range of the March flows are then significantly affected by the early snowmelt runoff events. Thus, the runoff volume at each station is more likely to be uniform due to the undisturbed snowpack, which then causes the governing March snowmelt events to be more uniform across the basin.

The May monthly flows also are due mostly to spring snowmelt but usually include the recession portion of the hydrograph. The recession of the snowmelt in the basin can be

highly variable due to differences in basin storage, drainage density and drainage length. Also, spring rainstorms which can occur during May may not encompass the entire basin and then lead to more variable yields with a correspondingly low $r^2$ value.

The regional regression analysis was conducted on the other sample statistics, even though the plots indicated no relationship between the statistics and drainage area. This apparent lack of relationship was supported by the values of the estimated parameters, which were not statistically different from zero, and the low $r^2$ values for the regression analysis.

The results from the REG procedure of the SAS program provided measures of the strength of the studied relationships but also included some statistical tools with which to identify anomalous stations. The regression analysis provided least squares estimates of the regression parameters relating the central tendency (mean, median and yield) and the dispersion (standard deviation, range and maximum) of the streamflow data to the drainage area. Because of the strength of these relationships ($r^2$ values in the range 0.90 to 0.98) it was felt that any significant deviation from the regression line by individual stations may indicate incongruities in the recorded streamflow data.

The first statistical tool used to identify anomalous stations was the use of two confidence intervals for the regional regression line. One confidence interval

investigated was the interval for the expected value (mean) of the response. The other confidence interval investigated was the interval for the individual forecast (prediction), which is the expected value plus error.

The 95% confidence interval for the expected value of the regional regression line is defined as that interval that contains the true expected value of the response with 95% probability. Thus, the true regression should lie between these limits and is determined from first calculating the standard error of $\hat{\hat{y}}_k$, which is the mean value of the family of the possible predicted values $\hat{y}_k$ for a given $x_k$. Thus, $\hat{\hat{y}}_k$ corresponds to the value of y predicted by the regional regression equation:

$$\hat{\hat{y}}_k = a + bx_k \qquad (3.27)$$

which leads to the standard error of the predicted value $\hat{\hat{y}}_k$ defined as $SEP_k$ and calculated by:

$$SEP_k = Sr \left[ \frac{1}{n} + \frac{(x_k - \bar{x})^2}{\Sigma (x_i - \bar{x})^2} \right]^{0.5} \qquad (3.25)$$

where: n is the number of calculated sample statistic values in group used to derive regional regression equation.
$x_k$ is the independent $x_i$ value for which the interval is being calculated.
$\bar{x}$ is the mean of the data sample statistics used in the regional regression equation.
Sr is the standard error of the regression equation (sometimes called the mean square error) and estimated from:

$$Sr = \left[ \frac{\Sigma (y_i - \hat{\hat{y}}_i)^2}{n - 2} \right]^{0.5} \qquad (3.26)$$

and, $y_i$ are the y dependent values.

This value for the standard error of the predicted value ($SEP_k$) is then used in the following manner to calculate the lower ($Lm_k$) and upper ($Um_k$) limits of the 95% confidence interval with respect to the regression line.

$$Lm_k = \hat{y}_k - SEP_k \, t_{0.975,n-2} \qquad (3.30a)$$

and

$$Um_k = \hat{y}_k + SEP_k \, t_{0.975,n-2} \qquad (3.30b)$$

where: $t_{0.975,n-2}$ is the Student's t value for the 95% confidence limit (two tailed) with n-2 degrees of freedom.

The confidence interval on an individual predicted value is wider than the confidence interval on the regression line since an error term of $Sr^2$ (the variance of the error) is added to $SEP_k$. The lower ($Lp_k$) and upper ($Up_k$) limits of the 95% confidence interval with respect to the predicted value are:

$$Lp_k = \hat{y}_k - (Sr^2 + SEP_k)t_{0.975,n-2} \qquad (3.31a)$$

and

$$Up_k = \hat{y}_k + (Sr^2 + SEP_k)t_{0.975,n-2} \qquad (3.31b)$$

In referring to prediction, these confidence limits indicate the range about the regression line within which a $Y_k$ should fall within for a given $X_k$, allowing that the relationship holds. Station sample statistics which fall outside these limits indicate those station data for which the regional relationship may not hold. With respect to the

regression line, the confidence limits indicate the most likely location of the regression line. If the relationship is strong, most of the samples should fall within this interval. Values which fall outside these limits would indicate stations for which the relationship is not very strong and which may have incongruities in the streamflow data.

The regression results for the mean, median, standard deviation, range and maximum were examined with respect to these two confidence intervals at the 95% level of significance. Table 3.5 presents the stations for which the sample statistics derived from the annual mean data fell outside the confidence intervals for the specific regression.

The results presented in Table 3.5 suggest that the standard deviation, range and maximum identify essentially the same anomalous stations. The mean and median identified the same stations as being outside the prediction confidence interval, but identified different stations as being outside the regression confidence interval. This difference may be due to the nature of these two statistics, where the mean is more influenced by the larger values in the sample and the median is not.

Table 3.6 presents the stations for which the sample statistics derived from the daily mean peak flow data fell outside of the confidence intervals. Only one station (05OB016) has a sample statistic which fell outside of the prediction confidence interval, similar to what was found for the annual mean flow data. However, many more stations were

identified as falling outside of the regression confidence interval for the daily mean peak flow data.

Table 3.5

Stations Whose Annual Mean Sample Statistics Fell Outside of the 95% Confidence Intervals

| Confidence Interval | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean ($\bar{X}$) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| Prediction | 05OA013<br>05OB016 | 05OA013<br>05OB016 | 05OB016 | 05OB016 | 05OB016 |
| Expected Value[1] of Regression | 05OB006 | 05OA007<br>05OB025 | 05OA005<br>05OA013<br>05OB001<br>05OB006<br>05OB008 | 05OA005<br>05OB006<br>05OB001<br>05OB008 | 05OA005<br>05OB006<br>05OA008<br>05OB008 |

1 Stations which fall outside of the predicted confidence interval also fall outside of the confidence interval for the expected value of regression. Thus, the stations listed as failing predicition should be added to the stations failing this test.

Table 3.6 does support the observation that the measures of dispersion identify essentially the same anomalous stations. However, the large number of stations which fell outside of the regression confidence interval suggest that this interval is less discriminating for the regression equations which have lower $r^2$ values and that only the prediction confidence interval would be of any use as an outlier detection measure.

Table 3.6

Stations Whose Daily Peak Sample Statistics
Fell Outside of the 95% Confidence Intervals

| Confidence Interval | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean (X) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| Prediction | 05OB016 | | | | |
| Expected Value of Regression | 05OA007 | 05OA008 | 05OA007 | 05OA006 | 05OA006 |
| | 05OB008 | 05OB008 | 05OA013 | 05OA007 | 05OA007 |
| | 05OB010 | 05OB010 | 05OB001 | 05OA008 | 05OB008 |
| | 05OB016 | 05OB016 | 05OB010 | 05OA013 | 05OA013 |
| | 05OB021 | 05OB019 | 05OB016 | 05OB010 | 05OB010 |
| | 05OB025 | 05OB021 | 05OB019 | 05OB016 | 05OB016 |
| | 05OB031 | 05OB029 | 05OB021 | 05OB021 | 05OB021 |
| | | 05OB031 | 05OB023 | 05OB023 | 05OB023 |
| | | 05Oc004 | 05OB031 | 05OB031 | 05OB031 |

On this basis, only the prediction confidence interval was used to detect outliers in the monthly mean data sets. The results of the confidence interval outlier detection using the monthly mean data for the months March to October are presented in Appendix B, Table B-2.

A practical problem was encountered in detecting outliers using the prediction confidence interval from the regression analysis with the sample median of the monthly data. For the headwater stations, the sample median is zero for the months of March and July to October. Thus, these stations are not included in the log-log regression analysis. The logarithm of the sample median relates well to the logarithm of the gross drainage area; however, the equations for these low-

flow months are generated without all of the stations in the basin. For these months, the median is a poor detector of outliers.

The second statistical measure used to detect outliers was the "studentized" residual (RS). This diagnostic measure modifies the residuals to enhance the detection of problem data. The studentized residual is calculated:

$$RS = \frac{(y_i - \hat{y}_i)}{SER_i} \tag{3.32}$$

where: $\hat{y}_i$ is the predicted y value from the regression equation for the sample value $x_i$ (equivalent to $\hat{y}_k$ in Equation 3.27 with $k = i$).

The term $(y_i - \hat{y}_i)$ is the residual.

$SER_i$ is the standard error of the residual, which is estimated from:

$$SER_i = Sr\left[1 - \frac{1}{n} + \frac{(x_i - \bar{x})^2}{\Sigma (x_i - \bar{x})^2}\right]^{0.5} \tag{3.33}$$

According to Belsley et al. [1980], the studentized residual (RS) is distributed closely to the t-distribution with n-3 degrees of freedom for simple regression. Belsley et al. [1980] proposed that a cutoff value of 2.0 be considered if an observation is to be deleted from a sample. However, it is not the intent of this analysis to delete observations to produce a better regression equation. Rather, the use of RS is to detect sample statistics (and hence stations) whose residuals are anomalously high. The cutoff value for outlier

detection was then arbitrarily relaxed to a value of 1.5, based on engineering judgement.

Table 3.7 presents those stations whose absolute value of RS exceeds 1.5 for the measures of central tendency and dispersion based on the annual mean flow data and daily mean peak flow data. The results of the outlier detection based on RS greater than 1.5, using the monthly mean data for the months March to October, are presented in Appendix B, Table B-3.

Table 3.7

Stations Whose Sample Statistics
Have a $|$Studentized Residual$|$ Value > 1.5

| Data Source | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean ($\bar{X}$) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| Annual Mean Flows | 05OA013<br>05OB016 | 05OA013<br>05OB016 | 05OA005<br>05OB006<br>05OB016 | 05OA005<br>05OB006<br>05OB016 | 05OA005<br>05OB006<br>05OB016 |
| Daily Mean Peak Flows | 05OB016 | 05OB025<br>05OC004 | 05OB016 | 05OB016 | 05OB016 |

The third statistical measure used to detect outliers is the distance measure developed by Cook [1977, 1979]. Cook's D is a scaled measure of the change to the predicted value $\hat{y}_i$ by deleting the observed $y_i$. Cook's D is used to identify those observations which influence the estimated

parameters of the regression equation the most and is calculated using:

$$CookD_i = \frac{RS_i^2}{2}\left[\frac{SEP_i}{SER_i}\right]^2 \qquad (3.34)$$

Cook's D is an empirical function which has been reported to follow the central F distribution with a $(1 - \alpha)$ probability point (Vinod and Ullah [1981]). The degrees of freedom are p (the number of regressors which equal 2 for simple regression) and N-p-1 (which equals 17 for the 20 stations involved in the regression analysis). Hence, the critical value for F assumed in this study is 0.164, below which it is 99% certain that the influence on the regression parameters caused by the deletion of a certain observation is not significant. Therefore, values with Cook's D above 0.164 are significant and may warrant closer inspection of the observation. Table 3.8 presents those stations whose Cook's D value exceeds 0.164 for the measures of central tendency and dispersion based on the annual mean flow data and daily mean peak flow data. The results of the outlier detection test based on $CookD_i$ greater than 0.164 using the monthly mean data for the months March to October are presented in Appendix B, Table B-4.

During the regression analysis procedure, the outlier detection measures for the other poorly-related sample statistics identified certain stations to be outliers.

However, since there is no linear relationship between these statistics and drainage area and such a relationship is assumed as a condition for these outlier detection measures, these identified outliers are believed to be due mainly to chance and are not examined further here. The observed scatter exhibited by these statistics when plotted against drainage area together with the wide confidence intervals calculated for these statistics support this hypothesis.

Table 3.8

Stations Whose Sample Statistics
Have a Cook's D Value > 0.164

| Confidence Interval | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean ($\bar{X}$) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| Annual Mean Flows | 05OA013<br>05OB016 | 05OA013 | 05OA005<br>05OB006 | 05OA005 | 05OA005<br>05OB006 |
| Daily Mean Peak flows | 05OB016 | 05OB025<br>05OC004 | - | - | - |

### 3.3.4 General Summary and Discussion of Results

The sample statistics were investigated in several ways in the screening of the hydrometric data for the Pembina River basin. Once the sample statistics were calculated, they were plotted against the drainage area to better visualize and interpret the data. Several possible relationships were noted, and the sample statistics were transformed to

logarithms and regressed with the logarithms of the station drainage area. Since the relationships between the statistics and drainage area were strong, several outlier detection methods were employed to identify possible anomalous stations.

For each regression equation, the locations of the observed values with respect to the values predicted by the regression equation were checked with confidence intervals. The residuals between the observed and predicted values were scaled and analyzed for anomalies. Also, the influence of each observed value on the regression equation was investigated to determine anomalous data sets. The results of these investigations with respect to the Pembina River basin data are discussed in this section.

#### 3.3.4.1 Sample Statistics Plotted Against Drainage Area

The plotting of the sample statistics based on the annual mean and daily mean peak flow data for each station against the gross and effective drainage areas was important in visualizing the relationships involved in this investigation. Certain statistics were obviously unrelated to drainage area and plotted as widely scattered points without a pattern. These unrelated statistics included Cv, Ce, MXMN, MDMN and MXMI. Compared to these statistics, the Cs for the annual mean data plotted as a relatively constant band having an average value of 1.009; however, station 05OA013 (Long River near Killarney) had an extremely small Cs value (0.011). The

period of record for 05OA013 is only ten years (1967 to 1976). The calculation of Cs (see Equation 3.17) requires the use of the sample skew statistic (g). Because this sample is made up of only ten members, the use of the higher-moment statistic g is unreliable in estimating the population skew and may be the cause of the low Cs value.

The examination of the unrelated statistics did reveal one interesting and useful tendency. For the plot of MXMI, based on annual mean flow data against both gross and effective drainage area, certain stations seemed anomalously high. As was discussed in Section 3.3.3.1, these stations were found to be downstream of reservoirs, and the operation of these reservoirs may have caused these extreme values by passing relatively unchanged high flows in large runoff years and by passing flows reduced below the natural values in low runoff years.

The visual presentation afforded by these plots was important for those statistics which were related to drainage area. The plots revealed a gap in the drainage areas for the gauging stations in the Pembina River basin. No stations have a gross drainage area which falls in the range 1500 to 4500 $km^2$. However, in the case of the Pembina River basin, this gap is due to the configuration of the stream. As can be seen in Figure 3.2, two large tributaries join the Pembina River just below Lorne Lake and two more enter downstream of Rock Lake. WSC has gauging stations on each of these tributaries. Thus, the gap in the gauged drainage area of

1500 to 4500 $km^2$ could be filled by combining records from the tributaries if required. For example, the inflow to Rock Lake could be estimated from the recorded flows of the WSC stations as follows:

Rock Lake Inflow = 05OA010 + 05OA006 + 05OA007 + LI

where: LI is the local inflow to Rock Lake for the area below the gauging stations.

The plots of the sample statistics for the annual mean and daily peak flow data showed that the relationships with the drainage area were most likely log-log. With the linear-log plots it was apparent even by visual inspection that some points (hence station data sets) were suspect. Relating the sample statistics to drainage area allows outlier detection techniques to be used with the regression analysis to identify anomalous stations.

### 3.3.4.2 Linear Regression Analysis

The regression analysis focused on the relationships between the sample statistics (mean, median, standard deviation, range, maximum and yield ) and the gross drainage area. The regression analysis was conducted to investigate the relative strengths of the relationships and to determine if outlier detection techniques could be used to identify anomalous stations. The adjusted $r^2$ values were used to indicate the strength of the regression equations and were presented in Table 3.4. These $r^2$ values resulted in some interesting observations.

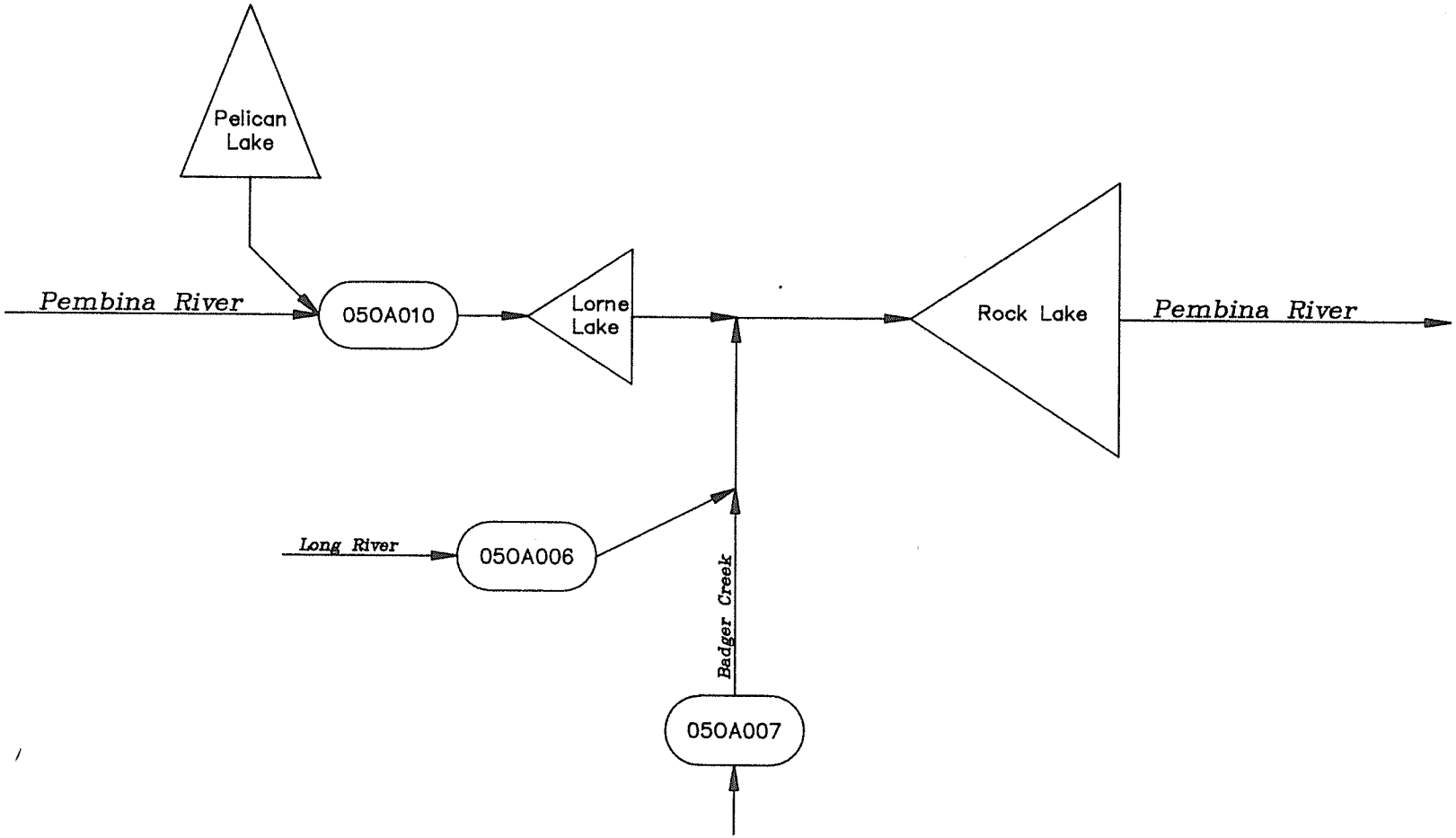



Figure 3.2

Schematic of Pembina River System
Upstream of Swan Lake

1. The annual means and high flow months (April, May and June) all had comparable $r^2$ values for the five main statistics (mean, median, standard deviation, range and maximum). This linkage occurred because the majority of the annual flow volume is due to the same flow generating mechanism; namely, the spring snowmelt runoff during these three months.

2. The regression equations for the daily mean peaks and the low flow months were not as strong as the annual means and spring monthly flows but still had respectable $r^2$ values (with minor exceptions, above 0.64). The lower $r^2$ values were due to the variability between low and high flows in the data sets.

   The summer and fall low-flow months sometimes included rainfall runoff events. The precipitation events which occur on the prairies are usually localized storms which do not encompass large areas like the Pembina River basin and then would not produce runoff on every stream in the basin. In such cases only small local watersheds in the vicinity of the event would show the major effects of the runoff-producing events, thereby weakening the total relationship among all stations.

3. The sample statistics which measure the dispersion of the data, the standard deviation, range and maximum all had similar $r^2$ values in the regression analysis. The similarity between $r^2$ values for the range and maximum was not surprising since, for most data sets, the minimum

values were zero or near zero, and hence these two sample statistics had essentially the same value. Due to the similarity between these three measures, it is likely that only one measure needs to be considered for data screening. The standard deviation should be used since this statistic has the advantage of reflecting the frequency and magnitude of values that deviate from the mean, while the range and maximum do not.

4. The two measures of central tendency, mean and median had differing $r^2$ values for the regression analysis. The mean was better related to drainage area and had higher $r^2$ values. The median had reasonable $r^2$ values for the annual mean and spring monthly mean flows. However, for the low flow months, the median did not have as strong a relationship with drainage area. In these months, the sample median for certain stations were zero (i.e. at least half the years had no flow in these months). Since the regional regressional equation used the logarithms of the medians, these stations were excluded from the analysis. These months therefore had less stations in the regression analysis, which caused the lower $r^2$ values.

5. The composite statistic yield was related to drainage area for only the daily mean peaks and March and April monthly mean flow data. There is a connection between the daily mean peaks and April flows because most of the recorded daily mean peaks occur during the spring runoff

which, in this basin, usually occurs in April. The volume of runoff in a month in which the snowmelt peak occurs is generally directly related to the size of that peak.

The strength of the relationship involving March mean flows is due to the general low flows prior to spring runoff and the rarity of localized storms in this month and the fact that most significant runoff is caused by the snowmelt of a more-uniform snowpack. The occurrence of localized precipitation events and certain anomalous stations may be responsible for the poor performance of the yield with respect to the other data sets investigated.

The results indicated that the five main statistics of mean, median, standard deviation, range and maximum were related to drainage area and based on the strength of the relationships, the regional regression analyses could be used to detect outliers.

#### 3.3.4.3 Outlier Detection - Confidence Intervals

The results presented in Tables 3.5 and 3.6 indicate that the outlier detection technique does flag a number of station data sets as having statistical values which deviate significantly from the expected regional values. The values which fall outside of the prediction confidence interval are far enough from the regional regression equation that the difference is unlikely to be due to chance alone (although,

by definition in the 95% test used, there is a 5% chance that a single value will fall outside of these limits). Therefore, the data sets (hence stations) that lie outside the prediction confidence interval warrant further scrutiny.

Deviation outside of the less-stringent regression confidence interval has a different interpretation. The regression confidence interval delimits the most probable location of the regional regression equation. It is hoped that most of the points used to determine the regression equation would fall within these limits; however, due to the scatter of the data, some points fall outside of these limits. For regional regression equations with high $r^2$ values, indicating a strong relationship, few points fall outside of these limits. Examples of this situation can be seen in Table 3.5. However, as in the case of the daily mean peaks, for those regional relationships that are poorly defined, many points will fall outside of these limits. Therefore, the regression interval is a poor detector of outliers or deviant data samples.

The station data for the annual mean flow and daily mean peak flow which were identified as having sample statistics which fell outside of the prediction confidence interval were scrutinized, and possible explanations for the deviancy were sought. The sample statistics for both sets of data for station 05OB016 (Snowflake Creek near Snowflake) were outside of the confidence interval. The regional regressions were conducted against the gross drainage area. Station 05OB016

is poorly drained, with only 25% of the basin area being effective. Thus, since this station is so poorly drained as compared to the rest of the basin stations, it is not surprising that 05OB016 has anomalously low values for the statistics and does not fit the regional regression equations.

The measures of central tendency for station 05OA013 (Long River near Killarney) are anomalously high against the regional regressions. The short record period (1967-76) for this station includes some extreme runoff years (1969, 1974, 1976). Furthermore, for one of the years in that period, namely 1974, the runoff at station 05OC004 was the largest in the 73 years of its record. Also, the short period of record for 05OA013 does not encompass the low-flow years of the early 1960's. These factors cause the mean for the station to be substantially larger than stations of comparable size. Table 3.9 includes possible explanations for additional anomalous station data sets identified as being outside of the prediction confidence interval based on the open-water monthly data sets.

#### 3.3.4.4 Outlier Detection - Studentized Residual

Several data sets were identified as having sample statistics significantly different than the regional regression equation based on the value of the studentized residual (RS). Applying an absolute cutoff value of 1.5 to RS yielded the stations listed in Table 3.7 and Appendix B, Table B-3. The previous section provided possible

explanations for certain station data sets. The employment of studentized residuals exposed some additional stations which require closer scrutiny of the data sets.

Table 3.9

Explanation of Anomalous Monthly Data Sets
Based on the Prediction Confidence Interval

| Station Number | Monthly Data Set | Sample Statistics Affected | Explanation |
|---|---|---|---|
| 05OB031 | June | s,R,Mx | Two extreme rainfall runoff flood events (1963, 1970) led to high dispersion statistic values in comparison with the normal near-zero baseflow conditions. |
| 05OB006 | July | all | No rainfall runoff events recorded for July, which led to lower sample statistic values as compared to regional equation. Neighbouring stations (05OB010, 05OB031) recorded a few rainfall floods; perhaps storage projects above 05OB006 captured these runoff events. |
| 05OB021 | August | all | No rainfall events recorded. Missed 05OB016 as well. |
| 05OB010 | October | all | No baseflow and no substantial rainfall events recorded, which led to low statistic values. Confirmed by flow record at upstream station (05OB031). |

The measures of dispersion for the annual mean flows at station 05OA005 (Hidden Island Coulee near Hansboro) were identified as being anomalously high. An examination of the streamflow data identified several zero or near-zero flow years (1977, 1963 and 1962) as well as various high flow

years (1974, 1979 and 1969), which account for the high values for standard deviation, range and maximum. These extreme annual mean flows followed the pattern observed in the annual mean flows of nearby stations. It was not possible, however, to obtain a clear explanation for the observed high measures of dispersion for the annual mean flows at 050A005.

The measures of dispersion for the annual mean flows at station 050B006 (Crystal Creek near Crystal City) were also identified as being anomalously low. Again, an examination of the recorded flows at 050B006 and nearby stations yielded no obvious incongruities. However, the effective drainage area for this station is smaller than those stations with comparable gross drainage areas. Since the gross drainage area was used in the regional regression analysis, this may explain the observed low measures of dispersion for the station when compared to the regional regression prediction. Another factor in the low dispersion observed in the data may be the effect on the flow of several small dams upstream of the station and the possible backwater effect caused by the Crystal City reservoir during high flows. In low flow years the minor projects may intercept a large portion of the spring runoff yielding lower recorded flows at the station.

The observed median daily mean peak flow at station 050B025 (Pilot Creek near Pilot Mound) was identified as being anomalously lower than the predicted value from the regional regression equation. This low median value is

attributed to the upstream regulation of the stream by the Pilot Mound Dam. Due to the relatively small storage capacity of the reservoir, large floods pass relatively unattenuated through the reservoir. However, smaller flood peaks may be significantly reduced by the reservoir, hence the low median value.

The sample median daily mean peak flow at station 050C004 (Pembina River at Neche) had a large positive residual difference from the regional regression equation, which indicated a high median value for the daily mean peak data set.

An investigation of the daily mean peak flow data set for 050C004 revealed some interesting problems associated with the data set. Previous work by the International Pembina Engineering Board [1964] determined that the Pembina River overflows its banks between Walhalla, North Dakota and Neche, North Dakota at moderate stages and loses water from the basin to the north into Canada and south to the Tongue River basin. This breakout reportedly occurs at flows above 56.6 $m^3/s$ (2000 cfs) and is assumed to be caused by the decrease in slope of the streambed once the river exits the Pembina Excarpment and flows through the Red River Plain. The loss of water from the stream channel would reduce the daily mean peak flow for the larger floods, which should then lead to a lower median value for this data set.

However, another complicating factor is the shape of the runoff hydrographs recorded at 050C004. An examination of the recorded flow hydrographs for several moderate flood

events (90 to 130 $m^3/s$) at stations 05OB001, 05OB007, 05OB008 and 05OC004 showed that a double peak occurred during most floods. The first of these peaks is thought to be due to local runoff from the drainage area below Swan Lake, while the second peak is due to runoff from the area upstream of Swan Lake and is delayed on the order of four or five days. The daily mean peak flow in any one year at 05OC004 is the greater of the two peaks. This peak is dependent on the modification of the runoff hydrograph for the area upstream of Swan Lake by the lake storage above that point and on local runoff conditions below Swan Lake. The complexity of the runoff phenomenon due to the timing and magnitude of outflows from Swan Lake and the local runoff hydrograph and because the larger of these peaks is chosen for the daily mean peak flow may possibly be the cause of the relatively larger median daily mean peak flow at 05OC004. Since the median is a single event in a series, any anomalous conditions in that year would also affect the value of the median daily mean peak flow.

A review of the anomalous stations listed in Appendix B, Table B-3, yielded only station 05OB008 (Pembina River near Kaleida) for which a possible explanation of the deviancy from the regional regression equation had not yet been offered. The range and maximum values for the May and June monthly mean flows for 05OB008 were lower than the regional regression equation. The station recorded flow only until 1969, and the short period of record included the low flows

of the 1960's, which may have led to the reduced range and maximum values

### 3.3.4.5 Outlier Detection - Cook's D

The use of the Cook's D statistic to indicate possible outliers identified several data sets as having sample statistics which significantly influence the regional regression equation. Use of this empirical influence function identified the stations listed in Table 3.8 and Appendix B, Table B-4 as having Cook's D values greater than 0.164. All of the stations in Table 3.8 and Table B-4 had previously been identified as being outliers using both the confidence intervals and the cutoff value for the studentized residual. Possible explanations for the anomalous data sets have been previously offered for all of the stations.

## 3.3.5 Implications of Sample Statistics Data Screening

The sample statistics from recorded data sets may be used in various ways in the data screening process. By plotting the sample statistics against drainage area the basin or regional data sets can be assessed for gaps in the range of drainage areas covered by the hydrometric network. On the other hand, these plots may identify ranges of drainage areas that include large numbers of stations, which may indicate some redundancy in coverage of the hydrometric network in terms of basin drainage areas.

These plots of sample statistics versus drainage area also indicate station data sets whose sample statistics obviously differ substantially from the other stations of the region. An example is the composite statistic MXMI, for which anomalously high values identified several data sets whose values appear to have been affected by nearby reservoirs.

The investigation of the sample statistics for the Pembina River data set indicated that only five sample statistics were related to drainage area. The other statistics were unrelated to drainage area or only related for small numbers of data sets. Problems with short data sample periods and unstable parameter estimation for the statistics based on higher moments led to wild fluctuations in some statistics in regional terms. Two measures of central tendency, mean and median, and three measures of dispersion, standard deviation, range and maximum, were clearly related to drainage area. Investigations into the strength of these relationships indicated that in comparison to the range and maximum, the standard deviation was the best index variable. Based on the strength of the relationship, the median is a poorer index variable than the mean but accounts for a different aspect of the central tendency and is not dependent on the larger values in the sample. Since the linear relationships between the logarithms of the sample statistics and gross drainage area were relatively strong, statistical

measures produced in the regression analysis were used to investigate further the station data sets for anomalies.

Three statistical tools were found to be useful in identifying anomalous station data sets. The prediction confidence interval identified stations whose sample statistic value was obviously different than that predicted by the regional regression equation. The use of an absolute cutoff value for the studentized residuals of the regional regressions identified additional stations whose data sets required closer scrutiny as to the cause of the nonconformance of the sample statistic relative to the regional regression equation. The use of the Cook's D statistic to identify influential data sets from the regional regression analysis identified essentially the same anomalous station data sets as the cutoff value for the studentized residual.

The annual mean flow and daily mean peak flow were the main data types examined in this analysis since these streamflow measures are important hydrologic parameters in any analysis of a stream system. The annual mean flow indicates the volume of water available from a basin and is used to size future developments. The daily peak flow is an indication of the flood potential at a site which must be considered in the design of a project. Knowledge of anomalous stations with respect to these two data types is important if any future development in a basin involves the use of these data sets. Any decisions based on the data from

the anomalous stations may be suspect and as such may require further investigations.

Identifying anomalous station data sets using the monthly mean flow data in the basin was found to be another helpful approach. In order to use all stations, including seasonal stations, for all analyses, the monthly examinations were for March through October, which is the period in which the seasonal stations operate. Generally, the anomalous monthly data sets were grouped into the low and high flow months. The high flow months of April to June included the spring snowmelt and early spring rains, which produced the majority of the annual flow for the stations under study. The low flow months (March and July to October) included minor or negligible base flow supplemented by extreme flow events, early snowmelt in March and rainfall events during the summer and fall. Due to the differing causes of the inconsistency in the data sets, some stations were identified as being anomalous with respect to one or both of these groups. Therefore, an investigation of both of these groups may be required to detect problem data sets in the region or basin.

The identification of stations whose data sets do not follow the regional norm may have some consequence for the evaluation of the hydrometric network. As has been discussed in previous sections, anomalous data may indicate metering problems, short or unusual periods of record, or basin regulation upstream of the station. On a regional or stream system basis, anomalous station data sets may indicate

subbasins which have hydrologic conditions dissimilar from the remainder of the stations being analyzed in the region. If these stations were to be used in a regional analysis for data extension or data transfer, these variations in basin conditions should be recognized and accounted for (e.g. included as additional factors in regression analysis).

Another cause for anomalous data sets may be random climatic factors which the data reviewer must take into account. This may be illustrated by considering the effects of an extreme rainfall runoff event on a stream system. If this extreme rain occurred only over a small portion of the stream system, the stations which recorded this runoff event would then have differing streamflow characteristics than those that had "missed" this event.

The identification of anomalous data sets in a network review focuses attention on specific problem areas. The data reviewer should investigate the stations that have been "flagged" to ascertain the reason for the problem station data sets. Judgement by the data reviewer will be needed to assess the effect of the anomalous data sets on flow parameters derived from the network under study.

## 3.4 REGIONAL CORRELATION ANALYSIS

Interstation correlation analysis of a hydrometric network investigates the strength of relationships between the streamflow data in a region or basin. An examination of these correlations should allow the data reviewer to identify

station data sets that are well correlated indicating "clustering" of these stations. This clustering will aid in identifying hydrologically-similar or homogeneous regions. Any anomalous station streamflow data sets should then be able to be identified from the poor correlation with the rest of the stations in the basin.

Regional correlation analysis has been conducted by several agencies on hydrometric networks. Davis and Coulson [1967] used a method developed by Langbein [1960] to identify hydrologic zones in the headwaters of the Saskatchewan River. This method correlates the logarithm of the deviations from the mean for the monthly flow data. Davis and Coulson [1967] found that seven general zones of hydrologic similarity could be identified from the correlation results, and they then provided hydrologic explanations for the observed results and groupings.

A regional hydrologic analysis of the Cypress Hills, located in southwestern Saskatchewan, was conducted by Environment Canada [1973]. This regional analysis included an assessment of the hydrometric network of the region and utilized the Langbein method in the correlation of the monthly mean flow data sets. This study used two methods to deal with the problem of incorporating zero monthly flows in the logarithmic correlation analysis. One approach assumed zero flows to be 0.004 cfs (0.0001 $m^3/s$), and the other approach excluded any monthly mean flows less than 1 cfs (0.028 $m^3/s$). The first approach yielded lower correlation

coefficient values for the majority of the station pairs considered, yet the alternative approach of excluding low flows obscures the regime modifying effects of man-made storage or flow diversion, which are greater at low flows. The results of the correlation analysis were used in determining hydrologic zones, which were then used along with management requirements for hydrologic information to develop certain hydrometric network recommendations for the Cypress Hills region.

The Manitoba hydrometric network was reviewed by Bowering and Bilozor [1972, 1977] in order to identify redundancies in the network and to determine an operation plan for the network. These studies used correlation analysis in conjunction with station classification and data use surveys to recommend changes in station operations. Certain stations in Manitoba were recommended to have their period of operation reduced where an "acceptable" regression equation for monthly flow using another station was found.

The correlation analysis conducted in this study was divided into two parts. The first part calculated Pearson and Spearman correlation coefficients for the hydrometric data of the Pembina River basin. The second part used these correlation coefficients to identify clusters between the station data sets. These statistical groupings were examined to identify anomalous stations and hydrologically homoeneous data sets.

### 3.4.1 Description of Correlation and Cluster Analysis

The interstation correlations for the Pembina River basin data sets were determined using the Pearson product-moment correlation coefficient and the Spearman rank-order correlation coefficient. These two correlation measures were then used to identify groupings in the station data sets using a cluster analysis method.

#### 3.4.1.1 Interstation Correlation

Correlation gives a measure of the strength of a linear relationship between two variables. In terms of streamflow, correlation measures the degree of similarity between the runoff production of two basins. If the correlation is high between two streams, it does not mean that flow changes in one stream will lead to changes in the other stream. The dependence in correlated streamflow variables is more stochastic in nature than a physical or cause and effect dependence.

The Pearson product-moment correlation coefficient (r) is computed from the station data sets as:

$$r = \frac{\Sigma (X - \bar{X})(Y - \bar{Y})}{\left[ \Sigma (X - \bar{X})^2 \ \Sigma (Y - \bar{Y})^2 \right]^{0.5}} \qquad (3.32)$$

Where: $\bar{X}$ is the mean value of the X station data set
$\bar{Y}$ is the mean value of the Y station data set

The Spearman rank-order correlation coefficient (rho) is a nonparametric measure of association that is calculated as the correlation of the ranks of the data. This statistic has been used previously (in another form) in the nonparametric tests for internal independence and trend (see Section 3.2.1). To calculate rho, the data for the X and Y series are ranked such that $r_i$ is the rank of the ith X value, and $s_i$ is the rank of the ith Y value. Averaged ranks are used in the case of ties. The Spearman rank-correlation is calculated as:

$$\text{rho} = \frac{\Sigma(r_i - \bar{r})(s_i - \bar{s})}{\left[\Sigma(r_i - \bar{r})^2 \quad \Sigma(s_i - \bar{s})^2\right]^{0.5}} \tag{3.33}$$

where: $\bar{r}$ is the mean of the X-ranks ($r_i$)
$\bar{s}$ is the mean of the Y-ranks ($s_i$)

These correlation coefficients were calculated using the correlation (CORR) procedure in the SAS (1982b) program. This procedure was applied to the station data sets for each data type under investigation. This resulted in two correlation matrices for each data type relating station to station. These interstation correlation matrices were then subjected to cluster analysis.

### 3.4.1.2 Cluster Analysis

A cluster analysis was used to divide the station data sets into associated groups. The McQuitty [1957] method of

linkage analysis was used in splitting each interstation correlation matrix into station groups.

The McQuitty linkage analysis method is an algorithm that uses a stored distance methodology of hierarchical clustering to identify cluster groups. This method was used by Wedel [1979] to identify groupings of hydrometric stations for small streams in Manitoba. The algorithm is best illustrated by a worked example.

Table 3.10 presents the correlation coefficient matrix for a hypothetical river basin consisting of six stations (A to F). The square metrix is split by a right diagonal consisting of ones (station data correlated with itself), and the two halves of the matrix are mirror images of each other.

The method proceeds in a step-by-step fashion:

1. Search each column and circle the highest value in each column (see Table 3.10).
2. Select the highest correlation coefficient in the matrix. The pair of stations so identified is the first reciprocal relation. In Table 3.10 this is C and E. These are the first two of the first group and are represented schematically as:

   C $\rightleftharpoons$ E

3. Read across the row for E to see if any other circled values fall in that row. Station B does fall in row

E. No other circled values fall in row C. These are known as the first relations and are represented as:

$$C \rightleftharpoons E \longrightarrow B$$

4. Examine the row for B to see if any other circled values fall in this row. Station A does fall in row B, and this is known as a second relation. Searching row A does not yield a third relation, and so the first group is represented as:

$$C \rightleftharpoons E \longrightarrow B \longrightarrow A$$

5. Excluding the correlation coefficients already used, find the next highest circled value in the matrix. This new pair, D and F, are the second reciprocal relation which make up the second group since no other stations are left unassigned.

$$D \rightleftharpoons F$$

This procedure was applied to the interstation correlation matrices for the Pembina River basin to identify groupings, reciprocal relations and simple relations.

Table 3.10

Hypothetical Basin Correlation Coefficients
to Illustrate McQuitty Procedure

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Station | A | B | C | D | E | F |
| A | 1 | 0.97 | 0.95 | 0.85 | 0.96 | 0.75 |
| B | (0.97) | 1 | 0.96 | 0.86 | 0.98 | 0.85 |
| C | 0.95 | 0.96 | 1 | 0.89 | (0.99) | 0.82 |
| D | 0.85 | 0.86 | 0.89 | 1 | 0.87 | (0.90) |
| E | 0.96 | (0.98) | (0.99) | 0.87 | 1 | 0.85 |
| F | 0.75 | 0.85 | 0.82 | (0.90) | 0.85 | 1 |

### 3.4.2 Data Investigated

Interstation correlation matrices were calculated for the period mean flows, the daily mean peak flows and each of the monthly mean flows for the open-water months March to October. The correlation analysis covered the period 1957 to 1980, and each interstation correlation spanned the period of concurrent record.

The period mean flows were investigated rather than the estimated annual mean flows because it has been shown by Davis and Coulson [1967] that the relationships between stations are not significantly affected by correlating mixed records (open-water and continuous periods) as the interstation correlation measured the relative relationship between stations. This would be especially true for the

nonparametric Spearman correlation, which correlates the ranks of the data sets.

### 3.4.3 Results of Correlation and Cluster Analysis

The Pearson and Spearman correlation matrices for the period mean flows are presented in Tables 3.11 and 3.12, respectively. In addition to the Pearson and Spearman correlation coefficients, these matrices include the number of concurrent observations used in the correlation analysis (n) and the probability that the calculated correlation (r or rho) is actually zero. This probability is calculated by treating the value Pz as coming from a two-tailed Student's t distribution with n-2 degrees of freedom, where Pz is calculated as:

$$Pz = (n-2)^{0.5} \, r/(1-r^2)^{0.5} \qquad (3.34)$$

where: r is the appropriate correlation coefficient

This probability becomes significantly large (> 10%) only for small r or rho values or for small sample sizes.

The Pearson and Spearman correlation matrices for the daily mean peak flows and the monthly mean flows are presented in Appendix C, Tables C-1 to C-18.

# Table 3.11

## Pearson Correlation Coefficients* for Pembina River Basin Period Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.84192<br>0.0001<br>19 | 0.95089<br>0.0001<br>10 | 0.84350<br>0.0001<br>19 | 0.82389<br>0.0001<br>19 | 0.79980<br>0.0006<br>14 | 0.78673<br>0.0069<br>10 | 0.91868<br>0.0001<br>15 | 0.82071<br>0.0001<br>18 | 0.93616<br>0.0001<br>19 | 0.87663<br>0.0043<br>8 | 0.80566<br>0.0001<br>19 | 0.70705<br>0.0022<br>16 | 0.87175<br>0.0001<br>19 | 0.91351<br>0.0002<br>10 | 0.77903<br>0.0001<br>19 | 0.93857<br>0.0001<br>18 | 0.86729<br>0.0001<br>18 | 0.79187<br>0.0001<br>19 | 0.92305<br>0.0001<br>19 |
| 050A006 | 0.84192<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.82366<br>0.0034<br>10 | 0.96328<br>0.0001<br>22 | 0.94326<br>0.0001<br>19 | 0.93940<br>0.0001<br>14 | 0.97600<br>0.0001<br>10 | 0.89939<br>0.0001<br>15 | 0.83674<br>0.0001<br>21 | 0.87719<br>0.0001<br>19 | 0.93854<br>0.0001<br>11 | 0.79679<br>0.0001<br>22 | 0.74350<br>0.0004<br>18 | 0.73497<br>0.0002<br>20 | 0.92310<br>0.0001<br>10 | 0.63926<br>0.0032<br>19 | 0.90873<br>0.0001<br>18 | 0.82327<br>0.0001<br>18 | 0.69888<br>0.0009<br>19 | 0.86258<br>0.0001<br>22 |
| 050A007 | 0.95089<br>0.0001<br>10 | 0.82366<br>0.0034<br>10 | 1.00000<br>0.0000<br>10 | 0.75237<br>0.0120<br>10 | 0.70703<br>0.0222<br>10 | 0.56013<br>0.2477<br>6 | 0.74380<br>0.0901<br>6 | 0.95995<br>0.0006<br>7 | 0.89403<br>0.0005<br>10 | 0.98953<br>0.0001<br>10 | <br><br>0 | 0.95936<br>0.0001<br>10 | 0.76178<br>0.0466<br>7 | 0.95420<br>0.0001<br>10 | 0.00000<br><br>1 | 0.93427<br>0.0001<br>10 | 0.96980<br>0.0001<br>10 | 0.94401<br>0.0001<br>10 | 0.97934<br>0.0001<br>10 | 0.98644<br>0.0001<br>10 |
| 050A008 | 0.84350<br>0.0001<br>19 | 0.96328<br>0.0001<br>22 | 0.75237<br>0.0120<br>10 | 1.00000<br>0.0000<br>22 | 0.98676<br>0.0001<br>19 | 0.98458<br>0.0001<br>14 | 0.94559<br>0.0001<br>10 | 0.84824<br>0.0001<br>15 | 0.77156<br>0.0001<br>21 | 0.81881<br>0.0001<br>19 | 0.94229<br>0.0001<br>11 | 0.68457<br>0.0004<br>22 | 0.68244<br>0.0018<br>18 | 0.67537<br>0.0011<br>20 | 0.89635<br>0.0004<br>10 | 0.55486<br>0.0137<br>19 | 0.87565<br>0.0001<br>18 | 0.78195<br>0.0001<br>18 | 0.62265<br>0.0044<br>19 | 0.80380<br>0.0001<br>22 |
| 050A010 | 0.82389<br>0.0001<br>19 | 0.94326<br>0.0001<br>19 | 0.70703<br>0.0222<br>10 | 0.98676<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.97807<br>0.0001<br>14 | 0.93444<br>0.0001<br>10 | 0.82358<br>0.0002<br>15 | 0.76288<br>0.0002<br>18 | 0.78310<br>0.0001<br>19 | 0.87906<br>0.0040<br>8 | 0.62956<br>0.0039<br>19 | 0.66179<br>0.0052<br>16 | 0.61012<br>0.0055<br>19 | 0.84057<br>0.0023<br>10 | 0.50693<br>0.0267<br>19 | 0.85089<br>0.0001<br>18 | 0.74647<br>0.0004<br>18 | 0.58983<br>0.0079<br>19 | 0.74918<br>0.0002<br>19 |
| 050A012 | 0.79980<br>0.0006<br>14 | 0.93940<br>0.0001<br>14 | 0.56013<br>0.2477<br>6 | 0.98458<br>0.0001<br>14 | 0.97807<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.95677<br>0.0001<br>10 | 0.84632<br>0.0001<br>14 | 0.74333<br>0.0036<br>13 | 0.76291<br>0.0015<br>14 | 0.94676<br>0.0012<br>7 | 0.81372<br>0.0602<br>14 | 0.65509<br>0.0110<br>14 | 0.60876<br>0.0206<br>14 | 0.85923<br>0.0030<br>9 | 0.46783<br>0.0916<br>14 | 0.84694<br>0.0001<br>14 | 0.75597<br>0.0018<br>14 | 0.53204<br>0.0502<br>14 | 0.71855<br>0.0037<br>14 |
| 050A013 | 0.78673<br>0.0069<br>10 | 0.97600<br>0.0001<br>10 | 0.74380<br>0.0901<br>6 | 0.94559<br>0.0001<br>10 | 0.93444<br>0.0001<br>10 | 0.95677<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.89312<br>0.0005<br>10 | 0.84756<br>0.0020<br>10 | 0.82593<br>0.0032<br>10 | 0.99993<br>0.0076<br>3 | 0.64375<br>0.0446<br>10 | 0.65813<br>0.0386<br>10 | 0.69076<br>0.0270<br>10 | 0.99270<br>0.0007<br>5 | 0.54786<br>0.1011<br>10 | 0.89235<br>0.0005<br>10 | 0.77513<br>0.0084<br>10 | 0.59972<br>0.0669<br>10 | 0.77871<br>0.0080<br>10 |
| 050B001 | 0.91868<br>0.0001<br>15 | 0.89939<br>0.0001<br>15 | 0.95995<br>0.0006<br>7 | 0.84824<br>0.0001<br>15 | 0.82358<br>0.0002<br>15 | 0.84632<br>0.0001<br>14 | 0.89312<br>0.0005<br>10 | 1.00000<br>0.0000<br>15 | 0.93123<br>0.0001<br>14 | 0.97996<br>0.0001<br>15 | 0.98971<br>0.0001<br>7 | 0.80506<br>0.0003<br>15 | 0.83087<br>0.0001<br>15 | 0.90012<br>0.0001<br>15 | 0.99332<br>0.0001<br>9 | 0.78152<br>0.0006<br>15 | 0.99326<br>0.0001<br>15 | 0.95250<br>0.0001<br>15 | 0.84380<br>0.0001<br>15 | 0.95903<br>0.0001<br>15 |
| 050B006 | 0.82071<br>0.0001<br>18 | 0.83674<br>0.0001<br>21 | 0.89403<br>0.0005<br>10 | 0.77156<br>0.0001<br>21 | 0.76288<br>0.0002<br>18 | 0.74333<br>0.0036<br>13 | 0.84756<br>0.0020<br>10 | 0.93123<br>0.0001<br>14 | 1.00000<br>0.0000<br>21 | 0.92265<br>0.0001<br>18 | 0.78470<br>0.0072<br>10 | 0.85650<br>0.0001<br>21 | 0.86419<br>0.0001<br>17 | 0.85878<br>0.0001<br>19 | 0.80926<br>0.0082<br>9 | 0.80215<br>0.0001<br>18 | 0.91417<br>0.0001<br>17 | 0.91103<br>0.0001<br>17 | 0.83872<br>0.0001<br>18 | 0.90896<br>0.0001<br>21 |
| 050B007 | 0.93616<br>0.0001<br>19 | 0.87719<br>0.0001<br>19 | 0.98953<br>0.0001<br>10 | 0.81881<br>0.0001<br>19 | 0.78310<br>0.0001<br>19 | 0.76291<br>0.0015<br>14 | 0.82593<br>0.0032<br>10 | 0.97996<br>0.0001<br>15 | 0.92265<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.99925<br>0.0001<br>8 | 0.89432<br>0.0001<br>19 | 0.83652<br>0.0001<br>16 | 0.93225<br>0.0001<br>19 | 0.95823<br>0.0001<br>10 | 0.86160<br>0.0001<br>19 | 0.98257<br>0.0001<br>18 | 0.94893<br>0.0001<br>18 | 0.89071<br>0.0001<br>19 | 0.99339<br>0.0001<br>19 |
| 050B008 | 0.87663<br>0.0043<br>8 | 0.93854<br>0.0001<br>11 | <br><br>0 | 0.94229<br>0.0001<br>11 | 0.87906<br>0.0040<br>8 | 0.94676<br>0.0012<br>7 | 0.99993<br>0.0076<br>3 | 0.98971<br>0.0001<br>7 | 0.78470<br>0.0072<br>10 | 0.99925<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.65744<br>0.0279<br>11 | 0.93467<br>0.0001<br>10 | 0.90037<br>0.0009<br>9 | 0.97534<br>0.0001<br>8 | 0.56510<br>0.1444<br>8 | 0.98197<br>0.0001<br>7 | 0.98610<br>0.0001<br>7 | 0.79689<br>0.0179<br>8 | 0.98548<br>0.0001<br>12 |
| 050B010 | 0.80566<br>0.0001<br>19 | 0.79679<br>0.0001<br>22 | 0.95936<br>0.0001<br>10 | 0.68457<br>0.0004<br>22 | 0.62956<br>0.0039<br>19 | 0.51372<br>0.0602<br>14 | 0.64375<br>0.0446<br>10 | 0.80506<br>0.0003<br>15 | 0.85650<br>0.0001<br>21 | 0.89432<br>0.0001<br>19 | 0.65744<br>0.0279<br>11 | 1.00000<br>0.0000<br>22 | 0.69648<br>0.0013<br>18 | 0.86787<br>0.0001<br>20 | 0.59202<br>0.0714<br>10 | 0.81389<br>0.0001<br>19 | 0.85032<br>0.0001<br>18 | 0.74880<br>0.0003<br>18 | 0.86591<br>0.0001<br>19 | 0.90915<br>0.0001<br>22 |
| 050B013 | 0.70705<br>0.0022<br>16 | 0.74350<br>0.0004<br>18 | 0.76178<br>0.0466<br>7 | 0.68244<br>0.0018<br>18 | 0.66179<br>0.0052<br>16 | 0.65509<br>0.0110<br>14 | 0.65813<br>0.0386<br>10 | 0.83087<br>0.0001<br>15 | 0.86419<br>0.0001<br>17 | 0.83652<br>0.0001<br>16 | 0.93467<br>0.0001<br>10 | 0.69648<br>0.0013<br>18 | 1.00000<br>0.0000<br>18 | 0.75708<br>0.0004<br>17 | 0.70846<br>0.0218<br>10 | 0.73289<br>0.0012<br>16 | 0.82512<br>0.0002<br>15 | 0.86755<br>0.0001<br>15 | 0.82957<br>0.0001<br>16 | 0.87175<br>0.0001<br>18 |
| 050B016 | 0.87175<br>0.0001<br>19 | 0.73497<br>0.0002<br>20 | 0.95420<br>0.0001<br>10 | 0.67537<br>0.0011<br>20 | 0.61012<br>0.0055<br>19 | 0.60976<br>0.0206<br>14 | 0.69076<br>0.0270<br>10 | 0.90012<br>0.0001<br>15 | 0.85878<br>0.0001<br>19 | 0.93225<br>0.0001<br>19 | 0.90037<br>0.0009<br>9 | 0.86787<br>0.0001<br>20 | 0.75708<br>0.0004<br>17 | 1.00000<br>0.0000<br>20 | 0.81591<br>0.0040<br>10 | 0.94730<br>0.0001<br>19 | 0.86363<br>0.0001<br>18 | 0.87129<br>0.0001<br>18 | 0.80559<br>0.0001<br>19 | 0.94074<br>0.0001<br>20 |
| 050B019 | 0.91351<br>0.0002<br>10 | 0.92310<br>0.0001<br>10 | 0.00000<br><br>1 | 0.89635<br>0.0004<br>10 | 0.84057<br>0.0023<br>10 | 0.85923<br>0.0030<br>9 | 0.99270<br>0.0007<br>5 | 0.99332<br>0.0001<br>9 | 0.80926<br>0.0082<br>9 | 0.95823<br>0.0001<br>10 | 0.97534<br>0.0001<br>8 | 0.59202<br>0.0714<br>10 | 0.70846<br>0.0218<br>10 | 0.81591<br>0.0040<br>10 | 1.00000<br>0.0000<br>10 | 0.57354<br>0.0830<br>10 | 0.99391<br>0.0001<br>9 | 0.95766<br>0.0001<br>9 | 0.80205<br>0.0052<br>10 | 0.91823<br>0.0002<br>10 |
| 050B021 | 0.77903<br>0.0001<br>19 | 0.63926<br>0.0032<br>19 | 0.93427<br>0.0001<br>10 | 0.55486<br>0.0137<br>19 | 0.50693<br>0.0267<br>19 | 0.46783<br>0.0916<br>14 | 0.54786<br>0.1011<br>10 | 0.78152<br>0.0006<br>15 | 0.80215<br>0.0001<br>18 | 0.86160<br>0.0001<br>19 | 0.56510<br>0.1444<br>8 | 0.81389<br>0.0001<br>19 | 0.73289<br>0.0012<br>16 | 0.94730<br>0.0001<br>19 | 0.57354<br>0.0830<br>10 | 1.00000<br>0.0000<br>19 | 0.76660<br>0.0002<br>18 | 0.79825<br>0.0001<br>18 | 0.78575<br>0.0001<br>19 | 0.89590<br>0.0001<br>19 |
| 050B023 | 0.93857<br>0.0001<br>18 | 0.90873<br>0.0001<br>18 | 0.96980<br>0.0001<br>10 | 0.87565<br>0.0001<br>18 | 0.85089<br>0.0001<br>18 | 0.84694<br>0.0001<br>14 | 0.89235<br>0.0005<br>10 | 0.99326<br>0.0001<br>15 | 0.91417<br>0.0001<br>17 | 0.98257<br>0.0001<br>18 | 0.98197<br>0.0001<br>7 | 0.85032<br>0.0001<br>18 | 0.82512<br>0.0002<br>15 | 0.86363<br>0.0001<br>18 | 0.99391<br>0.0001<br>9 | 0.76660<br>0.0002<br>18 | 1.00000<br>0.0000<br>18 | 0.94370<br>0.0001<br>18 | 0.87127<br>0.0001<br>18 | 0.96322<br>0.0001<br>18 |
| 050B025 | 0.86729<br>0.0001<br>18 | 0.82327<br>0.0001<br>18 | 0.94401<br>0.0001<br>10 | 0.78195<br>0.0001<br>18 | 0.74647<br>0.0004<br>18 | 0.75597<br>0.0018<br>14 | 0.77513<br>0.0084<br>10 | 0.95250<br>0.0001<br>15 | 0.91103<br>0.0001<br>17 | 0.94893<br>0.0001<br>18 | 0.98610<br>0.0001<br>7 | 0.74880<br>0.0003<br>18 | 0.86755<br>0.0001<br>15 | 0.87129<br>0.0001<br>18 | 0.95766<br>0.0001<br>9 | 0.79825<br>0.0001<br>18 | 0.94370<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.84412<br>0.0001<br>18 | 0.93525<br>0.0001<br>18 |
| 050B031 | 0.79187<br>0.0001<br>19 | 0.69888<br>0.0009<br>19 | 0.97934<br>0.0001<br>10 | 0.62265<br>0.0044<br>19 | 0.58983<br>0.0079<br>19 | 0.53204<br>0.0502<br>14 | 0.59972<br>0.0669<br>10 | 0.84380<br>0.0001<br>15 | 0.83872<br>0.0001<br>18 | 0.89071<br>0.0001<br>19 | 0.79689<br>0.0179<br>8 | 0.86591<br>0.0001<br>19 | 0.82957<br>0.0001<br>16 | 0.80559<br>0.0001<br>19 | 0.80205<br>0.0052<br>10 | 0.78575<br>0.0001<br>19 | 0.87127<br>0.0001<br>18 | 0.84412<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.91416<br>0.0001<br>19 |
| 050C004 | 0.92305<br>0.0001<br>19 | 0.86258<br>0.0001<br>22 | 0.98644<br>0.0001<br>10 | 0.80380<br>0.0001<br>22 | 0.74918<br>0.0002<br>19 | 0.71955<br>0.0037<br>14 | 0.77871<br>0.0080<br>10 | 0.95903<br>0.0001<br>15 | 0.90896<br>0.0001<br>21 | 0.99339<br>0.0001<br>19 | 0.98548<br>0.0001<br>12 | 0.90915<br>0.0001<br>22 | 0.87175<br>0.0001<br>18 | 0.94074<br>0.0001<br>20 | 0.91823<br>0.0002<br>10 | 0.89590<br>0.0001<br>19 | 0.96322<br>0.0001<br>18 | 0.93525<br>0.0001<br>18 | 0.91416<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table 3.12

## Spearman Correlation Coefficients* for Pembina River Basin Period Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.80526<br>0.0001<br>19 | 0.95152<br>0.0001<br>10 | 0.81404<br>0.0001<br>19 | 0.79596<br>0.0001<br>19 | 0.77582<br>0.0011<br>14 | 0.72121<br>0.0186<br>10 | 0.90714<br>0.0001<br>15 | 0.74819<br>0.0004<br>18 | 0.90877<br>0.0001<br>19 | 0.76190<br>0.0280<br>8 | 0.68596<br>0.0012<br>19 | 0.65294<br>0.0061<br>16 | 0.85263<br>0.0001<br>19 | 0.90303<br>0.0003<br>10 | 0.69825<br>0.0009<br>19 | 0.93808<br>0.0001<br>18 | 0.86378<br>0.0001<br>18 | 0.62571<br>0.0042<br>19 | 0.88772<br>0.0001<br>19 |
| 050A006 | 0.80526<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.75758<br>0.0111<br>10 | 0.94466<br>0.0001<br>22 | 0.92497<br>0.0001<br>19 | 0.92527<br>0.0001<br>14 | 0.92727<br>0.0001<br>10 | 0.88571<br>0.0001<br>15 | 0.78571<br>0.0001<br>21 | 0.86140<br>0.0001<br>19 | 0.83636<br>0.0013<br>11 | 0.82835<br>0.0001<br>22 | 0.70691<br>0.0010<br>18 | 0.75291<br>0.0001<br>20 | 0.79394<br>0.0061<br>10 | 0.60000<br>0.0066<br>19 | 0.88854<br>0.0001<br>18 | 0.78122<br>0.0001<br>18 | 0.68188<br>0.0013<br>19 | 0.88029<br>0.0001<br>22 |
| 050A007 | 0.95152<br>0.0001<br>10 | 0.75758<br>0.0111<br>10 | 1.00000<br>0.0000<br>10 | 0.76970<br>0.0092<br>10 | 0.78420<br>0.0072<br>10 | 0.65714<br>0.1562<br>6 | 0.60000<br>0.2080<br>6 | 0.92857<br>0.0025<br>7 | 0.87879<br>0.0008<br>10 | 0.97576<br>0.0001<br>10 | 0 | 0.96364<br>0.0001<br>10 | 0.64286<br>0.1194<br>7 | 0.96364<br>0.0001<br>10 | 0.00000<br>1 | 0.91515<br>0.0002<br>10 | 0.95152<br>0.0001<br>10 | 0.97576<br>0.0001<br>10 | 0.93010<br>0.0001<br>10 | 0.97576<br>0.0001<br>10 |
| 050A008 | 0.81404<br>0.0001<br>19 | 0.94466<br>0.0001<br>22 | 0.76970<br>0.0092<br>10 | 1.00000<br>0.0000<br>22 | 0.96358<br>0.0001<br>19 | 0.97363<br>0.0001<br>14 | 0.90303<br>0.0003<br>10 | 0.83929<br>0.0001<br>15 | 0.69610<br>0.0005<br>21 | 0.81053<br>0.0001<br>19 | 0.73636<br>0.0098<br>11 | 0.72106<br>0.0002<br>22 | 0.69040<br>0.0015<br>18 | 0.66642<br>0.0013<br>20 | 0.86667<br>0.0012<br>10 | 0.52456<br>0.0211<br>19 | 0.86171<br>0.0001<br>18 | 0.72343<br>0.0007<br>18 | 0.56253<br>0.0122<br>19 | 0.83173<br>0.0001<br>22 |
| 050A010 | 0.79596<br>0.0001<br>19 | 0.92497<br>0.0001<br>19 | 0.78420<br>0.0072<br>10 | 0.96358<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.93407<br>0.0001<br>14 | 0.90303<br>0.0003<br>10 | 0.82500<br>0.0002<br>15 | 0.72690<br>0.0006<br>18 | 0.78631<br>0.0001<br>19 | 0.52381<br>0.1827<br>8 | 0.68363<br>0.0013<br>19 | 0.66471<br>0.0050<br>16 | 0.61957<br>0.0047<br>19 | 0.74545<br>0.0133<br>10 | 0.51953<br>0.0226<br>19 | 0.85803<br>0.0001<br>18 | 0.72380<br>0.0007<br>18 | 0.54873<br>0.0150<br>19 | 0.78894<br>0.0001<br>19 |
| 050A012 | 0.77582<br>0.0011<br>14 | 0.92527<br>0.0001<br>14 | 0.65714<br>0.1562<br>6 | 0.97363<br>0.0001<br>14 | 0.93407<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.97576<br>0.0001<br>10 | 0.81978<br>0.0003<br>14 | 0.70330<br>0.0073<br>13 | 0.76264<br>0.0015<br>14 | 0.67857<br>0.0938<br>7 | 0.60440<br>0.0221<br>14 | 0.64835<br>0.0121<br>14 | 0.56484<br>0.0353<br>14 | 0.80000<br>0.0096<br>9 | 0.46813<br>0.0914<br>14 | 0.81538<br>0.0004<br>14 | 0.62198<br>0.0176<br>14 | 0.51648<br>0.0586<br>14 | 0.74066<br>0.0024<br>14 |
| 050A013 | 0.72121<br>0.0186<br>10 | 0.92727<br>0.0001<br>10 | 0.60000<br>0.2080<br>6 | 0.90303<br>0.0003<br>10 | 0.90303<br>0.0003<br>10 | 0.97576<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.84242<br>0.0022<br>10 | 0.81818<br>0.0038<br>10 | 0.74545<br>0.0133<br>10 | 1.00000<br>0.0000<br>3 | 0.60000<br>0.0667<br>10 | 0.63636<br>0.0479<br>10 | 0.57576<br>0.0816<br>10 | 0.90000<br>0.0374<br>5 | 0.40606<br>0.2443<br>10 | 0.78182<br>0.0075<br>10 | 0.68485<br>0.0289<br>10 | 0.60000<br>0.0667<br>10 | 0.70909<br>0.0217<br>10 |
| 050B001 | 0.90714<br>0.0001<br>15 | 0.88571<br>0.0001<br>15 | 0.92857<br>0.0025<br>7 | 0.83929<br>0.0001<br>15 | 0.82500<br>0.0002<br>15 | 0.81978<br>0.0003<br>14 | 0.84242<br>0.0022<br>10 | 1.00000<br>0.0000<br>15 | 0.93846<br>0.0001<br>14 | 0.98214<br>0.0001<br>15 | 0.96429<br>0.0005<br>7 | 0.84286<br>0.0001<br>15 | 0.85000<br>0.0001<br>15 | 0.91429<br>0.0001<br>15 | 0.88333<br>0.0016<br>9 | 0.76786<br>0.0008<br>15 | 0.98929<br>0.0001<br>15 | 0.94643<br>0.0001<br>15 | 0.79286<br>0.0004<br>15 | 0.97500<br>0.0001<br>15 |
| 050B006 | 0.74819<br>0.0004<br>18 | 0.78571<br>0.0001<br>21 | 0.87879<br>0.0008<br>10 | 0.69610<br>0.0005<br>21 | 0.72690<br>0.0006<br>18 | 0.70330<br>0.0073<br>13 | 0.81818<br>0.0038<br>10 | 0.93846<br>0.0001<br>14 | 1.00000<br>0.0000<br>21 | 0.88442<br>0.0001<br>18 | 0.58788<br>0.0739<br>10 | 0.85844<br>0.0001<br>21 | 0.87010<br>0.0001<br>17 | 0.83860<br>0.0001<br>19 | 0.56667<br>0.1116<br>9 | 0.76471<br>0.0002<br>18 | 0.88480<br>0.0001<br>17 | 0.93382<br>0.0001<br>17 | 0.85493<br>0.0001<br>18 | 0.88783<br>0.0001<br>21 |
| 050B007 | 0.90877<br>0.0001<br>19 | 0.86140<br>0.0001<br>19 | 0.97576<br>0.0001<br>10 | 0.81053<br>0.0001<br>19 | 0.78631<br>0.0001<br>19 | 0.76264<br>0.0015<br>14 | 0.74545<br>0.0133<br>10 | 0.98214<br>0.0001<br>15 | 0.88442<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 1.00000<br>0.0000<br>8 | 0.85088<br>0.0001<br>19 | 0.83235<br>0.0001<br>16 | 0.94035<br>0.0001<br>19 | 0.85455<br>0.0016<br>10 | 0.82982<br>0.0001<br>19 | 0.97317<br>0.0001<br>18 | 0.97317<br>0.0001<br>18 | 0.82405<br>0.0001<br>19 | 0.98772<br>0.0001<br>19 |
| 050B008 | 0.76190<br>0.0280<br>8 | 0.83636<br>0.0013<br>11 | .<br>0 | 0.73636<br>0.0098<br>11 | 0.52381<br>0.1827<br>8 | 0.67857<br>0.0938<br>7 | 1.00000<br>0.0000<br>3 | 0.96429<br>0.0005<br>7 | 0.58788<br>0.0739<br>10 | 1.00000<br>0.0000<br>8 | 1.00000<br>0.0000<br>12 | 0.70909<br>0.0146<br>11 | 0.87879<br>0.0008<br>10 | 0.92051<br>0.0004<br>9 | 0.71429<br>0.0465<br>8 | 0.69048<br>0.0580<br>8 | 0.92857<br>0.0025<br>7 | 0.82143<br>0.0234<br>7 | 0.28571<br>0.4927<br>8 | 0.99301<br>0.0001<br>12 |
| 050B010 | 0.68596<br>0.0012<br>19 | 0.82835<br>0.0001<br>22 | 0.96364<br>0.0001<br>10 | 0.72106<br>0.0002<br>22 | 0.68363<br>0.0013<br>19 | 0.60440<br>0.0221<br>14 | 0.60000<br>0.0667<br>10 | 0.84286<br>0.0001<br>15 | 0.85844<br>0.0001<br>21 | 0.85088<br>0.0001<br>19 | 0.70909<br>0.0146<br>11 | 1.00000<br>0.0000<br>22 | 0.72549<br>0.0007<br>18 | 0.80406<br>0.0001<br>20 | 0.44242<br>0.2004<br>10 | 0.74386<br>0.0003<br>19 | 0.85965<br>0.0001<br>18 | 0.84314<br>0.0001<br>18 | 0.84515<br>0.0001<br>19 | 0.91417<br>0.0001<br>22 |
| 050B013 | 0.65294<br>0.0061<br>16 | 0.70691<br>0.0010<br>18 | 0.64286<br>0.1194<br>7 | 0.69040<br>0.0015<br>18 | 0.66471<br>0.0050<br>16 | 0.64835<br>0.0121<br>14 | 0.63636<br>0.0479<br>10 | 0.85000<br>0.0001<br>15 | 0.87010<br>0.0001<br>17 | 0.83235<br>0.0001<br>16 | 0.87879<br>0.0008<br>10 | 0.72549<br>0.0007<br>18 | 1.00000<br>0.0000<br>18 | 0.80809<br>0.0001<br>17 | 0.52727<br>0.1173<br>10 | 0.73235<br>0.0013<br>16 | 0.83214<br>0.0001<br>15 | 0.90000<br>0.0001<br>15 | 0.68235<br>0.0036<br>16 | 0.85552<br>0.0001<br>18 |
| 050B016 | 0.85263<br>0.0001<br>19 | 0.75291<br>0.0001<br>20 | 0.96364<br>0.0001<br>10 | 0.66642<br>0.0013<br>20 | 0.61957<br>0.0047<br>19 | 0.56484<br>0.0353<br>14 | 0.57576<br>0.0816<br>10 | 0.91429<br>0.0001<br>15 | 0.83860<br>0.0001<br>19 | 0.94035<br>0.0001<br>19 | 0.92051<br>0.0004<br>9 | 0.80406<br>0.0001<br>20 | 0.80809<br>0.0001<br>17 | 1.00000<br>0.0000<br>20 | 0.78182<br>0.0075<br>10 | 0.92456<br>0.0001<br>19 | 0.88029<br>0.0001<br>18 | 0.94427<br>0.0001<br>18 | 0.77315<br>0.0001<br>19 | 0.93343<br>0.0001<br>20 |
| 050B019 | 0.90303<br>0.0003<br>10 | 0.79394<br>0.0061<br>10 | 0.00000<br>1 | 0.86667<br>0.0012<br>10 | 0.74545<br>0.0133<br>10 | 0.80000<br>0.0096<br>9 | 0.90000<br>0.0374<br>5 | 0.88333<br>0.0016<br>9 | 0.56667<br>0.1116<br>9 | 0.85455<br>0.0016<br>10 | 0.71429<br>0.0465<br>8 | 0.44242<br>0.2004<br>10 | 0.52727<br>0.1173<br>10 | 0.78182<br>0.0075<br>10 | 1.00000<br>0.0000<br>10 | 0.60000<br>0.0667<br>10 | 0.90000<br>0.0009<br>9 | 0.81667<br>0.0072<br>9 | 0.44242<br>0.2004<br>10 | 0.81818<br>0.0038<br>10 |
| 050B021 | 0.69825<br>0.0009<br>19 | 0.60000<br>0.0066<br>19 | 0.91515<br>0.0002<br>10 | 0.52456<br>0.0211<br>19 | 0.51953<br>0.0226<br>19 | 0.46813<br>0.0914<br>14 | 0.40606<br>0.2443<br>10 | 0.76786<br>0.0008<br>15 | 0.76471<br>0.0002<br>18 | 0.82982<br>0.0001<br>19 | 0.69048<br>0.0580<br>8 | 0.74386<br>0.0003<br>19 | 0.73235<br>0.0013<br>16 | 0.92456<br>0.0001<br>19 | 0.60000<br>0.0667<br>10 | 1.00000<br>0.0000<br>19 | 0.74200<br>0.0004<br>18 | 0.82043<br>0.0001<br>18 | 0.74594<br>0.0002<br>19 | 0.86491<br>0.0001<br>19 |
| 050B023 | 0.93808<br>0.0001<br>18 | 0.88854<br>0.0001<br>18 | 0.95152<br>0.0001<br>10 | 0.86171<br>0.0001<br>18 | 0.85803<br>0.0001<br>18 | 0.81538<br>0.0004<br>14 | 0.78182<br>0.0075<br>10 | 0.98929<br>0.0001<br>15 | 0.88480<br>0.0001<br>17 | 0.97317<br>0.0001<br>18 | 0.92857<br>0.0025<br>7 | 0.85965<br>0.0001<br>18 | 0.83214<br>0.0001<br>15 | 0.88029<br>0.0001<br>18 | 0.90000<br>0.0009<br>9 | 0.74200<br>0.0004<br>18 | 1.00000<br>0.0000<br>18 | 0.94014<br>0.0001<br>18 | 0.82808<br>0.0001<br>18 | 0.96698<br>0.0001<br>18 |
| 050B025 | 0.86378<br>0.0001<br>18 | 0.78122<br>0.0001<br>18 | 0.97576<br>0.0001<br>10 | 0.72343<br>0.0007<br>18 | 0.72380<br>0.0007<br>18 | 0.62198<br>0.0176<br>14 | 0.68485<br>0.0289<br>10 | 0.94643<br>0.0001<br>15 | 0.93382<br>0.0001<br>17 | 0.97317<br>0.0001<br>18 | 0.82143<br>0.0234<br>7 | 0.84314<br>0.0001<br>18 | 0.90000<br>0.0001<br>15 | 0.94427<br>0.0001<br>18 | 0.81667<br>0.0072<br>9 | 0.82043<br>0.0001<br>18 | 0.94014<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.83738<br>0.0001<br>18 | 0.95666<br>0.0001<br>18 |
| 050B031 | 0.62571<br>0.0042<br>19 | 0.68188<br>0.0013<br>19 | 0.93010<br>0.0001<br>10 | 0.56253<br>0.0122<br>19 | 0.54873<br>0.0150<br>19 | 0.51648<br>0.0586<br>14 | 0.60000<br>0.0667<br>10 | 0.79286<br>0.0004<br>15 | 0.85493<br>0.0001<br>18 | 0.82405<br>0.0001<br>19 | 0.28571<br>0.4927<br>8 | 0.94515<br>0.0001<br>19 | 0.68235<br>0.0036<br>16 | 0.77315<br>0.0001<br>19 | 0.44242<br>0.2004<br>10 | 0.74594<br>0.0002<br>19 | 0.82808<br>0.0001<br>18 | 0.83738<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.84511<br>0.0001<br>19 |
| 050C004 | 0.88772<br>0.0001<br>19 | 0.88029<br>0.0001<br>22 | 0.97576<br>0.0001<br>10 | 0.83173<br>0.0001<br>22 | 0.78894<br>0.0001<br>19 | 0.74066<br>0.0024<br>14 | 0.70909<br>0.0217<br>10 | 0.97500<br>0.0001<br>15 | 0.88783<br>0.0001<br>21 | 0.98772<br>0.0001<br>19 | 0.99301<br>0.0001<br>12 | 0.91417<br>0.0001<br>22 | 0.85552<br>0.0001<br>18 | 0.93343<br>0.0001<br>20 | 0.81818<br>0.0038<br>10 | 0.86491<br>0.0001<br>19 | 0.96698<br>0.0001<br>18 | 0.95666<br>0.0001<br>18 | 0.84511<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

The interstation correlation analysis included every station in the Pembina River basin regardless of the years of concurrent record (pairwise default method). The overlapping period of record for certain stations was quite low (less than ten years) or nonexistent. It was recognized that using a pairwise or missing correlation method may lead to statistical difficulties; however, the application of the McQuitty algorithm for cluster analysis is flexible enough to accommodate these correlations.

The McQuitty cluster analysis was conducted on the interstation correlation matrices with the condition that at least ten years of concurrent record were required for a correlation to be included in the cluster analysis. This limited the number of pairs of stations included in the cluster analysis, but this limitation makes sense in hydrological terms since any use of these grouping must recognize the number of years which were considered. An example is the Pearson correlation between station 05OA013 and 05OB008 found in Table 3.11. The r value is 0.99993 but is based on only three concurrent years. This extremely high r value suggests that there is a substantial relationship between the period mean flows for the two stations. However, with such a small overlap in the number of years, this knowledge is of little help since any extension technique or data transfer technique could not be used with any confidence based on such a short overlapping period.

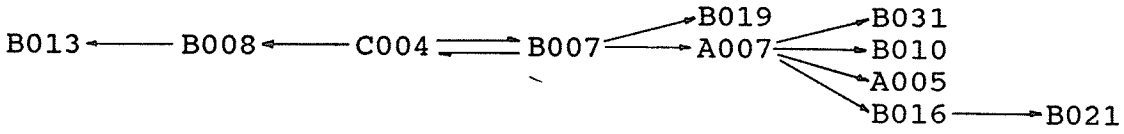
The results of the McQuitty cluster analysis for the period mean flows are presented in Figures 3.3 and 3.4. The results of the cluster analysis for the daily peaks and monthly mean flows are presented in Appendix C, Figures C-1 to C-18.

