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Analysis of pipe temperature data - TL-100 loggers

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FINAL REPORT

ANALYSIS OF PIPE TEMPERATURE DATA - TL-100 LOGGERS

to the
Land Resources Division
Northern Affairs Program
Indian and Northern Affairs Canada
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FOREWORD

This report documents work undertaken as part of the federal government's Permafrost and Terrain Research and Monitoring Program along the 868 km Norman Wells to Zama oil pipeline. The 324 mm diameter, shallow burial (1 m) pipeline, traverses the discontinuous permafrost zone of northwestern Canada and began operation in April 1985. A joint monitoring program with Interprovincial Pipe Line Inc. was established following the signing of an environmental agreement between the pipeline company and the Department of Indian and Northern Affairs (INAC) in 1983. INAC coordinates the government's monitoring program in which Energy, Mines and Resources' Geological Survey of Canada and Agriculture Canada's Land Resource Research Institute participate.

A major component of this research and monitoring program involves the detailed quantification of changes in the ground thermal regime and geomorphic conditions at a series of instrumented sites along the route. This project was developed in cooperation with the Terrain Sciences Division of the Geological Survey in order to examine and quantify the effects of pipeline construction, operation and maintenance in thaw sensitive terrain. Many components of this research are contracted out.

The work undertaken in this contract report describes but one aspect of these site investigations. Interpretations contained herein are often limited to the specific data base under analysis and may thus not present an integrated or comprehensive analysis of all site observations. The opinions and views expressed by the authors are their own and do not necessarily reflect those of the Geological Survey of Canada or Indian and Northern Affairs.

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Margo Burgess
Scientific Authority
Terrain Sciences Division
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Acknowledgments

This report is based on field measurements undertaken by many people from Agriculture Canada (Land Resources Research Centre [AG-CAN]), Energy, Mines & Resources Canada (Permafrost Research Section, GSC), the Department of Indian & Northern Affairs (INAC) and Interprovincial Pipe Line Ltd. as part of the **Permafrost and Terrain Research & Monitoring Program.** Funding for this contract came from Dr. K.L MacInnes (INAC, Yellowknife), and pipe temperature data were obtained from Dr. C. Tarnocai and D. Kroetsch (AG-CAN). Many thanks to M.M Burgess (GSC) for initially generating the tasks and providing effective discussions throughout the contract.

ANALYSIS OF PIPE TEMPERATURE DATA - TL-100 LOGGERS

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INTRODUCTION

Pipe and ground temperature data have been collected at a number of monitoring sites along the Norman Wells pipeline since 1984 as part of the government Permafrost & Terrain Research and Monitoring Program (Burgess et al., 1986; Burgess and Naufal, 1990; MacInnes et al., 1990a,b). This report analyses pipe temperature data collected between August 1987 and September 1990 from 14-single channel Brancker loggers installed adjacent to the pipe.

A series of tasks (Statement of Work denoted as S.W.) were followed during the analyses and these are listed below.

S.W.1. Examine IPL mean daily throughputs and shutdown data for the period May 89 to September 90, and hourly pipe logger data at Pump Station 1 in order to determine periods of lengthy shutdown. Suggest possible shutdowns for analysis (i.e. 2 in summer and 2 in winter).

S.W.2. Study the effect on pipe temperatures of both shutdown and start-up, using hourly and/or daily logger data. For the 4 shutdowns identified in step 1:
(i) Examine at each of the recommended sites the change in pipe temperature following shutdown and start-up (e.g. amplitude, the length of time required to reach equilibrium with the surrounding soil), determine equilibrium temperatures and their respective increases and/or decreases.
(ii) Examine how the temperature response changes along the pipeline. Determine the time lags associated with shutdowns, the pattern in amplitude change and the relationship between length of shutdown and distance affected down the line from a pump station.

S.W.3. Generate mean daily and mean monthly graphs for all recommended pipe temperature stations for the period August 87 to September 1990. Perform basic statistical analysis on the data.

S.W.4. Generate running mean annual plots for the recommended sites to determine long term trends and their amplitude.

As requested by the scientific authority, products from the tasks specified above only consist of listings of information, printed graphs and tables, and not of a description and/or interpretation of the analyses. Additional tasks were included sporadically by the scientific authority in order to give a better portrayal of certain analyses and trends in the pipe temperature data.

