TECHNICAL REPORT TO THE
PPWB COMMITTEE ON HYDROLOGY
NATURAL FLOW

PIPESTONE CREEK
AT THE SASKATCHEWAN-MANITOBA BOUNDARY

PPWB Report № 116

APPENDIX C

PIPESTONE CREEK

NATURAL FLOW MODEL DOCUMENTATION
AND USER MANUAL

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DECEMBER, 1992

ABSTRACT

The Pipestone Creek Natural Flow Model was developed to compute natural flows for Pipestone Creek at the Saskatchewan-Manitoba boundary. The model was developed by the Hydrology Branch of Sask Water for the Prairie Provinces Water Board (PPWB) under the terms agreed to in a Memorandum of Understanding signed in April 1989. The model, PIPENAT, was written in VAX FORTRAN VERSION 5.3 using Sask Water's DEC MICRO-VAX II. This appendix describes the engineering principles and the computational procedures used to develop the model as well as giving instruction as to the use of the model. This appendix has been bound separately from the main report "Natural Flow - Pipestone Creek at the Saskatchewan-Manitoba Boundary" in order to allow for the model documentation to be revised and updated as required.

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1.0 INTRODUCTION

The Pipestone Creek Natural Flow Model, PIPENAT, was developed as the result of a Memorandum of Understanding between the Prairie Provinces Water Board and Sask Water signed in April 1989. The model was developed specifically for the Pipestone Creek Basin and is configured to calculate natural flows using the best information currently available.

The model was developed to meet a number of design criteria. These criteria include:

1. Model structure and coding should allow for future modifications and updates;

2. The model should allow for user input of variables whose values are subject to revision or adjustment; and

3. The model should reflect the basin configuration.

This Appendix documents the principles and computational procedures used by the model, and describes the procedures and data formats required to run the model. Chapter 2 outlines the underlying engineering and hydrologic principles employed by the model while Chapter 3 describes the computational procedures and model structure. The remaining three chapters describe how to run the model, the model output, and the possible errors and the accuracy of the model.

2.0 ENGINEERING PRINCIPLES

2.1 METHOD OF CALCULATING NATURAL FLOW

The model calculates natural flow at the boundary using the project depletion method. The project depletion method calculates natural flow by adding known or estimated depletions upstream of a streamflow gauging station to the recorded flows at that streamflow gauging site. In addition to calculating natural flows at the Saskatchewan-Manitoba boundary (station 05NG024), PIPENAT also calculates natural flows at streamflow stations Pipestone Creek above Moosomin Reservoir (station 05NE003), Pipestone Creek near Moosomin (station 05NE001), and Pipestone Creek near Pipestone (station 05NG003).

2.2 INFLOW AT AN UNGAUGED SITE

It is often necessary to estimate flows at an ungauged (project) site. This is accomplished by transferring known natural flows at a gauged site to the ungauged site using the ratio of their contributing drainage areas. This standard approach assumes that the areas tributary to the gauge and to the project are hydrologically similar, i.e. similar land use, soil moisture and type, similar precipitation and temperature regime, similar basin and channel slopes, etc.

The contributing drainage area (CDA) to a site varies from year to year depending primarily on the magnitude of the runoff. The CDA also depends on soil moisture, and the state of the ground (ie. frozen or thawed). Since the CDA for a gauge or a site is not measured or recorded, the standard practice is to relate CDA to the gross and effective drainage areas (GDA and EDA, respectively), and to the return period of the annual runoff volume. If the return period is two years or less, then the CDA is assumed to be equal to the EDA. The CDA increases with increasing return period until at some return period defined by the modeller (termed the 'endpoint') the CDA equals the GDA. The methodology used to calculate CDA ratios is described in "Magnitude and Frequency of Peak Flows and Flow Volumes in Saskatchewan" by Aaston and Banga, 1986.

2.3 DRAINAGE PROJECTS

There are three small drainage projects in the Pipestone Creek basin; the Silverwood Conservation Area No. 34, the Highway No. 8 drainage project, and the Moosomin Conservation Area No. 3 drainage project. Each of these projects tend to increase the flow in the creek over what would have occurred naturally.

Each of these projects is located outside of the effective drainage of Pipestone Creek. In years with median flow or less, the entire project area adds to the flow in the creek. In years with higher flow, some of the project area would have contributed to flow in the creek under natural conditions.

PIPENAT calculates the area within each project that would have contributed under natural conditions using the contributing drainage area technique described in the previous section. In years with median flow or less, the contributing area is zero. This naturally contributing area is subtracted from the project drainage area to determine the area causing an incremental increase in flow in the creek over natural conditions. This area, and the natural flow and CDA at one of the streamflow stations, is used to calculate the incremental flow increase due to the drainage project.

2.4 NET EVAPORATION

The Natural Flow Model uses separate arrays of net evaporation for Pipestone Lake and for Moosomin Reservoir. Pipestone Lake net evaporation was calculated using the gross evaporation at Broadview and recorded precipitation at Broadview. Net evaporation for Moosomin Reservoir was calculated using the Broadview gross evaporation multiplied by a transfer factor of 1.126 from which was subtracted the recorded precipitation at Moosomin. Gross evaporation at Broadview was taken from Prairie Farm Rehabilitation Administration's (PFRA) Hydrology Report #121, "Gross Evaporation for the 30-Year Period 1951-80 in the Canadian Prairies".

Pipestone Lake evaporation volumes were calculated using the surface area corresponding to the average of the water levels at the beginning of one month and the beginning of the next month. Moosomin Reservoir evaporation volumes were calculated using the surface area corresponding to the monthly average water level.

2.5 ROUTING OF DEPLETIONS

Ideally, depletions should be routed to the station in question to account for hydraulic travel time from the project to the station. No routing is done in the Natural Flow Model for a number of reasons. The travel times involved were assumed to be small relative to the monthly time-steps used in the model. The largest single depletion is evaporation from Moosomin Reservoir. The travel time from the reservoir to the boundary is from two to four days. For most depletions, the uncertainty in the magnitude of the depletion and the uncertainty of its timing would outweigh any improvement that could be made by the use of routing transfer factors.

2.6 RESERVOIR ROUTING

As with the routing of depletions, flows should ideally be routed through Pipestone Lake and Moosomin Reservoir. And as with the routing of depletions, this was not done in the Natural Flow Model. Again, the monthly model time-step was assumed to be much longer than the time to peak of a typical runoff hydrograph in this watershed. Therefore the potential improvement offered by routing flows through the reservoir and Pipestone Lake would be masked by the monthly time-step. The most significant impact of not using a reservoir routing procedure is that simulated levels on Pipestone Lake and Moosomin Reservoir will never go above the full supply level (FSL). That is, any inflow in excess of the storage capacity at FSL in any month will spill in the same month.

2.7 GROUNDWATER

Losses and gains to groundwater were not simulated in the Natural Flow Model due to the absence of quantitative data on which to base either losses or gains.

2.8 ICE

Losses and gains of water to temporary storage in ice on Moosomin Reservoir and in the creek channel were not simulated in the Natural Flow Model due to lack of quantitative data.

3.0 COMPUTATIONAL PROCEDURE

3.1 MODEL STRUCTURE

The Natural Flow Model has a modular structure as shown on Figure C-1. PIPENAT is made up of a main program, five primary subroutines and nine smaller subroutines. The program creates a number of output files containing the natural flows at each of the streamflow stations and the boundary, and the estimated project depletions or drainage volumes calculated by the model. PIPENAT requires a run control input file named PIPE.DAT and input data files containing recorded streamflows, recorded Moosomin reservoir elevations, net evaporation, and water use data for each of the sub-basins.

3.2 MAIN PROGRAM AND INPUT DATA FILES

The function of the main program in PIPENAT is to call the various subroutines. The MAIN program calculates natural flow one year at a time for each station in operation that year. The logic of the program examines the calendar year to determine which stations are in service, and thus which subroutines to call.

The first subroutine called is READIN which reads the data from the input data files. These input data files can be longer than the number of years to be modelled. The entire array is read into a dummy array and values are extracted from the dummy array according to the specified number of years and starting year.

There are four types of input data files: recorded data files, water use data files, net evaporation files, and the run control file.

3.2.1 Recorded Data Files

There are two types of recorded data files: streamflow data files, and water level data files.

Streamflow Data Files

Separate data files are required for each of the four streamflow stations 05NE003, 05NE001, 05NG024, and 05NG003. All streamflow data are in units of cubic decametres (dam^3).

The first line in a streamflow data file contains the number of years of recorded flows in that file in FORMAT(I2). The remaining lines in a streamflow file contain the year and the twelve monthly flow volumes in FORMAT (I4,1X,12F10.2). Missing data is entered as -9.99.

Water Level Data Files

Separate data files are required for Moosomin first-of-the-month elevations and for Moosomin monthly average elevations. First-of-month elevations are required for each month of the year. First-of-month elevations outside of the normal recording period of March 1 through October 31 were linearly interpolated outside of the PIPENAT program. Average water levels in months in which there were no recorded elevations were calculated as the average of the interpolated first-of-month elevations for that month and the subsequent month. All elevations are in metres and are to GSC datum less 500.000 m.

The first line in a water level data file contains the number of years of data in that file in FORMAT(I2). The remaining lines in the file contain the year and the twelve monthly elevations in FORMAT (I4,1X,12F10.3). Missing data is entered as -9.999.

3.2.2 Water Use Files

Seven separate water use files are required for the model: one for each of the five sub-basins, one for the Town of Moosomin water consumption, and one for Kipling Marsh drainage. The five sub-basins are:

1. Effective drainage area above Pipestone Lake;
2. Effective drainage area between Pipestone Lake and station 05NE003;
3. Effective drainage area between stations 05NE003 and 05NE001; and
4. Effective drainage area between station 05NE001 and the Saskatchewan-Manitoba boundary.
5. Effective drainage area between the Saskatchewan-Manitoba boundary and station 05NG003.

Projects included in the sub-basin water use files are individually too small to warrant estimation of project inflows on a monthly basis in order to determine their individual depletions.

The first line in a water use data file contains the number of years of data in that file in FORMAT(I2). The remaining lines in the file contain the year and the twelve monthly water use (or drainage) volumes in FORMAT (I4,1X,12F10.2). All water use volumes are in dam^3.

3.2.3 Net Evaporation Files

Two separate net evaporation files are required to run the model: one for Moosomin Reservoir, and one for Pipestone Lake. Net evaporation is calculated externally to the model and is in units of millimetres.

The first line in a net evaporation data file contains the number of years of data in that file in FORMAT(I2). The remaining lines in the file contain the year and the twelve monthly net evaporation values in FORMAT (I4,1X,12F10.2).

3.2.4 Run Control File

The run control file must be named PIPE.DAT and contains the filenames of all the other data files, and other input data required to run PIPENAT.

Two of the variables in PIPE.DAT are the number of years to be run and the starting year of the run. The main program in its current configuration is designed to run starting in January of the first year through to December of the final year. In its current form, PIPENAT is not capable of running partial years.

The format and contents of each line in PIPE.DAT are summarized on the following page.

Line	Contents	Format
1	File name and extension - Pipestone Net Evaporation	A25
2	File name and extension - Moosomin Net Evaporation	A25
3	File name and extension - Uses above Pipestone Lake	A25
4	File name and extension - Uses above Station 05NE003	A25
5	File name and extension - Kipling Marsh Drainage Volumes	A25
6	File name and extension - Recorded Flows at Station 05NE003	A25
7	File name and extension - Recorded Flows at Station 05NE001	A25
8	File name and extension - First-of-Month Moosomin Levels	A25
9	File name and extension - Average Monthly Moosomin Levels	A25
10	File name and extension - Uses above Station 05NE001	A25
11	File name and extension - Town of Moosomin Consumption	A25
12	File name and extension - Recorded Flows at Station 05NG024	A25
13	File name and extension - Uses above Station 05NG024	A25
14	File name and extension - Recorded Flows at 05NG003	A25
15	File name and extension - Uses above Station 05NG003	A25
16	Number of years, Starting Year	1X,I2,5X,I2
17	Initial natural and existing Pipestone Lake Levels	2 F10.3
18	Natural and Existing Pipestone Lake FSLs	2 F10.3
19	Factor to apply to Town of Moosomin consumption, 0 to 1	F10.3
20-32	Effective and Gross Drainage Area, and return period at which entire gross area contributes (end point) for the following:	3 F10.3
20	Station 05NE003	
21	Station 05NE001	
22	Station 05NG024	
23	Station 05NG003	
24	Grenfell Diversion	
25	Pipestone Lake	
26	Silverwood Drainage Project*	
27	Highway #8 Drainage Project*	
28	Irrigation Project #14251	
29	Moosomin CAA #3 Drainage Project*	
30	Local area between Stations 05NE003 and 05NE001	
31	Local area between Stations 05NE001 and 05NG003	
32	Local area between Stations 05NE001 and 05NG024	
33	Number of points defining the flow volume frequency curve for Station 05NE003	1X,I2
34	Return periods on flow volume frequency curve for Station 05NE003	20 F9.1
35	Flow volumes corresponding to Line 35	20 F9.1
36	Number of points defining the flow volume frequency curve for Station 05NE001	1X,I2
37	Return periods on flow volume frequency curve for Station 05NE001	20 F9.1
38	Flow volumes corresponding to Line 38	20 F9.1

39	Number of points defining the flow volume frequency curve for Station 05NG024	1X,I2
40	Return periods on flow volume frequency curve for Station 05NG024	20 F9.1
41	Flow volumes corresponding to Line 41	20 F9.1
42	Number of points defining the flow volume frequency curve for Station 05NG003	1X,I2
43	Return periods on flow volume frequency curve for Station 05NG003	20 F9.1
44	Flow volumes corresponding to Line 44	20 F9.1

* For these three projects, use an effective drainage area of zero, see Section 3.3.

Arrays in PIPENAT are dimensioned to handle up to sixty years of data. An I2 format is used for the number of years, thus limiting the number to 99. The program implicitly assumes that the starting year is in the 1900's, thus some modification will be required to model starting years of 2000 or later in order to distinguish from years in the 1900's.

3.3 CONTRIBUTING DRAINAGE AREAS

Contributing drainage areas (CDA's) are required throughout the PIPENAT program to estimate flows at ungauged project sites. Two subroutines were developed to calculate CDA's: RETURN to calculate the return period for the station flow, and CDARATIO to calculate the CDA ratio of the site to the station for a given return period.

The source code for RETURN was extracted from a Sask Water in-house program called QEST which is used to transfer annual volumes from a gauged site to an ungauged site. Return periods between the points given in PIPE.DAT are interpolated as if the flow volume frequency curves were plotted on lognormal probability paper.