### 3.4.4 Discussion of the Correlation Analysis

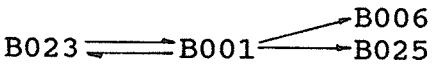
An examination of the interstation correlation matrices indicated that the parametric Pearson and nonparametric Spearman coefficients gave the same relative measures of correlation. The correlation matrices also showed that the correlations were stronger for the period mean flows and the monthly mean flows of the high flow months (April, May and June) than for the daily peak flows and the monthly mean flows of the low flow months (March and July to October). This phenomenon was noted previously when comparing the strengths of the linear relationships between the sample statistics and drainage area.

The results of cluster analyses on the interstation correlation matrices suggested that the groupings based on the Pearson correlation coefficients were generally the same as those based on the Spearman correlation coefficients. It was found that the groupings were reasonable in a hydrologic sense. For example, stations on the same tributary being grouped together, adjacent stations being grouped together, stations from the same general area being related. The cluster analysis did not identify anomalous stations.

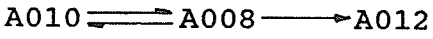
First Group




Second Group




Third Group




Fourth Group

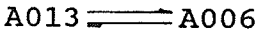
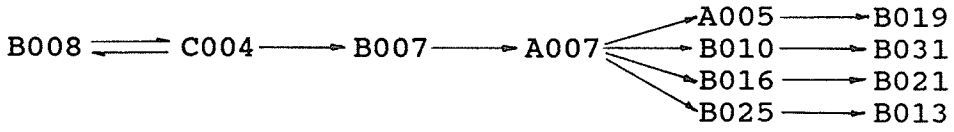


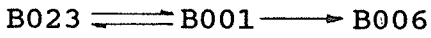

Figure 3.3

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on Period Mean Flows

First Group




Second Group




Third Group




Figure 3.4

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on Period Mean Flows

### 3.4.5 Implications of Correlation Analysis on Data Screening

The information given with the correlation matrices may be used as a method of checking the number of overlapping years in a basin. Also, the correlation matrices give the strength of the linear relationship between stations in a basin. Knowing which stations have overlapping records and which station records are well correlated is an important step in extending or transferring streamflow records within the basin. The cluster analysis indicates to the data reviewer the groupings in the basin and may be used to indicate homogeneous hydrologic areas.

# 4. CONCLUSIONS AND NETWORK REVIEW

Three types of statistical techniques were applied to the station data sets of the Pembina River basin. The results and corresponding conclusions derived from the application of the techniques are as follows:

1. Nonparametric data screening is a good general tool for identifying station data sets which should be scrutinized for possible data or metering problems.
2. The general plots of sample statistics versus drainage area give a good indication of the basic relationships in the basin and the range of drainage areas covered by the hydrometric network of a basin. The mean, median, standard deviation, maximum, range and yield sample statistics were found to relate well to the drainage area.
3. Outlier detection techniques were able to identify station data sets which had sample statistics which deviated significantly from the regional norm. These anomalous station data sets could then be scrutinized for possible explanations.
4. Any data transfer or data extension technique employed within the basin must recognize that: (1) good correlations were found for the monthly mean flows of high flow months of April, May and June and the period mean flows, and (2) poor correlations were found for the monthly mean flows of the low flow months of

March and July to October and the daily mean peak flows.

5. The cluster analysis was able to identify station groups that were "reasonable" in a hydrologic sense.

The basin seems to possess a very good hydrometric network; however, a few minor problems were noted in the study:

1. There are no stations with gross drainage areas less than 68 $km^2$. Stations covering areas of this size are indispensable in the design of small agricultural and domestic projects. There is a paucity of data for basins of this size and any extra information gathered would be helpful for hydrologic engineers who are asked to size, develop and design small projects.
2. The overflow of the Pembina River above station 05OC004 (Pembina River at Neche) is not measured or accounted for. This reduces the usefulness of this gauging station as a long-term indicator of basin yield, especially for points upstream of the station.
3. Recognizing that some of the stations in the basin are for operational purposes only, certain stations are located below or near to structures which may affect the usefulness of data transferred from these stations (or used to extend data at) sites without regulation.

There are also several general comments pertaining to hydrometric networks and hydrometric data collection based on

the author's personal experiences and observations as a hydrologic engineer.

1. The hydrologic system is a complicated phenomenon that the engineer is trying to understand and to know. The recorded streamflow is the basic result of the integration over the basin of all the various combinations of inputs to the system (precipitation, soil conditions, basin conditions, melting conditions, etc.). The hydrologist is left only with "snapshots" of the runoff phenomenon, which are published as daily mean flows, daily and instantaneous peak flows, monthly mean flows, and annual and period mean flows. Any deterministic, stochastic or probabilistic modelling of runoff in the basin is limited by the availability of this streamflow data and the confidence placed in the modelling by the modeller is directly related to the quantity and quality of this data.
2. Usually, data has not been collected at a proposed development site, and therefore a technique for transferring data to the site is required. However, if data has not been recorded on nearby streams or on hydrologically-similar streams in the area, the hydrologist does not necessarily have too much confidence in the transferred data that eventually must be used.

3. Most hydrologic models depend on a relatively long data record in order to predict the response of a basin. Therefore, data records must also be extensive enough temporally to be of use to the hydrologist.
4. It is recognized that every data need for a basin is impossible to cover both in space and time. However, based on the author's experience in being unable to obtain data for projects, it is difficult to recommend station discontinuance. Every year and every station for which streamflow data is collected yields more pieces to the puzzle that is called "hydrology."

# 5. RECOMMENDATIONS AND LIMITATIONS

## 5.1 STREAMFLOW DATA

1. The data screening techniques discussed in this study should be applied to several basin-wide hydrometric networks to test the general suitability of the techniques for networks of various sizes.
2. The Pembina River basin has many stations with most having long periods of record. The techniques should be tested on basins (or regions) with fewer stations and on basins with limited overlapping periods of record.
3. At the time of this study, few stations had substantial periods of record for instantaneous peak flows. Perhaps in the near future enough instantaneous peak flow data will be made available to apply these statistical techniques to this type of hydrometric data.
4. The summation of flows from March to October may be a more appropriate streamflow parameter to be investigated than the period mean flows or the extended annual mean flows. This parameter would need to be extracted from the monthly mean flows published by Water Survey of Canada.

## 5.2 STATISTICAL TECHNIQUES

1. Parametric tests for independence, trend, homogeneity and randomness should be applied for the station data sets

and the results compared with the nonparametric tests.

2. Simple statistics for the logarithms of the station data should be calculated and relationships based on this transformed data investigated.
3. Other basin physical characteristics such as basin slope, longest channel length, drainage density, percentage of basin covered by lakes and sloughs, etc., should be included in any further work on regional regression analysis.
4. Langbein's (1960) correlation procedure, which correlates the logarithm of the deviations from the mean for the monthly flow data, should be applied to the station data as an alternative to the Pearson and Spearman correlation procedures.
5. Other cluster analysis techniques may be applied to the correlation matrices in order to study further the groupings of the hydrometric stations.
6. As more hydrometric data is collected, the more complex network evaluation techniques of square grid regionalization, kriging techniques and Bayesian analysis, etc., may become more viable

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# APPENDIX A

# DEVIATION OF SAMPLE STATISTICS

# FOR PEMBINA RIVER STREAMFLOW DATA

# Table A-1

## Listing of the SIMPSTATS Program

```
      C
      C
      C
 1          INTEGER YR,MLF,YER(30),AREA(30),EFAREA(30),DUMMY,SF,DU2,TYPE
 2          REAL*8 STA,STANAM(30),NEWSPG
 3          REAL*8 STOPER/'-999999'/,STATN
 4          DIMENSION PM(1030),F(1030),ARY(200),FY(10),BM(10),SEAS(200)
 5          DIMENSION ADJBM(10),ADJFY(10),D(1000)
      C SET UP
 6          KS=0
 7          IDOZ=0
 8          NAM=0
 9          FY(1)=-400.
10          IJK=1
      C
      C READ IN DATA TYPE  1=ANN 2=PEAK 3=MONTHLY
      C
11          READ, TYPE
12          IF(TYPE.NE.3) GOTO 1
13          READ, MONTH
14          WRITE(6,1000) MONTH
15    1000  FORMAT('1',////,10X,'DATA FOR MONTH NUMBER ',I2,//)
      C
      C READ IN STATION DATA FOR STATIONS TO BE ANALYZED
16    1     READ, NSTA
      C READ IN THE FIRST STATION IN SEQUENCE
17          READ(5,100) STATN
18    100   FORMAT(A7)
19           DO 10 I=1,NSTA
20          READ(5,200) STANAM(I),AREA(I),EFAREA(I),YER(I)
21          WRITE(6,200) STANAM(I),AREA(I),EFAREA(I),YER(I)
22    200   FORMAT(A7,5X,I5,4X,I5,3X,I3)
23    10     CONTINUE
      C
      C BRANCH FOR PEAK AND MONTHLY DATA
      C
24          IF(TYPE.GT.1) GOTO 240
      C
      C
      C               ANNUAL FLOW SECTION
      C
      C
      C READ IN ANNUAL FLOW DATA
25    20    READ(5,300) STA,YR,MLF,(PM(K),K=1,6),AM
      C CHECK FOR END OF ANNUAL DATA
26          IF(YR.LT.0) GOTO 390
27          DU2=0
28           DO 30 K=1,6
29          IF(PM(K).GE.0) GOTO 30
30          DU2=1
31    30     CONTINUE
32    300   FORMAT(1X,A7,I3,1X,I1,6(1X,G5),T75,G5)
      C     WRITE(6,303) STA,YR,MLF,(PM(K),K=1,6),AM
      C     WRITE(8,303) STA,YR,MLF,(PM(K),K=1,6),AM
      C303  FORMAT(5X,A7,10X,'1',I3,5X,I1,6(3X,F8.4),20X,F8.4)
      C IS STATION THE CORRECT STATION?
33          IF(STA.NE.STATN) GOTO 190
      C CHECK FOR CORRECT PERIOD
34    40    IF(YR.LT.YER(IJK)) GOTO 20
35          IF(PM(3).LT.0.OR.PM(4).LT.0) GOTO 20
      C BRANCH IF FALLTIME FLOWS

36          IF(MLF.GE.7) GOTO 90
37          IF(AM.LT.29.AND.DU2.EQ.0) GOTO 140
38          DUMMY=0
      C PUT FLOWS INTO SPRING MONTH FLOW ARRAY
      C     WRITE(6,304)
39           DO 50 K=1,6
40          BM(K)=PM(K)
      C304  FORMAT(5X,'SPRING FLOWS')
      C     PRINT, K,BM(K)
41    50     CONTINUE
      C CHECK FOR MISSING SPRING FLOW AND RECORD MONTH
      C  THAT FIRST FLOW OCCURS IN
42           DO 60 K=1,6
43          IF(BM(K)) 61,62,62
44    61    GOTO 60
45    62    SF=K
46          IF(SF.GT.3) GOTO 20
47          GOTO 63
48    60     CONTINUE
49          GOTO 20
      C CHECK TO SEE IF THIS IS THE FIRST YEAR OF RECORD
      C AND IF NOT SEND BOTH PREV FALL AND CURRENT SPRING FLOWS
      C  TO THE LOG RECESSION SUBROUTINE
50    63    IF(FY(1).LT.0) GOTO 150
51          CALL SPGYLD(FY,LF,BM,SF,ADJBM,ADJFY)
      C PUT ADJUSTED FLOWS INTO THE FLOW ARRAYS
52           DO 70 K=1,6
53          BM(K)=ADJBM(K)
54          FY(K)=ADJFY(K)
55    70     CONTINUE
      C CALCULATE THE SUMMED FLOW FOR THE PREV FALL AND THE
      C  CURRENT SPRING
56          SUMFAL=0
57          NEWSPG=0
58           DO 80 K=1,6
59          SUMFAL=FY(K)+SUMFAL
60          NEWSPG=BM(K)+NEWSPG
61    80     CONTINUE
```

Table A-1 (cont'd)

```
      C CALCULATE THE AVERAGE ANNUAL FLOW FOR THE PREV YEAR
   82         ANPREV=SUMFAL+SUMSPG
   83         ANPREV=ANPREV/12.
   84         NAM=NAM+1
   85         ARY(NAM)=ANPREV
      C       WRITE(6,330)
      C330    FORMAT(//)
      C       PRINT, ANPREV,NAM,ARY(NAM),SUMFAL,NEWSPG
      C       WRITE(6,330)
      C SET THE CURRENT SPRING FLOW INTO THE SPOT THAT IT IS USED
      C  TO FIND THE ANNUAL AVERAGE FLOW
   86         SUMSPG=NEWSPG
   87         GOTO 20
      C
      C FALL MONTH FLOWS AND/OR STRAIGHT ANNUAL FLOW
      C
      C CHECK TO SEE IF LOG RECESSION IS NEEDED
   88 90      IF(DUMMY.GT.0) GOTO 125
      C LOG RECESSION TO BE USED
      C CHECK FOR LAST FALL MONTH OF FLOW
      C       WRITE(6,305)
      C305    FORMAT(5X,'FALL FLOWS')
   89         DO 110 K=1,6
   90         FY(K)=PM(K)
   91 110      CONTINUE
   92          DO 120 K=1,6
   93         IF(FY(K)) 123,120,120
   94 123     LF=K-1
   95         GOTO 124
   96 120      CONTINUE
   97         GOTO 125
      C SAVE THE AVERAGE FLOW OF THE PERIOD
   98 124     KS=KS+1
   99         SEAS(KS)=AM
  100         GOTO 20
      C USE ANNUAL FLOW AS GIVEN IN FLOW RECORD
      C
  101 125     NAM=NAM+1
      C STORE MONTHLY FLOWS IN CASE THE NEXT SPRING IS MISSING FLOWS
      C       WRITE(6,306)
      C306    FORMAT(5X,'ANNUAL FLOWS USED')
  102          DO 130 K=1,6
  103         FY(K)=PM(K)
  104 130      CONTINUE
  105         ARY(NAM)=AM
      C       PRINT, NAM,ARY(NAM),DUMMY
      C NO MONTHLY FLOWS ARE MISSING, SET FLAG VARIABLE TO SHOW
      C  THIS
  106 140     DUMMY=1
  107         GOTO 20
      C THIS IS THE FIRST YEAR OF RECORD FOR THE STATION AND
      C  THE FIRST MONTHS ARE MISSING AND NO VALUES ARE AVAILABLE
      C  FOR THE PREV FALL
      C
      C FOR A ZERO FIRST SPRING FLOW ASSUME THE FIRST TWO MONTHS
      C  HAVE A ZERO FLOW ALSO
  108 150     IF(BM(SF).GT.0) GOTO 160
  109         BM(SF-1)=0.
  110         BM(1)=0.
  111         GOTO 170
      C ASSUME THE PREV FALL LAST FLOW WAS ZERO AND LOG RECESS THE
      C  FIRST TWO MONTHLY FLOWS
  112 160     BM(2)=EXP((ALOG(BM(3))+ALOG(.0005))*.5)
  113         BM(1)=EXP((ALOG(BM(2))+ALOG(.0005))*.5)
  114 170     SUMSPG=0
      C CALCULATE THE SUMMED SPRING FLOWS
  115          DO 180 K=1,6
  116         SUMSPG=BM(K)+SUMSPG
  117 180      CONTINUE
  118         GOTO 20
      C
      C
      C THE STATION READ IN IS NOT THE SAME AS THE STATION THAT IS
      C  CURRENTLY BEING INVESTIGATED
      C
      C CHECK THAT THE NEXT STATION ON THE RECORD IS NEEDED
      C  IF NOT THEN READ UNTIL THAT POINT IS REACHED
  119 190     IF(STA.NE.STANAM(IJK+1)) GOTO 20
  120         IF(DUMMY.NE.0) GOTO 350
  121         IF(FY(LF).GT.0) GOTO 210
  122         FY(5)=0.0
  123         FY(6)=0.0
  124         GOTO 220
      C
      C ASSUME LAST YEAR HAS RECESSING FALL FLOWS
      C
  125 210     FY(5)=EXP((ALOG(FY(4))+ALOG(.0005))*.5)
  126         FY(6)=EXP((ALOG(FY(5))+ALOG(.0005))*.5)
  127 220     SUMFAL=0
  128          DO 230 K=1,6
  129         SUMFAL=SUMFAL+FY(K)
  130 230      CONTINUE
  131         ANPREV=SUMSPG+SUMFAL
  132         NAM=NAM+1

  133         ARY(NAM)=ANPREV/12.0
  134         GOTO 350
      C
      C            END OF ANNUAL SECTION
      C
      C
      C
```

Table A-1 (cont'd)

```
C                PEAK FLOW SECTION
C
C
115   240    IF(TYPE.GT.2) GOTO 280
116          K=0
117          IJ=1
      C
      C
118   250    READ(5,400) STA,DMAX1,DMAX2
119   400    FORMAT(2X,A7,T19,G8,T50,G8)
      C      PRINT, STA,DMAX1,DMAX2
120          IF(STA.NE.STANAM(IJK))GO TO 260
121          K=K+2
122          D(K)=DMAX1
123          J=K+1
124          D(J)=DMAX2
      C      PRINT, D(K),D(J)
125          GOTO 250
126   260    KK=K
127          DUM1=DMAX1
128          DUM2=DMAX2
129          K=0
130           DO 270 I=2,KK
      C NOTE:  IF DAILY MAX = 0 FOR THE YEAR THIS WILL NOT ACCOUNT
      C          FOR IT... WOULD HAVE TO CHECK INPUT DATA FOR THIS
131          IF(D(I).LE.0)GO TO 270
132          K=K+1
133          ARY(K)=D(I)
134   270     CONTINUE
135          NAM=K
136          GOTO 350
      C
      C          END OF PEAK SECTION
      C
      C
      C         MONTHLY FLOW SECTION
      C
      C
137   280    K=0
138          IJK=1
139   290    READ(5,500) STA,YR,HLF,(PM(J),J=1,6)
140   500    FORMAT(1X,A7,I3,1X,I1,6(1X,G5))
141          IF(YR.LT.0) GOTO 390
142          IF(STA.NE.STATN) GOTO 330
143   310    IF(YR.LT.YER(IJK)) GOTO 290
144          IF(HLF.GT.6.AND.MONTH.GT.6) GOTO 320
145          IF(HLF.LT.6.AND.MONTH.LE.6) GOTO 311
146          GOTO 290
147   311    K=K+1
148          F(K)=PM(MONTH)
149          GOTO 290
150   320    K=K+1
151          MOND=MONTH-6
152          F(K)=PM(MOND)
153          GOTO 290
154   330    IF(STA.NE.STANAM(IJK+1)) GOTO 290
155   331    NAM=0
156           DO 340 I=1,K
157          IF(F(I).LT.0) GOTO 340
158          NAM=NAM+1
159          ARY(NAM)=F(I)
160   340     CONTINUE
      C
      C
      C             END OF MONTH SECTION
      C
      C
161   350    A=AREA(IJK)
162          AE=EFAREA(IJK)
      C      PRINT, NAM,(ARY(I),I=1,NAM)
      C
      C CALL THE SUBROUTINES THAT OUTPUT THE STATISTICS
      C
163          CALL MEAN(ARY,NAM,XB,A,AE,STATN,YER(IJK))
164          CALL SIMP(ARY,NAM,XB,A,AE)
165          CALL KURT(ARY,NAM,XB,A,AE)
166          CALL RANGE(ARY,NAM,XB,A,AE)
167          CALL MED(ARY,NAM,XB,A,AE)
      C METHOD TO STOP PROGRAM
168          IF(IDOZ.GT.0) GOTO 999
      C
      C BRANCH FOR REINITIALIZATION OF PEAK AND MONTHLY FLOWS
      C
169          IF(TYPE.GE.2) GOTO 370
      C REINITIALIZE VARIABLES AND INCREMENT STATION COUNTERS
170          NAM=0
171          KS=0
172          IJK=IJK+1
173          STATN=STA
174          FY(1)=-400
175          JJ=0
      C      WRITE(6,307)
      C307   FORMAT(4X,'NEW STATION')
      C      PRINT, DUMMY,DU2
176          DU2=0
177           DO 360 K=1,6
      C      PRINT, PM(K)
178          IF(PM(K).GE.0) GOTO 360
179          DU2=1
180   360     CONTINUE
181          IF(AM.LT.29.AND.DU2.EQ.0) GOTO 140
182          DUMMY=0
183          GOTO 40
```

Table A-1 (cont'd)

```
      C
      C  PEAK FLOW REINITIALIZATION
      C
184   370    IF(TYPE.GT.2) GOTO 380
185          STATN=STA
186          IJK=IJK+1
187          K=2
188          D(2)=DUM1
189          D(3)=DUM2
190          IF(STA.EQ.STOPER) STOP
191          GOTO 250
      C
      C MONTHLY FLOW REINITIALIZATION
      C
192   380    NAM=0
193          K=0
194          IJK=IJK+1
195          STATN=STA
196          GOTO 290
      C METHOD TO STOP PROGRAM
197   390    IDO2=100
198          IF(TYPE.EQ.3) GOTO 331

199          GOTO 350
200   999    STOP
201          END
      C
      C
      C
      C
      C FINDING THE MEAN -- SUBPROGRAM
      C

202          SUBROUTINE MEAN(X,N,XB,A,AE,STA,YER)
203          DIMENSION X(200),DX(200)
204          REAL*8 STA
205          INTEGER YER
206          NUM=0
207           DO 10 I=1,N
208          IF(X(I).LT.0) GOTO 10
209          NUM=NUM+1
210          DX(NUM)=X(I)
211   10      CONTINUE
212           DO 20 I=1,NUM
213          X(I)=DX(I)
214   20      CONTINUE
215          N=NUM
216          SUM=0
217           DO 30 I=1,N
218   30      SUM=SUM+X(I)
219          RAT=AE/A
220          XB=SUM/N
221          XBA=XB/A
222          XBAE=XB/AE
223          WRITE(6,100) STA,A,AE
224   100    FORMAT('1',/////,T20,'STATION',5X,A8,///,T20,'DRAINAGE AREA',
           $5X,F10.2,///,T20,'EFFECTIVE DRAINAGE AREA',F10.2,//)
225          WRITE(6,200) RAT
226   200    FORMAT(15X,'RATIO OF EFF TO GROSS AREA IS     ',F10.5,//)
227          WRITE(6,500) (X(J),J=1,N)
228   500    FORMAT(4(5X,F12.4))
229          WRITE(6,600) N,YER
230   600    FORMAT(//,5X,I3,' YEARS OF DATA SINCE 1',I3)
231          WRITE(6,300)
232   300    FORMAT('1',5X,'MEAN',10X,'MEAN / D.A.',10X,
           1'MEAN / E.D.A.',/)
233          WRITE(6,400) XB,XBA,XBAE
234   400    FORMAT(3X,F8.4,8X,F10.7,8X,F10.7,/)
235          RETURN
236          END
      C
      C
      C  SIMPLE STATS SUBPROGRAM
      C

237          SUBROUTINE SIMP(X,N,XB,A,AE)
238          DIMENSION X(200)
239          SUM2=0
240          SUM3=0
241           DO 10 I=1,N
242          DIFF=X(I)-XB
243          SUM2=SUM2+DIFF**2
244   10      SUM3=SUM3+DIFF**3
245          S=SQRT(SUM2/(N-1))
246          AL=N*SUM3/(N-1)/(N-2)
247          CS=AL/(S**3)
248          CV=S/XB
249          SA=S/A
250          SAE=S/AE
251          ALA=AL/A
252          ALAE=AL/AE
253          CSA=CS/A
254          CSAE=CS/AE
255          CVA=CV/A
256          CVAE=CV/AE
257          WRITE(6,100)
258   100    FORMAT(///,5X,'STD. DEV.',18X,'CV.',15X,
           1'SKEW',10X,'COEFF. OF SKEW',/)
259          WRITE(6,200) S,CV,AL,CS
260   200    FORMAT(5X,F10.6,10X,F10.6,10X,F10.6,10X,
           1F10.7/)
261          WRITE(6,300)
```

Table A-1 (cont'd)

```
      300   FORMAT(15X,'DIVIDED BY DRAINAGE AREA',/)
            WRITE(6,200) SA,CVA,ALA,CSA
            WRITE(6,400)
      400   FORMAT(15X,'DIVIDED BY EFFECTIVE DRAINAGE AREA',/)
            WRITE(6,200) SAE,CVAE,ALAE,CSAE
            RETURN
            END
      C
      C
      C KURTOSIS SUBPROGRAM
      C
      C

            SUBROUTINE KURT(X,N,XB,A,AE)
            DIMENSION X(200)
            REAL KUR
            SUM2=0
            SUM4=0
             DO 10 I=1,N
            DIFF=X(I)-XB
            SUM2=SUM2+DIFF**2
      10     SUM4=SUM4+DIFF**4
            KUR=SUM4/N/(SUM2/N)**2
            KUR=KUR*N**3/(N-3)/(N-2)/(N-1)
            CE=KUR-3
            WRITE(6,100)
      100   FORMAT(/,5X,'KURTOSIS',10X,'COEFF. OF EXCESS',/)
            WRITE(6,200) KUR,CE
      200   FORMAT(5X,F10.6,10X,F10.6,/)
            RETURN
            END
      C
      C
      C RANGER SUBPROGRAM
      C
      C

            SUBROUTINE RANGE(X,N,XB,A,AE)
            DIMENSION X(200)
            REAL MAX,MIN,MXMI,MXXB
            MAX=X(1)
            MIN=X(1)
             DO 10 I=2,N
            IF(X(I).LT.MAX)GO TO 20
            MAX=X(I)
      20    IF(X(I).GT.MIN)GO TO 10
            MIN=X(I)
      10     CONTINUE
            RANG=MAX-MIN
            RANGA=RANG/A
            RANGAE=RANG/AE
            IF(MIN.NE.0.AND.XB.NE.0)GOTO 40
            IF(XB.EQ.0)GOTO 30

            WRITE(6,100)
      100   FORMAT(15X,'MIN. IS EQUAL TO ZERO ')
            MXMI=0
            MXXB=MAX/XB
            GOTO 50
      30    WRITE(6,200)
      200   FORMAT(15X,'THE MEAN IS EQUAL TO ZERO')
            GOTO 50
      40    MXMI=MAX/MIN
            MXXB=MAX/XB
      50    WRITE(6,300)
      300   FORMAT(/,5X,'RANGE',10X,'RANGA',10X,'RANGAE',
           110X,'MAX BY MIN',10X,'MAX BY MEAN'/)
            WRITE(6,400) RANG,RANGA,RANGAE,MXMI,MXXB
      400   FORMAT(5X,F7.2,8X,F10.4,8X,F10.4,5X,F15.5,10X,
           1F9.5,10X//)
            RETURN
            END
      C
      C
      C
      C SUBROUTINE SPRINGYIELD LOG LINEAR DATA FILL IN
      C
      C

            SUBROUTINE SPGYLD(FY,LF,BM,SF,XRY,YRY)
            DIMENSION FY(10),BM(10),XRY(10),YRY(10)
            INTEGER LF,SF,SF2
      C     WRITE(6,307)
      C307  FORMAT(5X,'SPGYLD PROGRAM')
             DO 10 K=1,6
      C     PRINT, K,BM(K),FY(K),LF,SF
      10     CONTINUE
            IF(SF.LT.3.OR.LF.GT.4) GOTO 130
            IF(FY(4).GT.0) GOTO 40
            IF(BM(3).GT.0) GOTO 40
             DO 20 I=1,3
            BM(I)=0
      20     CONTINUE
             DO 30 I=4,6
            FY(I)=0
      30     CONTINUE
            GOTO 110
      40    IF(FY(4).GT.0) GOTO 80
            BM(1)=0
             DO 50 I=4,6
            FY(I)=0
      50     CONTINUE
```

Table A-1 (cont'd)

```
339           BM(2)=EXP((ALOG(BM(3))+ALOG(.0005))*.5)
340           GOTO 110
341     80    IF(BM(3).EQ.0) GOTO 90
342           IF(FY(4).GT.BM(3)) GOTO 80
343           BM(2)=EXP((ALOG(BM(3))+ALOG(.0005))*.5)
344           IF(FY(4).LT.BM(2)) GOTO 70
345           FY(5)=EXP((ALOG(FY(4))-ALOG(BM(2)))*.75+ALOG(BM(2)))
346           FY(6)=EXP((ALOG(FY(4))+ALOG(BM(2)))*.5)
347           BM(1)=EXP((ALOG(FY(4))-ALOG(BM(2)))*.25+ALOG(BM(2)))
348           GOTO 110
349     70    BM(1)=EXP((ALOG(BM(2))+ALOG(.0005))*.5)
350           FY(5)=EXP((ALOG(FY(4))-ALOG(BM(1)))*2.0/3.0+ALOG(BM(1)))
351           FY(6)=EXP((ALOG(FY(4))-ALOG(BM(1)))/3.+ALOG(BM(1)))
352           GOTO 110
      C24     WRITE(6,205) SF,BM(SF),LF,FY(LF)
      C205    FORMAT(5X,I5,F20.5,I5,F10.5)
353     80    BM(2)=EXP((ALOG(BM(3))+ALOG(.0005))*.5)
354           FY(5)=EXP((ALOG(FY(4))-ALOG(BM(2)))*.75+ALOG(BM(2)))
355           FY(6)=EXP((ALOG(FY(4))-ALOG(BM(2)))*.50+ALOG(BM(2)))
356           BM(1)=EXP((ALOG(FY(4))-ALOG(BM(2)))*.25+ALOG(BM(2)))
357           GOTO 110
358     90    FY(5)=EXP((ALOG(FY(4))-ALOG(.0005))*.8+ALOG(.0005))
359           FY(6)=EXP((ALOG(FY(4))-ALOG(.0005))*.6+ALOG(.0005))
360           BM(1)=EXP((ALOG(FY(4))-ALOG(.0005))*.4+ALOG(.0005))
361           BM(2)=EXP((ALOG(FY(LF))-ALOG(.0005))*.2+ALOG(.0005))
362     110    DO 120 I=1,6
363           XRY(I)=BM(I)
364           YRY(I)=FY(I)
365     120    CONTINUE
366           GOTO 190
367     130   IF(LF.EQ.6.AND.SF.EQ.1) GOTO 110
368           IF(LF.GT.4) GOTO 160
369           IF(SF.LT.2) GOTO 150
370           IF(BM(2).GT.0) GOTO 140
371           BM(1)=0.0
372           IF(FY(4).EQ.0) GOTO 180
373           FY(5)=EXP((ALOG(FY(4))-ALOG(.0005))*2.0/3.0)
374           FY(6)=EXP((ALOG(FY(5))-ALOG(.0005))/3.0)
375           GOTO 110
376     140   BM(1)=0.0
377           IF(FY(4).EQ.0) GOTO 180
378           FY(5)=EXP((ALOG(FY(4))-ALOG(.0005))*2.0/3.0)
379           FY(6)=EXP((ALOG(FY(5))-ALOG(.0005))/3.0)
380           GOTO 110
381     150   IF(FY(4).EQ.0) GOTO 180
382           FY(5)=EXP((ALOG(FY(4))-ALOG(.0005))*2.0/3.0)
383           FY(6)=EXP((ALOG(FY(5))-ALOG(.0005))/3.0)
384           GOTO 110
385     160   IF(LF.GT.5) GOTO 170
386           BM(1)=0.0
387           BM(2)=0.0
388           IF(FY(5).EQ.0) GOTO 180
389           FY(6)=EXP((ALOG(FY(5))-ALOG(.0005))*.5)
390           GOTO 110
391     170   BM(1)=0.0
392           BM(2)=0.0
393           GOTO 110
394     180   FY(5)=0.0
395           FY(6)=0.0
396           GOTO 110
      C       WRITE(6,100) LF,(FY(I),I=1,6)
      C       WRITE(6,100) SF,(BM(I),I=1,6)
      C       WRITE(6,200)
      C100    FORMAT(5X,I5,'MONTH',5X,6(F10.3,5X))
397     190   RETURN
398           END
      C
      C
      C  SUBROUTINE MEDIAN FINDS MEDIAN
      C
      C


399           SUBROUTINE MED(ARY,NAM,XB,A,AE)
400           DIMENSION ARY(200)
401           REAL MEDI,MEDXB,MEDA,MEDAE
      C       PRINT,NAM,(ARY(I),I=1,NAM)
402           LAST=NAM-1
403            DO 10 I=1,LAST
404           AMIN=ARY(I)
405           JMIN=I
406           JFIRST=I+1
407             DO 20 J=JFIRST,NAM
      C       PRINT, I,J,AMIN,ARY(J)
408           IF(AMIN.LE.ARY(J)) GOTO 20
409           AMIN=ARY(J)
410           JMIN=J
411     20      CONTINUE
412           ARY(JMIN)=ARY(I)
413           ARY(I)=AMIN
414     10     CONTINUE
415           IVAL=NAM/2+NAM/2
416           IF(IVAL.LT.NAM) GOTO 30
417           MEDI=(ARY(NAM/2)+ARY(NAM/2+1))*.5
418           GOTO 40
419     30    MEDI=ARY(NAM/2+1)
420     40    MEDXB=MEDI/XB
421           MEDA=MEDI/A
422           MEDAE=MEDI/AE
423           WRITE(6,100)
424     100   FORMAT(/,5X,'MEDIAN',14X,'MED BY MEAN',9X,'MED BY AREA',
            $9X,'MED BY EFF AREA',/)
425           WRITE(6,200) MEDI,MEDXB,MEDA,MEDAE
426     200   FORMAT(5X,F10.5,3(10X,F10.5))
427           RETURN
428           END
```

# Table A-2

## Sample Statistics for Pembina River Basin Annual Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max/Min | Max/$\bar{x}$ | Med/$\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 7.885 | 0.0009 | 0.0015 | 6.02 | 6.310 | 0.800 | 1.035 | 1.479 | 23.76 | 24.5 | 33.0 | 3.107 | 0.763 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 6.506 | 0.0009 | 0.0015 | 4.46 | 5.620 | 0.864 | 1.039 | 1.376 | 20.57 | 20.8 | 90.0 | 3.197 | 0.686 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 4.782 | 0.0007 | 0.0011 | 3.60 | 4.043 | 0.845 | 1.793 | 5.663 | 13.43 | 14.5 | 13.6 | 3.032 | 0.753 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 5.543 | 0.0010 | 0.0016 | 3.75 | 4.744 | 0.856 | 1.086 | 1.641 | 16.34 | 16.5 | 106 | 2.977 | 0.677 |
| 050B019 | Pembina River near Swan Lake | 11 | 1962–1972(S) | 4983 | 3127 | 4.452 | 0.0009 | 0.0014 | 2.81 | 3.521 | 0.791 | 1.267 | 2.604 | 10.70 | 12.3 | 7.89 | 2.753 | 0.632 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 4.182 | 0.0009 | 0.0015 | 2.68 | 3.678 | 0.879 | 0.923 | 0.970 | 12.87 | 12.9 | 379 | 3.085 | 0.641 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 1.230 | 0.0008 | 0.0016 | 0.578 | 1.309 | 1.065 | 1.224 | 1.261 | 4.25 | 4.280 | 171 | 3.480 | 0.467 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.479 | 0.0005 | 0.0020 | 0.268 | 0.565 | 1.178 | 1.279 | 1.636 | 1.85 | 1.880 | 155 | 3.881 | 0.558 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.601 | 0.0010 | 0.0012 | 0.618 | 0.439 | 0.730 | 0.764 | 0.850 | 1.64 | 1.690 | 31.1 | 2.810 | 1.027 |
| 050A010 | Pembina River above Lorne Lake | 19 | 1962–1980(S) | 542 | 360 | 0.624 | 0.0011 | 0.0017 | 0.407 | 0.465 | 0.745 | 0.988 | 0.772 | 1.63 | 1.730 | 18.7 | 2.766 | 0.652 |
| 050A012 | Pembina River above Diversion | 14 | 1963–1976(S) | 485 | 328 | 0.671 | 0.0015 | 0.0020 | 0.499 | 0.482 | 0.718 | 0.659 | 0.030 | 1.42 | 1.580 | 9.68 | 2.353 | 0.744 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.373 | 0.0010 | 0.0013 | 0.264 | 0.315 | 0.844 | 0.880 | 0.648 | 1.08 | 1.090 | 168 | 2.921 | 0.707 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.515 | 0.0015 | 0.0018 | 0.437 | 0.403 | 0.783 | 0.899 | 0.680 | 1.44 | 1.490 | 30.0 | 2.885 | 0.848 |
| 050B021 | Mowbray Creek near Mowbray | 19 | 1962–1980(S) | 262 | 168 | 0.270 | 0.0010 | 0.0016 | 0.178 | 0.253 | 0.940 | 1.012 | 1.400 | 0.891 | 0.906 | 59.2 | 3.359 | 0.659 |
| 050A013 | Long River near Killarney | 10 | 1967–1976(S) | 209 | 180 | 0.475 | 0.0023 | 0.0026 | 0.467 | 0.274 | 0.576 | 0.011 | 0.452 | 0.775 | 0.899 | 7.23 | 1.892 | 0.983 |
| 050B031 | Cypress Creek near Sarles | 19 | 1961–1980 | 149 | 133 | 0.181 | 0.0012 | 0.0014 | 0.138 | 0.148 | 0.810 | 1.087 | 1.440 | 0.496 | 0.502 | 83.7 | 2.778 | 0.764 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.132 | 0.0009 | 0.0015 | 0.114 | 0.108 | 0.817 | 0.821 | 1.446 | 0.411 | 0.412 | 566 | 3.131 | 0.868 |
| 050B025 | Pilot Creek near Pilot Mound | 18 | 1963–1980(S) | 147 | 103 | 0.150 | 0.0010 | 0.0015 | 0.088 | 0.165 | 1.099 | 1.456 | 2.548 | 0.564 | 0.565 | 593 | 3.757 | 0.571 |
| 050B013 | Mary Jane Creek at La Riviere | 18 | 1960–1980(S) | 136 | 112 | 0.213 | 0.0016 | 0.0019 | 0.182 | 0.170 | 0.797 | 0.774 | 0.479 | 0.539 | 0.550 | 49.1 | 2.583 | 0.853 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.110 | 0.0016 | 0.0018 | 0.082 | 0.104 | 0.951 | 1.184 | 2.220 | 0.392 | 0.392 | --- | 3.570 | 0.747 |

# Table A-3

## Sample Statistics for Pembina River Basin Daily Mean Peak Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 20 | 1903–1980 | 8474 | 5382 | 89.51 | 0.0106 | 0.0166 | 88.0 | 77.46 | 0.865 | 0.928 | 1.156 | 275.9 | 282 | 46.5 | 3.150 | 0.984 |
| 050B007 | Pembina River near Windygates | 17 | 1962–1980 | 7503 | 4477 | 74.98 | 0.0100 | 0.0167 | 45.6 | 87.58 | 1.168 | 1.779 | 3.875 | 314.1 | 317 | 108 | 4.228 | 0.608 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 55.24 | 0.0078 | 0.0132 | 34.8 | 77.23 | 1.398 | 0.958 | 1.567 | 257.6 | 266 | 31.5 | 4.662 | 0.630 |
| 050B001 | Pembina River near La Riviere | 13 | 1963–1977 | 5320 | 3367 | 65.72 | 0.0124 | 0.0195 | 21.3 | 98.63 | 1.501 | 2.044 | 4.538 | 298.3 | 303 | 64.1 | 4.611 | 0.324 |
| 050B019 | Pembina River near Swan Lake | 9 | 1962–1972(S) | 4983 | 3127 | 46.78 | 0.0094 | 0.0150 | 16.5 | 91.54 | 1.957 | 2.915 | 12.00 | 283.3 | 289 | 51.1 | 6.178 | 0.353 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 64.27 | 0.0143 | 0.0236 | 20.7 | 93.75 | 1.459 | 2.118 | 4.856 | 316.9 | 317 | 2600 | 4.932 | 0.322 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 44.40 | 0.0293 | 0.0604 | 17.0 | 58.98 | 1.328 | 1.804 | 3.204 | 206.2 | 207 | 267 | 4.662 | 0.383 |
| 050B016 | Snowflake Creek near Snowflake | 19 | 1961–1980 | 980 | 245 | 7.652 | 0.0078 | 0.0312 | 6.37 | 8.525 | 1.114 | 1.526 | 3.295 | 31.72 | 32.0 | 114 | 4.182 | 0.832 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 11.68 | 0.0203 | 0.0231 | 7.76 | 10.74 | 0.919 | 1.436 | 2.309 | 39.52 | 40.5 | 41.4 | 3.466 | 0.664 |
| 050A010 | Pembina River above Lorne Lake | 17 | 1962–1980(S) | 542 | 360 | 16.88 | 0.0312 | 0.0469 | 7.33 | 15.95 | 0.945 | 1.045 | 0.899 | 49.98 | 52.1 | 24.6 | 3.086 | 0.434 |
| 050A012 | Pembina River above Diversion | 13 | 1963–1976(S) | 485 | 328 | 17.39 | 0.0381 | 0.0530 | 7.93 | 19.29 | 1.109 | 1.296 | 1.562 | 55.74 | 58.3 | 22.8 | 3.353 | 0.456 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 18.71 | 0.0482 | 0.0663 | 11.4 | 21.24 | 1.136 | 1.718 | 2.608 | 72.54 | 72.5 | 450 | 3.876 | 0.609 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 16.05 | 0.0453 | 0.0571 | 10.7 | 17.32 | 1.079 | 1.970 | 5.150 | 70.78 | 71.4 | 115 | 4.448 | 0.667 |
| 050B021 | Mowbray Creek near Mowbray | 17 | 1962–1980(S) | 262 | 168 | 7.328 | 0.0281 | 0.0436 | 8.64 | 6.013 | 0.821 | 0.405 | 0.004 | 18.34 | 18.6 | 71.3 | 2.538 | 1.179 |
| 050A013 | Long River near Killarney | 9 | 1967–1976(S) | 209 | 180 | 7.474 | 0.0358 | 0.0415 | 5.01 | 6.567 | 0.879 | 1.390 | 2.964 | 18.19 | 20.2 | 10.0 | 2.703 | 0.670 |
| 050B031 | Cypress Creek near Sarles | 18 | 1961–1980 | 149 | 133 | 13.67 | 0.0917 | 0.1028 | 7.64 | 12.92 | 0.945 | 1.125 | 1.052 | 43.52 | 44.2 | 65.0 | 3.234 | 0.559 |
| 050B006 | Crystal Creek near Crystal City | 19 | 1959–1980(S) | 154 | 88.0 | 7.558 | 0.0491 | 0.0859 | 4.70 | 7.014 | 0.928 | 0.937 | 0.357 | 21.99 | 22.0 | 1571 | 2.911 | 0.622 |
| 050B025 | Pilot Creek near Pilot Mound | 17 | 1963–1980(S) | 147 | 103 | 4.642 | 0.0316 | 0.0451 | 1.72 | 6.444 | 1.388 | 1.955 | 4.239 | 22.68 | 22.7 | 946 | 4.890 | 0.371 |
| 050B013 | Mary Jane Creek at La Riviere | 19 | 1960–1980(S) | 136 | 112 | 8.901 | 0.0654 | 0.0795 | 5.27 | 9.343 | 1.050 | 1.356 | 1.932 | 31.95 | 32.0 | 627 | 3.595 | 0.592 |
| 050A005 | Hidden Island Coulee near Hansboro | 18 | 1962–1980 | 68.1 | 60.9 | 7.022 | 0.1033 | 0.1151 | 4.04 | 8.209 | 1.169 | 1.619 | 2.903 | 28.30 | 28.3 | 9433 | 4.030 | 0.575 |

## Table A-4

## Sample Statistics for Pembina River Basin January Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 0.344 | 0.00004 | 0.00006 | 0.229 | 0.402 | 1.168 | 2.920 | 11.87 | 1.86 | 1.87 | 187 | 5.430 | 0.665 |
| 050B007 | Pembina River near Windygates | 18 | 1962–1980 | 7503 | 4477 | 0.194 | 0.00003 | 0.00004 | 0.159 | 0.185 | 0.954 | 0.617 | 0.050 | 0.543 | 0.543 | --- | 2.800 | 0.820 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 0.269 | 0.00004 | 0.00006 | 0.104 | 0.475 | 1.764 | 2.615 | 10.00 | 1.55 | 1.55 | --- | 5.754 | 0.386 |
| 050B001 | Pembina River near La Riviere | 14 | 1963–1977 | 5320 | 3367 | 0.134 | 0.00003 | 0.00004 | 0.079 | 0.156 | 1.157 | 1.254 | 2.798 | 0.524 | 0.524 | --- | 3.898 | 0.584 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 0.187 | 0.00004 | 0.00007 | 0.024 | 0.383 | 2.056 | 3.310 | 13.56 | 1.57 | 1.57 | --- | 8.417 | 0.129 |
| 050A007 | Badger Creek near Cartwright | 9 | 1959–1980 | 1513 | 735 | 0.004 | 0.0 | 0.0 | 0.004 | 0.003 | 0.829 | 0.141 | 0.654 | 0.008 | 0.008 | --- | 2.182 | 1.091 |



## Table A-5

## Sample Statistics for Pembina River Basin February Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 0.238 | 0.00003 | 0.00004 | 0.143 | 0.259 | 1.091 | 2.190 | 7.294 | 1.13 | 1.13 | 282 | 4.756 | 0.602 |
| 050B007 | Pembina River near Windygates | 18 | 1962–1980 | 7503 | 4477 | 0.188 | 0.00003 | 0.00004 | 0.075 | 0.307 | 1.633 | 2.740 | 10.31 | 1.26 | 1.26 | --- | 6.694 | 0.398 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 0.185 | 0.00003 | 0.00004 | 0.0 | 0.393 | 2.129 | 2.621 | 9.807 | 1.24 | 1.24 | --- | 6.714 | 0.0 |
| 050B001 | Pembina River near La Riviere | 14 | 1963–1977 | 5320 | 3367 | 0.195 | 0.00004 | 0.00006 | 0.015 | 0.459 | 2.359 | 2.383 | 14.10 | 1.74 | 1.74 | --- | 8.948 | 0.077 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 0.095 | 0.00002 | 0.00003 | 0.024 | 0.143 | 1.511 | 1.890 | 4.063 | 0.485 | 0.485 | --- | 5.128 | 0.254 |
| 050A007 | Badger Creek near Cartwright | 9 | 1959–1980 | 1513 | 735 | 0.002 | 0.0 | 0.0 | 0.001 | 0.004 | 1.624 | 2.115 | 7.460 | 0.012 | 0.012 | --- | 4.909 | 0.409 |

# Table A-6

## Sample Statistics for Pembina River Basin March Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max/Min | Max/$\bar{x}$ | Med/$\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 1.491 | 0.0002 | 0.0003 | 0.457 | 2.588 | 1.722 | 3.040 | 11.77 | 11.20 | 11.2 | 5600 | 7.513 | 0.307 |
| 050B007 | Pembina River near Windygates | 18 | 1962–1980 | 7503 | 4477 | 1.437 | 0.0002 | 0.0003 | 0.339 | 2.434 | 1.694 | 2.099 | 4.412 | 7.67 | 7.67 | --- | 5.339 | 0.236 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 1.138 | 0.0002 | 0.0003 | 0.593 | 1.630 | 1.432 | 1.914 | 5.359 | 4.99 | 4.99 | --- | 4.385 | 0.521 |
| 050B001 | Pembina River near La Riviere | 14 | 1963–1977 | 5320 | 3367 | 0.728 | 0.0001 | 0.0002 | 0.477 | 0.980 | 1.347 | 1.595 | 2.804 | 2.92 | 2.92 | --- | 4.012 | 0.655 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 0.643 | 0.0001 | 0.0002 | 0.049 | 1.366 | 2.124 | 2.693 | 10.25 | 4.34 | 4.34 | --- | 6.752 | 0.075 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 1.042 | 0.0002 | 0.0004 | 0.083 | 2.252 | 2.161 | 2.830 | 9.721 | 8.44 | 8.44 | 2813 | 8.101 | 0.080 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 0.329 | 0.0002 | 0.0004 | 0.007 | 1.023 | 3.109 | 4.029 | 18.47 | 4.59 | 4.59 | --- | 13.95 | 0.021 |
| 050B016 | Snowflake Creek near Snowflake | 19 | 1961–1980 | 980 | 245 | 0.098 | 0.0001 | 0.0004 | 0.013 | 0.172 | 1.758 | 2.353 | 8.279 | 0.624 | 0.624 | --- | 6.388 | 0.133 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.304 | 0.0005 | 0.0006 | 0.002 | 0.743 | 2.443 | 3.152 | 11.16 | 3.03 | 3.03 | --- | 9.966 | 0.007 |
| 050A010 | Pembina River above Lorne Lake | 18 | 1962–1980(S) | 542 | 360 | 0.345 | 0.0006 | 0.0010 | 0.039 | 0.837 | 2.425 | 3.521 | 14.84 | 3.49 | 3.49 | --- | 10.11 | 0.113 |
| 050A012 | Pembina River above Diversion | 13 | 1963–1976(S) | 485 | 328 | 0.419 | 0.0009 | 0.0013 | 0.035 | 0.913 | 2.178 | 2.830 | 10.31 | 3.21 | 3.21 | --- | 7.660 | 0.084 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.253 | 0.0006 | 0.0009 | 0.0 | 0.771 | 3.043 | 3.904 | 17.45 | 3.42 | 3.42 | --- | 13.51 | 0.0 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.349 | 0.0010 | 0.0012 | 0.029 | 0.711 | 2.038 | 3.117 | 12.22 | 3.06 | 3.06 | --- | 8.768 | 0.083 |
| 050B021 | Mowbray Creek near Mowbray | 18 | 1962–1980(S) | 262 | 168 | 0.148 | 0.0006 | 0.0009 | 0.0 | 0.372 | 2.510 | 2.906 | 9.676 | 1.41 | 1.41 | --- | 9.502 | 0.003 |
| 050A013 | Long River near Killarney | 9 | 1967–1976(S) | 209 | 180 | 0.211 | 0.0010 | 0.0012 | 0.003 | 0.389 | 1.846 | 2.369 | 8.956 | 1.18 | 1.18 | --- | 5.604 | 0.014 |
| 050B031 | Cypress Creek near Sarles | 18 | 1961–1980 | 149 | 133 | 0.144 | 0.0010 | 0.0014 | 0.0 | 0.332 | 2.303 | 2.548 | 7.023 | 1.17 | 1.17 | --- | 8.116 | 0.0 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.167 | 0.0011 | 0.0019 | 0.002 | 0.389 | 2.333 | 2.516 | 6.599 | 1.39 | 1.39 | --- | 8.328 | 0.009 |
| 050B025 | Pilot Creek near Pilot Mound | 17 | 1963–1980(S) | 147 | 103 | 0.071 | 0.0005 | 0.0007 | 0.0 | 0.189 | 2.384 | 2.365 | 5.769 | 0.549 | 0.549 | --- | 7.688 | 0.0 |
| 050B013 | Mary Jane Creek at La Riviere | 17 | 1960–1980(S) | 136 | 112 | 0.235 | 0.0017 | 0.0021 | 0.015 | 0.477 | 2.031 | 2.135 | 4.832 | 1.60 | 1.60 | --- | 6.815 | 0.064 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.066 | 0.0010 | 0.0011 | 0.0 | 0.168 | 2.529 | 3.244 | 12.74 | 0.688 | 0.688 | --- | 10.38 | 0.0 |

# Table A-7

## Sample Statistics for Pembina River Basin April Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max/Min | Max/$\bar{x}$ | Med/$\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 33.74 | 0.0040 | 0.0063 | 28.1 | 28.77 | 0.853 | 0.657 | 0.151 | 87.24 | 89.2 | 45.5 | 2.644 | 0.774 |
| 050B007 | Pembina River near Windygates | 18 | 1962–1980 | 7503 | 4477 | 28.50 | 0.0038 | 0.0064 | 17.2 | 29.25 | 1.026 | 1.065 | 0.734 | 87.50 | 88.1 | 146 | 3.091 | 0.602 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 22.84 | 0.0032 | 0.0055 | 11.0 | 28.76 | 1.259 | 2.113 | 6.987 | 91.77 | 95.0 | 29.4 | 4.159 | 0.483 |
| 050B001 | Pembina River near La Riviere | 14 | 1963–1977 | 5320 | 3367 | 24.79 | 0.0047 | 0.0074 | 12.3 | 29.42 | 1.187 | 1.333 | 1.658 | 88.94 | 89.1 | 564 | 3.595 | 0.496 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 18.55 | 0.0037 | 0.0059 | 10.3 | 24.13 | 1.301 | 2.366 | 8.677 | 80.18 | 81.7 | 53.8 | 4.404 | 0.556 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 23.53 | 0.0052 | 0.0086 | 11.7 | 28.55 | 1.128 | 1.293 | 1.349 | 80.13 | 80.2 | 1084 | 3.408 | 0.497 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 9.310 | 0.0062 | 0.0127 | 3.46 | 11.72 | 1.259 | 1.402 | 1.701 | 38.74 | 38.8 | 693 | 4.168 | 0.372 |
| 050B016 | Snowflake Creek near Snowflake | 19 | 1961–1980 | 980 | 245 | 2.653 | 0.0027 | 0.0108 | 1.31 | 2.880 | 1.085 | 0.830 | 0.070 | 8.36 | 8.37 | 1395 | 3.155 | 0.494 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 3.558 | 0.0062 | 0.0070 | 2.50 | 3.416 | 0.960 | 1.216 | 1.386 | 11.07 | 11.2 | 83.6 | 3.148 | 0.703 |
| 050A010 | Pembina River above Lorne Lake | 18 | 1962–1980(S) | 542 | 360 | 4.382 | 0.0081 | 0.0122 | 2.16 | 4.512 | 1.030 | 1.084 | 0.537 | 12.85 | 13.1 | 51.6 | 2.990 | 0.493 |
| 050A012 | Pembina River above Diversion | 13 | 1963–1976(S) | 485 | 328 | 4.970 | 0.0109 | 0.0152 | 3.17 | 4.871 | 0.980 | 0.870 | 0.265 | 12.60 | 12.9 | 43.7 | 2.596 | 0.638 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 3.211 | 0.0083 | 0.0114 | 2.29 | 3.370 | 1.050 | 1.168 | 1.196 | 10.89 | 10.9 | 2180 | 3.394 | 0.713 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 3.462 | 0.0098 | 0.0123 | 2.26 | 3.603 | 1.041 | 1.147 | 0.929 | 11.99 | 12.1 | 107 | 3.496 | 0.653 |
| 050B021 | Mowbray Creek near Mowbray | 18 | 1962–1980(S) | 262 | 168 | 2.204 | 0.0084 | 0.0131 | 1.98 | 2.035 | 0.923 | 0.547 | 0.163 | 5.85 | 5.88 | 196 | 2.667 | 0.898 |
| 050A013 | Long River near Killarney | 9 | 1967–1976(S) | 209 | 180 | 2.981 | 0.0143 | 0.0166 | 2.43 | 2.418 | 0.811 | 0.616 | 1.699 | 7.17 | 7.32 | 47.8 | 2.455 | 0.815 |
| 050B031 | Cypress Creek near Sarles | 18 | 1961–1980 | 149 | 133 | 1.460 | 0.0098 | 0.0110 | 0.820 | 1.563 | 1.071 | 0.985 | 0.604 | 4.83 | 4.83 | 4830 | 3.308 | 0.562 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 1.178 | 0.0076 | 0.0134 | 0.877 | 1.099 | 0.933 | 0.564 | 0.352 | 3.45 | 3.45 | 3450 | 2.930 | 0.744 |
| 050B025 | Pilot Creek near Pilot Mound | 17 | 1963–1980(S) | 147 | 103 | 1.218 | 0.0083 | 0.0118 | 0.601 | 1.361 | 1.117 | 1.451 | 2.490 | 4.65 | 4.65 | 2325 | 3.818 | 0.493 |
| 050B013 | Mary Jane Creek at La Riviere | 17 | 1960–1980(S) | 136 | 112 | 1.665 | 0.0122 | 0.0149 | 1.19 | 1.658 | 0.996 | 0.914 | 0.441 | 4.76 | 4.76 | ---- | 2.860 | 0.715 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.912 | 0.0134 | 0.0150 | 0.413 | 1.039 | 1.139 | 1.080 | 0.787 | 3.31 | 3.31 | ---- | 3.629 | 0.453 |

# Table A-8

## Sample Statistics for Pembina River Basin May Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max/Min | Max/$\bar{x}$ | Med/$\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 31.03 | 0.0037 | 0.0058 | 25.2 | 32.84 | 1.058 | 1.777 | 4.348 | 129.0 | 131 | 65.1 | 4.222 | 0.812 |
| 050B007 | Pembina River near Windygates | 18 | 1962–1980 | 7503 | 4477 | 27.59 | 0.0037 | 0.0062 | 19.1 | 28.58 | 1.036 | 1.441 | 2.740 | 101.0 | 102 | 104 | 3.697 | 0.692 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 16.57 | 0.0023 | 0.0040 | 13.9 | 14.54 | 0.878 | 1.178 | 2.936 | 45.80 | 47.4 | 29.4 | 2.861 | 0.837 |
| 050B001 | Pembina River near La Riviere | 14 | 1963–1977 | 5320 | 3367 | 22.86 | 0.0043 | 0.0068 | 16.6 | 20.95 | 0.916 | 1.257 | 3.305 | 75.47 | 76.4 | 62.6 | 3.343 | 0.724 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 17.53 | 0.0035 | 0.0056 | 13.8 | 13.87 | 0.791 | 0.788 | 1.429 | 42.05 | 42.7 | 65.6 | 2.436 | 0.790 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 15.83 | 0.0035 | 0.0058 | 13.2 | 15.17 | 0.959 | 0.901 | 0.790 | 49.82 | 49.9 | 601 | 3.153 | 0.834 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 2.834 | 0.0019 | 0.0039 | 1.50 | 3.887 | 1.371 | 1.703 | 3.161 | 13.89 | 13.9 | 1158 | 4.905 | 0.529 |
| 050B016 | Snowflake Creek near Snowflake | 19 | 1961–1980 | 980 | 245 | 2.284 | 0.0023 | 0.0093 | 1.23 | 3.353 | 1.468 | 2.015 | 4.497 | 11.10 | 11.1 | 5550 | 4.859 | 0.538 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 1.633 | 0.0028 | 0.0032 | 1.12 | 1.628 | 0.997 | 1.652 | 3.914 | 6.58 | 6.57 | 821 | 4.023 | 0.686 |
| 050A010 | Pembina River above Lorne Lake | 18 | 1962–1980(S) | 542 | 360 | 1.493 | 0.0028 | 0.0041 | 0.899 | 1.573 | 1.053 | 2.108 | 5.731 | 6.23 | 6.33 | 64.6 | 4.239 | 0.602 |
| 050A012 | Pembina River above Diversion | 13 | 1963–1976(S) | 485 | 328 | 1.583 | 0.0035 | 0.0048 | 1.11 | 1.491 | 0.942 | 1.729 | 4.217 | 5.25 | 5.41 | 33.4 | 3.418 | 0.701 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.413 | 0.0011 | 0.0015 | 0.098 | 0.671 | 1.625 | 2.088 | 4.611 | 2.40 | 2.40 | 2400 | 5.817 | 0.238 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 1.194 | 0.0034 | 0.0042 | 0.733 | 1.235 | 1.034 | 1.708 | 3.941 | 4.90 | 4.91 | 614 | 4.113 | 0.614 |
| 050B021 | Mowbray Creek near Mowbray | 18 | 1962–1980(S) | 262 | 168 | 0.698 | 0.0027 | 0.0042 | 0.213 | 1.157 | 1.658 | 2.483 | 7.963 | 4.51 | 4.51 | ---- | 6.465 | 0.305 |
| 050A013 | Long River near Killarney | 9 | 1967–1976(S) | 209 | 180 | 1.547 | 0.0074 | 0.0086 | 1.51 | 1.272 | 0.822 | 1.190 | 4.160 | 4.10 | 4.26 | 27.5 | 2.753 | 0.976 |
| 050B031 | Cypress Creek near Sarles | 18 | 1961–1980 | 149 | 133 | 0.164 | 0.0011 | 0.0012 | 0.041 | 0.288 | 1.753 | 3.115 | 12.68 | 1.21 | 1.21 | ---- | 7.376 | 0.250 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.143 | 0.0009 | 0.0016 | 0.028 | 0.317 | 2.221 | 3.448 | 13.97 | 1.36 | 1.36 | ---- | 9.530 | 0.196 |
| 050B025 | Pilot Creek near Pilot Mound | 17 | 1963–1980(S) | 147 | 103 | 0.411 | 0.0028 | 0.0040 | 0.203 | 0.647 | 1.575 | 2.814 | 10.46 | 2.62 | 2.62 | ---- | 6.382 | 0.494 |
| 050B013 | Mary Jane Creek at La Riviere | 17 | 1960–1980(S) | 136 | 112 | 0.332 | 0.0024 | 0.0030 | 0.124 | 0.545 | 1.640 | 2.456 | 6.478 | 1.91 | 1.93 | 102 | 5.807 | 0.373 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.186 | 0.0027 | 0.0031 | 0.037 | 0.334 | 1.792 | 2.273 | 6.143 | 1.24 | 1.24 | ---- | 6.653 | 0.199 |

# Table A-9

## Sample Statistics for Pembina River Basin June Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 13.08 | 0.0015 | 0.0024 | 10.1 | 12.76 | 0.975 | 1.791 | 4.208 | 49.26 | 50.3 | 48.4 | 3.845 | 0.772 |
| 050B007 | Pembina River near Windygates | 18 | 1962–1980 | 7503 | 4477 | 10.87 | 0.0014 | 0.0024 | 8.46 | 11.20 | 1.030 | 1.689 | 4.056 | 42.26 | 42.8 | 80.0 | 3.936 | 0.778 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 6.514 | 0.0009 | 0.0016 | 6.64 | 4.278 | 0.657 | 0.061 | 0.763 | 12.69 | 13.4 | 18.9 | 2.057 | 1.019 |
| 050B001 | Pembina River near La Riviere | 14 | 1963–1977 | 5320 | 3367 | 9.650 | 0.0018 | 0.0029 | 8.32 | 9.602 | 0.995 | 1.704 | 4.873 | 35.30 | 35.6 | 118 | 3.689 | 0.862 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 7.450 | 0.0015 | 0.0024 | 5.74 | 6.821 | 0.916 | 2.114 | 7.865 | 24.47 | 24.9 | 58.2 | 3.342 | 0.771 |
| 050B023 | Pembina River below Crystal Creek | 17 | 1962–1980(S) | 4487 | 2729 | 6.051 | 0.0013 | 0.0022 | 5.60 | 6.535 | 1.080 | 1.516 | 2.887 | 21.54 | 21.6 | 354 | 3.570 | 0.925 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 0.993 | 0.0007 | 0.0014 | 0.495 | 1.399 | 1.409 | 2.293 | 6.355 | 5.58 | 5.58 | 5580 | 5.619 | 0.498 |
| 050B016 | Snowflake Creek near Snowflake | 19 | 1961–1980 | 980 | 245 | 0.582 | 0.0006 | 0.0024 | 0.157 | 0.928 | 1.591 | 2.235 | 5.983 | 3.48 | 3.48 | --- | 5.970 | 0.270 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.891 | 0.0015 | 0.0018 | 0.560 | 0.812 | 0.910 | 0.856 | 0.482 | 2.64 | 2.64 | 528 | 2.962 | 0.628 |
| 050A010 | Pembina River above Lorne Lake | 18 | 1962–1980(S) | 542 | 360 | 0.612 | 0.0011 | 0.0017 | 0.487 | 0.610 | 0.997 | 1.979 | 6.618 | 2.54 | 2.56 | 160 | 4.183 | 0.796 |
| 050A012 | Pembina River above Diversion | 13 | 1963–1976(S) | 485 | 328 | 0.634 | 0.0014 | 0.0019 | 0.410 | 0.517 | 0.816 | 1.171 | 2.920 | 1.84 | 1.89 | 36.3 | 2.982 | 0.647 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.339 | 0.0009 | 0.0012 | 0.041 | 0.903 | 2.662 | 3.311 | 12.07 | 3.71 | 3.71 | +-- | 10.94 | 0.121 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.599 | 0.0017 | 0.0021 | 0.427 | 0.619 | 1.034 | 1.655 | 4.157 | 2.51 | 2.51 | --- | 4.193 | 0.713 |
| 050B021 | Mowbray Creek near Mowbray | 18 | 1962–1980(S) | 262 | 168 | 0.127 | 0.0005 | 0.0008 | 0.042 | 0.207 | 1.628 | 2.376 | 6.850 | 0.784 | 0.784 | --- | 6.168 | 0.330 |
| 050A013 | Long River near Killarney | 9 | 1967–1976(S) | 209 | 180 | 0.754 | 0.0036 | 0.0042 | 0.716 | 0.473 | 0.627 | 0.059 | 1.114 | 1.45 | 1.46 | 146 | 1.936 | 0.950 |
| 050B031 | Cypress Creek near Sarles | 18 | 1961–1980 | 149 | 133 | 0.282 | 0.0019 | 0.0021 | 0.005 | 0.821 | 2.909 | 3.457 | 13.96 | 3.32 | 3.32 | --- | 11.77 | 0.018 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.035 | 0.0002 | 0.0004 | 0.001 | 0.097 | 2.756 | 3.792 | 16.79 | 0.422 | 0.423 | --- | 12.05 | 0.028 |
| 050B025 | Pilot Creek near Pilot Mound | 17 | 1963–1980(S) | 147 | 103 | 0.087 | 0.0006 | 0.0008 | 0.008 | 0.145 | 1.675 | 1.659 | 2.208 | 0.409 | 0.409 | --- | 4.730 | 0.093 |
| 050B013 | Mary Jane Creek at La Riviere | 17 | 1960–1980(S) | 136 | 112 | 0.062 | 0.0005 | 0.0005 | 0.040 | 0.047 | 0.764 | 0.804 | 0.338 | 0.154 | 0.165 | 15.0 | 2.679 | 0.649 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.036 | 0.0005 | 0.0006 | 0.008 | 0.065 | 1.817 | 2.192 | 5.269 | 0.231 | 0.231 | --- | 6.454 | 0.224 |

# Table A-10

## Sample Statistics for Pembina River Basin July Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 5.879 | 0.0007 | 0.0011 | 5.14 | 5.443 | 0.926 | 1.725 | 4.374 | 22.58 | 22.9 | 72.01 | 3.895 | 0.874 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 4.406 | 0.0006 | 0.0010 | 3.24 | 4.518 | 1.025 | 1.695 | 4.261 | 17.86 | 17.9 | 407 | 4.063 | 0.735 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 2.647 | 0.0004 | 0.0006 | 2.18 | 2.204 | 0.832 | 1.140 | 3.698 | 7.44 | 7.52 | 94.0 | 2.841 | 0.825 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 4.138 | 0.0008 | 0.0012 | 3.20 | 3.823 | 0.924 | 1.181 | 2.350 | 13.55 | 13.6 | 296 | 3.287 | 0.773 |
| 050B019 | Pembina River near Swan Lake | 11 | 1962–1972(S) | 4983 | 3127 | 4.481 | 0.0009 | 0.0014 | 2.61 | 4.069 | 0.908 | 1.798 | 5.581 | 14.20 | 14.7 | 29.7 | 3.281 | 0.583 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 2.573 | 0.0006 | 0.0009 | 1.36 | 3.008 | 1.168 | 1.669 | 3.225 | 10.45 | 10.5 | 202 | 4.081 | 0.529 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 0.618 | 0.0004 | 0.0008 | 0.121 | 1.246 | 2.016 | 2.490 | 6.612 | 4.69 | 4.69 | --- | 7.587 | 0.196 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.212 | 0.0002 | 0.0009 | 0.028 | 0.296 | 1.397 | 1.435 | 2.025 | 0.990 | 0.990 | --- | 4.672 | 0.120 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.367 | 0.0006 | 0.0007 | 0.181 | 0.543 | 1.481 | 2.381 | 6.873 | 2.16 | 2.16 | --- | 5.891 | 0.494 |
| 050A010 | Pembina River above Lorne Lake | 19 | 1962–1980(S) | 542 | 360 | 0.255 | 0.0005 | 0.0007 | 0.121 | 0.250 | 0.980 | 1.051 | 0.833 | 0.803 | 0.808 | 162 | 3.171 | 0.475 |
| 050A012 | Pembina River above Diversion | 14 | 1963–1976(S) | 485 | 328 | 0.332 | 0.0007 | 0.0010 | 0.182 | 0.436 | 1.314 | 2.230 | 7.097 | 1.58 | 1.61 | 48.8 | 4.851 | 0.548 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.147 | 0.0004 | 0.0005 | 0.006 | 0.294 | 1.994 | 2.403 | 6.992 | 1.14 | 1.14 | --- | 7.733 | 0.041 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.251 | 0.0007 | 0.0009 | 0.048 | 0.473 | 1.888 | 2.940 | 10.69 | 2.00 | 2.00 | --- | 7.977 | 0.191 |
| 050B021 | Mowbray Creek near Mowbray | 19 | 1962–1980(S) | 262 | 168 | 0.066 | 0.0003 | 0.0004 | 0.009 | 0.145 | 2.215 | 3.290 | 13.05 | 0.606 | 0.606 | --- | 9.248 | 0.137 |
| 050A013 | Long River near Killarney | 10 | 1967–1976(S) | 209 | 180 | 0.288 | 0.0014 | 0.0016 | 0.169 | 0.370 | 1.286 | 1.549 | 3.109 | 1.03 | 1.03 | 1030 | 3.575 | 0.587 |
| 050B031 | Cypress Creek near Sarles | 19 | 1961–1980 | 149 | 133 | 0.112 | 0.0007 | 0.0008 | 0.002 | 0.260 | 2.329 | 2.347 | 5.437 | 0.861 | 0.861 | --- | 7.713 | 0.018 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.006 | 0.00004 | 0.00007 | 0.0 | 0.014 | 2.404 | 2.673 | 7.874 | 0.052 | 0.052 | --- | 9.044 | 0.0 |
| 050B025 | Pilot Creek near Pilot Mound | 18 | 1963–1980(S) | 147 | 103 | 0.040 | 0.0003 | 0.0004 | 0.004 | 0.093 | 2.303 | 2.727 | 7.867 | 0.332 | 0.332 | --- | 8.209 | 0.087 |
| 050B013 | Mary Jane Creek at La Riviere | 18 | 1960–1980(S) | 136 | 112 | 0.072 | 0.0005 | 0.0006 | 0.020 | 0.123 | 1.703 | 2.256 | 5.226 | 0.410 | 0.413 | 138 | 5.736 | 0.278 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.062 | 0.0009 | 0.0010 | 0.0 | 0.145 | 2.327 | 2.821 | 8.988 | 0.551 | 0.551 | --- | 8.857 | 0.0 |

# Table A-11

## Sample Statistics for Pembina River Basin August Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 2.985 | 0.0004 | 0.0006 | 2.41 | 2.308 | 0.773 | 1.187 | 2.303 | 9.06 | 9.13 | 134.3 | 3.057 | 0.807 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 2.544 | 0.0003 | 0.0006 | 1.87 | 2.266 | 0.891 | 1.403 | 2.521 | 8.26 | 8.27 | 919 | 3.251 | 0.735 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 1.840 | 0.0003 | 0.0004 | 1.85 | 1.212 | 0.659 | 0.031 | 0.975 | 3.80 | 3.81 | 254 | 2.071 | 1.006 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 2.351 | 0.0004 | 0.0007 | 1.74 | 1.821 | 0.775 | 0.843 | 1.383 | 6.47 | 6.48 | 926 | 2.757 | 0.740 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 2.763 | 0.0006 | 0.0009 | 2.48 | 2.034 | 0.736 | 1.017 | 2.805 | 6.81 | 6.89 | 85.1 | 2.493 | 0.890 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 1.027 | 0.0002 | 0.0004 | 0.440 | 1.251 | 1.218 | 1.123 | 0.631 | 3.56 | 3.57 | 714 | 3.476 | 0.428 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 0.305 | 0.0002 | 0.0004 | 0.027 | 0.645 | 2.118 | 3.215 | 12.86 | 2.79 | 2.79 | ---- | 9.163 | 0.089 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.079 | 0.0001 | 0.0003 | 0.007 | 0.109 | 1.379 | 1.177 | 0.734 | 0.312 | 0.312 | ---- | 3.957 | 0.082 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.152 | 0.0003 | 0.0003 | 0.066 | 0.216 | 1.425 | 1.621 | 2.071 | 0.652 | 0.652 | ---- | 4.304 | 0.436 |
| 050A010 | Pembina River above Lorne Lake | 19 | 1962–1980(S) | 542 | 360 | 0.189 | 0.0003 | 0.0005 | 0.057 | 0.296 | 1.561 | 2.147 | 5.024 | 1.06 | 1.07 | 214 | 5.649 | 0.301 |
| 050A012 | Pembina River above Diversion | 14 | 1963–1976(S) | 485 | 328 | 0.147 | 0.0003 | 0.0004 | 0.040 | 0.268 | 1.820 | 2.723 | 9.751 | 0.979 | 0.985 | 164 | 6.684 | 0.271 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.081 | 0.0002 | 0.0003 | 0.0 | 0.194 | 2.393 | 2.648 | 7.494 | 0.718 | 0.718 | ---- | 8.854 | 0.0 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.071 | 0.0002 | 0.0003 | 0.022 | 0.119 | 1.681 | 2.658 | 8.956 | 0.492 | 0.492 | ---- | 6.958 | 0.311 |
| 050B021 | Mowbray Creek near Mowbray | 19 | 1962–1980(S) | 262 | 168 | 0.015 | 0.0001 | 0.0001 | 0.0 | 0.029 | 1.895 | 2.445 | 7.864 | 0.113 | 0.113 | ---- | 7.378 | 0.0 |
| 050A013 | Long River near Killarney | 10 | 1967–1976(S) | 209 | 180 | 0.082 | 0.0004 | 0.0005 | 0.017 | 0.125 | 1.523 | 1.597 | 3.240 | 0.342 | 0.342 | ---- | 4.181 | 0.202 |
| 050B031 | Cypress Creek near Sarles | 19 | 1961–1980 | 149 | 133 | 0.042 | 0.0003 | 0.0003 | 0.0 | 0.117 | 2.766 | 3.179 | 11.83 | 0.467 | 0.467 | ---- | 11.05 | 0.0 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.038 | 0.0002 | 0.0004 | 0.0 | 0.166 | 4.327 | 4.465 | 21.79 | 0.743 | 0.743 | ---- | 19.37 | 0.0 |
| 050B025 | Pilot Creek near Pilot Mound | 18 | 1963–1980(S) | 147 | 103 | 0.018 | 0.0001 | 0.0002 | 0.001 | 0.067 | 3.674 | 4.210 | 19.74 | 0.285 | 0.285 | ---- | 15.69 | 0.055 |
| 050B013 | Mary Jane Creek at La Riviere | 18 | 1960–1980(S) | 136 | 112 | 0.065 | 0.0008 | 0.0006 | 0.011 | 0.220 | 3.366 | 4.228 | 19.86 | 0.944 | 0.944 | ---- | 14.47 | 0.169 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.028 | 0.0004 | 0.0005 | 0.0 | 0.111 | 3.937 | 4.325 | 20.70 | 0.484 | 0.484 | ---- | 17.22 | 0.0 |

# Table A-12

## Sample Statistics for Pembina River Basin September Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean gross da | mean eff. da | Md | S | Cv | Cs | Ce | R | Max | Max/Min | Max/$\bar{x}$ | Med/$\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 2.356 | 0.0003 | 0.0004 | 1.75 | 2.131 | 0.905 | 2.234 | 7.586 | 9.61 | 9.71 | 94.3 | 4.121 | 0.743 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 1.993 | 0.0003 | 0.0004 | 1.29 | 2.109 | 1.058 | 2.373 | 8.592 | 9.19 | 9.21 | 542 | 4.621 | 0.647 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 2.324 | 0.0003 | 0.0006 | 1.27 | 3.318 | 1.427 | 2.616 | 10.27 | 11.28 | 11.3 | 513 | 4.862 | 0.544 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 1.975 | 0.0004 | 0.0006 | 1.49 | 2.482 | 1.257 | 2.884 | 11.40 | 10.08 | 10.2 | 85.71 | 5.166 | 0.755 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 2.378 | 0.0005 | 0.0007 | 1.80 | 2.992 | 1.258 | 2.628 | 10.49 | 10.46 | 10.5 | 263 | 4.416 | 0.759 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 1.029 | 0.0002 | 0.0004 | 0.118 | 2.966 | 2.883 | 4.104 | 19.05 | 12.79 | 12.8 | 2133 | 12.44 | 0.114 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 0.245 | 0.0002 | 0.0003 | 0.024 | 0.738 | 3.014 | 4.199 | 19.90 | 3.37 | 3.37 | --- | 13.76 | 0.098 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.047 | 0.00005 | 0.0002 | 0.006 | 0.071 | 1.509 | 1.709 | 2.821 | 0.233 | 0.233 | --- | 4.963 | 0.117 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.122 | 0.0002 | 0.0002 | 0.030 | 0.281 | 2.302 | 3.875 | 17.66 | 1.28 | 1.28 | --- | 10.50 | 0.246 |
| 050A010 | Pembina River above Lorne Lake | 19 | 1962–1980(S) | 542 | 360 | 0.138 | 0.0003 | 0.0004 | 0.024 | 0.323 | 2.338 | 3.931 | 18.00 | 1.43 | 1.43 | --- | 10.34 | 0.174 |
| 050A012 | Pembina River above Diversion | 14 | 1963–1976(S) | 485 | 328 | 0.088 | 0.0002 | 0.0003 | 0.013 | 0.146 | 1.702 | 2.078 | 5.44 | 0.489 | 0.489 | --- | 5.696 | 0.151 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.028 | 0.0001 | 0.0001 | 0.0 | 0.112 | 4.285 | 4.562 | 22.65 | 0.513 | 0.513 | --- | 19.59 | 0.0 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.082 | 0.0002 | 0.0003 | 0.003 | 0.183 | 2.218 | 2.838 | 9.590 | 0.738 | 0.738 | --- | 8.958 | 0.036 |
| 050B021 | Mowbray Creek near Mowbray | 19 | 1962–1980(S) | 262 | 168 | 0.021 | 0.0001 | 0.0001 | 0.0 | 0.058 | 2.628 | 3.202 | 12.20 | 0.228 | 0.228 | --- | 10.62 | 0.0 |
| 050A013 | Long River near Killarney | 10 | 1967–1976(S) | 209 | 180 | 0.079 | 0.0004 | 0.0004 | 0.015 | 0.174 | 2.196 | 2.920 | 11.71 | 0.563 | 0.563 | --- | 7.109 | 0.183 |
| 050B031 | Cypress Creek near Sarles | 19 | 1961–1980 | 149 | 133 | 0.019 | 0.0001 | 0.0001 | 0.0 | 0.077 | 4.143 | 4.343 | 20.80 | 0.337 | 0.337 | --- | 18.09 | 0.0 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.007 | 0.00005 | 0.0001 | 0.0 | 0.028 | 4.078 | 4.418 | 21.50 | 0.126 | 0.126 | --- | 18.26 | 0.0 |
| 050B025 | Pilot Creek near Pilot Mound | 18 | 1963–1980(S) | 147 | 103 | 0.033 | 0.0002 | 0.0003 | 0.001 | 0.084 | 2.514 | 3.161 | 11.80 | 0.330 | 0.330 | --- | 9.450 | 0.030 |
| 050B013 | Mary Jane Creek at La Riviere | 18 | 1960–1980(S) | 136 | 112 | 0.032 | 0.0002 | 0.0003 | 0.012 | 0.071 | 2.225 | 3.911 | 17.71 | 0.311 | 0.311 | --- | 9.685 | 0.389 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.028 | 0.0004 | 0.0005 | 0.0 | 0.108 | 3.830 | 4.319 | 20.61 | 0.474 | 0.474 | --- | 16.77 | 0.0 |