The reports submitted to the scientific authority after completion of each task are included and form an integral part of this **Final Report.** Additional information and/or analyses performed after completion of a particular task are incorporated in each of the "Reports on Statement of Work" where applicable. **Tables** and all figures (under **"Appendices"**) produced are located at the end of the report.

INSTALLATION OF PIPE TEMPERATURES

The pipe temperature data used in this report were collected from the installations designed by the Land Resources Research Centre of Agriculture Canada (AG-CAN). The main objective of this dataset was to complement the temperature measurements obtained by the Departments of Indian & Northern Affairs (INAC) and Energy, Mines & Resources (EMR) and to offer more frequent pipe temperature measurements. A total of fourteen sites were installed by AG-CAN. Figure 1 illustrates the location of the seven monitoring sites selected for this report.

Each installation consisted of a single thermistor mounted as near as possible to the pipe (Figure 2) and connected to a single-channel Brancker datalogger (model RBL TL-100). Dataloggers were initially programmed to record temperatures at hourly intervals until September 1989 and at 3-hr intervals thereafter. All data records were then entered in LOTUS 1-2-3 spreadsheet format to generate varying calculations.

METHODS & DATA HANDLING

The methods used to generate and manipulate the data for this report were all performed on a personal computer and identified in each task. A series of calculations, interpolations and plotting of temperatures were conducted from original data records. All files generated for this report were copied on floppy disks and have been supplied to the scientific authority. The software used is familiar to most scientist dealing with spreadsheets, varying data formats, statistical analysis and graphic display.

A number of problems and difficulties associated with the handling of the dataset were encountered while undertaking **S.W. 1** and **S.W. 2.** They included the following:

- AG-CAN data filenames and extensions were confused with other projects (i.e. identical or duplicate filenames in several cases).