The source code for CDARATIO was also extracted from the Sask Water in-house QEST program. CDARATIO uses the return period calculated by RETURN, and the station and project effective drainage area, gross drainage area, and end point.

For the three drainage projects, the contributing drainage area is decreased as the return period increases. This is done to avoid double counting of the area drained by the project that would contribute naturally in higher flow years. In years with less than median runoff, the entire drainage project contributes. At the end point return period, the drainage project incremental flow increase would be zero but the area drained by the project would be included in the contributing area of the next streamflow station downstream.

3.4 PIPESTONE LAKE DEPLETIONS

The depletion due to Pipestone Lake is calculated by subroutine LAKELOSS. Total depletions at Pipestone Lake are the difference between the spill from the lake under historic conditions and the spill that would have occurred under natural conditions. Natural inflow to the lake was estimated using contributing drainage area ratios and the estimated natural flow at the furthest upstream station in operation (ie. station 05NG003 from 1943 to 1957, station 05NE001 for 1958, 1959 and 1974 to 1986, and station 05NE003 for 1960 to 1973, 1987 and 1988). Historic inflow to the lake was estimated by adding the drainage from Kipling Marsh and the incremental flow increase from the Silverwood Conservation Area, and subtracting the minor uses above Pipestone Lake and the amount diverted to Grenfell.

The calculated depletion of the Grenfell Diversion was set equal to the natural flow at the furthest upstream station in operation multiplied by the ratio of contributing area to the diversion. The diversion was limited to the licensed diversion of 253 dam^3 annually.

Using the estimated historic and natural inflows, LAKELOSS simulates the elevation changes, net evaporation losses (and gains), and spills from the lake under both conditions. The subroutine is called in each month of the study period by either subroutine NE3, NE1, or NG3, depending on which of the three stations is in operation. The CALL statements provide LAKELOSS with the estimated natural flow for the month, an estimate of the return period of the annual natural flow for the year, and a station identifier so that LAKELOSS uses the correct CDA ratios. LAKELOSS returns to the calling subroutine the estimate of the net depletion, calculated as the spill under natural conditions minus the spill under historic conditions.

3.5 NATURAL FLOW AT STATION 05NE003

The subroutine NE3 uses the project depletion method to calculate natural flows and depletions at station 05NE003 for the years and months that the station is in operation. Pipestone Lake depletions plus local minor uses between Pipestone Lake and station 05NE003 are added to the recorded flow at the station. Net depletions at Pipestone Lake are calculated by subroutine LAKELOSS.

3.6 NATURAL FLOW AT STATION 05NE001

The NE1 subroutine calculates the natural flows and depletions at station 05NE001. For the years and months that 05NE003 is operated, NE1 estimates the depletions in the local sub-basin only and adds the depletions at station 05NE003 calculated by subroutine NE3. The depletions in the local sub-basin are the minor uses between stations 05NE003 and 05NE001, the Moosomin Reservoir evaporation and change in storage, the depletion due to irrigation project 14251, the Town of Moosomin municipal consumption, and the incremental flow increase from the Highway No. 8 drainage project.

Evaporation from Moosomin Reservoir is obtained by multiplying the net evaporation in millimetres by the surface area corresponding to the monthly average water level. The reservoir's change in storage is calculated using the first-of-month recorded elevations.

The depletion due to irrigation project 14251 is based on the estimated runoff to the project up to an annual maximum of 138 dam^3. The runoff to the project is based on the ratio of its contributing drainage area to either the local natural inflow between stations 05NE003 and 05NE001, or to station 05NE001 when station 05NE003 was not in operation. Similarly, the incremental flow increases from the Highway No. 8 drainage project are based on the local natural inflows when station 05NE003 is in operation and on the natural flow at station 05NE001 when station 05NE003 was not in operation.

The Town of Moosomin withdrawal from the reservoir is obtained by multiplying town's consumption by the factor input by the user. This factor (between 0 and 1) reflects the proportion of the consumption supplied by the reservoir. The town operates two shallow wells adjacent to the reservoir which are hydraulically connected to the reservoir by infiltration galleries. It is possible that some of the water pumped from these wells is groundwater and not surface water from the reservoir drawn through the infiltration galleries. The groundwater portion should be excluded from the calculation of natural flow.

For the periods that station 05NE003 was not in operation; NE1 calls LAKELOSS to calculate the Pipestone Lake depletion. NE1 then sums the Pipestone Lake depletion, the minor uses between Pipestone Lake and station 05NE003, and all the depletions between station 05NE003 and station 05NE001 described above. The sum is added to the recorded flow to get the natural flow at station 05NE001.

3.7 NATURAL FLOW AT STATION 05NG024

The subroutine NG24 estimates natural flow at station 05NG024 for the period that the gauge has been in operation. The subroutine adds the local depletions to those calculated at station 05NE001. The local depletions are due to the Moosomin CAA #3 drainage project and local minor uses.

Incremental flow increases due to the Moosomin CAA #3 drainage project are based on the local natural inflow between stations 05NE001 and 05NG024, and the contributing drainage area ratio described in Sections 2.3 and 3.3.

3.8 NATURAL FLOW AT STATION 05NG003

The subroutine NG3 estimates the natural flow at station 05NG003 for the period that the gauge has been in operation. Total depletions are calculated by adding the local minor uses below station 05NG024 to the depletions at station 05NG024. If station 05NG024 was not in operation, then the subroutine adds the local minor uses between station 05NE001 and station 05NG003 to the depletions at 05NE001. If station 05NE001 was not in operation, then the subroutine calculates all the depletions above 05NE001 as well. The subroutine LAKELOSS is called to calculate the depletion due to Pipestone Lake. Net evaporation for Moosomin reservoir is calculated for the years 1955 through 1957 (station 05NE001 began operation in 1958).

3.9 NATURAL FLOW AT THE BOUNDARY

BDRY calculates natural flows at the boundary. When natural flows are available from station 05NG024, they are taken to be the natural flow at the boundary. When natural flows at station 05NG024 are not available, but natural flows at stations 05NE001 and 05NG003 are, then BDRY interpolates between the two stations. The interpolation is done by finding the difference between the natural flow at station 05NG003 and station 05NE001. This difference is multiplied by the contributing drainage area ratio of the local area between station 05NE001 and the boundary, and the local area between stations 05NE001 and 05NG003. This product is then added to the natural flow at station 05NE001.

If natural flows are available only at station 05NG003, then the natural flow at the boundary is found by multiplying the natural flow at station 05NG003 by the contributing drainage area ratio of the boundary to station 05NG003.

Natural flows in the months of January, February, November and December are transferred from station 05NG003 to the boundary using the effective drainage area ratio.

3.10 PROJECT DEPLETIONS BASED ON NATURAL FLOW ESTIMATES

Throughout the preceding six sections (3.4 through 3.9), statements have been made to the effect that a project's depletion is calculated based on some estimate of natural flow or of local natural inflow. It is evident however, that the depletion due to the project has an effect on the natural flow *estimate* used to calculate the depletion. The magnitude of the natural flow estimate in turn impacts on the contributing drainage area ratios between the project and the site at which natural flows are being calculated since larger estimates of natural flow result in higher return periods. While this sounds complicated, and in fact would be complicated if the calculations were being done by hand, this problem is handled quite easily by repeating the natural flow calculations for each year and each streamflow station until the annual natural flow volume estimate from the current iteration is within a set tolerance (0.5 dam^3) from the previous iteration. If this tolerance is not obtained within twenty iterations, a warning is sent to the screen and the program continues.

3.11 AREA/CAPACITY CURVES

Four subroutines were created to provide area or storage capacity for a given elevation of either Pipestone Lake or Moosomin Reservoir. A fifth subroutine was created to provide Pipestone Lake elevation for a given storage capacity. The five subroutines and their respective functions are listed below:

Subroutine	Function
MOOSAREA	Provides Moosomin Reservoir surface area given elevation
MOOSSTOR	Provides Moosomin Reservoir storage given elevation
PIPEAREA	Provides Pipestone Lake surface area given elevation
PIPELEV	Provides Pipestone Lake elevation given storage
PIPESTOR	Provides Pipestone Lake storage given elevation

The five subroutines are based on the area/capacity tables given on the figures 2 and 3 of the main report. The subroutines use linear interpolation between the tabulated points.

3.12 WINTER FLOWS

Natural winter flows are estimated only when there are recorded winter flows available at either station 05NG024 or at station 05NG003. The depletions include the decrease (or increase) in storage in Moosomin Reservoir between November 1 and March 1, net evaporation, Moosomin town consumption, and uses above the boundary. These depletions were added to the recorded flow at stations 05NG024 and 05NG003. Winter flows prior to 1956/1957 are not calculated by the program. Natural winter flows prior to 1982/83 were transferred from station 05NG003 to the Saskatchewan-Manitoba boundary using the effective drainage area ratio.

3.13 UNITS

All units used in the model are metric. All flows, uses, depletions, drainage volumes and storage capacities are expressed in cubic decametres (dam^3). Drainage areas are in square kilometres (km^2). Surface area is in units of hectares (ha). Pipestone Lake and Moosomin Reservoir elevations are in metres.

Moosomin Reservoir elevations are in metres to the GSC datum less 500.000 m. No provision was made for imperial units in input data or output.

4.0 RUNNING PIPENAT

To run PIPENAT, all the input files must be prepared. PIPE.DAT can be prepared either using a computer file editor or by invoking the command file PIPENAT.COM by typing @PIPENAT which provides prompts for all the information required for PIPE.DAT and creates the PIPE.DAT. Once PIPE.DAT has been created using the command @PIPENAT, it is more convenient to edit the PIPE.DAT file for subsequent runs rather than invoking the command file. When not using the command file to run PIPENAT, simply issue the command RUN PIPENAT.

5.0 PIPENAT OUTPUT

The following output files are created when PIPENAT is run. All the natural flow and project water use files are in FORMAT (1X,I4,13F9.1). The files give the year, twelve monthly volumes and the annual volume. The evaporation files are in FORMAT (1X,I4,12F9.1). They give the year and the twelve monthly net evaporation volumes. All units are in cubic decametres (dam^3).

FILENAME	CONTENTS
BDRY.OUT	Natural flows at the Saskatchewan-Manitoba boundary.
NE3NAT.OUT	Natural flows at station 05NE003.
NE1.OUT	Natural flows at station 05NE001.
NG24NAT.OUT	Natural flows at station 05NG024.
NG3NAT.OUT	Natural flows at station 05NG003.
GRENUSE.OUT	Monthly and annual volumes of the Grenfell Diversion.
SILVDR.OUT	Drainage volumes for the Silverwood drainage project. This file is not created if the stream depletion method is used to calculate natural flows at station 05NE001.
IRR.OUT	Monthly and annual irrigation volumes for project 14251. This file is not created if the stream depletion method is used to calculate natural flows at station 05NE001.
HWY8DR.OUT	Drainage volumes from the Highway No. 8 drainage project.
MOOSDR.OUT	Drainage volumes from the Moosomin Conservation Area drainage project.
NE3EVAP.OUT	Monthly net evaporation volumes from Pipestone Lake under existing and natural conditions. The array of natural net evaporation is given first followed by the array of net evaporation under current conditions. This file is created by subroutine NE3 and contains net evaporation for only those years that station 05NE003 has been operated.
LAKEEVAP.OUT	Monthly net evaporation volumes from Pipestone Lake under existing and natural conditions. The array of natural net evaporation is given first followed by the array of net

evaporation under current conditions. This file is created by subroutine LAKELOSS and contains net evaporation for only those years that station 05NE003 has NOT been operated.

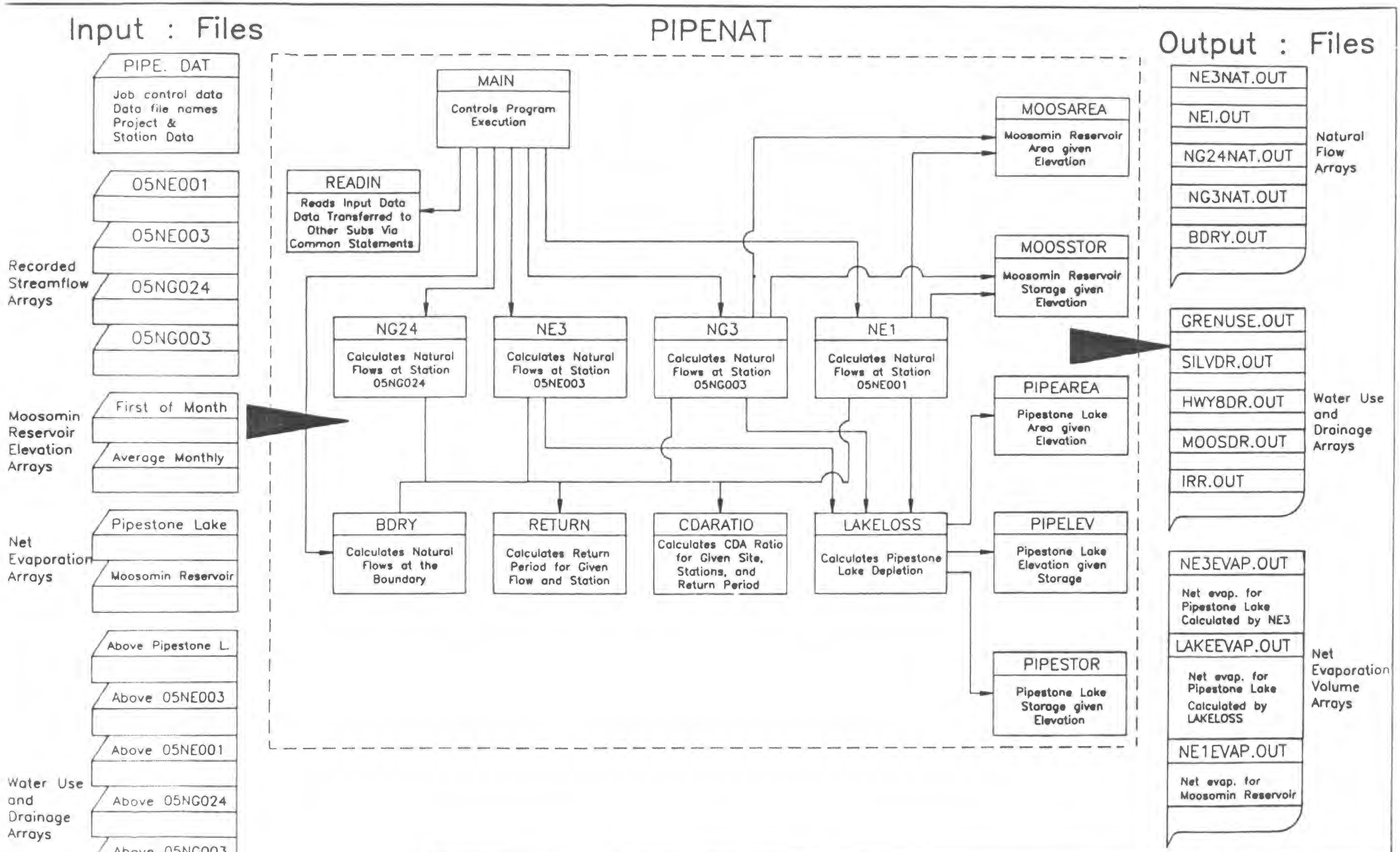
<u>NE1EVAP.OUT</u> Monthly net evaporation volumes from Moosomin Reservoir.