# Table A-13

## Sample Statistics for Pembina River Basin October Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 1.875 | 0.0002 | 0.0003 | 1.29 | 2.188 | 1.167 | 3.582 | 15.90 | 10.58 | 10.7 | 89.2 | 5.708 | 0.688 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 1.518 | 0.0002 | 0.0003 | 1.09 | 2.099 | 1.383 | 3.613 | 16.14 | 9.66 | 9.71 | 187 | 6.395 | 0.718 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 1.850 | 0.0003 | 0.0004 | 0.637 | 3.411 | 1.843 | 2.977 | 12.12 | 11.39 | 11.4 | 1629 | 6.161 | 0.344 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 1.485 | 0.0003 | 0.0004 | 0.746 | 2.314 | 1.559 | 3.299 | 13.80 | 9.39 | 9.47 | 127 | 6.378 | 0.502 |
| 050B019 | Pembina River near Swan Lake | 10 | 1962–1972(S) | 4983 | 3127 | 1.522 | 0.0003 | 0.0005 | 0.784 | 2.317 | 1.522 | 2.743 | 10.93 | 7.85 | 7.87 | 394 | 5.170 | 0.515 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 0.467 | 0.0001 | 0.0002 | 0.090 | 1.520 | 2.473 | 3.874 | 17.50 | 4.94 | 4.95 | 550 | 10.63 | 0.193 |
| 050A007 | Badger Creek near Cartwright | 21 | 1959–1980 | 1513 | 735 | 0.092 | 0.0001 | 0.0001 | 0.019 | 0.154 | 1.671 | 2.362 | 7.134 | 0.616 | 0.616 | ---- | 6.689 | 0.206 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.041 | 0.00004 | 0.0002 | 0.002 | 0.082 | 2.002 | 3.049 | 11.91 | 0.347 | 0.347 | ---- | 8.463 | 0.037 |
| 050A006 | Long River near Holmfield | 21 | 1959–1980(S) | 576 | 505 | 0.102 | 0.0002 | 0.0002 | 0.061 | 0.126 | 1.234 | 1.828 | 4.543 | 0.496 | 0.496 | ---- | 4.863 | 0.598 |
| 050A010 | Pembina River above Lorne Lake | 19 | 1962–1980(S) | 542 | 360 | 0.105 | 0.0002 | 0.0003 | 0.031 | 0.132 | 1.282 | 1.536 | 2.658 | 0.463 | 0.464 | 464 | 4.435 | 0.296 |
| 050A012 | Pembina River above Diversion | 14 | 1963–1976(S) | 485 | 328 | 0.110 | 0.0002 | 0.0003 | 0.032 | 0.159 | 1.448 | 1.696 | 4.049 | 0.530 | 0.530 | ---- | 4.834 | 0.287 |
| 050B010 | Cypress Creek near Clearwater | 21 | 1959–1980(S) | 388 | 282 | 0.002 | 0.0 | 0.0 | 0.0 | 0.007 | 4.044 | 4.540 | 22.50 | 0.031 | 0.031 | ---- | 18.60 | 0.0 |
| 050A008 | Pembina River near Killarney | 21 | 1959–1980(S) | 354 | 281 | 0.097 | 0.0003 | 0.0003. | 0.005 | 0.213 | 2.191 | 3.271 | 13.20 | 0.923 | 0.923 | ---- | 9.474 | 0.051 |
| 050B021 | Mowbray Creek near Mowbray | 19 | 1962–1980(S) | 262 | 168 | 0.015 | 0.0001 | 0.0001 | 0.0 | 0.043 | 2.910 | 2.812 | 7.851 | 0.146 | 0.146 | ---- | 9.802 | 0.0 |
| 050A013 | Long River near Killarney | 10 | 1967–1976(S) | 209 | 180 | 0.081 | 0.0004 | 0.0005 | 0.052 | 0.086 | 1.058 | 0.737 | 1.124 | 0.244 | 0.244 | ---- | 2.998 | 0.639 |
| 050B031 | Cypress Creek near Sarles | 19 | 1961–1980 | 149 | 133 | 0.001 | 0.0 | 0.0 | 0.0 | 0.003 | 3.037 | 2.940 | 9.000 | 0.011 | 0.011 | ---- | 11.00 | 0.0 |
| 050B006 | Crystal Creek near Crystal City | 20 | 1959–1980(S) | 154 | 88.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | ---- | 0.0 | 0.0 |
| 050B025 | Pilot Creek near Pilot Mound | 18 | 1963–1980(S) | 147 | 103 | 0.008 | 0.0001 | 0.0001 | 0.0 | 0.021 | 2.733 | 2.802 | 8.126 | 0.075 | 0.075 | ---- | 9.574 | 0.0 |
| 050B013 | Mary Jane Creek at La Riviere | 18 | 1960–1980(S) | 136 | 112 | 0.017 | 0.0001 | 0.0002 | 0.013 | 0.017 | 1.007 | 1.814 | 4.760 | 0.068 | 0.068 | ---- | 3.987 | 0.733 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.003 | 0.00004 | 0.00005 | 0.0 | 0.008 | 2.728 | 3.200 | 12.12 | 0.030 | 0.030 | ---- | 10.96 | 0.0 |

## Table A-14

## Sample Statistics for Pembina River Basin November Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 1.095 | 0.0001 | 0.0002 | 0.778 | 1.131 | 1.033 | 3.034 | 12.27 | 5.32 | 5.41 | 82.0 | 4.940 | 0.710 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 0.851 | 0.0001 | 0.0002 | 0.594 | 1.066 | 1.252 | 3.141 | 13.10 | 4.76 | 4.83 | 72.1 | 5.682 | 0.698 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 0.876 | 0.0001 | 0.0002 | 0.331 | 1.420 | 1.621 | 2.723 | 10.70 | 4.75 | 4.75 | ---- | 5.425 | 0.378 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 0.780 | 0.0001 | 0.0002 | 0.392 | 0.988 | 1.267 | 2.707 | 10.47 | 3.97 | 4.00 | 121 | 5.126 | 0.502 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 0.164 | 0.00004 | 0.0001 | 0.055 | 0.207 | 1.262 | 1.490 | 2.337 | 0.700 | 0.701 | 701 | 4.282 | 0.336 |
| 050A007 | Badger Creek near Cartwright | 10 | 1959–1980 | 1513 | 735 | 0.057 | 0.00004 | 0.0001 | 0.015 | 0.095 | 1.663 | 2.129 | 6.570 | 0.293 | 0.293 | ---- | 5.113 | 0.253 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.021 | 0.00002 | 0.0001 | 0.001 | 0.042 | 1.992 | 2.184 | 5.021 | 0.148 | 0.148 | ---- | 7.048 | 0.024 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.001 | 0.00001 | 0.00002 | 0.0 | 0.004 | 3.388 | 3.771 | 16.41 | 0.015 | 0.015 | ---- | 14.25 | 0.0 |



## Table A-15

## Sample Statistics for Pembina River Basin December Monthly Mean Flows

| STATION NUMBER | HYDROMETRIC STATION NAME | YEARS OF RECORD IN SAMPLE | PERIOD OF RECORD | DRAINAGE AREA | | mean | mean / gross da | mean / eff. da | Md | S | Cv | Cs | Ce | R | Max | Max / Min | Max / $\bar{x}$ | Med / $\bar{x}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | GROSS ($km^2$) | EFFECTIVE ($km^2$) | ($m^3/s$) | ($m^3/s/km^2$) | ($m^3/s/km^2$) | ($m^3/s$) | ($m^3/s$) | | | | ($m^3/s$) | ($m^3/s$) | | | |
| 050C004 | Pembina River near Neche | 21 | 1903–1980 | 8474 | 5382 | 0.444 | 0.00005 | 0.00008 | 0.240 | 0.398 | 0.891 | 1.445 | 2.952 | 1.57 | 1.60 | 59.3 | 3.600 | 0.540 |
| 050B007 | Pembina River near Windygates | 19 | 1962–1980 | 7503 | 4477 | 0.358 | 0.00005 | 0.00008 | 0.254 | 0.376 | 1.050 | 1.235 | 1.552 | 1.27 | 1.28 | 213 | 3.576 | 0.710 |
| 050B008 | Pembina River near Kaleida | 10 | 1957–1969 | 7132 | 4188 | 0.348 | 0.00005 | 0.00008 | 0.093 | 0.445 | 1.279 | 1.368 | 3.367 | 1.33 | 1.33 | ---- | 3.825 | 0.268 |
| 050B001 | Pembina River near La Riviere | 15 | 1963–1977 | 5320 | 3367 | 0.288 | 0.00005 | 0.00009 | 0.178 | 0.350 | 1.216 | 1.563 | 3.682 | 1.21 | 1.23 | 58.6 | 4.274 | 0.618 |
| 050B023 | Pembina River below Crystal Creek | 18 | 1962–1980(S) | 4487 | 2729 | 0.143 | 0.00003 | 0.00005 | 0.025 | 0.267 | 1.864 | 2.788 | 9.675 | 1.06 | 1.06 | 1060 | 7.393 | 0.171 |
| 050A007 | Badger Creek near Cartwright | 10 | 1959–1980 | 1513 | 735 | 0.012 | 0.00001 | 0.00002 | 0.008 | 0.013 | 1.040 | 1.069 | 1.893 | 0.037 | 0.037 | ---- | 3.033 | 0.615 |
| 050B016 | Snowflake Creek near Snowflake | 20 | 1961–1980 | 980 | 245 | 0.001 | 0.0 | 0.0 | 0.0 | 0.003 | 2.712 | 2.897 | 8.790 | 0.012 | 0.012 | ---- | 10.00 | 0.0 |
| 050A005 | Hidden Island Coulee near Hansboro | 19 | 1962–1980 | 68.1 | 60.9 | 0.0001 | 0.0 | 0.0 | 0.0 | 0.0002 | 4.359 | 4.359 | 20.91 | 0.001 | 0.001 | ---- | 19.00 | 0.0 |

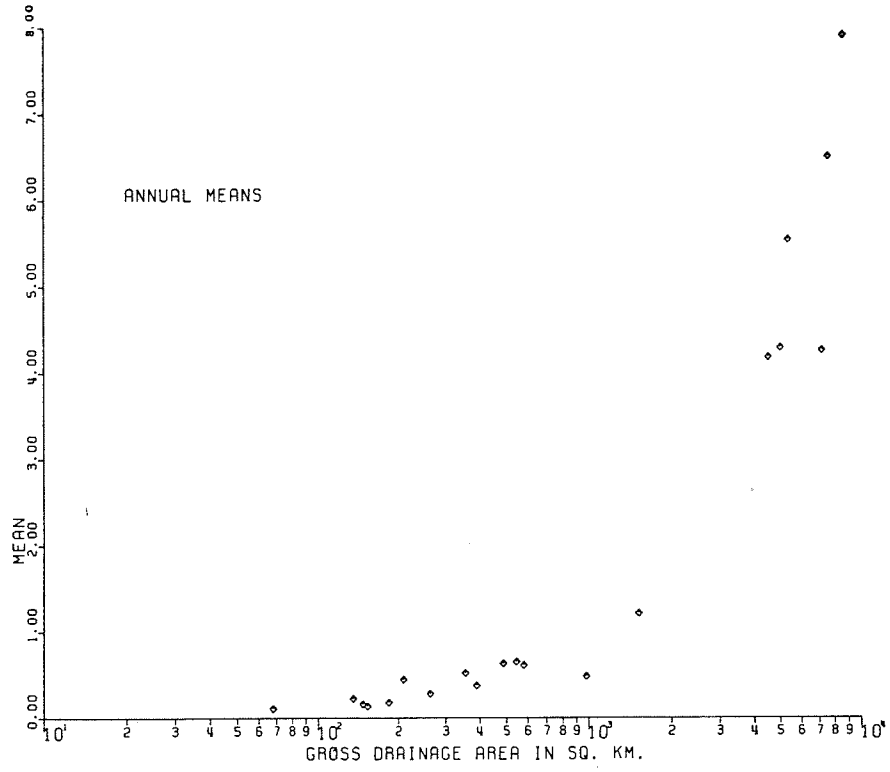



Figure A-1

Annual Mean Flows
Sample Mean versus Gross Drainage Area

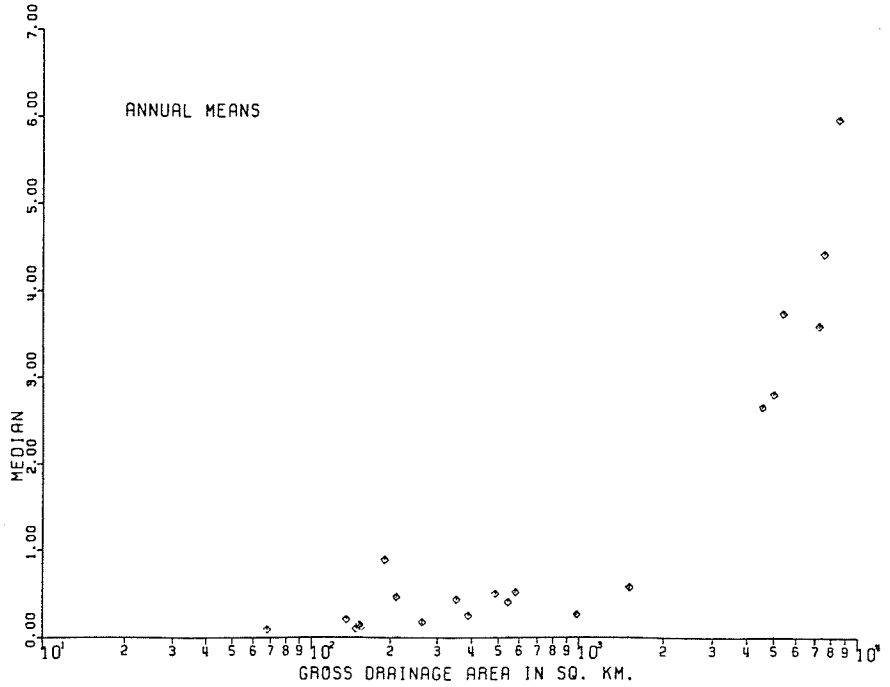



Figure A-2

Annual Mean Flows
Sample Median versus Gross Drainage Area

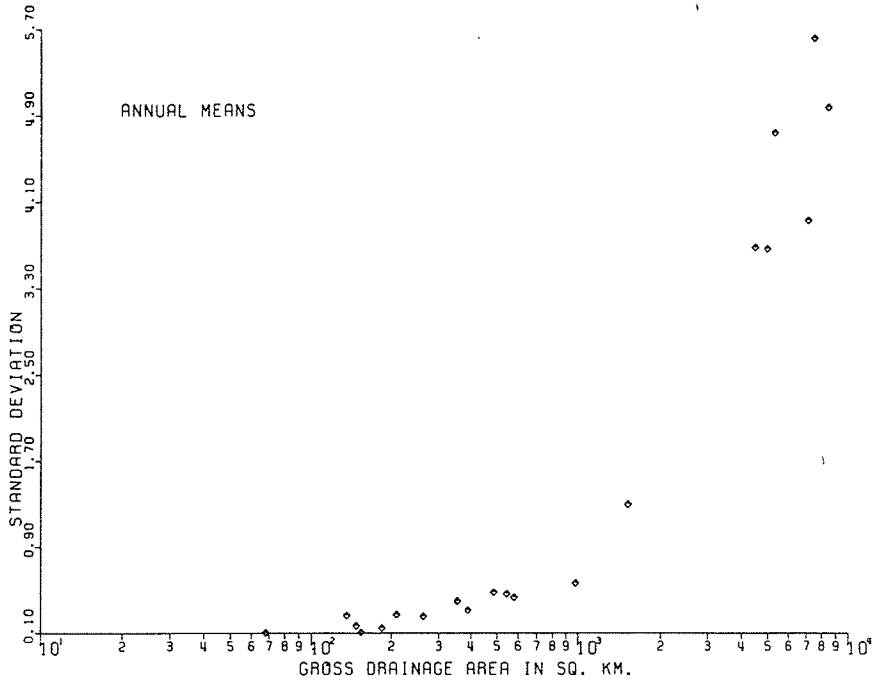



Figure A-3

Annual Mean Flows
Sample Standard Deviation
versus Gross Drainage Area

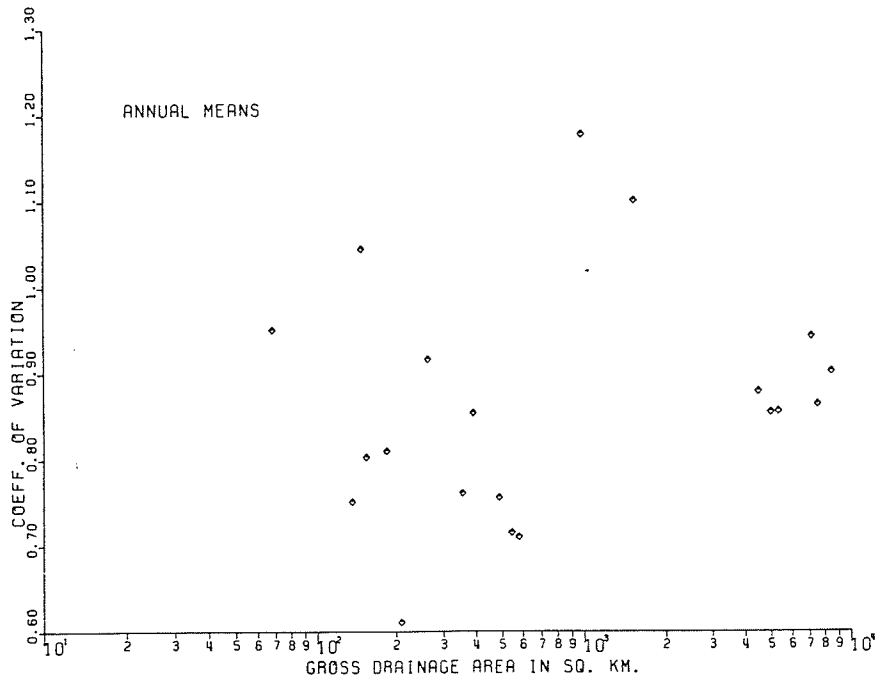



Figure A-4

Annual Mean Flows
Sample Coefficient of Variation
versus Gross Drainage Area

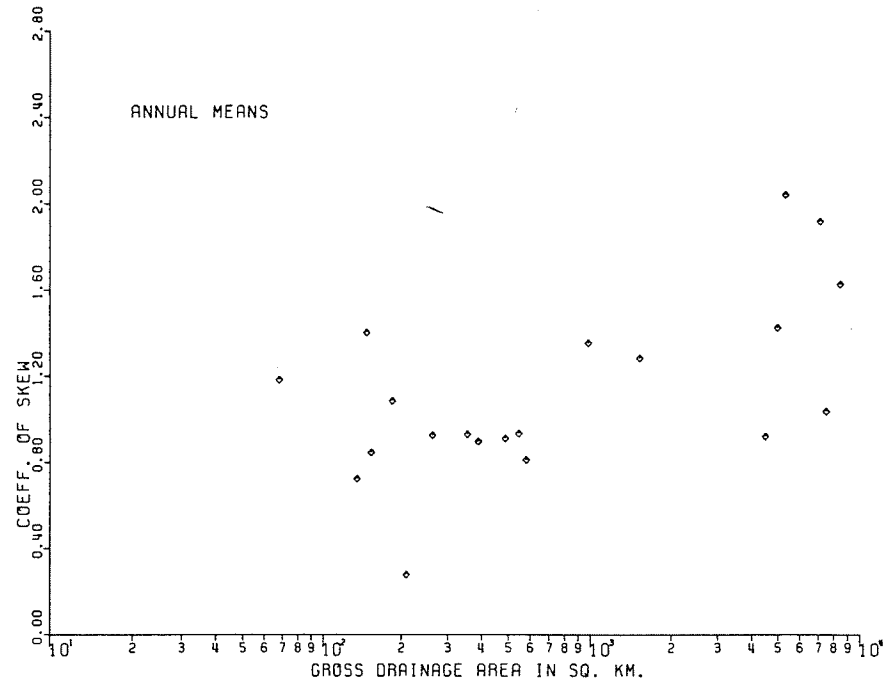



Figure A-5

Annual Mean Flows
Sample Coefficient of Skew
versus Gross Drainage Area

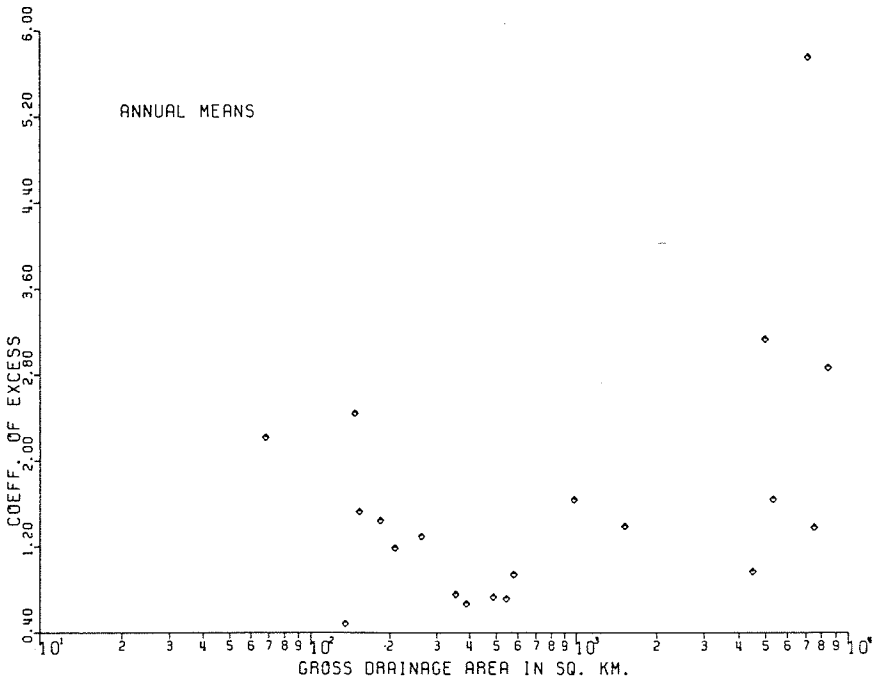



Figure A-6

Annual Mean Flows
Sample Coefficient of Excess
versus Gross Drainage Area

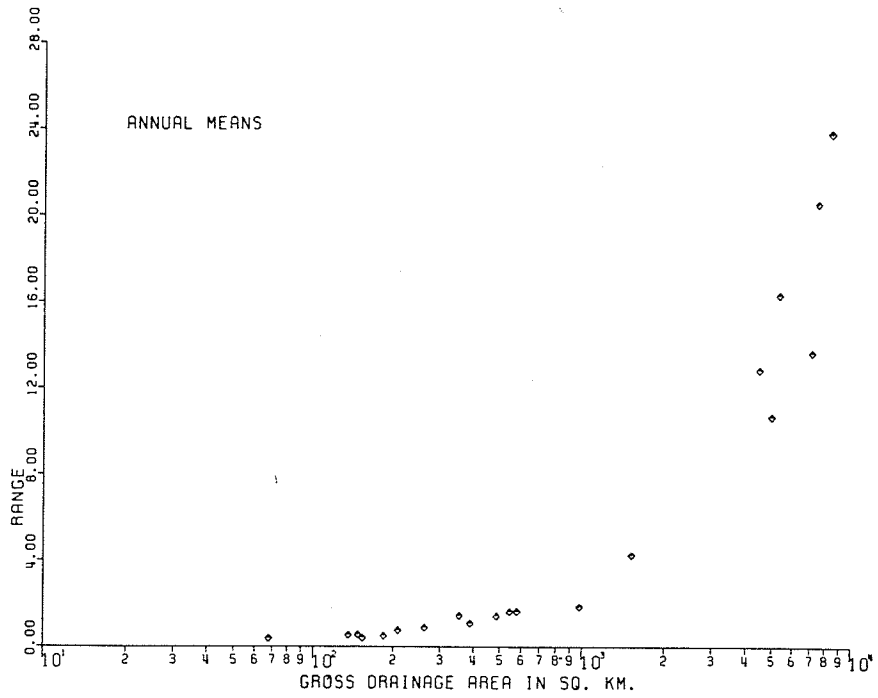



Figure A-7

Annual Mean Flows
Sample Range versus Gross Drainage Area

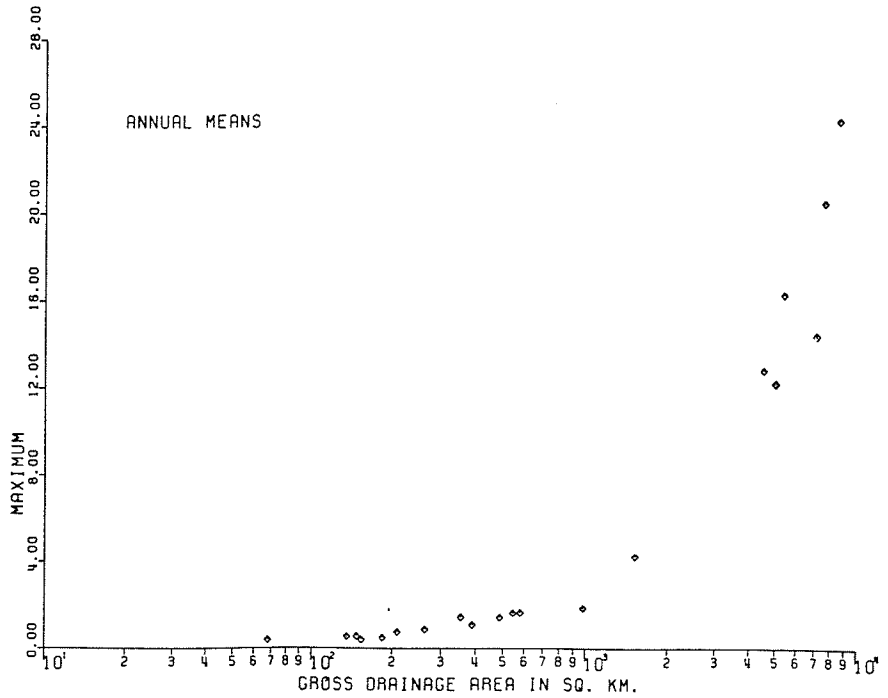



Figure A-8

Annual Mean Flows
Sample Maximum versus Gross Drainage Area

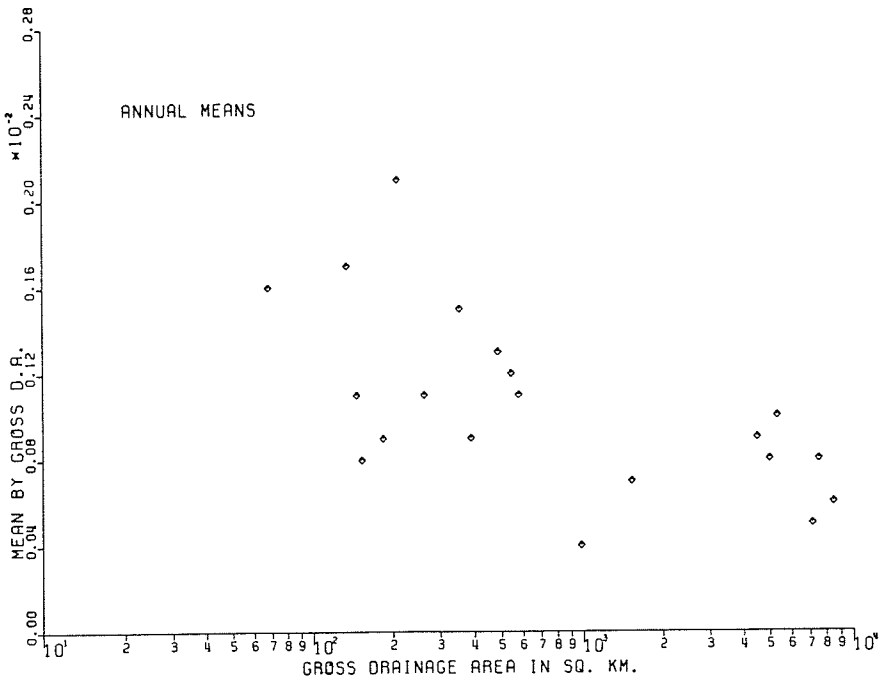



Figure A-9

Annual Mean Flows
Sample Yield (Mean/Gross Drainage Area)
versus Gross Drainage Area

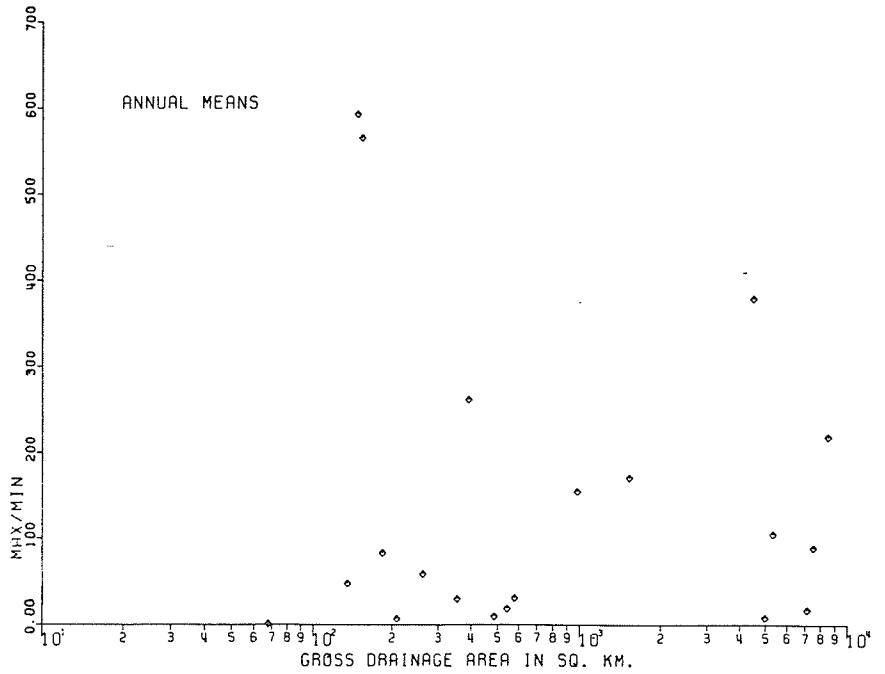



Figure A-10

Annual Mean Flows
Sample Maximum/Minimum
versus Gross Drainage Area

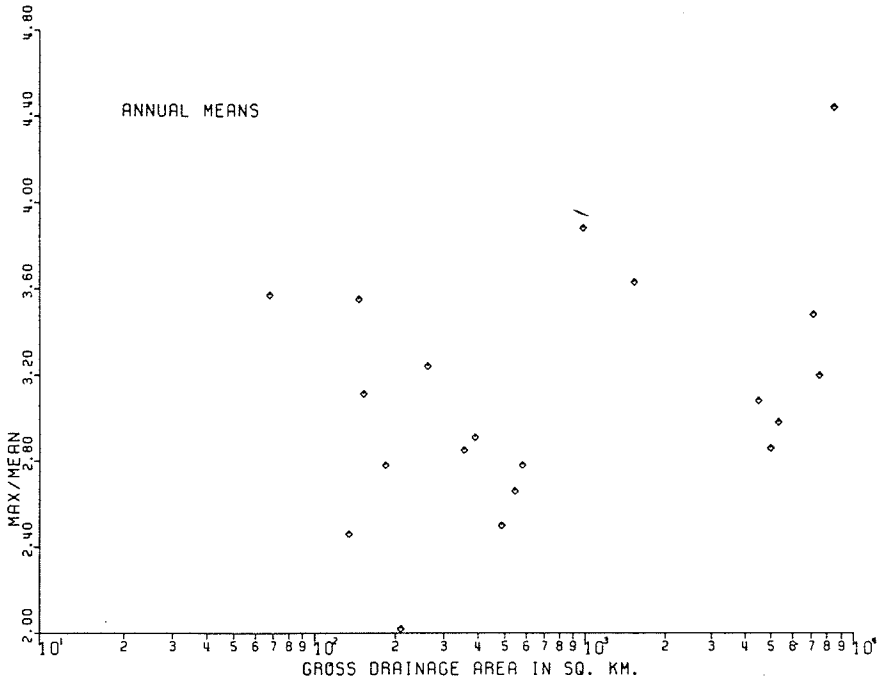



Figure A-11

Annual Mean Flows
Sample Maximum/Mean
versus Gross Drainage Area

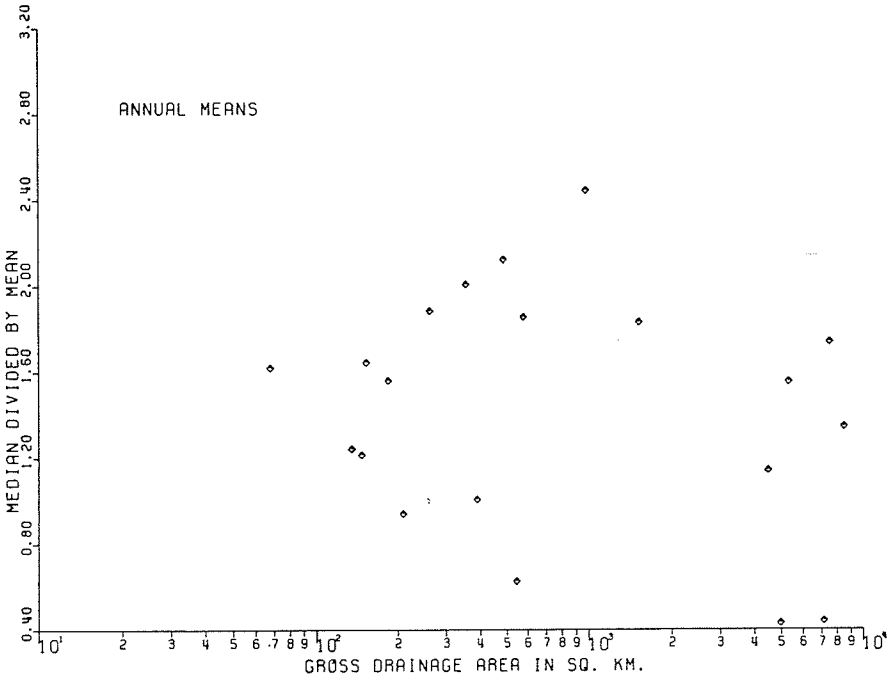



Figure A-12

Annual Mean Flows
Sample Median/Mean versus Gross Drainage Area

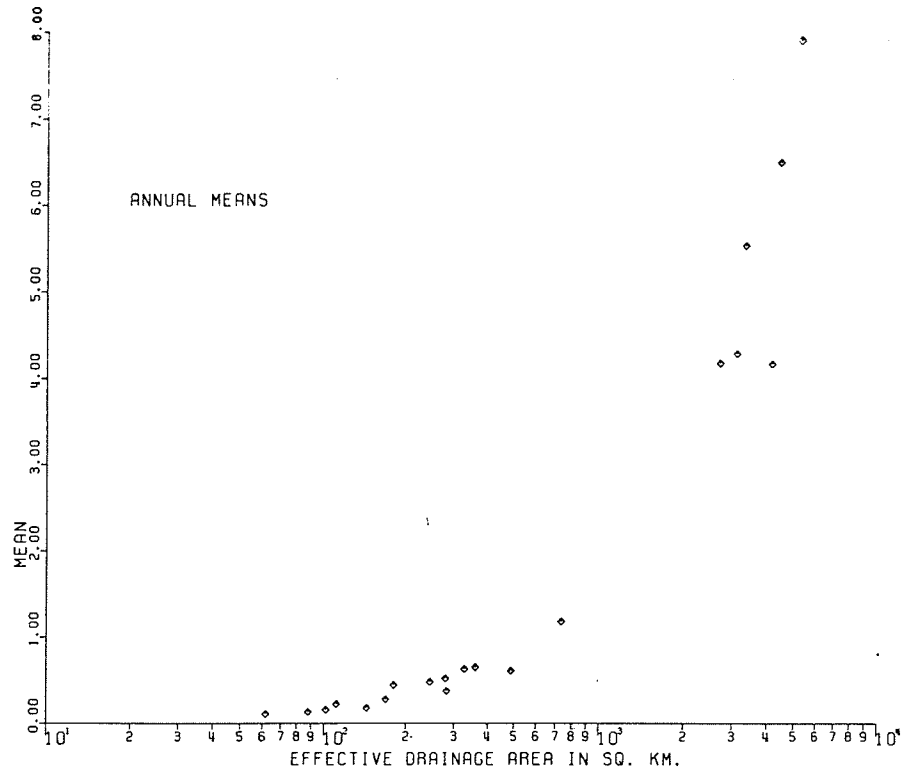



Figure A-13

Annual Mean Flows
Sample Mean versus Effective Drainage Area

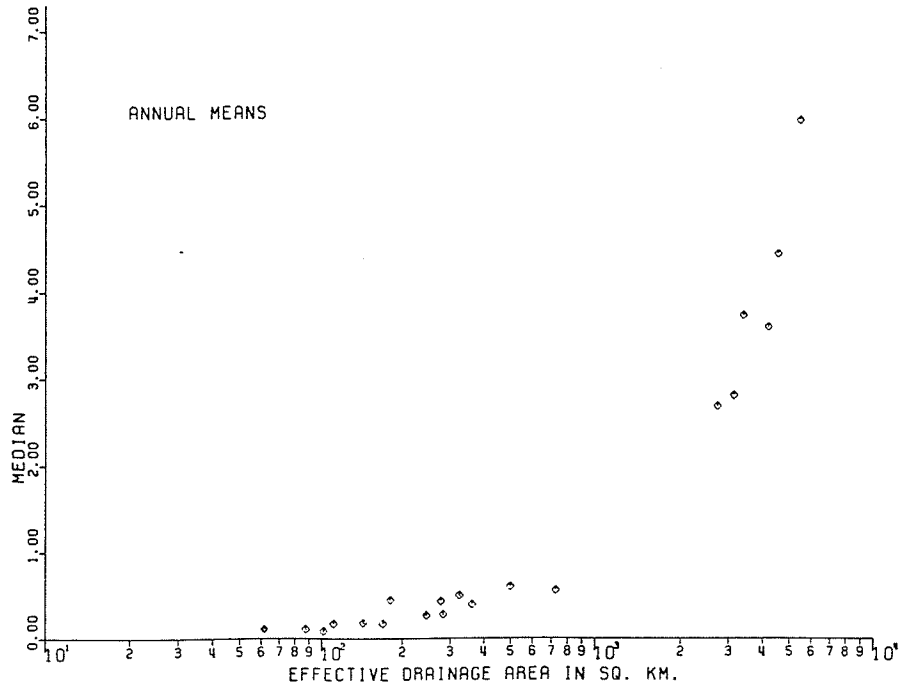



Figure A-14

Annual Mean Flows
Sample Median versus Effective Drainage Area

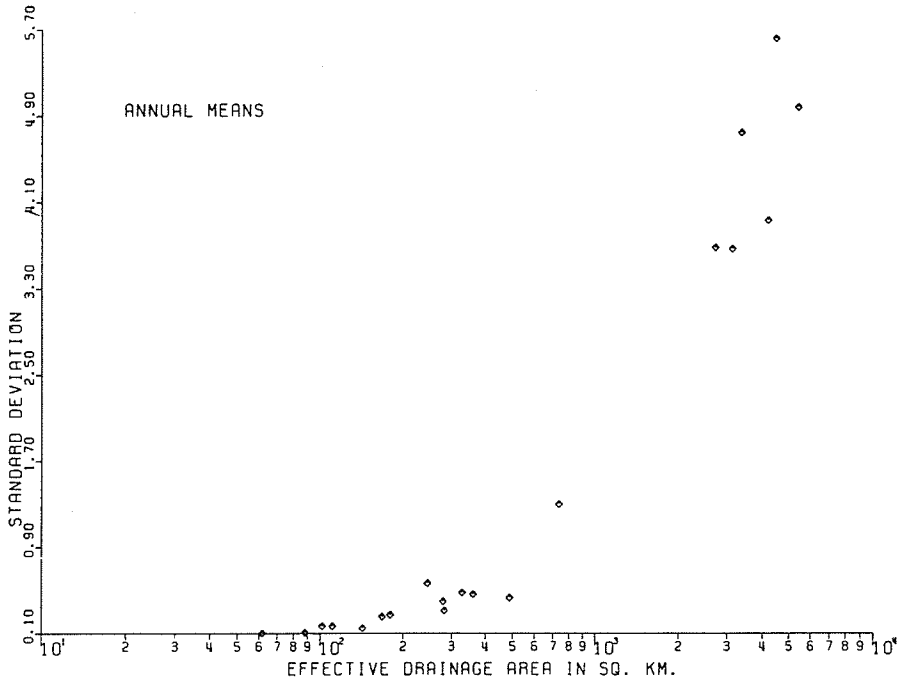



Figure A-15

Annual Mean Flows
Sample Standard Deviation
versus Effective Drainage Area

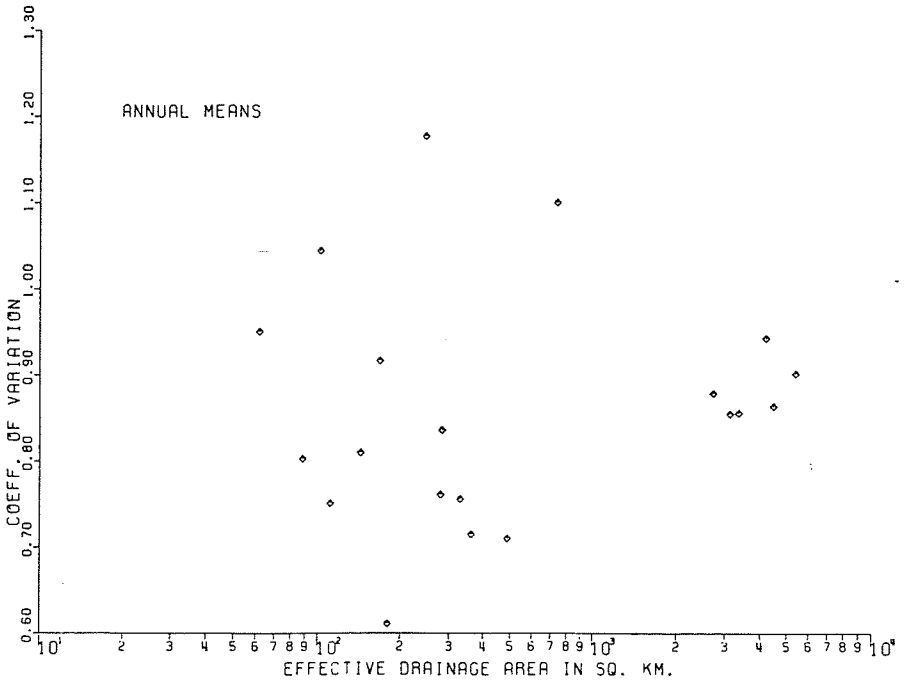



Figure A-16

Annual Mean Flows
Sample Coefficient of Variation
versus Effective Drainage Area

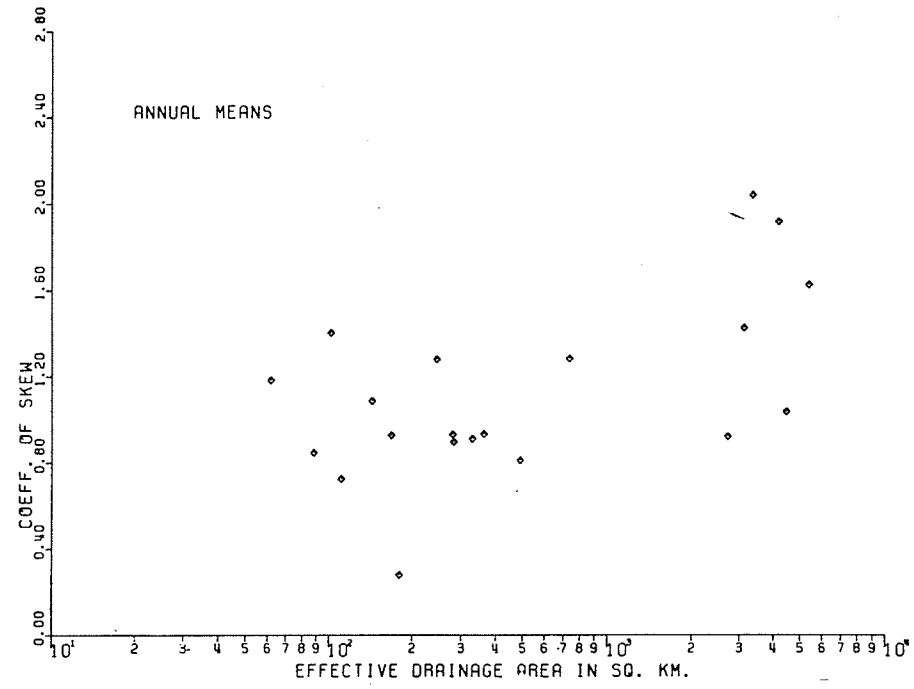



Figure A-17

Annual Mean Flows
Sample Coefficient of Skew
versus Effective Drainage Area

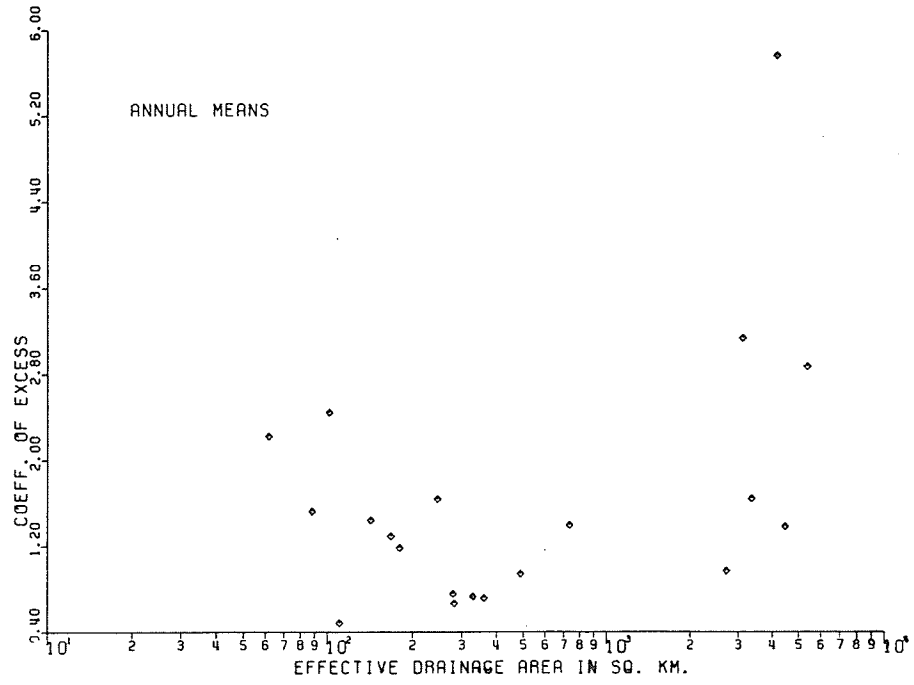



Figure A-18

Annual Mean Flows
Sample Coefficient of Excess
versus Effective Drainage Area

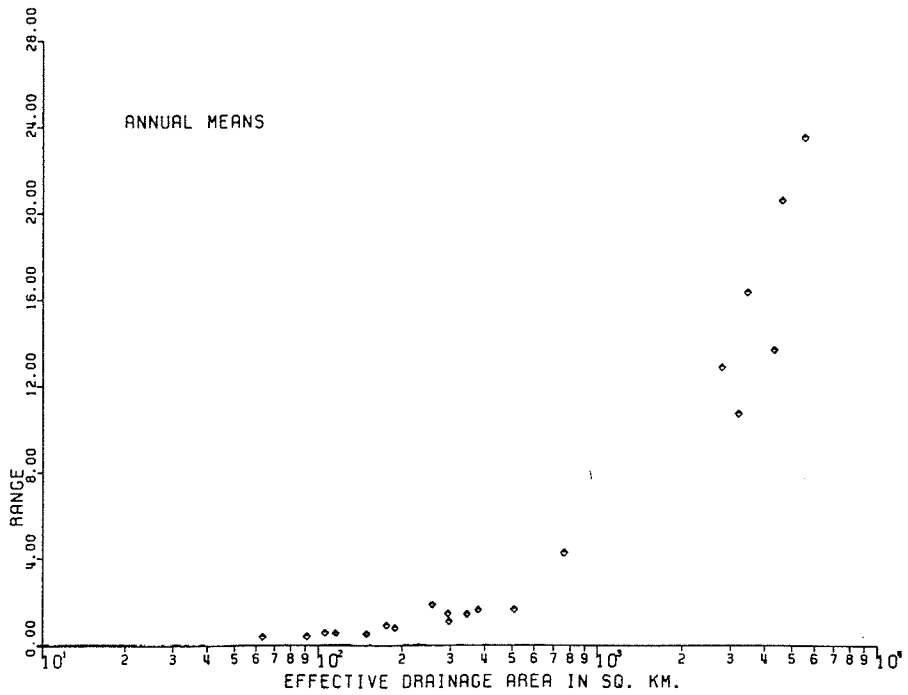



Figure A-19

Annual Mean Flows
Sample Range versus Effective Drainage Area

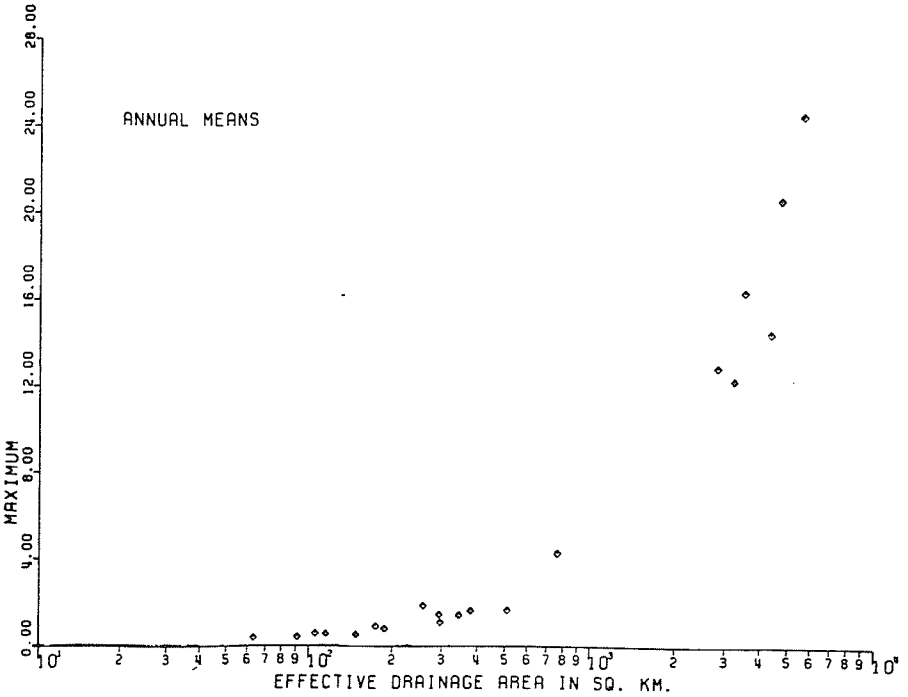



Figure A-20

Annual Mean Flows
Sample Maximum versus Effective Drainage Area

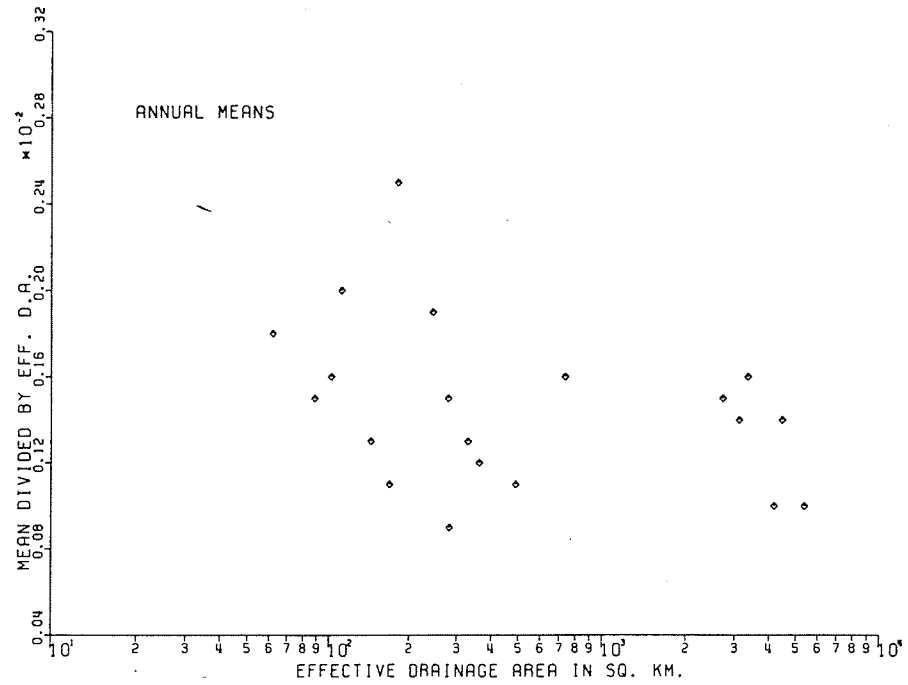



Figure A-21

Annual Mean Flows
Sample Yield (Mean/Effective Drainage Area)
versus Effective Drainage Area

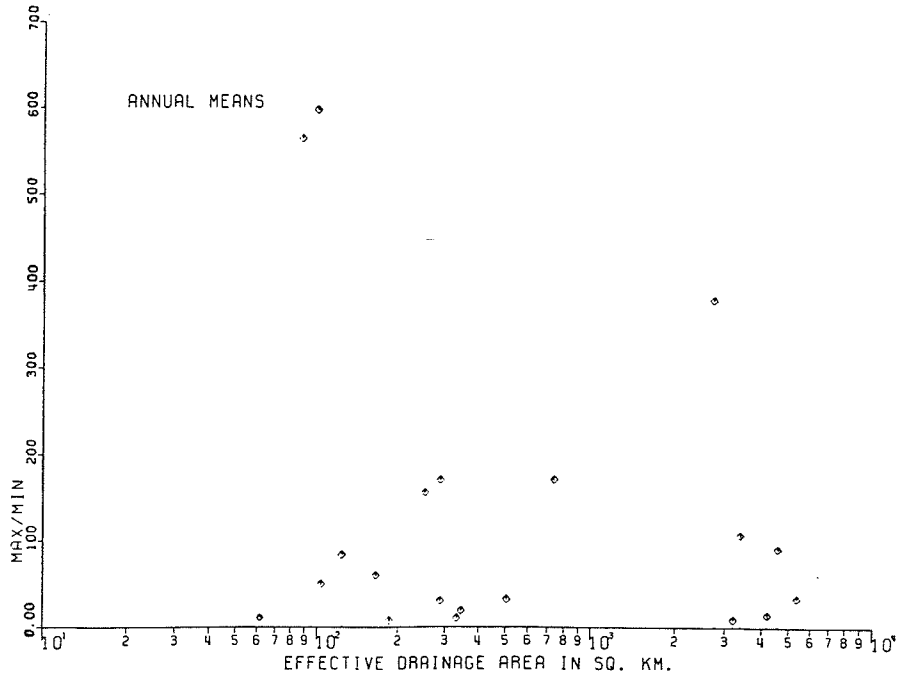



Figure A-22

Annual Mean Flows
Sample Maximum/Minimum
versus Effective Drainage Area

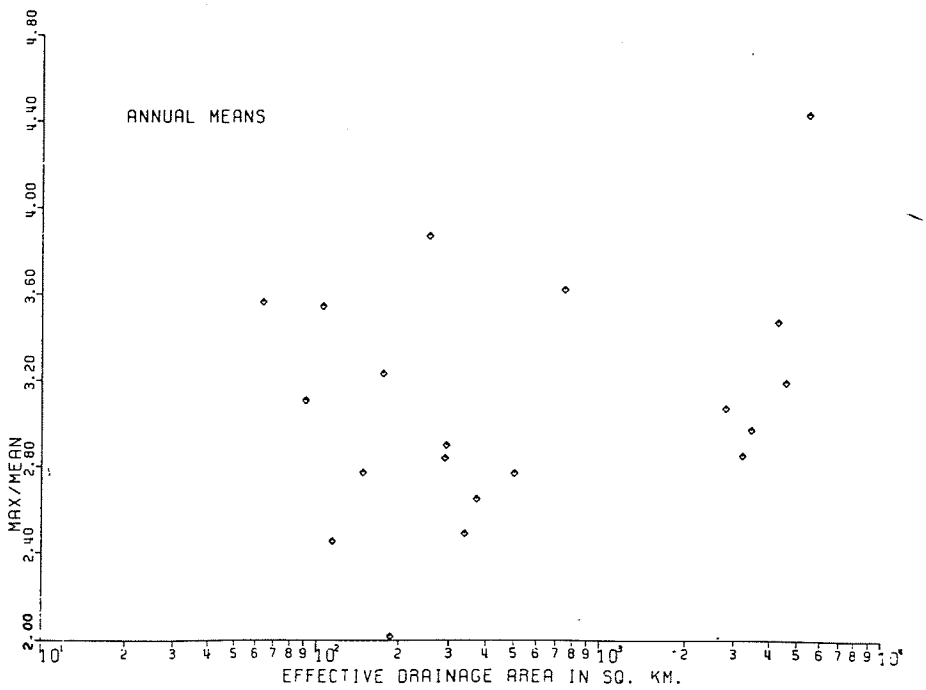



Figure A-23

Annual Mean Flows
Sample Maximum/Mean
versus Effective Drainage Area

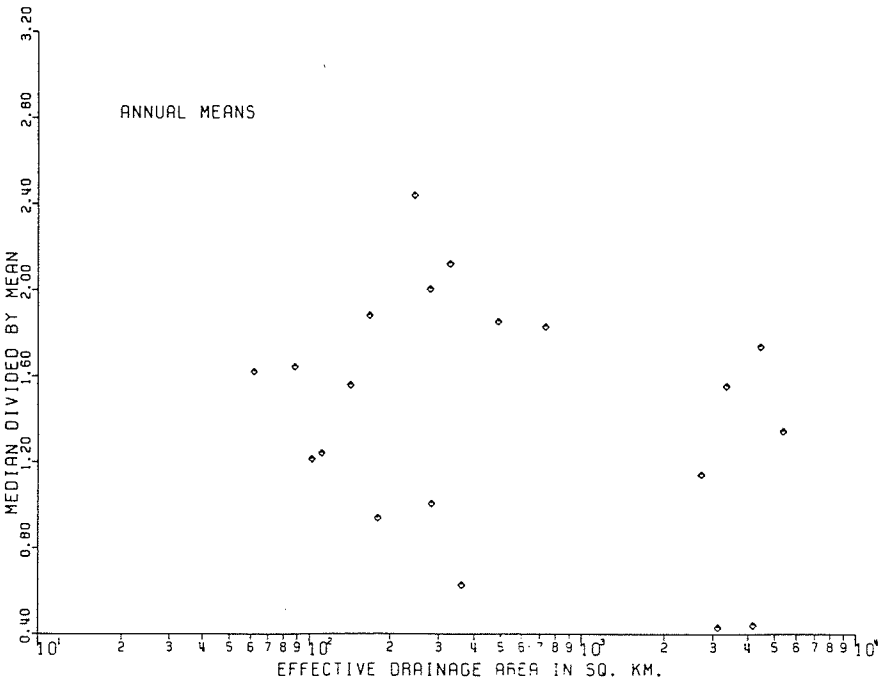



Figure A-24

Annual Mean Flows
Sample Median/Mean
versus Effective Drainage Area

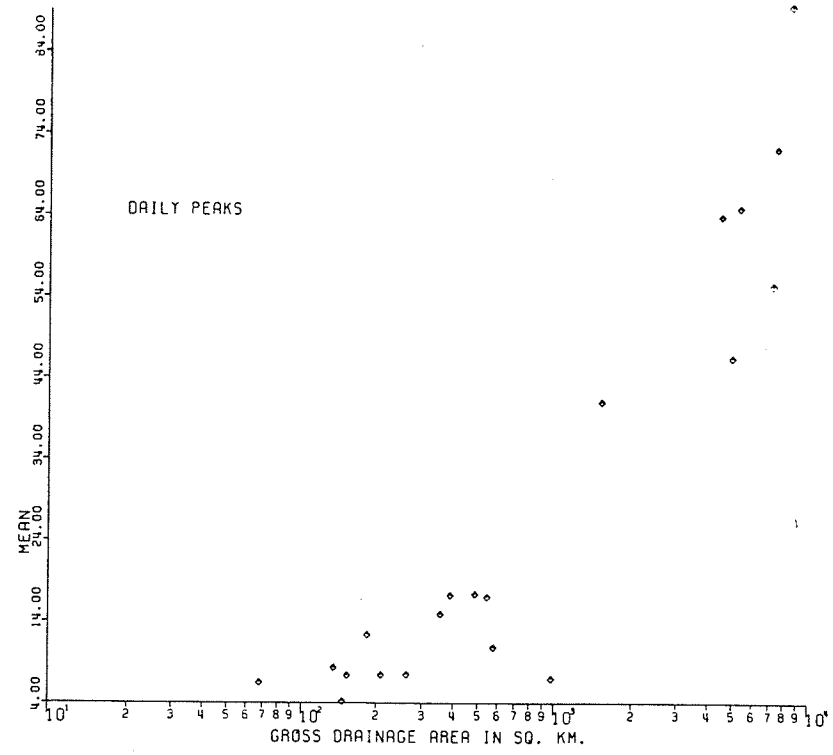



Figure A-25

Daily Mean Peak Flows
Sample Mean versus Gross Drainage Area

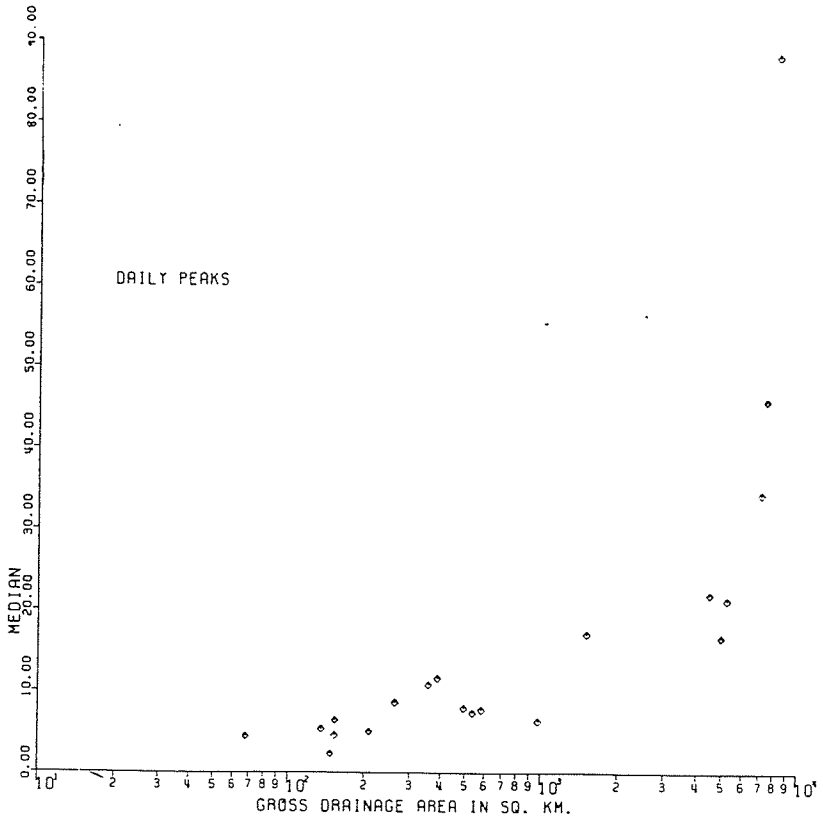



Figure A-26

Daily Mean Peak Flows
Sample Median versus Gross Drainage Area

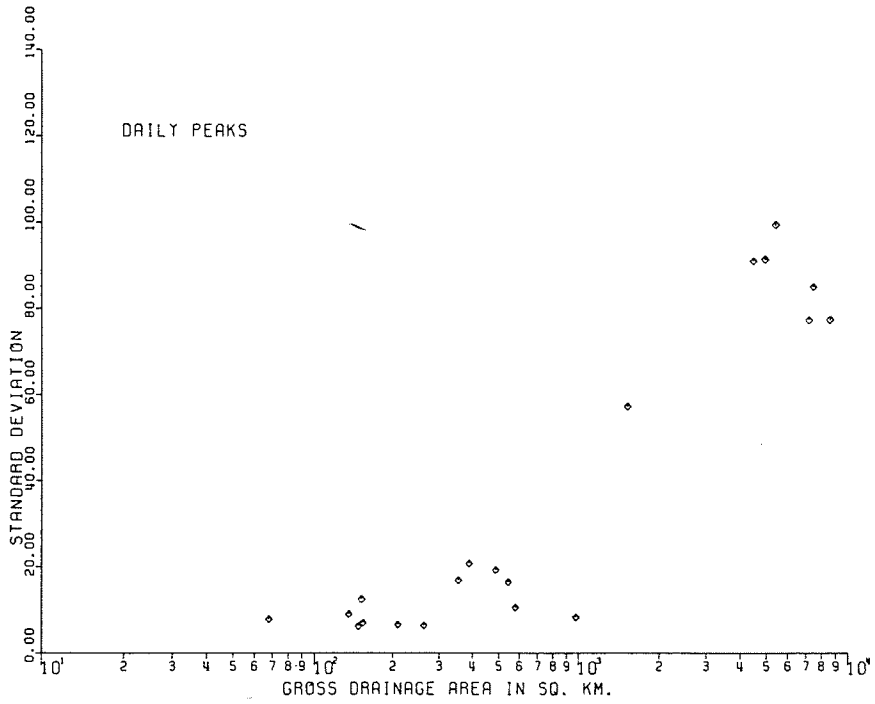



Figure A-27

Daily Mean Peak Flows
Sample Standard Deviation
versus Gross Drainage Area

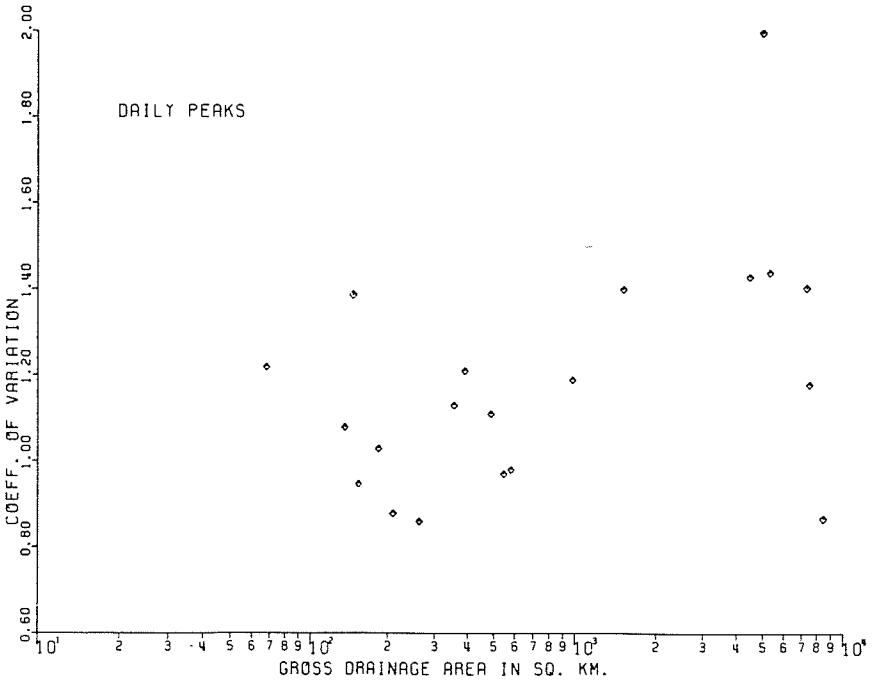



Figure A-28

Daily Mean Peak Flows
Sample Coefficient of Variation
versus Gross Drainage Area

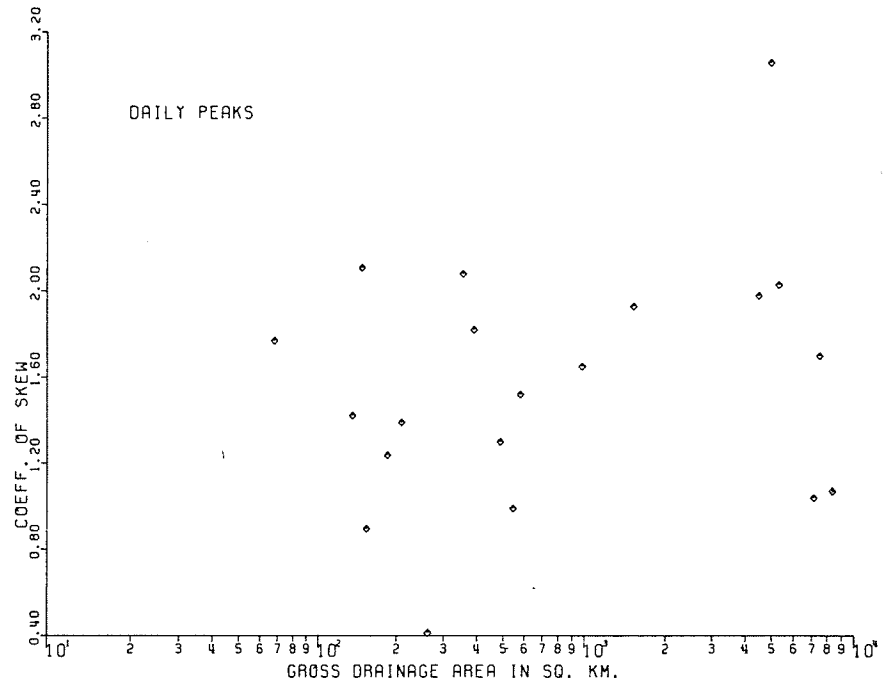



Figure A-29

Daily Mean Peak Flows
Sample Coefficient of Skew
versus Gross Drainage Area

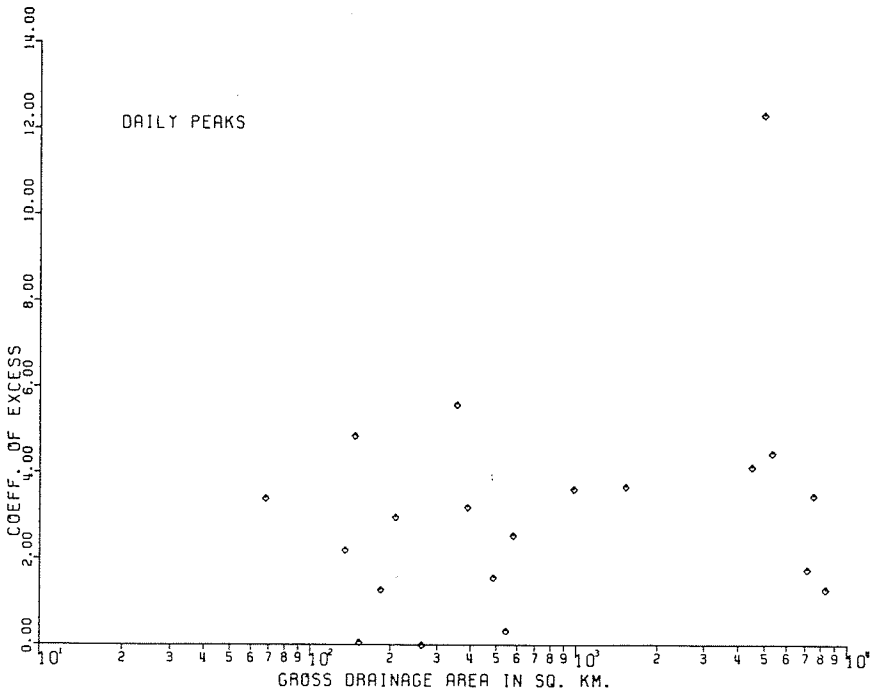



Figure A-30

Daily Mean Peak flows
Sample Coefficient of Excess
versus Gross Drainage Area

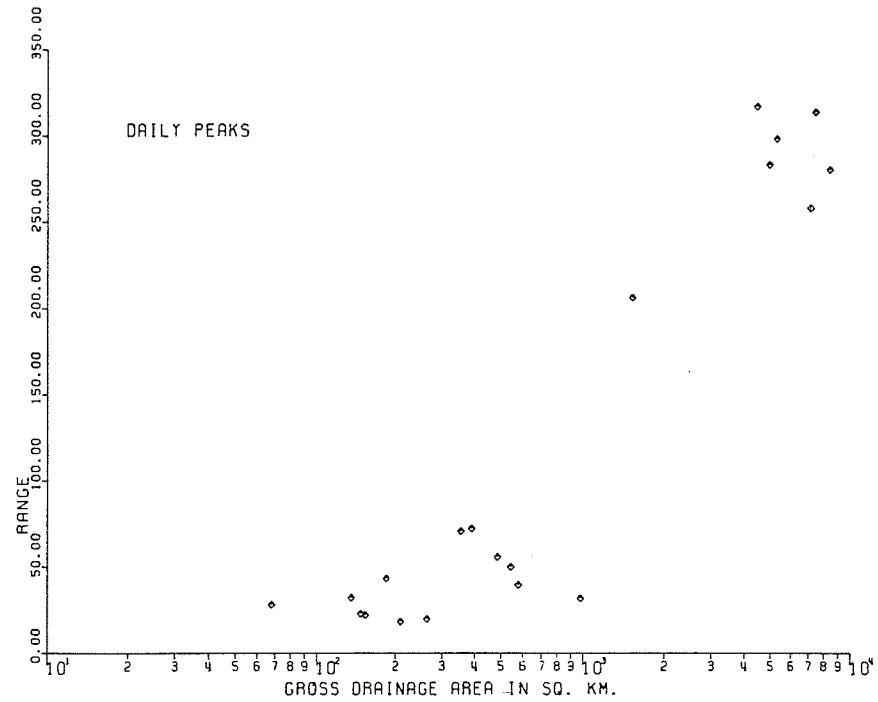



Figure A-31

Daily Mean Peak Flows
Sample Range versus Gross Drainage Area

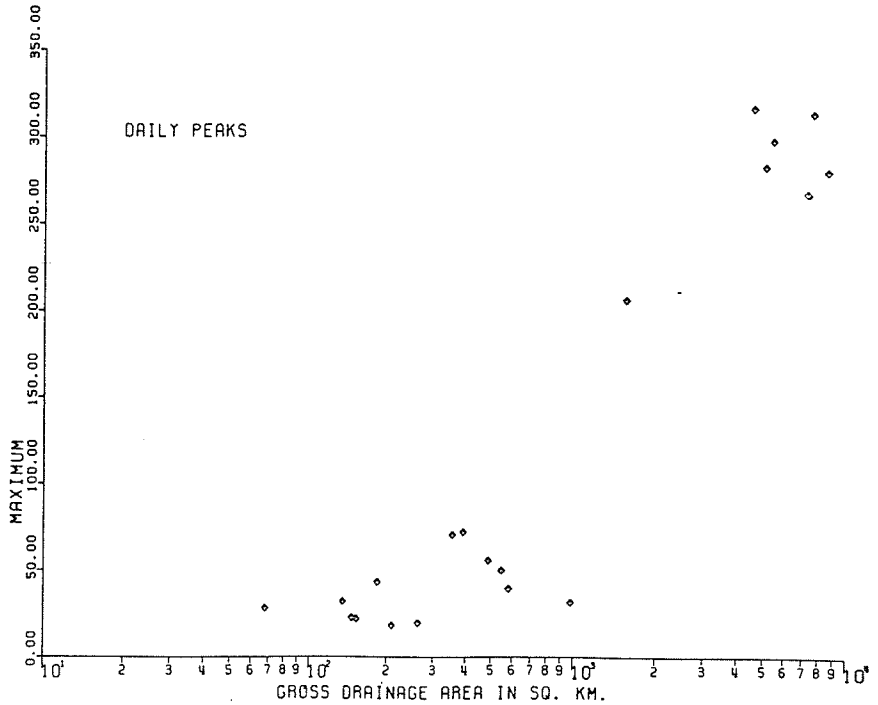



Figure A-32

Daily Mean Peak Flows
Sample Maximum versus Gross Drainage Area

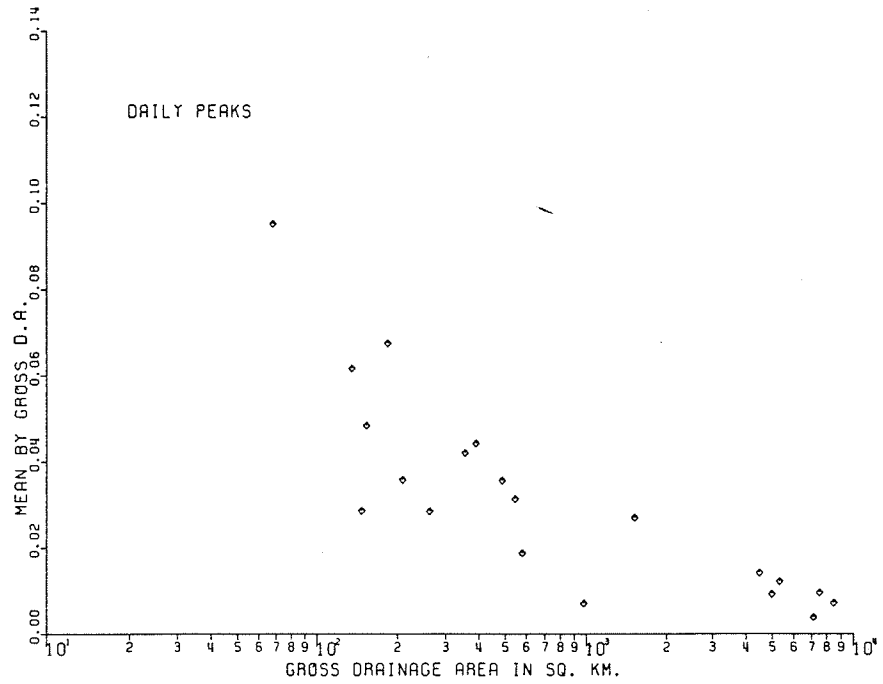



Figure A-33

Daily Mean Peak Flows
Sample Yield (Mean/Gross Drainage Area)
versus Gross Drainage Area