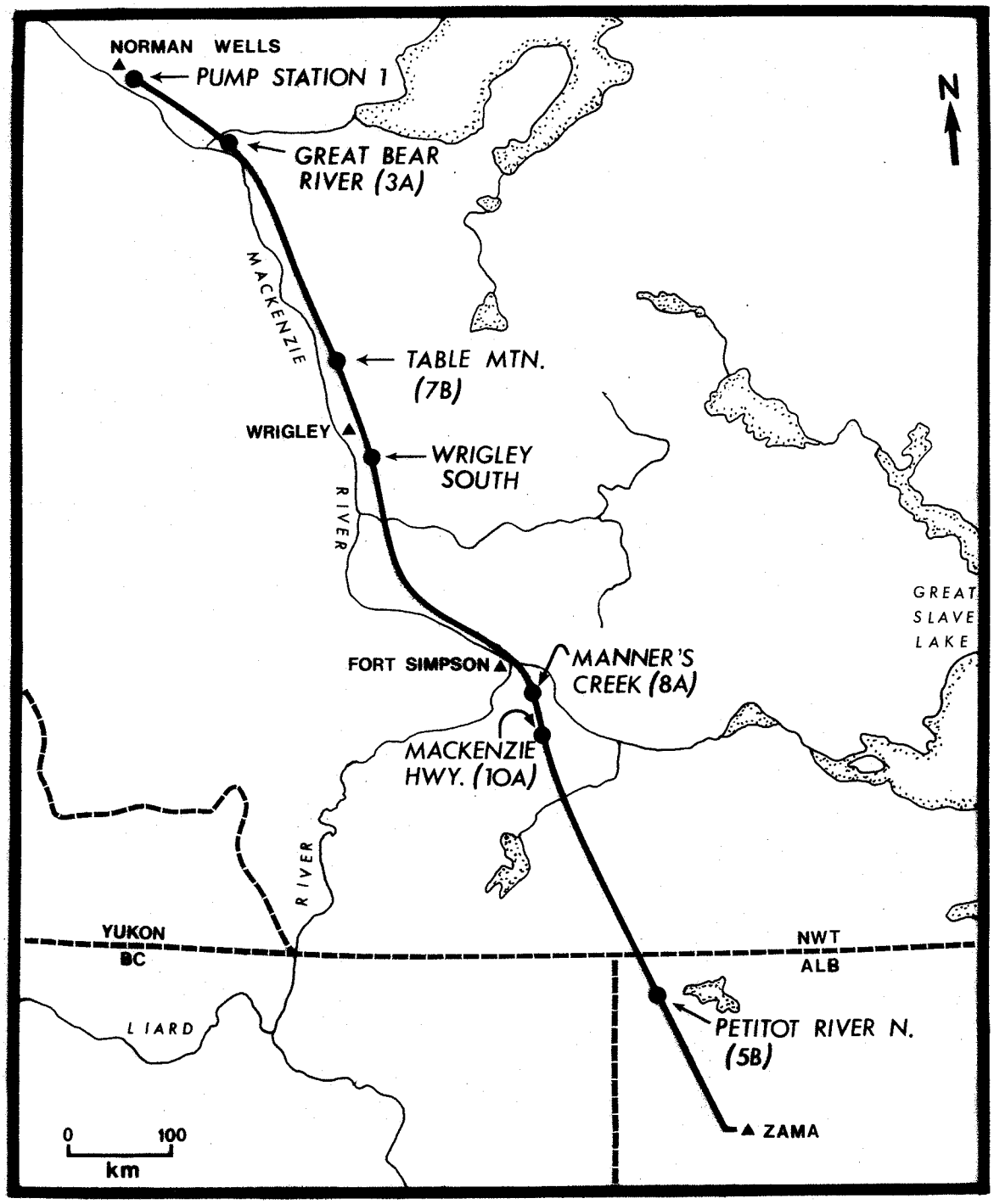

Figure 1. Location of TL-100 pipe temperature dataloggers along the Norman Wells pipeline. note: The locations only correspond to sites analyzed in this report.