6.0 ERROR MESSAGES

PIPENAT does not check input data for errors, nor does it analyze computed natural flows and depletions for errors. The model user must ensure the input data files are error-free and should closely examine all program output.

PIPENAT provides warning messages when accuracy tolerances on annual natural flow volumes are not achieved. Where iterations were required to calculate natural flows, the tolerance criteria was 0.5 dam^3. This tolerance value is equivalent to a monthly average flow of 0.0002 m^3/s. If the tolerance is not achieved in twenty iterations, a warning message is sent to the screen and the program continues execution using the values obtained from the last iteration. The warning message indicates in which subroutine, year and month the exceedence occurred.

This tolerance criteria does not reflect the accuracy of the model results due to inaccuracies inherent in the input data and in the assumptions incorporated into the model. The errors in the input data are probably at least an order of magnitude greater than the tolerance criteria. These errors include streamflow measurement and rating errors, errors in the storage tables for Pipestone Lake and Moosomin reservoir, errors in assuming licensed project use equals actual project use, errors in the timing of the project use, errors in estimating net evaporation, etc. Errors in the model include the estimates of ungauged inflow.



Designed ______	SASKATCHEWAN WATER CORPORATION	**FLOW CHART**	Date July 23,1992
Drawn ___ D. F. _		**PIPESTONE CREEK**	Sheet of
Recm'd ______		**NATURAL FLOW MODEL**	**PLAN No. H1-6 (1)**
Approved ______			**FIGURE C-1**