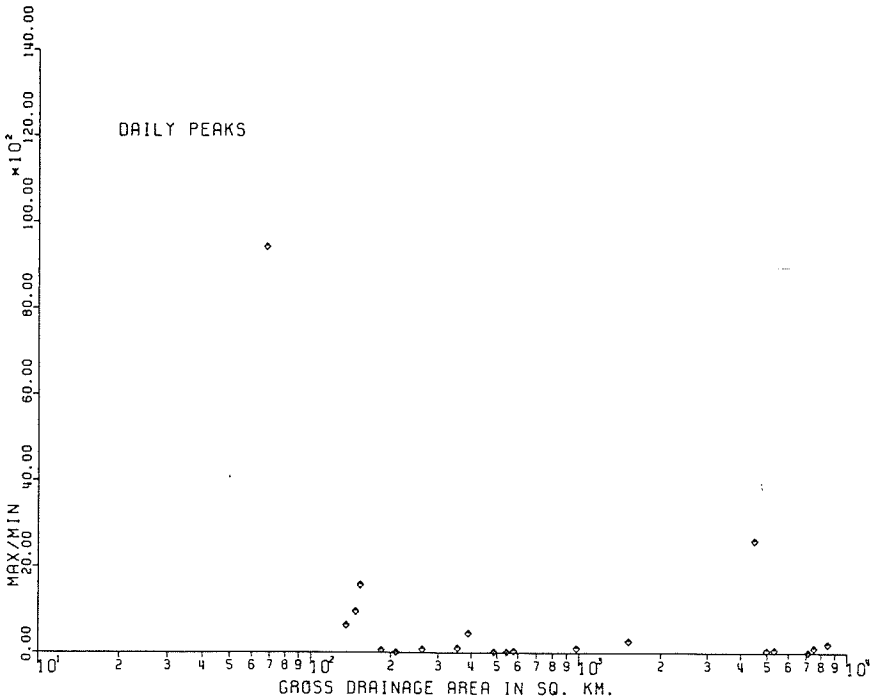



Figure A-34

Daily Mean Peak flows
Sample Maximum/Minimum
versus Gross Drainage Area

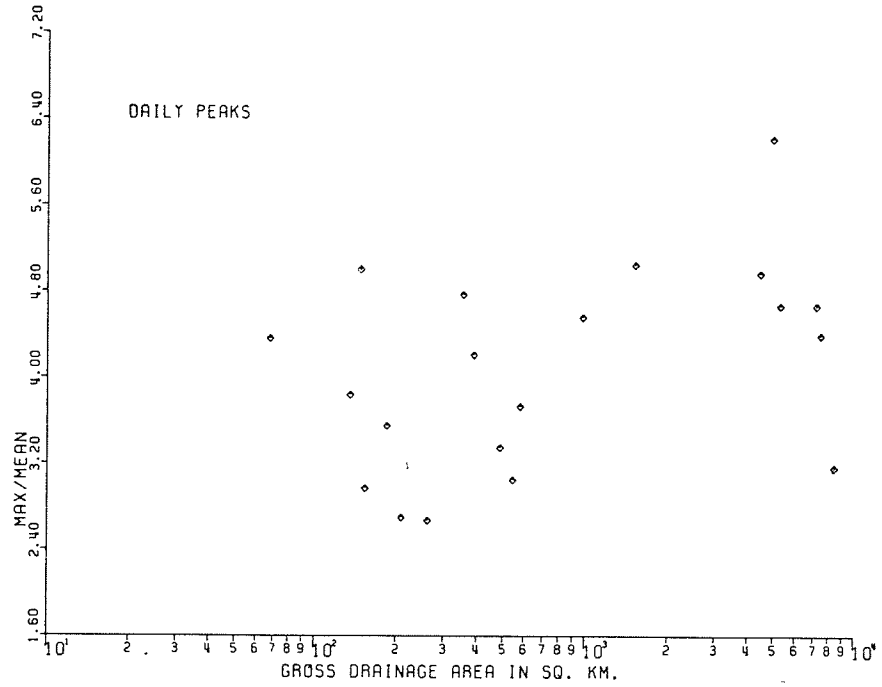



Figure A-35

Daily Mean Peak Flows
Sample Maximum/Mean versus Gross Drainage Area

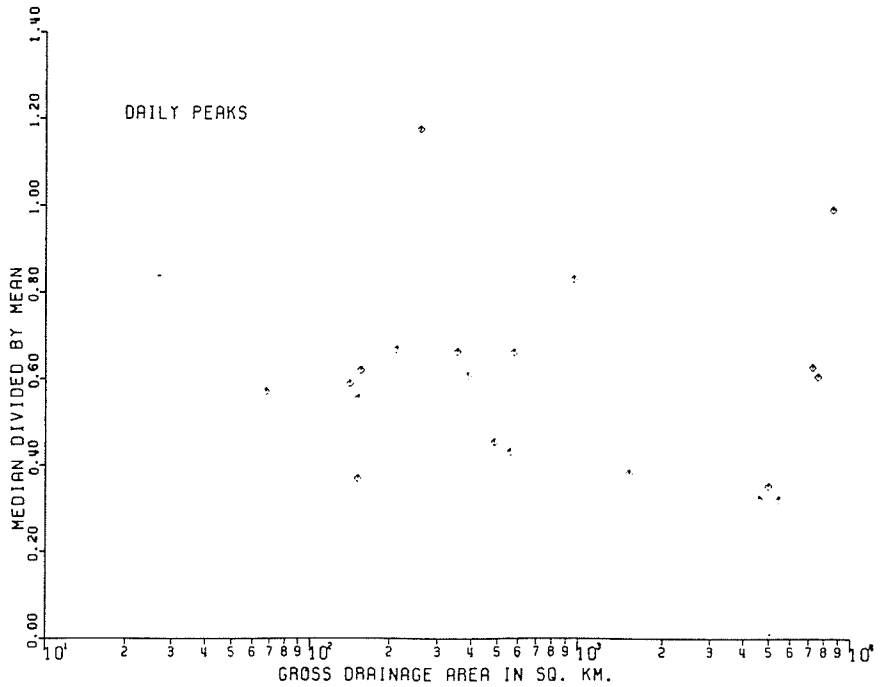



Figure A-36

Daily Mean Peak Flows
Sample Median/Mean versus Gross Drainage Area

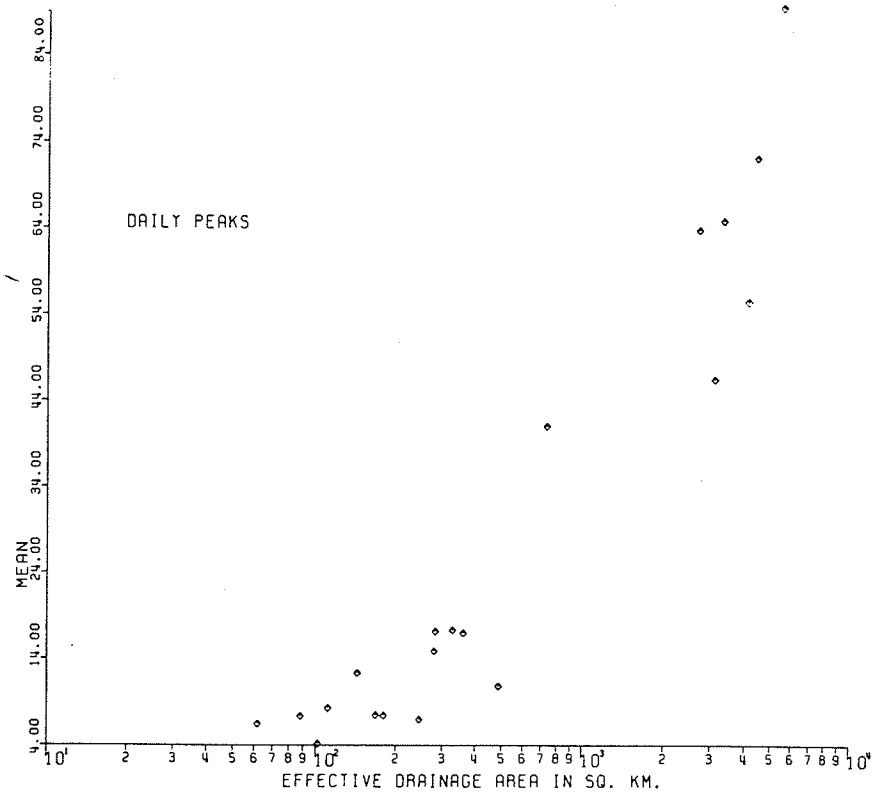



Figure A-37

Daily Mean Peak Flows
Sample Mean versus Effective Drainage Area

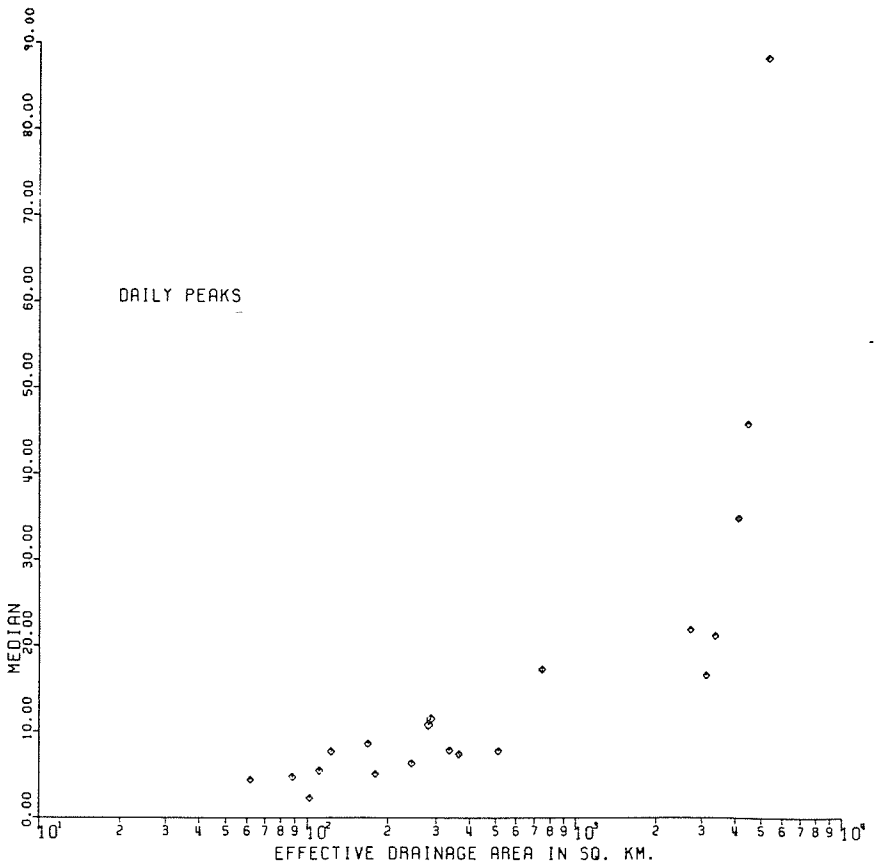



Figure A-38

Daily Mean Peak Flows
Sample Median versus Effective Drainage Area

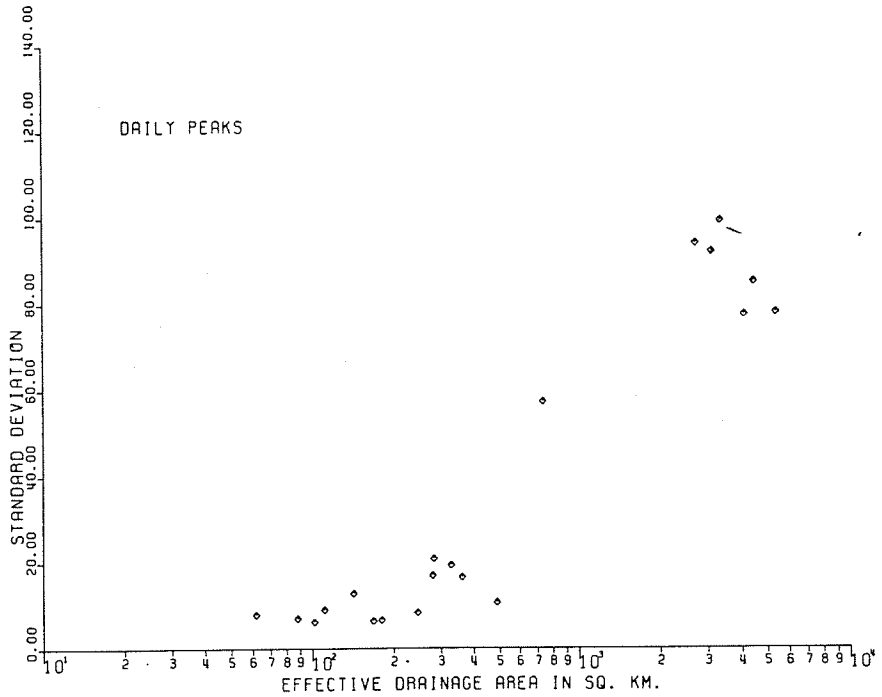



Figure A-39

Daily Mean Peak Flows
Sample Standard Deviation
versus Effective Drainage Area

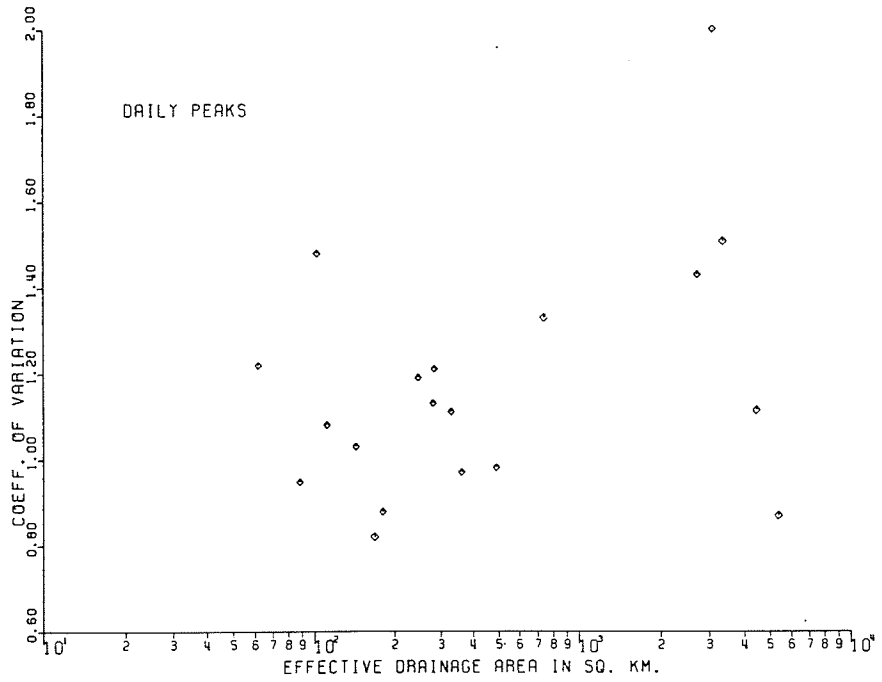



Figure A-40

Daily Mean Peak Flows
Sample Coefficient of Variation
versus Effective Drainage Area

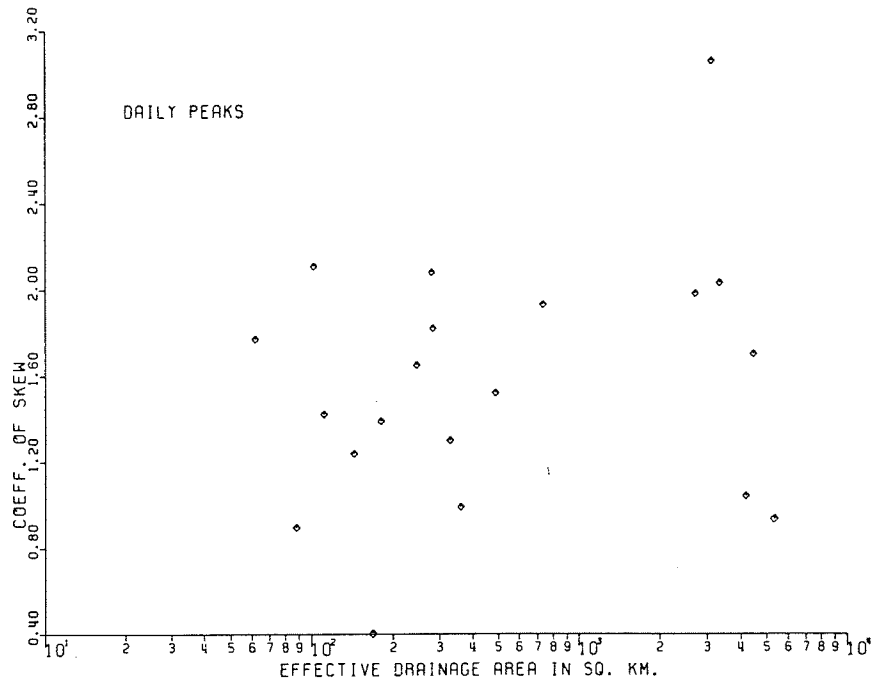



Figure A-41

Daily Mean Peak Flows
Sample Coefficient of Skew
versus Effective Drainage Area

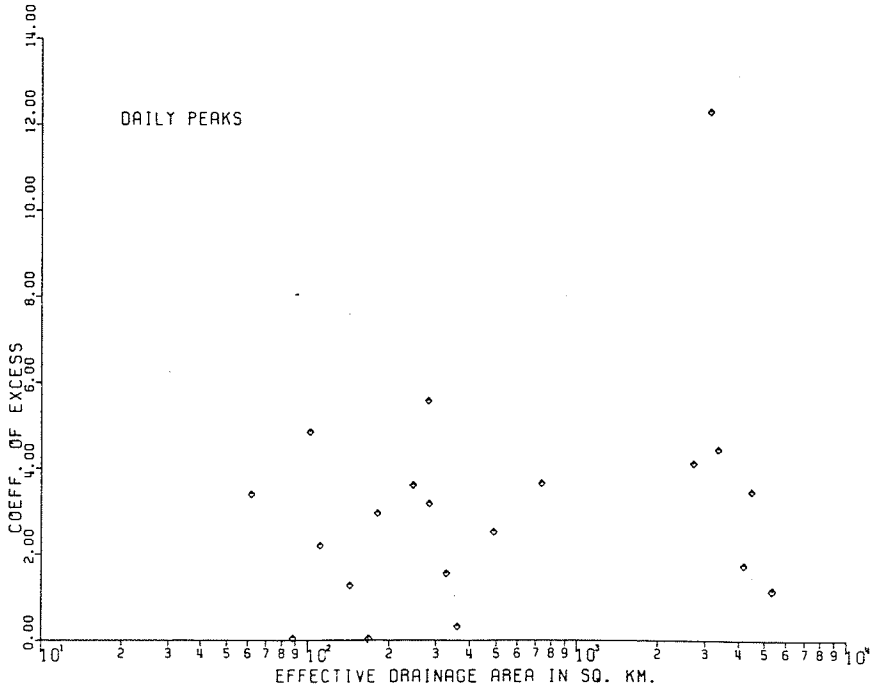



Figure A-42

Daily Mean Peak Flows
Sample Coefficient of Excess
versus Effective Drainage Area

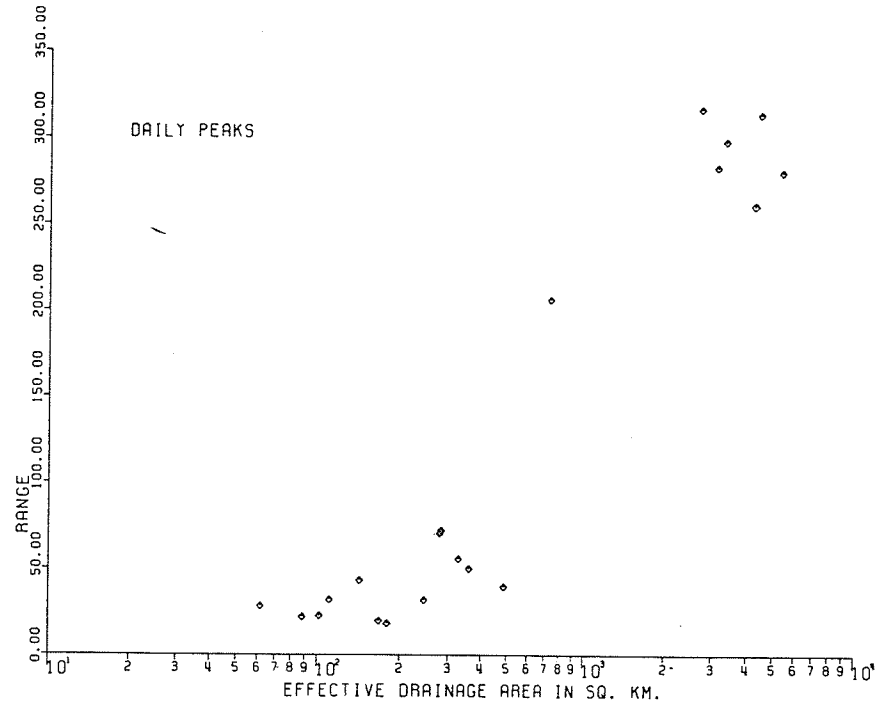



Figure A-43

Daily Mean Peak Flows
Sample Range versus Effective Drainage Area

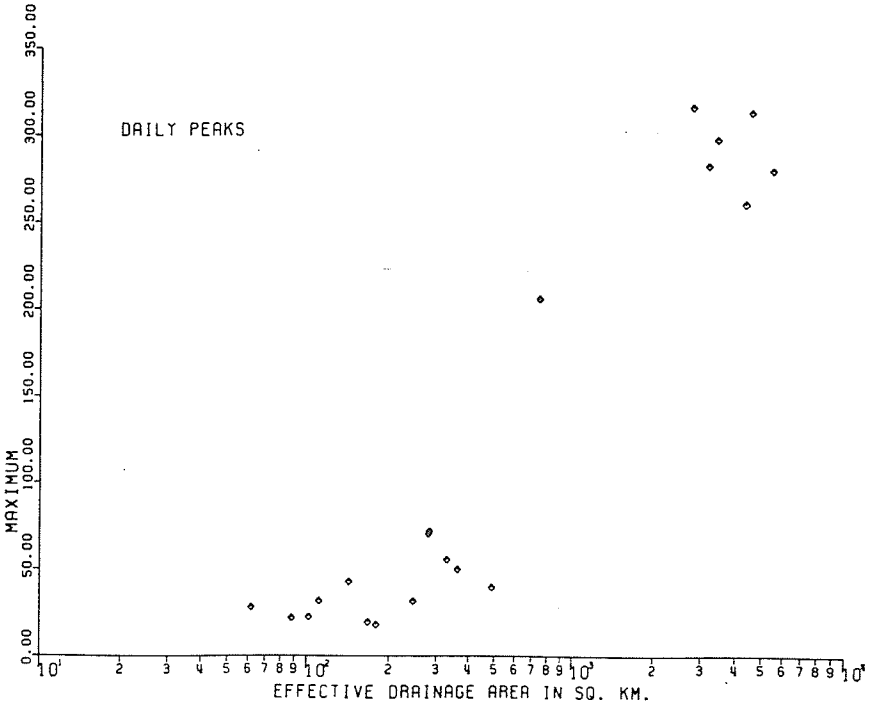



Figure A-44

Daily Mean Peak Flows
Sample Maximum versus Effective Drainage Area

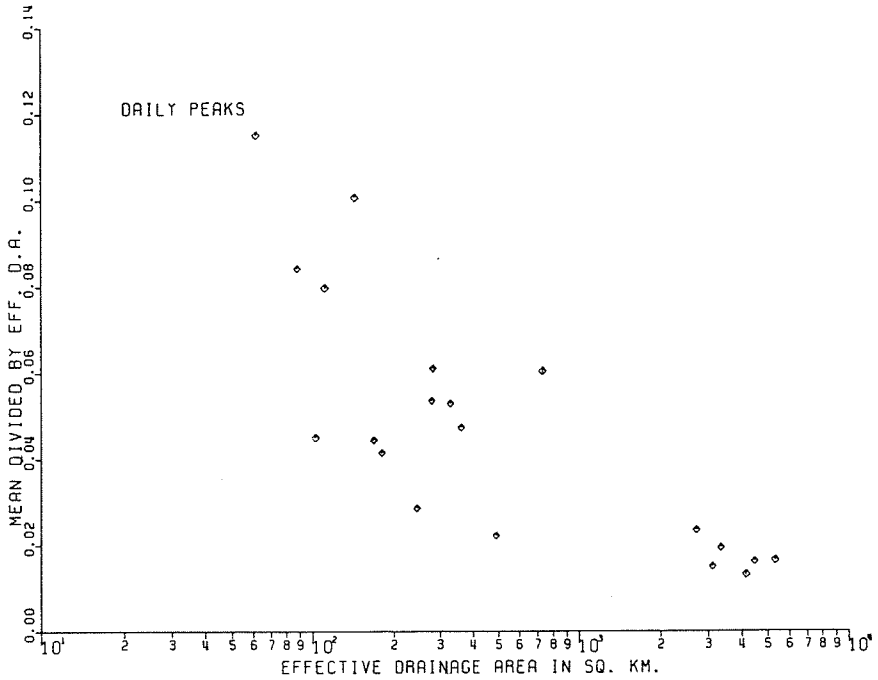



Figure A-45

Daily Mean Peak Flows
Sample Yield (Mean/Effective Drainage Area)
versus Effective Drainage Area

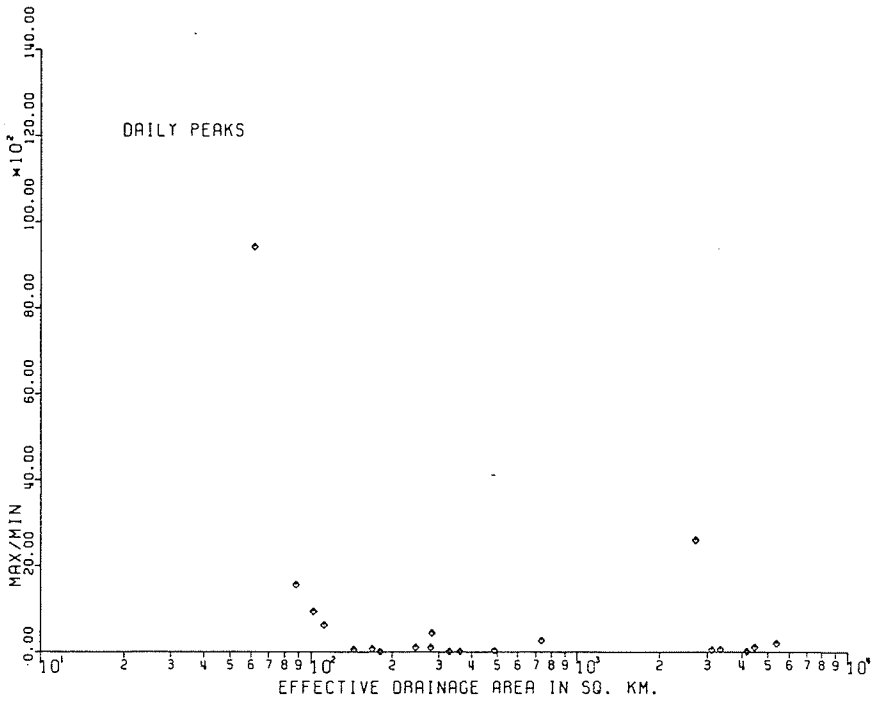



Figure A-46

Daily Mean Peak Flows
Sample Maximum/Minimum
versus Effective Drainage Area

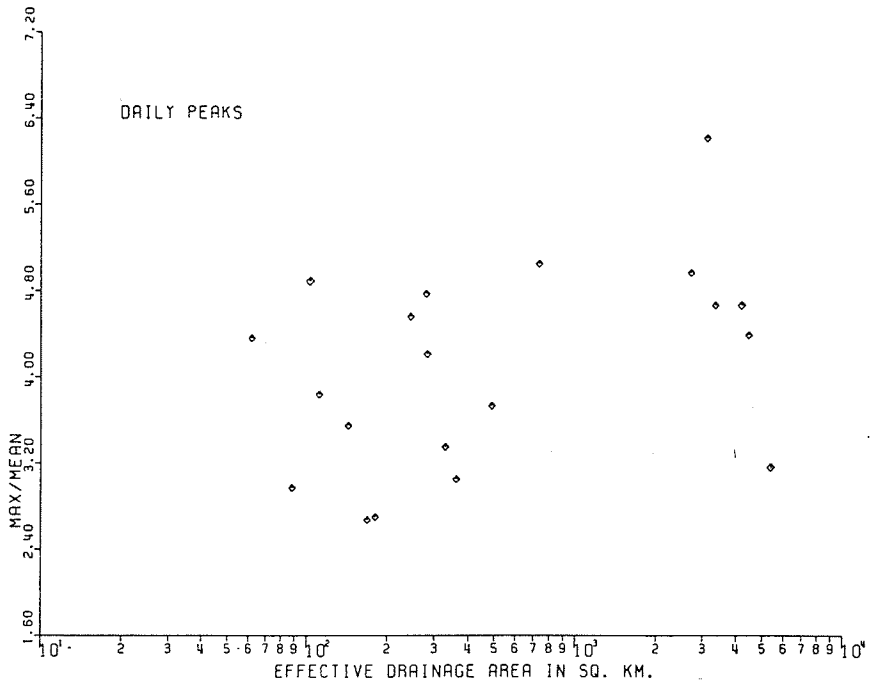



Figure A-47

Daily Mean Peak Flows
Sample Maximum/Mean
versus Effective Drainage Area

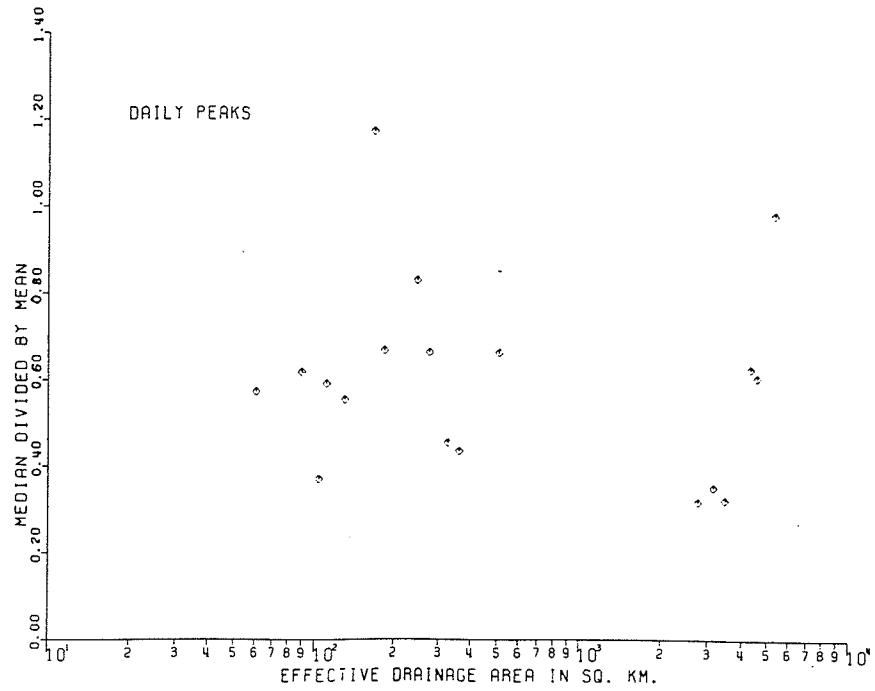



Figure A-48

Daily Mean Peak Flows
Sample Median/Mean
versus Effective Drainage Area

# APPENDIX B

# REGIONAL REGRESSION ANALYSIS OF SELECTED SAMPLE STATISTICS

# Table B-1

## Example Output from SAS Regression Developed Using Sample Statistics Based on Annual Mean Flows

DEP VARIABLE: LMN log(mean)

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PROB>F |
|---|---|---|---|---|---|
| MODEL | 1 | 7.076997 | 7.076997 | 440.502 | 0.0001 |
| ERROR | 18 | 0.289183 | 0.016066 | | |
| C TOTAL | 19 | 7.366180 | | | |

| | | | |
|---|---|---|---|
| ROOT MSE | 0.126751 | R-SQUARE | 0.9607 |
| DEP MEAN | -0.105560 | ADJ R-SQ | 0.9586 |
| C.V. | -120.074 | | |

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > \|T\| | TYPE I SS | TYPE II SS | STANDARDIZED ESTIMATE | TOLERANCE |
|---|---|---|---|---|---|---|---|---|---|
| INTERCEP | 1 | -2.642600 | 0.124158 | -21.284 | 0.0001 | 0.222859 | 7.278052 | 0.000000 | . |
| LGA | 1 | 0.883586 | 0.042099 | 20.988 | 0.0001 | 7.076997 | 7.076997 | 0.980174 | 1.000000 |

[log(gross D.A.)]

COVARIANCE OF ESTIMATES

| COVB | INTERCEP | LGA |
|---|---|---|
| INTERCEP | 0.01541519 | -0.00508895 |
| LGA | -0.00508895 | 0.001772351 |

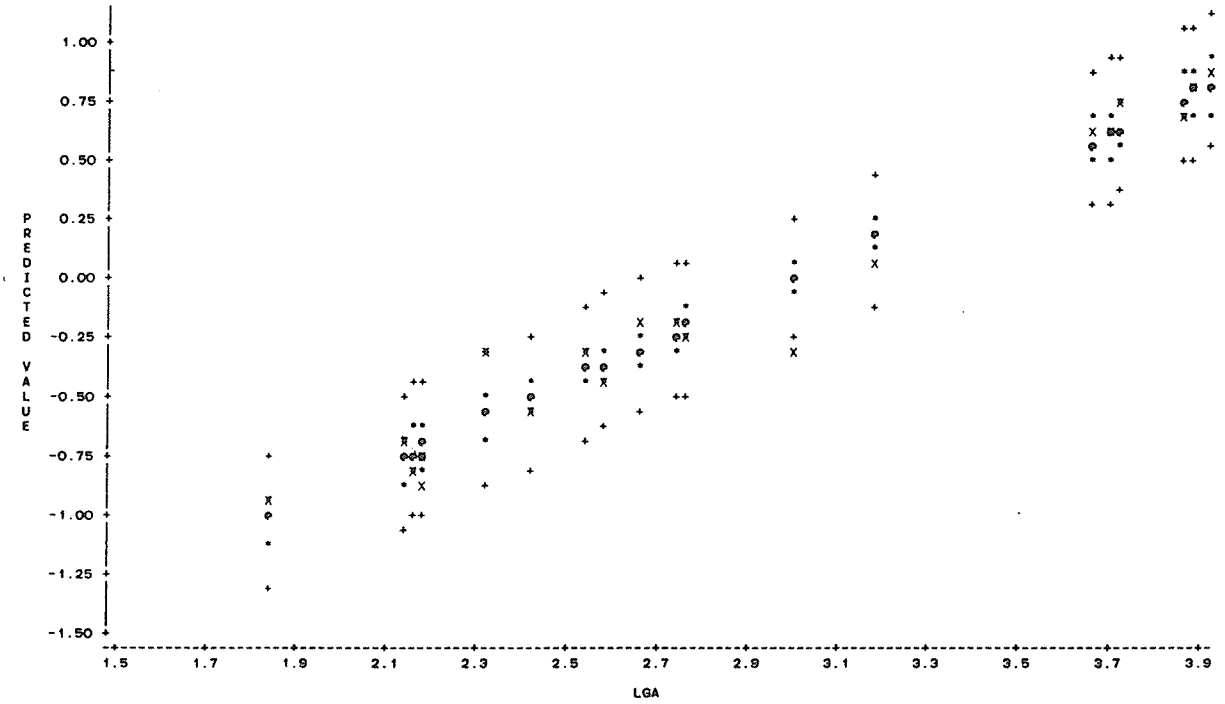
CORRELATION OF ESTIMATES

| CORRB | INTERCEP | LGA |
|---|---|---|
| INTERCEP | 1.0000 | -0.9736 |
| LGA | -0.9736 | 1.0000 |

| OBS | ACTUAL | PREDICT VALUE | STD ERR PREDICT | LOWER95% MEAN | UPPER95% MEAN | LOWER95% PREDICT | UPPER95% PREDICT | RESIDUAL | STD ERR RESIDUAL | STUDENT RESIDUAL | -2-1-0 1 2 | COOK'S D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.959398 | -1.023 | 0.052113 | -1.133 | -.913936 | -1.311 | -.735501 | 0.064023 | 0.115542 | 0.554 | \| * \| | 0.031 |
| 2 | -.220837 | -.203530 | 0.028724 | -.263876 | -.143183 | -.476573 | 0.069514 | -.017307 | 0.123453 | -0.140 | \| \| | 0.001 |
| 3 | 0.089834 | 0.167061 | 0.031177 | 0.101561 | 0.232561 | -.107168 | 0.441290 | -.077226 | 0.122857 | -0.629 | \| * \| | 0.013 |
| 4 | -.288193 | -.390337 | 0.031423 | -.456353 | -.324320 | -.664689 | -.115984 | 0.102144 | 0.122784 | 0.832 | \| * \| | 0.023 |
| 5 | -.205024 | -.226877 | 0.028926 | -.287647 | -.166106 | -.500015 | 0.046261 | 0.021853 | 0.123406 | 0.177 | \| \| | 0.001 |
| 6 | -.173342 | -.292336 | 0.029707 | -.354746 | -.229925 | -.565843 | -.018828 | 0.118993 | 0.123220 | 0.966 | \| * \| | 0.027 |
| 7 | -.322941 | -.592552 | 0.036629 | -.669505 | -.515598 | -.869739 | -.315364 | 0.269611 | 0.121343 | 2.222 | \| **** \| | 0.225 |
| 8 | 0.743706 | 0.649563 | 0.045801 | 0.553339 | 0.745787 | 0.366420 | 0.932707 | 0.094143 | 0.118186 | 0.797 | \| * \| | 0.048 |
| 9 | -.881074 | -.709738 | 0.040397 | -.794609 | -.624866 | -.989227 | -.430248 | -.171337 | 0.120141 | -1.426 | \| ** \| | 0.115 |
| 10 | 0.813281 | 0.781503 | 0.050888 | 0.674592 | 0.888415 | 0.494551 | 1.068 | 0.031778 | 0.116087 | 0.274 | \| \| | 0.007 |
| 11 | 0.679610 | 0.762043 | 0.050121 | 0.656744 | 0.867343 | 0.475688 | 1.048 | -.082434 | 0.116420 | -0.708 | \| * \| | 0.046 |
| 12 | -.427942 | -.355145 | 0.030736 | -.419718 | -.290571 | -.629154 | -.081136 | -.072797 | 0.122968 | -0.592 | \| * \| | 0.011 |
| 13 | -.671213 | -.757435 | 0.042047 | -.845772 | -.669098 | -1.038 | -.476874 | 0.086222 | 0.118573 | 0.721 | \| * \| | 0.032 |
| 14 | -.319483 | 4.1E-04 | 0.028789 | -.060077 | 0.060887 | -.272669 | 0.273479 | -.319888 | 0.123438 | -2.591 | \| ***** \| | 0.183 |
| 15 | 0.648506 | 0.624451 | 0.044867 | 0.530189 | 0.718713 | 0.341968 | 0.906934 | 0.024055 | 0.118544 | 0.203 | \| \| | 0.003 |
| 16 | -.569119 | -.507291 | 0.034200 | -.579142 | -.435439 | -.783105 | -.231476 | -.061828 | 0.122050 | -0.507 | \| * \| | 0.010 |
| 17 | 0.621394 | 0.584217 | 0.043398 | 0.493041 | 0.675393 | 0.302749 | 0.865685 | 0.037177 | 0.119090 | 0.312 | \| \| | 0.006 |
| 18 | -.822752 | -.727589 | 0.041008 | -.813743 | -.641435 | -1.007 | -.447708 | -.095163 | 0.119934 | -0.793 | \| * \| | 0.037 |
| 19 | -.743042 | -.722403 | 0.040830 | -.808183 | -.636624 | -1.002 | -.442637 | -.020639 | 0.119995 | -0.172 | \| \| | 0.002 |
| 20 | 0.896824 | 0.828204 | 0.052751 | 0.717379 | 0.939028 | 0.539771 | 1.117 | 0.068620 | 0.115252 | 0.595 | \| * \| | 0.037 |

SUM OF RESIDUALS -2.8047OE-14
SUM OF SQUARED RESIDUALS 0.2891835

PLOT OF LMN*LGA SYMBOL USED IS X OBSERVED VALUE
PLOT OF P1*LGA SYMBOL USED IS @ VALUE PREDICTED BY REGRESSION
PLOT OF L951*LGA SYMBOL USED IS + ] PREDICTION CONFIDENCE INTERVAL
PLOT OF U951*LGA SYMBOL USED IS + ]
PLOT OF L95M1*LGA SYMBOL USED IS * ] REGRESSION CONFIDENCE INTERVAL (ABOUT MEAN)
PLOT OF U95M1*LGA SYMBOL USED IS * ]



# Table B-1 (cont'd)

DEP VARIABLE: LSDEV log(standard deviation)

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PROB>F |
|---|---|---|---|---|---|
| MODEL | 1 | 7.158936 | 7.158936 | 928.159 | 0.0001 |
| ERROR | 18 | 0.138835 | 0.007713052 | | |
| C TOTAL | 19 | 7.297771 | | | |

| | | | |
|---|---|---|---|
| ROOT MSE | 0.087824 | R-SQUARE | 0.9810 |
| DEP MEAN | -0.179200 | ADJ R-SQ | 0.9799 |
| C.V. | -49.0088 | | |

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > \|T\| | TYPE I SS | TYPE II SS | STANDARDIZED ESTIMATE | TOLERANCE |
|---|---|---|---|---|---|---|---|---|---|
| INTERCEP | 1 | -2.730886 | 0.086027 | -31.744 | 0.0001 | 0.642256 | 7.772473 | 0.000000 | . |
| LGA | 1 | 0.888686 | 0.029170 | 30.466 | 0.0001 | 7.158936 | 7.158936 | 0.990442 | 1.000000 |

[log(gross D.A.)]

COVARIANCE OF ESTIMATES

| COVB | INTERCEP | LGA |
|---|---|---|
| INTERCEP | 0.007400721 | -0.00244317 |
| LGA | -0.00244317 | 0.0008508929 |

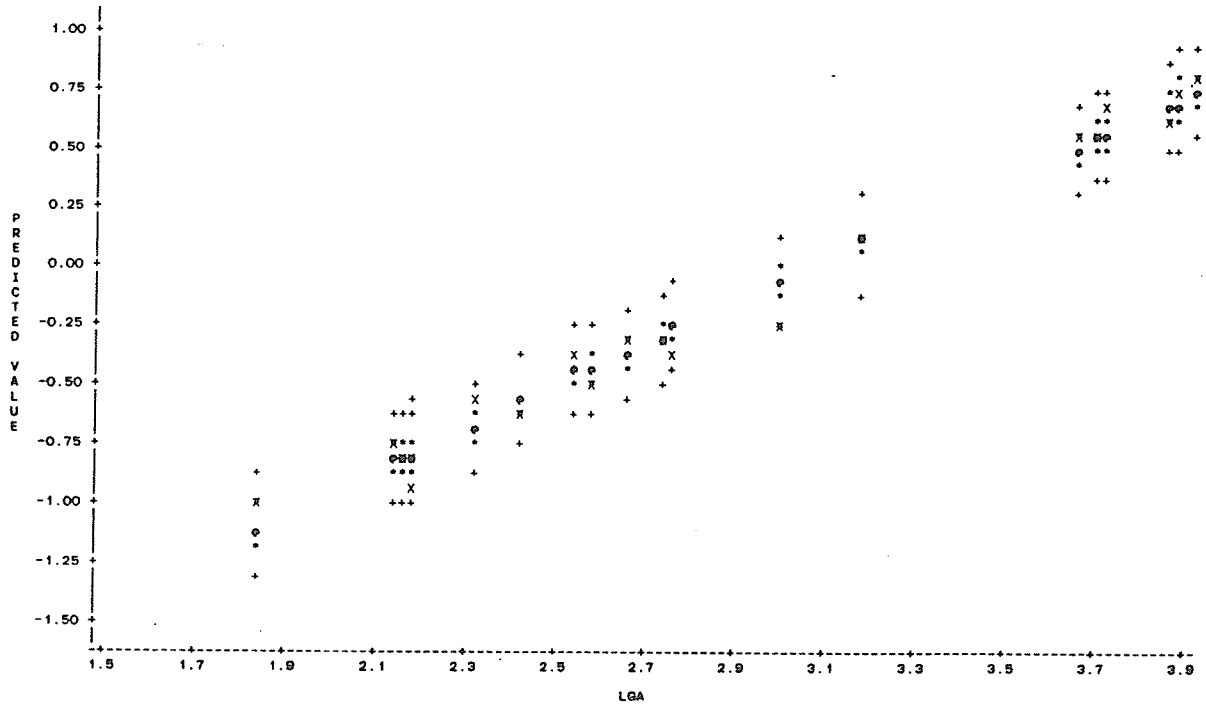
CORRELATION OF ESTIMATES

| CORRB | INTERCEP | LGA |
|---|---|---|
| INTERCEP | 1.0000 | -0.9736 |
| LGA | -0.9736 | 1.0000 |

| OBS | ACTUAL | PREDICT VALUE | STD ERR PREDICT | LOWER95% MEAN | UPPER95% MEAN | LOWER95% PREDICT | UPPER95% PREDICT | RESIDUAL | STD ERR RESIDUAL | STUDENT RESIDUAL | -2-1-0 1 2 | COOK'S D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.981312 | -1.102 | 0.036109 | -1.178 | -1.026 | -1.302 | -.902863 | 0.121048 | 0.080058 | 1.512 | *** | 0.233 |
| 2 | -.357231 | -.277735 | 0.019903 | -.319549 | -.235922 | -.466924 | -.088547 | -.079495 | 0.085539 | -0.929 | * | 0.023 |
| 3 | 0.117034 | 0.094994 | 0.021602 | 0.049610 | 0.140379 | -.095015 | 0.285004 | 0.022040 | 0.085126 | 0.259 | | 0.002 |
| 4 | -.394659 | -.465621 | 0.021772 | -.511363 | -.419879 | -.655716 | -.275525 | 0.070961 | 0.085082 | 0.834 | * | 0.023 |
| 5 | -.332968 | -.301217 | 0.020042 | -.343324 | -.259110 | -.490471 | -.111964 | -.031750 | 0.085506 | -0.371 | | 0.004 |
| 6 | -.317115 | -.367054 | 0.020583 | -.410298 | -.323810 | -.556564 | -.177544 | 0.049939 | 0.085378 | 0.585 | * | 0.010 |
| 7 | -.562222 | -.669003 | 0.025380 | -.722323 | -.615683 | -.861063 | -.476943 | 0.106780 | 0.084077 | 1.270 | ** | 0.073 |
| 8 | 0.676170 | 0.580282 | 0.031735 | 0.513609 | 0.646954 | 0.384095 | 0.776468 | 0.095888 | 0.081890 | 1.171 | ** | 0.103 |
| 9 | -.968503 | -.786865 | 0.027991 | -.845672 | -.728059 | -.980520 | -.593211 | -.181637 | 0.083244 | -2.182 | **** | 0.269 |
| 10 | 0.749751 | 0.712983 | 0.035260 | 0.638906 | 0.787061 | 0.514158 | 0.911809 | 0.036768 | 0.080435 | 0.457 | | 0.020 |
| 11 | 0.606722 | 0.693411 | 0.034728 | 0.620451 | 0.766372 | 0.495000 | 0.891823 | -.086690 | 0.080666 | -1.075 | ** | 0.107 |
| 12 | -.501649 | -.430226 | 0.021297 | -.474968 | -.385484 | -.620083 | -.240368 | -.071424 | 0.085203 | -0.838 | * | 0.022 |
| 13 | -.769676 | -.834838 | 0.029134 | -.896046 | -.773631 | -1.029 | -.640441 | 0.065162 | 0.082851 | 0.786 | * | 0.038 |
| 14 | -.248262 | -.072623 | 0.019947 | -.114531 | -.030716 | -.261833 | 0.116586 | -.175639 | 0.085529 | -2.054 | **** | 0.115 |
| 15 | 0.546607 | 0.555025 | 0.031088 | 0.489712 | 0.620338 | 0.359296 | 0.750753 | -.008418 | 0.082138 | -0.102 | | 0.001 |
| 16 | -.596147 | -.583250 | 0.023697 | -.633035 | -.533465 | -.774358 | -.392141 | -.012897 | 0.084567 | -0.153 | | 0.001 |
| 17 | 0.565566 | 0.514558 | 0.030070 | 0.451384 | 0.577733 | 0.319533 | 0.709584 | 0.051008 | 0.082516 | 0.618 | * | 0.025 |
| 18 | -.781711 | -.804820 | 0.028414 | -.864515 | -.745125 | -.998746 | -.610894 | 0.023109 | 0.083101 | 0.278 | | 0.005 |
| 19 | -.834403 | -.799604 | 0.028290 | -.859040 | -.740169 | -.993451 | -.605758 | -.034798 | 0.083143 | -0.419 | | 0.010 |
| 20 | 0.800000 | 0.759954 | 0.036550 | 0.683165 | 0.836743 | 0.560102 | 0.959805 | 0.040046 | 0.079857 | 0.501 | * | 0.026 |

SUM OF RESIDUALS -2.53686E-14
SUM OF SQUARED RESIDUALS 0.1388349

PLOT OF LSDEV*LGA SYMBOL USED IS X OBSERVED VALUE
PLOT OF P3*LGA SYMBOL USED IS @ VALUE PREDICTED BY REGRESSION
PLOT OF L953*LGA SYMBOL USED IS + ] PREDICTION CONFIDENCE INTERVAL
PLOT OF U953*LGA SYMBOL USED IS + ]
PLOT OF L95M3*LGA SYMBOL USED IS * ] REGRESSION CONFIDENCE INTERVAL (ABOUT MEAN)
PLOT OF U95M3*LGA SYMBOL USED IS * ]



# Table B-1 (cont'd)

DEP VARIABLE: LRNG log (range)

| SOURCE | DF | SUM OF SQUARES | MEAN SQUARE | F VALUE | PROB>F |
|---|---|---|---|---|---|
| MODEL | 1 | 7.184716 | 7.184716 | 933.993 | 0.0001 |
| ERROR | 18 | 0.138464 | 0.007692472 | | |
| C TOTAL | 19 | 7.323180 | | | |

| | | | |
|---|---|---|---|
| ROOT MSE | 0.087707 | R-SQUARE | 0.9811 |
| DEP MEAN | 0.352971 | ADJ R-SQ | 0.9800 |
| C.V. | 24.84816 | | |

| VARIABLE | DF | PARAMETER ESTIMATE | STANDARD ERROR | T FOR HO: PARAMETER=0 | PROB > \|T\| | TYPE I SS | TYPE II SS | STANDARDIZED ESTIMATE | TOLERANCE |
|---|---|---|---|---|---|---|---|---|---|
| INTERCEP | 1 | -2.203305 | 0.085913 | -25.646 | 0.0001 | 2.491767 | 5.059426 | 0.000000 | . |
| LGA | 1 | 0.890285 | 0.029131 | 30.561 | 0.0001 | 7.184716 | 7.184716 | 0.990501 | 1.000000 |

[log (gross D.A.)]

COVARIANCE OF ESTIMATES

| COVB | INTERCEP | LGA |
|---|---|---|
| INTERCEP | 0.007380974 | -0.00243665 |
| LGA | -0.00243665 | 0.0008486226 |

CORRELATION OF ESTIMATES

| CORRB | INTERCEP | LGA |
|---|---|---|
| INTERCEP | 1.0000 | -0.9736 |
| LGA | -0.9736 | 1.0000 |

| OBS | ACTUAL | PREDICT VALUE | STD ERR PREDICT | LOWER95% MEAN | UPPER95% MEAN | LOWER95% PREDICT | UPPER95% PREDICT | RESIDUAL | STD ERR RESIDUAL | STUDENT RESIDUAL | -2-1-0 1 2 | COOK'S D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -.406714 | -.571849 | 0.036061 | -.647609 | -.496089 | -.771079 | -.372619 | 0.165135 | 0.079951 | 2.065 | \|**** \| | 0.434 |
| 2 | 0.213544 | 0.254259 | 0.019876 | 0.212501 | 0.296016 | 0.065323 | 0.443195 | -.040714 | 0.085425 | -0.477 | \| \| | 0.006 |
| 3 | 0.628900 | 0.627659 | 0.021573 | 0.582335 | 0.672982 | 0.437903 | 0.817415 | 0.001241 | 0.085012 | 0.015 | \| \| | 0.000 |
| 4 | 0.157275 | 0.066035 | 0.021743 | 0.020354 | 0.111716 | -.123806 | 0.255877 | 0.091240 | 0.084969 | 1.074 | \| ** \| | 0.038 |
| 5 | 0.213039 | 0.230734 | 0.020016 | 0.188684 | 0.272785 | 0.041733 | 0.419735 | -.017695 | 0.085392 | -0.207 | \| \| | 0.001 |
| 6 | 0.151002 | 0.164779 | 0.020556 | 0.121593 | 0.207965 | -.024477 | 0.354036 | -.013777 | 0.085264 | -0.162 | \| \| | 0.001 |
| 7 | -.110810 | -.137713 | 0.025346 | -.190962 | -.084464 | -.329516 | 0.054091 | 0.026902 | 0.083965 | 0.320 | \| \| | 0.005 |
| 8 | 1.213 | 1.114 | 0.031693 | 1.047 | 1.180 | 0.917895 | 1.310 | 0.099539 | 0.081780 | 1.217 | \| ** \| | 0.111 |
| 9 | -.386053 | -.255787 | 0.027954 | -.314515 | -.197060 | -.449183 | -.062391 | -.130265 | 0.083133 | -1.567 | *** \| | 0.139 |
| 10 | 1.313 | 1.247 | 0.035213 | 1.173 | 1.321 | 1.048 | 1.445 | 0.066433 | 0.080328 | 0.827 | \| * \| | 0.066 |
| 11 | 1.128 | 1.227 | 0.034682 | 1.154 | 1.300 | 1.029 | 1.425 | -.099076 | 0.080558 | -1.230 | ** \| | 0.140 |
| 12 | 0.034909 | 0.101494 | 0.021268 | 0.056812 | 0.146176 | -.088110 | 0.291098 | -.066585 | 0.085089 | -0.783 | * \| | 0.019 |
| 13 | -.268170 | -.303847 | 0.029095 | -.364973 | -.242721 | -.497984 | -.109709 | 0.035677 | 0.082740 | 0.431 | \| \| | 0.011 |
| 14 | 0.266702 | 0.459740 | 0.019921 | 0.417888 | 0.501591 | 0.270783 | 0.648696 | -.193038 | 0.085415 | -2.260 | **** \| | 0.139 |
| 15 | 1.030 | 1.089 | 0.031047 | 1.023 | 1.154 | 0.893049 | 1.284 | -.059011 | 0.082028 | -0.719 | \| * \| | 0.037 |
| 16 | -.050415 | -.051805 | 0.023665 | -.101524 | -.002087 | -.242659 | 0.139048 | 0.001391 | 0.084454 | 0.016 | \| \| | 0.000 |
| 17 | 1.109 | 1.048 | 0.030030 | 0.984888 | 1.111 | 0.853213 | 1.243 | 0.061466 | 0.082406 | 0.746 | \| * \| | 0.037 |
| 18 | -.248644 | -.273774 | 0.028376 | -.333389 | -.214159 | -.467442 | -.080107 | 0.025130 | 0.082990 | 0.303 | \| \| | 0.005 |
| 19 | -.304518 | -.268549 | 0.028253 | -.327905 | -.209193 | -.462137 | -.074961 | -.035969 | 0.083032 | -0.433 | \| \| | 0.011 |
| 20 | 1.376 | 1.294 | 0.036502 | 1.217 | 1.371 | 1.094 | 1.493 | 0.081977 | 0.079750 | 1.028 | \| ** \| | 0.111 |

SUM OF RESIDUALS -2.36339E-14
SUM OF SQUARED RESIDUALS 0.1384645

PLOT OF LRNG*LGA SYMBOL USED IS X OBSERVED VALUE
PLOT OF P7*LGA SYMBOL USED IS @ VALUE PREDICTED BY REGRESSION
PLOT OF L957*LGA SYMBOL USED IS + ] PREDICTION CONFIDENCE INTERVAL
PLOT OF U957*LGA SYMBOL USED IS + ]
PLOT OF L95M7*LGA SYMBOL USED IS * ] REGRESSION CONFIDENCE INTERVAL (ABOUT MEAN)
PLOT OF U95M7*LGA SYMBOL USED IS * ]

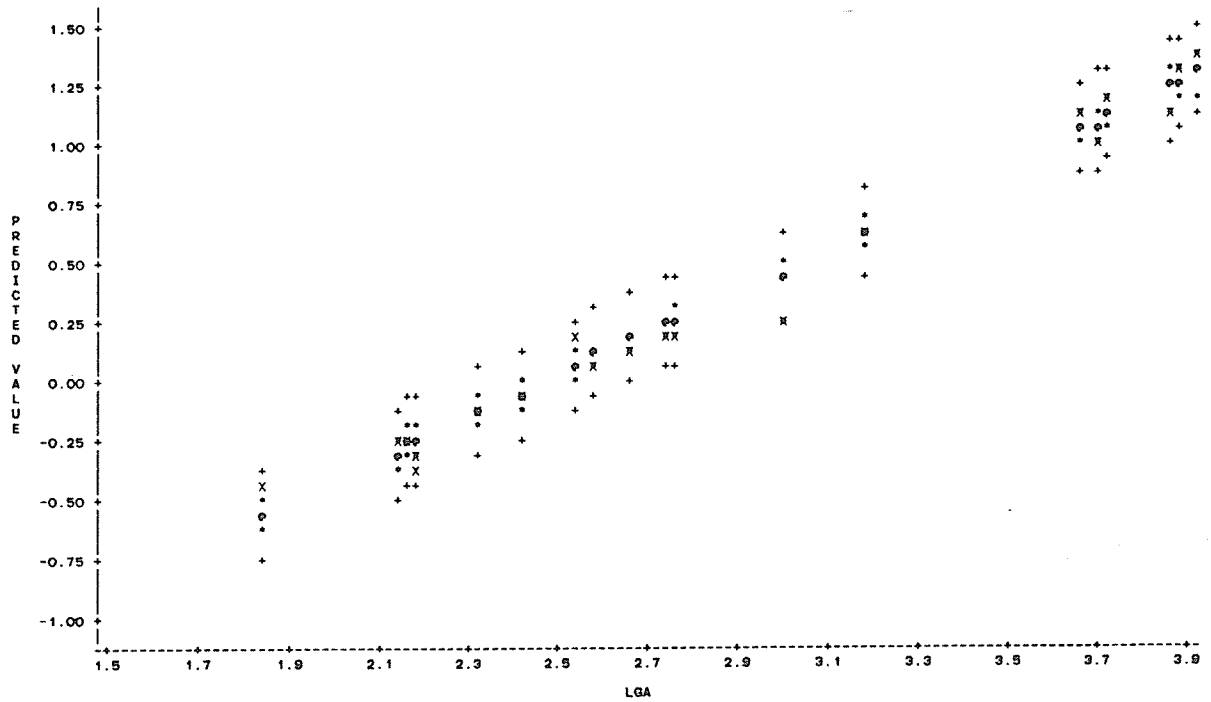


Table B-2

Stations Whose Sample Statistics Fell Outside of the Prediction 95% Confidence Interval

| Monthly Mean Flow Data | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean ($\bar{X}$) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| March | 05OB016 | -[1] | 05OB016 | 05OB016 | - |
| April | 05OB016 | 05OB016 | 05OB016 | 05OB016 | 05OB016 |
| May | 05OA013 | 05OA013 | - | - | - |
| June | 05OA013 | 05OA013<br>05OB006 | 05OB013<br>05OB031 | 05OB031 | 05OB031 |
| July | 05OB006 | -[1] | 05OB006 | 05OB006 | 05OB006 |
| August | 05OB021 | -[1] | 05OB021 | 05OB016<br>05OB021 | 05OB016<br>05OB021 |
| September | - | 05OB016[1] | 05OB016 | 05OB016 | 05OB016 |
| October | 05OB010 | 05OB016[1] | 05OB010 | 05OB010 | 05OB010 |

1 The median data set for these months included stations whose sample medians were zero and hence were not included in the regional logorithmic regression analysis.

Table B-3

Stations Whose Sample Statistics
Have a $|\text{Studentized Residual}| > 1.5$

| Monthly Mean Flow Data | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean ($\bar{X}$) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| March | 05OB016 | 05OB013[1]<br>05OB021 | 05OB016 | 05OB016<br>05OB025 | 05OB016<br>05OB025 |
| April | 05OA013<br>05OB016 | 05OA013<br>05OB016 | 05OB016 | 05OB016 | 05OB016 |
| May | 05OA013<br>05OB006<br>05OB010<br>05OB031 | 05OA013<br>05OB006<br>05OB010 | 05OA013<br>05OB006<br>05OB010<br>05OB031 | 05OB008<br>05OB010 | 05OB008<br>05OB010 |
| June | 05OA013<br>05OB006 | 05OA013<br>05OB006 | 05OB013<br>05OB031 | 05OB008<br>05OB013<br>05OB031 | 05OB008<br>05OB013 |
| July | 05OA013<br>05OB006 | 05OA013[1]<br>05OB010<br>05OB016 | 05OB006 | 05OB006 | 05OB006 |
| August | 05OB016<br>05OB021 | 05OA007[1]<br>05OB016 | 05OB013<br>05OB016<br>05OB021 | 05OB013<br>05OB016<br>05OB021 | 05OB013<br>05OB016<br>05OB021 |
| September | 05OA005<br>05OB006<br>05OB016 | 05OA005[1]<br>05OB006<br>05OB016 | 05OB013<br>05OB016 | 05OA005<br>05OB016 | 05OA005<br>05OB016 |
| October | 05OA013<br>05OB010<br>05OB031 | 05OB016[1] | 05OA008<br>05OB010<br>05OB031 | 05OA008<br>05OB010<br>05OB031 | 05OA008<br>05OB010<br>05OB031 |

1 The median data set for these months included stations whose sample medians were zero and hence were not included in the regional logorithmic regression analysis.

Table B-4

Stations Whose Sample Statistics
Have a Cook's D Value > 0.164

| Monthly Mean Flow Data | Central Tendency | | Dispersion | | |
|---|---|---|---|---|---|
| | Mean ($\bar{X}$) | Median (Md) | Standard Deviation (s) | Range (R) | Maximum (Mx) |
| March | 05OB016 | 05OB013[1]<br>05OB021 | 05OB016 | 05OB016 | 05OB016 |
| April | 05OB016 | 05OB016<br>05OC004 | 05OB016 | 05OB016 | 05OB016 |
| May | 05OA013<br>05OB006 | 05OA013<br>05OB006 | 05OB031 | 05OB008<br>05OC004 | 05OB008<br>05OC004 |
| June | 05OA013<br>05OB006 | 05OA013<br>05OB006 | 05OB008<br>05OB013<br>05OB031 | 05OB008<br>05OB013<br>05OB031 | 05OB008<br>05OB013<br>05OB031 |
| July | 05OB006 | 05OA013[1] | 05OA005<br>05OB006 | 05OA005<br>05OB006 | 05OA005<br>05OB006 |
| August | 05OB019 | 05OB013[1]<br>05OB016<br>05OB025 | 05OA005<br>05OB021 | 05OA005<br>05OB021 | 05OA005<br>05OB021 |
| September | 05OA005<br>05OB006 | 05OB013 | 05OA005<br>05OB016 | 05OA005<br>05OB016 | 05OA005<br>05OB016 |
| October | 05OB010<br>05OB031 | 05OA013[1]<br>05OB016 | 05OB010<br>05OB031 | 05OB010<br>05OB031 | 05OB010<br>05OB031 |

1 The median data set for these months included stations whose sample medians were zero and hence were not included in the regional logorithmic regression analysis.

# APPENDIX C

Correlation Analysis for
Pembina River Basin
Streamflow Data

# Table C-1

## Pearson Correlation Coefficients* for Pembina River Basin Daily Mean Peak Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>20 | 0.82436<br>0.0001<br>20 | 0.90533<br>0.0001<br>20 | 0.90922<br>0.0001<br>20 | 0.83936<br>0.0001<br>20 | 0.81080<br>0.0004<br>14 | 0.72037<br>0.9188<br>10 | 0.93040<br>0.0001<br>15 | 0.69192<br>0.0010<br>19 | 0.84452<br>0.0001<br>20 | 0.96142<br>0.0001<br>8 | 0.64107<br>0.0023<br>20 | 0.56958<br>0.0088<br>20 | 0.91133<br>0.0001<br>20 | 0.89624<br>0.0002<br>11 | 0.74550<br>0.0002<br>20 | 0.86612<br>0.0001<br>20 | 0.90775<br>0.0001<br>19 | 0.65010<br>0.0019<br>20 | 0.85615<br>0.0001<br>20 |
| 050A006 | 0.82436<br>0.0001<br>20 | 1.00000<br>0.0000<br>23 | 0.90453<br>0.0001<br>23 | 0.79848<br>0.0001<br>23 | 0.94019<br>0.0001<br>20 | 0.90480<br>0.0001<br>14 | 0.92009<br>0.0002<br>10 | 0.84774<br>0.0001<br>15 | 0.84167<br>0.0001<br>22 | 0.88456<br>0.0001<br>20 | 0.94541<br>0.0001<br>11 | 0.64241<br>0.0010<br>23 | 0.72632<br>0.0001<br>22 | 0.71888<br>0.0002<br>21 | 0.92272<br>0.0001<br>11 | 0.61193<br>0.0041<br>20 | 0.94398<br>0.0001<br>20 | 0.90885<br>0.0001<br>19 | 0.60605<br>0.0046<br>20 | 0.77981<br>0.0001<br>23 |
| 050A007 | 0.90533<br>0.0001<br>20 | 0.90453<br>0.0001<br>23 | 1.00000<br>0.0000<br>23 | 0.83233<br>0.0001<br>23 | 0.84402<br>0.0001<br>20 | 0.84937<br>0.0001<br>14 | 0.82111<br>0.0036<br>10 | 0.96560<br>0.0001<br>15 | 0.78436<br>0.0001<br>22 | 0.89169<br>0.0001<br>20 | 0.97480<br>0.0001<br>11 | 0.61539<br>0.0018<br>23 | 0.71761<br>0.0002<br>22 | 0.85481<br>0.0001<br>21 | 0.99269<br>0.0001<br>11 | 0.67610<br>0.0011<br>20 | 0.95364<br>0.0001<br>20 | 0.92563<br>0.0001<br>19 | 0.66785<br>0.0013<br>20 | 0.81715<br>0.0001<br>23 |
| 050A008 | 0.90922<br>0.0001<br>20 | 0.79848<br>0.0001<br>23 | 0.83233<br>0.0001<br>23 | 1.00000<br>0.0000<br>23 | 0.90067<br>0.0001<br>20 | 0.97293<br>0.0001<br>14 | 0.76073<br>0.0106<br>10 | 0.82063<br>0.0002<br>15 | 0.66548<br>0.0007<br>22 | 0.65789<br>0.0016<br>20 | 0.91578<br>0.0001<br>11 | 0.48264<br>0.0197<br>23 | 0.48610<br>0.0218<br>22 | 0.81306<br>0.0001<br>21 | 0.88682<br>0.0003<br>11 | 0.58236<br>0.0071<br>20 | 0.73871<br>0.0002<br>20 | 0.76512<br>0.0001<br>19 | 0.48026<br>0.0321<br>20 | 0.71448<br>0.0001<br>23 |
| 050A010 | 0.83936<br>0.0001<br>20 | 0.94019<br>0.0001<br>20 | 0.84402<br>0.0001<br>20 | 0.90067<br>0.0001<br>20 | 1.00000<br>0.0000<br>20 | 0.95993<br>0.0001<br>14 | 0.81665<br>0.0039<br>10 | 0.85563<br>0.0001<br>15 | 0.78886<br>0.0001<br>19 | 0.76866<br>0.0001<br>20 | 0.83186<br>0.0104<br>8 | 0.49066<br>0.0281<br>20 | 0.66875<br>0.0013<br>20 | 0.67711<br>0.0010<br>20 | 0.77544<br>0.0050<br>11 | 0.54955<br>0.0121<br>20 | 0.84896<br>0.0001<br>20 | 0.84507<br>0.0001<br>19 | 0.54642<br>0.0127<br>20 | 0.71940<br>0.0003<br>20 |
| 050A012 | 0.81080<br>0.0004<br>14 | 0.90480<br>0.0001<br>14 | 0.84937<br>0.0001<br>14 | 0.97293<br>0.0001<br>14 | 0.95993<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.78712<br>0.0069<br>10 | 0.81164<br>0.0004<br>14 | 0.75360<br>0.0029<br>13 | 0.68980<br>0.0063<br>14 | 0.96841<br>0.0003<br>7 | 0.33010<br>0.2491<br>14 | 0.65090<br>0.0117<br>14 | 0.57506<br>0.0314<br>14 | 0.95190<br>0.0001<br>10 | 0.35542<br>0.2124<br>14 | 0.82164<br>0.0003<br>14 | 0.71073<br>0.0044<br>14 | 0.46564<br>0.0933<br>14 | 0.54443<br>0.0441<br>14 |
| 050A013 | 0.72037<br>0.0188<br>10 | 0.92009<br>0.0002<br>10 | 0.82111<br>0.0036<br>10 | 0.76073<br>0.0106<br>10 | 0.81665<br>0.0039<br>10 | 0.78712<br>0.0069<br>10 | 1.00000<br>0.0000<br>10 | 0.85600<br>0.0016<br>10 | 0.91623<br>0.0002<br>10 | 0.77013<br>0.0092<br>10 | 0.99603<br>0.0568<br>3 | 0.57419<br>0.0826<br>10 | 0.61279<br>0.0596<br>10 | 0.63089<br>0.0505<br>10 | 0.97679<br>0.0008<br>6 | 0.56013<br>0.0922<br>10 | 0.85254<br>0.0017<br>10 | 0.78792<br>0.0068<br>10 | 0.44205<br>0.2008<br>10 | 0.65753<br>0.0388<br>10 |
| 050B001 | 0.93040<br>0.0001<br>15 | 0.94774<br>0.0001<br>15 | 0.96560<br>0.0001<br>15 | 0.82063<br>0.0002<br>15 | 0.85563<br>0.0001<br>15 | 0.81164<br>0.0004<br>14 | 0.85600<br>0.0016<br>10 | 1.00000<br>0.0000<br>15 | 0.91164<br>0.0001<br>14 | 0.94437<br>0.0001<br>15 | 0.98902<br>0.0001<br>7 | 0.59870<br>0.0184<br>15 | 0.73268<br>0.0019<br>15 | 0.83276<br>0.0001<br>15 | 0.99797<br>0.0001<br>10 | 0.66151<br>0.0072<br>15 | 0.99471<br>0.0001<br>15 | 0.97901<br>0.0001<br>15 | 0.60222<br>0.0175<br>15 | 0.80389<br>0.0003<br>15 |
| 050B006 | 0.69192<br>0.0010<br>19 | 0.84167<br>0.0001<br>22 | 0.78436<br>0.0001<br>22 | 0.66548<br>0.0007<br>22 | 0.79886<br>0.0001<br>19 | 0.75360<br>0.0029<br>13 | 0.91623<br>0.0002<br>10 | 0.91164<br>0.0001<br>14 | 1.00000<br>0.0000<br>22 | 0.78728<br>0.0001<br>19 | 0.67461<br>0.0324<br>10 | 0.61727<br>0.0022<br>22 | 0.74106<br>0.0001<br>21 | 0.66283<br>0.0014<br>20 | 0.62812<br>0.0518<br>10 | 0.66951<br>0.0017<br>19 | 0.81105<br>0.0001<br>19 | 0.89586<br>0.0001<br>18 | 0.60095<br>0.0065<br>19 | 0.76935<br>0.0001<br>22 |
| 050B007 | 0.84452<br>0.0001<br>20 | 0.88456<br>0.0001<br>20 | 0.89169<br>0.0001<br>20 | 0.65789<br>0.0016<br>20 | 0.76866<br>0.0001<br>20 | 0.68980<br>0.0063<br>14 | 0.77013<br>0.0092<br>10 | 0.94437<br>0.0001<br>15 | 0.78728<br>0.0001<br>19 | 1.00000<br>0.0000<br>20 | 0.99541<br>0.0001<br>8 | 0.79409<br>0.0001<br>20 | 0.73072<br>0.0003<br>20 | 0.80192<br>0.0001<br>20 | 0.87137<br>0.0005<br>11 | 0.80036<br>0.0001<br>20 | 0.95704<br>0.0001<br>20 | 0.94208<br>0.0001<br>19 | 0.78925<br>0.0001<br>20 | 0.90797<br>0.0001<br>20 |
| 050B008 | 0.96142<br>0.0001<br>8 | 0.94541<br>0.0001<br>11 | 0.97480<br>0.0001<br>11 | 0.91578<br>0.0001<br>11 | 0.83186<br>0.0104<br>8 | 0.96841<br>0.0003<br>7 | 0.99603<br>0.0568<br>3 | 0.98902<br>0.0001<br>7 | 0.67461<br>0.0324<br>10 | 0.99541<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.46479<br>0.1498<br>11 | 0.93871<br>0.0001<br>10 | 0.93341<br>0.0002<br>9 | 0.98562<br>0.0001<br>8 | 0.57203<br>0.1385<br>8 | 0.98705<br>0.0001<br>8 | 0.99008<br>0.0001<br>7 | 0.94069<br>0.0005<br>8 | 0.86261<br>0.0003<br>12 |
| 050B010 | 0.64107<br>0.0023<br>20 | 0.64241<br>0.0010<br>23 | 0.61539<br>0.0018<br>23 | 0.48264<br>0.0197<br>23 | 0.49066<br>0.0281<br>20 | 0.33010<br>0.2491<br>14 | 0.57419<br>0.0826<br>10 | 0.59870<br>0.0184<br>15 | 0.61727<br>0.0022<br>22 | 0.79409<br>0.0001<br>20 | 0.46479<br>0.1498<br>11 | 1.00000<br>0.0000<br>23 | 0.37801<br>0.0828<br>22 | 0.67509<br>0.0008<br>21 | 0.17660<br>0.6035<br>11 | 0.79510<br>0.0001<br>20 | 0.65472<br>0.0017<br>20 | 0.65528<br>0.0023<br>19 | 0.66850<br>0.0013<br>20 | 0.77317<br>0.0001<br>23 |
| 050B013 | 0.56958<br>0.0088<br>20 | 0.72632<br>0.0001<br>22 | 0.71761<br>0.0002<br>22 | 0.48610<br>0.0218<br>22 | 0.66875<br>0.0013<br>20 | 0.65090<br>0.0117<br>14 | 0.61279<br>0.0596<br>10 | 0.73268<br>0.0019<br>15 | 0.74106<br>0.0001<br>21 | 0.73072<br>0.0003<br>20 | 0.93871<br>0.0001<br>10 | 0.37801<br>0.0828<br>22 | 1.00000<br>0.0000<br>22 | 0.56052<br>0.0082<br>21 | 0.72742<br>0.0112<br>11 | 0.56520<br>0.0094<br>20 | 0.75799<br>0.0001<br>20 | 0.70022<br>0.0008<br>19 | 0.78024<br>0.0001<br>20 | 0.72284<br>0.0001<br>22 |
| 050B016 | 0.91133<br>0.0001<br>20 | 0.71888<br>0.0002<br>21 | 0.85481<br>0.0001<br>21 | 0.81306<br>0.0001<br>21 | 0.67711<br>0.0010<br>20 | 0.57506<br>0.0314<br>14 | 0.63089<br>0.0505<br>10 | 0.83276<br>0.0001<br>15 | 0.66283<br>0.0014<br>20 | 0.80192<br>0.0001<br>20 | 0.93341<br>0.0002<br>9 | 0.67509<br>0.0008<br>21 | 0.56052<br>0.0082<br>21 | 1.00000<br>0.0000<br>21 | 0.75136<br>0.0077<br>11 | 0.86435<br>0.0001<br>20 | 0.76451<br>0.0001<br>20 | 0.81825<br>0.0001<br>19 | 0.67133<br>0.0012<br>20 | 0.89303<br>0.0001<br>21 |
| 050B019 | 0.89624<br>0.0002<br>11 | 0.92272<br>0.0001<br>11 | 0.99269<br>0.0001<br>11 | 0.88682<br>0.0003<br>11 | 0.77544<br>0.0050<br>11 | 0.95190<br>0.0001<br>10 | 0.97679<br>0.0008<br>6 | 0.99797<br>0.0001<br>10 | 0.62812<br>0.0518<br>10 | 0.87137<br>0.0005<br>11 | 0.98562<br>0.0001<br>8 | 0.17660<br>0.6035<br>11 | 0.72742<br>0.0112<br>11 | 0.75136<br>0.0077<br>11 | 1.00000<br>0.0000<br>11 | 0.37044<br>0.2621<br>11 | 0.98997<br>0.0001<br>11 | 0.99352<br>0.0001<br>10 | 0.53501<br>0.0899<br>11 | 0.62491<br>0.0398<br>11 |
| 050B021 | 0.74550<br>0.0002<br>20 | 0.61193<br>0.0041<br>20 | 0.67610<br>0.0011<br>20 | 0.58236<br>0.0071<br>20 | 0.54955<br>0.0121<br>20 | 0.35542<br>0.2124<br>14 | 0.56013<br>0.0922<br>10 | 0.66151<br>0.0072<br>15 | 0.66951<br>0.0017<br>19 | 0.80036<br>0.0001<br>20 | 0.57203<br>0.1385<br>8 | 0.79510<br>0.0001<br>20 | 0.56520<br>0.0094<br>20 | 0.86435<br>0.0001<br>20 | 0.37044<br>0.2621<br>11 | 1.00000<br>0.0000<br>20 | 0.67239<br>0.0012<br>20 | 0.72907<br>0.0004<br>19 | 0.72714<br>0.0003<br>20 | 0.92897<br>0.0001<br>20 |
| 050B023 | 0.86612<br>0.0001<br>20 | 0.94398<br>0.0001<br>20 | 0.95364<br>0.0001<br>20 | 0.73871<br>0.0002<br>20 | 0.84896<br>0.0001<br>20 | 0.82164<br>0.0003<br>14 | 0.85254<br>0.0017<br>10 | 0.99471<br>0.0001<br>15 | 0.81105<br>0.0001<br>19 | 0.95704<br>0.0001<br>20 | 0.98705<br>0.0001<br>8 | 0.65472<br>0.0017<br>20 | 0.75799<br>0.0001<br>20 | 0.76451<br>0.0001<br>20 | 0.98997<br>0.0001<br>11 | 0.67239<br>0.0012<br>20 | 1.00000<br>0.0000<br>20 | 0.96960<br>0.0001<br>19 | 0.69859<br>0.0006<br>20 | 0.82409<br>0.0001<br>20 |
| 050B025 | 0.90775<br>0.0001<br>19 | 0.90885<br>0.0001<br>19 | 0.92563<br>0.0001<br>19 | 0.76512<br>0.0001<br>19 | 0.84507<br>0.0001<br>19 | 0.71073<br>0.0044<br>14 | 0.78792<br>0.0068<br>10 | 0.97901<br>0.0001<br>15 | 0.89586<br>0.0001<br>18 | 0.94208<br>0.0001<br>19 | 0.99008<br>0.0001<br>7 | 0.65528<br>0.0023<br>19 | 0.70022<br>0.0008<br>19 | 0.81825<br>0.0001<br>19 | 0.99352<br>0.0001<br>10 | 0.72907<br>0.0004<br>19 | 0.96960<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.64316<br>0.0030<br>19 | 0.86145<br>0.0001<br>19 |
| 050B031 | 0.65010<br>0.0019<br>20 | 0.60605<br>0.0046<br>20 | 0.66785<br>0.0013<br>20 | 0.48026<br>0.0321<br>20 | 0.54642<br>0.0127<br>20 | 0.46564<br>0.0933<br>14 | 0.44205<br>0.2009<br>10 | 0.60222<br>0.0175<br>15 | 0.60095<br>0.0065<br>19 | 0.78925<br>0.0001<br>20 | 0.94069<br>0.0005<br>8 | 0.66850<br>0.0013<br>20 | 0.78024<br>0.0001<br>20 | 0.67133<br>0.0012<br>20 | 0.53501<br>0.0899<br>11 | 0.72714<br>0.0003<br>20 | 0.69859<br>0.0006<br>20 | 0.64316<br>0.0030<br>19 | 1.00000<br>0.0000<br>20 | 0.84076<br>0.0001<br>20 |
| 050C004 | 0.85615<br>0.0001<br>20 | 0.77981<br>0.0001<br>23 | 0.81715<br>0.0001<br>23 | 0.71448<br>0.0001<br>23 | 0.71940<br>0.0003<br>20 | 0.54443<br>0.0441<br>14 | 0.65753<br>0.0388<br>10 | 0.80389<br>0.0003<br>15 | 0.76935<br>0.0001<br>22 | 0.90797<br>0.0001<br>20 | 0.86261<br>0.0003<br>12 | 0.77317<br>0.0001<br>23 | 0.72284<br>0.0001<br>22 | 0.89303<br>0.0001<br>21 | 0.62491<br>0.0398<br>11 | 0.92897<br>0.0001<br>20 | 0.82409<br>0.0001<br>20 | 0.86145<br>0.0001<br>19 | 0.84076<br>0.0001<br>20 | 1.00000<br>0.0000<br>27 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-2

## Spearman Correlation Coefficients* for Pembina River Basin Daily Mean Peak Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>20 | 0.75188<br>0.0001<br>20 | 0.88379<br>0.0001<br>20 | 0.68571<br>0.0008<br>20 | 0.71278<br>0.0004<br>20 | 0.77582<br>0.0011<br>14 | 0.73333<br>0.0158<br>10 | 0.92143<br>0.0001<br>15 | 0.67018<br>0.0017<br>19 | 0.81353<br>0.0001<br>20 | 0.66667<br>0.0710<br>8 | 0.69575<br>0.0007<br>20 | 0.60752<br>0.0045<br>20 | 0.84812<br>0.0001<br>20 | 0.93636<br>0.0001<br>11 | 0.70128<br>0.0006<br>20 | 0.87368<br>0.0001<br>20 | 0.86667<br>0.0001<br>19 | 0.62505<br>0.0032<br>20 | 0.73083<br>0.0003<br>20 |
| 050A006 | 0.75188<br>0.0001<br>20 | 1.00000<br>0.0000<br>23 | 0.89795<br>0.0001<br>23 | 0.86166<br>0.0001<br>23 | 0.93383<br>0.0001<br>20 | 0.88571<br>0.0001<br>14 | 0.87879<br>0.0008<br>10 | 0.85714<br>0.0001<br>15 | 0.80124<br>0.0001<br>22 | 0.78346<br>0.0001<br>20 | 0.60909<br>0.0467<br>11 | 0.76748<br>0.0001<br>23 | 0.77414<br>0.0001<br>22 | 0.77273<br>0.0001<br>21 | 0.57273<br>0.0655<br>11 | 0.59443<br>0.0057<br>20 | 0.88421<br>0.0001<br>20 | 0.83684<br>0.0001<br>19 | 0.71004<br>0.0005<br>20 | 0.81818<br>0.0001<br>23 |
| 050A007 | 0.88379<br>0.0001<br>20 | 0.89795<br>0.0001<br>23 | 1.00000<br>0.0000<br>23 | 0.83568<br>0.0001<br>23 | 0.88078<br>0.0001<br>20 | 0.86374<br>0.0001<br>14 | 0.87879<br>0.0008<br>10 | 0.86071<br>0.0001<br>15 | 0.73482<br>0.0001<br>22 | 0.77247<br>0.0001<br>20 | 0.58182<br>0.0604<br>11 | 0.80672<br>0.0001<br>23 | 0.72635<br>0.0001<br>22 | 0.79701<br>0.0001<br>21 | 0.81818<br>0.0021<br>11 | 0.65487<br>0.0017<br>20 | 0.85145<br>0.0001<br>20 | 0.83370<br>0.0001<br>19 | 0.68924<br>0.0008<br>20 | 0.76452<br>0.0001<br>23 |
| 050A008 | 0.68571<br>0.0008<br>20 | 0.86166<br>0.0001<br>23 | 0.83568<br>0.0001<br>23 | 1.00000<br>0.0000<br>23 | 0.90677<br>0.0001<br>20 | 0.94725<br>0.0001<br>14 | 0.87879<br>0.0008<br>10 | 0.77857<br>0.0006<br>15 | 0.71428<br>0.0002<br>22 | 0.65865<br>0.0016<br>20 | 0.41818<br>0.2006<br>11 | 0.64986<br>0.0008<br>23 | 0.58216<br>0.0045<br>22 | 0.60909<br>0.0034<br>21 | 0.44545<br>0.1697<br>11 | 0.48457<br>0.0304<br>20 | 0.81353<br>0.0001<br>20 | 0.71228<br>0.0006<br>19 | 0.56788<br>0.0090<br>20 | 0.66798<br>0.0005<br>23 |
| 050A010 | 0.71278<br>0.0004<br>20 | 0.93383<br>0.0001<br>20 | 0.88078<br>0.0001<br>20 | 0.90677<br>0.0001<br>20 | 1.00000<br>0.0000<br>20 | 0.93407<br>0.0001<br>14 | 0.87879<br>0.0008<br>10 | 0.75714<br>0.0011<br>15 | 0.70000<br>0.0008<br>19 | 0.66466<br>0.0014<br>20 | 0.04762<br>0.9108<br>8 | 0.65664<br>0.0017<br>20 | 0.66165<br>0.0015<br>20 | 0.62857<br>0.0030<br>20 | 0.36364<br>0.2716<br>11 | 0.52445<br>0.0176<br>20 | 0.76391<br>0.0001<br>20 | 0.70351<br>0.0008<br>19 | 0.59722<br>0.0054<br>20 | 0.67820<br>0.0010<br>20 |
| 050A012 | 0.77582<br>0.0011<br>14 | 0.88571<br>0.0001<br>14 | 0.86974<br>0.0001<br>14 | 0.94725<br>0.0001<br>14 | 0.93407<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.86667<br>0.0012<br>10 | 0.72308<br>0.0035<br>14 | 0.59890<br>0.0306<br>13 | 0.50769<br>0.0638<br>14 | 0.03571<br>0.9394<br>7 | 0.51485<br>0.0596<br>14 | 0.37143<br>0.1910<br>14 | 0.50769<br>0.0638<br>14 | 0.69697<br>0.0251<br>10 | 0.30989<br>0.2809<br>14 | 0.72747<br>0.0032<br>14 | 0.56044<br>0.0371<br>14 | 0.42418<br>0.1306<br>14 | 0.49890<br>0.0694<br>14 |
| 050A013 | 0.73333<br>0.0158<br>10 | 0.87879<br>0.0008<br>10 | 0.87879<br>0.0008<br>10 | 0.87879<br>0.0008<br>10 | 0.87879<br>0.0008<br>10 | 0.86667<br>0.0012<br>10 | 1.00000<br>0.0000<br>10 | 0.89091<br>0.0005<br>10 | 0.66061<br>0.0376<br>10 | 0.69697<br>0.0251<br>10 | 1.00000<br>0.0000<br>3 | 0.64848<br>0.0425<br>10 | 0.46667<br>0.1739<br>10 | 0.64848<br>0.0425<br>10 | 0.94286<br>0.0048<br>6 | 0.53939<br>0.1076<br>10 | 0.86667<br>0.0012<br>10 | 0.69697<br>0.0251<br>10 | 0.50303<br>0.1383<br>10 | 0.61212<br>0.0600<br>10 |
| 050B001 | 0.92143<br>0.0001<br>15 | 0.85714<br>0.0001<br>15 | 0.86071<br>0.0001<br>15 | 0.77857<br>0.0006<br>15 | 0.75714<br>0.0011<br>15 | 0.72308<br>0.0035<br>14 | 0.89091<br>0.0005<br>10 | 1.00000<br>0.0000<br>15 | 0.82418<br>0.0003<br>14 | 0.94643<br>0.0001<br>15 | 0.96429<br>0.0005<br>7 | 0.77569<br>0.0007<br>15 | 0.69286<br>0.0042<br>15 | 0.94286<br>0.0001<br>15 | 0.96364<br>0.0001<br>10 | 0.80000<br>0.0003<br>15 | 0.95714<br>0.0001<br>15 | 0.88929<br>0.0001<br>15 | 0.71429<br>0.0028<br>15 | 0.86786<br>0.0001<br>15 |
| 050B006 | 0.67018<br>0.0017<br>19 | 0.80124<br>0.0001<br>22 | 0.73482<br>0.0001<br>22 | 0.71429<br>0.0002<br>22 | 0.70000<br>0.0008<br>19 | 0.59890<br>0.0306<br>13 | 0.66061<br>0.0376<br>10 | 0.82418<br>0.0003<br>14 | 1.00000<br>0.0000<br>22 | 0.75263<br>0.0002<br>19 | 0.62424<br>0.0537<br>10 | 0.73348<br>0.0001<br>22 | 0.80909<br>0.0001<br>21 | 0.74286<br>0.0002<br>20 | 0.22424<br>0.5334<br>10 | 0.58911<br>0.0080<br>19 | 0.82807<br>0.0001<br>19 | 0.90712<br>0.0001<br>18 | 0.74155<br>0.0003<br>19 | 0.80576<br>0.0001<br>22 |
| 050B007 | 0.81353<br>0.0001<br>20 | 0.78346<br>0.0001<br>20 | 0.77247<br>0.0001<br>20 | 0.65865<br>0.0016<br>20 | 0.66466<br>0.0014<br>20 | 0.50769<br>0.0638<br>14 | 0.69697<br>0.0251<br>10 | 0.94643<br>0.0001<br>15 | 0.75263<br>0.0002<br>19 | 1.00000<br>0.0000<br>20 | 0.95238<br>0.0003<br>8 | 0.81158<br>0.0001<br>20 | 0.80602<br>0.0001<br>20 | 0.96241<br>0.0001<br>20 | 0.85455<br>0.0008<br>11 | 0.85403<br>0.0001<br>20 | 0.92782<br>0.0001<br>20 | 0.93860<br>0.0001<br>19 | 0.81610<br>0.0001<br>20 | 0.93383<br>0.0001<br>20 |
| 050B008 | 0.66667<br>0.0710<br>8 | 0.60909<br>0.0467<br>11 | 0.58182<br>0.0604<br>11 | 0.41818<br>0.2006<br>11 | 0.04762<br>0.9108<br>8 | 0.03571<br>0.9394<br>7 | 1.00000<br>0.0000<br>3 | 0.96429<br>0.0005<br>7 | 0.62424<br>0.0537<br>10 | 0.95238<br>0.0003<br>8 | 1.00000<br>0.0000<br>12 | 0.55125<br>0.0788<br>11 | 0.84242<br>0.0022<br>10 | 0.93333<br>0.0002<br>8 | 0.83333<br>0.0102<br>8 | 0.85031<br>0.0075<br>8 | 0.85714<br>0.0065<br>8 | 0.85714<br>0.0137<br>7 | 0.30952<br>0.4556<br>8 | 0.86014<br>0.0003<br>12 |
| 050B010 | 0.69575<br>0.0007<br>20 | 0.76748<br>0.0001<br>23 | 0.80672<br>0.0001<br>23 | 0.64986<br>0.0008<br>23 | 0.65664<br>0.0017<br>20 | 0.51485<br>0.0596<br>14 | 0.64848<br>0.0425<br>10 | 0.77569<br>0.0007<br>15 | 0.73348<br>0.0001<br>22 | 0.81158<br>0.0001<br>20 | 0.55125<br>0.0788<br>11 | 1.00000<br>0.0000<br>23 | 0.71392<br>0.0002<br>22 | 0.74959<br>0.0001<br>21 | 0.47836<br>0.1367<br>11 | 0.73617<br>0.0002<br>20 | 0.77247<br>0.0001<br>20 | 0.77139<br>0.0001<br>19 | 0.92701<br>0.0001<br>20 | 0.87176<br>0.0001<br>23 |
| 050B013 | 0.60752<br>0.0045<br>20 | 0.77414<br>0.0001<br>22 | 0.72635<br>0.0001<br>22 | 0.58216<br>0.0045<br>22 | 0.66165<br>0.0015<br>20 | 0.37143<br>0.1910<br>14 | 0.46667<br>0.1739<br>10 | 0.69286<br>0.0042<br>15 | 0.80909<br>0.0001<br>21 | 0.80602<br>0.0001<br>20 | 0.84242<br>0.0022<br>10 | 0.71392<br>0.0002<br>22 | 1.00000<br>0.0000<br>22 | 0.78312<br>0.0001<br>21 | 0.37273<br>0.2589<br>11 | 0.69451<br>0.0007<br>20 | 0.75940<br>0.0001<br>20 | 0.83860<br>0.0001<br>19 | 0.74991<br>0.0001<br>20 | 0.82722<br>0.0001<br>22 |
| 050B016 | 0.84812<br>0.0001<br>20 | 0.77273<br>0.0001<br>21 | 0.79701<br>0.0001<br>21 | 0.60909<br>0.0034<br>21 | 0.62857<br>0.0030<br>20 | 0.50769<br>0.0638<br>14 | 0.64848<br>0.0425<br>10 | 0.94286<br>0.0001<br>15 | 0.74286<br>0.0002<br>20 | 0.96241<br>0.0001<br>20 | 0.93333<br>0.0002<br>9 | 0.74959<br>0.0001<br>21 | 0.78312<br>0.0001<br>21 | 1.00000<br>0.0000<br>21 | 0.83636<br>0.0013<br>11 | 0.87208<br>0.0001<br>20 | 0.89023<br>0.0001<br>20 | 0.94035<br>0.0001<br>19 | 0.73637<br>0.0002<br>20 | 0.87532<br>0.0001<br>21 |
| 050B019 | 0.93636<br>0.0001<br>11 | 0.57273<br>0.0655<br>11 | 0.81818<br>0.0021<br>11 | 0.44545<br>0.1697<br>11 | 0.36364<br>0.2716<br>11 | 0.69697<br>0.0251<br>10 | 0.94286<br>0.0048<br>6 | 0.96364<br>0.0001<br>10 | 0.22424<br>0.5334<br>10 | 0.85455<br>0.0008<br>11 | 0.83333<br>0.0102<br>8 | 0.47836<br>0.1367<br>11 | 0.37273<br>0.2589<br>11 | 0.83636<br>0.0013<br>11 | 1.00000<br>0.0000<br>11 | 0.68793<br>0.0193<br>11 | 0.86364<br>0.0006<br>11 | 0.90303<br>0.0003<br>10 | 0.42727<br>0.1899<br>11 | 0.69091<br>0.0186<br>11 |
| 050B021 | 0.70128<br>0.0006<br>20 | 0.59443<br>0.0057<br>20 | 0.65487<br>0.0017<br>20 | 0.48457<br>0.0304<br>20 | 0.52445<br>0.0176<br>20 | 0.30989<br>0.2809<br>14 | 0.53939<br>0.1076<br>10 | 0.80000<br>0.0003<br>15 | 0.58911<br>0.0080<br>19 | 0.85403<br>0.0001<br>20 | 0.85031<br>0.0075<br>8 | 0.73617<br>0.0002<br>20 | 0.69451<br>0.0007<br>20 | 0.87208<br>0.0001<br>20 | 0.68793<br>0.0193<br>11 | 1.00000<br>0.0000<br>20 | 0.72385<br>0.0003<br>20 | 0.78719<br>0.0001<br>19 | 0.72337<br>0.0003<br>20 | 0.84801<br>0.0001<br>20 |
| 050B023 | 0.87368<br>0.0001<br>20 | 0.88421<br>0.0001<br>20 | 0.85145<br>0.0001<br>20 | 0.81353<br>0.0001<br>20 | 0.76391<br>0.0001<br>20 | 0.72747<br>0.0032<br>14 | 0.86667<br>0.0012<br>10 | 0.95714<br>0.0001<br>15 | 0.82807<br>0.0001<br>19 | 0.92782<br>0.0001<br>20 | 0.85714<br>0.0065<br>8 | 0.77247<br>0.0001<br>20 | 0.75940<br>0.0001<br>20 | 0.89023<br>0.0001<br>20 | 0.86364<br>0.0006<br>11 | 0.72385<br>0.0003<br>20 | 1.00000<br>0.0000<br>20 | 0.95088<br>0.0001<br>19 | 0.76119<br>0.0001<br>20 | 0.90526<br>0.0001<br>20 |
| 050B025 | 0.86667<br>0.0001<br>19 | 0.83684<br>0.0001<br>19 | 0.83370<br>0.0001<br>19 | 0.71228<br>0.0006<br>19 | 0.70351<br>0.0008<br>19 | 0.56044<br>0.0371<br>14 | 0.69697<br>0.0251<br>10 | 0.88929<br>0.0001<br>15 | 0.90712<br>0.0001<br>18 | 0.93860<br>0.0001<br>19 | 0.85714<br>0.0137<br>7 | 0.77139<br>0.0001<br>19 | 0.83860<br>0.0001<br>19 | 0.94035<br>0.0001<br>19 | 0.90303<br>0.0003<br>10 | 0.78719<br>0.0001<br>19 | 0.95088<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.79596<br>0.0001<br>19 | 0.91930<br>0.0001<br>19 |
| 050B031 | 0.62505<br>0.0032<br>20 | 0.71004<br>0.0005<br>20 | 0.68924<br>0.0008<br>20 | 0.56788<br>0.0090<br>20 | 0.59722<br>0.0054<br>20 | 0.42418<br>0.1306<br>14 | 0.50303<br>0.1383<br>10 | 0.71429<br>0.0028<br>15 | 0.74155<br>0.0003<br>19 | 0.81610<br>0.0001<br>20 | 0.30952<br>0.4556<br>8 | 0.92701<br>0.0001<br>20 | 0.74991<br>0.0001<br>20 | 0.73637<br>0.0002<br>20 | 0.42727<br>0.1899<br>11 | 0.72337<br>0.0003<br>20 | 0.76119<br>0.0001<br>20 | 0.79596<br>0.0001<br>19 | 1.00000<br>0.0000<br>20 | 0.90861<br>0.0001<br>20 |
| 050C004 | 0.73083<br>0.0003<br>20 | 0.81818<br>0.0001<br>23 | 0.76452<br>0.0001<br>23 | 0.66798<br>0.0005<br>23 | 0.67820<br>0.0010<br>20 | 0.49890<br>0.0694<br>14 | 0.61212<br>0.0600<br>10 | 0.86786<br>0.0001<br>15 | 0.80576<br>0.0001<br>22 | 0.93383<br>0.0001<br>20 | 0.86014<br>0.0003<br>12 | 0.87176<br>0.0001<br>23 | 0.82722<br>0.0001<br>22 | 0.87532<br>0.0001<br>21 | 0.69091<br>0.0186<br>11 | 0.84801<br>0.0001<br>20 | 0.90526<br>0.0001<br>20 | 0.91930<br>0.0001<br>19 | 0.90861<br>0.0001<br>20 | 1.00000<br>0.0000<br>27 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-3

## Pearson Correlation Coefficients* for Pembina River Basin March Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.94548<br>0.0001<br>19 | 0.95365<br>0.0001<br>19 | 0.98173<br>0.0001<br>19 | 0.94446<br>0.0001<br>19 | 0.92085<br>0.0001<br>14 | 0.97303<br>0.0001<br>10 | 0.80910<br>0.0003<br>15 | 0.90569<br>0.0001<br>18 | 0.69378<br>0.0010<br>19 | 0.80618<br>0.0157<br>8 | 0.95195<br>0.0001<br>19 | 0.80878<br>0.0001<br>16 | 0.75177<br>0.0002<br>19 | 0.98697<br>0.0001<br>11 | 0.69914<br>0.0008<br>19 | 0.92385<br>0.0001<br>18 | 0.85783<br>0.0001<br>18 | 0.90458<br>0.0001<br>19 | 0.87402<br>0.0001<br>19 |
| 050A006 | 0.94548<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.96063<br>0.0001<br>22 | 0.92439<br>0.0001<br>22 | 0.96842<br>0.0001<br>19 | 0.97484<br>0.0001<br>14 | 0.97660<br>0.0001<br>10 | 0.89342<br>0.0001<br>15 | 0.92003<br>0.0001<br>21 | 0.73745<br>0.0003<br>19 | 0.83355<br>0.0014<br>11 | 0.96573<br>0.0001<br>22 | 0.88077<br>0.0001<br>18 | 0.87063<br>0.0001<br>20 | 0.96362<br>0.0001<br>11 | 0.84626<br>0.0001<br>19 | 0.97656<br>0.0001<br>18 | 0.93988<br>0.0001<br>18 | 0.95054<br>0.0001<br>19 | 0.90350<br>0.0001<br>22 |
| 050A007 | 0.95365<br>0.0001<br>19 | 0.96063<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.92088<br>0.0001<br>22 | 0.99303<br>0.0001<br>19 | 0.97933<br>0.0001<br>14 | 0.94542<br>0.0001<br>10 | 0.81479<br>0.0002<br>15 | 0.87900<br>0.0001<br>21 | 0.73314<br>0.0004<br>19 | 0.87508<br>0.0004<br>11 | 0.99753<br>0.0001<br>22 | 0.86404<br>0.0001<br>18 | 0.74870<br>0.0001<br>20 | 0.99913<br>0.0001<br>11 | 0.69350<br>0.0010<br>19 | 0.96079<br>0.0001<br>18 | 0.88849<br>0.0001<br>18 | 0.90811<br>0.0001<br>19 | 0.92644<br>0.0001<br>22 |
| 050A008 | 0.98173<br>0.0001<br>19 | 0.92439<br>0.0001<br>22 | 0.92088<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.94948<br>0.0001<br>19 | 0.94235<br>0.0001<br>14 | 0.98689<br>0.0001<br>10 | 0.81191<br>0.0002<br>15 | 0.88389<br>0.0001<br>21 | 0.70294<br>0.0008<br>19 | 0.55167<br>0.0785<br>11 | 0.92516<br>0.0001<br>22 | 0.79781<br>0.0001<br>18 | 0.71522<br>0.0004<br>20 | 0.99105<br>0.0001<br>11 | 0.68477<br>0.0012<br>19 | 0.90830<br>0.0001<br>18 | 0.84135<br>0.0001<br>18 | 0.86271<br>0.0001<br>19 | 0.85683<br>0.0001<br>22 |
| 050A010 | 0.94446<br>0.0001<br>19 | 0.96842<br>0.0001<br>19 | 0.99303<br>0.0001<br>19 | 0.94948<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.98743<br>0.0001<br>14 | 0.95999<br>0.0001<br>10 | 0.82655<br>0.0001<br>15 | 0.92460<br>0.0001<br>18 | 0.75808<br>0.0002<br>19 | 0.91749<br>0.0013<br>8 | 0.98885<br>0.0001<br>19 | 0.86652<br>0.0001<br>16 | 0.76609<br>0.0001<br>19 | 0.99897<br>0.0001<br>11 | 0.71052<br>0.0007<br>19 | 0.95593<br>0.0001<br>18 | 0.88839<br>0.0001<br>18 | 0.90438<br>0.0001<br>19 | 0.95310<br>0.0001<br>19 |
| 050A012 | 0.92085<br>0.0001<br>14 | 0.97484<br>0.0001<br>14 | 0.97933<br>0.0001<br>14 | 0.94235<br>0.0001<br>14 | 0.98743<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.95376<br>0.0001<br>10 | 0.85372<br>0.0001<br>14 | 0.94965<br>0.0001<br>13 | 0.74186<br>0.0024<br>14 | 0.80646<br>0.0284<br>7 | 0.98220<br>0.0001<br>14 | 0.87346<br>0.0001<br>14 | 0.78085<br>0.0010<br>14 | 0.98152<br>0.0001<br>10 | 0.72166<br>0.0036<br>14 | 0.95344<br>0.0001<br>14 | 0.89164<br>0.0001<br>14 | 0.90609<br>0.0001<br>14 | 0.95450<br>0.0001<br>14 |
| 050A013 | 0.97303<br>0.0001<br>10 | 0.97660<br>0.0001<br>10 | 0.94542<br>0.0001<br>10 | 0.98689<br>0.0001<br>10 | 0.95999<br>0.0001<br>10 | 0.95376<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.85069<br>0.0018<br>10 | 0.92782<br>0.0001<br>10 | 0.66096<br>0.0374<br>10 | 0.76411<br>0.4464<br>3 | 0.93537<br>0.0001<br>10 | 0.78698<br>0.0069<br>10 | 0.85122<br>0.0018<br>10 | 0.99823<br>0.0001<br>6 | 0.94448<br>0.0001<br>10 | 0.91684<br>0.0002<br>10 | 0.87834<br>0.0008<br>10 | 0.89062<br>0.0005<br>10 | 0.90677<br>0.0003<br>10 |
| 050B001 | 0.80910<br>0.0003<br>15 | 0.89342<br>0.0001<br>15 | 0.81479<br>0.0002<br>15 | 0.81191<br>0.0002<br>15 | 0.82655<br>0.0001<br>15 | 0.85372<br>0.0001<br>14 | 0.85069<br>0.0018<br>10 | 1.00000<br>0.0000<br>15 | 0.92429<br>0.0001<br>14 | 0.86150<br>0.0001<br>15 | 0.98021<br>0.0001<br>7 | 0.83582<br>0.0001<br>15 | 0.94156<br>0.0001<br>15 | 0.88430<br>0.0001<br>15 | 0.82662<br>0.0032<br>10 | 0.85552<br>0.0001<br>15 | 0.91782<br>0.0001<br>15 | 0.95471<br>0.0001<br>15 | 0.89003<br>0.0001<br>15 | 0.87375<br>0.0001<br>15 |
| 050B006 | 0.90569<br>0.0001<br>18 | 0.92003<br>0.0001<br>21 | 0.87900<br>0.0001<br>21 | 0.88389<br>0.0001<br>21 | 0.92460<br>0.0001<br>18 | 0.94965<br>0.0001<br>13 | 0.92782<br>0.0001<br>10 | 0.92429<br>0.0001<br>14 | 1.00000<br>0.0000<br>21 | 0.75257<br>0.0003<br>18 | 0.73872<br>0.0147<br>10 | 0.89995<br>0.0001<br>21 | 0.88337<br>0.0001<br>17 | 0.86235<br>0.0001<br>19 | 0.92938<br>0.0001<br>10 | 0.89113<br>0.0001<br>18 | 0.98188<br>0.0001<br>17 | 0.98029<br>0.0001<br>17 | 0.96930<br>0.0001<br>18 | 0.83443<br>0.0001<br>21 |
| 050B007 | 0.69378<br>0.0010<br>19 | 0.73745<br>0.0003<br>19 | 0.73314<br>0.0004<br>19 | 0.70294<br>0.0008<br>19 | 0.75808<br>0.0002<br>19 | 0.74186<br>0.0024<br>14 | 0.66096<br>0.0374<br>10 | 0.86150<br>0.0001<br>15 | 0.75257<br>0.0003<br>18 | 1.00000<br>0.0000<br>19 | 0.80811<br>0.0152<br>8 | 0.74698<br>0.0002<br>19 | 0.93965<br>0.0001<br>16 | 0.70923<br>0.0007<br>19 | 0.74165<br>0.0090<br>11 | 0.60342<br>0.0062<br>19 | 0.77554<br>0.0002<br>18 | 0.84794<br>0.0001<br>18 | 0.72782<br>0.0004<br>19 | 0.90149<br>0.0001<br>19 |
| 050B008 | 0.80618<br>0.0157<br>8 | 0.83355<br>0.0014<br>11 | 0.87508<br>0.0004<br>11 | 0.55167<br>0.0785<br>11 | 0.91749<br>0.0013<br>8 | 0.80646<br>0.0284<br>7 | 0.76411<br>0.4464<br>3 | 0.98021<br>0.0001<br>7 | 0.73872<br>0.0147<br>10 | 0.80811<br>0.0152<br>8 | 1.00000<br>0.0000<br>12 | 0.87268<br>0.0005<br>11 | 0.96085<br>0.0001<br>10 | 0.90140<br>0.0009<br>9 | 0.93740<br>0.0006<br>8 | 0.85165<br>0.0073<br>8 | 0.89792<br>0.0060<br>7 | 0.97391<br>0.0002<br>7 | 0.82194<br>0.0123<br>8 | 0.88819<br>0.0001<br>12 |
| 050B010 | 0.95195<br>0.0001<br>19 | 0.96573<br>0.0001<br>22 | 0.99753<br>0.0001<br>22 | 0.92516<br>0.0001<br>22 | 0.98885<br>0.0001<br>19 | 0.98220<br>0.0001<br>14 | 0.93537<br>0.0001<br>10 | 0.83582<br>0.0001<br>15 | 0.89995<br>0.0001<br>21 | 0.74698<br>0.0002<br>19 | 0.87268<br>0.0005<br>11 | 1.00000<br>0.0000<br>22 | 0.88261<br>0.0001<br>18 | 0.76967<br>0.0001<br>20 | 0.99894<br>0.0001<br>11 | 0.71153<br>0.0006<br>19 | 0.96890<br>0.0001<br>18 | 0.90547<br>0.0001<br>18 | 0.92141<br>0.0001<br>19 | 0.92574<br>0.0001<br>22 |
| 050B013 | 0.80878<br>0.0001<br>16 | 0.88077<br>0.0001<br>18 | 0.86404<br>0.0001<br>18 | 0.79781<br>0.0001<br>18 | 0.86652<br>0.0001<br>16 | 0.87346<br>0.0001<br>14 | 0.78698<br>0.0069<br>10 | 0.94156<br>0.0001<br>15 | 0.88337<br>0.0001<br>17 | 0.93965<br>0.0001<br>16 | 0.96085<br>0.0001<br>10 | 0.88261<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.83187<br>0.0001<br>17 | 0.87744<br>0.0004<br>11 | 0.76478<br>0.0006<br>16 | 0.91664<br>0.0001<br>15 | 0.96917<br>0.0001<br>15 | 0.87316<br>0.0001<br>16 | 0.92988<br>0.0001<br>18 |
| 050B016 | 0.75177<br>0.0002<br>19 | 0.87063<br>0.0001<br>20 | 0.74970<br>0.0001<br>20 | 0.71522<br>0.0004<br>20 | 0.76609<br>0.0001<br>19 | 0.78085<br>0.0010<br>14 | 0.85122<br>0.0018<br>10 | 0.88430<br>0.0001<br>15 | 0.86235<br>0.0001<br>19 | 0.70923<br>0.0007<br>19 | 0.90140<br>0.0009<br>9 | 0.76967<br>0.0001<br>20 | 0.83187<br>0.0001<br>17 | 1.00000<br>0.0000<br>20 | 0.74547<br>0.0085<br>11 | 0.95524<br>0.0001<br>19 | 0.86053<br>0.0001<br>18 | 0.91517<br>0.0001<br>18 | 0.92721<br>0.0001<br>19 | 0.75524<br>0.0001<br>20 |
| 050B019 | 0.98697<br>0.0001<br>11 | 0.96362<br>0.0001<br>11 | 0.99913<br>0.0001<br>11 | 0.99105<br>0.0001<br>11 | 0.99897<br>0.0001<br>11 | 0.98152<br>0.0001<br>10 | 0.99823<br>0.0001<br>6 | 0.82662<br>0.0032<br>10 | 0.92938<br>0.0001<br>10 | 0.74165<br>0.0090<br>11 | 0.93740<br>0.0006<br>8 | 0.99894<br>0.0001<br>11 | 0.87744<br>0.0004<br>11 | 0.74547<br>0.0085<br>11 | 1.00000<br>0.0000<br>11 | 0.67886<br>0.0216<br>11 | 0.96293<br>0.0001<br>10 | 0.88977<br>0.0006<br>10 | 0.90201<br>0.0001<br>11 | 0.95031<br>0.0001<br>11 |
| 050B021 | 0.69914<br>0.0009<br>19 | 0.84626<br>0.0001<br>19 | 0.69350<br>0.0010<br>19 | 0.68477<br>0.0012<br>19 | 0.71052<br>0.0007<br>19 | 0.72166<br>0.0036<br>14 | 0.94448<br>0.0001<br>10 | 0.85552<br>0.0001<br>15 | 0.89113<br>0.0001<br>18 | 0.60342<br>0.0062<br>19 | 0.85165<br>0.0073<br>8 | 0.71153<br>0.0006<br>19 | 0.76478<br>0.0006<br>16 | 0.95524<br>0.0001<br>19 | 0.67886<br>0.0216<br>11 | 1.00000<br>0.0000<br>19 | 0.83144<br>0.0001<br>18 | 0.88564<br>0.0001<br>18 | 0.86838<br>0.0001<br>19 | 0.66545<br>0.0019<br>19 |
| 050B023 | 0.92385<br>0.0001<br>18 | 0.97656<br>0.0001<br>18 | 0.96079<br>0.0001<br>18 | 0.90830<br>0.0001<br>18 | 0.95593<br>0.0001<br>18 | 0.95344<br>0.0001<br>14 | 0.91684<br>0.0002<br>10 | 0.91782<br>0.0001<br>15 | 0.98188<br>0.0001<br>17 | 0.77554<br>0.0002<br>18 | 0.89792<br>0.0060<br>7 | 0.96890<br>0.0001<br>18 | 0.91664<br>0.0001<br>15 | 0.86053<br>0.0001<br>18 | 0.96293<br>0.0001<br>10 | 0.83144<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.96265<br>0.0001<br>18 | 0.95518<br>0.0001<br>18 | 0.91568<br>0.0001<br>18 |
| 050B025 | 0.85783<br>0.0001<br>18 | 0.93988<br>0.0001<br>18 | 0.88849<br>0.0001<br>18 | 0.84135<br>0.0001<br>18 | 0.88839<br>0.0001<br>18 | 0.89164<br>0.0001<br>14 | 0.87834<br>0.0008<br>10 | 0.95471<br>0.0001<br>15 | 0.98029<br>0.0001<br>17 | 0.84794<br>0.0001<br>18 | 0.97391<br>0.0002<br>7 | 0.90547<br>0.0001<br>18 | 0.96917<br>0.0001<br>15 | 0.91517<br>0.0001<br>18 | 0.88977<br>0.0006<br>10 | 0.88564<br>0.0001<br>18 | 0.96265<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.94116<br>0.0001<br>18 | 0.88974<br>0.0001<br>18 |
| 050B031 | 0.90458<br>0.0001<br>19 | 0.95054<br>0.0001<br>19 | 0.90811<br>0.0001<br>19 | 0.86271<br>0.0001<br>19 | 0.90438<br>0.0001<br>19 | 0.90609<br>0.0001<br>14 | 0.89062<br>0.0005<br>10 | 0.89003<br>0.0001<br>15 | 0.96930<br>0.0001<br>18 | 0.72782<br>0.0004<br>19 | 0.82194<br>0.0123<br>8 | 0.92141<br>0.0001<br>19 | 0.87316<br>0.0001<br>16 | 0.92721<br>0.0001<br>19 | 0.90201<br>0.0001<br>11 | 0.86838<br>0.0001<br>19 | 0.95518<br>0.0001<br>18 | 0.94116<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.85439<br>0.0001<br>19 |
| 050C004 | 0.87402<br>0.0001<br>19 | 0.90350<br>0.0001<br>22 | 0.92644<br>0.0001<br>22 | 0.85683<br>0.0001<br>22 | 0.95310<br>0.0001<br>19 | 0.95450<br>0.0001<br>14 | 0.90677<br>0.0003<br>10 | 0.87375<br>0.0001<br>15 | 0.83443<br>0.0001<br>21 | 0.90149<br>0.0001<br>19 | 0.88819<br>0.0001<br>12 | 0.92574<br>0.0001<br>22 | 0.92988<br>0.0001<br>18 | 0.75524<br>0.0001<br>20 | 0.95031<br>0.0001<br>11 | 0.66545<br>0.0019<br>19 | 0.91568<br>0.0001<br>18 | 0.88974<br>0.0001<br>18 | 0.85439<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-4

## Spearman Correlation Coefficients* for Pembina River Basin March Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.80460<br>0.0001<br>19 | 0.70605<br>0.0007<br>19 | 0.71630<br>0.0006<br>19 | 0.71461<br>0.0006<br>19 | 0.78971<br>0.0008<br>14 | 0.96129<br>0.0001<br>10 | 0.70154<br>0.0036<br>15 | 0.57092<br>0.0133<br>18 | 0.84926<br>0.0001<br>19 | 0.86249<br>0.0058<br>8 | 0.66291<br>0.0020<br>19 | 0.65023<br>0.0064<br>16 | 0.72325<br>0.0005<br>19 | 0.85606<br>0.0008<br>11 | 0.67664<br>0.0015<br>19 | 0.70060<br>0.0012<br>18 | 0.71094<br>0.0009<br>18 | 0.82773<br>0.0001<br>19 | 0.81419<br>0.0001<br>19 |
| 050A006 | 0.80460<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.94803<br>0.0001<br>22 | 0.82462<br>0.0001<br>22 | 0.90005<br>0.0001<br>19 | 0.92792<br>0.0001<br>14 | 0.95386<br>0.0001<br>10 | 0.73099<br>0.0020<br>15 | 0.78392<br>0.0001<br>21 | 0.74904<br>0.0002<br>19 | 0.75324<br>0.0074<br>11 | 0.87755<br>0.0001<br>22 | 0.68649<br>0.0017<br>18 | 0.76960<br>0.0001<br>20 | 0.85742<br>0.0007<br>11 | 0.87641<br>0.0001<br>19 | 0.54965<br>0.0181<br>18 | 0.75244<br>0.0003<br>18 | 0.78680<br>0.0001<br>19 | 0.60320<br>0.0030<br>22 |
| 050A007 | 0.70605<br>0.0007<br>19 | 0.94803<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.85562<br>0.0001<br>22 | 0.91598<br>0.0001<br>19 | 0.97961<br>0.0001<br>14 | 0.84825<br>0.0019<br>10 | 0.74260<br>0.0015<br>15 | 0.77390<br>0.0001<br>21 | 0.72678<br>0.0004<br>19 | 0.74904<br>0.0080<br>11 | 0.87843<br>0.0001<br>22 | 0.71459<br>0.0009<br>18 | 0.76748<br>0.0001<br>20 | 0.85742<br>0.0007<br>11 | 0.86901<br>0.0001<br>19 | 0.49742<br>0.0357<br>18 | 0.74774<br>0.0004<br>18 | 0.75378<br>0.0002<br>19 | 0.58263<br>0.0044<br>22 |
| 050A008 | 0.71630<br>0.0006<br>19 | 0.82462<br>0.0001<br>22 | 0.85562<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.91729<br>0.0001<br>19 | 0.95056<br>0.0001<br>14 | 0.88624<br>0.0006<br>10 | 0.68262<br>0.0050<br>15 | 0.61703<br>0.0029<br>21 | 0.64994<br>0.0026<br>19 | 0.56492<br>0.0702<br>11 | 0.67178<br>0.0006<br>22 | 0.61574<br>0.0065<br>18 | 0.72063<br>0.0003<br>20 | 0.70476<br>0.0154<br>11 | 0.67229<br>0.0016<br>19 | 0.46486<br>0.0519<br>18 | 0.67333<br>0.0022<br>18 | 0.66985<br>0.0017<br>19 | 0.52299<br>0.0125<br>22 |
| 050A010 / | 0.71461<br>0.0006<br>19 | 0.90005<br>0.0001<br>19 | 0.91598<br>0.0001<br>19 | 0.91729<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.94719<br>0.0001<br>14 | 0.84825<br>0.0019<br>10 | 0.69885<br>0.0037<br>15 | 0.64543<br>0.0038<br>18 | 0.69267<br>0.0010<br>19 | 0.77846<br>0.0229<br>8 | 0.79140<br>0.0001<br>19 | 0.62722<br>0.0093<br>16 | 0.73923<br>0.0003<br>19 | 0.72857<br>0.0110<br>11 | 0.80288<br>0.0001<br>19 | 0.56416<br>0.0147<br>18 | 0.76638<br>0.0002<br>18 | 0.77017<br>0.0001<br>19 | 0.66669<br>0.0018<br>19 |
| 050A012 | 0.78971<br>0.0008<br>14 | 0.92792<br>0.0001<br>14 | 0.97961<br>0.0001<br>14 | 0.95056<br>0.0001<br>14 | 0.94719<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.81027<br>0.0045<br>10 | 0.75087<br>0.0020<br>14 | 0.80557<br>0.0009<br>13 | 0.82075<br>0.0003<br>14 | 0.90094<br>0.0056<br>7 | 0.89831<br>0.0001<br>14 | 0.79878<br>0.0006<br>14 | 0.84157<br>0.0002<br>14 | 0.78495<br>0.0072<br>10 | 0.87862<br>0.0001<br>14 | 0.56003<br>0.0373<br>14 | 0.76923<br>0.0013<br>/ 14 | 0.86385<br>0.0001<br>14 | 0.81317<br>0.0004<br>14 |
| 050A013 | 0.96129<br>0.0001<br>10 | 0.95386<br>0.0001<br>10 | 0.84825<br>0.0019<br>10 | 0.88624<br>0.0006<br>10 | 0.84825<br>0.0019<br>10 | 0.81027<br>0.0045<br>10 | 1.00000<br>0.0000<br>10 | 0.56277<br>0.0903<br>10 | 0.68334<br>0.0294<br>10 | 0.88793<br>0.0006<br>10 | 1.00000<br>0.0000<br>3 | 0.68334<br>0.0294<br>10 | 0.63183<br>0.0500<br>10 | 0.71935<br>0.0190<br>10 | 0.78269<br>0.0657<br>6 | 0.72560<br>0.0175<br>10 | 0.46898<br>0.1715<br>10 | 0.71151<br>0.0210<br>10 | 0.66925<br>0.0343<br>10 | 0.85667<br>0.0015<br>10 |
| 050B001 | 0.70154<br>0.0036<br>15 | 0.73099<br>0.0020<br>15 | 0.74260<br>0.0015<br>15 | 0.68262<br>0.0050<br>15 | 0.69885<br>0.0037<br>15 | 0.75087<br>0.0020<br>14 | 0.56277<br>0.0903<br>10 | 1.00000<br>0.0000<br>15 | 0.48636<br>0.0778<br>14 | 0.90779<br>0.0001<br>15 | 0.95499<br>0.0008<br>7 | 0.70565<br>0.0033<br>15 | 0.75605<br>0.0011<br>15 | 0.46302<br>0.0822<br>15 | 0.84311<br>0.0022<br>10 | 0.65525<br>0.0080<br>15 | 0.86327<br>0.0001<br>15 | 0.57668<br>0.0244<br>15 | 0.68959<br>0.0044<br>15 | 0.87835<br>0.0001<br>15 |
| 050B006 | 0.57092<br>0.0133<br>18 | 0.78392<br>0.0001<br>21 | 0.77390<br>0.0001<br>21 | 0.61703<br>0.0029<br>21 | 0.64543<br>0.0038<br>18 | 0.80557<br>0.0009<br>13 | 0.68334<br>0.0294<br>10 | 0.48636<br>0.0778<br>14 | 1.00000<br>0.0000<br>21 | 0.46467<br>0.0520<br>18 | 0.66908<br>0.0344<br>10 | 0.93560<br>0.0001<br>21 | 0.82542<br>0.0001<br>17 | 0.79810<br>0.0001<br>19 | 0.72040<br>0.0188<br>10 | 0.90105<br>0.0001<br>18 | 0.42598<br>0.0882<br>17 | 0.80599<br>0.0001<br>17 | 0.80277<br>0.0001<br>18 | 0.36206<br>0.1068<br>21 |
| 050B007 | 0.84926<br>0.0001<br>19 | 0.74904<br>0.0002<br>19 | 0.72678<br>0.0004<br>19 | 0.64994<br>0.0026<br>19 | 0.69267<br>0.0010<br>19 | 0.82075<br>0.0003<br>14 | 0.88793<br>0.0006<br>10 | 0.90779<br>0.0001<br>15 | 0.46467<br>0.0520<br>18 | 1.00000<br>0.0000<br>19 | 0.93415<br>0.0007<br>8 | 0.65363<br>0.0024<br>19 | 0.74306<br>0.0010<br>16 | 0.58660<br>0.0083<br>19 | 0.86732<br>0.0005<br>11 | 0.66027<br>0.0021<br>19 | 0.87913<br>0.0001<br>18 | 0.68907<br>0.0016<br>18 | 0.78001<br>0.0001<br>19 | 0.94598<br>0.0001<br>19 |
| 050B008 | 0.86249<br>0.0058<br>8 | 0.75324<br>0.0074<br>11 | 0.74904<br>0.0080<br>11 | 0.56492<br>0.0702<br>11 | 0.77846<br>0.0229<br>8 | 0.90094<br>0.0056<br>7 | 1.00000<br>0.0000<br>3 | 0.95499<br>0.0008<br>7 | 0.66908<br>0.0344<br>10 | 0.93415<br>0.0007<br>8 | 1.00000<br>0.0000<br>12 | 0.70556<br>0.0153<br>11 | 0.82675<br>0.0032<br>10 | 0.85356<br>0.0034<br>9 | 0.93859<br>0.0006<br>8 | 0.91322<br>0.0015<br>8 | 0.85714<br>0.0137<br>7 | 0.80781<br>0.0280<br>7 | 0.86249<br>0.0058<br>8 | 0.91068<br>0.0001<br>12 |
| 050B010 | 0.66291<br>0.0020<br>19 | 0.87755<br>0.0001<br>22 | 0.87843<br>0.0001<br>22 | 0.67178<br>0.0006<br>22 | 0.79140<br>0.0001<br>19 | 0.89831<br>0.0001<br>14 | 0.68334<br>0.0294<br>10 | 0.70565<br>0.0033<br>15 | 0.93560<br>0.0001<br>21 | 0.65363<br>0.0024<br>19 | 0.70556<br>0.0153<br>11 | 1.00000<br>0.0000<br>22 | 0.77541<br>0.0002<br>18 | 0.76681<br>0.0001<br>20 | 0.85742<br>0.0007<br>11 | 0.97744<br>0.0001<br>19 | 0.54795<br>0.0186<br>18 | 0.77611<br>0.0002<br>18 | 0.87604<br>0.0001<br>19 | 0.50154<br>0.0174<br>22 |
| 050B013 | 0.65023<br>0.0064<br>16 | 0.68649<br>0.0017<br>18 | 0.71459<br>0.0009<br>18 | 0.61574<br>0.0065<br>18 | 0.62722<br>0.0093<br>16 | 0.79978<br>0.0006<br>14 | 0.63183<br>0.0500<br>10 | 0.75605<br>0.0011<br>15 | 0.82542<br>0.0001<br>17 | 0.74306<br>0.0010<br>16 | 0.82675<br>0.0032<br>10 | 0.77541<br>0.0002<br>18 | 1.00000<br>0.0000<br>18 | 0.69463<br>0.0020<br>17 | 0.69048<br>0.0187<br>11 | 0.72769<br>0.0014<br>16 | 0.65708<br>0.0078<br>15 | 0.62835<br>0.0121<br>15 | 0.78833<br>0.0003<br>16 | 0.79415<br>0.0001<br>18 |
| 050B016 | 0.72325<br>0.0005<br>19 | 0.76960<br>0.0001<br>20 | 0.76748<br>0.0001<br>20 | 0.72063<br>0.0003<br>20 | 0.73923<br>0.0003<br>19 | 0.84157<br>0.0002<br>14 | 0.71935<br>0.0190<br>10 | 0.46302<br>0.0822<br>15 | 0.79810<br>0.0001<br>19 | 0.58660<br>0.0083<br>19 | 0.85356<br>0.0034<br>9 | 0.76681<br>0.0001<br>20 | 0.69463<br>0.0020<br>17 | 1.00000<br>0.0000<br>20 | 0.66190<br>0.0265<br>11 | 0.78506<br>0.0001<br>19 | 0.37457<br>0.1257<br>18 | 0.74752<br>0.0004<br>18 | 0.81894<br>0.0001<br>19 | 0.62568<br>0.0032<br>20 |
| 050B019 | 0.85606<br>0.0008<br>11 | 0.85742<br>0.0007<br>11 | 0.85742<br>0.0007<br>11 | 0.70476<br>0.0154<br>11 | 0.72857<br>0.0110<br>11 | 0.78495<br>0.0072<br>10 | 0.78269<br>0.0657<br>6 | 0.84311<br>0.0022<br>10 | 0.72040<br>0.0188<br>10 | 0.86732<br>0.0005<br>11 | 0.93859<br>0.0006<br>8 | 0.85742<br>0.0007<br>11 | 0.69048<br>0.0187<br>11 | 0.66190<br>0.0265<br>11 | 1.00000<br>0.0000<br>11 | 0.82697<br>0.0017<br>11 | 0.79147<br>0.0064<br>10 | 0.75343<br>0.0119<br>10 | 0.79653<br>0.0033<br>11 | 0.85800<br>0.0007<br>11 |
| 050B021 | 0.67664<br>0.0015<br>19 | 0.87641<br>0.0001<br>19 | 0.86901<br>0.0001<br>19 | 0.67229<br>0.0016<br>19 | 0.80288<br>0.0001<br>19 | 0.87862<br>0.0001<br>14 | 0.72560<br>0.0175<br>10 | 0.65525<br>0.0080<br>15 | 0.90105<br>0.0001<br>18 | 0.66027<br>0.0021<br>18 | 0.91322<br>0.0015<br>8 | 0.97744<br>0.0001<br>19 | 0.72769<br>0.0014<br>16 | 0.78506<br>0.0001<br>19 | 0.82697<br>0.0017<br>11 | 1.00000<br>0.0000<br>19 | 0.57000<br>0.0135<br>18 | 0.84046<br>0.0001<br>18 | 0.88063<br>0.0001<br>19 | 0.63484<br>0.0035<br>19 |
| 050B023 | 0.70060<br>0.0012<br>18 | 0.54965<br>0.0181<br>18 | 0.49742<br>0.0357<br>18 | 0.46486<br>0.0519<br>18 | 0.56416<br>0.0147<br>18 | 0.56003<br>0.0373<br>14 | 0.46898<br>0.1715<br>10 | 0.86327<br>0.0001<br>15 | 0.42598<br>0.0882<br>17 | 0.87913<br>0.0001<br>18 | 0.85714<br>0.0137<br>7 | 0.54795<br>0.0186<br>18 | 0.65708<br>0.0078<br>15 | 0.37457<br>0.1257<br>18 | 0.79147<br>0.0064<br>10 | 0.57000<br>0.0135<br>18 | 1.00000<br>0.0000<br>18 | 0.60109<br>0.0083<br>18 | 0.68836<br>0.0016<br>18 | 0.79401<br>0.0001<br>18 |
| 050B025 | 0.71094<br>0.0009<br>18 | 0.75244<br>0.0003<br>18 | 0.74774<br>0.0004<br>18 | 0.67333<br>0.0022<br>18 | 0.76638<br>0.0002<br>18 | 0.76923<br>0.0013<br>14 | 0.71151<br>0.0210<br>10 | 0.57668<br>0.0244<br>15 | 0.80599<br>0.0001<br>17 | 0.68907<br>0.0016<br>18 | 0.80781<br>0.0280<br>7 | 0.77611<br>0.0002<br>18 | 0.62835<br>0.0121<br>15 | 0.74752<br>0.0004<br>18 | 0.75343<br>0.0119<br>10 | 0.84046<br>0.0001<br>18 | 0.60109<br>0.0083<br>18 | 1.00000<br>0.0000<br>18 | 0.86750<br>0.0001<br>18 | 0.71577<br>0.0008<br>18 |
| 050B031 | 0.82773<br>0.0001<br>19 | 0.78680<br>0.0001<br>19 | 0.75378<br>0.0002<br>19 | 0.66985<br>0.0017<br>19 | 0.77017<br>0.0001<br>19 | 0.86385<br>0.0001<br>14 | 0.66925<br>0.0343<br>10 | 0.68959<br>0.0044<br>15 | 0.80277<br>0.0001<br>18 | 0.78001<br>0.0001<br>19 | 0.86249<br>0.0058<br>8 | 0.87604<br>0.0001<br>19 | 0.78833<br>0.0003<br>16 | 0.81894<br>0.0001<br>19 | 0.79653<br>0.0033<br>11 | 0.88063<br>0.0001<br>19 | 0.68836<br>0.0016<br>18 | 0.86750<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.78499<br>0.0001<br>19 |
| 050C004 | 0.81419<br>0.0001<br>19 | 0.60320<br>0.0030<br>22 | 0.58263<br>0.0044<br>22 | 0.52299<br>0.0125<br>22 | 0.66669<br>0.0018<br>19 | 0.81317<br>0.0004<br>14 | 0.85667<br>0.0015<br>10 | 0.87835<br>0.0001<br>15 | 0.36206<br>0.1068<br>21 | 0.94598<br>0.0001<br>19 | 0.91068<br>0.0001<br>12 | 0.50154<br>0.0174<br>22 | 0.79415<br>0.0001<br>18 | 0.62568<br>0.0032<br>20 | 0.85800<br>0.0007<br>11 | 0.63484<br>0.0035<br>19 | 0.79401<br>0.0001<br>18 | 0.71577<br>0.0008<br>18 | 0.78499<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-5

## Pearson Correlation Coefficients* for Pembina River Basin April Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.81690<br>0.0001<br>19 | 0.91444<br>0.0001<br>19 | 0.89952<br>0.0001<br>19 | 0.86403<br>0.0001<br>19 | 0.86931<br>0.0001<br>14 | 0.69606<br>0.0254<br>10 | 0.79209<br>0.0004<br>15 | 0.80966<br>0.0001<br>18 | 0.77970<br>0.0001<br>19 | 0.92383<br>0.0010<br>8 | 0.78620<br>0.0001<br>19 | 0.64829<br>0.0066<br>16 | 0.76523<br>0.0001<br>19 | 0.90574<br>0.0001<br>11 | 0.75207<br>0.0002<br>19 | 0.85566<br>0.0001<br>18 | 0.83825<br>0.0001<br>18 | 0.89094<br>0.0001<br>19 | 0.77551<br>0.0001<br>19 |
| 050A006 | 0.81690<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.87984<br>0.0001<br>22 | 0.96014<br>0.0001<br>22 | 0.96429<br>0.0001<br>19 | 0.95975<br>0.0001<br>14 | 0.96403<br>0.0001<br>10 | 0.90350<br>0.0001<br>15 | 0.84310<br>0.0001<br>21 | 0.88067<br>0.0001<br>19 | 0.94151<br>0.0001<br>11 | 0.73362<br>0.0001<br>22 | 0.74392<br>0.0004<br>18 | 0.73251<br>0.0002<br>20 | 0.91369<br>0.0001<br>11 | 0.60079<br>0.0065<br>19 | 0.92223<br>0.0001<br>18 | 0.83973<br>0.0001<br>18 | 0.76313<br>0.0001<br>19 | 0.84913<br>0.0001<br>22 |
| 050A007 | 0.91444<br>0.0001<br>19 | 0.87984<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.87584<br>0.0001<br>22 | 0.85727<br>0.0001<br>19 | 0.87053<br>0.0001<br>14 | 0.81626<br>0.0040<br>10 | 0.95633<br>0.0001<br>15 | 0.87232<br>0.0001<br>21 | 0.93404<br>0.0001<br>19 | 0.96927<br>0.0001<br>11 | 0.80556<br>0.0001<br>22 | 0.72858<br>0.0006<br>18 | 0.88010<br>0.0001<br>20 | 0.97243<br>0.0001<br>11 | 0.76030<br>0.0002<br>19 | 0.97914<br>0.0001<br>18 | 0.94986<br>0.0001<br>18 | 0.93448<br>0.0001<br>19 | 0.90819<br>0.0001<br>22 |
| 050A008 | 0.89952<br>0.0001<br>19 | 0.96014<br>0.0001<br>22 | 0.87584<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.98829<br>0.0001<br>19 | 0.97522<br>0.0001<br>14 | 0.88501<br>0.0007<br>10 | 0.82546<br>0.0002<br>15 | 0.80787<br>0.0001<br>21 | 0.79278<br>0.0001<br>19 | 0.91745<br>0.0001<br>11 | 0.71062<br>0.0002<br>22 | 0.70154<br>0.0012<br>18 | 0.66255<br>0.0015<br>20 | 0.90510<br>0.0001<br>11 | 0.56765<br>0.0112<br>19 | 0.87693<br>0.0001<br>18 | 0.81820<br>0.0001<br>18 | 0.76815<br>0.0001<br>19 | 0.76736<br>0.0001<br>22 |
| 050A010 | 0.86403<br>0.0001<br>19 | 0.96429<br>0.0001<br>19 | 0.85727<br>0.0001<br>19 | 0.98829<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.99253<br>0.0001<br>14 | 0.91851<br>0.0002<br>10 | 0.83859<br>0.0001<br>15 | 0.77719<br>0.0001<br>18 | 0.79257<br>0.0001<br>19 | 0.92063<br>0.0012<br>8 | 0.62941<br>0.0039<br>19 | 0.68856<br>0.0032<br>16 | 0.62728<br>0.0040<br>19 | 0.90233<br>0.0001<br>11 | 0.52385<br>0.0213<br>19 | 0.87576<br>0.0001<br>18 | 0.80785<br>0.0001<br>18 | 0.73847<br>0.0003<br>19 | 0.74314<br>0.0003<br>19 |
| 050A012 | 0.86931<br>0.0001<br>14 | 0.95975<br>0.0001<br>14 | 0.87053<br>0.0001<br>14 | 0.97522<br>0.0001<br>14 | 0.99253<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.92761<br>0.0001<br>10 | 0.86890<br>0.0001<br>14 | 0.79797<br>0.0011<br>13 | 0.79798<br>0.0006<br>14 | 0.92555<br>0.0028<br>7 | 0.56322<br>0.0360<br>14 | 0.71328<br>0.0042<br>14 | 0.60729<br>0.0213<br>14 | 0.90921<br>0.0003<br>10 | 0.49434<br>0.0724<br>14 | 0.88928<br>0.0001<br>14 | 0.82751<br>0.0003<br>14 | 0.73433<br>0.0028<br>14 | 0.74294<br>0.0023<br>14 |
| 050A013 | 0.69606<br>0.0254<br>10 | 0.96403<br>0.0001<br>10 | 0.81626<br>0.0040<br>10 | 0.88501<br>0.0007<br>10 | 0.91851<br>0.0002<br>10 | 0.92761<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.89622<br>0.0004<br>10 | 0.82294<br>0.0035<br>10 | 0.85588<br>0.0016<br>10 | 0.99930<br>0.0239<br>3 | 0.59031<br>0.0724<br>10 | 0.64762<br>0.0429<br>10 | 0.69236<br>0.0265<br>10 | 0.95629<br>0.0028<br>6 | 0.49789<br>0.1431<br>10 | 0.88743<br>0.0006<br>10 | 0.76406<br>0.0101<br>10 | 0.65544<br>0.0396<br>10 | 0.82188<br>0.0035<br>10 |
| 050B001 | 0.79209<br>0.0004<br>15 | 0.90350<br>0.0001<br>15 | 0.95633<br>0.0001<br>15 | 0.82546<br>0.0002<br>15 | 0.83859<br>0.0001<br>15 | 0.86890<br>0.0001<br>14 | 0.89622<br>0.0004<br>10 | 1.00000<br>0.0000<br>15 | 0.89884<br>0.0001<br>14 | 0.97040<br>0.0001<br>15 | 0.98992<br>0.0001<br>7 | 0.69649<br>0.0039<br>15 | 0.78459<br>0.0005<br>15 | 0.85634<br>0.0001<br>15 | 0.99792<br>0.0001<br>10 | 0.71172<br>0.0029<br>15 | 0.98758<br>0.0001<br>15 | 0.95537<br>0.0001<br>15 | 0.86232<br>0.0001<br>15 | 0.93006<br>0.0001<br>15 |
| 050B006 | 0.80966<br>0.0001<br>18 | 0.84310<br>0.0001<br>21 | 0.87232<br>0.0001<br>21 | 0.80787<br>0.0001<br>21 | 0.77719<br>0.0001<br>18 | 0.79797<br>0.0011<br>13 | 0.82294<br>0.0035<br>10 | 0.89884<br>0.0001<br>14 | 1.00000<br>0.0000<br>21 | 0.88422<br>0.0001<br>18 | 0.80162<br>0.0053<br>10 | 0.84816<br>0.0001<br>21 | 0.86664<br>0.0001<br>17 | 0.80982<br>0.0001<br>19 | 0.71737<br>0.0195<br>10 | 0.81438<br>0.0001<br>18 | 0.92139<br>0.0001<br>17 | 0.90235<br>0.0001<br>17 | 0.91998<br>0.0001<br>18 | 0.88962<br>0.0001<br>21 |
| 050B007 | 0.77970<br>0.0001<br>19 | 0.88067<br>0.0001<br>19 | 0.93404<br>0.0001<br>19 | 0.79278<br>0.0001<br>19 | 0.79257<br>0.0001<br>19 | 0.79798<br>0.0006<br>14 | 0.85588<br>0.0016<br>10 | 0.97040<br>0.0001<br>15 | 0.88422<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.99842<br>0.0001<br>8 | 0.81164<br>0.0001<br>19 | 0.77340<br>0.0004<br>16 | 0.91402<br>0.0001<br>19 | 0.95514<br>0.0001<br>11 | 0.80573<br>0.0001<br>19 | 0.97280<br>0.0001<br>18 | 0.92380<br>0.0001<br>18 | 0.89880<br>0.0001<br>19 | 0.97950<br>0.0001<br>19 |
| 050B008 | 0.92383<br>0.0010<br>8 | 0.94151<br>0.0001<br>11 | 0.96927<br>0.0001<br>11 | 0.91745<br>0.0001<br>11 | 0.92063<br>0.0012<br>8 | 0.92555<br>0.0028<br>7 | 0.99930<br>0.0239<br>3 | 0.98992<br>0.0001<br>7 | 0.80162<br>0.0053<br>10 | 0.99842<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.67260<br>0.0233<br>11 | 0.90388<br>0.0003<br>10 | 0.97903<br>0.0001<br>9 | 0.98767<br>0.0001<br>8 | 0.75344<br>0.0309<br>8 | 0.98191<br>0.0001<br>7 | 0.98878<br>0.0001<br>7 | 0.91635<br>0.0014<br>8 | 0.97728<br>0.0001<br>12 |
| 050B010 | 0.78620<br>0.0001<br>19 | 0.73362<br>0.0001<br>22 | 0.80556<br>0.0001<br>22 | 0.71062<br>0.0002<br>22 | 0.62941<br>0.0039<br>19 | 0.56322<br>0.0360<br>14 | 0.59031<br>0.0724<br>10 | 0.69649<br>0.0039<br>15 | 0.84816<br>0.0001<br>21 | 0.81164<br>0.0001<br>19 | 0.67260<br>0.0233<br>11 | 1.00000<br>0.0000<br>22 | 0.56571<br>0.0144<br>18 | 0.86617<br>0.0001<br>20 | 0.44478<br>0.1705<br>11 | 0.89481<br>0.0001<br>19 | 0.78722<br>0.0001<br>18 | 0.68600<br>0.0017<br>18 | 0.86750<br>0.0001<br>19 | 0.84336<br>0.0001<br>22 |
| 050B013 | 0.64829<br>0.0066<br>16 | 0.74392<br>0.0004<br>18 | 0.72858<br>0.0006<br>18 | 0.70154<br>0.0012<br>18 | 0.68856<br>0.0032<br>16 | 0.71328<br>0.0042<br>14 | 0.64762<br>0.0429<br>10 | 0.78459<br>0.0005<br>15 | 0.86664<br>0.0001<br>17 | 0.77340<br>0.0004<br>16 | 0.90388<br>0.0003<br>10 | 0.56571<br>0.0144<br>18 | 1.00000<br>0.0000<br>18 | 0.60798<br>0.0096<br>17 | 0.60812<br>0.0471<br>11 | 0.66599<br>0.0049<br>16 | 0.78282<br>0.0006<br>15 | 0.87892<br>0.0001<br>15 | 0.78502<br>0.0003<br>16 | 0.80847<br>0.0001<br>18 |
| 050B016 | 0.76523<br>0.0001<br>19 | 0.73251<br>0.0002<br>20 | 0.88010<br>0.0001<br>20 | 0.66255<br>0.0015<br>20 | 0.62728<br>0.0040<br>19 | 0.60729<br>0.0213<br>14 | 0.69236<br>0.0265<br>10 | 0.85634<br>0.0001<br>15 | 0.80982<br>0.0001<br>19 | 0.91402<br>0.0001<br>19 | 0.97903<br>0.0001<br>9 | 0.86617<br>0.0001<br>20 | 0.60798<br>0.0096<br>17 | 1.00000<br>0.0000<br>20 | 0.82799<br>0.0016<br>11 | 0.88422<br>0.0001<br>19 | 0.86389<br>0.0001<br>18 | 0.82302<br>0.0001<br>18 | 0.86337<br>0.0001<br>19 | 0.94144<br>0.0001<br>20 |
| 050B019 | 0.90574<br>0.0001<br>11 | 0.91369<br>0.0001<br>11 | 0.97243<br>0.0001<br>11 | 0.90510<br>0.0001<br>11 | 0.90233<br>0.0001<br>11 | 0.90921<br>0.0003<br>10 | 0.95629<br>0.0028<br>6 | 0.99792<br>0.0001<br>10 | 0.71737<br>0.0195<br>10 | 0.95514<br>0.0001<br>11 | 0.98767<br>0.0001<br>8 | 0.44478<br>0.1705<br>11 | 0.60812<br>0.0471<br>11 | 0.82799<br>0.0016<br>11 | 1.00000<br>0.0000<br>11 | 0.54211<br>0.0849<br>11 | 0.99146<br>0.0001<br>10 | 0.95957<br>0.0001<br>10 | 0.81317<br>0.0023<br>11 | 0.89080<br>0.0002<br>11 |
| 050B021 | 0.75207<br>0.0002<br>19 | 0.60079<br>0.0065<br>19 | 0.76030<br>0.0002<br>19 | 0.56765<br>0.0112<br>19 | 0.52385<br>0.0213<br>19 | 0.49434<br>0.0724<br>14 | 0.49789<br>0.1431<br>10 | 0.71172<br>0.0029<br>15 | 0.81438<br>0.0001<br>18 | 0.80573<br>0.0001<br>19 | 0.75344<br>0.0309<br>8 | 0.89481<br>0.0001<br>19 | 0.66599<br>0.0049<br>16 | 0.88422<br>0.0001<br>19 | 0.54211<br>0.0849<br>11 | 1.00000<br>0.0000<br>19 | 0.75363<br>0.0003<br>18 | 0.74036<br>0.0004<br>18 | 0.89145<br>0.0001<br>19 | 0.88196<br>0.0001<br>19 |
| 050B023 | 0.85566<br>0.0001<br>18 | 0.92223<br>0.0001<br>18 | 0.97914<br>0.0001<br>18 | 0.87693<br>0.0001<br>18 | 0.87576<br>0.0001<br>18 | 0.88928<br>0.0001<br>14 | 0.88743<br>0.0006<br>10 | 0.98758<br>0.0001<br>15 | 0.92139<br>0.0001<br>17 | 0.97280<br>0.0001<br>18 | 0.98191<br>0.0001<br>7 | 0.78722<br>0.0001<br>18 | 0.78282<br>0.0006<br>15 | 0.86389<br>0.0001<br>18 | 0.99146<br>0.0001<br>10 | 0.75363<br>0.0003<br>18 | 1.00000<br>0.0000<br>18 | 0.95421<br>0.0001<br>18 | 0.91507<br>0.0001<br>18 | 0.93632<br>0.0001<br>18 |
| 050B025 | 0.83825<br>0.0001<br>18 | 0.83973<br>0.0001<br>18 | 0.94986<br>0.0001<br>18 | 0.81820<br>0.0001<br>18 | 0.80785<br>0.0001<br>18 | 0.82751<br>0.0003<br>14 | 0.76406<br>0.0101<br>10 | 0.95537<br>0.0001<br>15 | 0.90235<br>0.0001<br>17 | 0.92380<br>0.0001<br>18 | 0.98878<br>0.0001<br>7 | 0.68600<br>0.0017<br>18 | 0.87892<br>0.0001<br>15 | 0.82302<br>0.0001<br>18 | 0.95957<br>0.0001<br>10 | 0.74036<br>0.0004<br>18 | 0.95421<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.91349<br>0.0001<br>18 | 0.90756<br>0.0001<br>18 |
| 050B031 | 0.89094<br>0.0001<br>19 | 0.76313<br>0.0001<br>19 | 0.93448<br>0.0001<br>19 | 0.76815<br>0.0001<br>19 | 0.73847<br>0.0003<br>19 | 0.73433<br>0.0028<br>14 | 0.65544<br>0.0396<br>10 | 0.86232<br>0.0001<br>15 | 0.91998<br>0.0001<br>18 | 0.89880<br>0.0001<br>19 | 0.91635<br>0.0014<br>8 | 0.86750<br>0.0001<br>19 | 0.78502<br>0.0003<br>16 | 0.86337<br>0.0001<br>19 | 0.81317<br>0.0023<br>11 | 0.89145<br>0.0001<br>19 | 0.91507<br>0.0001<br>18 | 0.91349<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.90570<br>0.0001<br>19 |
| 050C004 | 0.77551<br>0.0001<br>19 | 0.84913<br>0.0001<br>22 | 0.90819<br>0.0001<br>22 | 0.76736<br>0.0001<br>22 | 0.74314<br>0.0003<br>19 | 0.74294<br>0.0023<br>14 | 0.82188<br>0.0035<br>10 | 0.93006<br>0.0001<br>15 | 0.88962<br>0.0001<br>21 | 0.97950<br>0.0001<br>19 | 0.97728<br>0.0001<br>12 | 0.84336<br>0.0001<br>22 | 0.80847<br>0.0001<br>18 | 0.94144<br>0.0001<br>20 | 0.89080<br>0.0002<br>11 | 0.88196<br>0.0001<br>19 | 0.93632<br>0.0001<br>18 | 0.90756<br>0.0001<br>18 | 0.90570<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-6