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PIPESTOR C-63

PIPEAREA C-65

PIPELEV C-67

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MOOSAREA C-71

```
C
C      MAIN PROGRAM
C
C      PURPOSE:   TO CALCULATE NATURAL FLOWS OF THE PIPESTONE CREEK
C                 AT THE SASKATCHEWAN - MANITOBA BOUNDARY
C
C      PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                    B. OEGEMA
C                    JULY 1989
C                    REV: AUG/90 - INCLUDE SUBROUTINE NG3
C
C      PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                    PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C
      CHARACTER*1 METHOD
C
      COMMON NYEARS,IYEARS(60)
     * /PIPE/ELEVN(60,12),ELEVE(60,12),FSLE,FSLN,EVAPPIPE(60,12)
     * /NE3USES/UPIPE(60,12),UNE3(60,12),DRKIP(60,12)
     * /NE3NE1/FLNNE3(60,12),DEPLNE3(60,12),RNE3(60,12)
     * /NE1DATA/RNE1(60,12)
     * /NE1USES/UNE1(60,12),DEPLNE1(60,12),FLNNE1(60,12)
     * /MOOSOMIN/RNE2(60,12),RNE2AVG(60,12),EVAPMOOS(60,12),
     *          TOWNFACT,TOWN(60,12)
     * /NG24DATA/RNG24(60,12),FLNNG24(60,12)
     * /BDRYUSES/UNG24(60,12),DEPLNG24(60,12)
     * /NG3DATA/UNG3(60,12),RNG3(60,12),FLNNG3(60,12)
     * /AREAS/DAREA(13,3)
     * /RTRNPER/NUMRP(4),RPSTA(4,20),VOLSTA(4,20)
C
      CALL READIN
C
C  DO ONE YEAR AT A TIME
C
      DO 300 J=1,NYEARS
C
      IF ( IYEARS(J) .GE. 58 ) THEN
       IF (IYEARS(J) .GE. 60 .AND. IYEARS(J) .LE. 73 .OR. IYEARS(J)
     *     .GE. 87) THEN
         CALL NE3(J)
         METHOD = 'P'
        ELSE
         METHOD = 'L'
       ENDIF
       CALL NE1(METHOD,J)
       IF ( IYEARS(J) .GE. 82 ) CALL NG24(J)
      ENDIF
      CALL NG3(J)
      CALL BDRY(J)
300   CONTINUE
C
      END
```

```
C
C      SUBROUTINE READIN
C
C      PURPOSE:   TO READ IN COMMON DATA
C
C      PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                    B. OEGEMA
C                    JULY 1989
C
C      PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                    PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C  VARIABLE LIST
C      DEPLNE1       NET DEPLETIONS ABOVE STAION 05NE001
C      DEPLNE3       NET DEPLETIONS ABOVE STATION 05NE003
C      DRKIPLNG      ARRAY OF KIPLING MARSH DRAINAGE VOLUMES
C      EVAPMOOS      NET EVAPORATION (mm) AT MOOSOMIN RESERVOIR
C      EVAPPIPE      NET EVAPORATION (mm) AT PIPESTONE LAKE
C      FLNNE1        NATURAL FLOW AT STATION 05NE001
C      FLNNE3        NATURAL FLOW AT STATION 05NE003
C      FSLE          FSL OF PIPESTONE LAKE UNDER EXISTING CONDITIONS
C      FSLN          FSL OF PIPESTONE LAKE UNDER NATURAL CONDITIONS
C      IYEARS        ARRAY OF YEARS TO BE MODELLED
C      KIP           FILE CONTAINING KIPLING MARSH DRAINAGE VOLUMES
C      NDEPL         ARRAY OF NET DEPLETIONS
C      NE1R          FILE CONTAINING RECORDED FLOWS AT STATION 05NE001
C      NE1U          FILE CONTAINING USES UPSTREAM OF STATION 05NE001
C      NE2R          FILE CONTAINING RECORDED LEVELS AT STATION 05NE002
C      NE3R          FILE CONTAINING RECORDED FLOWS AT STATION 05NE003
C      NE3U          FILE CONTAINING USES UPSTREAM OF STATION 05NE003
C      NEMOOS        FILE CONTAINING NET EVAPORATION AT MOOSOMIN RESERVOIR
C      NEPIPE        FILE CONTAINING NET EVAPORATION AT PIPESTONE LAKE
C      NG24R         FILE CONTAINING RECORDED FLOWS AT STATION 05NG024
C      NG24U         FILE CONTAINING USES UPSTREAM OF STATION 05NG024
C      NYEARS        NUMBER OF YEARS TO BE MODELLED
C      PIPEU         FILE CONTAINING USES UPSTREAM OF PIPESTONE LAKE
C      RNE1          ARRAY OF RECORDED FLOWS AT STATION 05NE001
C      RNE2          ARRAY OF RECORDED LEVELS AT STATION 05NE002
C      RNE3          ARRAY OF RECORDED FLOWS AT STATION 05NE003
C      TOWNFACT      CONSTANT RATIO OF TOWN OF MOOSOMIN WATER SUPPLY WITHDRANW FROM RESERVOIR
C      TOWNU         FILE CONTAINING RECORDED AND EXTENDED TOWN OF MOOSOMIN WATER USE
C      UBNE3         NATURAL FLOW AT 05NE003 WITH NATURAL EFFECTS OF PIPESTONE LAKE REMOVED
C      UNE1          ARRAY OF USES ABOVE STATION 05NE001
C      UNE3          ARRAY OF USES ABOVE STATION 05NE003
C      UPIPE         ARRAY OF USES ABOVE PIPESTONE LAKE
C      YEAR          STARTING YEAR OF RUN TO BE MODELLED
C
C*******************************************************************************************
C
      SUBROUTINE READIN
C
      CHARACTER*25 PIPEU,NE3U,KIP,NE3R,NEMOOS,NEPIPE,NE1R,NE2R,NE1U,
     *       TOWNU,NG24R,NG24U,NE2RAVG,NG3R,NG3U
C
      INTEGER YEAR,YR(60)
      REAL DUMMY(60,12)
```

```
C
      COMMON NYEARS,IYEARS(60)
     * /PIPE/ELEVN(60,12),ELEVE(60,12),FSLE,FSLN,EVAPPIPE(60,12)
     * /NE3USES/UPIPE(60,12),UNE3(60,12),DRKIPLNG(60,12)
     * /NE3NE1/FLNNE3(60,12),DEPLNE3(60,12),RNE3(60,12)
     * /NE1DATA/RNE1(60,12)
     * /NE1USES/UNE1(60,12),DEPLNE1(60,12),FLNNE1(60,12)
     * /MOOSOMIN/RNE2(60,12),RNE2AVG(60,12),EVAPMOOS(60,12),
     *           TOWNFACT,TOWN(60,12)
     * /NG24DATA/RNG24(60,12),FLNNG24(60,12)
     * /BDRYUSES/UNG24(60,12),DEPLNG24(60,12)
     * /NG3DATA/UNG3(60,12),RNG3(60,12),FLNNG3(60,12)
     * /AREAS/DAREA(13,3)
     * /RTRNPER/NUMRP(4),RPSTA(4,20),VOLSTA(4,20)
C
C  OPEN INPUT FILES AND READ DATA
C
      OPEN(UNIT=5,FILE='PIPE.DAT',STATUS='OLD')
C
C     CONTROL DATA FILE
      READ(5,200)NEPIPE
      READ(5,200)NEMOOS
      READ(5,200)PIPEU
      READ(5,200)NE3U
      READ(5,200)KIP
      READ(5,200)NE3R
      READ(5,200)NE1R
      READ(5,200)NE2R
      READ(5,200)NE2RAVG
      READ(5,200)NE1U
      READ(5,200)TOWNU
      READ(5,200)NG24R
      READ(5,200)NG24U
      READ(5,200)NG3R
      READ(5,200)NG3U
200   FORMAT(A25)
      READ(5,220)NYEARS,IYEARS(1)
220   FORMAT(1X,I2,5X,I2)
      READ(5,240)ELEVN(1,1),ELEVE(1,1)
      READ(5,240)FSLN,FSLE
240   FORMAT(2F10.3)
      READ(5,250)TOWNFACT
250   FORMAT(F10.3)
      DO 10 I=2,NYEARS
        IYEARS(I)=IYEARS(1)+I-1
10    CONTINUE
      DO 50 J=1,13
        READ(5,260)(DAREA(J,I),I=1,3)
50    CONTINUE
260   FORMAT(3F10.3)
      DO 60 J=1,4
        READ(5,270)NUMRP(J)
        READ(5,280)(RPSTA(J,I),I=1,NUMRP(J))
        READ(5,280)(VOLSTA(J,I),I=1,NUMRP(J))
60    CONTINUE
270   FORMAT(1X,I2)
280   FORMAT(20F9.1)
```

```
C
C     OPEN STATEMENTS
C
        OPEN(UNIT=2,FILE=PIPEU,STATUS='OLD')
        OPEN(UNIT=3,FILE=NE3U,STATUS='OLD')
        OPEN(UNIT=4,FILE=KIP,STATUS='OLD')
        OPEN(UNIT=7,FILE=NE3R,STATUS='OLD')
        OPEN(UNIT=8,FILE=NEPIPE,STATUS='OLD')
        OPEN(UNIT=9,FILE=NEMOOS,STATUS='OLD')
        OPEN(UNIT=10,FILE=NG3R,STATUS='OLD')
        OPEN(UNIT=11,FILE=NE1U,STATUS='OLD')
        OPEN(UNIT=12,FILE=NG24U,STATUS='OLD')
        OPEN(UNIT=13,FILE=NE2R,STATUS='OLD')
        OPEN(UNIT=14,FILE=NE2RAVG,STATUS='OLD')
        OPEN(UNIT=15,FILE=TOWNU,STATUS='OLD')
        OPEN(UNIT=16,FILE=NG24R,STATUS='OLD')
        OPEN(UNIT=17,FILE=NG3U,STATUS='OLD')
        OPEN(UNIT=18,FILE=NE1R,STATUS='OLD')
C
C     READ IN DATA
C
        JJ=0
        READ(2,80)JYEARS
        DO 5 J=1,JYEARS
         READ(2,100)YEAR,(DUMMY(J,I),I=1,12)
         YEAR=YEAR-1900
         IF(YEAR.GE.IYEARS(1))THEN
           JJ=JJ+1
           DO 6 I=1,12
             UPIPE(JJ,I)=DUMMY(J,I)
6          CONTINUE
           IF (JJ.GE.NYEARS)GOTO 7
          ENDIF
5       CONTINUE
7       JJ=0
        READ(3,80)JYEARS
        DO 8 J=1,JYEARS
         READ(3,100)YEAR,(DUMMY(J,I),I=1,12)
         YEAR=YEAR-1900
         IF(YEAR.GE.IYEARS(1))THEN
           JJ=JJ+1
           DO 9 I=1,12
             UNE3(JJ,I)=DUMMY(J,I)
9          CONTINUE
           IF (JJ.GE.NYEARS)GOTO 11
          ENDIF
8       CONTINUE
11      JJ=0
        READ(4,80)JYEARS
        DO 12 J=1,JYEARS
         READ(4,100)YR(J),(DUMMY(J,I),I=1,12)
         YR(J)=YR(J)-1900
12      CONTINUE
        IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
        DO 112 J=1,JYEARS
         IF(YR(J).GE.IYEARS(1))THEN
           JJ=JJ+1
           DO 13 I=1,12
             DRKIPLNG(JJ,I)=DUMMY(J,I)
13         CONTINUE
           IF (JJ.GE.NYEARS)GOTO 14
          ENDIF
112     CONTINUE
14      JJ=0
        READ(7,80)JYEARS
        DO 15 J=1,JYEARS
         READ(7,100)YR(J),(DUMMY(J,I),I=1,12)
         YR(J)=YR(J)-1900
15      CONTINUE
```

```
      IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
      DO 115 K=1,JYEARS
       IF ( YR(K) .GE. IYEARS(1) ) THEN
        JJ=JJ+1
        DO 16 I=1,12
         RNE3(JJ,I)=DUMMY(K,I)
16      CONTINUE
        IF ( JJ .GE. NYEARS ) GOTO 17
       ENDIF
115   CONTINUE
17    JJ=0
      READ(8,80)JYEARS
      DO 18 J=1,JYEARS
       READ(8,100)YEAR,(DUMMY(J,I),I=1,12)
       YEAR=YEAR-1900
       IF(YEAR.GE.IYEARS(1))THEN
         JJ=JJ+1
         DO 19 I=1,12
           EVAPPIPE(JJ,I)=DUMMY(J,I)
19       CONTINUE
         IF (JJ.GE.NYEARS)GOTO 20
        ENDIF
18    CONTINUE
20    JJ=0
      READ(9,80)JYEARS
      DO 21 J=1,JYEARS
       READ(9,150)YR(J),(DUMMY(J,I),I=1,12)
       YR(J)=YR(J)-1900
21    CONTINUE
      IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
      DO 121 J=1,JYEARS
       IF(YR(J).GE.IYEARS(1))THEN
         JJ=JJ+1
         DO 22 I=1,12
           EVAPMOOS(JJ,I)=DUMMY(J,I)
22       CONTINUE
         IF (JJ.GE.NYEARS)GOTO 23
       ENDIF
121   CONTINUE
23    JJ=0
      READ(10,80)JYEARS
      DO 24 J=1,JYEARS
       READ(10,100)YEAR,(DUMMY(J,I),I=1,12)
       YEAR=YEAR-1900
       IF(YEAR.GE.IYEARS(1))THEN
         JJ=JJ+1
         DO 25 I=1,12
           RNG3(JJ,I)=DUMMY(J,I)
25       CONTINUE
         IF (JJ.GE.NYEARS)GOTO 26
        ENDIF
24    CONTINUE
26    JJ=0
      READ(11,80)JYEARS
      DO 27 J=1,JYEARS
       READ(11,100)YEAR,(DUMMY(J,I),I=1,12)
       YEAR=YEAR-1900
       IF(YEAR.GE.IYEARS(1))THEN
         JJ=JJ+1
         DO 28 I=1,12
           UNE1(JJ,I)=DUMMY(J,I)
28       CONTINUE
         IF (JJ.GE.NYEARS)GOTO 29
        ENDIF
27    CONTINUE
29    JJ=0
      READ(12,80)JYEARS
      DO 30 J=1,JYEARS
       READ(12,100)YEAR,(DUMMY(J,I),I=1,12)
```

```
        YEAR=YEAR-1900
        IF(YEAR.GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 31 I=1,12
            UNG24(JJ,I)=DUMMY(J,I)
31        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 32
         ENDIF
30      CONTINUE
32      JJ=0
        READ(13,80)JYEARS
        DO 33 J=1,JYEARS
         READ(13,100)YR(J),(DUMMY(J,I),I=1,12)
         YR(J)=YR(J)-1900
33      CONTINUE
        IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
        DO 133 J=1,JYEARS
         IF(YR(J).GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 34 I=1,12
            RNE2(JJ,I)=DUMMY(J,I)
34        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 35
         ENDIF
133     CONTINUE
35      JJ=0
        READ(14,80)JYEARS
        DO 36 J=1,JYEARS
         READ(14,100)YR(J),(DUMMY(J,I),I=1,12)
         YR(J)=YR(J)-1900
36      CONTINUE
        IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
        DO 136 J=1,JYEARS
         IF(YR(J).GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 37 I=1,12
            RNE2AVG(JJ,I)=DUMMY(J,I)
37        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 38
         ENDIF
136     CONTINUE
38      JJ=0
        READ(15,80)JYEARS
        DO 39 J=1,JYEARS
         READ(15,100)YR(J),(DUMMY(J,I),I=1,12)
         YR(J)=YR(J)-1900
39      CONTINUE
        IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
        DO 139 J=1,JYEARS
         IF(YR(J).GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 40 I=1,12
            TOWN(JJ,I)=DUMMY(J,I)
40        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 41
         ENDIF
139     CONTINUE
41      JJ=0
        READ(16,80)JYEARS
        DO 42 J=1,JYEARS
         READ(16,100)YR(J),(DUMMY(J,I),I=1,12)
         YR(J)=YR(J)-1900
42      CONTINUE
        IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
        DO 142 J=1,JYEARS
         IF(YR(J).GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 43 I=1,12
            RNG24(JJ,I)=DUMMY(J,I)
```

```
43        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 44
        ENDIF
142    CONTINUE
44     JJ=0
       READ(17,80)JYEARS
       DO 45 J=1,JYEARS
        READ(17,100)YEAR,(DUMMY(J,I),I=1,12)
        YEAR=YEAR-1900
        IF(YEAR.GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 46 I=1,12
            UNG3(JJ,I)=DUMMY(J,I)
46        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 47
         ENDIF
45     CONTINUE
47     JJ=0
       READ(18,80)JYEARS
       DO 48 J=1,JYEARS
        READ(18,100)YR(J),(DUMMY(J,I),I=1,12)
        YR(J)=YR(J)-1900
48     CONTINUE
       IF ( YR(1) .GT. IYEARS(1) ) JJ = YR(1) - IYEARS(1)
       DO 148 J=1,JYEARS
        IF(YR(J).GE.IYEARS(1))THEN
          JJ=JJ+1
          DO 49 I=1,12
            RNE1(JJ,I)=DUMMY(J,I)
49        CONTINUE
          IF (JJ.GE.NYEARS)GOTO 51
        ENDIF
148    CONTINUE
80     FORMAT(I2)
90     FORMAT(I4,1X,2F10.2)
100    FORMAT(I4,1X,12F10.2)
150    FORMAT(I4,1X,12F9.1)
C
C     CLOSE STATEMENTS
C
51     CLOSE(UNIT=2)
       CLOSE(UNIT=3)
       CLOSE(UNIT=4)
       CLOSE(UNIT=7)
       CLOSE(UNIT=8)
       CLOSE(UNIT=9)
       CLOSE(UNIT=10)
       CLOSE(UNIT=11)
       CLOSE(UNIT=12)
       CLOSE(UNIT=13)
       CLOSE(UNIT=14)
       CLOSE(UNIT=15)
       CLOSE(UNIT=16)
       CLOSE(UNIT=17)
       CLOSE(UNIT=18)
C
      RETURN
      END
```

```
C
C     SUBROUTINE RETURN
C
C     PROGRAMMER : B. OEGEMA
C     DATE       : JANUARY 1991
C     PURPOSE    : TO CALCULATE THE RETURN PERIOD FOR A GIVEN ANNUAL VOLUME
C                  FOR THE PIPESTONE CREEK NATURAL FLOW STUDY
C
C                  PROGRAM IS BASED ON "QEST" BY B. KALLENBACH, METHODOLOGY
C                  IS DESCRIBED IN AASTON AND BANGA, 1986
C
********************************************************************************
C
C                                    QEST
C
C     PROGRAMMER : B. KALLENBACH
C     DATE       : SEPTEMBER 1986
C     PURPOSE    : THIS PROGRAM IS USED TO TRANSFER ANNUAL VOLUMES FROM
C                  A GAUGED SITE TO AN UNGAUGED SITE BASED ON DRAINAGE
C                  AREA RATIOS AND ANNUAL YIELD. OUTPUT IS PROVIDED IN
C                  TWO FORMS:
C                     1)  OUTPUT FOR THE PRINTER
C                     2)  OUTPUT COMPATIBLE TO THE INPUT REQUIREMENTS OF
C                         THE PROGRAM "MONFLOW"
C
C
C
********************************************************************************
*
*     VARIABLE DESCRIPTIONS:
*
*        INTEGER:
*
*         NUMYR      -  NUMBER OF YEARS OF X-BASIN DATA
*
*         NUMRP      -  NUMBER OF VALUES ENTERED TO DEFINE THE X-BASIN
*                       FREQUENCY CURVE
*
*         NUMTAB     -  NUMBER OF VALUES DESCRIBING THE HORIZONTAL DISTANCE,
*                       ON A NORMAL PROBABALITY SCALE, FOR A SET OF RETURN
*                       PERIODS
*
*         STA        -  STATION IDENTFIER
*
*        REAL:
*
*         XVOLUM(I) -   X-BASIN ANNUAL VOLUME
*
*         RETURN(I) -   RETURN PERIOD CALCULATED BASED ON ENTERED FREQUENCY CURVE
*
*         D(I)       -  DISTANCE OF PLOTTING POSITION FROM 1:2 RETURN PERIOD
*                       BASED ON ENTERED FREQUENCY CURVE
*
*         TRP(J)     -  TABLE OF RETURN PERIODS FOR CALCULATING PLOTTING POSITION
*
*         TDIST(J)   -  DISTANCE OF PLOTTING POSITION FROM 1:2 RETURN PERIOD
*                       CORRESPONDING TO THE RPT(J) RETURN PERIODS. VALUES
*                       ENTERED IN EQUAL INCREMENTS OF (0.2).
*
*         RP(K)      -  TABLE OF RETURN PERIODS DEFINING X-BASIN FREQUENCY CURVE
*
*         VOL(K)     -  VOLUME FOR X-BASIN CORRESPONDING TO THE RP1(I)
*                       RETURN PERIODS
*
*         DIST(K)    -  DISTANCE OF PLOTTING POSITION FROM 1:2 RETURN PERIOD
*                       CORRESPONDING TO THE RP1(K) RETURN PERIODS
```

```
*************************************************************************************
C
      SUBROUTINE RTRNPER(STA,XVOLUM,R,DISTANCE)
C
      INTEGER STA
C
      REAL TRP(51), TDIST(51), RP(20), VOL(20), DIST(20), VLOG(20),
     *     RETURN(2), D(2), XLOG(2)
C
      COMMON NYEARS,IYEARS(60)
     */RTRNPER/NUMRP(4),RPSTA(4,20),VOLSTA(4,20)
C
      DATA NUMTAB/51/
      DATA TRP/1.0000003,1.0000008,1.0000021,1.0000054,1.0000133,
     * 1.0000317,1.0000720,1.000159,1.000337,1.000688,
     * 1.00135,1.00256,1.004683,1.008266,1.01410,
     * 1.02328,1.03727,1.05798,1.08785,1.1300,
     * 1.1886,1.2688,1.3779,1.5257,1.7263,
     * 2.0,
     * 2.377,2.902,3.646,4.720,6.303,
     * 8.690,12.38,18.25,27.83,43.96,
     * 71.92,122.0,214.5,391.4,740.7,
     * 1456.,2967.,6289.,13890.,31570.,
     * 74930.,184800.,473400.,1261000.,3489000./
      DATA TDIST/-5.0,-4.8,-4.6,-4.4,-4.2,-4.0,-3.8,-3.6,-3.4,-3.2,
     * -3.0,-2.8,-2.6,-2.4,-2.2,-2.0,-1.8,-1.6,-1.4,-1.2,-1.0,-0.8,
     * -0.6,-0.4,-0.2,0.0,0.2,0.4,0.6,0.8,1.0,1.2,1.4,1.6,1.8,2.0,
     * 2.2,2.4,2.6,2.8,3.0,3.2,3.4,3.6,3.8,4.0,4.2,4.4,4.6,4.8,5.0/
C
C
      DO 100 J=1,NUMRP(STA)
       RP(J) = RPSTA(STA,J)
       VOL(J) = VOLSTA(STA,J)
  100 CONTINUE
C
C        CALCULATE RETURN PERIOD FOR EACH XBASIN VALUE BASED ON
C        FREQUENCY CURVE DEFINED BY RP AND VOL
C
C        CALCULATE HORIZONTAL DISTANCE ON GRAPH FOR EACH RETURN PERIOD ENTERED
C        WHICH DEFINES THE FREQUENCY CURVE
C
      CALL DISTAN(RP,DIST,TRP,TDIST,NUMRP(STA),NUMTAB)
C
C      CALCULATE HORIZONTAL DISTANCE ON GRAPH FOR XBASIN VALUE
C      TAKE LOG OF VOLUMES TO MATCH LOGNORMAL PROBABILITY PAPER
C
      NUMYR = 1
      XLOG(1) = LOG(XVOLUM)
C
      DO 210 J=1,NUMRP(STA)
      VLOG(J) = LOG(VOL(J))
  210 CONTINUE
C
      CALL DISTAN(XLOG,D,VLOG,DIST,NUMYR,NUMRP(STA))
C
      CALL DISTAN(D,RETURN,TDIST,TRP,NUMYR,NUMTAB)
      R = RETURN(1)
      DISTANCE = D(1)
C
      RETURN
      END
C
      SUBROUTINE DISTAN(A,AA,B,BB,NA,NB)
C
C       THIS SUBROUTINE DOES LINEAR INTERPOLATION, BETWEEN POINTS DEFINING A
C       CURVE, ON AN ARRAY DEFINING ONE OF THE CURVE PARAMETERS.
C       THE B ARRAY MUST BE ORDERED FROM SMALLEST TO LARGEST.
C       SUBROUTINE OUTPUT IS THE AA ARRAY BASED ON WHERE THE A ARRAY
C       INTERSECTED THE B-BB CURVE.
```

```
C
      REAL A(NA), AA(NA), B(NB), BB(NB)
C
      DO 200 I=1,NA
      DO 250 J=1,NB-1
      K = J
      IF (A(I).GT.B(J).AND.A(I).LE.B(J+1)) GOTO 300
  250 CONTINUE
C
  300 KK = K+1
      AA(I) = BB(K) + (BB(KK)-BB(K)) * (A(I)-B(K))/(B(KK)-B(K))
  200 CONTINUE
C
      RETURN
      END
```

C-42

```
C     SUBROUTINE  CDARATIO
C
C     PROGRAMMER : B. OEGEMA
C     DATE       : JANUARY 1991
C     PURPOSE    : CALCULATE CONTRIBUTING DRAINAGE AREA RATIO
C
C                  BASED ON "QEST" PROGRAM BY B. KALLENBACH, METHODOLOGY IS
C                  DESCRIBED IN AASTON AND BANGA, 1986
C
*******************************************************************************
C
C                                    QEST
C
C     PROGRAMMER : B. KALLENBACH
C     DATE       : SEPTEMBER 1986
C     PURPOSE    : THIS PROGRAM IS USED TO TRANSFER ANNUAL VOLUMES FROM
C                  A GAUGED SITE TO AN UNGAUGED SITE BASED ON DRAINAGE
C                  AREA RATIOS AND ANNUAL YIELD. OUTPUT IS PROVIDED IN
C                  TWO FORMS:
C                     1)  OUTPUT FOR THE PRINTER
C                     2)  OUTPUT COMPATIBLE TO THE INPUT REQUIREMENTS OF
C                         THE PROGRAM "MONFLOW"
C
C
C
*******************************************************************************
*
*     VARIABLE DESCRIPTIONS:
*
*        INTEGER:
*
*         NUMTAB    -  NUMBER OF VALUES DESCRIBING THE HORIZONTAL DISTANCE,
*                      ON A NORMAL PROBABALITY SCALE, FOR A SET OF RETURN
*                      PERIODS
*
*        REAL:
*
*         D         -  DISTANCE OF PLOTTING POSITION FROM 1:2 RETURN PERIOD
*                      BASED ON ENTERED FREQUENCY CURVE
*
*         RATIO     -  DRAINAGE AREA RATIO FOR GIVEN RETURN PERIOD
*
*
*         TRP(J)    -  TABLE OF RETURN PERIODS FOR CALCULATING PLOTTING POSITION
*
*         TDIST(J)  -  DISTANCE OF PLOTTING POSITION FROM 1:2 RETURN PERIOD
*                      CORRESPONDING TO THE RPT(J) RETURN PERIODS. VALUES
*                      ENTERED IN EQUAL INCREMENTS OF (0.2).
*
*******************************************************************************
C
      SUBROUTINE CDARATIO(PROJ,STA,D,RATIO)
C
      REAL TRP(51), TDIST(51)
      INTEGER PROJ,STA
C
      COMMON NYEARS,IYEARS(60)
     */AREAS/DAREA(13,3)
      DATA NUMTAB/51/
```

```
      DATA TRP/1.0000003,1.0000008,1.0000021,1.0000054,1.0000133,
     * 1.0000317,1.0000720,1.000159,1.000337,1.000688,
     * 1.00135,1.00256,1.004683,1.008266,1.01410,
     * 1.02328,1.03727,1.05798,1.08785,1.1300,
     * 1.1886,1.2688,1.3779,1.5257,1.7263,
     * 2.0,
     * 2.377,2.902,3.646,4.720,6.303,
     * 8.690,12.38,18.25,27.83,43.96,
     * 71.92,122.0,214.5,391.4,740.7,
     * 1456.,2967.,6289.,13890.,31570.,
     * 74930.,184800.,473400.,1261000.,3489000./
      DATA TDIST/-5.0,-4.8,-4.6,-4.4,-4.2,-4.0,-3.8,-3.6,-3.4,-3.2,
     * -3.0,-2.8,-2.6,-2.4,-2.2,-2.0,-1.8,-1.6,-1.4,-1.2,-1.0,-0.8,
     * -0.6,-0.4,-0.2,0.0,0.2,0.4,0.6,0.8,1.0,1.2,1.4,1.6,1.8,2.0,
     * 2.2,2.4,2.6,2.8,3.0,3.2,3.4,3.6,3.8,4.0,4.2,4.4,4.6,4.8,5.0/
C
      XEFFEC = DAREA(STA,1)
      XGROSS = DAREA(STA,2)
      XEND = DAREA(STA,3)
      YEFFEC = DAREA(PROJ,1)
      YGROSS = DAREA(PROJ,2)
      YEND = DAREA(PROJ,3)
C
C
C          COMPUTE PLOTTING DISTANCES FOR END POINTS
C
      DO 250 K=1,NUMTAB
      IF (XEND.GT.TRP(K).AND.XEND.LE.TRP(K+1)) THEN
        DISTX = TDIST(K) + (TDIST(K+1)-TDIST(K)) * (XEND-TRP(K))/
     * (TRP(K+1)-TRP(K))
        GOTO 260
      ENDIF
  250 CONTINUE
  260 CONTINUE
C
      DO 270 K=1,NUMTAB
      IF (YEND.GT.TRP(K).AND.YEND.LE.TRP(K+1)) THEN
        DISTY = TDIST(K) + (TDIST(K+1)-TDIST(K)) * (YEND-TRP(K))/
     * (TRP(K+1)-TRP(K))
        GOTO 280
      ENDIF
  270 CONTINUE
  280 CONTINUE
C
C          COMPUTE DRAINAGE AREA FOR X AND Y BASIN AND AREA RATIO
C
      XAREA = XEFFEC + (XGROSS-XEFFEC) * (D/DISTX)
      YAREA = YEFFEC + (YGROSS-YEFFEC) * (D/DISTY)
      IF (XAREA.GT.XGROSS) XAREA = XGROSS
      IF (YAREA.GT.YGROSS) YAREA = YGROSS
      IF (XAREA.LT.XEFFEC) XAREA = XEFFEC
      IF (YAREA.LT.YEFFEC) YAREA = YEFFEC
      RATIO = YAREA / XAREA
C
C         RATIO FOR DRAINAGE PROJECTS
      IF (PROJ .EQ. 7 .OR. PROJ .EQ. 8 .OR. PROJ .EQ. 10) THEN
       RATIO = (YGROSS - YAREA) / XAREA
      ENDIF
      RETURN
      END
```

```
C
C      SUBROUTINE NE3
C
C      PURPOSE:   TO CALCULATE NET DEPLETIONS AND NATURAL
C                 FLOWS AT STATION 05NE003
C                 USING PROJECT DEPLETION  METHOD
C
C      PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                    B. OEGEMA
C                    JULY 1989
C
C      PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                    PRAIRIE PROVINCES WATER BOARD
C
C***************************************************************************
C
C  VARIABLE LIST
C      DEPLNE3      ARRAY OF NET DEPLETIONS
C      FLN          NATURAL FLOW AT STATION 05NE003
C      FLOWSAVE     ANNUAL NATURAL FLOW FROM PREVIOUS ITERATION
C      FLOWSUM      ANNUAL NATURAL FLOW
C      RNE3         RECORDED FLOW AT STATION 05NE003
C      UNE3         USES IN LOCAL EDA ABOVE STATION 05NE003
C
C*******************************************************************************************
C
       SUBROUTINE NE3(J)
C
       INTEGER YEAR
C
       REAL NFLTRY
C
       COMMON NYEARS,IYEARS(60)
     * /NE3USES/UPIPE(60,12),UNE3(60,12),DRKIPLNG(60,12)
     * /NE3NE1/FLN(60,12),DEPLNE3(60,12),RNE3(60,12)
C
        OPEN(UNIT=19,FILE='NE3NAT.OUT',STATUS='NEW')
        OPEN(UNIT=20,FILE='NE3DEPL.OUT',STATUS='NEW')
        D = 0
C
       LCOUNT = 0
60     CONTINUE
       FLOWSUM = 0
C
C
       DO 50 I=1,12
C
C  NO RECORDED WINTER FLOWS
       IF ( RNE3(J,I) .LT. 0.0 ) THEN
         DEPLNE3(J,I)=0.0
         CALL LAKELOSS(DEPLPIPE,J,I,0,0,1)
         FLN(J,I)=-9.99
         GOTO 50
       ENDIF
C
C    INITIAL ESTIMATE OF NATURAL FLOW
       NFLTRY=RNE3(J,I)+UNE3(J,I)+UPIPE(J,I)-DRKIPLNG(J,I)
       IF ( NFLTRY .LT. 0 ) NFLTRY = 0
C
       KCOUNT=1
C
20     CONTINUE
C
```

```
C
      CALL LAKELOSS(DEPLPIPE,J,I,D,NFLTRY,1)
      FLN(J,I) = RNE3(J,I) + UNE3(J,I) + DEPLPIPE
      IF (FLN(J,I) .LT. 0) FLN(J,I)=0
      TEST=ABS(NFLTRY-FLN(J,I))
      IF (TEST .GT. 0.5) THEN
        NFLTRY = FLN(J,I)
        KCOUNT=KCOUNT+1
        IF (KCOUNT .GT. 20) GOTO 1000
        GOTO 20
      ENDIF
C
C NET DEPLETION
C
      DEPLNE3(J,I) = FLN(J,I) - RNE3(J,I)
C
      FLOWSUM = FLOWSUM + FLN(J,I)
      IF ( I .EQ. 10 ) THEN
       IF (LCOUNT .GE. 20) GOTO 1300
       IF ( FLOWSUM .LE. 0 ) FLOWSUM = 10.0
       CALL RTRNPER(1,FLOWSUM,T,D)
       IF (T .LE. 2) GOTO 70
       IF (LCOUNT .GE. 1) THEN
        TEST = ABS(FLOWSAVE-FLOWSUM)
        IF (TEST .LT. 0.5) GOTO 50
       ENDIF
       FLOWSAVE = FLOWSUM
       LCOUNT = LCOUNT + 1
       GOTO 60
      ENDIF
C
50    CONTINUE
C
70    WRITE(19,970)IYEARS(J),(FLN(J,I),I=1,12),FLOWSUM
      WRITE(19,975)IYEARS(J),T,D
      WRITE(20,980)IYEARS(J),(DEPLNE3(J,I),I=1,12)
970   FORMAT(1X,I4,13F9.1)
975   FORMAT(1X,I4,2F9.5)
980   FORMAT(1X,I4,12F9.1)
      GOTO 80
C
C ERROR MESSAGES
1000  WRITE(*,1001)IYEARS(J),I
1001  FORMAT(' WARNING: ALLOWABLE ITERATIONS EXCEEDED, NE3, YEAR ',I2,
     * ' MONTH ',I2)
      GOTO 50
1300  WRITE(*,1301)IYEARS(J)
1301  FORMAT(' WARNING: ALLOWABLE ITERATIONS EXCEEDED, NE3, YEAR ',I2)
      GOTO 50
80    CONTINUE
      RETURN
      END
```

```
C
C     SUBROUTINE NE1
C
C     PURPOSE:   TO CALCULATE NATURAL FLOWS AT STATION 05NE001
C                USING THE PROJECT DEPLETION METHOD
C
C     PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                   B. OEGEMA
C                   JULY 1989
C
C     PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                   PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C  VARIABLE LIST
C     AVGAREA      MOOSOMIN SURFACE AREA CORRESPONDING TO MONTHLY AVERAGE ELEVATION
C     DEPLIRR      DEPLETION DUE TO IRRIGATION PROJECT 14251
C     DEPLNE1      ARRAY OF NET DEPLETIONS AT STATION 05NE001
C     DEPLNE3      ARRAY OF NET DEPLETIONS AT STATION 05NE003
C     EVAP         NET EVAPORATION (dams) FROM MOOSOMIN
C     EVAPMOOS     NET EVAPORATION (mm) FROM MOOSOMIN RESERVOIR
C     FLN          NATURAL FLOW AT STATION 05NE001
C     FLNNE3       NATURAL FLOW AT STATION 05NE003
C     HWY8DR       MONTHLY DRAINAGE FLOW FROM HIGHWAY No. 8 DRAINAGE PROJECT
C     INFLOW       LOCAL NATURAL INFLOW
C     METHOD       INDICATOR OF METHOD BY WHICH TO CALCULATE NATURAL FLOWS
C     RHWY8LOC     RATIO OF HWY 8 DRAINAGE PROJECT CDA TO LOCAL CDA
C     RIRR         RATIO OF IRRIGATION PROJECT CDA TO LOCAL CDA
C     RLOCNE3      RATIO OF LOCAL CDA TO STATION 05NE003 CDA
C     RNE1         RECORDED FLOWS AT STATION 05NE001
C     RNE2         RECORDED FIRST OF MONTH MOOSOMIN ELEVATIONS
C     RNE2AVG      RECORDED MONTHLY AVERAGE MOOSOMIN ELEVATIONS
C     STORE        MOOSOMIN MONTHLY CHANGE IN STORAGE
C     SUMIRR       ANNUAL SUM OF IRRIGATION DEPLETION
C     TOWN         TOWN OF MOOSOMIN WATER USE
C     TOWNFACT     CONSTANT RATIO OF TOWN WATER USE SUPPLIED BY RESERVOIR ( 0.0 - 1.0 )
C     TOWNU        FILE CONTAINING TOWN OF MOOSOMIN WATER USE
C     UNE1         WATER USE IN 05NE001 LOCAL EFFECTIVE DRAINAGE AREA
C     UNE3         WATER USE IN 05NE003 LOCAL EFFECTIVE DRAINAGE AREA
C
C***********************************************************************************************
C
      SUBROUTINE NE1(METHOD,J)
C
      REAL INFLOW,NFLTRY,STORE,EVAP(60,12),
     *     DEPLIRR(12),HWY8DR(12),HWY8SUM
C
      CHARACTER*1 METHOD
C
      INTEGER YEAR
C
      COMMON NYEARS,IYEARS(60)
     * /NE3USES/UPIPE(60,12),UNE3(60,12),DRKIPLNG(60,12)
     * /NE3NE1/FLNNE3(60,12),DEPLNE3(60,12),RNE3(60,12)
     * /NE1DATA/RNE1(60,12)
     * /NE1USES/UNE1(60,12),DEPLNE1(60,12),FLN(60,12)
     * /MOOSOMIN/RNE2(60,12),RNE2AVG(60,12),EVAPMOOS(60,12),
     *          TOWNFACT,TOWN(60,12)
C
      OPEN(UNIT=10,FILE='HWY8DR.OUT',STATUS='NEW')
      OPEN(UNIT=11,FILE='IRR.OUT',STATUS='NEW')
      OPEN(UNIT=12,FILE='NE1.OUT',STATUS='NEW')
      OPEN(UNIT=13,FILE='NE1EVAP.OUT',STATUS='NEW')
      OPEN(UNIT=14,FILE='NE1DEPL.OUT',STATUS='NEW')
C
```

```
C   INITIALIZE
C
      LCOUNT = 0
      D = 0
20    HWY8SUM = 0
      FLOWSUM = 0
      SUMIRR=0
C
      DO 60 I=1,12
C
C  CALCULATE WINTER FLOW
C
       IF ( I .LE. 2 .OR. I .GE. 11 ) THEN
        CALL MOOSSTOR(STORE2,RNE2(J,I))
        IF ( I .LE. 11 ) CALL MOOSSTOR(STORE1,RNE2(J,I+1))
        IF ( I .GE. 12) THEN
          IF ( J .EQ. NYEARS ) THEN