## Spearman Correlation Coefficients* for Pembina River Basin April Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.86567<br>0.0001<br>19 | 0.93813<br>0.0001<br>19 | 0.87495<br>0.0001<br>19 | 0.89328<br>0.0001<br>19 | 0.86374<br>0.0001<br>14 | 0.70909<br>0.0217<br>10 | 0.78642<br>0.0005<br>15 | 0.84667<br>0.0001<br>18 | 0.81878<br>0.0001<br>19 | 0.69048<br>0.0580<br>8 | 0.85037<br>0.0001<br>19 | 0.72848<br>0.0014<br>16 | 0.78280<br>0.0001<br>19 | 0.74545<br>0.0085<br>11 | 0.85294<br>0.0001<br>19 | 0.87248<br>0.0001<br>18 | 0.82602<br>0.0001<br>18 | 0.90654<br>0.0001<br>19 | 0.82265<br>0.0001<br>19 |
| 050A006 | 0.86567<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.94663<br>0.0001<br>22 | 0.97035<br>0.0001<br>22 | 0.95916<br>0.0001<br>19 | 0.96810<br>0.0001<br>14 | 0.96657<br>0.0001<br>10 | 0.86327<br>0.0001<br>15 | 0.86002<br>0.0001<br>21 | 0.87319<br>0.0001<br>19 | 0.77273<br>0.0053<br>11 | 0.84157<br>0.0001<br>22 | 0.79504<br>0.0001<br>18 | 0.78225<br>0.0001<br>20 | 0.87273<br>0.0005<br>11 | 0.73222<br>0.0004<br>19 | 0.94373<br>0.0001<br>18 | 0.85183<br>0.0001<br>18 | 0.77929<br>0.0001<br>19 | 0.83277<br>0.0001<br>22 |
| 050A007 | 0.93813<br>0.0001<br>19 | 0.94663<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.94805<br>0.0001<br>22 | 0.93854<br>0.0001<br>19 | 0.93407<br>0.0001<br>14 | 0.86667<br>0.0012<br>10 | 0.90000<br>0.0001<br>15 | 0.91948<br>0.0001<br>21 | 0.90702<br>0.0001<br>19 | 0.80909<br>0.0026<br>11 | 0.92547<br>0.0001<br>22 | 0.82250<br>0.0001<br>18 | 0.85414<br>0.0001<br>20 | 0.81818<br>0.0021<br>11 | 0.84247<br>0.0001<br>19 | 0.96904<br>0.0001<br>18 | 0.89680<br>0.0001<br>18 | 0.90526<br>0.0001<br>19 | 0.90201<br>0.0001<br>22 |
| 050A008 | 0.87495<br>0.0001<br>19 | 0.97035<br>0.0001<br>22 | 0.94805<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.98332<br>0.0001<br>19 | 0.97363<br>0.0001<br>14 | 0.92727<br>0.0001<br>10 | 0.81429<br>0.0002<br>15 | 0.84805<br>0.0001<br>21 | 0.80877<br>0.0001<br>19 | 0.76364<br>0.0062<br>11 | 0.83512<br>0.0001<br>22 | 0.81011<br>0.0001<br>18 | 0.71579<br>0.0004<br>20 | 0.70000<br>0.0165<br>11 | 0.69241<br>0.0010<br>19 | 0.91125<br>0.0001<br>18 | 0.81631<br>0.0001<br>18 | 0.78246<br>0.0001<br>19 | 0.79243<br>0.0001<br>22 |
| 050A010 | 0.89328<br>0.0001<br>19 | 0.95916<br>0.0001<br>19 | 0.93854<br>0.0001<br>19 | 0.98332<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.97250<br>0.0001<br>14 | 0.94225<br>0.0001<br>10 | 0.80608<br>0.0003<br>15 | 0.81302<br>0.0001<br>18 | 0.79543<br>0.0001<br>19 | 0.59524<br>0.1195<br>8 | 0.78666<br>0.0001<br>19 | 0.77851<br>0.0004<br>16 | 0.67252<br>0.0016<br>19 | 0.67273<br>0.0233<br>11 | 0.69390<br>0.0010<br>19 | 0.88017<br>0.0001<br>18 | 0.79132<br>0.0001<br>18 | 0.79017<br>0.0001<br>19 | 0.77207<br>0.0001<br>19 |
| 050A012 | 0.86374<br>0.0001<br>14 | 0.96810<br>0.0001<br>14 | 0.93407<br>0.0001<br>14 | 0.97363<br>0.0001<br>14 | 0.97250<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.95152<br>0.0001<br>10 | 0.79341<br>0.0007<br>14 | 0.78022<br>0.0017<br>13 | 0.79341<br>0.0007<br>14 | 0.71429<br>0.0713<br>7 | 0.70989<br>0.0045<br>14 | 0.76703<br>0.0014<br>14 | 0.64835<br>0.0121<br>14 | 0.75758<br>0.0111<br>10 | 0.67547<br>0.0080<br>14 | 0.87692<br>0.0001<br>14 | 0.76703<br>0.0014<br>14 | 0.76703<br>0.0014<br>14 | 0.76703<br>0.0014<br>14 |
| 050A013 | 0.70909<br>0.0217<br>10 | 0.96657<br>0.0001<br>10 | 0.86667<br>0.0012<br>10 | 0.92727<br>0.0001<br>10 | 0.94225<br>0.0001<br>10 | 0.95152<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.86667<br>0.0012<br>10 | 0.83030<br>0.0029<br>10 | 0.85455<br>0.0016<br>10 | 1.00000<br>0.0000<br>3 | 0.67273<br>0.0330<br>10 | 0.68485<br>0.0289<br>10 | 0.70909<br>0.0217<br>10 | 0.94286<br>0.0048<br>6 | 0.64848<br>0.0425<br>10 | 0.90303<br>0.0003<br>10 | 0.80606<br>0.0049<br>10 | 0.68485<br>0.0289<br>10 | 0.81818<br>0.0038<br>10 |
| 050B001 | 0.78642<br>0.0005<br>15 | 0.86327<br>0.0001<br>15 | 0.90000<br>0.0001<br>15 | 0.81429<br>0.0002<br>15 | 0.80608<br>0.0003<br>15 | 0.79341<br>0.0007<br>14 | 0.86667<br>0.0012<br>10 | 1.00000<br>0.0000<br>15 | 0.90330<br>0.0001<br>14 | 0.98929<br>0.0001<br>15 | 0.96429<br>0.0005<br>7 | 0.90357<br>0.0001<br>15 | 0.88929<br>0.0001<br>15 | 0.89286<br>0.0001<br>15 | 0.98788<br>0.0001<br>10 | 0.90259<br>0.0001<br>15 | 0.96429<br>0.0001<br>15 | 0.97500<br>0.0001<br>15 | 0.85357<br>0.0001<br>15 | 0.97143<br>0.0001<br>15 |
| 050B006 | 0.84667<br>0.0001<br>18 | 0.86002<br>0.0001<br>21 | 0.91948<br>0.0001<br>21 | 0.84805<br>0.0001<br>21 | 0.81302<br>0.0001<br>18 | 0.78022<br>0.0017<br>13 | 0.83030<br>0.0029<br>10 | 0.90330<br>0.0001<br>14 | 1.00000<br>0.0000<br>21 | 0.91950<br>0.0001<br>18 | 0.75758<br>0.0111<br>10 | 0.93506<br>0.0001<br>21 | 0.86520<br>0.0001<br>17 | 0.84211<br>0.0001<br>19 | 0.64848<br>0.0425<br>10 | 0.90093<br>0.0001<br>18 | 0.94853<br>0.0001<br>17 | 0.93627<br>0.0001<br>17 | 0.92982<br>0.0001<br>18 | 0.89055<br>0.0001<br>21 |
| 050B007 | 0.81878<br>0.0001<br>19 | 0.87319<br>0.0001<br>19 | 0.90702<br>0.0001<br>19 | 0.80877<br>0.0001<br>19 | 0.79543<br>0.0001<br>19 | 0.79341<br>0.0007<br>14 | 0.85455<br>0.0016<br>10 | 0.98929<br>0.0001<br>15 | 0.91950<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 1.00000<br>0.0000<br>8 | 0.91579<br>0.0001<br>19 | 0.88529<br>0.0001<br>16 | 0.93684<br>0.0001<br>19 | 0.95455<br>0.0001<br>11 | 0.92497<br>0.0001<br>19 | 0.96698<br>0.0001<br>18 | 0.97110<br>0.0001<br>18 | 0.88421<br>0.0001<br>19 | 0.99166<br>0.0001<br>19 |
| 050B008 | 0.69048<br>0.0580<br>8 | 0.77273<br>0.0053<br>11 | 0.80909<br>0.0026<br>11 | 0.76364<br>0.0062<br>11 | 0.59524<br>0.1195<br>8 | 0.71429<br>0.0713<br>7 | 1.00000<br>0.0000<br>3 | 0.96429<br>0.0005<br>7 | 0.75758<br>0.0111<br>10 | 1.00000<br>0.0000<br>8 | 1.00000<br>0.0000<br>12 | 0.84545<br>0.0010<br>11 | 0.86667<br>0.0012<br>10 | 0.78333<br>0.0125<br>9 | 0.90476<br>0.0020<br>8 | 0.92857<br>0.0009<br>8 | 0.96429<br>0.0005<br>7 | 0.96429<br>0.0005<br>7 | 0.69048<br>0.0580<br>8 | 0.96503<br>0.0001<br>12 |
| 050B010 | 0.85037<br>0.0001<br>19 | 0.84157<br>0.0001<br>22 | 0.92547<br>0.0001<br>22 | 0.83512<br>0.0001<br>22 | 0.78666<br>0.0001<br>19 | 0.70989<br>0.0045<br>14 | 0.67273<br>0.0330<br>10 | 0.90357<br>0.0001<br>15 | 0.93506<br>0.0001<br>21 | 0.91579<br>0.0001<br>19 | 0.84545<br>0.0010<br>11 | 1.00000<br>0.0000<br>22 | 0.82663<br>0.0001<br>18 | 0.89023<br>0.0001<br>20 | 0.72727<br>0.0112<br>11 | 0.90391<br>0.0001<br>19 | 0.91950<br>0.0001<br>18 | 0.90299<br>0.0001<br>18 | 0.92982<br>0.0001<br>19 | 0.92008<br>0.0001<br>22 |
| 050B013 | 0.72848<br>0.0014<br>16 | 0.79504<br>0.0001<br>18 | 0.82250<br>0.0001<br>18 | 0.81011<br>0.0001<br>18 | 0.77851<br>0.0004<br>16 | 0.76703<br>0.0014<br>14 | 0.68485<br>0.0289<br>10 | 0.88929<br>0.0001<br>15 | 0.86520<br>0.0001<br>17 | 0.88529<br>0.0001<br>16 | 0.86667<br>0.0012<br>10 | 0.82663<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.79167<br>0.0002<br>17 | 0.54545<br>0.0827<br>11 | 0.81972<br>0.0001<br>16 | 0.86071<br>0.0001<br>15 | 0.93929<br>0.0001<br>15 | 0.80000<br>0.0002<br>16 | 0.89886<br>0.0001<br>18 |
| 050B016 | 0.78280<br>0.0001<br>19 | 0.78225<br>0.0001<br>20 | 0.85414<br>0.0001<br>20 | 0.71579<br>0.0004<br>20 | 0.67252<br>0.0016<br>19 | 0.64835<br>0.0121<br>14 | 0.70909<br>0.0217<br>10 | 0.89286<br>0.0001<br>15 | 0.84211<br>0.0001<br>19 | 0.93684<br>0.0001<br>19 | 0.78333<br>0.0125<br>9 | 0.89023<br>0.0001<br>20 | 0.79167<br>0.0002<br>17 | 1.00000<br>0.0000<br>20 | 0.82727<br>0.0017<br>11 | 0.91356<br>0.0001<br>19 | 0.87822<br>0.0001<br>18 | 0.89680<br>0.0001<br>18 | 0.83684<br>0.0001<br>19 | 0.93795<br>0.0001<br>20 |
| 050B019 | 0.74545<br>0.0085<br>11 | 0.87273<br>0.0005<br>11 | 0.81818<br>0.0021<br>11 | 0.70000<br>0.0165<br>11 | 0.67273<br>0.0233<br>11 | 0.75758<br>0.0111<br>10 | 0.94286<br>0.0048<br>6 | 0.98788<br>0.0001<br>10 | 0.64848<br>0.0425<br>10 | 0.95455<br>0.0001<br>11 | 0.90476<br>0.0020<br>8 | 0.72727<br>0.0112<br>11 | 0.54545<br>0.0827<br>11 | 0.82727<br>0.0017<br>11 | 1.00000<br>0.0000<br>11 | 0.70909<br>0.0146<br>11 | 0.98788<br>0.0001<br>10 | 0.90303<br>0.0003<br>10 | 0.57273<br>0.0655<br>11 | 0.90909<br>0.0001<br>11 |
| 050B021 | 0.85294<br>0.0001<br>19 | 0.73222<br>0.0004<br>19 | 0.84247<br>0.0001<br>19 | 0.69241<br>0.0010<br>19 | 0.69390<br>0.0010<br>19 | 0.67547<br>0.0080<br>14 | 0.64848<br>0.0425<br>10 | 0.90259<br>0.0001<br>15 | 0.90093<br>0.0001<br>18 | 0.92497<br>0.0001<br>19 | 0.92857<br>0.0009<br>8 | 0.90391<br>0.0001<br>19 | 0.81972<br>0.0001<br>16 | 0.91356<br>0.0001<br>19 | 0.70909<br>0.0146<br>11 | 1.00000<br>0.0000<br>19 | 0.87042<br>0.0001<br>18 | 0.91895<br>0.0001<br>18 | 0.93989<br>0.0001<br>19 | 0.94381<br>0.0001<br>19 |
| 050B023 | 0.87248<br>0.0001<br>18 | 0.94373<br>0.0001<br>18 | 0.96904<br>0.0001<br>18 | 0.91125<br>0.0001<br>18 | 0.88017<br>0.0001<br>18 | 0.87692<br>0.0001<br>14 | 0.90303<br>0.0003<br>10 | 0.96429<br>0.0001<br>15 | 0.94853<br>0.0001<br>17 | 0.96698<br>0.0001<br>18 | 0.96429<br>0.0005<br>7 | 0.91950<br>0.0001<br>18 | 0.86071<br>0.0001<br>15 | 0.87822<br>0.0001<br>18 | 0.98788<br>0.0001<br>10 | 0.87042<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.94014<br>0.0001<br>18 | 0.88235<br>0.0001<br>18 | 0.95096<br>0.0001<br>18 |
| 050B025 | 0.82602<br>0.0001<br>18 | 0.85183<br>0.0001<br>18 | 0.89680<br>0.0001<br>18 | 0.81631<br>0.0001<br>18 | 0.79132<br>0.0001<br>18 | 0.76703<br>0.0014<br>14 | 0.80606<br>0.0049<br>10 | 0.97500<br>0.0001<br>15 | 0.93627<br>0.0001<br>17 | 0.97110<br>0.0001<br>18 | 0.96429<br>0.0005<br>7 | 0.90299<br>0.0001<br>18 | 0.93929<br>0.0001<br>15 | 0.89680<br>0.0001<br>18 | 0.90303<br>0.0003<br>10 | 0.91895<br>0.0001<br>18 | 0.94014<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.88648<br>0.0001<br>18 | 0.97883<br>0.0001<br>18 |
| 050B031 | 0.90654<br>0.0001<br>19 | 0.77929<br>0.0001<br>19 | 0.90526<br>0.0001<br>19 | 0.78246<br>0.0001<br>19 | 0.79017<br>0.0001<br>19 | 0.76703<br>0.0014<br>14 | 0.68485<br>0.0289<br>10 | 0.85357<br>0.0001<br>15 | 0.92982<br>0.0001<br>18 | 0.88421<br>0.0001<br>19 | 0.69048<br>0.0580<br>8 | 0.92982<br>0.0001<br>19 | 0.80000<br>0.0002<br>16 | 0.83684<br>0.0001<br>19 | 0.57273<br>0.0655<br>11 | 0.93989<br>0.0001<br>19 | 0.88235<br>0.0001<br>18 | 0.88648<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.89162<br>0.0001<br>19 |
| 050C004 | 0.82265<br>0.0001<br>19 | 0.83277<br>0.0001<br>22 | 0.90201<br>0.0001<br>22 | 0.79243<br>0.0001<br>22 | 0.77207<br>0.0001<br>19 | 0.76703<br>0.0014<br>14 | 0.81818<br>0.0038<br>10 | 0.97143<br>0.0001<br>15 | 0.89055<br>0.0001<br>21 | 0.99166<br>0.0001<br>19 | 0.96503<br>0.0001<br>12 | 0.92008<br>0.0001<br>22 | 0.89886<br>0.0001<br>18 | 0.93795<br>0.0001<br>20 | 0.90909<br>0.0001<br>11 | 0.94381<br>0.0001<br>19 | 0.95096<br>0.0001<br>18 | 0.97883<br>0.0001<br>18 | 0.89162<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-7

## Pearson Correlation Coefficients* for Pembina River Basin May Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.87467<br>0.0001<br>19 | 0.89208<br>0.0001<br>19 | 0.90449<br>0.0001<br>19 | 0.91572<br>0.0001<br>19 | 0.90860<br>0.0001<br>14 | 0.90591<br>0.0003<br>10 | 0.77281<br>0.0007<br>15 | 0.84180<br>0.0001<br>18 | 0.80950<br>0.0001<br>19 | 0.15860<br>0.7076<br>8 | 0.96603<br>0.0001<br>19 | 0.91010<br>0.0001<br>16 | 0.73344<br>0.0004<br>19 | 0.48022<br>0.1349<br>11 | 0.80026<br>0.0001<br>19 | 0.83691<br>0.0001<br>18 | 0.90004<br>0.0001<br>18 | 0.85962<br>0.0001<br>19 | 0.83399<br>0.0001<br>19 |
| 050A006 | 0.87467<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.90807<br>0.0001<br>22 | 0.96266<br>0.0001<br>22 | 0.95838<br>0.0001<br>19 | 0.98065<br>0.0001<br>14 | 0.98539<br>0.0001<br>10 | 0.89645<br>0.0001<br>15 | 0.77038<br>0.0001<br>21 | 0.88509<br>0.0001<br>19 | 0.91431<br>0.0001<br>11 | 0.86034<br>0.0001<br>22 | 0.81851<br>0.0001<br>18 | 0.76414<br>0.0001<br>20 | 0.79793<br>0.0032<br>11 | 0.76189<br>0.0002<br>19 | 0.94570<br>0.0001<br>18 | 0.88493<br>0.0001<br>18 | 0.79695<br>0.0001<br>19 | 0.89847<br>0.0001<br>22 |
| 050A007 | 0.89208<br>0.0001<br>19 | 0.90807<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.83135<br>0.0001<br>22 | 0.84370<br>0.0001<br>19 | 0.89554<br>0.0001<br>14 | 0.91997<br>0.0002<br>10 | 0.92208<br>0.0001<br>15 | 0.81554<br>0.0001<br>21 | 0.96460<br>0.0001<br>19 | 0.83768<br>0.0013<br>11 | 0.91415<br>0.0001<br>22 | 0.87913<br>0.0001<br>18 | 0.88984<br>0.0001<br>20 | 0.91187<br>0.0001<br>11 | 0.79219<br>0.0001<br>19 | 0.95276<br>0.0001<br>18 | 0.91552<br>0.0001<br>18 | 0.77929<br>0.0001<br>19 | 0.95694<br>0.0001<br>22 |
| 050A008 | 0.90449<br>0.0001<br>19 | 0.96266<br>0.0001<br>22 | 0.83135<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.96862<br>0.0001<br>19 | 0.98391<br>0.0001<br>14 | 0.96183<br>0.0001<br>10 | 0.80253<br>0.0003<br>15 | 0.71433<br>0.0003<br>21 | 0.79070<br>0.0001<br>19 | 0.73855<br>0.0094<br>11 | 0.85982<br>0.0001<br>22 | 0.85044<br>0.0001<br>18 | 0.67786<br>0.0010<br>20 | 0.58517<br>0.0586<br>11 | 0.75444<br>0.0002<br>19 | 0.86553<br>0.0001<br>18 | 0.86901<br>0.0001<br>18 | 0.81945<br>0.0001<br>19 | 0.81711<br>0.0001<br>22 |
| 050A010 | 0.91572<br>0.0001<br>19 | 0.95838<br>0.0001<br>19 | 0.84370<br>0.0001<br>19 | 0.96862<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.98888<br>0.0001<br>14 | 0.93956<br>0.0001<br>10 | 0.80504<br>0.0003<br>15 | 0.79684<br>0.0001<br>18 | 0.78836<br>0.0001<br>19 | 0.37044<br>0.3663<br>8 | 0.88108<br>0.0001<br>19 | 0.83365<br>0.0001<br>16 | 0.67120<br>0.0017<br>19 | 0.53797<br>0.0878<br>11 | 0.76314<br>0.0001<br>19 | 0.86937<br>0.0001<br>18 | 0.86144<br>0.0001<br>18 | 0.83823<br>0.0001<br>19 | 0.80462<br>0.0001<br>19 |
| 050A012 | 0.90860<br>0.0001<br>14 | 0.98065<br>0.0001<br>14 | 0.89554<br>0.0001<br>14 | 0.98391<br>0.0001<br>14 | 0.98888<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.96214<br>0.0001<br>10 | 0.83861<br>0.0002<br>14 | 0.80595<br>0.0009<br>13 | 0.85971<br>0.0001<br>14 | 0.68434<br>0.0899<br>7 | 0.89984<br>0.0001<br>14 | 0.85359<br>0.0001<br>14 | 0.77988<br>0.0010<br>14 | 0.61794<br>0.0569<br>10 | 0.76515<br>0.0014<br>14 | 0.91389<br>0.0001<br>14 | 0.86773<br>0.0001<br>14 | 0.86306<br>0.0001<br>14 | 0.85825<br>0.0001<br>14 |
| 050A013 | 0.90591<br>0.0003<br>10 | 0.98539<br>0.0001<br>10 | 0.91997<br>0.0002<br>10 | 0.96183<br>0.0001<br>10 | 0.93956<br>0.0001<br>10 | 0.96214<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.90293<br>0.0003<br>10 | 0.81921<br>0.0037<br>10 | 0.91214<br>0.0002<br>10 | 0.97971<br>0.1284<br>3 | 0.85608<br>0.0016<br>10 | 0.82811<br>0.0031<br>10 | 0.81173<br>0.0043<br>10 | 0.75736<br>0.0812<br>6 | 0.74824<br>0.0128<br>10 | 0.93844<br>0.0001<br>10 | 0.90310<br>0.0003<br>10 | 0.84889<br>0.0019<br>10 | 0.90364<br>0.0003<br>10 |
| 050B001 | 0.77281<br>0.0007<br>15 | 0.89645<br>0.0001<br>15 | 0.92208<br>0.0001<br>15 | 0.80253<br>0.0003<br>15 | 0.80504<br>0.0003<br>15 | 0.83861<br>0.0002<br>14 | 0.90293<br>0.0003<br>10 | 1.00000<br>0.0000<br>15 | 0.77783<br>0.0011<br>14 | 0.98485<br>0.0001<br>15 | 0.98645<br>0.0001<br>7 | 0.74687<br>0.0014<br>15 | 0.73092<br>0.0020<br>15 | 0.88304<br>0.0001<br>15 | 0.98822<br>0.0001<br>10 | 0.69444<br>0.0041<br>15 | 0.95328<br>0.0001<br>15 | 0.86462<br>0.0001<br>15 | 0.70981<br>0.0030<br>15 | 0.86540<br>0.0001<br>15 |
| 050B006 | 0.84180<br>0.0001<br>18 | 0.77038<br>0.0001<br>21 | 0.81554<br>0.0001<br>21 | 0.71433<br>0.0003<br>21 | 0.79684<br>0.0001<br>18 | 0.80595<br>0.0009<br>13 | 0.81921<br>0.0037<br>10 | 0.77783<br>0.0011<br>14 | 1.00000<br>0.0000<br>21 | 0.83746<br>0.0001<br>18 | 0.10023<br>0.7829<br>10 | 0.82548<br>0.0001<br>21 | 0.78633<br>0.0002<br>17 | 0.85186<br>0.0001<br>19 | 0.42882<br>0.2162<br>10 | 0.90979<br>0.0001<br>18 | 0.72691<br>0.0009<br>17 | 0.91346<br>0.0001<br>17 | 0.92079<br>0.0001<br>18 | 0.85551<br>0.0001<br>21 |
| 050B007 | 0.80950<br>0.0001<br>19 | 0.88509<br>0.0001<br>19 | 0.96460<br>0.0001<br>19 | 0.79070<br>0.0001<br>19 | 0.78836<br>0.0001<br>19 | 0.85971<br>0.0001<br>14 | 0.91214<br>0.0002<br>10 | 0.98485<br>0.0001<br>15 | 0.83746<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.99756<br>0.0001<br>8 | 0.83816<br>0.0001<br>19 | 0.80706<br>0.0002<br>16 | 0.94611<br>0.0001<br>19 | 0.96003<br>0.0001<br>11 | 0.81138<br>0.0001<br>19 | 0.94369<br>0.0001<br>18 | 0.88972<br>0.0001<br>18 | 0.75426<br>0.0002<br>19 | 0.99410<br>0.0001<br>19 |
| 050B008 | 0.15860<br>0.7076<br>8 | 0.91431<br>0.0001<br>11 | 0.83768<br>0.0013<br>11 | 0.73855<br>0.0094<br>11 | 0.37044<br>0.3663<br>8 | 0.68434<br>0.0899<br>7 | 0.97971<br>0.1284<br>3 | 0.98645<br>0.0001<br>7 | 0.10023<br>0.7829<br>10 | 0.99756<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.20500<br>0.5454<br>11 | 0.06059<br>0.8680<br>10 | 0.82296<br>0.0064<br>9 | 0.97367<br>0.0001<br>8 | 0.24537<br>0.5581<br>8 | 0.95607<br>0.0008<br>7 | 0.94641<br>0.0012<br>7 | 0.20419<br>0.6277<br>8 | 0.98400<br>0.0001<br>12 |
| 050B010 | 0.96603<br>0.0001<br>19 | 0.86034<br>0.0001<br>22 | 0.91415<br>0.0001<br>22 | 0.85982<br>0.0001<br>22 | 0.88108<br>0.0001<br>19 | 0.89984<br>0.0001<br>14 | 0.85608<br>0.0016<br>10 | 0.74687<br>0.0014<br>15 | 0.82548<br>0.0001<br>21 | 0.83816<br>0.0001<br>19 | 0.20500<br>0.5454<br>11 | 1.00000<br>0.0000<br>22 | 0.95795<br>0.0001<br>18 | 0.81337<br>0.0001<br>20 | 0.47328<br>0.1415<br>11 | 0.82858<br>0.0001<br>19 | 0.84080<br>0.0001<br>18 | 0.88406<br>0.0001<br>18 | 0.85908<br>0.0001<br>19 | 0.85770<br>0.0001<br>22 |
| 050B013 | 0.91010<br>0.0001<br>16 | 0.81951<br>0.0001<br>18 | 0.87913<br>0.0001<br>18 | 0.85044<br>0.0001<br>18 | 0.83365<br>0.0001<br>16 | 0.85359<br>0.0001<br>14 | 0.82811<br>0.0031<br>10 | 0.73092<br>0.0020<br>15 | 0.78633<br>0.0002<br>17 | 0.80706<br>0.0002<br>16 | 0.06059<br>0.8680<br>10 | 0.95795<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.84215<br>0.0001<br>17 | 0.40598<br>0.2154<br>11 | 0.82108<br>0.0001<br>16 | 0.77130<br>0.0008<br>15 | 0.90500<br>0.0001<br>15 | 0.87414<br>0.0001<br>16 | 0.83431<br>0.0001<br>18 |
| 050B016 | 0.73344<br>0.0004<br>19 | 0.76414<br>0.0001<br>20 | 0.88994<br>0.0001<br>20 | 0.67786<br>0.0010<br>20 | 0.67120<br>0.0017<br>19 | 0.77988<br>0.0010<br>14 | 0.81173<br>0.0043<br>10 | 0.88304<br>0.0001<br>15 | 0.85186<br>0.0001<br>19 | 0.94611<br>0.0001<br>19 | 0.82296<br>0.0064<br>9 | 0.81337<br>0.0001<br>20 | 0.84215<br>0.0001<br>17 | 1.00000<br>0.0000<br>20 | 0.79648<br>0.0033<br>11 | 0.86150<br>0.0001<br>19 | 0.81272<br>0.0001<br>18 | 0.84859<br>0.0001<br>18 | 0.76076<br>0.0002<br>19 | 0.94903<br>0.0001<br>20 |
| 050B019 | 0.48022<br>0.1349<br>11 | 0.79793<br>0.0032<br>11 | 0.91187<br>0.0001<br>11 | 0.58517<br>0.0586<br>11 | 0.53797<br>0.0878<br>11 | 0.61794<br>0.0569<br>10 | 0.75736<br>0.0812<br>6 | 0.98822<br>0.0001<br>10 | 0.42882<br>0.2162<br>10 | 0.96003<br>0.0001<br>11 | 0.97367<br>0.0001<br>8 | 0.47328<br>0.1415<br>11 | 0.40598<br>0.2154<br>11 | 0.79648<br>0.0033<br>11 | 1.00000<br>0.0000<br>11 | 0.11860<br>0.7283<br>11 | 0.90817<br>0.0003<br>10 | 0.80914<br>0.0046<br>10 | 0.27057<br>0.4210<br>11 | 0.92914<br>0.0001<br>11 |
| 050B021 | 0.80026<br>0.0001<br>19 | 0.76189<br>0.0002<br>19 | 0.79219<br>0.0001<br>19 | 0.75444<br>0.0002<br>19 | 0.76314<br>0.0001<br>19 | 0.76515<br>0.0014<br>14 | 0.74824<br>0.0128<br>10 | 0.69444<br>0.0041<br>15 | 0.90979<br>0.0001<br>18 | 0.81138<br>0.0001<br>19 | 0.24537<br>0.5581<br>8 | 0.82858<br>0.0001<br>19 | 0.82108<br>0.0001<br>16 | 0.86150<br>0.0001<br>19 | 0.11860<br>0.7283<br>11 | 1.00000<br>0.0000<br>19 | 0.68596<br>0.0017<br>18 | 0.89557<br>0.0001<br>18 | 0.93117<br>0.0001<br>19 | 0.85478<br>0.0001<br>19 |
| 050B023 | 0.83691<br>0.0001<br>18 | 0.94570<br>0.0001<br>18 | 0.95276<br>0.0001<br>18 | 0.86553<br>0.0001<br>18 | 0.86937<br>0.0001<br>18 | 0.91389<br>0.0001<br>14 | 0.93844<br>0.0001<br>10 | 0.95328<br>0.0001<br>15 | 0.72691<br>0.0009<br>17 | 0.94369<br>0.0001<br>18 | 0.95607<br>0.0008<br>7 | 0.84080<br>0.0001<br>18 | 0.77130<br>0.0008<br>15 | 0.81272<br>0.0001<br>18 | 0.90817<br>0.0003<br>10 | 0.68596<br>0.0017<br>18 | 1.00000<br>0.0000<br>18 | 0.83676<br>0.0001<br>18 | 0.68325<br>0.0018<br>18 | 0.93104<br>0.0001<br>18 |
| 050B025 | 0.90004<br>0.0001<br>18 | 0.88493<br>0.0001<br>18 | 0.91552<br>0.0001<br>18 | 0.86901<br>0.0001<br>18 | 0.86144<br>0.0001<br>18 | 0.86773<br>0.0001<br>14 | 0.90310<br>0.0003<br>10 | 0.86462<br>0.0001<br>15 | 0.91346<br>0.0001<br>17 | 0.88972<br>0.0001<br>18 | 0.94641<br>0.0012<br>7 | 0.88406<br>0.0001<br>18 | 0.90500<br>0.0001<br>15 | 0.84859<br>0.0001<br>18 | 0.80914<br>0.0046<br>10 | 0.89557<br>0.0001<br>18 | 0.83676<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.92276<br>0.0001<br>18 | 0.92598<br>0.0001<br>18 |
| 050B031 | 0.85962<br>0.0001<br>19 | 0.79695<br>0.0001<br>19 | 0.77929<br>0.0001<br>19 | 0.81945<br>0.0001<br>19 | 0.83823<br>0.0001<br>19 | 0.86306<br>0.0001<br>14 | 0.84889<br>0.0019<br>10 | 0.70981<br>0.0030<br>15 | 0.92079<br>0.0001<br>18 | 0.75426<br>0.0002<br>19 | 0.20419<br>0.6277<br>8 | 0.85908<br>0.0001<br>19 | 0.87414<br>0.0001<br>16 | 0.76076<br>0.0002<br>19 | 0.27057<br>0.4210<br>11 | 0.93117<br>0.0001<br>19 | 0.68325<br>0.0018<br>18 | 0.92276<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.80675<br>0.0001<br>19 |
| 050C004 | 0.83399<br>0.0001<br>19 | 0.89847<br>0.0001<br>22 | 0.95694<br>0.0001<br>22 | 0.81711<br>0.0001<br>22 | 0.80462<br>0.0001<br>19 | 0.85825<br>0.0001<br>14 | 0.90364<br>0.0003<br>10 | 0.96540<br>0.0001<br>15 | 0.85551<br>0.0001<br>21 | 0.99410<br>0.0001<br>19 | 0.98400<br>0.0001<br>12 | 0.85770<br>0.0001<br>22 | 0.83431<br>0.0001<br>18 | 0.94903<br>0.0001<br>20 | 0.92914<br>0.0001<br>11 | 0.85478<br>0.0001<br>19 | 0.93104<br>0.0001<br>18 | 0.92598<br>0.0001<br>18 | 0.80675<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-8

## Spearman Correlation Coefficients* for Pembina River Basin May Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.85375<br>0.0001<br>19 | 0.90430<br>0.0001<br>19 | 0.80246<br>0.0001<br>19 | 0.84109<br>0.0001<br>19 | 0.81538<br>0.0004<br>14 | 0.80606<br>0.0049<br>10 | 0.75961<br>0.0010<br>15 | 0.77536<br>0.0002<br>18 | 0.84197<br>0.0001<br>19 | 0.69048<br>0.0580<br>8 | 0.82529<br>0.0001<br>19 | 0.65195<br>0.0062<br>16 | 0.74100<br>0.0003<br>19 | 0.72727<br>0.0112<br>11 | 0.83970<br>0.0001<br>19 | 0.88430<br>0.0001<br>18 | 0.84961<br>0.0001<br>18 | 0.66740<br>0.0018<br>19 | 0.85338<br>0.0001<br>19 |
| 050A006 | 0.85375<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.91387<br>0.0001<br>22 | 0.93081<br>0.0001<br>22 | 0.84862<br>0.0001<br>19 | 0.91529<br>0.0001<br>14 | 0.98788<br>0.0001<br>10 | 0.87936<br>0.0001<br>15 | 0.59141<br>0.0047<br>21 | 0.89601<br>0.0001<br>19 | 0.95455<br>0.0001<br>11 | 0.74802<br>0.0001<br>22 | 0.49355<br>0.0374<br>18 | 0.70026<br>0.0006<br>20 | 0.86105<br>0.0007<br>11 | 0.64881<br>0.0027<br>19 | 0.92824<br>0.0001<br>18 | 0.85950<br>0.0001<br>18 | 0.61397<br>0.0052<br>19 | 0.87433<br>0.0001<br>22 |
| 050A007 | 0.90430<br>0.0001<br>19 | 0.91387<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.80689<br>0.0001<br>22 | 0.79825<br>0.0001<br>19 | 0.81538<br>0.0004<br>14 | 0.95152<br>0.0001<br>10 | 0.88571<br>0.0001<br>15 | 0.73236<br>0.0002<br>21 | 0.90877<br>0.0001<br>19 | 0.82727<br>0.0017<br>11 | 0.78961<br>0.0001<br>22 | 0.54386<br>0.0196<br>18 | 0.79398<br>0.0001<br>20 | 0.96364<br>0.0001<br>11 | 0.70557<br>0.0007<br>19 | 0.93808<br>0.0001<br>18 | 0.91791<br>0.0001<br>18 | 0.66813<br>0.0018<br>19 | 0.88255<br>0.0001<br>22 |
| 050A008 | 0.80246<br>0.0001<br>19 | 0.93081<br>0.0001<br>22 | 0.80689<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.92281<br>0.0001<br>19 | 0.95165<br>0.0001<br>14 | 0.87879<br>0.0008<br>10 | 0.63214<br>0.0115<br>15 | 0.48301<br>0.0232<br>21 | 0.69298<br>0.0010<br>19 | 0.90000<br>0.0002<br>11 | 0.74668<br>0.0001<br>22 | 0.46956<br>0.0493<br>18 | 0.51278<br>0.0208<br>20 | 0.58182<br>0.0604<br>11 | 0.58534<br>0.0085<br>19 | 0.75232<br>0.0003<br>18 | 0.71554<br>0.0008<br>18 | 0.61457<br>0.0051<br>19 | 0.70073<br>0.0003<br>22 |
| 050A010 | 0.84109<br>0.0001<br>19 | 0.84862<br>0.0001<br>19 | 0.79825<br>0.0001<br>19 | 0.92281<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.88132<br>0.0001<br>14 | 0.74545<br>0.0133<br>10 | 0.59286<br>0.0198<br>15 | 0.58872<br>0.0102<br>18 | 0.66316<br>0.0020<br>19 | 0.66667<br>0.0710<br>8 | 0.76842<br>0.0001<br>19 | 0.44412<br>0.0848<br>16 | 0.50351<br>0.0280<br>19 | 0.58182<br>0.0604<br>11 | 0.61694<br>0.0049<br>19 | 0.75232<br>0.0003<br>18 | 0.69799<br>0.0013<br>18 | 0.60492<br>0.0061<br>19 | 0.62632<br>0.0041<br>19 |
| 050A012 | 0.81538<br>0.0004<br>14 | 0.91529<br>0.0001<br>14 | 0.81538<br>0.0004<br>14 | 0.95165<br>0.0001<br>14 | 0.88132<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.96364<br>0.0001<br>10 | 0.73187<br>0.0029<br>14 | 0.62448<br>0.0225<br>13 | 0.68791<br>0.0065<br>14 | 0.82143<br>0.0234<br>7 | 0.79341<br>0.0007<br>14 | 0.63956<br>0.0138<br>14 | 0.50769<br>0.0638<br>14 | 0.60000<br>0.0667<br>10 | 0.67033<br>0.0087<br>14 | 0.78022<br>0.0010<br>14 | 0.67033<br>0.0087<br>14 | 0.83388<br>0.0002<br>14 | 0.65275<br>0.0114<br>14 |
| 050A013 | 0.80606<br>0.0049<br>10 | 0.98788<br>0.0001<br>10 | 0.95152<br>0.0001<br>10 | 0.87879<br>0.0008<br>10 | 0.74545<br>0.0133<br>10 | 0.96364<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.87879<br>0.0008<br>10 | 0.69301<br>0.0263<br>10 | 0.85455<br>0.0016<br>10 | 1.00000<br>0.0000<br>3 | 0.75758<br>0.0111<br>10 | 0.46667<br>0.1739<br>10 | 0.66061<br>0.0376<br>10 | 0.88571<br>0.0188<br>6 | 0.61212<br>0.0600<br>10 | 0.96364<br>0.0001<br>10 | 0.80606<br>0.0049<br>10 | 0.77812<br>0.0080<br>10 | 0.80606<br>0.0049<br>10 |
| 050B001 | 0.75961<br>0.0010<br>15 | 0.87936<br>0.0001<br>15 | 0.88571<br>0.0001<br>15 | 0.63214<br>0.0115<br>15 | 0.59286<br>0.0198<br>15 | 0.73187<br>0.0029<br>14 | 0.87879<br>0.0008<br>10 | 1.00000<br>0.0000<br>15 | 0.67767<br>0.0077<br>14 | 0.98214<br>0.0001<br>15 | 0.89286<br>0.0068<br>7 | 0.58571<br>0.0218<br>15 | 0.58571<br>0.0218<br>15 | 0.81786<br>0.0002<br>15 | 0.97576<br>0.0001<br>10 | 0.65952<br>0.0075<br>15 | 0.97500<br>0.0001<br>15 | 0.84643<br>0.0001<br>15 | 0.45934<br>0.0850<br>15 | 0.94643<br>0.0001<br>15 |
| 050B006 | 0.77536<br>0.0002<br>18 | 0.59141<br>0.0047<br>21 | 0.73236<br>0.0002<br>21 | 0.49301<br>0.0232<br>21 | 0.58872<br>0.0102<br>18 | 0.62448<br>0.0225<br>13 | 0.69301<br>0.0263<br>10 | 0.67767<br>0.0077<br>14 | 1.00000<br>0.0000<br>21 | 0.69012<br>0.0015<br>18 | 0.30909<br>0.3848<br>10 | 0.84450<br>0.0001<br>21 | 0.45984<br>0.0633<br>17 | 0.70154<br>0.0008<br>19 | 0.55152<br>0.0984<br>10 | 0.73565<br>0.0005<br>18 | 0.71912<br>0.0011<br>17 | 0.60394<br>0.0102<br>17 | 0.74327<br>0.0004<br>18 | 0.67642<br>0.0008<br>21 |
| 050B007 | 0.84197<br>0.0001<br>19 | 0.89601<br>0.0001<br>19 | 0.90877<br>0.0001<br>19 | 0.69298<br>0.0010<br>19 | 0.66316<br>0.0020<br>19 | 0.68791<br>0.0065<br>14 | 0.85455<br>0.0016<br>10 | 0.98214<br>0.0001<br>15 | 0.69012<br>0.0015<br>18 | 1.00000<br>0.0000<br>19 | 0.97619<br>0.0001<br>8 | 0.66842<br>0.0018<br>19 | 0.55000<br>0.0273<br>16 | 0.88421<br>0.0001<br>19 | 0.95455<br>0.0001<br>11 | 0.72839<br>0.0004<br>19 | 0.96491<br>0.0001<br>18 | 0.92927<br>0.0001<br>18 | 0.56190<br>0.0123<br>19 | 0.98596<br>0.0001<br>19 |
| 050B008 | 0.69048<br>0.0580<br>8 | 0.95455<br>0.0001<br>11 | 0.82727<br>0.0017<br>11 | 0.90000<br>0.0002<br>11 | 0.66667<br>0.0710<br>8 | 0.82143<br>0.0234<br>7 | 1.00000<br>0.0000<br>3 | 0.89286<br>0.0068<br>7 | 0.30909<br>0.3848<br>10 | 0.97619<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.64237<br>0.0331<br>11 | 0.15152<br>0.6761<br>10 | 0.56667<br>0.1116<br>9 | 0.88095<br>0.0039<br>8 | 0.76190<br>0.0280<br>8 | 0.85714<br>0.0137<br>7 | 0.92857<br>0.0025<br>7 | 0.64286<br>0.0856<br>8 | 0.95105<br>0.0001<br>12 |
| 050B010 | 0.82529<br>0.0001<br>19 | 0.74802<br>0.0001<br>22 | 0.78961<br>0.0001<br>22 | 0.74668<br>0.0001<br>22 | 0.76842<br>0.0001<br>19 | 0.79341<br>0.0007<br>14 | 0.75758<br>0.0111<br>10 | 0.58571<br>0.0218<br>15 | 0.84450<br>0.0001<br>21 | 0.66842<br>0.0018<br>19 | 0.64237<br>0.0331<br>11 | 1.00000<br>0.0000<br>22 | 0.60165<br>0.0083<br>18 | 0.68271<br>0.0009<br>20 | 0.48182<br>0.1334<br>11 | 0.79509<br>0.0001<br>19 | 0.72136<br>0.0007<br>18 | 0.67837<br>0.0020<br>18 | 0.88323<br>0.0001<br>19 | 0.71618<br>0.0002<br>22 |
| 050B013 | 0.65195<br>0.0062<br>16 | 0.49355<br>0.0374<br>18 | 0.54386<br>0.0196<br>18 | 0.46956<br>0.0493<br>18 | 0.44412<br>0.0848<br>16 | 0.63956<br>0.0138<br>14 | 0.46667<br>0.1739<br>10 | 0.58571<br>0.0218<br>15 | 0.45984<br>0.0633<br>17 | 0.55000<br>0.0273<br>16 | 0.15152<br>0.6761<br>10 | 0.60165<br>0.0083<br>18 | 1.00000<br>0.0000<br>18 | 0.68627<br>0.0023<br>17 | 0.10909<br>0.7495<br>11 | 0.69021<br>0.0031<br>16 | 0.56786<br>0.0272<br>15 | 0.66786<br>0.0065<br>15 | 0.62693<br>0.0093<br>16 | 0.59752<br>0.0088<br>18 |
| 050B016 | 0.74100<br>0.0003<br>19 | 0.70026<br>0.0006<br>20 | 0.79398<br>0.0001<br>20 | 0.51278<br>0.0208<br>20 | 0.50351<br>0.0280<br>19 | 0.50769<br>0.0638<br>14 | 0.66061<br>0.0376<br>10 | 0.81786<br>0.0002<br>15 | 0.70154<br>0.0008<br>19 | 0.88421<br>0.0001<br>19 | 0.56667<br>0.1116<br>9 | 0.68271<br>0.0009<br>20 | 0.68627<br>0.0023<br>17 | 1.00000<br>0.0000<br>20 | 0.76364<br>0.0062<br>11 | 0.77578<br>0.0001<br>19 | 0.80805<br>0.0001<br>18 | 0.90036<br>0.0001<br>18 | 0.61984<br>0.0046<br>19 | 0.89323<br>0.0001<br>20 |
| 050B019 | 0.72727<br>0.0112<br>11 | 0.86105<br>0.0007<br>11 | 0.96364<br>0.0001<br>11 | 0.58182<br>0.0604<br>11 | 0.58182<br>0.0604<br>11 | 0.60000<br>0.0667<br>10 | 0.88571<br>0.0188<br>6 | 0.97576<br>0.0001<br>10 | 0.55152<br>0.0984<br>10 | 0.95455<br>0.0001<br>11 | 0.88095<br>0.0039<br>8 | 0.48182<br>0.1334<br>11 | 0.10909<br>0.7495<br>11 | 0.76364<br>0.0062<br>11 | 1.00000<br>0.0000<br>11 | 0.60000<br>0.0510<br>11 | 0.97576<br>0.0001<br>10 | 0.92727<br>0.0001<br>10 | 0.50000<br>0.1173<br>11 | 0.90909<br>0.0001<br>11 |
| 050B021 | 0.83970<br>0.0001<br>19 | 0.64881<br>0.0027<br>19 | 0.70557<br>0.0007<br>19 | 0.58534<br>0.0085<br>19 | 0.61694<br>0.0049<br>19 | 0.67033<br>0.0087<br>14 | 0.61212<br>0.0600<br>10 | 0.65952<br>0.0075<br>15 | 0.73565<br>0.0005<br>18 | 0.72839<br>0.0004<br>19 | 0.76190<br>0.0280<br>8 | 0.79509<br>0.0001<br>19 | 0.69021<br>0.0031<br>16 | 0.77578<br>0.0001<br>19 | 0.60000<br>0.0510<br>11 | 1.00000<br>0.0000<br>19 | 0.69902<br>0.0012<br>18 | 0.72572<br>0.0007<br>18 | 0.76899<br>0.0001<br>19 | 0.76613<br>0.0001<br>19 |
| 050B023 | 0.88430<br>0.0001<br>18 | 0.92824<br>0.0001<br>18 | 0.93808<br>0.0001<br>18 | 0.75232<br>0.0003<br>18 | 0.75232<br>0.0003<br>18 | 0.78022<br>0.0010<br>14 | 0.96364<br>0.0001<br>10 | 0.97500<br>0.0001<br>15 | 0.71912<br>0.0011<br>17 | 0.96491<br>0.0001<br>18 | 0.85714<br>0.0137<br>7 | 0.72136<br>0.0007<br>18 | 0.56786<br>0.0272<br>15 | 0.80805<br>0.0001<br>18 | 0.97576<br>0.0001<br>10 | 0.69902<br>0.0012<br>18 | 1.00000<br>0.0000<br>18 | 0.89520<br>0.0001<br>18 | 0.58574<br>0.0106<br>18 | 0.95046<br>0.0001<br>18 |
| 050B025 | 0.84961<br>0.0001<br>18 | 0.85950<br>0.0001<br>18 | 0.91791<br>0.0001<br>18 | 0.71554<br>0.0008<br>18 | 0.69799<br>0.0013<br>18 | 0.67033<br>0.0087<br>14 | 0.80606<br>0.0049<br>10 | 0.84643<br>0.0001<br>15 | 0.60394<br>0.0102<br>17 | 0.92927<br>0.0001<br>18 | 0.92857<br>0.0025<br>7 | 0.67837<br>0.0020<br>18 | 0.66786<br>0.0065<br>15 | 0.90036<br>0.0001<br>18 | 0.92727<br>0.0001<br>10 | 0.72572<br>0.0007<br>18 | 0.89520<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.63411<br>0.0047<br>18 | 0.93134<br>0.0001<br>18 |
| 050B031 | 0.66740<br>0.0018<br>19 | 0.61397<br>0.0052<br>19 | 0.66813<br>0.0018<br>19 | 0.61457<br>0.0051<br>19 | 0.60492<br>0.0061<br>19 | 0.83388<br>0.0002<br>14 | 0.77812<br>0.0080<br>10 | 0.45934<br>0.0850<br>15 | 0.74327<br>0.0004<br>18 | 0.56190<br>0.0123<br>19 | 0.64286<br>0.0856<br>8 | 0.88323<br>0.0001<br>19 | 0.62693<br>0.0093<br>16 | 0.61984<br>0.0046<br>19 | 0.50000<br>0.1173<br>11 | 0.76899<br>0.0001<br>19 | 0.58574<br>0.0106<br>18 | 0.63411<br>0.0047<br>18 | 1.00000<br>0.0000<br>19 | 0.61896<br>0.0047<br>19 |
| 050C004 | 0.85338<br>0.0001<br>19 | 0.87433<br>0.0001<br>22 | 0.88255<br>0.0001<br>22 | 0.70073<br>0.0003<br>22 | 0.62632<br>0.0041<br>19 | 0.65275<br>0.0114<br>14 | 0.80606<br>0.0049<br>10 | 0.94643<br>0.0001<br>15 | 0.67642<br>0.0008<br>21 | 0.98596<br>0.0001<br>19 | 0.95105<br>0.0001<br>12 | 0.71618<br>0.0002<br>22 | 0.59752<br>0.0088<br>18 | 0.89323<br>0.0001<br>20 | 0.90909<br>0.0001<br>11 | 0.76613<br>0.0001<br>19 | 0.95046<br>0.0001<br>18 | 0.93134<br>0.0001<br>18 | 0.61896<br>0.0047<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-9

## Pearson Correlation Coefficients* for Pembina River Basin June Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.36494<br>0.1245<br>19 | 0.33765<br>0.1574<br>19 | 0.35673<br>0.1338<br>19 | 0.18932<br>0.4376<br>19 | 0.33162<br>0.2467<br>14 | 0.39226<br>0.2622<br>10 | 0.26649<br>0.3370<br>15 | 0.00914<br>0.9713<br>18 | 0.29162<br>0.2258<br>19 | 0.34722<br>0.3994<br>8 | -0.10986<br>0.6544<br>19 | -0.25565<br>0.3393<br>16 | 0.29888<br>0.2139<br>19 | 0.04972<br>0.8846<br>11 | 0.06245<br>0.7995<br>19 | 0.27678<br>0.2662<br>18 | 0.19751<br>0.4321<br>18 | -0.13575<br>0.5795<br>19 | 0.24824<br>0.3055<br>19 |
| 050A006 | 0.36494<br>0.1245<br>19 | 1.00000<br>0.0000<br>22 | 0.53547<br>0.0102<br>22 | 0.79159<br>0.0001<br>22 | 0.77494<br>0.0001<br>19 | 0.77196<br>0.0012<br>14 | 0.88220<br>0.0007<br>10 | 0.44260<br>0.0985<br>15 | 0.14231<br>0.5383<br>21 | 0.41980<br>0.0736<br>19 | 0.44904<br>0.1659<br>11 | 0.19852<br>0.3758<br>22 | -0.10402<br>0.6812<br>18 | 0.28280<br>0.2270<br>20 | 0.14425<br>0.6722<br>11 | 0.18739<br>0.4424<br>19 | 0.56726<br>0.0141<br>18 | 0.39330<br>0.1064<br>18 | 0.12957<br>0.5970<br>19 | 0.45078<br>0.0352<br>22 |
| 050A007 | 0.33765<br>0.1574<br>19 | 0.53547<br>0.0102<br>22 | 1.00000<br>0.0000<br>22 | 0.15097<br>0.5025<br>22 | 0.13808<br>0.5729<br>19 | 0.04975<br>0.8659<br>14 | 0.49501<br>0.1458<br>10 | 0.74479<br>0.0014<br>15 | 0.83224<br>0.0001<br>21 | 0.78733<br>0.0001<br>19 | 0.74995<br>0.0079<br>11 | 0.70808<br>0.0002<br>22 | 0.29208<br>0.2396<br>18 | 0.75005<br>0.0001<br>20 | 0.88900<br>0.0003<br>11 | 0.84224<br>0.0001<br>19 | 0.87715<br>0.0001<br>18 | 0.75343<br>0.0003<br>18 | 0.71241<br>0.0006<br>19 | 0.82122<br>0.0001<br>22 |
| 050A008 | 0.35673<br>0.1338<br>19 | 0.79159<br>0.0001<br>22 | 0.15097<br>0.5025<br>22 | 1.00000<br>0.0000<br>22 | 0.85455<br>0.0001<br>19 | 0.91951<br>0.0001<br>14 | 0.60422<br>0.0643<br>10 | -0.05016<br>0.8591<br>15 | -0.14801<br>0.5220<br>21 | -0.00937<br>0.9696<br>19 | 0.33942<br>0.3072<br>11 | -0.02432<br>0.9145<br>22 | -0.24276<br>0.3317<br>18 | -0.12316<br>0.6049<br>20 | -0.11350<br>0.7397<br>11 | -0.20229<br>0.4062<br>19 | 0.14424<br>0.5680<br>18 | 0.01245<br>0.9609<br>18 | -0.08992<br>0.7143<br>19 | 0.03597<br>0.8737<br>22 |
| 050A010 | 0.18932<br>0.4376<br>19 | 0.77494<br>0.0001<br>19 | 0.13808<br>0.5729<br>19 | 0.85455<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.94507<br>0.0001<br>14 | 0.72066<br>0.0187<br>10 | 0.17122<br>0.5418<br>15 | -0.00742<br>0.9767<br>18 | 0.10961<br>0.6551<br>19 | -0.12814<br>0.7624<br>8 | 0.02468<br>0.9201<br>19 | -0.29535<br>0.2668<br>16 | -0.02123<br>0.9312<br>19 | -0.04101<br>0.9047<br>11 | -0.06019<br>0.8066<br>19 | 0.34921<br>0.1555<br>18 | 0.09444<br>0.7093<br>18 | 0.01262<br>0.9591<br>19 | 0.10303<br>0.6747<br>19 |
| 050A012 | 0.33162<br>0.2467<br>14 | 0.77196<br>0.0012<br>14 | 0.04975<br>0.8659<br>14 | 0.91951<br>0.0001<br>14 | 0.94507<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.71099<br>0.0212<br>10 | 0.03655<br>0.9013<br>14 | -0.17845<br>0.5597<br>13 | 0.02944<br>0.9204<br>14 | 0.39807<br>0.3765<br>7 | -0.05895<br>0.8413<br>14 | -0.25817<br>0.3728<br>14 | -0.13385<br>0.6483<br>14 | -0.01148<br>0.9749<br>10 | -0.24953<br>0.3896<br>14 | 0.14657<br>0.6171<br>14 | -0.10092<br>0.7314<br>14 | -0.09915<br>0.7360<br>14 | -0.02935<br>0.9207<br>14 |
| 050A013 | 0.39226<br>0.2622<br>10 | 0.88220<br>0.0007<br>10 | 0.49501<br>0.1458<br>10 | 0.60422<br>0.0643<br>10 | 0.72066<br>0.0187<br>10 | 0.71099<br>0.0212<br>10 | 1.00000<br>0.0000<br>10 | 0.64021<br>0.0462<br>10 | 0.18883<br>0.6013<br>10 | 0.64648<br>0.0434<br>10 | 0.92626<br>0.2460<br>3 | 0.07329<br>0.8405<br>10 | -0.03476<br>0.9240<br>10 | 0.48042<br>0.1599<br>10 | 0.34773<br>0.4994<br>6 | 0.23357<br>0.5160<br>10 | 0.68350<br>0.0293<br>10 | 0.40670<br>0.2435<br>10 | 0.05525<br>0.8795<br>10 | 0.59145<br>0.0717<br>10 |
| 050B001 | 0.26649<br>0.3370<br>15 | 0.44260<br>0.0985<br>15 | 0.74479<br>0.0014<br>15 | -0.05016<br>0.8591<br>15 | 0.17122<br>0.5418<br>15 | 0.03655<br>0.9013<br>14 | 0.64021<br>0.0462<br>10 | 1.00000<br>0.0000<br>15 | 0.61730<br>0.0187<br>14 | 0.99427<br>0.0001<br>15 | 0.97748<br>0.0001<br>7 | 0.30550<br>0.2682<br>15 | 0.19587<br>0.4842<br>15 | 0.93744<br>0.0001<br>15 | 0.97644<br>0.0001<br>10 | 0.74995<br>0.0013<br>15 | 0.94452<br>0.0001<br>15 | 0.77328<br>0.0007<br>15 | 0.32568<br>0.2362<br>15 | 0.98331<br>0.0001<br>15 |
| 050B006 | 0.00914<br>0.9713<br>18 | 0.14231<br>0.5383<br>21 | 0.83224<br>0.0001<br>21 | -0.14801<br>0.5220<br>21 | -0.00742<br>0.9767<br>18 | -0.17845<br>0.5597<br>13 | 0.18883<br>0.6013<br>10 | 0.61730<br>0.0187<br>14 | 1.00000<br>0.0000<br>21 | 0.67157<br>0.0023<br>18 | -0.07180<br>0.8437<br>10 | 0.94638<br>0.0001<br>21 | 0.38968<br>0.1221<br>17 | 0.68774<br>0.0011<br>19 | 0.90862<br>0.0003<br>10 | 0.87880<br>0.0001<br>18 | 0.75879<br>0.0004<br>17 | 0.60023<br>0.0109<br>17 | 0.94065<br>0.0001<br>18 | 0.71787<br>0.0002<br>21 |
| 050B007 | 0.29162<br>0.2258<br>19 | 0.41980<br>0.0736<br>19 | 0.78733<br>0.0001<br>19 | -0.00937<br>0.9696<br>19 | 0.10961<br>0.6551<br>19 | 0.02944<br>0.9204<br>14 | 0.64648<br>0.0434<br>10 | 0.99427<br>0.0001<br>15 | 0.67157<br>0.0023<br>18 | 1.00000<br>0.0000<br>19 | 0.99205<br>0.0001<br>8 | 0.36574<br>0.1236<br>19 | 0.21706<br>0.4194<br>16 | 0.95229<br>0.0001<br>19 | 0.97961<br>0.0001<br>11 | 0.72292<br>0.0005<br>19 | 0.95265<br>0.0001<br>18 | 0.75655<br>0.0003<br>18 | 0.38261<br>0.1059<br>19 | 0.99433<br>0.0001<br>19 |
| 050B008 | 0.34722<br>0.3994<br>8 | 0.44904<br>0.1659<br>11 | 0.74995<br>0.0079<br>11 | 0.33942<br>0.3072<br>11 | -0.12814<br>0.7624<br>8 | 0.39807<br>0.3765<br>7 | 0.92626<br>0.2460<br>3 | 0.97748<br>0.0001<br>7 | -0.07180<br>0.8437<br>10 | 0.99205<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.07073<br>0.8363<br>11 | 0.23535<br>0.5127<br>10 | 0.64516<br>0.0606<br>9 | 0.95873<br>0.0002<br>8 | 0.78181<br>0.0219<br>8 | 0.83600<br>0.0191<br>7 | 0.65145<br>0.1129<br>7 | -0.05839<br>0.8908<br>8 | 0.98447<br>0.0001<br>12 |
| 050B010 | -0.10986<br>0.6544<br>19 | 0.19852<br>0.3758<br>22 | 0.70808<br>0.0002<br>22 | -0.02432<br>0.9145<br>22 | 0.02468<br>0.9201<br>19 | -0.05895<br>0.8413<br>14 | 0.07329<br>0.8405<br>10 | 0.30550<br>0.2682<br>15 | 0.94638<br>0.0001<br>21 | 0.36574<br>0.1236<br>19 | 0.07073<br>0.8363<br>11 | 1.00000<br>0.0000<br>22 | 0.41278<br>0.0887<br>18 | 0.34728<br>0.1336<br>20 | 0.74752<br>0.0082<br>11 | 0.70810<br>0.0007<br>19 | 0.54592<br>0.0191<br>18 | 0.42614<br>0.0778<br>18 | 0.98442<br>0.0001<br>19 | 0.44446<br>0.0382<br>22 |
| 050B013 | -0.25565<br>0.3393<br>16 | -0.10402<br>0.6812<br>18 | 0.29208<br>0.2396<br>18 | -0.24276<br>0.3317<br>16 | -0.29535<br>0.2668<br>14 | -0.25817<br>0.3728<br>14 | -0.03476<br>0.9240<br>10 | 0.19587<br>0.4842<br>15 | 0.38968<br>0.1221<br>17 | 0.21706<br>0.4194<br>16 | 0.23535<br>0.5127<br>10 | 0.41278<br>0.0887<br>18 | 1.00000<br>0.0000<br>18 | 0.23587<br>0.3621<br>17 | 0.38012<br>0.2488<br>11 | 0.48349<br>0.0578<br>16 | 0.27403<br>0.3230<br>15 | 0.58713<br>0.0214<br>15 | 0.37802<br>0.1488<br>16 | 0.27093<br>0.2769<br>18 |
| 050B016 | 0.29888<br>0.2139<br>19 | 0.28280<br>0.2270<br>20 | 0.75005<br>0.0001<br>20 | -0.12316<br>0.6049<br>20 | -0.02123<br>0.9312<br>19 | -0.13385<br>0.6483<br>14 | 0.48042<br>0.1599<br>10 | 0.93744<br>0.0001<br>15 | 0.68774<br>0.0011<br>19 | 0.95229<br>0.0001<br>19 | 0.64516<br>0.0606<br>9 | 0.34728<br>0.1336<br>20 | 0.23587<br>0.3621<br>17 | 1.00000<br>0.0000<br>20 | 0.89580<br>0.0002<br>11 | 0.72344<br>0.0005<br>19 | 0.86356<br>0.0001<br>18 | 0.71521<br>0.0008<br>18 | 0.35862<br>0.1316<br>19 | 0.94872<br>0.0001<br>20 |
| 050B019 | 0.04972<br>0.8846<br>11 | 0.14425<br>0.6722<br>11 | 0.88900<br>0.0003<br>11 | -0.11350<br>0.7397<br>11 | -0.04101<br>0.9047<br>11 | -0.01148<br>0.9749<br>10 | 0.34773<br>0.4994<br>6 | 0.97644<br>0.0001<br>10 | 0.90862<br>0.0003<br>10 | 0.97961<br>0.0001<br>11 | 0.95873<br>0.0002<br>8 | 0.74752<br>0.0082<br>11 | 0.38012<br>0.2488<br>11 | 0.89580<br>0.0002<br>11 | 1.00000<br>0.0000<br>11 | 0.93752<br>0.0001<br>11 | 0.95937<br>0.0001<br>10 | 0.74422<br>0.0136<br>10 | 0.80526<br>0.0028<br>11 | 0.98283<br>0.0001<br>11 |
| 050B021 | 0.06245<br>0.7995<br>19 | 0.18739<br>0.4424<br>19 | 0.84224<br>0.0001<br>19 | -0.20229<br>0.4062<br>19 | -0.06019<br>0.8066<br>19 | -0.24953<br>0.3896<br>14 | 0.23357<br>0.5160<br>10 | 0.74995<br>0.0013<br>15 | 0.87880<br>0.0001<br>18 | 0.72292<br>0.0005<br>19 | 0.78181<br>0.0219<br>8 | 0.70810<br>0.0007<br>19 | 0.48349<br>0.0578<br>16 | 0.72344<br>0.0005<br>19 | 0.93752<br>0.0001<br>11 | 1.00000<br>0.0000<br>19 | 0.78945<br>0.0001<br>18 | 0.85249<br>0.0001<br>18 | 0.73448<br>0.0003<br>19 | 0.77516<br>0.0001<br>19 |
| 050B023 | 0.27678<br>0.2662<br>18 | 0.56726<br>0.0141<br>18 | 0.87715<br>0.0001<br>18 | 0.14424<br>0.5680<br>18 | 0.34921<br>0.1555<br>18 | 0.14657<br>0.6171<br>14 | 0.68350<br>0.0293<br>10 | 0.94452<br>0.0001<br>15 | 0.75879<br>0.0004<br>17 | 0.95265<br>0.0001<br>18 | 0.83600<br>0.0191<br>7 | 0.54592<br>0.0191<br>18 | 0.27403<br>0.3230<br>15 | 0.86356<br>0.0001<br>18 | 0.95937<br>0.0001<br>10 | 0.78945<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.78680<br>0.0001<br>18 | 0.56206<br>0.0152<br>18 | 0.96182<br>0.0001<br>18 |
| 050B025 | 0.19751<br>0.4321<br>18 | 0.39330<br>0.1064<br>18 | 0.75343<br>0.0003<br>18 | 0.01245<br>0.9609<br>18 | 0.09444<br>0.7093<br>18 | -0.10092<br>0.7314<br>14 | 0.40670<br>0.2435<br>10 | 0.77328<br>0.0007<br>15 | 0.60023<br>0.0109<br>17 | 0.75655<br>0.0003<br>18 | 0.65145<br>0.1129<br>7 | 0.42614<br>0.0778<br>18 | 0.58713<br>0.0214<br>15 | 0.71521<br>0.0008<br>18 | 0.74422<br>0.0136<br>10 | 0.85249<br>0.0001<br>18 | 0.78680<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.41537<br>0.0865<br>18 | 0.77400<br>0.0002<br>18 |
| 050B031 | -0.13575<br>0.5795<br>19 | 0.12957<br>0.5970<br>19 | 0.71241<br>0.0006<br>19 | -0.08992<br>0.7143<br>19 | 0.01262<br>0.9591<br>19 | -0.09915<br>0.7360<br>14 | 0.05525<br>0.8795<br>10 | 0.32568<br>0.2362<br>15 | 0.94065<br>0.0001<br>18 | 0.38261<br>0.1059<br>19 | -0.05839<br>0.8908<br>8 | 0.98442<br>0.0001<br>19 | 0.37802<br>0.1488<br>16 | 0.35862<br>0.1316<br>19 | 0.80526<br>0.0028<br>11 | 0.73448<br>0.0003<br>19 | 0.56206<br>0.0152<br>18 | 0.41537<br>0.0865<br>18 | 1.00000<br>0.0000<br>19 | 0.45482<br>0.0504<br>19 |
| 050C004 | 0.24824<br>0.3055<br>19 | 0.45078<br>0.0352<br>22 | 0.82122<br>0.0001<br>22 | 0.03597<br>0.8737<br>22 | 0.10303<br>0.6747<br>19 | -0.02935<br>0.9207<br>14 | 0.59145<br>0.0717<br>10 | 0.98331<br>0.0001<br>15 | 0.71787<br>0.0002<br>21 | 0.99433<br>0.0001<br>19 | 0.98447<br>0.0001<br>12 | 0.44446<br>0.0382<br>22 | 0.27093<br>0.2769<br>18 | 0.94872<br>0.0001<br>20 | 0.98283<br>0.0001<br>11 | 0.77516<br>0.0001<br>19 | 0.96182<br>0.0001<br>18 | 0.77400<br>0.0002<br>18 | 0.45482<br>0.0504<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-10

## Spearman Correlation Coefficients* for Pembina River Basin June Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.75054<br>0.0002<br>19 | 0.71667<br>0.0006<br>19 | 0.81650<br>0.0001<br>19 | 0.77406<br>0.0001<br>19 | 0.68509<br>0.0069<br>14 | 0.76693<br>0.0096<br>10 | 0.22183<br>0.4268<br>15 | 0.11580<br>0.6473<br>18 | 0.49828<br>0.0299<br>19 | 0.16869<br>0.6897<br>8 | 0.42594<br>0.0690<br>19 | -0.14540<br>0.5911<br>16 | 0.17835<br>0.4651<br>19 | 0.38357<br>0.2442<br>11 | 0.05315<br>0.8289<br>19 | 0.61315<br>0.0068<br>18 | 0.53521<br>0.0221<br>18 | 0.17716<br>0.4681<br>19 | 0.42965<br>0.0664<br>19 |
| 050A006 | 0.75054<br>0.0002<br>19 | 1.00000<br>0.0000<br>22 | 0.77866<br>0.0001<br>22 | 0.87691<br>0.0001<br>22 | 0.88021<br>0.0001<br>19 | 0.78462<br>0.0009<br>14 | 0.93939<br>0.0001<br>10 | 0.47143<br>0.0761<br>15 | 0.15564<br>0.5005<br>21 | 0.54912<br>0.0149<br>19 | 0.54545<br>0.0827<br>11 | 0.65932<br>0.0008<br>22 | 0.05576<br>0.8261<br>18 | 0.31215<br>0.1803<br>20 | 0.48182<br>0.1334<br>11 | 0.33231<br>0.1645<br>19 | 0.78535<br>0.0001<br>18 | 0.76805<br>0.0002<br>18 | 0.24078<br>0.3207<br>19 | 0.59458<br>0.0035<br>22 |
| 050A007 | 0.71667<br>0.0006<br>19 | 0.77866<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.67363<br>0.0006<br>22 | 0.57832<br>0.0095<br>19 | 0.38462<br>0.1745<br>14 | 0.67273<br>0.0330<br>10 | 0.65000<br>0.0087<br>15 | 0.21452<br>0.3504<br>21 | 0.77018<br>0.0001<br>19 | 0.80909<br>0.0026<br>11 | 0.70229<br>0.0003<br>22 | 0.21270<br>0.3968<br>18 | 0.60925<br>0.0044<br>20 | 0.80909<br>0.0026<br>11 | 0.55736<br>0.0132<br>19 | 0.84314<br>0.0001<br>18 | 0.83966<br>0.0001<br>18 | 0.20600<br>0.3975<br>19 | 0.71767<br>0.0002<br>22 |
| 050A008 | 0.81650<br>0.0001<br>19 | 0.87691<br>0.0001<br>22 | 0.67363<br>0.0006<br>22 | 1.00000<br>0.0000<br>22 | 0.90127<br>0.0001<br>19 | 0.83736<br>0.0002<br>14 | 0.75758<br>0.0111<br>10 | 0.12857<br>0.6479<br>15 | 0.03316<br>0.8865<br>21 | 0.31579<br>0.1878<br>19 | 0.50909<br>0.1097<br>11 | 0.51682<br>0.0138<br>22 | -0.13423<br>0.5954<br>18 | 0.01805<br>0.9398<br>20 | 0.23636<br>0.4841<br>11 | -0.05714<br>0.8163<br>19 | 0.53767<br>0.0214<br>18 | 0.48989<br>0.0390<br>18 | 0.15695<br>0.5211<br>19 | 0.39130<br>0.0717<br>22 |
| 050A010 | 0.77406<br>0.0001<br>19 | 0.88021<br>0.0001<br>19 | 0.57832<br>0.0095<br>19 | 0.90127<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.85934<br>0.0001<br>14 | 0.87879<br>0.0008<br>10 | 0.31429<br>0.2539<br>15 | 0.23510<br>0.3477<br>18 | 0.41773<br>0.0751<br>19 | -0.04762<br>0.9108<br>8 | 0.47824<br>0.0383<br>19 | -0.21134<br>0.4320<br>16 | 0.06102<br>0.8040<br>19 | 0.25057<br>0.4574<br>11 | 0.04398<br>0.8581<br>19 | 0.65738<br>0.0030<br>18 | 0.50338<br>0.0332<br>18 | 0.36089<br>0.1290<br>19 | 0.37209<br>0.1167<br>19 |
| 050A012 | 0.68509<br>0.0069<br>14 | 0.78462<br>0.0009<br>14 | 0.38462<br>0.1745<br>14 | 0.83736<br>0.0002<br>14 | 0.85934<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.78182<br>0.0075<br>10 | 0.17363<br>0.5528<br>14 | -0.17919<br>0.5580<br>13 | 0.27033<br>0.3499<br>14 | 0.64286<br>0.1194<br>7 | 0.29043<br>0.3138<br>14 | -0.15182<br>0.6044<br>14 | -0.13407<br>0.6477<br>14 | 0.52727<br>0.1173<br>10 | -0.08801<br>0.7648<br>14 | 0.47692<br>0.0846<br>14 | 0.26872<br>0.3529<br>14 | 0.11451<br>0.6967<br>14 | 0.17363<br>0.5528<br>14 |
| 050A013 | 0.76693<br>0.0096<br>10 | 0.93939<br>0.0001<br>10 | 0.67273<br>0.0330<br>10 | 0.75758<br>0.0111<br>10 | 0.87879<br>0.0008<br>10 | 0.78182<br>0.0075<br>10 | 1.00000<br>0.0000<br>10 | 0.55152<br>0.0984<br>10 | 0.32972<br>0.3522<br>10 | 0.64848<br>0.0425<br>10 | 1.00000<br>0.0000<br>3 | 0.56535<br>0.0885<br>10 | 0.11550<br>0.7507<br>10 | 0.26061<br>0.4671<br>10 | 0.54286<br>0.2657<br>6 | 0.29787<br>0.4032<br>10 | 0.79394<br>0.0061<br>10 | 0.54104<br>0.1063<br>10 | 0.43698<br>0.2067<br>10 | 0.60000<br>0.0667<br>10 |
| 050B001 | 0.22183<br>0.4268<br>15 | 0.47143<br>0.0761<br>15 | 0.65000<br>0.0087<br>15 | 0.12857<br>0.6479<br>15 | 0.31429<br>0.2539<br>15 | 0.17363<br>0.5528<br>14 | 0.55152<br>0.0984<br>10 | 1.00000<br>0.0000<br>15 | 0.75452<br>0.0018<br>14 | 0.97857<br>0.0001<br>15 | 1.00000<br>0.0000<br>7 | 0.57909<br>0.0237<br>15 | 0.14835<br>0.5978<br>15 | 0.77500<br>0.0007<br>15 | 0.95152<br>0.0001<br>10 | 0.69534<br>0.0040<br>15 | 0.88571<br>0.0001<br>15 | 0.69776<br>0.0038<br>15 | 0.34521<br>0.2076<br>15 | 0.98929<br>0.0001<br>15 |
| 050B006 | 0.11580<br>0.6473<br>18 | 0.15564<br>0.5005<br>21 | 0.21452<br>0.3504<br>21 | 0.03316<br>0.8865<br>21 | 0.23510<br>0.3477<br>18 | -0.17919<br>0.5580<br>13 | 0.32972<br>0.3522<br>10 | 0.75452<br>0.0018<br>14 | 1.00000<br>0.0000<br>21 | 0.60895<br>0.0073<br>18 | 0.01251<br>0.9726<br>10 | 0.45413<br>0.0386<br>21 | 0.43920<br>0.0778<br>17 | 0.41512<br>0.0772<br>19 | 0.40285<br>0.2484<br>10 | 0.39817<br>0.1017<br>18 | 0.61747<br>0.0083<br>17 | 0.46124<br>0.0624<br>17 | 0.65579<br>0.0031<br>18 | 0.52445<br>0.0147<br>21 |
| 050B007 | 0.49828<br>0.0299<br>19 | 0.54912<br>0.0149<br>19 | 0.77018<br>0.0001<br>19 | 0.31579<br>0.1878<br>19 | 0.41773<br>0.0751<br>19 | 0.27033<br>0.3499<br>14 | 0.64848<br>0.0425<br>10 | 0.97857<br>0.0001<br>15 | 0.60895<br>0.0073<br>18 | 1.00000<br>0.0000<br>19 | 1.00000<br>0.0000<br>8 | 0.63093<br>0.0038<br>19 | 0.12656<br>0.6404<br>16 | 0.83984<br>0.0001<br>19 | 0.93636<br>0.0001<br>11 | 0.49319<br>0.0319<br>19 | 0.94840<br>0.0001<br>18 | 0.77116<br>0.0002<br>18 | 0.27467<br>0.2551<br>19 | 0.99123<br>0.0001<br>19 |
| 050B008 | 0.16869<br>0.6897<br>8 | 0.54545<br>0.0827<br>11 | 0.80909<br>0.0026<br>11 | 0.50909<br>0.1097<br>11 | -0.04762<br>0.9108<br>8 | 0.64286<br>0.1194<br>7 | 1.00000<br>0.0000<br>3 | 1.00000<br>0.0000<br>7 | 0.01251<br>0.9726<br>10 | 1.00000<br>0.0000<br>8 | 1.00000<br>0.0000<br>12 | 0.57403<br>0.0648<br>11 | 0.13939<br>0.7009<br>10 | 0.68333<br>0.0424<br>9 | 0.90476<br>0.0020<br>8 | 0.69048<br>0.0580<br>8 | 0.89286<br>0.0068<br>7 | 0.57660<br>0.1754<br>7 | -0.09581<br>0.8215<br>8 | 0.97902<br>0.0001<br>12 |
| 050B010 | 0.42594<br>0.0690<br>19 | 0.65932<br>0.0008<br>22 | 0.70229<br>0.0003<br>22 | 0.51682<br>0.0138<br>22 | 0.47824<br>0.0383<br>19 | 0.29043<br>0.3138<br>14 | 0.56535<br>0.0885<br>10 | 0.57909<br>0.0237<br>15 | 0.45413<br>0.0386<br>21 | 0.63093<br>0.0038<br>19 | 0.57403<br>0.0648<br>11 | 1.00000<br>0.0000<br>22 | 0.44628<br>0.0634<br>18 | 0.46252<br>0.0400<br>20 | 0.56364<br>0.0710<br>11 | 0.54073<br>0.0168<br>19 | 0.71665<br>0.0008<br>18 | 0.65939<br>0.0029<br>18 | 0.69503<br>0.0010<br>19 | 0.65140<br>0.0010<br>22 |
| 050B013 | -0.14540<br>0.5911<br>16 | 0.05576<br>0.8261<br>18 | 0.21270<br>0.3968<br>18 | -0.13423<br>0.5954<br>18 | -0.21134<br>0.4320<br>16 | -0.15182<br>0.6044<br>14 | 0.11550<br>0.7507<br>10 | 0.14835<br>0.5978<br>15 | 0.43920<br>0.0778<br>17 | 0.12656<br>0.6404<br>16 | 0.13939<br>0.7009<br>10 | 0.44628<br>0.0634<br>18 | 1.00000<br>0.0000<br>18 | 0.10491<br>0.6886<br>17 | 0.30000<br>0.3701<br>11 | 0.26568<br>0.3200<br>16 | 0.20554<br>0.4624<br>15 | 0.50898<br>0.0527<br>15 | 0.48392<br>0.0575<br>16 | 0.21064<br>0.4015<br>18 |
| 050B016 | 0.17835<br>0.4651<br>19 | 0.31215<br>0.1803<br>20 | 0.60925<br>0.0044<br>20 | 0.01805<br>0.9398<br>20 | 0.06102<br>0.8040<br>19 | -0.13407<br>0.6477<br>14 | 0.26061<br>0.4671<br>10 | 0.77500<br>0.0007<br>15 | 0.41512<br>0.0772<br>19 | 0.83984<br>0.0001<br>19 | 0.68333<br>0.0424<br>9 | 0.46252<br>0.0400<br>20 | 0.10491<br>0.6886<br>17 | 1.00000<br>0.0000<br>20 | 0.50909<br>0.1097<br>11 | 0.52243<br>0.0217<br>19 | 0.76058<br>0.0002<br>18 | 0.63208<br>0.0049<br>18 | 0.02900<br>0.9062<br>19 | 0.85145<br>0.0001<br>20 |
| 050B019 | 0.38357<br>0.2442<br>11 | 0.48182<br>0.1334<br>11 | 0.80909<br>0.0026<br>11 | 0.23636<br>0.4841<br>11 | 0.25057<br>0.4574<br>11 | 0.52727<br>0.1173<br>10 | 0.54286<br>0.2657<br>6 | 0.95152<br>0.0001<br>10 | 0.40285<br>0.2484<br>10 | 0.93636<br>0.0001<br>11 | 0.90476<br>0.0020<br>8 | 0.56364<br>0.0710<br>11 | 0.30000<br>0.3701<br>11 | 0.50909<br>0.1087<br>11 | 1.00000<br>0.0000<br>11 | 0.63636<br>0.0353<br>11 | 0.90303<br>0.0003<br>10 | 0.76596<br>0.0098<br>10 | 0.21866<br>0.5183<br>11 | 0.92727<br>0.0001<br>11 |
| 050B021 | 0.05315<br>0.8289<br>19 | 0.33231<br>0.1645<br>19 | 0.55736<br>0.0132<br>19 | -0.05714<br>0.8163<br>19 | 0.04398<br>0.8581<br>19 | -0.08801<br>0.7648<br>14 | 0.29787<br>0.4032<br>10 | 0.69534<br>0.0040<br>15 | 0.39817<br>0.1017<br>18 | 0.49319<br>0.0319<br>19 | 0.69048<br>0.0580<br>8 | 0.54073<br>0.0168<br>19 | 0.26568<br>0.3200<br>16 | 0.52243<br>0.0217<br>19 | 0.63636<br>0.0353<br>11 | 1.00000<br>0.0000<br>19 | 0.49250<br>0.0379<br>18 | 0.55203<br>0.0175<br>18 | 0.30611<br>0.2025<br>19 | 0.48000<br>0.0375<br>19 |
| 050B023 | 0.61315<br>0.0068<br>18 | 0.78535<br>0.0001<br>18 | 0.84314<br>0.0001<br>18 | 0.53767<br>0.0214<br>18 | 0.65738<br>0.0030<br>18 | 0.47692<br>0.0846<br>14 | 0.79394<br>0.0061<br>10 | 0.88571<br>0.0001<br>15 | 0.61747<br>0.0083<br>17 | 0.94840<br>0.0001<br>18 | 0.89286<br>0.0068<br>7 | 0.71665<br>0.0008<br>18 | 0.20554<br>0.4624<br>15 | 0.76058<br>0.0002<br>18 | 0.90303<br>0.0003<br>10 | 0.49250<br>0.0379<br>18 | 1.00000<br>0.0000<br>18 | 0.87184<br>0.0001<br>18 | 0.35251<br>0.1514<br>18 | 0.92776<br>0.0001<br>18 |
| 050B025 | 0.53521<br>0.0221<br>18 | 0.76805<br>0.0002<br>18 | 0.83966<br>0.0001<br>18 | 0.48989<br>0.0390<br>18 | 0.50338<br>0.0332<br>18 | 0.26872<br>0.3529<br>14 | 0.54104<br>0.1063<br>10 | 0.69776<br>0.0038<br>15 | 0.46124<br>0.0624<br>17 | 0.77116<br>0.0002<br>18 | 0.57660<br>0.1754<br>7 | 0.65939<br>0.0029<br>18 | 0.50898<br>0.0527<br>15 | 0.63208<br>0.0049<br>18 | 0.76596<br>0.0098<br>10 | 0.55203<br>0.0175<br>18 | 0.87184<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.23441<br>0.3491<br>18 | 0.76286<br>0.0002<br>18 |
| 050B031 | 0.17716<br>0.4681<br>19 | 0.24078<br>0.3207<br>19 | 0.20600<br>0.3975<br>19 | 0.15695<br>0.5211<br>19 | 0.36089<br>0.1290<br>19 | 0.11451<br>0.6967<br>14 | 0.43698<br>0.2067<br>10 | 0.34521<br>0.2076<br>15 | 0.65579<br>0.0031<br>18 | 0.27467<br>0.2551<br>19 | -0.09581<br>0.8215<br>8 | 0.69503<br>0.0010<br>19 | 0.48392<br>0.0575<br>16 | 0.02900<br>0.9062<br>19 | 0.21866<br>0.5183<br>11 | 0.30611<br>0.2025<br>19 | 0.35251<br>0.1514<br>18 | 0.23441<br>0.3491<br>18 | 1.00000<br>0.0000<br>19 | 0.25773<br>0.2868<br>19 |
| 050C004 | 0.42965<br>0.0664<br>19 | 0.59458<br>0.0035<br>22 | 0.71767<br>0.0002<br>22 | 0.39130<br>0.0717<br>22 | 0.37209<br>0.1167<br>19 | 0.17363<br>0.5528<br>14 | 0.60000<br>0.0667<br>10 | 0.98929<br>0.0001<br>15 | 0.52445<br>0.0147<br>21 | 0.99123<br>0.0001<br>19 | 0.97902<br>0.0001<br>12 | 0.65140<br>0.0010<br>22 | 0.21064<br>0.4015<br>18 | 0.85145<br>0.0001<br>20 | 0.92727<br>0.0001<br>11 | 0.48000<br>0.0375<br>19 | 0.92776<br>0.0001<br>18 | 0.76286<br>0.0002<br>18 | 0.25773<br>0.2868<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-11