            STORE1 = STORE2
           ELSE
            CALL MOOSSTOR(STORE1,RNE2(J+1,1))
          ENDIF
        ENDIF
        DELSTOR = STORE1 - STORE2
        CALL MOOSAREA(AVGAREA,RNE2AVG(J,I))
        EVAP(J,I) = AVGAREA * EVAPMOOS(J,I) * 0.01
        DEPLNE1(J,I) = DELSTOR + TOWNFACT * TOWN(J,I) + EVAP(J,I)
C
C    KEEP TRACK OF PIPESTONE LAKE LEVELS
        CALL LAKELOSS(PIPEDEPL,J,I,0,0,2)
        FLN(J,I)=-9.99
        GOTO 50
       ENDIF
C
C  WHEN RECORDED FLOWS AVAILABLE
C
        HWY8DR(I) = 0
        DEPLIRR(I) = 0
        CALL MOOSAREA(AVGAREA,RNE2AVG(J,I))
        EVAP(J,I)=AVGAREA*EVAPMOOS(J,I)*0.01
        EL=RNE2(J,I+1)
        IF (I .EQ. 12) THEN
          EL=RNE2(J+1,1)
          IF (J.EQ.NYEARS) EL=RNE2(J,I)
        ENDIF
        CALL MOOSSTOR(STORAGE,EL)
        CALL MOOSSTOR(STORE,RNE2(J,I))
        STORE = STORAGE - STORE
C
C
C PROJECT DEPLETION WHEN STATION 05NE003 IN-SERVICE
C
       IF (METHOD .EQ.'P') THEN
C
C INITIAL ESTIMATE OF NATURAL FLOW
C
        KCOUNT=0
        TOWN(J,I) = TOWNFACT * TOWN(J,I)
        DEPLNE1(J,I) = TOWN(J,I)+EVAP(J,I)+UNE1(J,I)
     *       +DEPLNE3(J,I)+STORE
        BASE = RNE1(J,I) + DEPLNE1(J,I)
        IF (BASE.LT.0) BASE=0
        NFLTRY=BASE
C
30      INFLOW=NFLTRY-FLNNE3(J,I)
        IF (INFLOW .LT. 0) INFLOW=0
```

```
C
C  DRAINAGE PROJECT
C
        HWY8DR(I) = RHWY8 * INFLOW
C
C  ESTIMATE OF DEPLETION DUE TO IRRIGATION PROJECT 14251
C
        IF (IYEARS(J) .GE. 81) THEN
          DEPLIRR(I) = INFLOW * RIRR
          IF (DEPLIRR(I)+SUMIRR .GT. 138) DEPLIRR(I)=138-SUMIRR
        ENDIF
C
C    NATURAL FLOW IS SUM OF RECORDED FLOW AND DEPLETIONS
C
        FLN(J,I)=BASE+DEPLIRR(I)-HWY8DR(I)
        IF (FLN(J,I) .LT.0) FLN(J,I)=0
C
C IMPROVE ESTIMATE OF NATURAL FLOW
C
        TEST=ABS(NFLTRY-FLN(J,I))
        IF (TEST.GT.0.5)THEN
         NFLTRY=FLN(J,I)
         KCOUNT=KCOUNT+1
         IF (KCOUNT .GT. 20) THEN
           WRITE(*,2000)IYEARS(J),I
           GOTO 800
         ENDIF
         GOTO 30
        ENDIF
800     DEPLNE1(J,I) = DEPLNE1(J,I) + DEPLIRR(I) - HWY8DR(I)
C
C PROJECT DEPLETION WHEN STATION 05NE003 NOT IN-SERVICE
C
       ELSEIF (METHOD.EQ.'L') THEN
C
        KCOUNT=0
C  CALCULATE DEPLETIONS
C
C INITIAL ESTIMATE OF NATURAL FLOW
        PIPEDEPL=0
        DEPLNE1(J,I) = TOWN(J,I)+EVAP(J,I)+UNE1(J,I)+UNE3(J,I)
     *                 +STORE
        BASE=RNE1(J,I) + DEPLNE1(J,I)
        IF (BASE.LT.0)BASE=0
        NFLTRY=BASE
C
C  DRAINAGE PROJECTS
C
40      HWY8DR(I) = RHWY8 * NFLTRY
C
C  ESTIMATE OF DEPLETION DUE TO IRRIGATION PROJECT 14251
C
        IF (IYEARS(J) .GE. 81) THEN
          DEPLIRR(I)=NFLTRY*RIRR
          IF (DEPLIRR(I)+SUMIRR .GT. 138) DEPLIRR(I)=138-SUMIRR
        ENDIF
C
C ESTIMATE DEPLETIONS DUE TO PIPESTONE LAKE
C
        CALL LAKELOSS(PIPEDEPL,J,I,D,NFLTRY,2)
        FLN(J,I)=BASE+PIPEDEPL-HWY8DR(I)+DEPLIRR(I)
        IF (FLN(J,I).LT.0) FLN(J,I)=0
C
```

```
C IMPROVE ESTIMATE OF NATURAL FLOW
C
        TEST=ABS(NFLTRY-FLN(J,I))
        IF (TEST.GT.0.5)THEN
         NFLTRY=FLN(J,I)
         KCOUNT=KCOUNT+1
         IF (KCOUNT .GT. 20) THEN
           WRITE(*,2000)IYEARS(J),I
           GOTO 900
         ENDIF
         GOTO 40
        ENDIF
900     DEPLNE1(J,I)=DEPLNE1(J,I)+PIPEDEPL+DEPLIRR(I)-HWY8DR(I)
       ENDIF
C
C    DO NEXT MONTH, NEXT YEAR
1000   SUMIRR=SUMIRR+DEPLIRR(I)
       HWY8SUM=HWY8SUM+HWY8DR(I)
C
50     CONTINUE
C
       IF ( I .GT. 2 .AND. I .LE. 10 ) THEN
        FLOWSUM = FLOWSUM + FLN(J,I)
        IF ( I .EQ. 10 ) THEN
         IF ( LCOUNT .GE. 20 ) GOTO 60
         IF (FLOWSUM .LE. 0 ) FLOWSUM = 10.0
         CALL RTRNPER(2,FLOWSUM,R,D)
         IF (R .GT. 2) THEN
          IF (LCOUNT .GE. 1) THEN
           TEST = ABS(FLOWSUM - FLOWSAVE)
           IF (TEST .LT. 0.5) GOTO 60
          ENDIF
          IF (METHOD .EQ. 'P') THEN
            CALL CDARATIO(8,11,D,RHWY8)
            CALL CDARATIO(9,11,D,RIRR)
           ELSEIF (METHOD .EQ. 'L') THEN
            CALL CDARATIO(8,2,D,RHWY8)
            CALL CDARATIO(9,2,D,RIRR)
          ENDIF
          FLOWSAVE = FLOWSUM
          LCOUNT = LCOUNT + 1
          GOTO 20
         ENDIF
        ENDIF
       ENDIF
C
60     CONTINUE
C
C  WRITE OUTPUT
70     WRITE(10,480)IYEARS(J),(HWY8DR(I),I=1,12),HWY8SUM
       WRITE(11,480)IYEARS(J),(DEPLIRR(I),I=1,12),SUMIRR
480    FORMAT(1X,I4,13F9.1)
485    FORMAT(1X,I4,2F9.5)
       WRITE(12,480)IYEARS(J),(FLN(J,I),I=1,12),FLOWSUM
       WRITE(12,485)IYEARS(J),R,D
       WRITE(13,500)IYEARS(J),(EVAP(J,I),I=1,12)
       WRITE(14,500)IYEARS(J),(DEPLNE1(J,I),I=1,12)
500    FORMAT(1X,I4,12F9.1)
C FORMAT STATEMENT FOR ERROR MESSAGE
2000   FORMAT(' WARNING: ALLOWABLE ITERATIONS EXCEEDED, NE1 SUB, YEAR ',
     * I2,' MONTH ',I2)
       RETURN
       END
```

```
C
C      SUBROUTINE NG24
C
C      PURPOSE:   TO CALCULATE NATURAL FLOWS AT STATION 05NG024
C                 USING THE PROJECT DEPLETION METHOD
C
C      PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                    B. OEGEMA
C                    OCTOBER 1989
C
C      PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                    PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C  VARIABLE LIST
C      DEPLNE1      ARRAY OF NET DEPLETIONS ABOVE STATION 05NE001
C      DEPLNG24     ARRAY OF NET DEPLETIONS ABOVE STATION 05NG024
C      DRAIN        MONTHLY DRAINAGE FROM MOOSOMIN CAA #3
C      FLNLOC       LOCAL NATURAL FLOW
C      FLNNE1       NATURAL FLOW AT STATION 05NE001
C      NYEARS       NUMBER OF YEARS
C      RNG24        RECORDED FLOWS AT STATION 05NG024
C      UNG24        WATER USE IN 05NG024 LOCAL EFFECTIVE DRAINAGE AREA
C
C*****************************************************************************************
C
      SUBROUTINE NG24(J)
C
      INTEGER YEAR
      REAL INFLOW,DRAIN(12)
C
      COMMON NYEARS,IYEARS(60)
     * /NG24DATA/RNG24(60,12),FLNNG24(60,12)
     * /BDRYUSES/UNG24(60,12),DEPLNG24(60,12)
     * /NE1USES/UNE1(60,12),DEPLNE1(60,12),FLNNE1(60,12)
C
      OPEN(UNIT=21,FILE='MOOSDR.OUT',STATUS='NEW')
      OPEN(UNIT=22,FILE='NG24NAT.OUT',STATUS='NEW')
      OPEN(UNIT=23,FILE='NG24DEPL.OUT',STATUS='NEW')
      CALL CDARATIO(10,13,0,RMOOS)
      LCOUNT = 0
60    FLOWSUM = 0
      DRAINSUM=0
C
      DO 50 I=1,12
C
C  CHECK FOR AVAILABLE DATA
     IF(RNG24(J,I) .EQ.-9.99) THEN
       FLNNG24(J,I)=-9.99
       DEPLNG24(J,I) = 0.0
       GOTO 50
     ENDIF
C
C INITIAL ESTIMATE
C
      KCOUNT=0
      DEPLNG24(J,I) = DEPLNE1(J,I) + UNG24(J,I)
      FLNTRY=RNG24(J,I)+DEPLNG24(J,I)
      IF (FLNTRY .LT. 0) FLNTRY=0
C
```

```
40     INFLOW = FLNTRY - FLNNE1(J,I)
       IF ( INFLOW .LT. 0 ) INFLOW = 0
       IF ( I .GT. 2 .AND. I .LT. 11) THEN
         DRAIN(I) = INFLOW * RMOOS
        ELSE
         DRAIN(I) = 0.0
       ENDIF
       FLNNG24(J,I) = RNG24(J,I) + DEPLNG24(J,I) - DRAIN(I)
       IF (FLNNG24(J,I) .LT. 0 ) FLNNG24(J,I) = 0
       TEST=ABS(FLNTRY - FLNNG24(J,I))
       IF (TEST.GT.0.5) THEN
        FLNTRY = FLNNG24(J,I)
        KCOUNT=KCOUNT+1
        IF (KCOUNT .GT. 20) GOTO 1000
        GOTO 40
       ENDIF
C
C CALCULATE NET DEPLETION AND NATURAL FLOW
C
45     DEPLNG24(J,I)=DEPLNG24(J,I) - DRAIN(I)
       IF (FLNNG24(J,I) .EQ. 0 ) DEPLNG24(J,I) = -1.0 * RNG24(J,I)
       DRAINSUM = DRAINSUM + DRAIN(I)
       IF ( I .GT. 2 .AND. I .LT. 11 ) FLOWSUM = FLOWSUM + FLNNG24(J,I)
C
50     CONTINUE
C
       IF (LCOUNT .GE. 20 ) GOTO 70
       IF ( FLOWSUM .LE. 0 ) FLOWSUM = 10.0
       CALL RTRNPER(3,FLOWSUM,R,D)
       IF (R .GT. 2) THEN
        IF (LCOUNT .GE. 1) THEN
         TEST = ABS(FLOWSUM - FLOWSAVE)
         IF (TEST .LT. 0.5) GOTO 70
        ENDIF
        CALL CDARATIO(10,13,D,RMOOS)
        FLOWSAVE = FLOWSUM
        LCOUNT = LCOUNT + 1
        GOTO 60
       ENDIF
C
C  SEND OUT OUTPUT
C
70     WRITE(22,495)IYEARS(J),(FLNNG24(J,I),I=1,12),FLOWSUM
       WRITE(21,495)IYEARS(J),(DRAIN(I),I=1,12),DRAINSUM
       WRITE(23,500)IYEARS(J),(DEPLNG24(J,I),I=1,12)
495    FORMAT(1X,I4,13F9.1)
500    FORMAT(1X,I4,12F9.1)
       GOTO 80
C
C   ERROR MESSAGE
1000   WRITE(*,1001)IYEARS(J),I
1001   FORMAT('ALLOWED NUMBER OF ITERATIONS EXCEEDED IN NG24 SUBROUTINE
     * IN ',I2,'MONTH',I2)
       GOTO 45
C
80     RETURN
       END
```

```
C
C       SUBROUTINE NG3
C
C       PURPOSE:   TO CALCULATE NATURAL FLOWS USING THE PROJECT DEPLETION
C                  METHOD AT STATION 05NG003
C                  PIPESTONE CREEK NEAR PIPESTONE, MANITOBA
C
C       PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                     B. OEGEMA
C                     AUGUST 1990
C
C       PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                     PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C   VARIABLE LIST
C       DEPLNG3       NET DEPLETIONS ABOVE STATION 05NG003
C       DRAIN         MONTHLY DRAINAGE FROM MOOSOMIN CAA #3
C       IYEARS        ARRAY OF YEARS TO BE MODELLED
C       NYEARS        NUMBER OF YEARS TO BE MODELLED
C
C*********************************************************************************************
C
        SUBROUTINE NG3(J)
C
        REAL DEPLNG3(60,12),INFLOW,NFLTRY,EVAP(60,12),DRAIN(12)
C
        COMMON NYEARS,IYEARS(60)
     * /NE3USES/UPIPE(60,12),UNE3(60,12),DRKIPLING(60,12)
     * /NE1USES/UNE1(60,12),DEPLNE1(60,12),FLN(60,12)
     * /MOOSOMIN/RNE2(60,12),RNE2AVG(60,12),EVAPMOOS(60,12),
     *           TOWNFACT,TOWN(60,12)
     * /BDRYUSES/UNG24(60,12),DEPLNG24(60,12)
     * /NG3DATA/UNG3(60,12),RNG3(60,12),FLNNG3(60,12)
C
        OPEN(UNIT=13,FILE='NE1EVAP.OUT',STATUS='NEW')
        OPEN(UNIT=21,FILE='MOOSDR.OUT',STATUS='NEW')
        OPEN(UNIT=24,FILE='NG3NAT.OUT',STATUS='NEW')
        OPEN(UNIT=25,FILE='NG3DEPL.OUT',STATUS='NEW')
C
        D = 0
        LCOUNT = 0
        IF (IYEARS(J).GE.78 .AND. IYEARS(J).LE.82) THEN
          CALL CDARATIO(10,12,D,RMOOS)
          DRAINSUM = 0
        ENDIF
C
30      FLOWSUM = 0
C
        DO 50 I=1,12
C
C
C   WHEN RECORDED FLOWS AVAILABLE PRIOR TO STATION 05NE001
C
       IF ( IYEARS(J) .LT. 58 ) THEN
C
```

```
C   ESTIMATE WINTER FLOWS
C
      IF ( I .LE. 2 .OR. I .GE. 11 ) THEN
       IF(IYEARS(J).GE.56.OR.IYEARS(J).EQ.55.AND.I.GE.11)THEN
        CALL MOOSSTOR(STORE2,RNE2(J,I))
        IF ( I .LE. 11 ) CALL MOOSSTOR(STORE1,RNE2(J,I+1))
        IF (J .EQ. 12 )  THEN
         IF ( J .EQ. NYEARS ) THEN
           CALL MOOSSTOR(STORE1,RNE2(J,12))
          ELSE
           CALL MOOSSTOR(STORE1,RNE2(J+1,1))
         ENDIF
        ENDIF
        DELSTOR = STORE1 - STORE2
        CALL MOOSAREA(AVGAREA,RNE2AVG(J,I))
        EVAP(J,I) = AVGAREA * EVAPMOOS(J,I) * 0.01
       ENDIF
       IF (RNG3(J,I).EQ.-9.99) THEN
         FLNNG3(J,I)=-9.99
        ELSE
         DEPLNG3(J,I) = DELSTOR + EVAP(J,I) + TOWNFACT*TOWN(J,I)
         FLNNG3(J,I) = RNG3(J,I) + DEPLNG3(J,I)
       ENDIF
C      KEEP TRACK OF PIPESTONE LAKE LEVELS
       CALL LAKELOSS(DEPLPIPE,J,I,0,0,4)
       GOTO 50
      ENDIF
C
C   OPEN WATER SEASON
C
       KCOUNT=0
C
C INITIAL ESTIMATE OF NATURAL FLOW
C
        DEPLNG3(J,I)=UNE1(J,I)+UNE3(J,I)+UNG24(J,I)+UNG3(J,I)
        IF ( IYEARS(J) .GE. 56.OR.IYEARS(J).EQ.55.AND.I.GE.4 ) THEN
         CALL MOOSAREA(AVGAREA,RNE2AVG(J,I))
         EVAP(J,I) = AVGAREA * EVAPMOOS(J,I) * 0.01
         CALL MOOSSTOR(STORE1,RNE2(J,I+1))
         CALL MOOSSTOR(STORE2,RNE2(J,I))
         DEPLNG3(J,I) = DEPLNG3(J,I) + EVAP(J,I) + STORE1 - STORE2
        ENDIF
C
C   CHECK FOR RECORDED FLOWS
        IF (RNG3(J,I).EQ.-9.99) THEN
         FLNNG3(J,I)=-9.99
C
C        KEEP TRACK OF PIPESTONE LAKE LEVELS
         CALL LAKELOSS(DEPLPIPE,J,I,0,0,4)
         GOTO 50
        ENDIF
C
        BASE = RNG3(J,I) + DEPLNG3(J,I)
        FLNNG3(J,I) = BASE
C
C ESTIMATE DEPLETIONS DUE TO PIPESTONE LAKE STORAGE AND EVAPORATION
C
40      CALL LAKELOSS(PIPEDEPL,J,I,D,FLNNG3(J,I),4)
        NFLTRY = BASE + PIPEDEPL
        IF ( NFLTRY .LT. 0 ) NFLTRY = 0
C
```

```
C IMPROVE ESTIMATE OF NATURAL FLOW
C
        TEST=ABS(NFLTRY-FLNNG3(J,I))
        FLNNG3(J,I) = NFLTRY
        IF (TEST.GT.0.5) THEN
         KCOUNT=KCOUNT+1
         IF (KCOUNT .GT. 20) THEN
           WRITE(*,2000)IYEARS(J),I
           GOTO 900
         ENDIF
         GOTO 40
        ENDIF
C
C   ADD ALL DEPLETIONS TOGETHER
C
900   DEPLNG3(J,I) = DEPLNG3(J,I) + PIPEDEPL
C
      ELSEIF ( IYEARS(J)  .GT. 57 .AND. IYEARS(J) .LT. 82
     *         .OR. IYEARS(J) .EQ. 82 .AND. I .LE. 8) THEN
       DEPLNG3(J,I) = DEPLNE1(J,I) + UNG24(J,I) + UNG3(J,I)
       BASE = RNG3(J,I) + DEPLNG3(J,I)
       NFLTRY = BASE
       DRAIN(I) = 0
C
60     INFLOW = NFLTRY - FLN(J,I)
       IF (INFLOW .LT. 0 ) INFLOW = 0
       IF (IYEARS(J) .GE. 78 .AND. I .GT. 2 .AND. I .LT. 11)
     *    DRAIN(I) = RMOOS * INFLOW
       TEST = ABS( NFLTRY - (BASE - DRAIN(I)))
       IF (TEST.GT.0.5) THEN
        NFLTRY = BASE - DRAIN(I)
        KCOUNT = KCOUNT + 1
        IF (KCOUNT .GT. 20) THEN
          WRITE(*,2000)IYEARS(J),I
          GOTO 800
        ENDIF
        GOTO 60
       ENDIF
800    DEPLNG3(J,I) = DEPLNG3(J,I) - DRAIN(I)
       DRAINSUM = DRAINSUM + DRAIN(I)
C
      ELSE
       DEPLNG3(J,I) = DEPLNG24(J,I) + UNG3(J,I)
      ENDIF
C
C   NATURAL FLOW AT STATION 05NG003
C
       FLNNG3(J,I) = RNG3(J,I) + DEPLNG3(J,I)
       IF ( FLNNG3(J,I) .LT. 0 ) THEN
        FLNNG3(J,I) = 0
       ENDIF
       IF(I .GE. 3 .AND. I .LE. 10 .AND. FLNNG3(J,I) .GE. 0 )
     * FLOWSUM = FLOWSUM + FLNNG3(J,I)
C
50    CONTINUE
```

```
C
      IF ( LCOUNT .GE. 20 ) GOTO 70
      IF (FLOWSUM .LE. 0 ) FLOWSUM = 10.0
      CALL RTRNPER(4,FLOWSUM,R,D)
      IF ( R .GT. 2 ) THEN
       IF ( LCOUNT .GE. 1 ) THEN
        TEST = ABS( FLOWSUM - FLOWSAVE )
        IF ( TEST .LT. 0.5 ) GOTO 70
       ENDIF
       IF (IYEARS(J).GE.78 .AND. IYEARS(J).LE.82) THEN
         CALL CDARATIO(10,12,D,RMOOS)
         DRAINSUM = 0
       ENDIF
       FLOWSAVE = FLOWSUM
       LCOUNT = LCOUNT + 1
       GOTO 30
      ENDIF
C
70    IF ( IYEARS(J) .GE. 55 .AND. IYEARS(J) .LE. 57 )
     * WRITE(13,490)IYEARS(J),(EVAP(J,I),I=1,12)
      IF ( IYEARS(J) .GE. 78 .AND. IYEARS(J) .LE. 82)
     * WRITE(21,500)IYEARS(J),(DRAIN(I),I=1,12),DRAINSUM
      WRITE(24,500)IYEARS(J),(FLNNG3(J,I),I=1,12),FLOWSUM
      WRITE(24,495)IYEARS(J),R,D
      WRITE(25,490)IYEARS(J),(DEPLNG3(J,I),I=1,12)
490   FORMAT(1X,I4,12F9.1)
495   FORMAT(1X,I4,2F9.5)
500   FORMAT(1X,I4,13F9.1)
C
C FORMAT STATEMENT FOR ERROR MESSAGE
2000   FORMAT(' WARNING: ALLOWABLE ITERATIONS EXCEEDED, NG3 SUB, YEAR ',
     * I2,' MONTH ',I2)
       RETURN
       END
```

```
C
C      SUBROUTINE BDRY
C
C      PURPOSE:   TO CALCULATE NATURAL FLOWS AT THE SASKATCHEWAN-MANITOBA
C                 BOUNDARY
C
C      PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                    B. OEGEMA
C                    OCTOBER 1989
C
C      PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                    PRAIRIE PROVINCES WATER BOARD
C
C****************************************************************************
C
C  VARIABLE LIST
C      FLNBDRY       NATURAL FLOW AT SASK-MAN BOUNDARY
C      FLNNE1        NATURAL FLOW AT STATION 05NE001
C      FLNNG24       NATURAL FLOW AT STATION 05NG024
C      FLNNG3        NATURAL FLOW AT STATION 05NG003
C      NYEARS        NUMBER OF YEARS
C
C******************************************************************************************
C
      SUBROUTINE BDRY(J)
C
      REAL FLNBDRY(60,12)
C
      COMMON NYEARS,IYEARS(60)
     * /NG24DATA/RNG24(60,12),FLNNG24(60,12)
     * /NG3DATA/UNG3(60,12),RNG3(60,12),FLNNG3(60,12)
     * /NE1USES/UNE1(60,12),DEPLNE1(60,12),FLNNE1(60,12)
C
      IF (IYEARS(J) .LE. 82 ) THEN
       CALL CDARATIO(3,4,0,RNG24NG3)
       CALL CDARATIO(13,12,0,RLOCAL)
       LCOUNT = 0
      ENDIF
40    FLOWSUM = 0
C
      DO 50 I=1,12
C
      IF ( FLNNG3(J,I) .LT. 0 ) THEN
        FLNBDRY(J,I) = -9.99
        GOTO 50
C
      ELSEIF (IYEARS(J) .LT. 58) THEN
        FLNBDRY(J,I) = FLNNG3(J,I) * RNG24NG3
C
      ELSEIF (IYEARS(J) .LE. 82 .AND. FLNNE1(J,I) .LT. 0 ) THEN
        FLNBDRY(J,I) = FLNNG3(J,I) * RNG24NG3
C
      ELSEIF ( IYEARS(J) .LE. 82 .AND. FLNNE1(J,I) .GE. 0 ) THEN
       FLNBDRY(J,I)=FLNNE1(J,I)+(FLNNG3(J,I)-FLNNE1(J,I))*RLOCAL
C
      ENDIF
      IF (IYEARS(J).EQ.82 .AND. I.GE.8)FLNBDRY(J,I)=FLNNG24(J,I)
      IF ( IYEARS(J) .GT. 82 ) FLNBDRY(J,I) = FLNNG24(J,I)
      IF ( FLNBDRY(J,I) .LT. 0) FLNBDRY(J,I) = 0.0
C
      IF(I.GT.2 .AND. I.LT.11) FLOWSUM = FLOWSUM + FLNBDRY(J,I)
C
50    CONTINUE
```

```
C
       IF ( IYEARS(J) .GT. 82 ) GOTO 60
       IF ( LCOUNT .GE. 20 ) GOTO 1000
       IF ( FLOWSUM .LE. 0 ) THEN
         D = 0
        ELSE
         CALL RTRNPER(3,FLOWSUM,R,D)
       ENDIF
       IF ( R .LE. 2 ) GOTO 60
       IF (LCOUNT .GE. 1 ) THEN
        TEST = ABS(FLOWSUM - FLOWSAVE)
        IF ( TEST .LT. 0.5 ) GOTO 60
       ENDIF
       CALL CDARATIO(3,4,D,RNG24NG3)
       CALL CDARATIO(13,12,D,RLOCAL)
       FLOWSAVE = FLOWSUM
       LCOUNT = LCOUNT + 1
       GOTO 40
C
C  OUTPUT
C
60     OPEN(UNIT=26,FILE='BDRY.OUT',STATUS='NEW')
       WRITE(26,495)IYEARS(J),(FLNBDRY(J,I),I=1,12),FLOWSUM
495    FORMAT(1X,I4,13F9.1)
       GOTO 70
C
C   ERROR MESSAGE
1000   WRITE(*,1001)IYEARS(J)
1001   FORMAT('ALLOWED NUMBER OF ITERATIONS EXCEEDED IN BDRY SUBROUTINE
     * IN ')
       GOTO 60
C
70     RETURN
       END
```

```
C
C       SUBROUTINE LAKELOSS
C
C       PURPOSE:   TO CALCULATE PIPESTONE LAKE DEPLETIONS
C
C       PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                     B. OEGEMA
C                     AUGUST 1989
C
C       PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                     PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C   VARIABLE LIST
C       AREAN        PIPESTONE LAKE AREAS AT THE BEGINNING OF THE MONTH
C       AREAE          FOR NATURAL AND EXISTING CONDITIONS RESPECTIVELY
C       DRAIN        MONTHLY DRAINAGE
C       DRKIPLNG     RECORDED PUMPAGE FROM KIPLING MARSH
C       ELEVN        ARRAYS OF PIPESTONE LAKE ELEVATIONS AT THE BEGINNING OF THE MONTH
C       ELEVE          FOR NATURAL AND EXISTING CONDITIONS RESPECTIVELY
C       EVAPN        ARRAY OF PIPESTONE LAKE EVAPORATION FOR NATURAL CONDITIONS
C       EVAPE        ARRAY OF PIPESTONE LAKE EVAPORATION FOR EXISTING CONDITIONS
C       EVAPPIPE     NET EVAPORATION (mm) FROM PIPESTONE LAKE
C       GRENDEPL     DEPLETION DUE TO DIVERSION TO GRENFELL WATER SUPPLY
C       NEVAP        TEMPORARY VALUE OF PIPESTONE LAKE EVAPORATION
C       RGREN        RATIO OF GRENFELL DIVERSION CDA TO STATION CDA
C       RPIPE        RATIO OF PIPESTONE LAKE CDA TO STATION CDA
C       RSILV        RATIO OF SILVERWOOD CDA TO STATION CDA
C       STOREN       PIPESTONE LAKE STORAGES AT THE BEGINNING OF THE MONTH
C       STOREE          FOR NATURAL AND EXISTING CONDITIONS RESPECTIVELY
C       UPIPE        USES ABOVE PIPESTONE LAKE
C
C*******************************************************************************************
C
        SUBROUTINE LAKELOSS(DEPLPIPE,J,IKEEP,D,FLNTRY,STA)
C
        INTEGER YEAR
C
        REAL NEVAP,DELPIPE(60,12),DRAIN(12),INFLOW,GRENDEPL(12)
        REAL EVAPN(60,12),EVAPE(60,12)
C
        COMMON NYEARS,IYEARS(60)
      * /PIPE/ELEVN(60,12),ELEVE(60,12),FSLE,FSLN,EVAPPIPE(60,12)
      * /NE3USES/UPIPE(60,12),UNE3(60,12),DRKIPLNG(60,12)
C
        OPEN(UNIT=8,FILE='GRENUSE.OUT',STATUS='NEW')
        OPEN(UNIT=9,FILE='SILVDR.OUT',STATUS='NEW')
C
        I=IKEEP
        DELPIPE(J,I) = 0.0
        CALL PIPEAREA(ELEVE(J,I),AREAE)
        CALL PIPEAREA(ELEVN(J,I),AREAN)
C
```

```
C        KEEP TRACK OF PIPESTONE LAKE LEVELS IN WINTER
C        CHANGE IN STORAGE IS DUE TO NET EVAPORATION
        IF ( I .LE. 2 .OR. I .GE. 11 ) THEN
         IF(I .LT. 12) THEN
           ELEVN(J,I+1)=ELEVN(J,I) - EVAPPIPE(J,I)/1000
           ELEVE(J,I+1)=ELEVE(J,I) - EVAPPIPE(J,I)/1000
           CALL PIPEAREA(ELEVN(J,I+1),ARN)
           CALL PIPEAREA(ELEVE(J,I+1),ARE)
          ELSE
           ELEVN(J+1,1)=ELEVN(J,I) - EVAPPIPE(J,I)/1000
           ELEVE(J+1,1)=ELEVE(J,I) - EVAPPIPE(J,I)/1000
           CALL PIPEAREA(ELEVN(J+1,1),ARN)
           CALL PIPEAREA(ELEVE(J+1,1),ARE)
         ENDIF
        AVGAREA=(AREAE+ARE)/2.0
        EVAPE(J,I)=AVGAREA*EVAPPIPE(J,I)*0.01
        AVGAREA=(AREAN+ARN)/2.0
        EVAPN(J,I)=AVGAREA*EVAPPIPE(J,I)*0.01
        GOTO 2000
       ENDIF
C
C  OPEN WATER SEASON
C
       CALL CDARATIO(5,STA,D,RGREN)
       CALL CDARATIO(6,STA,D,RPIPE)
       CALL CDARATIO(7,STA,D,RSILV)
       NEVAP=0
C