## Pearson Correlation Coefficients* for Pembina River Basin July Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.48594<br>0.0349<br>19 | 0.77522<br>0.0001<br>19 | 0.13892<br>0.5706<br>19 | 0.25602<br>0.2901<br>19 | 0.00009<br>0.9998<br>14 | 0.29683<br>0.4049<br>10 | 0.73388<br>0.0018<br>15 | -0.14194<br>0.5742<br>18 | 0.77203<br>0.0001<br>19 | 0.33660<br>0.4149<br>8 | 0.40443<br>0.0859<br>19 | 0.07148<br>0.7925<br>16 | 0.71687<br>0.0006<br>19 | 0.89097<br>0.0002<br>11 | 0.72476<br>0.0004<br>19 | 0.78910<br>0.0001<br>18 | 0.30350<br>0.2208<br>18 | 0.00929<br>0.9699<br>19 | 0.70125<br>0.0008<br>19 |
| 050A006 | 0.48594<br>0.0349<br>19 | 1.00000<br>0.0000<br>22 | 0.86608<br>0.0001<br>22 | 0.82530<br>0.0001<br>22 | 0.87162<br>0.0001<br>19 | 0.75171<br>0.0019<br>14 | 0.98374<br>0.0001<br>10 | 0.42526<br>0.1140<br>15 | 0.09036<br>0.6969<br>21 | 0.44301<br>0.0575<br>19 | 0.87178<br>0.0005<br>11 | 0.20238<br>0.3664<br>22 | 0.15769<br>0.5320<br>18 | 0.41360<br>0.0699<br>20 | 0.36200<br>0.2740<br>11 | 0.07826<br>0.7501<br>19 | 0.66974<br>0.0024<br>18 | 0.86436<br>0.0001<br>18 | 0.02967<br>0.9040<br>19 | 0.36505<br>0.0948<br>22 |
| 050A007 | 0.77522<br>0.0001<br>19 | 0.86608<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.62766<br>0.0018<br>22 | 0.60625<br>0.0059<br>19 | 0.51623<br>0.0588<br>14 | 0.82878<br>0.0030<br>10 | 0.67189<br>0.0061<br>15 | 0.10798<br>0.6413<br>21 | 0.70580<br>0.0007<br>19 | 0.83325<br>0.0014<br>11 | 0.24494<br>0.2719<br>22 | 0.25939<br>0.2986<br>18 | 0.69585<br>0.0007<br>20 | 0.71810<br>0.0128<br>11 | 0.46828<br>0.0432<br>19 | 0.82650<br>0.0001<br>18 | 0.81243<br>0.0001<br>18 | -0.07424<br>0.7626<br>19 | 0.60384<br>0.0029<br>22 |
| 050A008 | 0.13892<br>0.5706<br>19 | 0.82530<br>0.0001<br>22 | 0.62766<br>0.0018<br>22 | 1.00000<br>0.0000<br>22 | 0.86150<br>0.0001<br>19 | 0.98239<br>0.0001<br>14 | 0.87486<br>0.0009<br>10 | 0.24812<br>0.3726<br>15 | 0.31225<br>0.1682<br>21 | 0.26570<br>0.2716<br>19 | 0.83767<br>0.0013<br>11 | 0.15584<br>0.4886<br>22 | 0.39805<br>0.1018<br>18 | 0.20433<br>0.3875<br>20 | 0.11775<br>0.7302<br>11 | 0.04771<br>0.8462<br>19 | 0.30271<br>0.2221<br>18 | 0.90324<br>0.0001<br>18 | -0.06905<br>0.7788<br>19 | 0.23658<br>0.2891<br>22 |
| 050A010 | 0.25602<br>0.2901<br>19 | 0.87162<br>0.0001<br>19 | 0.60625<br>0.0059<br>19 | 0.86150<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.85291<br>0.0001<br>14 | 0.94008<br>0.0001<br>10 | 0.22982<br>0.4099<br>15 | 0.06386<br>0.8013<br>18 | 0.24773<br>0.3065<br>19 | 0.84235<br>0.0087<br>8 | 0.21683<br>0.3726<br>19 | 0.07943<br>0.7700<br>16 | 0.08711<br>0.7229<br>19 | 0.17500<br>0.6068<br>11 | -0.07419<br>0.7628<br>19 | 0.43445<br>0.0716<br>18 | 0.73230<br>0.0005<br>18 | 0.08205<br>0.7384<br>19 | 0.14174<br>0.5627<br>19 |
| 050A012 | 0.00009<br>0.9998<br>14 | 0.75171<br>0.0019<br>14 | 0.51623<br>0.0588<br>14 | 0.98239<br>0.0001<br>14 | 0.85291<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.85384<br>0.0017<br>10 | 0.19920<br>0.4948<br>14 | 0.26695<br>0.3780<br>13 | 0.15900<br>0.5872<br>14 | 0.89531<br>0.0064<br>7 | -0.03695<br>0.9002<br>14 | 0.33109<br>0.2476<br>14 | 0.08798<br>0.7649<br>14 | 0.08575<br>0.8138<br>10 | 0.02903<br>0.9215<br>14 | 0.22292<br>0.4437<br>14 | 0.86722<br>0.0001<br>14 | -0.18264<br>0.5320<br>14 | 0.07955<br>0.7869<br>14 |
| 050A013 | 0.29683<br>0.4049<br>10 | 0.98374<br>0.0001<br>10 | 0.82878<br>0.0030<br>10 | 0.87486<br>0.0009<br>10 | 0.94008<br>0.0001<br>10 | 0.85384<br>0.0017<br>10 | 1.00000<br>0.0000<br>10 | 0.33952<br>0.3372<br>10 | 0.07730<br>0.8319<br>10 | 0.31945<br>0.3683<br>10 | 0.99044<br>0.0881<br>3 | 0.14299<br>0.6935<br>10 | 0.13742<br>0.7050<br>10 | 0.29833<br>0.4025<br>10 | 0.24430<br>0.6408<br>6 | 0.03781<br>0.9174<br>10 | 0.57456<br>0.0823<br>10 | 0.93423<br>0.0001<br>10 | 0.30625<br>0.3895<br>10 | 0.17291<br>0.6329<br>10 |
| 050B001 | 0.73388<br>0.0018<br>15 | 0.42526<br>0.1140<br>15 | 0.67189<br>0.0061<br>15 | 0.24812<br>0.3726<br>15 | 0.22982<br>0.4099<br>15 | 0.19920<br>0.4948<br>14 | 0.33952<br>0.3372<br>10 | 1.00000<br>0.0000<br>15 | -0.09678<br>0.7421<br>14 | 0.99079<br>0.0001<br>15 | 0.97705<br>0.0002<br>7 | 0.24704<br>0.3747<br>15 | 0.12912<br>0.6465<br>15 | 0.85451<br>0.0001<br>15 | 0.93850<br>0.0001<br>10 | 0.75027<br>0.0013<br>15 | 0.83377<br>0.0001<br>15 | 0.39692<br>0.1430<br>15 | -0.13443<br>0.6329<br>15 | 0.96935<br>0.0001<br>15 |
| 050B006 | -0.14194<br>0.5742<br>18 | 0.09036<br>0.6969<br>21 | 0.10798<br>0.6413<br>21 | 0.31225<br>0.1682<br>21 | 0.06386<br>0.8013<br>18 | 0.26695<br>0.3780<br>13 | 0.07730<br>0.8319<br>10 | -0.09678<br>0.7421<br>14 | 1.00000<br>0.0000<br>21 | -0.09010<br>0.7222<br>18 | 0.20584<br>0.5683<br>10 | -0.00429<br>0.9853<br>21 | 0.94143<br>0.0001<br>17 | -0.04797<br>0.8454<br>19 | -0.25068<br>0.4848<br>10 | 0.00034<br>0.9989<br>18 | -0.16205<br>0.5344<br>17 | 0.34264<br>0.1782<br>17 | -0.14841<br>0.5567<br>18 | -0.06085<br>0.7933<br>21 |
| 050B007 | 0.77203<br>0.0001<br>19 | 0.44301<br>0.0575<br>19 | 0.70580<br>0.0007<br>19 | 0.26570<br>0.2716<br>19 | 0.24773<br>0.3065<br>19 | 0.15900<br>0.5872<br>14 | 0.31945<br>0.3683<br>10 | 0.99079<br>0.0001<br>15 | -0.09010<br>0.7222<br>18 | 1.00000<br>0.0000<br>19 | 0.99606<br>0.0001<br>8 | 0.26596<br>0.2711<br>19 | 0.16145<br>0.5503<br>16 | 0.87669<br>0.0001<br>19 | 0.95795<br>0.0001<br>11 | 0.76016<br>0.0002<br>19 | 0.83891<br>0.0001<br>18 | 0.41140<br>0.0899<br>18 | -0.13364<br>0.5855<br>19 | 0.97707<br>0.0001<br>19 |
| 050B008 | 0.33660<br>0.4149<br>8 | 0.87178<br>0.0005<br>11 | 0.83325<br>0.0014<br>11 | 0.83767<br>0.0013<br>11 | 0.84235<br>0.0087<br>8 | 0.89531<br>0.0064<br>7 | 0.99044<br>0.0881<br>3 | 0.97705<br>0.0002<br>7 | 0.20584<br>0.5683<br>10 | 0.99606<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.33853<br>0.3085<br>11 | 0.27530<br>0.4414<br>10 | 0.66799<br>0.0493<br>9 | 0.67607<br>0.0657<br>8 | 0.90393<br>0.0021<br>8 | 0.87902<br>0.0092<br>7 | 0.85671<br>0.0138<br>7 | 0.03169<br>0.9406<br>8 | 0.98076<br>0.0001<br>12 |
| 050B010 | 0.40443<br>0.0859<br>19 | 0.20238<br>0.3664<br>22 | 0.24494<br>0.2719<br>22 | 0.15584<br>0.4886<br>22 | 0.21683<br>0.3726<br>19 | -0.03695<br>0.9002<br>14 | 0.14299<br>0.6935<br>10 | 0.24704<br>0.3747<br>15 | -0.00429<br>0.9853<br>21 | 0.26596<br>0.2711<br>19 | 0.33853<br>0.3085<br>11 | 1.00000<br>0.0000<br>22 | 0.10458<br>0.6796<br>18 | 0.07363<br>0.7577<br>20 | 0.15647<br>0.6459<br>11 | 0.31523<br>0.1886<br>19 | 0.09441<br>0.7094<br>18 | 0.04594<br>0.8564<br>18 | 0.81356<br>0.0001<br>19 | 0.31178<br>0.1578<br>22 |
| 050B013 | 0.07148<br>0.7925<br>16 | 0.15769<br>0.5320<br>18 | 0.25939<br>0.2986<br>18 | 0.39805<br>0.1018<br>18 | 0.07943<br>0.7700<br>16 | 0.33109<br>0.2476<br>14 | 0.13742<br>0.7050<br>10 | 0.12912<br>0.6465<br>15 | 0.94143<br>0.0001<br>17 | 0.16145<br>0.5503<br>16 | 0.27530<br>0.4414<br>10 | 0.10458<br>0.6796<br>18 | 1.00000<br>0.0000<br>18 | 0.14904<br>0.5681<br>17 | 0.04111<br>0.9045<br>11 | 0.32207<br>0.2238<br>16 | -0.00497<br>0.9860<br>15 | 0.44813<br>0.0939<br>15 | -0.18548<br>0.4916<br>16 | 0.16576<br>0.5110<br>18 |
| 050B016 | 0.71687<br>0.0006<br>19 | 0.41360<br>0.0699<br>20 | 0.69585<br>0.0007<br>20 | 0.20433<br>0.3875<br>20 | 0.08711<br>0.7229<br>19 | 0.08798<br>0.7649<br>14 | 0.29833<br>0.4025<br>10 | 0.85451<br>0.0001<br>15 | -0.04797<br>0.8454<br>19 | 0.87669<br>0.0001<br>19 | 0.66799<br>0.0493<br>9 | 0.07363<br>0.7577<br>20 | 0.14904<br>0.5681<br>17 | 1.00000<br>0.0000<br>20 | 0.83750<br>0.0013<br>11 | 0.72237<br>0.0005<br>19 | 0.71522<br>0.0008<br>18 | 0.39799<br>0.1019<br>18 | -0.28766<br>0.2324<br>19 | 0.87724<br>0.0001<br>20 |
| 050B019 | 0.89097<br>0.0002<br>11 | 0.36200<br>0.2740<br>11 | 0.71810<br>0.0128<br>11 | 0.11775<br>0.7302<br>11 | 0.17500<br>0.6068<br>11 | 0.08575<br>0.8138<br>10 | 0.24430<br>0.6408<br>6 | 0.93850<br>0.0001<br>10 | -0.25068<br>0.4848<br>10 | 0.95795<br>0.0001<br>11 | 0.67607<br>0.0657<br>8 | 0.15647<br>0.6459<br>11 | 0.04111<br>0.9045<br>11 | 0.83750<br>0.0013<br>11 | 1.00000<br>0.0000<br>11 | 0.84985<br>0.0009<br>11 | 0.86996<br>0.0011<br>10 | 0.28765<br>0.4203<br>10 | -0.29867<br>0.3723<br>11 | 0.92709<br>0.0001<br>11 |
| 050B021 | 0.72476<br>0.0004<br>19 | 0.07826<br>0.7501<br>19 | 0.46828<br>0.0432<br>19 | 0.04771<br>0.8462<br>19 | -0.07419<br>0.7628<br>19 | 0.02903<br>0.9215<br>14 | 0.03781<br>0.9174<br>10 | 0.75027<br>0.0013<br>15 | 0.00034<br>0.9989<br>18 | 0.76016<br>0.0002<br>19 | 0.90393<br>0.0021<br>8 | 0.31523<br>0.1886<br>19 | 0.32207<br>0.2238<br>16 | 0.72237<br>0.0005<br>19 | 0.84985<br>0.0009<br>11 | 1.00000<br>0.0000<br>19 | 0.46954<br>0.0493<br>18 | 0.15297<br>0.5445<br>18 | -0.14141<br>0.5636<br>19 | 0.77067<br>0.0001<br>19 |
| 050B023 | 0.78910<br>0.0001<br>18 | 0.66974<br>0.0024<br>18 | 0.82650<br>0.0001<br>18 | 0.30271<br>0.2221<br>18 | 0.43445<br>0.0716<br>18 | 0.22292<br>0.4437<br>14 | 0.57456<br>0.0823<br>10 | 0.83377<br>0.0001<br>15 | -0.16205<br>0.5344<br>17 | 0.83891<br>0.0001<br>18 | 0.87902<br>0.0092<br>7 | 0.09441<br>0.7094<br>18 | -0.00497<br>0.9860<br>15 | 0.71522<br>0.0008<br>18 | 0.86996<br>0.0011<br>10 | 0.46954<br>0.0493<br>18 | 1.00000<br>0.0000<br>18 | 0.51362<br>0.0292<br>18 | -0.14689<br>0.5608<br>18 | 0.73105<br>0.0006<br>18 |
| 050B025 | 0.30350<br>0.2208<br>18 | 0.86436<br>0.0001<br>18 | 0.81243<br>0.0001<br>18 | 0.90324<br>0.0001<br>18 | 0.73230<br>0.0005<br>18 | 0.86722<br>0.0001<br>14 | 0.93423<br>0.0001<br>10 | 0.39692<br>0.1430<br>15 | 0.34264<br>0.1782<br>17 | 0.41140<br>0.0899<br>18 | 0.85671<br>0.0138<br>7 | 0.04594<br>0.8564<br>18 | 0.44813<br>0.0939<br>15 | 0.39799<br>0.1019<br>18 | 0.28765<br>0.4203<br>10 | 0.15297<br>0.5445<br>18 | 0.51362<br>0.0292<br>18 | 1.00000<br>0.0000<br>18 | -0.14751<br>0.5591<br>18 | 0.31345<br>0.2053<br>18 |
| 050B031 | 0.00929<br>0.9699<br>19 | 0.02967<br>0.9040<br>19 | -0.07424<br>0.7626<br>19 | -0.06905<br>0.7788<br>19 | 0.08205<br>0.7384<br>19 | -0.18264<br>0.5320<br>14 | 0.30625<br>0.3895<br>10 | -0.13443<br>0.6329<br>15 | -0.14841<br>0.5567<br>18 | -0.13364<br>0.5855<br>19 | 0.03169<br>0.9406<br>8 | 0.81356<br>0.0001<br>19 | -0.18548<br>0.4916<br>16 | -0.28766<br>0.2324<br>19 | -0.29867<br>0.3723<br>11 | -0.14141<br>0.5636<br>19 | -0.14689<br>0.5608<br>18 | -0.14751<br>0.5591<br>18 | 1.00000<br>0.0000<br>19 | -0.10443<br>0.6705<br>19 |
| 050C004 | 0.70125<br>0.0008<br>19 | 0.36505<br>0.0948<br>22 | 0.60384<br>0.0029<br>22 | 0.23658<br>0.2891<br>22 | 0.14174<br>0.5627<br>19 | 0.07955<br>0.7869<br>14 | 0.17291<br>0.6329<br>10 | 0.96935<br>0.0001<br>15 | -0.06085<br>0.7933<br>21 | 0.97707<br>0.0001<br>19 | 0.98076<br>0.0001<br>12 | 0.31178<br>0.1578<br>22 | 0.16576<br>0.5110<br>18 | 0.87724<br>0.0001<br>20 | 0.92709<br>0.0001<br>11 | 0.77067<br>0.0001<br>19 | 0.73105<br>0.0006<br>18 | 0.31345<br>0.2053<br>18 | -0.10443<br>0.6705<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-12

## Spearman Correlation Coefficients* for Pembina River Basin July Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.84461<br>0.0001<br>19 | 0.68738<br>0.0011<br>19 | 0.73058<br>0.0004<br>19 | 0.76680<br>0.0001<br>19 | 0.59700<br>0.0242<br>14 | 0.66282<br>0.0367<br>10 | 0.51689<br>0.0485<br>15 | -0.17665<br>0.4832<br>18 | 0.48874<br>0.0337<br>19 | 0.60882<br>0.1092<br>8 | 0.14893<br>0.5429<br>19 | 0.04616<br>0.8652<br>16 | 0.25307<br>0.2959<br>19 | 0.64669<br>0.0315<br>11 | 0.13065<br>0.5940<br>19 | 0.64425<br>0.0039<br>18 | 0.37845<br>0.1215<br>18 | 0.27189<br>0.2601<br>19 | 0.41661<br>0.0760<br>19 |
| 050A006 | 0.84461<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.77687<br>0.0001<br>22 | 0.86974<br>0.0001<br>22 | 0.82281<br>0.0001<br>19 | 0.83828<br>0.0002<br>14 | 0.90303<br>0.0003<br>10 | 0.61429<br>0.0148<br>15 | 0.06552<br>0.7778<br>21 | 0.60000<br>0.0066<br>19 | 0.80909<br>0.0026<br>11 | 0.24805<br>0.2657<br>22 | 0.06715<br>0.7912<br>18 | 0.35620<br>0.1232<br>20 | 0.58182<br>0.0604<br>11 | 0.10754<br>0.6612<br>19 | 0.71311<br>0.0009<br>18 | 0.42633<br>0.0777<br>18 | 0.27450<br>0.2554<br>19 | 0.61226<br>0.0025<br>22 |
| 050A007 | 0.68738<br>0.0011<br>19 | 0.77687<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.68600<br>0.0004<br>22 | 0.73804<br>0.0003<br>19 | 0.52974<br>0.0514<br>14 | 0.71125<br>0.0211<br>10 | 0.74173<br>0.0015<br>15 | 0.22218<br>0.3331<br>21 | 0.70118<br>0.0008<br>19 | 0.74315<br>0.0088<br>11 | 0.34917<br>0.1112<br>22 | 0.03727<br>0.8833<br>18 | 0.51898<br>0.0190<br>20 | 0.66971<br>0.0242<br>11 | 0.50618<br>0.0270<br>19 | 0.73516<br>0.0005<br>18 | 0.39677<br>0.1031<br>18 | 0.40265<br>0.0874<br>19 | 0.68985<br>0.0004<br>22 |
| 050A008 | 0.73058<br>0.0004<br>19 | 0.86974<br>0.0001<br>22 | 0.68600<br>0.0004<br>22 | 1.00000<br>0.0000<br>22 | 0.91531<br>0.0001<br>19 | 0.93289<br>0.0001<br>14 | 0.92727<br>0.0001<br>10 | 0.28571<br>0.3019<br>15 | 0.04692<br>0.8399<br>21 | 0.34050<br>0.1537<br>19 | 0.72727<br>0.0112<br>11 | 0.15258<br>0.4978<br>22 | 0.02687<br>0.9157<br>18 | 0.16452<br>0.4882<br>20 | 0.50570<br>0.1125<br>11 | -0.07143<br>0.7714<br>19 | 0.50464<br>0.0327<br>18 | 0.34340<br>0.1630<br>18 | 0.11226<br>0.6473<br>19 | 0.43051<br>0.0455<br>22 |
| 050A010 | 0.76680<br>0.0001<br>19 | 0.82281<br>0.0001<br>19 | 0.73804<br>0.0003<br>19 | 0.91531<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.93509<br>0.0001<br>14 | 0.90303<br>0.0003<br>10 | 0.41786<br>0.1212<br>15 | -0.09200<br>0.7166<br>18 | 0.42807<br>0.0675<br>19 | 0.73810<br>0.0366<br>8 | 0.17820<br>0.4655<br>19 | 0.01620<br>0.9525<br>16 | 0.09692<br>0.6931<br>19 | 0.45455<br>0.1601<br>11 | 0.08991<br>0.7143<br>19 | 0.56514<br>0.0107<br>18 | 0.27536<br>0.2688<br>18 | 0.31901<br>0.1831<br>19 | 0.35439<br>0.1366<br>19 |
| 050A012 | 0.59700<br>0.0242<br>14 | 0.83828<br>0.0002<br>14 | 0.52974<br>0.0514<br>14 | 0.93289<br>0.0001<br>14 | 0.93509<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.94833<br>0.0001<br>10 | 0.33443<br>0.2425<br>14 | -0.25721<br>0.3963<br>13 | 0.35424<br>0.2140<br>14 | 0.57143<br>0.1802<br>7 | -0.09226<br>0.7838<br>14 | -0.04626<br>0.8752<br>14 | -0.10121<br>0.7306<br>14 | 0.56364<br>0.0897<br>10 | 0.19801<br>0.4974<br>14 | 0.55006<br>0.0416<br>14 | 0.40305<br>0.1530<br>14 | 0.16212<br>0.5798<br>14 | 0.23762<br>0.4133<br>14 |
| 050A013 | 0.66282<br>0.0367<br>10 | 0.90303<br>0.0003<br>10 | 0.71125<br>0.0211<br>10 | 0.92727<br>0.0001<br>10 | 0.90303<br>0.0003<br>10 | 0.94833<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.44242<br>0.2004<br>10 | -0.20042<br>0.5788<br>10 | 0.36970<br>0.2931<br>10 | 1.00000<br>0.0000<br>3 | -0.01251<br>0.9726<br>10 | -0.01216<br>0.9734<br>10 | 0.03030<br>0.9338<br>10 | 0.60000<br>0.2080<br>6 | 0.25234<br>0.4818<br>10 | 0.58788<br>0.0739<br>10 | 0.37426<br>0.2867<br>10 | 0.54623<br>0.1023<br>10 | 0.32121<br>0.3655<br>10 |
| 050B001 | 0.51689<br>0.0485<br>15 | 0.61429<br>0.0148<br>15 | 0.74173<br>0.0015<br>15 | 0.28571<br>0.3019<br>15 | 0.41786<br>0.1212<br>15 | 0.33443<br>0.2425<br>14 | 0.44242<br>0.2004<br>10 | 1.00000<br>0.0000<br>15 | 0.40213<br>0.1540<br>14 | 0.98929<br>0.0001<br>15 | 0.96429<br>0.0005<br>7 | 0.25635<br>0.3564<br>15 | -0.10555<br>0.7081<br>15 | 0.73280<br>0.0019<br>15 | 0.79394<br>0.0061<br>10 | 0.60959<br>0.0158<br>15 | 0.86071<br>0.0001<br>15 | 0.70775<br>0.0032<br>15 | 0.32733<br>0.2337<br>15 | 0.95357<br>0.0001<br>15 |
| 050B006 | -0.17665<br>0.4832<br>18 | 0.06552<br>0.7778<br>21 | 0.22218<br>0.3331<br>21 | 0.04692<br>0.8399<br>21 | -0.09200<br>0.7166<br>18 | -0.25721<br>0.3963<br>13 | -0.20042<br>0.5788<br>10 | 0.40213<br>0.1540<br>14 | 1.00000<br>0.0000<br>21 | 0.25555<br>0.3061<br>18 | 0.23116<br>0.5205<br>10 | 0.60856<br>0.0034<br>21 | 0.63224<br>0.0065<br>17 | 0.38899<br>0.0998<br>19 | -0.03414<br>0.9254<br>10 | 0.28900<br>0.2448<br>18 | 0.16889<br>0.5170<br>17 | 0.50106<br>0.0405<br>17 | 0.18322<br>0.4668<br>18 | 0.37515<br>0.0938<br>21 |
| 050B007 | 0.48874<br>0.0337<br>19 | 0.60000<br>0.0066<br>19 | 0.70118<br>0.0008<br>19 | 0.34050<br>0.1537<br>19 | 0.42807<br>0.0675<br>19 | 0.35424<br>0.2140<br>14 | 0.36970<br>0.2931<br>10 | 0.98929<br>0.0001<br>15 | 0.25555<br>0.3061<br>18 | 1.00000<br>0.0000<br>19 | 0.92857<br>0.0009<br>8 | 0.18889<br>0.4387<br>19 | -0.17673<br>0.5126<br>16 | 0.78503<br>0.0001<br>19 | 0.75455<br>0.0073<br>11 | 0.49185<br>0.0324<br>19 | 0.85552<br>0.0001<br>18 | 0.59006<br>0.0099<br>18 | 0.13910<br>0.5701<br>19 | 0.96667<br>0.0001<br>19 |
| 050B008 | 0.60882<br>0.1092<br>8 | 0.80909<br>0.0026<br>11 | 0.74315<br>0.0088<br>11 | 0.72727<br>0.0112<br>11 | 0.73810<br>0.0366<br>8 | 0.57143<br>0.1802<br>7 | 1.00000<br>0.0000<br>3 | 0.96429<br>0.0005<br>7 | 0.23116<br>0.5205<br>10 | 0.92857<br>0.0009<br>8 | 1.00000<br>0.0000<br>12 | 0.27915<br>0.4058<br>11 | -0.18788<br>0.6032<br>10 | 0.56904<br>0.1098<br>9 | 0.28571<br>0.4927<br>8 | 0.47619<br>0.2329<br>8 | 0.57143<br>0.1802<br>7 | 0.47287<br>0.2839<br>7 | 0.46355<br>0.2473<br>8 | 0.96503<br>0.0001<br>12 |
| 050B010 | 0.14893<br>0.5429<br>19 | 0.24805<br>0.2657<br>22 | 0.34917<br>0.1112<br>22 | 0.15258<br>0.4979<br>22 | 0.17820<br>0.4655<br>19 | -0.09226<br>0.7538<br>14 | -0.01251<br>0.9726<br>10 | 0.25635<br>0.3564<br>15 | 0.60956<br>0.0034<br>21 | 0.18889<br>0.4387<br>19 | 0.27915<br>0.4058<br>11 | 1.00000<br>0.0000<br>22 | 0.61237<br>0.0069<br>18 | 0.09134<br>0.7017<br>20 | 0.03670<br>0.9147<br>11 | 0.17056<br>0.4851<br>19 | 0.18605<br>0.4598<br>18 | 0.10937<br>0.6657<br>18 | 0.70456<br>0.0008<br>19 | 0.23496<br>0.2926<br>22 |
| 050B013 | 0.04616<br>0.8652<br>16 | 0.06715<br>0.7912<br>18 | 0.03727<br>0.8833<br>18 | 0.02687<br>0.9157<br>18 | 0.01620<br>0.9525<br>16 | -0.04626<br>0.8752<br>14 | -0.01216<br>0.9734<br>10 | -0.10555<br>0.7081<br>15 | 0.63224<br>0.0065<br>17 | -0.17673<br>0.5126<br>16 | -0.18788<br>0.6032<br>10 | 0.61237<br>0.0069<br>18 | 1.00000<br>0.0000<br>18 | -0.17901<br>0.4918<br>17 | -0.02727<br>0.9366<br>11 | 0.01782<br>0.9478<br>16 | -0.00537<br>0.9849<br>15 | 0.22251<br>0.4254<br>15 | 0.30912<br>0.2440<br>16 | -0.16426<br>0.5149<br>18 |
| 050B016 | 0.25307<br>0.2959<br>19 | 0.35620<br>0.1232<br>20 | 0.51898<br>0.0190<br>20 | 0.16452<br>0.4882<br>20 | 0.09692<br>0.6931<br>19 | -0.10121<br>0.7306<br>14 | 0.03030<br>0.9338<br>10 | 0.73280<br>0.0019<br>15 | 0.38899<br>0.0998<br>19 | 0.78503<br>0.0001<br>19 | 0.56904<br>0.1098<br>9 | 0.09134<br>0.7017<br>20 | -0.17901<br>0.4918<br>17 | 1.00000<br>0.0000<br>20 | 0.29091<br>0.3855<br>11 | 0.57193<br>0.0105<br>19 | 0.51396<br>0.0291<br>18 | 0.57210<br>0.0131<br>18 | -0.06148<br>0.8026<br>19 | 0.83942<br>0.0001<br>20 |
| 050B019 | 0.64669<br>0.0315<br>11 | 0.58182<br>0.0604<br>11 | 0.66971<br>0.0242<br>11 | 0.50570<br>0.1125<br>11 | 0.45455<br>0.1601<br>11 | 0.56364<br>0.0897<br>10 | 0.60000<br>0.2080<br>6 | 0.79394<br>0.0061<br>10 | -0.03414<br>0.9254<br>10 | 0.75455<br>0.0073<br>11 | 0.28571<br>0.4927<br>8 | 0.03670<br>0.9147<br>11 | -0.02727<br>0.9366<br>11 | 0.29091<br>0.3855<br>11 | 1.00000<br>0.0000<br>11 | 0.51025<br>0.1088<br>11 | 0.93939<br>0.0001<br>11 | 0.58779<br>0.0739<br>10 | 0.12562<br>0.7129<br>11 | 0.73636<br>0.0098<br>11 |
| 050B021 | 0.13065<br>0.5940<br>19 | 0.10754<br>0.6612<br>19 | 0.50618<br>0.0270<br>19 | -0.07143<br>0.7714<br>19 | 0.08991<br>0.7143<br>19 | 0.19801<br>0.4974<br>14 | 0.25234<br>0.4818<br>10 | 0.60959<br>0.0158<br>15 | 0.28900<br>0.2448<br>18 | 0.49185<br>0.0324<br>19 | 0.47619<br>0.2329<br>8 | 0.17056<br>0.4851<br>19 | 0.01782<br>0.9478<br>16 | 0.57193<br>0.0105<br>19 | 0.51025<br>0.1088<br>11 | 1.00000<br>0.0000<br>19 | 0.35289<br>0.1509<br>18 | 0.47154<br>0.0482<br>18 | 0.24508<br>0.3119<br>19 | 0.57559<br>0.0099<br>19 |
| 050B023 | 0.64425<br>0.0039<br>18 | 0.71311<br>0.0009<br>18 | 0.73516<br>0.0005<br>18 | 0.50464<br>0.0327<br>18 | 0.58514<br>0.0107<br>18 | 0.55006<br>0.0416<br>14 | 0.58788<br>0.0739<br>10 | 0.86071<br>0.0001<br>15 | 0.16889<br>0.5170<br>17 | 0.85552<br>0.0001<br>18 | 0.57143<br>0.1802<br>7 | 0.18605<br>0.4598<br>18 | -0.00537<br>0.9849<br>15 | 0.51396<br>0.0291<br>18 | 0.93939<br>0.0001<br>10 | 0.35289<br>0.1509<br>18 | 1.00000<br>0.0000<br>18 | 0.58368<br>0.0110<br>18 | 0.20838<br>0.4067<br>18 | 0.78947<br>0.0001<br>18 |
| 050B025 | 0.37845<br>0.1215<br>18 | 0.42633<br>0.0777<br>18 | 0.39677<br>0.1031<br>18 | 0.34340<br>0.1630<br>18 | 0.27536<br>0.2688<br>18 | 0.40305<br>0.1530<br>14 | 0.37426<br>0.2867<br>10 | 0.70775<br>0.0032<br>15 | 0.50106<br>0.0405<br>17 | 0.59006<br>0.0099<br>18 | 0.47287<br>0.2839<br>7 | 0.10937<br>0.6657<br>18 | 0.22251<br>0.4254<br>15 | 0.57210<br>0.0131<br>18 | 0.58779<br>0.0739<br>10 | 0.47154<br>0.0482<br>18 | 0.58368<br>0.0110<br>18 | 1.00000<br>0.0000<br>18 | 0.06929<br>0.7847<br>18 | 0.53903<br>0.0210<br>18 |
| 050B031 | 0.27189<br>0.2601<br>19 | 0.27450<br>0.2554<br>19 | 0.40265<br>0.0874<br>19 | 0.11226<br>0.6473<br>19 | 0.31901<br>0.1831<br>19 | 0.16212<br>0.5798<br>14 | 0.54623<br>0.1023<br>10 | 0.32733<br>0.2337<br>15 | 0.18322<br>0.4668<br>18 | 0.13910<br>0.5701<br>19 | 0.46355<br>0.2473<br>8 | 0.70456<br>0.0008<br>19 | 0.30912<br>0.2440<br>16 | -0.06148<br>0.8026<br>19 | 0.12562<br>0.7129<br>11 | 0.24508<br>0.3119<br>19 | 0.20838<br>0.4067<br>18 | 0.06929<br>0.7847<br>18 | 1.00000<br>0.0000<br>19 | 0.15394<br>0.5292<br>19 |
| 050C004 | 0.41661<br>0.0760<br>19 | 0.61226<br>0.0025<br>22 | 0.68985<br>0.0004<br>22 | 0.43051<br>0.0455<br>22 | 0.35439<br>0.1366<br>19 | 0.23762<br>0.4133<br>14 | 0.32121<br>0.3655<br>10 | 0.95357<br>0.0001<br>15 | 0.37515<br>0.0938<br>21 | 0.96667<br>0.0001<br>19 | 0.96503<br>0.0001<br>12 | 0.23496<br>0.2926<br>22 | -0.16426<br>0.5149<br>18 | 0.83942<br>0.0001<br>20 | 0.73636<br>0.0098<br>11 | 0.57559<br>0.0099<br>19 | 0.78947<br>0.0001<br>18 | 0.53903<br>0.0210<br>18 | 0.15394<br>0.5292<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-13

## Pearson Correlation Coefficients* for Pembina River Basin August Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.52403<br>0.0213<br>19 | 0.90499<br>0.0001<br>19 | 0.80606<br>0.0001<br>19 | 0.31451<br>0.1897<br>19 | 0.21268<br>0.4654<br>14 | 0.72429<br>0.0178<br>10 | 0.13058<br>0.6427<br>15 | 0.99690<br>0.0001<br>18 | 0.11390<br>0.6424<br>19 | 0.29835<br>0.4729<br>8 | 0.52833<br>0.0201<br>19 | 0.99773<br>0.0001<br>16 | 0.47969<br>0.0377<br>19 | -0.16509<br>0.6486<br>10 | -0.11505<br>0.6391<br>19 | 0.53730<br>0.0215<br>18 | 0.99595<br>0.0001<br>18 | 0.37162<br>0.1172<br>19 | 0.12982<br>0.5963<br>19 |
| 050A006 | 0.52403<br>0.0213<br>19 | 1.00000<br>0.0000<br>22 | 0.61804<br>0.0022<br>22 | 0.65835<br>0.0009<br>22 | 0.81853<br>0.0001<br>19 | 0.65970<br>0.0103<br>14 | 0.97177<br>0.0001<br>10 | 0.22254<br>0.4253<br>15 | 0.52394<br>0.0148<br>21 | 0.18951<br>0.4371<br>19 | 0.28695<br>0.3922<br>11 | 0.37614<br>0.0845<br>22 | 0.52792<br>0.0243<br>18 | 0.05274<br>0.8252<br>20 | -0.21810<br>0.5450<br>10 | -0.28179<br>0.2425<br>19 | 0.50621<br>0.0321<br>18 | 0.58589<br>0.0106<br>18 | 0.23487<br>0.3331<br>19 | 0.14880<br>0.5087<br>22 |
| 050A007 | 0.90499<br>0.0001<br>19 | 0.61804<br>0.0022<br>22 | 1.00000<br>0.0000<br>22 | 0.64646<br>0.0012<br>22 | 0.29415<br>0.2216<br>19 | 0.16067<br>0.5832<br>14 | 0.68416<br>0.0291<br>10 | 0.35416<br>0.1953<br>15 | 0.87993<br>0.0001<br>21 | 0.36669<br>0.1225<br>19 | 0.37714<br>0.2529<br>11 | 0.47061<br>0.0271<br>22 | 0.88630<br>0.0001<br>18 | 0.57370<br>0.0082<br>20 | 0.06234<br>0.8642<br>10 | -0.07987<br>0.7452<br>19 | 0.74005<br>0.0004<br>18 | 0.89329<br>0.0001<br>18 | 0.33370<br>0.1626<br>19 | 0.39945<br>0.0655<br>22 |
| 050A008 | 0.80606<br>0.0001<br>19 | 0.65835<br>0.0009<br>22 | 0.64646<br>0.0012<br>22 | 1.00000<br>0.0000<br>22 | 0.37271<br>0.1161<br>19 | 0.37189<br>0.1904<br>14 | 0.70695<br>0.0222<br>10 | 0.01961<br>0.9447<br>15 | 0.71694<br>0.0003<br>21 | -0.01959<br>0.9365<br>19 | 0.17939<br>0.5976<br>11 | 0.31830<br>0.1488<br>22 | 0.82078<br>0.0001<br>18 | 0.27399<br>0.2424<br>20 | -0.28807<br>0.4196<br>10 | -0.15682<br>0.5214<br>19 | 0.46350<br>0.0527<br>18 | 0.81047<br>0.0001<br>18 | 0.26565<br>0.2717<br>19 | -0.07314<br>0.7463<br>22 |
| 050A010 | 0.31451<br>0.1897<br>19 | 0.81853<br>0.0001<br>19 | 0.29415<br>0.2216<br>19 | 0.37271<br>0.1161<br>19 | 1.00000<br>0.0000<br>19 | 0.94654<br>0.0001<br>14 | 0.86983<br>0.0011<br>10 | 0.24701<br>0.3748<br>15 | 0.33570<br>0.1732<br>18 | 0.14174<br>0.5627<br>19 | 0.28159<br>0.4993<br>8 | 0.24027<br>0.3218<br>19 | 0.31723<br>0.2312<br>16 | -0.14358<br>0.5576<br>19 | -0.18576<br>0.6074<br>10 | -0.27085<br>0.2620<br>19 | 0.33023<br>0.1808<br>18 | 0.43991<br>0.0677<br>18 | 0.04223<br>0.8637<br>19 | 0.08731<br>0.7223<br>19 |
| 050A012 | 0.21268<br>0.4654<br>14 | 0.65970<br>0.0103<br>14 | 0.16067<br>0.5832<br>14 | 0.37189<br>0.1904<br>14 | 0.94654<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.74682<br>0.0131<br>10 | 0.20123<br>0.4903<br>14 | 0.21584<br>0.4788<br>13 | 0.10809<br>0.7130<br>14 | 0.40060<br>0.3732<br>7 | 0.00552<br>0.9851<br>14 | 0.22086<br>0.4480<br>14 | -0.19152<br>0.5119<br>14 | -0.28663<br>0.4546<br>9 | -0.21762<br>0.4548<br>14 | 0.16711<br>0.5680<br>14 | 0.26715<br>0.3558<br>14 | -0.05196<br>0.8600<br>14 | 0.06380<br>0.8285<br>14 |
| 050A013 | 0.72429<br>0.0178<br>10 | 0.97177<br>0.0001<br>10 | 0.68416<br>0.0291<br>10 | 0.70695<br>0.0222<br>10 | 0.86983<br>0.0011<br>10 | 0.74682<br>0.0131<br>10 | 1.00000<br>0.0000<br>10 | 0.20958<br>0.5612<br>10 | 0.73385<br>0.0157<br>10 | 0.08181<br>0.8222<br>10 | 0.55772<br>0.6234<br>3 | 0.73649<br>0.0151<br>10 | 0.73882<br>0.0146<br>10 | 0.05353<br>0.8832<br>10 | -0.36296<br>0.5482<br>5 | -0.12272<br>0.7356<br>10 | 0.50605<br>0.1356<br>10 | 0.76291<br>0.0103<br>10 | 0.73318<br>0.0158<br>10 | 0.06103<br>0.8670<br>10 |
| 050B001 | 0.13058<br>0.6427<br>15 | 0.22254<br>0.4253<br>15 | 0.35416<br>0.1953<br>15 | 0.01961<br>0.9447<br>15 | 0.24701<br>0.3748<br>15 | 0.20123<br>0.4903<br>14 | 0.20958<br>0.5612<br>10 | 1.00000<br>0.0000<br>15 | 0.10160<br>0.7296<br>14 | 0.97801<br>0.0001<br>15 | 0.99515<br>0.0001<br>7 | 0.12328<br>0.6616<br>15 | 0.11274<br>0.6891<br>15 | 0.43683<br>0.1035<br>15 | 0.90302<br>0.0008<br>9 | 0.29844<br>0.2799<br>15 | 0.80916<br>0.0003<br>15 | 0.13819<br>0.6233<br>15 | 0.10124<br>0.7196<br>15 | 0.93319<br>0.0001<br>15 |
| 050B006 | 0.99690<br>0.0001<br>18 | 0.52394<br>0.0148<br>21 | 0.87993<br>0.0001<br>21 | 0.71694<br>0.0003<br>21 | 0.33570<br>0.1732<br>18 | 0.21584<br>0.4788<br>13 | 0.73385<br>0.0157<br>10 | 0.10160<br>0.7296<br>14 | 1.00000<br>0.0000<br>21 | 0.06837<br>0.7875<br>18 | 0.38061<br>0.2779<br>10 | 0.88732<br>0.0001<br>21 | 0.99895<br>0.0001<br>17 | 0.43693<br>0.0614<br>19 | -0.21684<br>0.5752<br>9 | -0.13554<br>0.5918<br>18 | 0.50654<br>0.0380<br>17 | 0.99772<br>0.0001<br>17 | 0.89945<br>0.0001<br>18 | 0.09866<br>0.6705<br>21 |
| 050B007 | 0.11390<br>0.6424<br>19 | 0.18951<br>0.4371<br>19 | 0.36669<br>0.1225<br>19 | -0.01959<br>0.9365<br>19 | 0.14174<br>0.5627<br>19 | 0.10809<br>0.7130<br>14 | 0.08181<br>0.8222<br>10 | 0.97801<br>0.0001<br>15 | 0.06837<br>0.7875<br>18 | 1.00000<br>0.0000<br>19 | 0.97249<br>0.0001<br>8 | 0.04635<br>0.8506<br>19 | 0.05204<br>0.8482<br>16 | 0.56516<br>0.0117<br>19 | 0.93335<br>0.0001<br>10 | -0.00108<br>0.9965<br>19 | 0.79850<br>0.0001<br>18 | 0.10930<br>0.6659<br>18 | 0.03015<br>0.9025<br>19 | 0.97278<br>0.0001<br>19 |
| 050B008 | 0.29835<br>0.4729<br>8 | 0.28695<br>0.3922<br>11 | 0.37714<br>0.2529<br>11 | 0.17939<br>0.5976<br>11 | 0.28159<br>0.4993<br>8 | 0.40060<br>0.3732<br>7 | 0.55772<br>0.6234<br>3 | 0.99515<br>0.0001<br>7 | 0.38061<br>0.2779<br>10 | 0.97249<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.53015<br>0.0934<br>11 | 0.32504<br>0.3595<br>10 | 0.44764<br>0.2270<br>9 | 0.63441<br>0.0911<br>8 | 0.39114<br>0.3380<br>8 | 0.79129<br>0.0340<br>7 | 0.32555<br>0.4762<br>7 | 0.40804<br>0.3156<br>8 | 0.96671<br>0.0001<br>12 |
| 050B010 | 0.52833<br>0.0201<br>19 | 0.37614<br>0.0845<br>22 | 0.47061<br>0.0271<br>22 | 0.31830<br>0.1488<br>22 | 0.24027<br>0.3218<br>19 | 0.00552<br>0.9851<br>14 | 0.73649<br>0.0151<br>10 | 0.12328<br>0.6616<br>15 | 0.88732<br>0.0001<br>21 | 0.04635<br>0.8506<br>19 | 0.53015<br>0.0934<br>11 | 1.00000<br>0.0000<br>22 | 0.55290<br>0.0173<br>18 | 0.06592<br>0.7825<br>20 | -0.21405<br>0.5526<br>10 | -0.17590<br>0.4713<br>19 | 0.30217<br>0.2230<br>18 | 0.54657<br>0.0189<br>18 | 0.94114<br>0.0001<br>19 | 0.10467<br>0.6430<br>22 |
| 050B013 | 0.99773<br>0.0001<br>16 | 0.52792<br>0.0243<br>18 | 0.88630<br>0.0001<br>18 | 0.82078<br>0.0001<br>18 | 0.31723<br>0.2312<br>16 | 0.22086<br>0.4480<br>14 | 0.73882<br>0.0146<br>10 | 0.11274<br>0.6891<br>15 | 0.99895<br>0.0001<br>17 | 0.05204<br>0.8482<br>16 | 0.32504<br>0.3595<br>10 | 0.55290<br>0.0173<br>18 | 1.00000<br>0.0000<br>18 | 0.43401<br>0.0817<br>17 | -0.19397<br>0.5913<br>10 | -0.12295<br>0.6501<br>16 | 0.52032<br>0.0468<br>15 | 0.99662<br>0.0001<br>15 | 0.38956<br>0.1358<br>16 | 0.08254<br>0.7447<br>18 |
| 050B016 | 0.47969<br>0.0377<br>19 | 0.05274<br>0.8252<br>20 | 0.57370<br>0.0082<br>20 | 0.27399<br>0.2424<br>20 | -0.14358<br>0.5576<br>19 | -0.19152<br>0.5119<br>14 | 0.05353<br>0.8832<br>10 | 0.43683<br>0.1035<br>15 | 0.43693<br>0.0614<br>19 | 0.56516<br>0.0117<br>19 | 0.44764<br>0.2270<br>9 | 0.06592<br>0.7825<br>20 | 0.43401<br>0.0817<br>17 | 1.00000<br>0.0000<br>20 | 0.40790<br>0.2419<br>10 | 0.07248<br>0.7681<br>19 | 0.56676<br>0.0142<br>18 | 0.44512<br>0.0642<br>18 | -0.00813<br>0.9737<br>19 | 0.66919<br>0.0013<br>20 |
| 050B019 | -0.16509<br>0.6486<br>10 | -0.21810<br>0.5450<br>10 | 0.06234<br>0.8642<br>10 | -0.28807<br>0.4196<br>10 | -0.18576<br>0.6074<br>10 | -0.28663<br>0.4546<br>9 | -0.36296<br>0.5482<br>5 | 0.90302<br>0.0008<br>9 | -0.21684<br>0.5752<br>9 | 0.93335<br>0.0001<br>10 | 0.63441<br>0.0911<br>8 | -0.21405<br>0.5526<br>10 | -0.19397<br>0.5913<br>10 | 0.40790<br>0.2419<br>10 | 1.00000<br>0.0000<br>10 | 0.18278<br>0.6133<br>10 | 0.61279<br>0.0793<br>9 | -0.17834<br>0.6462<br>9 | -0.18787<br>0.6032<br>10 | 0.84534<br>0.0021<br>10 |
| 050B021 | -0.11505<br>0.6391<br>19 | -0.28179<br>0.2425<br>19 | -0.07987<br>0.7452<br>19 | -0.15682<br>0.5214<br>19 | -0.27085<br>0.2620<br>19 | -0.21762<br>0.4548<br>14 | -0.12272<br>0.7356<br>10 | 0.29844<br>0.2799<br>15 | -0.13554<br>0.5918<br>18 | -0.00108<br>0.9965<br>19 | 0.38114<br>0.3380<br>8 | -0.17590<br>0.4713<br>19 | -0.12295<br>0.6501<br>16 | 0.07248<br>0.7681<br>19 | 0.18278<br>0.6133<br>10 | 1.00000<br>0.0000<br>19 | -0.09168<br>0.7175<br>18 | -0.14809<br>0.5576<br>18 | -0.13173<br>0.5909<br>19 | 0.08225<br>0.7378<br>19 |
| 050B023 | 0.53730<br>0.0215<br>18 | 0.50621<br>0.0321<br>18 | 0.74005<br>0.0004<br>18 | 0.46350<br>0.0527<br>18 | 0.33023<br>0.1808<br>18 | 0.16711<br>0.5680<br>14 | 0.50605<br>0.1356<br>10 | 0.80916<br>0.0003<br>15 | 0.50654<br>0.0380<br>17 | 0.79850<br>0.0001<br>18 | 0.79129<br>0.0340<br>7 | 0.30217<br>0.2230<br>18 | 0.52032<br>0.0468<br>15 | 0.56676<br>0.0142<br>18 | 0.61279<br>0.0793<br>9 | -0.09168<br>0.7175<br>18 | 1.00000<br>0.0000<br>18 | 0.53889<br>0.0210<br>18 | 0.20468<br>0.4152<br>18 | 0.75920<br>0.0003<br>18 |
| 050B025 | 0.99595<br>0.0001<br>18 | 0.58589<br>0.0106<br>18 | 0.89329<br>0.0001<br>18 | 0.81047<br>0.0001<br>18 | 0.43991<br>0.0677<br>18 | 0.26715<br>0.3558<br>14 | 0.76291<br>0.0103<br>10 | 0.13819<br>0.6233<br>15 | 0.99772<br>0.0001<br>17 | 0.10930<br>0.6659<br>18 | 0.32555<br>0.4762<br>7 | 0.54657<br>0.0189<br>18 | 0.99662<br>0.0001<br>15 | 0.44512<br>0.0642<br>18 | -0.17834<br>0.6462<br>9 | -0.14809<br>0.5576<br>18 | 0.53889<br>0.0210<br>18 | 1.00000<br>0.0000<br>18 | 0.36451<br>0.1370<br>18 | 0.11133<br>0.6601<br>18 |
| 050B031 | 0.37162<br>0.1172<br>19 | 0.23487<br>0.3331<br>19 | 0.33370<br>0.1626<br>19 | 0.26565<br>0.2717<br>19 | 0.04223<br>0.8637<br>19 | -0.05196<br>0.8600<br>14 | 0.73318<br>0.0158<br>10 | 0.10124<br>0.7196<br>15 | 0.89945<br>0.0001<br>18 | 0.03015<br>0.9025<br>19 | 0.40804<br>0.3156<br>8 | 0.94114<br>0.0001<br>19 | 0.38956<br>0.1358<br>16 | -0.00813<br>0.9737<br>19 | -0.18787<br>0.6032<br>10 | -0.13173<br>0.5909<br>19 | 0.20468<br>0.4152<br>18 | 0.36451<br>0.1370<br>18 | 1.00000<br>0.0000<br>19 | 0.05397<br>0.8263<br>19 |
| 050C004 | 0.12982<br>0.5963<br>19 | 0.14880<br>0.5087<br>22 | 0.39945<br>0.0655<br>22 | -0.07314<br>0.7463<br>22 | 0.08731<br>0.7223<br>19 | 0.06380<br>0.8285<br>14 | 0.06103<br>0.8670<br>10 | 0.93319<br>0.0001<br>15 | 0.09866<br>0.6705<br>21 | 0.97278<br>0.0001<br>19 | 0.96671<br>0.0001<br>12 | 0.10467<br>0.6430<br>22 | 0.08254<br>0.7447<br>18 | 0.66919<br>0.0013<br>20 | 0.84534<br>0.0021<br>10 | 0.08225<br>0.7378<br>19 | 0.75920<br>0.0003<br>18 | 0.11133<br>0.6601<br>18 | 0.05397<br>0.8263<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-14

## Spearman Correlation Coefficients* for Pembina River Basin August Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.44127<br>0.0586<br>19 | 0.69292<br>0.0010<br>19 | 0.18251<br>0.4546<br>19 | 0.23222<br>0.3387<br>19 | 0.06352<br>0.8292<br>14 | 0.43832<br>0.2051<br>10 | 0.37066<br>0.1738<br>15 | 0.21938<br>0.3818<br>18 | 0.47865<br>0.0382<br>19 | -0.08939<br>0.8333<br>8 | 0.42670<br>0.0685<br>19 | 0.41370<br>0.1112<br>16 | 0.33800<br>0.1570<br>19 | 0.20075<br>0.5781<br>10 | -0.13433<br>0.5835<br>19 | 0.54031<br>0.0206<br>18 | 0.49330<br>0.0375<br>18 | 0.04428<br>0.8572<br>19 | 0.44822<br>0.0543<br>19 |
| 050A006 | 0.44127<br>0.0586<br>19 | 1.00000<br>0.0000<br>22 | 0.67603<br>0.0006<br>22 | 0.81101<br>0.0001<br>22 | 0.73527<br>0.0003<br>19 | 0.86564<br>0.0001<br>14 | 0.83891<br>0.0024<br>10 | 0.45837<br>0.0857<br>15 | 0.52566<br>0.0144<br>21 | 0.60686<br>0.0059<br>19 | 0.46469<br>0.1498<br>11 | 0.63350<br>0.0106<br>22 | 0.37377<br>0.1265<br>18 | 0.07566<br>0.7512<br>20 | -0.07879<br>0.8287<br>10 | -0.31329<br>0.1915<br>19 | 0.68841<br>0.0016<br>18 | 0.35922<br>0.1432<br>18 | 0.35148<br>0.1400<br>19 | 0.44646<br>0.0373<br>22 |
| 050A007 | 0.69292<br>0.0010<br>19 | 0.67603<br>0.0006<br>22 | 1.00000<br>0.0000<br>22 | 0.62675<br>0.0018<br>22 | 0.34489<br>0.1482<br>19 | 0.41804<br>0.1369<br>14 | 0.66262<br>0.0368<br>10 | 0.66547<br>0.0068<br>15 | 0.19440<br>0.3984<br>21 | 0.63010<br>0.0038<br>19 | 0.50461<br>0.1134<br>11 | 0.42837<br>0.0467<br>22 | 0.48678<br>0.0405<br>18 | 0.47569<br>0.0340<br>20 | 0.20000<br>0.5796<br>10 | 0.21492<br>0.3769<br>19 | 0.71864<br>0.0008<br>18 | 0.51061<br>0.0304<br>18 | 0.20861<br>0.3914<br>19 | 0.57054<br>0.0056<br>22 |
| 050A008 | 0.18251<br>0.4546<br>19 | 0.81101<br>0.0001<br>22 | 0.62675<br>0.0018<br>22 | 1.00000<br>0.0000<br>22 | 0.67283<br>0.0016<br>19 | 0.84692<br>0.0001<br>14 | 0.91463<br>0.0002<br>10 | 0.16279<br>0.5621<br>15 | 0.44199<br>0.0448<br>21 | 0.25946<br>0.2834<br>19 | 0.38534<br>0.2419<br>11 | 0.37369<br>0.0867<br>22 | 0.31305<br>0.2059<br>18 | -0.05752<br>0.8097<br>20 | -0.20000<br>0.5796<br>10 | -0.13804<br>0.5730<br>19 | 0.37455<br>0.1257<br>18 | 0.17436<br>0.4890<br>18 | 0.27094<br>0.2619<br>19 | 0.14603<br>0.5167<br>22 |
| 050A010 | 0.23222<br>0.3387<br>19 | 0.73527<br>0.0003<br>19 | 0.34489<br>0.1482<br>19 | 0.67283<br>0.0016<br>19 | 1.00000<br>0.0000<br>19 | 0.84488<br>0.0001<br>14 | 0.88754<br>0.0006<br>10 | 0.28418<br>0.3046<br>15 | 0.47431<br>0.0467<br>18 | 0.24386<br>0.3144<br>19 | 0.50000<br>0.2070<br>8 | 0.37887<br>0.1097<br>19 | 0.48342<br>0.0578<br>16 | -0.37171<br>0.1171<br>19 | 0.03030<br>0.9338<br>10 | -0.30465<br>0.2047<br>19 | 0.27141<br>0.2760<br>18 | 0.22538<br>0.3686<br>18 | 0.26278<br>0.2771<br>19 | 0.06316<br>0.7973<br>19 |
| 050A012 | 0.06352<br>0.8292<br>14 | 0.86564<br>0.0001<br>14 | 0.41804<br>0.1369<br>14 | 0.84692<br>0.0001<br>14 | 0.84488<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.88146<br>0.0007<br>10 | 0.28855<br>0.3171<br>14 | 0.38628<br>0.1923<br>13 | 0.30363<br>0.2913<br>14 | 0.67857<br>0.0938<br>7 | 0.02115<br>0.9428<br>14 | 0.21279<br>0.4652<br>14 | -0.16593<br>0.5708<br>14 | -0.15000<br>0.7001<br>9 | -0.20001<br>0.4930<br>14 | 0.37404<br>0.1877<br>14 | 0.49813<br>0.0699<br>14 | 0.00689<br>0.9814<br>14 | 0.22882<br>0.4314<br>14 |
| 050A013 | 0.43832<br>0.2051<br>10 | 0.83891<br>0.0024<br>10 | 0.66262<br>0.0368<br>10 | 0.91463<br>0.0002<br>10 | 0.88754<br>0.0006<br>10 | 0.88146<br>0.0007<br>10 | 1.00000<br>0.0000<br>10 | 0.46201<br>0.1789<br>10 | 0.52382<br>0.1202<br>10 | 0.41338<br>0.2351<br>10 | 0.50000<br>0.6667<br>3 | 0.60268<br>0.0652<br>10 | 0.77812<br>0.0080<br>10 | -0.01220<br>0.9733<br>10 | 0.00000<br>1.0000<br>5 | -0.09723<br>0.7893<br>10 | 0.69909<br>0.0245<br>10 | 0.65746<br>0.0388<br>10 | 0.11713<br>0.7473<br>10 | 0.34651<br>0.3267<br>10 |
| 050B001 | 0.37066<br>0.1738<br>15 | 0.45837<br>0.0857<br>15 | 0.66547<br>0.0068<br>15 | 0.16279<br>0.5621<br>15 | 0.28418<br>0.3046<br>15 | 0.28855<br>0.3171<br>14 | 0.46201<br>0.1789<br>10 | 1.00000<br>0.0000<br>15 | 0.17219<br>0.5561<br>14 | 0.97587<br>0.0001<br>15 | 0.92857<br>0.0025<br>7 | 0.26947<br>0.3314<br>15 | 0.59498<br>0.0193<br>15 | 0.40706<br>0.1321<br>15 | 0.78333<br>0.0125<br>9 | 0.30538<br>0.2684<br>15 | 0.80965<br>0.0003<br>15 | 0.53315<br>0.0407<br>15 | -0.00918<br>0.9741<br>15 | 0.95442<br>0.0001<br>15 |
| 050B006 | 0.21938<br>0.3818<br>18 | 0.52566<br>0.0144<br>21 | 0.19440<br>0.3984<br>21 | 0.44199<br>0.0448<br>21 | 0.47431<br>0.0467<br>18 | 0.38629<br>0.1923<br>13 | 0.52382<br>0.1202<br>10 | 0.17219<br>0.5561<br>14 | 1.00000<br>0.0000<br>21 | 0.20598<br>0.4122<br>18 | 0.29081<br>0.4150<br>10 | 0.61592<br>0.0030<br>21 | 0.42112<br>0.0923<br>17 | 0.08778<br>0.7208<br>19 | -0.13693<br>0.7254<br>9 | -0.27082<br>0.2770<br>18 | 0.40825<br>0.1038<br>17 | 0.42470<br>0.0893<br>17 | 0.65103<br>0.0034<br>18 | -0.01920<br>0.9342<br>21 |
| 050B007 | 0.47865<br>0.0382<br>19 | 0.60686<br>0.0059<br>19 | 0.63010<br>0.0038<br>19 | 0.25946<br>0.2834<br>19 | 0.24386<br>0.3144<br>19 | 0.30363<br>0.2913<br>14 | 0.41338<br>0.2351<br>10 | 0.97587<br>0.0001<br>15 | 0.20598<br>0.4122<br>18 | 1.00000<br>0.0000<br>19 | 0.97619<br>0.0001<br>8 | 0.42574<br>0.0692<br>19 | 0.53648<br>0.0322<br>16 | 0.43321<br>0.0639<br>19 | 0.74545<br>0.0133<br>10 | -0.07812<br>0.7506<br>19 | 0.85552<br>0.0001<br>18 | 0.53743<br>0.0214<br>18 | -0.02021<br>0.9345<br>19 | 0.95439<br>0.0001<br>19 |
| 050B008 | -0.08939<br>0.8333<br>8 | 0.46469<br>0.1498<br>11 | 0.50461<br>0.1134<br>11 | 0.38534<br>0.2419<br>11 | 0.50000<br>0.2070<br>8 | 0.67857<br>0.0938<br>7 | 0.50000<br>0.6667<br>3 | 0.92857<br>0.0025<br>7 | 0.29081<br>0.4150<br>10 | 0.97619<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.41952<br>0.1990<br>11 | 0.54879<br>0.1004<br>10 | 0.54245<br>0.1313<br>9 | 0.54762<br>0.1600<br>8 | 0.30005<br>0.4703<br>8 | 0.82143<br>0.0234<br>7 | 0.59761<br>0.1565<br>7 | 0.48198<br>0.2265<br>8 | 0.95105<br>0.0001<br>12 |
| 050B010 | 0.42670<br>0.0685<br>19 | 0.53350<br>0.0106<br>22 | 0.42837<br>0.0467<br>22 | 0.37369<br>0.0867<br>22 | 0.37887<br>0.1097<br>19 | 0.02115<br>0.9428<br>14 | 0.60268<br>0.0652<br>10 | 0.26947<br>0.3314<br>15 | 0.61592<br>0.0030<br>21 | 0.42574<br>0.0692<br>19 | 0.41952<br>0.1990<br>11 | 1.00000<br>0.0000<br>22 | 0.64712<br>0.0037<br>18 | 0.03860<br>0.8716<br>20 | -0.06253<br>0.8637<br>10 | -0.21957<br>0.3664<br>19 | 0.46600<br>0.0513<br>18 | 0.06409<br>0.8005<br>18 | 0.61346<br>0.0052<br>19 | 0.28391<br>0.2004<br>22 |
| 050B013 | 0.41370<br>0.1112<br>16 | 0.37377<br>0.1265<br>18 | 0.48678<br>0.0405<br>18 | 0.31305<br>0.2059<br>18 | 0.48342<br>0.0578<br>16 | 0.21279<br>0.4652<br>14 | 0.77812<br>0.0080<br>10 | 0.59498<br>0.0193<br>15 | 0.42112<br>0.0923<br>17 | 0.53648<br>0.0322<br>16 | 0.54879<br>0.1004<br>10 | 0.64712<br>0.0037<br>18 | 1.00000<br>0.0000<br>18 | 0.02951<br>0.9105<br>17 | 0.29879<br>0.4017<br>10 | 0.21145<br>0.4318<br>16 | 0.63384<br>0.0112<br>15 | 0.15300<br>0.5862<br>15 | 0.39065<br>0.1346<br>16 | 0.34023<br>0.1671<br>18 |
| 050B016 | 0.33800<br>0.1570<br>19 | 0.07566<br>0.7512<br>20 | 0.47569<br>0.0340<br>20 | -0.05752<br>0.8097<br>20 | -0.37171<br>0.1171<br>19 | -0.16593<br>0.5708<br>14 | -0.01220<br>0.9733<br>10 | 0.40706<br>0.1321<br>15 | 0.08778<br>0.7208<br>19 | 0.43321<br>0.0639<br>19 | 0.54245<br>0.1313<br>9 | 0.03860<br>0.8716<br>20 | 0.02951<br>0.9105<br>17 | 1.00000<br>0.0000<br>20 | 0.21885<br>0.5436<br>10 | 0.23417<br>0.3346<br>19 | 0.48516<br>0.0413<br>18 | 0.46229<br>0.0534<br>18 | -0.05460<br>0.8243<br>19 | 0.63327<br>0.0027<br>20 |
| 050B019 | 0.20075<br>0.5781<br>10 | -0.07879<br>0.8287<br>10 | 0.20000<br>0.5796<br>10 | -0.20000<br>0.5796<br>10 | 0.03030<br>0.9338<br>10 | -0.15000<br>0.7001<br>9 | 0.00000<br>1.0000<br>5 | 0.78333<br>0.0125<br>9 | -0.13693<br>0.7254<br>9 | 0.74545<br>0.0133<br>10 | 0.54762<br>0.1600<br>8 | -0.06253<br>0.8637<br>10 | 0.29879<br>0.4017<br>10 | 0.21885<br>0.5436<br>10 | 1.00000<br>0.0000<br>10 | 0.17753<br>0.6237<br>10 | 0.40000<br>0.2861<br>9 | 0.21859<br>0.5720<br>9 | -0.25263<br>0.4813<br>10 | 0.67273<br>0.0330<br>10 |
| 050B021 | -0.13433<br>0.5835<br>19 | -0.31329<br>0.1915<br>19 | 0.21492<br>0.3769<br>19 | -0.13804<br>0.5730<br>19 | -0.30465<br>0.2047<br>19 | -0.20001<br>0.4930<br>14 | -0.09723<br>0.7893<br>10 | 0.30538<br>0.2684<br>15 | -0.27082<br>0.2770<br>18 | -0.07812<br>0.7506<br>19 | 0.30005<br>0.4703<br>8 | -0.21957<br>0.3664<br>19 | 0.21145<br>0.4318<br>16 | 0.23417<br>0.3346<br>19 | 0.17753<br>0.6237<br>10 | 1.00000<br>0.0000<br>19 | -0.20166<br>0.4223<br>18 | -0.07137<br>0.7784<br>18 | 0.02487<br>0.9195<br>19 | 0.09374<br>0.7027<br>19 |
| 050B023 | 0.54031<br>0.0206<br>18 | 0.68841<br>0.0016<br>18 | 0.71864<br>0.0008<br>18 | 0.37455<br>0.1257<br>18 | 0.27141<br>0.2760<br>18 | 0.37404<br>0.1877<br>14 | 0.69909<br>0.0245<br>10 | 0.80965<br>0.0003<br>15 | 0.40825<br>0.1038<br>17 | 0.85552<br>0.0001<br>18 | 0.82143<br>0.0234<br>7 | 0.46600<br>0.0513<br>18 | 0.63384<br>0.0112<br>15 | 0.48516<br>0.0413<br>18 | 0.40000<br>0.2861<br>9 | -0.20166<br>0.4223<br>18 | 1.00000<br>0.0000<br>18 | 0.50601<br>0.0321<br>18 | 0.12156<br>0.6309<br>18 | 0.80392<br>0.0001<br>18 |
| 050B025 | 0.49330<br>0.0375<br>18 | 0.35922<br>0.1432<br>18 | 0.51061<br>0.0304<br>18 | 0.17436<br>0.4890<br>18 | 0.22538<br>0.3686<br>18 | 0.49813<br>0.0699<br>14 | 0.65746<br>0.0388<br>10 | 0.53315<br>0.0407<br>15 | 0.42470<br>0.0893<br>17 | 0.53743<br>0.0214<br>18 | 0.59761<br>0.1565<br>7 | 0.06409<br>0.8005<br>18 | 0.15300<br>0.5862<br>15 | 0.46229<br>0.0534<br>18 | 0.21859<br>0.5720<br>9 | -0.07137<br>0.7784<br>18 | 0.50601<br>0.0321<br>18 | 1.00000<br>0.0000<br>18 | -0.13381<br>0.5966<br>18 | 0.59378<br>0.0094<br>18 |
| 050B031 | 0.04428<br>0.8572<br>19 | 0.35148<br>0.1400<br>19 | 0.20861<br>0.3914<br>19 | 0.27094<br>0.2619<br>19 | 0.26278<br>0.2771<br>19 | 0.00689<br>0.9814<br>14 | 0.11713<br>0.7473<br>10 | -0.00918<br>0.9741<br>15 | 0.65103<br>0.0034<br>18 | -0.02021<br>0.9345<br>19 | 0.48198<br>0.2265<br>8 | 0.61346<br>0.0052<br>19 | 0.39065<br>0.1346<br>16 | -0.05460<br>0.8243<br>19 | -0.25263<br>0.4813<br>10 | 0.02487<br>0.9195<br>19 | 0.12156<br>0.6309<br>18 | -0.13381<br>0.5966<br>18 | 1.00000<br>0.0000<br>19 | -0.04043<br>0.8695<br>19 |
| 050C004 | 0.44822<br>0.0543<br>19 | 0.44646<br>0.0373<br>22 | 0.57054<br>0.0056<br>22 | 0.14603<br>0.5167<br>22 | 0.06316<br>0.7973<br>19 | 0.22882<br>0.4314<br>14 | 0.34651<br>0.3267<br>10 | 0.95442<br>0.0001<br>15 | -0.01920<br>0.9342<br>21 | 0.95439<br>0.0001<br>19 | 0.95105<br>0.0001<br>12 | 0.28391<br>0.2004<br>22 | 0.34023<br>0.1671<br>18 | 0.63327<br>0.0027<br>20 | 0.67273<br>0.0330<br>10 | 0.09374<br>0.7027<br>19 | 0.80392<br>0.0001<br>18 | 0.59378<br>0.0094<br>18 | -0.04043<br>0.8695<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-15