C    BEGINNING OF MONTH
       CALL PIPESTOR(ELEVN(J,I),STOREN)
       CALL PIPESTOR(ELEVE(J,I),STOREE)
       CALL PIPESTOR(FSLE,CAPE)
       CALL PIPESTOR(FSLN,CAPN)
C
C
       KCOUNT=1
80     CONTINUE
C
C  EXISTING CONDITIONS
C
C    INFLOW INTO PIPESTONE LAKE UNDER PRESENT CONDITONS
C
       DRAIN(I) = 0
       GRENDEPL(I)=0
       IF (IYEARS(J) .GE. 58 ) THEN
         DRAIN(I) = FLNTRY * RSILV
         IF (IYEARS(J) .GE. 59) THEN
          GRENDEPL(I) = FLNTRY * RGREN
          GRENSUM = 0
          DO 85 L = 1,IKEEP
           GRENSUM = GRENSUM + GRENDEPL(L)
85        CONTINUE
          IF ( GRENSUM .GE. 253 )
     *     GRENDEPL(I) = 253 - ( GRENSUM - GRENDEPL(I) )
         ENDIF
       ENDIF
       INFLOW=FLNTRY*RPIPE-UPIPE(J,I)+DRKIPLNG(J,I)-GRENDEPL(I)+DRAIN(I)
       IF ( INFLOW .LT. 0 ) INFLOW = 0
C
```

```
C     MONTH END
        ICOUNT=1
90      VOLUMEE=STOREE+INFLOW-NEVAP
        IF (VOLUMEE .GE. CAPE) THEN
            ELE=FSLE
          ELSEIF (VOLUMEE .LE. 0) THEN
            CALL PIPELEV(0,ELE)
          ELSE
            CALL PIPELEV(VOLUMEE,ELE)
        ENDIF
        CALL PIPEAREA(ELE,ARE)
C
C     NET EVAPORATION
C
        AVGAREA=(AREAE+ARE)/2.0
        EVAPE(J,I)=AVGAREA*EVAPPIPE(J,I)*0.01
        TEST=ABS(EVAPE(J,I)-NEVAP)
        IF (TEST .GT. 0.5) THEN
          NEVAP=EVAPE(J,I)
          ICOUNT=ICOUNT+1
          IF (ICOUNT .GT. 20)GOTO 1000
          GOTO 90
        ENDIF
C
C     SPILLAGE
C
95      IF(VOLUMEE .LT. CAPE) THEN
           SPILLE = 0
         ELSE
           SPILLE = STOREE+INFLOW-EVAPE(J,I)-CAPE
        ENDIF
C
C NATURAL CONDITIONS
C
C     INFLOW INTO PIPESTONE LAKE UNDER NATURAL CONDITIONS
C
        INFLOW = FLNTRY * RPIPE
C
C     MONTH END
        JCOUNT=1
100     VOLUMEN=STOREN+INFLOW-NEVAP
        IF (VOLUMEN .GT. CAPN) THEN
            ELN=FSLN
          ELSEIF (VOLUMEN .LT. 0) THEN
            CALL PIPELEV(0,ELN)
          ELSE
            CALL PIPELEV(VOLUMEN,ELN)
        ENDIF
        CALL PIPEAREA(ELN,ARN)
C
C     NET EVAPORATION
C
        AVGAREA=(AREAN+ARN)/2.0
        EVAPN(J,I)=AVGAREA*EVAPPIPE(J,I)*0.01
        TEST=ABS(EVAPN(J,I)-NEVAP)
        IF (TEST .GT. 0.5) THEN
          NEVAP=EVAPN(J,I)
          JCOUNT=JCOUNT+1
          IF (JCOUNT .GT. 20) GOTO 1005
          GOTO 100
        ENDIF
C
```

```
C     SPILLAGE
C
110     IF(VOLUMEN .LT. CAPN)THEN
           SPILLN = 0
         ELSE
           SPILLN = STOREN+INFLOW-EVAPN(J,I)-CAPN
        ENDIF
C
C DEPLETION
C
        DELPIPE(J,I) = SPILLN - SPILLE
        DEPLPIPE = DELPIPE(J,I)
C
C     SET UP VARIABLES FOR NEXT MONTH, NEXT YEAR
        ELEVN(J,I+1)=ELN
        ELEVE(J,I+1)=ELE
        GOTO 2000
C
C
1000    WRITE(*,1001)IYEARS(J),I
        GOTO 95
1005    WRITE(*,1001)IYEARS(J),I
1001    FORMAT(' TOLERANCE NOT REACHED IN  ',I4,' MONTH  ',I2)
        GOTO 110
C
2000    CONTINUE
        IF ( IKEEP .EQ. 12 ) THEN
         GRENSUM = 0
         DRAINSUM = 0
         DO 1500 L=1,12
          GRENSUM = GRENDEPL(L) + GRENSUM
          DRAINSUM = DRAIN(L) + DRAINSUM
1500     CONTINUE
         WRITE(8,970)IYEARS(J),(GRENDEPL(I),I=1,12),GRENSUM
         WRITE(9,970)IYEARS(J),(DRAIN(I),I=1,12),DRAINSUM
         WRITE(9,975)IYEARS(J),RSILV,D
970      FORMAT(1X,I4,13F9.1)
975      FORMAT(1X,I4,F9.5,F9.5)
         IF ( J .EQ. NYEARS ) THEN
           OPEN(UNIT=6,FILE='LAKEEVAP.OUT',STATUS='NEW')
           WRITE(6,980)NYEARS
           WRITE(6,990)(IYEARS(L),(EVAPN(L,I),I=1,12),L=1,NYEARS)
           WRITE(6,980)NYEARS
           WRITE(6,990)(IYEARS(L),(EVAPE(L,I),I=1,12),L=1,NYEARS)
           WRITE(6,980)NYEARS
           WRITE(6,990)(IYEARS(L),(DELPIPE(L,I),I=1,12),L=1,NYEARS)
           CLOSE(UNIT=6)
980        FORMAT(I2)
990        FORMAT(1X,I4,12F9.1)
995        FORMAT(1X,I4,12F9.3)
         ENDIF
        ENDIF
        RETURN
        END
```

```
C
C       SUBROUTINE PIPESTOR
C
C       PURPOSE:   TO CALCULATE PIPESTONE LAKE STORAGE GIVEN STAGE
C
C*************************************************************************
C
C  VARIABLE LIST
C       EL       ELEVATION OF PIPESTONE LAKE (GIVEN)
C       ELEV     ARRAY OF ELEVATIONS IN METRES
C       ST       STORAGE OF PIPESTONE LAKE (CALCULATED)
C       STORE    VECTOR OF STORAGE IN CUBIC DECAMETRES BASED ON
C                 PFRA 1985 REDELINEATION OF 1938 TOPOGRAPHY
C
C*******************************************************************************************
C
        SUBROUTINE PIPESTOR(EL,ST)
C
C   TABLE OF ELEVATIONS AND STORAGE
        REAL ELEV(10),STORE(10)
        DATA ELEV/588.636,588.788,589.093,589.398,589.703,590.007,
     *           590.312,590.617,590.922,591.227/
        DATA STORE/0.0,17,130,324,593,936,1335,1766,2224,2710/
C
        DO 10 I = 2,10
         IF ( EL .LE. ELEV(I) ) THEN
          K=I-1
          ST=STORE(I)-(ELEV(I)-EL)*(STORE(I)-STORE(K))/(ELEV(I)-ELEV(K))
          GOTO 15
         ENDIF
10      CONTINUE
15      CONTINUE
        RETURN
        END
```

```
C
C       SUBROUTINE PIPEAREA
C
C       PURPOSE:   TO CALCULATE PIPESTONE LAKE AREA GIVEN STAGE
C
C       PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                     HYDROLOGY SERVICES UNIT
C                     B. OEGEMA
C                     JANUARY 1991
C
C       PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                     PRAIRIE PROVINCES WATER BOARD
C
C*****************************************************************************
C
C   VARIABLE LIST
C       AR      AREA OF PIPESTONE LAKE (CALCULATED)
C       AREA    VECTOR OF LAKE AREAS IN HECTARES BASED ON PFRA
C                1985 REDELINEATION OF 1938 TOPOGRAPHY
C       EL      ELEVATION OF PIPESTONE LAKE (GIVEN)
C       ELEV    VECTOR OF ELEVATIONS IN METRES
C
C**********************************************************************************************
C
      SUBROUTINE PIPEAREA(EL,AR)
C
C    TABLE OF ELEVATIONS AND AREAS
      REAL ELEV(10),AREA(10)
      DATA ELEV/588.636,588.788,589.093,589.398,589.703,590.007,
     *          590.312,590.617,590.922,591.227/
      DATA AREA/0.0,22,52,76,100,124,137,146,155,164/
C
      DO 10 I = 2,10
        IF ( EL .LE. ELEV(I) ) THEN
          K=I-1
          AR=AREA(I)-(ELEV(I)-EL)*(AREA(I)-AREA(K))/(ELEV(I)-ELEV(K))
          GOTO 15
        ENDIF
10    CONTINUE
15    CONTINUE
      RETURN
      END
```

```
C
C       SUBROUTINE PIPELEV
C
C       PURPOSE:   TO CALCULATE PIPESTONE LAKE STAGE GIVEN STORAGE
C
C       PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                     B. OEGEMA
C                     JANUARY 1991
C
C       PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                     PRAIRIE PROVINCES WATER BOARD
C
C***************************************************************************
C
C   VARIABLE LIST
C       ST       STORAGE OF PIPESTONE LAKE (GIVEN) IN CUBIC DECAMETRES
C                 BASED ON PFRA 1985 REDELINEATION OF 1938 TOPOGRAPHY
C       EL       IN METRES (GSC DATUM)
C
C******************************************************************************************
C
        SUBROUTINE PIPELEV(ST,EL)
C
C    TABLE OF ELEVATIONS AND STORAGE
        REAL ELEV(10),STORE(10)
        DATA ELEV/588.636,588.788,589.093,589.398,589.703,590.007,
     *            590.312,590.617,590.922,591.227/
        DATA STORE/0.0,17,130,324,593,936,1335,1766,2224,2710/
C
        DO 10 I = 2,10
         IF ( ST .LE. STORE(I) ) THEN
          K=I-1
          EL=ELEV(I)-(STORE(I)-ST)*(ELEV(I)-ELEV(K))/(STORE(I)-STORE(K))
          GOTO 15
         ENDIF
10      CONTINUE
15      CONTINUE
        RETURN
        END
```

```
C
C      SUBROUTINE MOOSSTOR
C
C      PURPOSE:   TO CALCULATE MOOSOMIN RESERVOIR STORAGE GIVEN STAGE
C
C      PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                    B. OEGEMA
C                    MAY 1989
C
C      PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                    PRAIRIE PROVINCES WATER BOARD
C
C******************************************************************************
C
C  VARIABLE LIST
C      EL      ELEVATION OF MOOSOMIN RESERVOIR (GIVEN) IN METRES, ADD 500.000 TO GET CGD
C      ST      STORAGE OF MOOSOMIN RESERVOIR (CALCULATED)
C
C*******************************************************************************************
C
      SUBROUTINE MOOSSTOR(ST,EL)
C
C   TABLE OF ELEVATIONS AND STORAGE
      REAL ELEV(15),STORE(15)
      DATA ELEV/36.27,38.16,38.77,39.38,39.99,40.60,41.21,41.82,
     *          42.43,43.04,43.65,43.91,44.26,44.87,45.48/
      DATA STORE/0.0,268.,515.,922.,1514.,2315.,3352.,4643.,6200.,
     *           8040.,10167.,11156.,12562.,15223.,18143./
C
      DO 10 I = 2,15
       IF ( EL .LE. ELEV(I) ) THEN
        K=I-1
        ST=STORE(I)-(ELEV(I)-EL)*(STORE(I)-STORE(K))/(ELEV(I)-ELEV(K))
        GOTO 15
       ENDIF
10    CONTINUE
15    CONTINUE
      RETURN
      END
```

```
C
C       SUBROUTINE MOOSAREA
C
C       PURPOSE:   TO CALCULATE MOOSOMIN RESERVOIR AREA GIVEN STAGE
C
C       PREPARED BY:  SASKATCHEWAN WATER CORPORATION
C                     B. OEGEMA
C                     MAY 1989
C
C       PREPARED FOR: PIPESTONE CREEK NATURAL FLOW STUDY
C                     PRAIRIE PROVINCES WATER BOARD
C
C***************************************************************************
C
C  VARIABLE LIST
C       AR      AREA OF MOOSOMIN RESERVOIR (CALCULATED)
C       AREA    VECTOR OF RESERVOIR AREAS IN HECTARES
C       EL      ELEVATION OF MOOSOMIN RESERVOIR (GIVEN)
C       ELEV    VECTOR OF ELEVATIONS IN METRES, ADD 500.000 m TO GET GSC DATUM
C
C******************************************************************************************
C
        SUBROUTINE MOOSAREA(AR,EL)
C
C   TABLE OF ELEVATIONS AND AREAS
        REAL ELEV(15),AREA(15)
        DATA ELEV/36.27,38.16,38.77,39.38,39.99,40.60,41.21,41.82,
     *           42.43,43.04,43.65,43.91,44.26,44.87,45.48/
        DATA AREA/0.0,28.,53.,81.,113.,150.,190.,233.,277.,326.,372.,
     *           389.,415.,457.,500./
C
        DO 10 I = 2,15
          IF ( EL .LE. ELEV(I) ) THEN
            K=I-1
            AR=AREA(I)-(ELEV(I)-EL)*(AREA(I)-AREA(K))/(ELEV(I)-ELEV(K))
            GOTO 15
          ENDIF
10      CONTINUE
15      CONTINUE
        RETURN
        END
```