## Pearson Correlation Coefficients* for Pembina River Basin September Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.94934<br>0.0001<br>19 | 0.96964<br>0.0001<br>19 | 0.82918<br>0.0001<br>19 | 0.97121<br>0.0001<br>19 | 0.80258<br>0.0006<br>14 | 0.98418<br>0.0001<br>10 | 0.91369<br>0.0001<br>15 | 0.99320<br>0.0001<br>18 | 0.81333<br>0.0001<br>19 | 0.95702<br>0.0002<br>8 | 0.99563<br>0.0001<br>19 | 0.97534<br>0.0001<br>16 | 0.38196<br>0.1066<br>19 | 0.95264<br>0.0001<br>10 | -0.08866<br>0.7181<br>19 | 0.98789<br>0.0001<br>18 | 0.88006<br>0.0001<br>18 | 0.99566<br>0.0001<br>19 | 0.78890<br>0.0001<br>19 |
| 050A006 | 0.94934<br>0.0001<br>19 | 1.00000<br>0.0000<br>22 | 0.97565<br>0.0001<br>22 | 0.91732<br>0.0001<br>22 | 0.96968<br>0.0001<br>19 | 0.86154<br>0.0001<br>14 | 0.99541<br>0.0001<br>10 | 0.89791<br>0.0001<br>15 | 0.94155<br>0.0001<br>21 | 0.83056<br>0.0001<br>19 | 0.96146<br>0.0001<br>11 | 0.94425<br>0.0001<br>22 | 0.90958<br>0.0001<br>18 | 0.37474<br>0.1035<br>20 | 0.95254<br>0.0001<br>10 | -0.17006<br>0.4864<br>19 | 0.96704<br>0.0001<br>18 | 0.83021<br>0.0001<br>18 | 0.95712<br>0.0001<br>19 | 0.79537<br>0.0001<br>22 |
| 050A007 | 0.96964<br>0.0001<br>19 | 0.97565<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.84550<br>0.0001<br>22 | 0.94426<br>0.0001<br>19 | 0.76448<br>0.0015<br>14 | 0.97703<br>0.0001<br>10 | 0.90962<br>0.0001<br>15 | 0.96894<br>0.0001<br>21 | 0.83311<br>0.0001<br>19 | 0.95411<br>0.0001<br>11 | 0.97272<br>0.0001<br>22 | 0.94350<br>0.0001<br>18 | 0.41830<br>0.0664<br>20 | 0.94791<br>0.0001<br>10 | -0.11038<br>0.6528<br>19 | 0.97452<br>0.0001<br>18 | 0.85985<br>0.0001<br>18 | 0.98041<br>0.0001<br>19 | 0.79429<br>0.0001<br>22 |
| 050A008 | 0.82918<br>0.0001<br>19 | 0.91732<br>0.0001<br>22 | 0.84550<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.92144<br>0.0001<br>19 | 0.97206<br>0.0001<br>14 | 0.88672<br>0.0006<br>10 | 0.74010<br>0.0016<br>15 | 0.81296<br>0.0001<br>21 | 0.64972<br>0.0026<br>19 | 0.95170<br>0.0001<br>11 | 0.81918<br>0.0001<br>22 | 0.77506<br>0.0002<br>18 | 0.22413<br>0.3421<br>20 | 0.93330<br>0.0001<br>10 | -0.16703<br>0.4943<br>19 | 0.83393<br>0.0001<br>18 | 0.67585<br>0.0021<br>18 | 0.83102<br>0.0001<br>19 | 0.62642<br>0.0018<br>22 |
| 050A010 | 0.97121<br>0.0001<br>19 | 0.96968<br>0.0001<br>19 | 0.94426<br>0.0001<br>19 | 0.92144<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.91297<br>0.0001<br>14 | 0.98778<br>0.0001<br>10 | 0.88853<br>0.0001<br>15 | 0.96059<br>0.0001<br>18 | 0.79619<br>0.0001<br>19 | 0.96638<br>0.0001<br>8 | 0.96801<br>0.0001<br>19 | 0.93374<br>0.0001<br>16 | 0.30291<br>0.2075<br>19 | 0.95527<br>0.0001<br>10 | -0.15583<br>0.5241<br>19 | 0.97135<br>0.0001<br>18 | 0.83326<br>0.0001<br>18 | 0.96752<br>0.0001<br>19 | 0.76585<br>0.0001<br>19 |
| 050A012 | 0.80258<br>0.0006<br>14 | 0.86154<br>0.0001<br>14 | 0.76448<br>0.0015<br>14 | 0.97206<br>0.0001<br>14 | 0.91297<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.86257<br>0.0013<br>10 | 0.71327<br>0.0042<br>14 | 0.78119<br>0.0016<br>13 | 0.63142<br>0.0154<br>14 | 0.98177<br>0.0001<br>7 | 0.79195<br>0.0007<br>14 | 0.77438<br>0.0011<br>14 | 0.12636<br>0.6669<br>14 | 0.95768<br>0.0001<br>9 | -0.25714<br>0.3748<br>14 | 0.80591<br>0.0005<br>14 | 0.63221<br>0.0153<br>14 | 0.78262<br>0.0007<br>14 | 0.58825<br>0.0269<br>14 |
| 050A013 | 0.98418<br>0.0001<br>10 | 0.99541<br>0.0001<br>10 | 0.97703<br>0.0001<br>10 | 0.88672<br>0.0006<br>10 | 0.98778<br>0.0001<br>10 | 0.86257<br>0.0013<br>10 | 1.00000<br>0.0000<br>10 | 0.90485<br>0.0003<br>10 | 0.96903<br>0.0001<br>10 | 0.83028<br>0.0029<br>10 | 0.98303<br>0.1174<br>3 | 0.97726<br>0.0001<br>10 | 0.97657<br>0.0001<br>10 | 0.25403<br>0.4788<br>10 | 0.96637<br>0.0074<br>5 | -0.15998<br>0.6589<br>10 | 0.98600<br>0.0001<br>10 | 0.83253<br>0.0028<br>10 | 0.97727<br>0.0001<br>10 | 0.78839<br>0.0067<br>10 |
| 050B001 | 0.91369<br>0.0001<br>15 | 0.89791<br>0.0001<br>15 | 0.90962<br>0.0001<br>15 | 0.74010<br>0.0016<br>15 | 0.88853<br>0.0001<br>15 | 0.71327<br>0.0042<br>14 | 0.90485<br>0.0003<br>10 | 1.00000<br>0.0000<br>15 | 0.92477<br>0.0001<br>14 | 0.98403<br>0.0001<br>15 | 0.99636<br>0.0001<br>7 | 0.91511<br>0.0001<br>15 | 0.88383<br>0.0001<br>15 | 0.49089<br>0.0632<br>15 | 0.99381<br>0.0001<br>9 | -0.20895<br>0.4548<br>15 | 0.94141<br>0.0001<br>15 | 0.91100<br>0.0001<br>15 | 0.91723<br>0.0001<br>15 | 0.96666<br>0.0001<br>15 |
| 050B006 | 0.99320<br>0.0001<br>18 | 0.94155<br>0.0001<br>21 | 0.96894<br>0.0001<br>21 | 0.81296<br>0.0001<br>21 | 0.96059<br>0.0001<br>18 | 0.78119<br>0.0016<br>13 | 0.96903<br>0.0001<br>10 | 0.92477<br>0.0001<br>14 | 1.00000<br>0.0000<br>21 | 0.84529<br>0.0001<br>18 | 0.94616<br>0.0001<br>10 | 0.98724<br>0.0001<br>21 | 0.97391<br>0.0001<br>17 | 0.44951<br>0.0535<br>19 | 0.95877<br>0.0001<br>9 | -0.10048<br>0.6916<br>18 | 0.98856<br>0.0001<br>17 | 0.88714<br>0.0001<br>17 | 0.99479<br>0.0001<br>18 | 0.80695<br>0.0001<br>21 |
| 050B007 | 0.81333<br>0.0001<br>19 | 0.83056<br>0.0001<br>19 | 0.83311<br>0.0001<br>19 | 0.64972<br>0.0026<br>19 | 0.79619<br>0.0001<br>19 | 0.63142<br>0.0154<br>14 | 0.83028<br>0.0029<br>10 | 0.98403<br>0.0001<br>15 | 0.84529<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.99742<br>0.0001<br>8 | 0.83019<br>0.0001<br>19 | 0.80414<br>0.0002<br>16 | 0.57398<br>0.0102<br>19 | 0.97256<br>0.0001<br>10 | -0.21865<br>0.3685<br>19 | 0.87591<br>0.0001<br>18 | 0.87209<br>0.0001<br>18 | 0.83145<br>0.0001<br>19 | 0.99225<br>0.0001<br>19 |
| 050B008 | 0.95702<br>0.0002<br>8 | 0.96146<br>0.0001<br>11 | 0.95411<br>0.0001<br>11 | 0.95170<br>0.0001<br>11 | 0.96638<br>0.0001<br>8 | 0.98177<br>0.0001<br>7 | 0.98303<br>0.1174<br>3 | 0.99636<br>0.0001<br>7 | 0.94616<br>0.0001<br>10 | 0.99742<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | 0.93075<br>0.0001<br>11 | 0.94625<br>0.0001<br>10 | 0.87365<br>0.0021<br>9 | 0.99556<br>0.0001<br>8 | -0.26513<br>0.5257<br>8 | 0.98104<br>0.0001<br>7 | 0.93952<br>0.0017<br>7 | 0.96405<br>0.0001<br>8 | 0.98996<br>0.0001<br>12 |
| 050B010 | 0.99563<br>0.0001<br>19 | 0.94425<br>0.0001<br>22 | 0.97272<br>0.0001<br>22 | 0.81918<br>0.0001<br>22 | 0.96801<br>0.0001<br>19 | 0.79195<br>0.0007<br>14 | 0.97726<br>0.0001<br>10 | 0.91511<br>0.0001<br>15 | 0.98724<br>0.0001<br>21 | 0.83019<br>0.0001<br>19 | 0.93075<br>0.0001<br>11 | 1.00000<br>0.0000<br>22 | 0.97332<br>0.0001<br>18 | 0.39816<br>0.0821<br>20 | 0.95441<br>0.0001<br>10 | -0.09904<br>0.6866<br>19 | 0.99038<br>0.0001<br>18 | 0.88372<br>0.0001<br>18 | 0.99984<br>0.0001<br>19 | 0.75786<br>0.0001<br>22 |
| 050B013 | 0.97534<br>0.0001<br>16 | 0.90958<br>0.0001<br>18 | 0.94350<br>0.0001<br>18 | 0.77506<br>0.0002<br>18 | 0.93374<br>0.0001<br>16 | 0.77438<br>0.0011<br>14 | 0.97657<br>0.0001<br>10 | 0.88383<br>0.0001<br>15 | 0.97391<br>0.0001<br>17 | 0.80414<br>0.0002<br>16 | 0.94625<br>0.0001<br>10 | 0.97332<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.33622<br>0.1870<br>17 | 0.96049<br>0.0001<br>10 | 0.10789<br>0.6908<br>16 | 0.96398<br>0.0001<br>15 | 0.85320<br>0.0001<br>15 | 0.97605<br>0.0001<br>16 | 0.75219<br>0.0003<br>18 |
| 050B016 | 0.38196<br>0.1066<br>19 | 0.37474<br>0.1035<br>20 | 0.41830<br>0.0664<br>20 | 0.22413<br>0.3421<br>20 | 0.30291<br>0.2075<br>19 | 0.12636<br>0.6669<br>14 | 0.25403<br>0.4788<br>10 | 0.49089<br>0.0632<br>15 | 0.44951<br>0.0535<br>19 | 0.57398<br>0.0102<br>19 | 0.87365<br>0.0021<br>9 | 0.39816<br>0.0821<br>20 | 0.33622<br>0.1870<br>17 | 1.00000<br>0.0000<br>20 | 0.55219<br>0.0979<br>10 | -0.01459<br>0.9527<br>19 | 0.39499<br>0.1047<br>18 | 0.44448<br>0.0646<br>18 | 0.39619<br>0.0931<br>19 | 0.63692<br>0.0025<br>20 |
| 050B019 | 0.95264<br>0.0001<br>10 | 0.95254<br>0.0001<br>10 | 0.94791<br>0.0001<br>10 | 0.93330<br>0.0001<br>10 | 0.95527<br>0.0001<br>10 | 0.95768<br>0.0001<br>9 | 0.96637<br>0.0074<br>5 | 0.99381<br>0.0001<br>9 | 0.95877<br>0.0001<br>9 | 0.97256<br>0.0001<br>10 | 0.99556<br>0.0001<br>8 | 0.95441<br>0.0001<br>10 | 0.96049<br>0.0001<br>10 | 0.55219<br>0.0979<br>10 | 1.00000<br>0.0000<br>10 | -0.23334<br>0.5165<br>10 | 0.96872<br>0.0001<br>9 | 0.90907<br>0.0007<br>9 | 0.95576<br>0.0001<br>10 | 0.95220<br>0.0001<br>10 |
| 050B021 | -0.08866<br>0.7181<br>19 | -0.17006<br>0.4864<br>19 | -0.11038<br>0.6528<br>19 | -0.16703<br>0.4943<br>19 | -0.15583<br>0.5241<br>19 | -0.25714<br>0.3748<br>14 | -0.15998<br>0.6589<br>10 | -0.20895<br>0.4548<br>15 | -0.10048<br>0.6916<br>18 | -0.21865<br>0.3685<br>19 | -0.26513<br>0.5257<br>8 | -0.09904<br>0.6866<br>19 | 0.10789<br>0.6908<br>16 | -0.01459<br>0.9527<br>19 | -0.23334<br>0.5165<br>10 | 1.00000<br>0.0000<br>19 | -0.13122<br>0.6038<br>18 | -0.16002<br>0.5259<br>18 | -0.09694<br>0.6930<br>19 | -0.21898<br>0.3677<br>19 |
| 050B023 | 0.98789<br>0.0001<br>18 | 0.96704<br>0.0001<br>18 | 0.97452<br>0.0001<br>18 | 0.83393<br>0.0001<br>18 | 0.97135<br>0.0001<br>18 | 0.80591<br>0.0005<br>14 | 0.98600<br>0.0001<br>10 | 0.94141<br>0.0001<br>15 | 0.98856<br>0.0001<br>17 | 0.87591<br>0.0001<br>18 | 0.98104<br>0.0001<br>7 | 0.99038<br>0.0001<br>18 | 0.96398<br>0.0001<br>15 | 0.39499<br>0.1047<br>18 | 0.96872<br>0.0001<br>9 | -0.13122<br>0.6038<br>18 | 1.00000<br>0.0000<br>18 | 0.88372<br>0.0001<br>18 | 0.99097<br>0.0001<br>18 | 0.84743<br>0.0001<br>18 |
| 050B025 | 0.88006<br>0.0001<br>18 | 0.83021<br>0.0001<br>18 | 0.85985<br>0.0001<br>18 | 0.67585<br>0.0021<br>18 | 0.83326<br>0.0001<br>18 | 0.63221<br>0.0153<br>14 | 0.83253<br>0.0028<br>10 | 0.91100<br>0.0001<br>15 | 0.88714<br>0.0001<br>17 | 0.87209<br>0.0001<br>18 | 0.93952<br>0.0017<br>7 | 0.88372<br>0.0001<br>18 | 0.85320<br>0.0001<br>15 | 0.44448<br>0.0646<br>18 | 0.90907<br>0.0007<br>9 | -0.16002<br>0.5259<br>18 | 0.88372<br>0.0001<br>18 | 1.00000<br>0.0000<br>18 | 0.88496<br>0.0001<br>18 | 0.84248<br>0.0001<br>18 |
| 050B031 | 0.99566<br>0.0001<br>19 | 0.95712<br>0.0001<br>19 | 0.98041<br>0.0001<br>19 | 0.83102<br>0.0001<br>19 | 0.96752<br>0.0001<br>19 | 0.79262<br>0.0007<br>14 | 0.97727<br>0.0001<br>10 | 0.91723<br>0.0001<br>15 | 0.99479<br>0.0001<br>18 | 0.83145<br>0.0001<br>19 | 0.96405<br>0.0001<br>8 | 0.99984<br>0.0001<br>19 | 0.97605<br>0.0001<br>16 | 0.39619<br>0.0931<br>19 | 0.95576<br>0.0001<br>10 | -0.09694<br>0.6930<br>19 | 0.99097<br>0.0001<br>18 | 0.88496<br>0.0001<br>18 | 1.00000<br>0.0000<br>19 | 0.80672<br>0.0001<br>19 |
| 050C004 | 0.78890<br>0.0001<br>19 | 0.79537<br>0.0001<br>22 | 0.79429<br>0.0001<br>22 | 0.62642<br>0.0018<br>22 | 0.76585<br>0.0001<br>19 | 0.58825<br>0.0269<br>14 | 0.78839<br>0.0067<br>10 | 0.96666<br>0.0001<br>15 | 0.80695<br>0.0001<br>21 | 0.99225<br>0.0001<br>19 | 0.98996<br>0.0001<br>12 | 0.75786<br>0.0001<br>22 | 0.75219<br>0.0003<br>18 | 0.63692<br>0.0025<br>20 | 0.95220<br>0.0001<br>10 | -0.21898<br>0.3677<br>19 | 0.84743<br>0.0001<br>18 | 0.84248<br>0.0001<br>18 | 0.80672<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-16

## Spearman Correlation Coefficients* for Pembina River Basin September Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.41662<br>0.0760<br>19 | 0.57990<br>0.0093<br>19 | 0.47116<br>0.0417<br>19 | 0.48313<br>0.0361<br>19 | 0.29107<br>0.3127<br>14 | 0.50007<br>0.1410<br>10 | 0.26126<br>0.3469<br>15 | 0.42417<br>0.0794<br>18 | 0.08374<br>0.7332<br>19 | 0.32733<br>0.4287<br>8 | 0.27538<br>0.2538<br>19 | 0.41211<br>0.1127<br>16 | 0.07130<br>0.7718<br>19 | 0.36538<br>0.2892<br>10 | 0.06172<br>0.8018<br>19 | 0.16326<br>0.5175<br>18 | -0.00821<br>0.9742<br>18 | 0.17636<br>0.4701<br>19 | 0.09619<br>0.6953<br>19 |
| 050A006 | 0.41662<br>0.0760<br>19 | 1.00000<br>0.0000<br>22 | 0.67187<br>0.0006<br>22 | 0.70415<br>0.0003<br>22 | 0.84257<br>0.0001<br>19 | 0.80176<br>0.0006<br>14 | 0.79414<br>0.0061<br>10 | 0.66786<br>0.0065<br>15 | 0.21216<br>0.3559<br>21 | 0.65555<br>0.0023<br>19 | 0.76150<br>0.0065<br>11 | 0.49012<br>0.0206<br>22 | 0.17918<br>0.4768<br>18 | 0.16151<br>0.4963<br>20 | 0.87879<br>0.0008<br>10 | -0.38824<br>0.1005<br>19 | 0.66701<br>0.0025<br>18 | 0.60757<br>0.9762<br>18 | 0.42413<br>0.0703<br>19 | 0.63726<br>0.0014<br>22 |
| 050A007 | 0.57990<br>0.0093<br>19 | 0.67187<br>0.0006<br>22 | 1.00000<br>0.0000<br>22 | 0.49058<br>0.0204<br>22 | 0.42983<br>0.0662<br>19 | 0.30651<br>0.2865<br>14 | 0.34392<br>0.3305<br>10 | 0.63986<br>0.0102<br>15 | 0.33176<br>0.1418<br>21 | 0.45479<br>0.0504<br>19 | 0.52107<br>0.1003<br>11 | 0.39637<br>0.0678<br>22 | 0.13566<br>0.5915<br>18 | 0.53513<br>0.0150<br>20 | 0.77812<br>0.0080<br>10 | 0.04469<br>0.8558<br>19 | 0.51833<br>0.0275<br>18 | 0.06868<br>0.7865<br>18 | 0.27159<br>0.2607<br>19 | 0.44690<br>0.0371<br>22 |
| 050A008 | 0.47116<br>0.0417<br>19 | 0.70415<br>0.0003<br>22 | 0.49058<br>0.0204<br>22 | 1.00000<br>0.0000<br>22 | 0.74828<br>0.0002<br>19 | 0.94436<br>0.0001<br>14 | 0.94839<br>0.0001<br>10 | 0.23244<br>0.4045<br>15 | 0.17228<br>0.4552<br>21 | 0.13314<br>0.5869<br>19 | 0.52232<br>0.0993<br>11 | 0.63829<br>0.0014<br>22 | 0.15546<br>0.5379<br>18 | -0.06114<br>0.7979<br>20 | 0.22511<br>0.5318<br>10 | -0.21588<br>0.3747<br>19 | 0.35844<br>0.1441<br>18 | -0.29236<br>0.2391<br>18 | 0.42909<br>0.0668<br>19 | 0.15795<br>0.4827<br>22 |
| 050A010 | 0.48313<br>0.0361<br>19 | 0.84257<br>0.0001<br>19 | 0.42983<br>0.0662<br>19 | 0.74828<br>0.0002<br>19 | 1.00000<br>0.0000<br>19 | 0.91814<br>0.0001<br>14 | 0.82478<br>0.0033<br>10 | 0.54839<br>0.0343<br>15 | -0.03180<br>0.9003<br>18 | 0.36659<br>0.1226<br>19 | 0.85031<br>0.0075<br>8 | 0.56747<br>0.0113<br>19 | 0.18168<br>0.5007<br>16 | -0.21172<br>0.3842<br>19 | 0.61968<br>0.0560<br>10 | -0.53064<br>0.0194<br>19 | 0.42939<br>0.0754<br>18 | -0.12085<br>0.6329<br>18 | 0.32246<br>0.1782<br>19 | 0.32879<br>0.1693<br>19 |
| 050A012 | 0.29107<br>0.3127<br>14 | 0.80176<br>0.0006<br>14 | 0.30651<br>0.2865<br>14 | 0.94436<br>0.0001<br>14 | 0.91814<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.92200<br>0.0001<br>10 | 0.33040<br>0.2486<br>14 | 0.07873<br>0.7982<br>13 | 0.37445<br>0.1872<br>14 | 0.93697<br>0.0019<br>7 | 0.58388<br>0.0285<br>14 | 0.21940<br>0.4511<br>14 | -0.19287<br>0.5088<br>14 | 0.50422<br>0.1663<br>9 | -0.51490<br>0.0595<br>14 | 0.55066<br>0.0413<br>14 | -0.15819<br>0.5891<br>14 | 0.31569<br>0.2716<br>14 | 0.31057<br>0.2798<br>14 |
| 050A013 | 0.50007<br>0.1410<br>10 | 0.79414<br>0.0061<br>10 | 0.34392<br>0.3305<br>10 | 0.94839<br>0.0001<br>10 | 0.82478<br>0.0033<br>10 | 0.92200<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.26888<br>0.4525<br>10 | 0.20080<br>0.5780<br>10 | 0.26888<br>0.4525<br>10 | 1.00000<br>0.0000<br>3 | 0.48693<br>0.1535<br>10 | 0.43277<br>0.2116<br>10 | -0.45926<br>0.1818<br>10 | 0.44721<br>0.4502<br>5 | -0.35921<br>0.3080<br>10 | 0.70034<br>0.0241<br>10 | -0.21952<br>0.5423<br>10 | 0.53882<br>0.1080<br>10 | 0.24387<br>0.4971<br>10 |
| 050B001 | 0.26126<br>0.3469<br>15 | 0.66786<br>0.0065<br>15 | 0.63986<br>0.0102<br>15 | 0.23244<br>0.4045<br>15 | 0.54839<br>0.0343<br>15 | 0.33040<br>0.2486<br>14 | 0.26888<br>0.4525<br>10 | 1.00000<br>0.0000<br>15 | 0.30887<br>0.2826<br>14 | 0.98571<br>0.0001<br>15 | 0.96429<br>0.0005<br>7 | 0.17670<br>0.5287<br>15 | 0.38606<br>0.1552<br>15 | 0.37333<br>0.1705<br>15 | 0.98333<br>0.0001<br>9 | -0.24293<br>0.3830<br>15 | 0.83929<br>0.0001<br>15 | 0.45412<br>0.0890<br>15 | 0.41357<br>0.1254<br>15 | 0.96429<br>0.0001<br>15 |
| 050B006 | 0.42417<br>0.0794<br>18 | 0.21216<br>0.3559<br>21 | 0.33176<br>0.1418<br>21 | 0.17228<br>0.4552<br>21 | -0.03180<br>0.9003<br>18 | 0.07873<br>0.7982<br>13 | 0.20080<br>0.5780<br>10 | 0.30887<br>0.2826<br>14 | 1.00000<br>0.0000<br>21 | 0.29069<br>0.2419<br>18 | 0.23355<br>0.5161<br>10 | 0.34232<br>0.1288<br>21 | 0.59991<br>0.0109<br>17 | 0.37467<br>0.1140<br>19 | 0.63901<br>0.0639<br>9 | 0.30356<br>0.2207<br>18 | 0.23952<br>0.3545<br>17 | 0.49608<br>0.0428<br>17 | 0.39557<br>0.1042<br>18 | 0.14500<br>0.5306<br>21 |
| 050B007 | 0.08374<br>0.7332<br>19 | 0.65555<br>0.0023<br>19 | 0.45479<br>0.0504<br>19 | 0.13314<br>0.5869<br>19 | 0.36659<br>0.1226<br>19 | 0.37445<br>0.1872<br>14 | 0.26888<br>0.4525<br>10 | 0.98571<br>0.0001<br>15 | 0.29069<br>0.2419<br>18 | 1.00000<br>0.0000<br>19 | 0.92857<br>0.0009<br>8 | 0.24121<br>0.3198<br>19 | 0.39175<br>0.1334<br>16 | 0.30307<br>0.2072<br>19 | 0.95152<br>0.0001<br>10 | -0.27643<br>0.2519<br>19 | 0.87616<br>0.0001<br>18 | 0.38162<br>0.1181<br>18 | 0.36318<br>0.1264<br>19 | 0.98246<br>0.0001<br>19 |
| 050B008 | 0.32733<br>0.4287<br>8 | 0.76150<br>0.0065<br>11 | 0.52107<br>0.1003<br>11 | 0.52232<br>0.0993<br>11 | 0.85031<br>0.0075<br>8 | 0.93697<br>0.0019<br>7 | 1.00000<br>0.0000<br>3 | 0.96429<br>0.0005<br>7 | 0.23355<br>0.5161<br>10 | 0.92857<br>0.0009<br>8 | 1.00000<br>0.0000<br>12 | 0.34746<br>0.2951<br>11 | 0.32827<br>0.3544<br>10 | 0.42649<br>0.2523<br>9 | 0.97619<br>0.0001<br>8 | -0.40526<br>0.3192<br>8 | 0.96429<br>0.0005<br>7 | 0.21673<br>0.6406<br>7 | 0.70921<br>0.0488<br>8 | 0.94406<br>0.0001<br>12 |
| 050B010 | 0.27538<br>0.2538<br>19 | 0.49012<br>0.0206<br>22 | 0.39637<br>0.0678<br>22 | 0.63829<br>0.0014<br>22 | 0.56747<br>0.0113<br>19 | 0.58358<br>0.0285<br>14 | 0.48693<br>0.1535<br>10 | 0.17670<br>0.5287<br>15 | 0.34232<br>0.1288<br>21 | 0.24121<br>0.3198<br>19 | 0.34746<br>0.2951<br>11 | 1.00000<br>0.0000<br>22 | 0.16757<br>0.5063<br>18 | 0.27946<br>0.2328<br>20 | 0.36538<br>0.2892<br>10 | -0.39119<br>0.0977<br>19 | 0.22352<br>0.3726<br>18 | -0.10681<br>0.6732<br>18 | 0.53215<br>0.0190<br>19 | 0.12236<br>0.5875<br>22 |
| 050B013 | 0.41211<br>0.1127<br>16 | 0.17918<br>0.4768<br>18 | 0.13566<br>0.5915<br>18 | 0.15546<br>0.5379<br>18 | 0.18168<br>0.5007<br>16 | 0.21940<br>0.4511<br>14 | 0.43277<br>0.2116<br>10 | 0.38606<br>0.1552<br>15 | 0.59991<br>0.0109<br>17 | 0.39175<br>0.1334<br>16 | 0.32827<br>0.3544<br>10 | 0.16757<br>0.5063<br>18 | 1.00000<br>0.0000<br>18 | -0.24033<br>0.3528<br>17 | 0.43161<br>0.2129<br>10 | 0.36374<br>0.1661<br>16 | 0.29669<br>0.2829<br>15 | 0.07853<br>0.7809<br>15 | 0.52715<br>0.0359<br>16 | 0.25530<br>0.3066<br>18 |
| 050B016 | 0.07130<br>0.7718<br>19 | 0.16151<br>0.4963<br>20 | 0.53513<br>0.0150<br>20 | -0.06114<br>0.7979<br>20 | -0.21172<br>0.3842<br>19 | -0.19287<br>0.5088<br>14 | -0.45926<br>0.1818<br>10 | 0.37333<br>0.1705<br>15 | 0.37467<br>0.1140<br>19 | 0.30307<br>0.2072<br>19 | 0.42649<br>0.2523<br>9 | 0.27946<br>0.2328<br>20 | -0.24033<br>0.3528<br>17 | 1.00000<br>0.0000<br>20 | 0.64422<br>0.0444<br>10 | 0.13505<br>0.5815<br>19 | 0.22850<br>0.3618<br>18 | 0.40823<br>0.0926<br>18 | 0.15787<br>0.5186<br>19 | 0.35429<br>0.1254<br>20 |
| 050B019 | 0.36538<br>0.2892<br>10 | 0.87879<br>0.0008<br>10 | 0.77812<br>0.0080<br>10 | 0.22511<br>0.5318<br>10 | 0.61968<br>0.0560<br>10 | 0.50422<br>0.1663<br>9 | 0.44721<br>0.4502<br>5 | 0.98333<br>0.0001<br>9 | 0.63901<br>0.0639<br>9 | 0.95152<br>0.0001<br>10 | 0.97619<br>0.0001<br>8 | 0.36538<br>0.2892<br>10 | 0.43161<br>0.2129<br>10 | 0.64422<br>0.0444<br>10 | 1.00000<br>0.0000<br>10 | -0.21624<br>0.5485<br>10 | 0.86667<br>0.0025<br>9 | 0.54834<br>0.1264<br>9 | 0.42503<br>0.2208<br>10 | 0.95152<br>0.0001<br>10 |
| 050B021 | 0.06172<br>0.8018<br>19 | -0.38824<br>0.1005<br>19 | 0.04469<br>0.8558<br>19 | -0.21588<br>0.3747<br>19 | -0.53064<br>0.0194<br>19 | -0.51490<br>0.0595<br>14 | -0.35921<br>0.3080<br>10 | -0.24293<br>0.3830<br>15 | 0.30356<br>0.2207<br>18 | -0.27643<br>0.2519<br>19 | -0.40526<br>0.3192<br>8 | -0.39119<br>0.0977<br>19 | 0.36374<br>0.1661<br>16 | 0.13505<br>0.5815<br>19 | -0.21624<br>0.5485<br>10 | 1.00000<br>0.0000<br>19 | -0.27657<br>0.2666<br>18 | -0.30325<br>0.2212<br>18 | -0.08703<br>0.7231<br>19 | -0.29982<br>0.2124<br>19 |
| 050B023 | 0.16326<br>0.5175<br>18 | 0.66701<br>0.0025<br>18 | 0.51833<br>0.0275<br>18 | 0.35844<br>0.1441<br>18 | 0.42939<br>0.0754<br>18 | 0.55066<br>0.0413<br>14 | 0.70034<br>0.0241<br>10 | 0.83929<br>0.0001<br>15 | 0.23952<br>0.3545<br>17 | 0.87616<br>0.0001<br>18 | 0.96429<br>0.0005<br>7 | 0.22352<br>0.3726<br>18 | 0.29669<br>0.2829<br>15 | 0.22850<br>0.3618<br>18 | 0.86667<br>0.0025<br>9 | -0.27657<br>0.2666<br>18 | 1.00000<br>0.0000<br>18 | 0.25297<br>0.3111<br>18 | 0.46542<br>0.0516<br>18 | 0.84107<br>0.0001<br>18 |
| 050B025 | -0.00821<br>0.9742<br>18 | 0.00757<br>0.9762<br>18 | 0.06868<br>0.7865<br>18 | -0.29236<br>0.2391<br>18 | -0.12085<br>0.6329<br>18 | -0.15819<br>0.5891<br>14 | -0.21952<br>0.5423<br>10 | 0.45412<br>0.0890<br>15 | 0.49608<br>0.0428<br>17 | 0.38162<br>0.1181<br>18 | 0.21673<br>0.6406<br>7 | -0.10681<br>0.6732<br>18 | 0.07853<br>0.7809<br>15 | 0.40823<br>0.0926<br>18 | 0.54834<br>0.1264<br>9 | -0.30325<br>0.2212<br>18 | 0.25297<br>0.3111<br>18 | 1.00000<br>0.0000<br>18 | 0.00000<br>1.0000<br>18 | 0.42162<br>0.0814<br>18 |
| 050B031 | 0.17636<br>0.4701<br>19 | 0.42413<br>0.0703<br>19 | 0.27159<br>0.2607<br>19 | 0.42909<br>0.0668<br>19 | 0.32246<br>0.1782<br>19 | 0.31569<br>0.2716<br>14 | 0.53882<br>0.1080<br>10 | 0.41357<br>0.1254<br>15 | 0.39557<br>0.1042<br>18 | 0.36318<br>0.1264<br>19 | 0.70921<br>0.0488<br>8 | 0.53215<br>0.0190<br>19 | 0.52715<br>0.0359<br>16 | 0.15787<br>0.5186<br>19 | 0.42503<br>0.2208<br>10 | -0.08703<br>0.7231<br>19 | 0.46542<br>0.0516<br>18 | 0.00000<br>1.0000<br>18 | 1.00000<br>0.0000<br>19 | 0.33694<br>0.1583<br>19 |
| 050C004 | 0.09619<br>0.6953<br>19 | 0.63726<br>0.0014<br>22 | 0.44690<br>0.0371<br>22 | 0.15795<br>0.4827<br>22 | 0.32879<br>0.1693<br>19 | 0.31057<br>0.2798<br>14 | 0.24387<br>0.4971<br>10 | 0.96429<br>0.0001<br>15 | 0.14500<br>0.5306<br>21 | 0.98246<br>0.0001<br>19 | 0.94406<br>0.0001<br>12 | 0.12236<br>0.5875<br>22 | 0.25530<br>0.3066<br>18 | 0.35429<br>0.1254<br>20 | 0.95152<br>0.0001<br>10 | -0.29982<br>0.2124<br>19 | 0.84107<br>0.0001<br>18 | 0.42162<br>0.0814<br>18 | 0.33694<br>0.1583<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

# Table C-17

## Pearson Correlation Coefficients* for Pembina River Basin October Monthly Mean Flows

| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.09556<br>0.6972<br>19 | 0.29149<br>0.2260<br>19 | 0.04291<br>0.8615<br>19 | 0.31063<br>0.1955<br>19 | -0.06667<br>0.8208<br>14 | 0.25509<br>0.4769<br>10 | 0.81770<br>0.0002<br>15 | 0.00000<br>1.0000<br>18 | 0.22878<br>0.3461<br>19 | 0.84831<br>0.0078<br>8 | 0.15887<br>0.5159<br>19 | 0.72949<br>0.0013<br>16 | 0.02397<br>0.9224<br>19 | 0.81202<br>0.0043<br>10 | 0.61897<br>0.0047<br>19 | 0.31750<br>0.1992<br>18 | 0.23074<br>0.3570<br>18 | 0.24889<br>0.3022<br>19 | 0.24051<br>0.3213<br>19 |
| 050A006 | 0.09556<br>0.6972<br>19 | 1.00000<br>0.0000<br>22 | 0.80674<br>0.0001<br>22 | 0.76527<br>0.0001<br>22 | 0.77877<br>0.0001<br>19 | 0.70036<br>0.0053<br>14 | 0.93900<br>0.0001<br>10 | 0.45089<br>0.0916<br>15 | 0.90828<br>0.0001<br>21 | 0.46225<br>0.0463<br>19 | 0.11121<br>0.7448<br>11 | -0.10807<br>0.6322<br>22 | 0.12456<br>0.6224<br>18 | 0.04066<br>0.8649<br>20 | 0.50445<br>0.1370<br>10 | -0.13627<br>0.5780<br>19 | 0.37040<br>0.1303<br>18 | 0.69016<br>0.0015<br>18 | 0.38726<br>0.1014<br>19 | 0.11853<br>0.5993<br>22 |
| 050A007 | 0.29149<br>0.2260<br>19 | 0.80674<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.50383<br>0.0168<br>22 | 0.26050<br>0.2814<br>19 | 0.05054<br>0.8638<br>14 | 0.69998<br>0.0242<br>10 | 0.47298<br>0.0750<br>15 | 0.68022<br>0.0007<br>21 | 0.40893<br>0.0821<br>19 | 0.25713<br>0.4453<br>11 | -0.10915<br>0.6287<br>22 | 0.28456<br>0.2524<br>18 | 0.10646<br>0.6551<br>20 | 0.42883<br>0.2162<br>10 | 0.06021<br>0.8066<br>19 | 0.45701<br>0.0566<br>18 | 0.41436<br>0.0873<br>18 | 0.74070<br>0.0003<br>19 | 0.26246<br>0.2380<br>22 |
| 050A008 | 0.04291<br>0.8615<br>19 | 0.76527<br>0.0001<br>22 | 0.50383<br>0.0168<br>22 | 1.00000<br>0.0000<br>22 | 0.89370<br>0.0001<br>19 | 0.91911<br>0.0001<br>14 | 0.68902<br>0.0275<br>10 | 0.02811<br>0.9208<br>15 | 0.60216<br>0.0039<br>21 | 0.03358<br>0.8914<br>19 | 0.04185<br>0.9028<br>11 | -0.07718<br>0.7328<br>22 | -0.15709<br>0.5336<br>18 | -0.06529<br>0.7845<br>20 | 0.30880<br>0.3853<br>10 | -0.03597<br>0.8838<br>19 | 0.01694<br>0.9468<br>18 | 0.15633<br>0.5356<br>18 | 0.00288<br>0.9907<br>19 | -0.01038<br>0.9635<br>22 |
| 050A010 | 0.31063<br>0.1955<br>19 | 0.77877<br>0.0001<br>19 | 0.26050<br>0.2814<br>19 | 0.89370<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.92070<br>0.0001<br>14 | 0.90140<br>0.0004<br>10 | 0.32483<br>0.2375<br>15 | 0.00000<br>1.0000<br>18 | 0.29356<br>0.2225<br>19 | 0.88848<br>0.0032<br>8 | 0.03482<br>0.8875<br>19 | 0.09935<br>0.7143<br>16 | -0.12495<br>0.6103<br>19 | 0.58783<br>0.0739<br>10 | 0.02645<br>0.9144<br>19 | 0.27275<br>0.2735<br>18 | 0.44985<br>0.0611<br>18 | 0.15353<br>0.5303<br>19 | 0.28789<br>0.2320<br>19 |
| 050A012 | -0.06667<br>0.8208<br>14 | 0.70036<br>0.0053<br>14 | 0.05054<br>0.8638<br>14 | 0.91911<br>0.0001<br>14 | 0.92070<br>0.0001<br>14 | 1.00000<br>0.0000<br>14 | 0.77275<br>0.0088<br>10 | 0.08545<br>0.7715<br>14 | 0.00000<br>1.0000<br>13 | 0.08693<br>0.7676<br>14 | 0.91870<br>0.0035<br>7 | -0.18389<br>0.5291<br>14 | -0.04958<br>0.8663<br>14 | -0.22849<br>0.4320<br>14 | 0.39094<br>0.2982<br>9 | -0.19327<br>0.5080<br>14 | 0.03692<br>0.9003<br>14 | 0.21771<br>0.4546<br>14 | -0.04307<br>0.8838<br>14 | 0.05930<br>0.8404<br>14 |
| 050A013 | 0.25509<br>0.4769<br>10 | 0.93900<br>0.0001<br>10 | 0.69998<br>0.0242<br>10 | 0.68902<br>0.0275<br>10 | 0.90140<br>0.0004<br>10 | 0.77275<br>0.0088<br>10 | 1.00000<br>0.0000<br>10 | 0.33102<br>0.3502<br>10 | 0.00000<br>1.0000<br>10 | 0.30838<br>0.3860<br>10 | 0.96447<br>0.1702<br>3 | -0.09018<br>0.8043<br>10 | 0.35582<br>0.3129<br>10 | -0.34775<br>0.3248<br>10 | 0.40348<br>0.5006<br>5 | -0.33196<br>0.3487<br>10 | 0.28477<br>0.4252<br>10 | 0.60953<br>0.0614<br>10 | 0.23490<br>0.5136<br>10 | 0.29842<br>0.4023<br>10 |
| 050B001 | 0.81770<br>0.0002<br>15 | 0.45089<br>0.0916<br>15 | 0.47298<br>0.0750<br>15 | 0.02811<br>0.9208<br>15 | 0.32483<br>0.2375<br>15 | 0.08545<br>0.7715<br>14 | 0.33102<br>0.3502<br>10 | 1.00000<br>0.0000<br>15 | 0.00000<br>1.0000<br>14 | 0.99674<br>0.0001<br>15 | 0.99871<br>0.0001<br>7 | -0.14802<br>0.5986<br>15 | 0.75978<br>0.0010<br>15 | -0.11539<br>0.6822<br>15 | 0.99893<br>0.0001<br>9 | 0.05081<br>0.8573<br>15 | 0.97382<br>0.0001<br>15 | 0.82309<br>0.0002<br>15 | 0.82539<br>0.0002<br>15 | 0.99489<br>0.0001<br>15 |
| 050B006 | 0.00000<br>1.0000<br>18 | 0.90828<br>0.0001<br>21 | 0.68022<br>0.0007<br>21 | 0.60216<br>0.0039<br>21 | 0.00000<br>1.0000<br>18 | 0.00000<br>1.0000<br>13 | 0.00000<br>1.0000<br>10 | 0.00000<br>1.0000<br>14 | 1.00000<br>0.0000<br>21 | 0.00000<br>1.0000<br>18 | -0.09466<br>0.7948<br>10 | -0.05666<br>0.8073<br>21 | 0.00000<br>1.0000<br>17 | 0.00000<br>1.0000<br>19 | 0.00000<br>1.0000<br>9 | 0.00000<br>1.0000<br>18 | 0.00000<br>1.0000<br>17 | 0.00000<br>1.0000<br>17 | 0.00000<br>1.0000<br>18 | -0.09954<br>0.6677<br>21 |
| 050B007 | 0.22878<br>0.3461<br>19 | 0.46225<br>0.0463<br>19 | 0.40893<br>0.0821<br>19 | 0.03358<br>0.8914<br>19 | 0.29356<br>0.2225<br>19 | 0.08693<br>0.7676<br>14 | 0.30838<br>0.3860<br>10 | 0.99674<br>0.0001<br>15 | 0.00000<br>1.0000<br>18 | 1.00000<br>0.0000<br>19 | 0.99966<br>0.0001<br>8 | -0.11027<br>0.6531<br>19 | 0.74311<br>0.0010<br>16 | -0.07164<br>0.7707<br>19 | 0.99825<br>0.0001<br>10 | -0.15982<br>0.5134<br>19 | 0.96179<br>0.0001<br>18 | 0.82669<br>0.0001<br>18 | 0.80417<br>0.0001<br>19 | 0.99425<br>0.0001<br>19 |
| 050B008 | 0.84831<br>0.0078<br>8 | 0.11121<br>0.7448<br>11 | 0.25713<br>0.4453<br>11 | 0.04185<br>0.9028<br>11 | 0.88848<br>0.0032<br>8 | 0.91870<br>0.0035<br>7 | 0.96447<br>0.1702<br>3 | 0.99871<br>0.0001<br>7 | -0.09466<br>0.7948<br>10 | 0.99966<br>0.0001<br>8 | 1.00000<br>0.0000<br>12 | -0.12989<br>0.7035<br>11 | 0.83673<br>0.0025<br>10 | -0.10972<br>0.7787<br>9 | 0.99885<br>0.0001<br>8 | 0.00000<br>1.0000<br>8 | 0.99624<br>0.0001<br>7 | 0.98708<br>0.0001<br>7 | 0.83770<br>0.0094<br>8 | 0.99509<br>0.0001<br>12 |
| 050B010 | 0.15887<br>0.5159<br>19 | -0.10807<br>0.6322<br>22 | -0.10915<br>0.6287<br>22 | -0.07718<br>0.7328<br>22 | 0.03482<br>0.8875<br>19 | -0.18389<br>0.5291<br>14 | -0.09018<br>0.8043<br>10 | -0.14802<br>0.5986<br>15 | -0.05666<br>0.8073<br>21 | -0.11027<br>0.6531<br>19 | -0.12989<br>0.7035<br>11 | 1.00000<br>0.0000<br>22 | -0.00512<br>0.9839<br>18 | -0.10077<br>0.6725<br>20 | -0.19182<br>0.5955<br>10 | -0.06795<br>0.7823<br>19 | -0.08687<br>0.7318<br>18 | -0.10285<br>0.6847<br>18 | -0.09042<br>0.7128<br>19 | -0.06776<br>0.7645<br>22 |
| 050B013 | 0.72949<br>0.0013<br>16 | 0.12456<br>0.6224<br>18 | 0.28456<br>0.2524<br>18 | -0.15709<br>0.5336<br>18 | 0.09935<br>0.7143<br>16 | -0.04958<br>0.8663<br>14 | 0.35582<br>0.3129<br>10 | 0.75978<br>0.0010<br>15 | 0.00000<br>1.0000<br>17 | 0.74311<br>0.0010<br>16 | 0.83673<br>0.0025<br>10 | -0.00512<br>0.9839<br>18 | 1.00000<br>0.0000<br>18 | -0.28805<br>0.2622<br>17 | 0.93502<br>0.0001<br>10 | -0.06367<br>0.8148<br>16 | 0.76894<br>0.0008<br>15 | 0.65987<br>0.0074<br>15 | 0.68429<br>0.0035<br>16 | 0.65559<br>0.0031<br>18 |
| 050B016 | 0.02397<br>0.9224<br>19 | 0.04066<br>0.8649<br>20 | 0.10646<br>0.6551<br>20 | -0.06529<br>0.7845<br>20 | -0.12495<br>0.6103<br>19 | -0.22849<br>0.4320<br>14 | -0.34775<br>0.3248<br>10 | -0.11539<br>0.6822<br>15 | 0.00000<br>1.0000<br>19 | -0.07164<br>0.7707<br>19 | -0.10972<br>0.7787<br>9 | -0.10077<br>0.6725<br>20 | -0.28805<br>0.2622<br>17 | 1.00000<br>0.0000<br>20 | -0.17286<br>0.6330<br>10 | -0.00943<br>0.9695<br>19 | -0.08839<br>0.7273<br>18 | -0.02122<br>0.9334<br>18 | 0.02163<br>0.9300<br>19 | -0.05453<br>0.8184<br>20 |
| 050B019 | 0.81202<br>0.0043<br>10 | 0.50445<br>0.1370<br>10 | 0.42883<br>0.2162<br>10 | 0.30880<br>0.3853<br>10 | 0.58783<br>0.0739<br>10 | 0.39094<br>0.2982<br>9 | 0.40348<br>0.5006<br>5 | 0.99893<br>0.0001<br>9 | 0.00000<br>1.0000<br>9 | 0.99825<br>0.0001<br>10 | 0.99885<br>0.0001<br>8 | -0.19182<br>0.5955<br>10 | 0.93502<br>0.0001<br>10 | -0.17286<br>0.6330<br>10 | 1.00000<br>0.0000<br>10 | 0.00878<br>0.9808<br>10 | 0.97706<br>0.0001<br>9 | 0.83650<br>0.0049<br>9 | 0.81631<br>0.0040<br>10 | 0.99603<br>0.0001<br>10 |
| 050B021 | 0.61897<br>0.0047<br>19 | -0.13627<br>0.5780<br>19 | 0.06021<br>0.8066<br>19 | -0.03597<br>0.8838<br>19 | 0.02645<br>0.9144<br>19 | -0.19327<br>0.5080<br>14 | -0.33196<br>0.3487<br>10 | 0.05081<br>0.8573<br>15 | 0.00000<br>1.0000<br>18 | -0.15982<br>0.5134<br>19 | 0.00000<br>1.0000<br>8 | -0.06795<br>0.7823<br>19 | -0.06367<br>0.8148<br>16 | -0.00943<br>0.9695<br>19 | 0.00878<br>0.9808<br>10 | 1.00000<br>0.0000<br>19 | -0.13691<br>0.5880<br>18 | -0.12910<br>0.6097<br>18 | -0.11946<br>0.6262<br>19 | -0.16667<br>0.4952<br>19 |
| 050B023 | 0.31750<br>0.1992<br>18 | 0.37040<br>0.1303<br>18 | 0.45701<br>0.0566<br>18 | 0.01694<br>0.9468<br>18 | 0.27275<br>0.2735<br>18 | 0.03692<br>0.9003<br>14 | 0.28477<br>0.4252<br>10 | 0.97382<br>0.0001<br>15 | 0.00000<br>1.0000<br>17 | 0.96179<br>0.0001<br>18 | 0.99624<br>0.0001<br>7 | -0.08687<br>0.7318<br>18 | 0.76894<br>0.0008<br>15 | -0.08839<br>0.7273<br>18 | 0.97706<br>0.0001<br>9 | -0.13691<br>0.5880<br>18 | 1.00000<br>0.0000<br>18 | 0.75873<br>0.0003<br>18 | 0.86643<br>0.0001<br>18 | 0.95321<br>0.0001<br>18 |
| 050B025 | 0.23074<br>0.3570<br>18 | 0.69016<br>0.0015<br>18 | 0.41436<br>0.0873<br>18 | 0.15633<br>0.5356<br>18 | 0.44985<br>0.0611<br>18 | 0.21771<br>0.4546<br>14 | 0.60953<br>0.0614<br>10 | 0.82309<br>0.0002<br>15 | 0.00000<br>1.0000<br>17 | 0.82669<br>0.0001<br>18 | 0.98708<br>0.0001<br>7 | -0.10285<br>0.6847<br>18 | 0.65987<br>0.0074<br>15 | -0.02122<br>0.9334<br>18 | 0.83650<br>0.0049<br>9 | -0.12910<br>0.6097<br>18 | 0.75873<br>0.0003<br>18 | 1.00000<br>0.0000<br>18 | 0.59649<br>0.0090<br>18 | 0.82416<br>0.0001<br>18 |
| 050B031 | 0.24989<br>0.3022<br>19 | 0.38726<br>0.1014<br>19 | 0.74070<br>0.0003<br>19 | 0.00288<br>0.9907<br>19 | 0.15353<br>0.5303<br>19 | -0.04307<br>0.8838<br>14 | 0.23490<br>0.5136<br>10 | 0.82539<br>0.0002<br>15 | 0.00000<br>1.0000<br>18 | 0.80417<br>0.0001<br>19 | 0.83770<br>0.0094<br>8 | -0.09042<br>0.7128<br>19 | 0.68429<br>0.0035<br>16 | 0.02163<br>0.9300<br>19 | 0.81631<br>0.0040<br>10 | -0.11946<br>0.6262<br>19 | 0.86643<br>0.0001<br>18 | 0.59649<br>0.0090<br>18 | 1.00000<br>0.0000<br>19 | 0.80155<br>0.0001<br>19 |
| 050C004 | 0.24051<br>0.3213<br>19 | 0.11853<br>0.5993<br>22 | 0.26246<br>0.2380<br>22 | -0.01038<br>0.9635<br>22 | 0.28789<br>0.2320<br>19 | 0.05930<br>0.8404<br>14 | 0.29842<br>0.4023<br>10 | 0.99489<br>0.0001<br>15 | -0.09954<br>0.6677<br>21 | 0.99425<br>0.0001<br>19 | 0.99509<br>0.0001<br>12 | -0.06776<br>0.7645<br>22 | 0.65559<br>0.0031<br>18 | -0.05453<br>0.8194<br>20 | 0.99603<br>0.0001<br>10 | -0.16667<br>0.4952<br>19 | 0.95321<br>0.0001<br>18 | 0.82416<br>0.0001<br>18 | 0.80155<br>0.0001<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

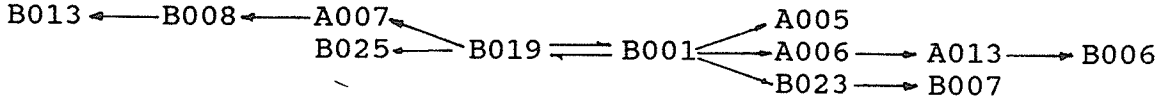
# Table C-18

## Spearman Correlation Coefficients* for Pembina River Basin October Monthly Mean Flows

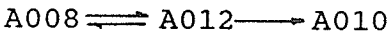
| | 050A005 | 050A006 | 050A007 | 050A008 | 050A010 | 050A012 | 050A013 | 050B001 | 050B006 | 050B007 | 050B008 | 050B010 | 050B013 | 050B016 | 050B019 | 050B021 | 050B023 | 050B025 | 050B031 | 050C004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 050A005 | 1.00000<br>0.0000<br>19 | 0.28790<br>0.2320<br>19 | 0.46096<br>0.0470<br>19 | 0.45402<br>0.0509<br>19 | 0.51428<br>0.0243<br>19 | 0.09696<br>0.7416<br>14 | 0.34151<br>0.3341<br>10 | 0.25529<br>0.3585<br>15 | 0.00000<br>1.0000<br>18 | -0.02952<br>0.9045<br>19 | 0.32733<br>0.4287<br>8 | 0.40207<br>0.0879<br>19 | 0.30507<br>0.2506<br>16 | 0.00639<br>0.9793<br>19 | 0.23355<br>0.5161<br>10 | 0.22651<br>0.3511<br>19 | 0.26922<br>0.2800<br>18 | -0.07855<br>0.7537<br>18 | 0.28605<br>0.2351<br>19 | -0.06887<br>0.7794<br>19 |
| 050A006 | 0.28790<br>0.2320<br>19 | 1.00000<br>0.0000<br>22 | 0.76535<br>0.0001<br>22 | 0.81780<br>0.0001<br>22 | 0.78665<br>0.0001<br>19 | 0.90585<br>0.0001<br>14 | 0.93872<br>0.0001<br>10 | 0.70357<br>0.0034<br>15 | 0.36927<br>0.0995<br>21 | 0.60904<br>0.0056<br>19 | 0.74545<br>0.0085<br>11 | 0.15957<br>0.4781<br>22 | -0.12726<br>0.6148<br>18 | 0.41952<br>0.0656<br>20 | 0.86667<br>0.0012<br>10 | -0.12019<br>0.6240<br>19 | 0.58854<br>0.0102<br>18 | 0.16932<br>0.5018<br>18 | 0.44116<br>0.0587<br>19 | 0.55408<br>0.0075<br>22 |
| 050A007 | 0.46096<br>0.0470<br>19 | 0.76535<br>0.0001<br>22 | 1.00000<br>0.0000<br>22 | 0.63596<br>0.0015<br>22 | 0.50868<br>0.0258<br>19 | 0.42529<br>0.1295<br>14 | 0.60741<br>0.0625<br>10 | 0.71492<br>0.0027<br>15 | 0.37060<br>0.0982<br>21 | 0.46154<br>0.0467<br>19 | 0.49580<br>0.1209<br>11 | 0.06757<br>0.7651<br>22 | 0.13173<br>0.6023<br>18 | 0.39816<br>0.0821<br>20 | 0.65649<br>0.0392<br>10 | 0.23181<br>0.3396<br>19 | 0.69525<br>0.0014<br>18 | -0.02986<br>0.9064<br>18 | 0.53099<br>0.0193<br>19 | 0.44136<br>0.0398<br>22 |
| 050A008 | 0.45402<br>0.0509<br>19 | 0.81780<br>0.0001<br>22 | 0.63596<br>0.0015<br>22 | 1.00000<br>0.0000<br>22 | 0.81446<br>0.0001<br>19 | 0.85460<br>0.0001<br>14 | 0.95031<br>0.0001<br>10 | 0.49912<br>0.0582<br>15 | 0.34611<br>0.1243<br>21 | 0.33284<br>0.1638<br>19 | 0.64835<br>0.0310<br>11 | 0.42001<br>0.0516<br>22 | 0.12152<br>0.6310<br>18 | 0.21989<br>0.3516<br>20 | 0.59404<br>0.0702<br>10 | -0.12745<br>0.6031<br>19 | 0.48353<br>0.0421<br>18 | -0.02746<br>0.9139<br>18 | 0.28685<br>0.2338<br>19 | 0.34913<br>0.1113<br>22 |
| 050A010 | 0.51428<br>0.0243<br>19 | 0.78665<br>0.0001<br>19 | 0.50968<br>0.0258<br>19 | 0.81446<br>0.0001<br>19 | 1.00000<br>0.0000<br>19 | 0.84291<br>0.0002<br>14 | 0.91418<br>0.0002<br>10 | 0.62500<br>0.0127<br>15 | 0.00000<br>1.0000<br>18 | 0.47301<br>0.0408<br>19 | 0.66667<br>0.0710<br>8 | 0.40144<br>0.0885<br>19 | 0.13717<br>0.6125<br>16 | 0.10896<br>0.6570<br>19 | 0.72121<br>0.0186<br>10 | -0.10154<br>0.6791<br>19 | 0.61022<br>0.0072<br>18 | -0.05625<br>0.8246<br>18 | 0.26009<br>0.2822<br>19 | 0.40720<br>0.0836<br>19 |
| 050A012 | 0.09696<br>0.7416<br>14 | 0.90585<br>0.0001<br>14 | 0.42529<br>0.1295<br>14 | 0.85460<br>0.0001<br>14 | 0.84291<br>0.0002<br>14 | 1.00000<br>0.0000<br>14 | 0.95389<br>0.0001<br>10 | 0.59566<br>0.0246<br>14 | 0.00000<br>1.0000<br>13 | 0.66758<br>0.0091<br>14 | 0.90633<br>0.0049<br>7 | 0.04066<br>0.8902<br>14 | 0.09472<br>0.7474<br>14 | 0.03448<br>0.9068<br>14 | 0.88780<br>0.0014<br>9 | -0.10555<br>0.7195<br>14 | 0.47877<br>0.0833<br>14 | 0.29908<br>0.2989<br>14 | 0.21023<br>0.4707<br>14 | 0.54171<br>0.0454<br>14 |
| 050A013 | 0.34151<br>0.3341<br>10 | 0.93872<br>0.0001<br>10 | 0.60741<br>0.0625<br>10 | 0.95031<br>0.0001<br>10 | 0.91418<br>0.0002<br>10 | 0.95389<br>0.0001<br>10 | 1.00000<br>0.0000<br>10 | 0.43562<br>0.2083<br>10 | 0.00000<br>1.0000<br>10 | 0.42334<br>0.2228<br>10 | 1.00000<br>0.0000<br>3 | 0.13135<br>0.7176<br>10 | 0.44925<br>0.1927<br>10 | -0.24224<br>0.5001<br>10 | 0.71818<br>0.1718<br>5 | -0.41120<br>0.2378<br>10 | 0.37426<br>0.2867<br>10 | 0.21673<br>0.5476<br>10 | 0.17623<br>0.6263<br>10 | 0.26382<br>0.4614<br>10 |
| 050B001 | 0.25529<br>0.3585<br>15 | 0.70357<br>0.0034<br>15 | 0.71492<br>0.0027<br>15 | 0.49912<br>0.0582<br>15 | 0.62500<br>0.0127<br>15 | 0.59566<br>0.0246<br>14 | 0.43562<br>0.2083<br>10 | 1.00000<br>0.0000<br>15 | 0.00000<br>1.0000<br>14 | 0.96429<br>0.0001<br>15 | 0.96429<br>0.0005<br>7 | -0.19657<br>0.4826<br>15 | 0.43868<br>0.1019<br>15 | 0.15123<br>0.5906<br>15 | 1.00000<br>0.0000<br>9 | 0.30929<br>0.2620<br>15 | 0.86786<br>0.0001<br>15 | 0.25095<br>0.3670<br>15 | 0.50709<br>0.0537<br>15 | 0.97500<br>0.0001<br>15 |
| 050B006 | 0.00000<br>1.0000<br>18 | 0.36927<br>0.0995<br>21 | 0.37060<br>0.0982<br>21 | 0.34611<br>0.1243<br>21 | 0.00000<br>1.0000<br>18 | 0.00000<br>1.0000<br>13 | 0.00000<br>1.0000<br>10 | 0.00000<br>1.0000<br>14 | 1.00000<br>0.0000<br>21 | 0.00000<br>1.0000<br>18 | 0.05803<br>0.8735<br>10 | -0.10779<br>0.6419<br>21 | 0.00000<br>1.0000<br>17 | 0.00000<br>1.0000<br>19 | 0.00000<br>1.0000<br>9 | 0.00000<br>1.0000<br>18 | 0.00000<br>1.0000<br>17 | 0.00000<br>1.0000<br>17 | 0.00000<br>1.0000<br>18 | -0.07385<br>0.7504<br>21 |
| 050B007 | -0.02952<br>0.9045<br>19 | 0.60904<br>0.0056<br>19 | 0.46154<br>0.0467<br>19 | 0.33284<br>0.1638<br>19 | 0.47301<br>0.0408<br>19 | 0.66758<br>0.0091<br>14 | 0.42334<br>0.2228<br>10 | 0.96429<br>0.0001<br>15 | 0.00000<br>1.0000<br>18 | 1.00000<br>0.0000<br>19 | 1.00000<br>0.0000<br>8 | -0.24125<br>0.3197<br>19 | 0.30089<br>0.2575<br>16 | 0.12578<br>0.6079<br>19 | 0.98788<br>0.0001<br>10 | -0.07043<br>0.7745<br>19 | 0.80805<br>0.0001<br>18 | 0.26273<br>0.2922<br>18 | 0.44426<br>0.0567<br>19 | 0.95789<br>0.0001<br>19 |
| 050B008 | 0.32733<br>0.4287<br>8 | 0.74545<br>0.0085<br>11 | 0.49580<br>0.1209<br>11 | 0.64835<br>0.0310<br>11 | 0.66667<br>0.0710<br>8 | 0.90633<br>0.0049<br>7 | 1.00000<br>0.0000<br>3 | 0.96429<br>0.0005<br>7 | 0.05803<br>0.8735<br>10 | 1.00000<br>0.0000<br>8 | 1.00000<br>0.0000<br>12 | -0.20000<br>0.5554<br>11 | 0.37690<br>0.2830<br>10 | 0.18257<br>0.6382<br>9 | 0.97619<br>0.0001<br>8 | 0.00000<br>1.0000<br>8 | 0.92857<br>0.0025<br>7 | 0.61237<br>0.1438<br>7 | 0.76376<br>0.0274<br>8 | 0.95804<br>0.0001<br>12 |
| 050B010 | 0.40207<br>0.0879<br>19 | 0.15957<br>0.4781<br>22 | 0.06757<br>0.7651<br>22 | 0.42001<br>0.0516<br>22 | 0.40144<br>0.0885<br>19 | 0.04066<br>0.8902<br>14 | 0.13135<br>0.7176<br>10 | -0.19657<br>0.4826<br>15 | -0.10779<br>0.6419<br>21 | -0.24125<br>0.3197<br>19 | -0.20000<br>0.5554<br>11 | 1.00000<br>0.0000<br>22 | -0.22774<br>0.3634<br>18 | 0.22118<br>0.3487<br>20 | -0.29013<br>0.4161<br>10 | 0.12498<br>0.6102<br>19 | -0.13616<br>0.5901<br>18 | -0.22943<br>0.3598<br>18 | -0.17547<br>0.4724<br>19 | -0.11251<br>0.6181<br>22 |
| 050B013 | 0.30507<br>0.2506<br>16 | -0.12726<br>0.6148<br>18 | 0.13173<br>0.6023<br>18 | 0.12152<br>0.6310<br>18 | 0.13717<br>0.6125<br>16 | 0.09472<br>0.7474<br>14 | 0.44925<br>0.1927<br>10 | 0.43868<br>0.1019<br>15 | 0.00000<br>1.0000<br>17 | 0.30089<br>0.2575<br>16 | 0.37690<br>0.2830<br>10 | -0.22774<br>0.3634<br>18 | 1.00000<br>0.0000<br>18 | -0.32038<br>0.2099<br>17 | 0.56099<br>0.0916<br>10 | -0.02809<br>0.9178<br>16 | 0.52641<br>0.0438<br>15 | 0.18872<br>0.5006<br>15 | 0.50000<br>0.0486<br>16 | 0.28143<br>0.2579<br>18 |
| 050B016 | 0.00639<br>0.9793<br>19 | 0.41952<br>0.0656<br>20 | 0.39816<br>0.0821<br>20 | 0.21989<br>0.3516<br>20 | 0.10896<br>0.6570<br>19 | 0.03448<br>0.9068<br>14 | -0.24224<br>0.5001<br>10 | 0.15123<br>0.5906<br>15 | 0.00000<br>1.0000<br>19 | 0.12578<br>0.6079<br>19 | 0.18257<br>0.6382<br>9 | 0.22118<br>0.3487<br>20 | -0.32038<br>0.2099<br>17 | 1.00000<br>0.0000<br>20 | 0.16883<br>0.6410<br>10 | 0.27835<br>0.2485<br>19 | -0.06273<br>0.8047<br>18 | -0.00946<br>0.9703<br>18 | 0.31799<br>0.1846<br>19 | 0.15450<br>0.5154<br>20 |
| 050B019 | 0.23355<br>0.5161<br>10 | 0.86667<br>0.0012<br>10 | 0.65649<br>0.0392<br>10 | 0.59404<br>0.0702<br>10 | 0.72121<br>0.0186<br>10 | 0.88780<br>0.0014<br>9 | 0.71818<br>0.1718<br>5 | 1.00000<br>0.0000<br>9 | 0.00000<br>1.0000<br>9 | 0.98788<br>0.0001<br>10 | 0.97619<br>0.0001<br>8 | -0.29013<br>0.4161<br>10 | 0.56099<br>0.0916<br>10 | 0.16883<br>0.6410<br>10 | 1.00000<br>0.0000<br>10 | 0.29013<br>0.4161<br>10 | 0.86667<br>0.0025<br>9 | 0.73030<br>0.0255<br>9 | 0.54495<br>0.1033<br>10 | 0.98788<br>0.0001<br>10 |
| 050B021 | 0.22651<br>0.3511<br>19 | -0.12019<br>0.6240<br>19 | 0.23181<br>0.3396<br>19 | -0.12745<br>0.6031<br>19 | -0.10154<br>0.6791<br>19 | -0.10555<br>0.7195<br>14 | -0.41120<br>0.2378<br>10 | 0.30929<br>0.2620<br>15 | 0.00000<br>1.0000<br>18 | -0.07043<br>0.7745<br>19 | 0.00000<br>1.0000<br>8 | 0.12498<br>0.6102<br>19 | -0.02809<br>0.9178<br>16 | 0.27835<br>0.2485<br>19 | 0.29013<br>0.4161<br>10 | 1.00000<br>0.0000<br>19 | -0.10325<br>0.6835<br>18 | -0.14304<br>0.5712<br>18 | -0.14765<br>0.5464<br>19 | -0.07319<br>0.7659<br>19 |
| 050B023 | 0.26922<br>0.2800<br>18 | 0.58854<br>0.0102<br>18 | 0.69525<br>0.0014<br>18 | 0.48353<br>0.0421<br>18 | 0.61022<br>0.0072<br>18 | 0.47877<br>0.0833<br>14 | 0.37426<br>0.2867<br>10 | 0.86786<br>0.0001<br>15 | 0.00000<br>1.0000<br>17 | 0.80805<br>0.0001<br>18 | 0.92857<br>0.0025<br>7 | -0.13616<br>0.5901<br>18 | 0.52641<br>0.0438<br>15 | -0.06273<br>0.8047<br>18 | 0.86667<br>0.0025<br>9 | -0.10325<br>0.6835<br>18 | 1.00000<br>0.0000<br>18 | -0.12047<br>0.6340<br>18 | 0.54612<br>0.0190<br>18 | 0.84107<br>0.0001<br>18 |
| 050B025 | -0.07855<br>0.7537<br>18 | 0.16932<br>0.5018<br>18 | -0.02986<br>0.9064<br>18 | -0.02746<br>0.9139<br>18 | -0.05625<br>0.8246<br>18 | 0.29908<br>0.2989<br>14 | 0.21673<br>0.5476<br>10 | 0.25095<br>0.3670<br>15 | 0.00000<br>1.0000<br>17 | 0.26273<br>0.2922<br>18 | 0.61237<br>0.1438<br>7 | -0.22943<br>0.3598<br>18 | 0.18872<br>0.5006<br>15 | -0.00946<br>0.9703<br>18 | 0.73030<br>0.0255<br>9 | -0.14304<br>0.5712<br>18 | -0.12047<br>0.6340<br>18 | 1.00000<br>0.0000<br>18 | 0.19643<br>0.4347<br>18 | 0.24667<br>0.3238<br>18 |
| 050B031 | 0.28605<br>0.2351<br>19 | 0.44116<br>0.0587<br>19 | 0.53099<br>0.0193<br>19 | 0.28685<br>0.2338<br>19 | 0.26009<br>0.2822<br>19 | 0.21023<br>0.4707<br>14 | 0.17623<br>0.6263<br>10 | 0.50709<br>0.0537<br>15 | 0.00000<br>1.0000<br>18 | 0.44426<br>0.0567<br>19 | 0.76376<br>0.0274<br>8 | -0.17547<br>0.4724<br>19 | 0.50000<br>0.0486<br>16 | 0.31799<br>0.1846<br>19 | 0.54495<br>0.1033<br>10 | -0.14765<br>0.5464<br>19 | 0.54612<br>0.0190<br>18 | 0.19643<br>0.4347<br>18 | 1.00000<br>0.0000<br>19 | 0.47388<br>0.0404<br>19 |
| 050C004 | -0.06887<br>0.7794<br>19 | 0.55408<br>0.0075<br>22 | 0.44136<br>0.0398<br>22 | 0.34913<br>0.1113<br>22 | 0.40720<br>0.0836<br>19 | 0.54171<br>0.0454<br>14 | 0.26382<br>0.4614<br>10 | 0.97500<br>0.0001<br>15 | -0.07385<br>0.7504<br>21 | 0.95789<br>0.0001<br>19 | 0.95804<br>0.0001<br>12 | -0.11251<br>0.6181<br>22 | 0.28143<br>0.2579<br>18 | 0.15450<br>0.5154<br>20 | 0.98788<br>0.0001<br>10 | -0.07319<br>0.7659<br>19 | 0.84107<br>0.0001<br>18 | 0.24667<br>0.3238<br>18 | 0.47388<br>0.0404<br>19 | 1.00000<br>0.0000<br>26 |

* Table contains correlation coefficient/probability |r| under Ho:r=0/number of observations.

First Group




Second Group




Third Group

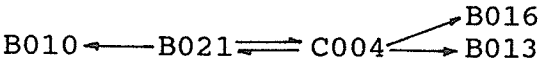


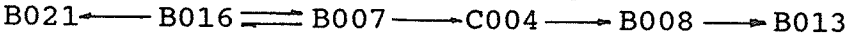

Figure C-1

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on Daily Mean Peak Flows

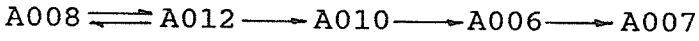
First Group




Second Group




Third Group




Fourth Group

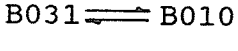
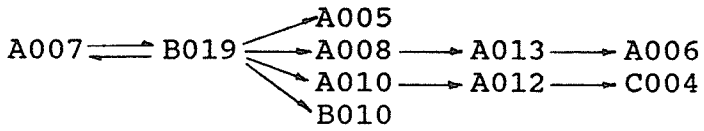



Figure C-2

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on Daily Mean Peak Flows

First Group




Second Group

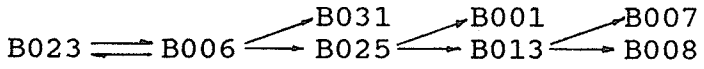
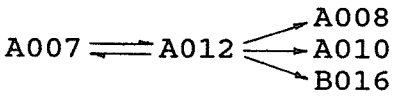


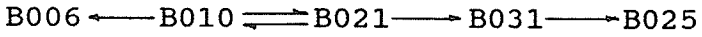

Figure C-3

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on March Mean Flows

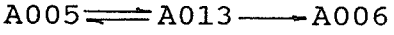
First Group




Second Group




Third Group



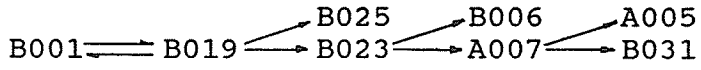

Fourth Group



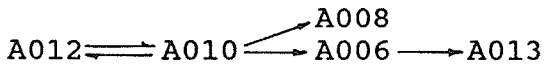

Figure C-4

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on March Mean Flows

First Group




Second Group




Third Group




Fourth Group

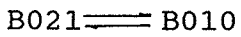
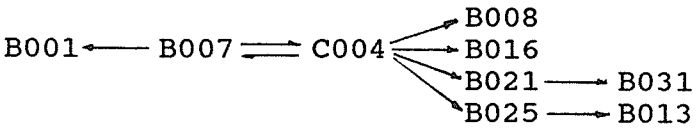


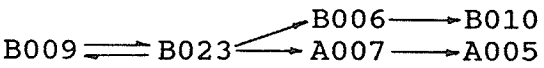

Figure C-5

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on April Mean Flows

First Group




Second Group



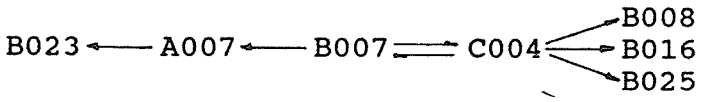

Third Group



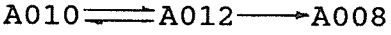

Figure C-6

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on April Mean Flows

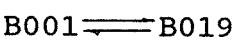
First Group



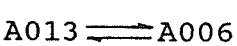

Second Group



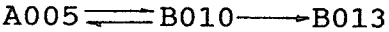

Third Group




Fourth Group




Fifth Group




Sixth Group

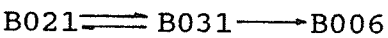
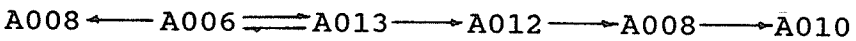


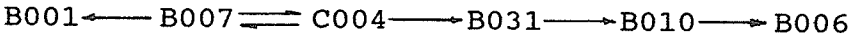

Figure C-7

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on May Mean Flows

First Group




Second Group




Third Group

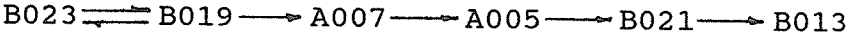


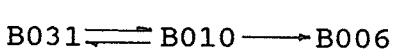

Figure C-8

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on May Mean Flows

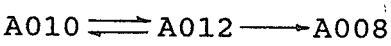
First Group



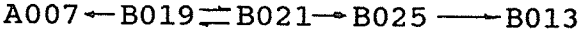

Second Group




Third Group




Fourth Group




Fifth Group

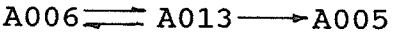
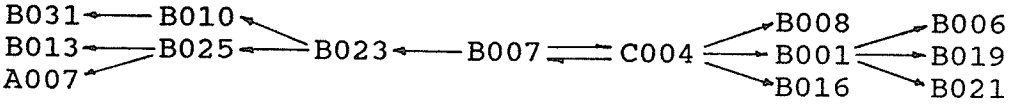


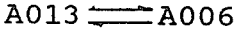

Figure C-9

Mcquitty Cluster Analysis
Pearson Correlation Coefficients
Based on June Mean Flows

First Group




Second Group




Third Group

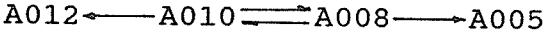
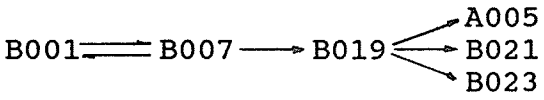



Figure C-10

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on June Mean Flows

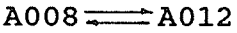
First Group



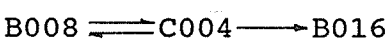

Second Group



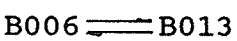

Third Group




Fourth Group




Fifth Group




Sixth Group

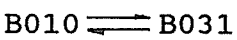


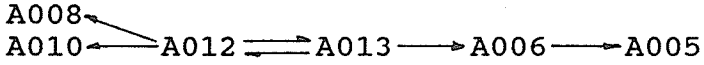

Figure C-11

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on July Mean Flows

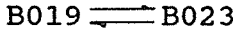
First Group



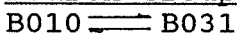

Second Group




Third Group




Fourth Group




Fifth Group

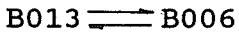
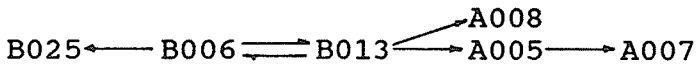


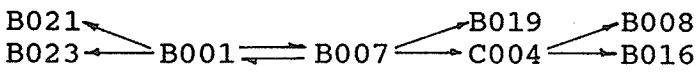

Figure C-12

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on July Mean Flows

First Group




Second Group




Third Group

A006 ⇌ A013

Fourth Group

A010 ⇌ A012

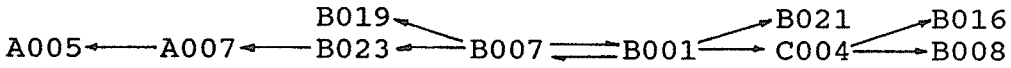
Fifth Group

B010 ⇌ B031

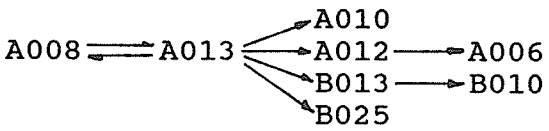
Figure C-13

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on August Mean Flows

First Group




Second Group



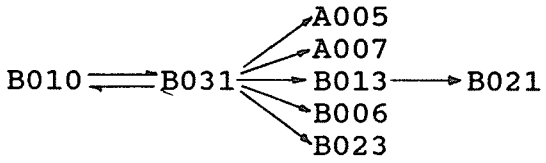

Third Group

B006 ⇌ B031

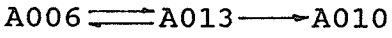
Figure C-14

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on August Mean Flows

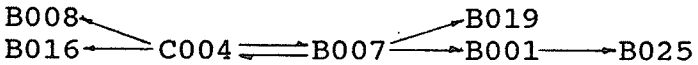
First Group




Second Group




Third Group




Fourth Group

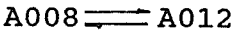
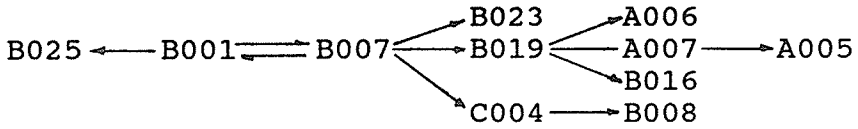



Figure C-15

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on September Mean Flows

First Group




Second Group




Third Group

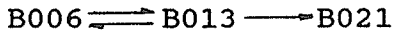
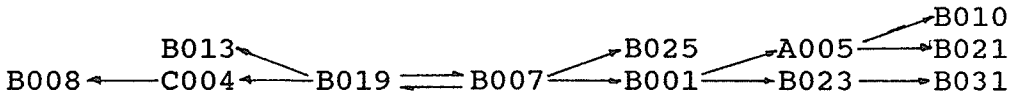


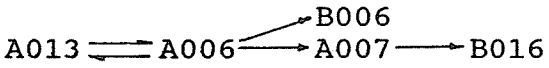

Figure C-16

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on Septembe Mean Flows

First Group




Second Group




Third Group

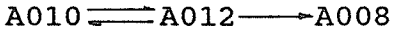
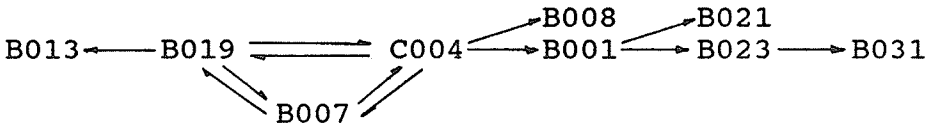



Figure C-17

McQuitty Cluster Analysis
Pearson Correlation Coefficients
Based on October Mean Flows

First Group




Second Group

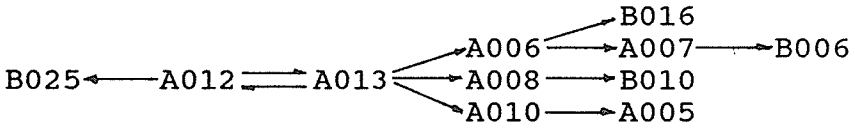



Figure C-18

McQuitty Cluster Analysis
Spearman Correlation Coefficients
Based on October Mean Flows