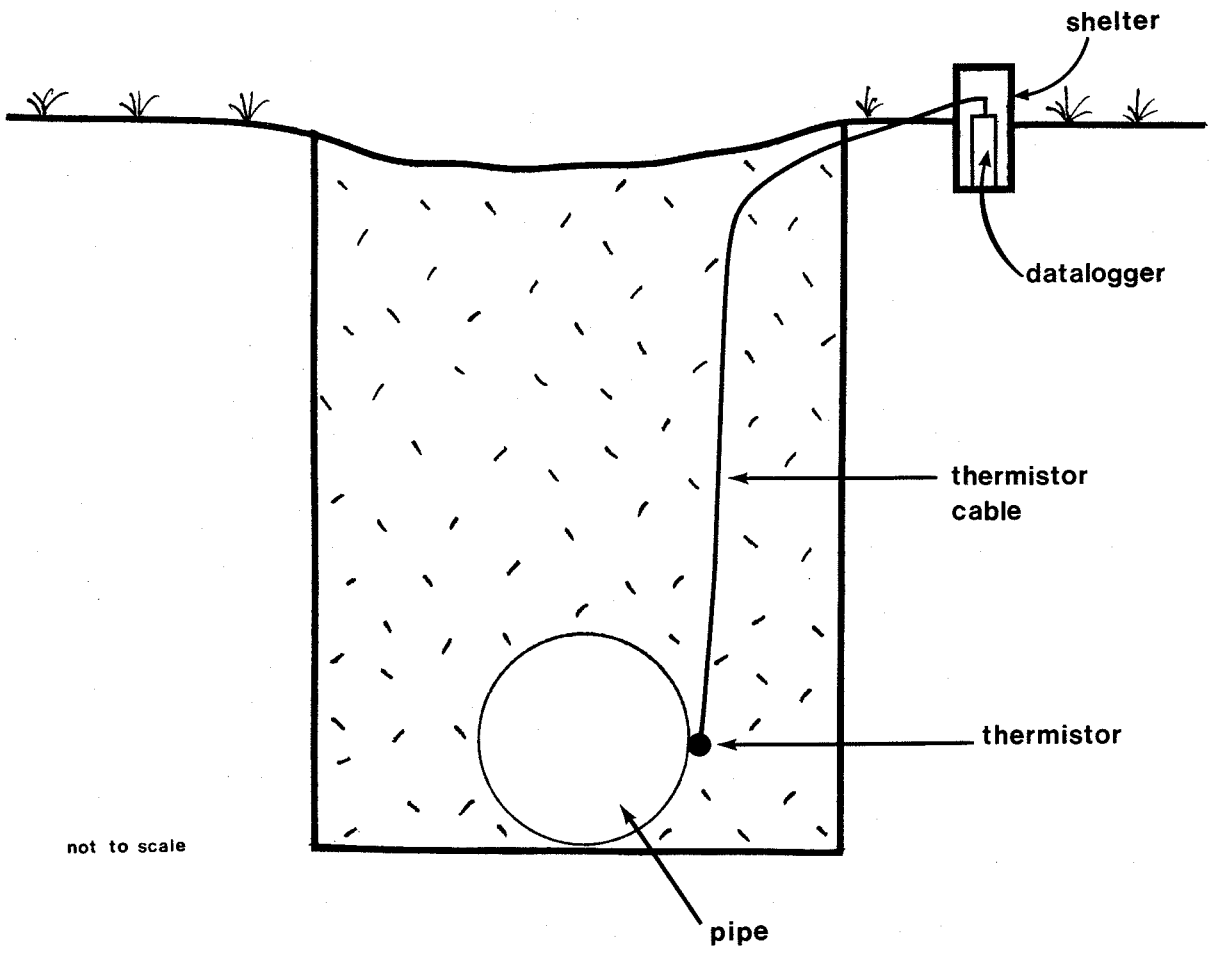

Figure 2. A cross-sectional example of a typical site installation.

- Not all of the data was delivered prior to start of **S.W. 1.**
- Many data files were truncated and/or missing information.
- Complete dataset was only obtained mid-way through **S.W. 2.**
- Mean, maximum and minimum temperature values produced by AG-CAN were not consistent with those calculated by the contractor.

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REPORT ON STATEMENT OF WORK 1 (S.W. 1)

S.W. 1.1 Introduction

IPL mean daily throughputs and shutdown data for the period **May 1989** to **September 1990**, and of the hourly pipe logger data at Pump Station 1 were examined. As requested from the Scientific Authority, data for the period **September 1988** to **April 1989** was also inspected for significant shutdowns. Periods of lengthy and/or prominent shutdown (i.e. date & length) were determined from the IPL data and pipe logger data. Since the time of each shutdown could not be determined from IPL data, it was approximated from pipe logger data. A list of all prominent shutdowns (in accordance with the selection criteria in section **S.W. 1.2**) and shutdowns of interest is provided in **Table S.W.1.1.**

S.W. 1.2 Selection of Shutdown

A number of shutdowns appear suitable for **S.W. 2** (i.e. the study of the effect on pipe temperatures of both shutdown and start-up). Although four (4) possible shutdowns were identified for analysis (two in summer and two in winter), as many as twenty (20) shutdowns could show the effects on pipe temperatures. The shutdowns identified as "shutdowns of interest" show the greatest number of shutdown hours over the summer and winter season, and may be regarded as suitable selections. In addition, they could offer interesting results if pursued with detailed analysis of pipe temperature fluctuations.

The selection criteria used in identifying the four (4) requested shutdowns are as follow:

(i) greatest number of shutdown hours according to IPL data;
(ii) isolated monthly occurrences;
(iii) greatest effect on pipe temperature following shutdown according to IPL data and pipe temperature data.

S.W. 1.3 Recommended Shutdowns

Of the twenty (20) shutdowns identified between September 1988 and August 1990, four (4) were recommended for further study (i.e. S.W. 2).

The shutdowns are:

1- March 1, 1990 (4.2 hrs)
2- April 4, 1990 (6.6 hrs)
3- August 23, 1989 (9.4 hrs)
4- August 12-15, 1990 (84 consecutive hrs).

S.W. 1.4 Summary

As requested in **Statement of Work 1 (S.W. 1)**, four (4) shutdowns were selected after examining both IPL data and pipe logger data. The periods of lengthy shutdowns (i.e. date and length) were determined and noted for many cases, and a listing was provided (**Table S.W.1.1**). Two shutdowns were selected in summer (August 23, 1989 & August 12-15, 1990) and two in winter (March 1, 1990 & April 4, 1990). Sufficient information was gathered in **S.W. 1** to proceed to **Statement of Work 2.**

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REPORT ON STATEMENT OF WORK 2 (S.W. 2)

S.W. 2.1 Introduction

IPL mean daily throughputs and shutdown data for the period **August 1987** to **August 1990**, and 1-hr & 3-hr pipe logger data at Pump Station 1 were re-examined since data gaps prevented further analyses to be conducted on certain shutdowns of interest. Additional TL-100 logger data were provided after completion of S.W.1 and supplementary sites were included in the analysis. As requested from the Scientific Authority, data from this period was inspected for fourteen (14) shutdowns. A list of these shutdowns is provided in **Table S.W.2.1.**

S.W. 2.2 Initial Analyses

The change in pipe temperature following shutdown and start-up were examined at each of the **six (6)** recommended sites [Pump Station 1 (PS1) 0.02 km, Great Bear River (3A) 79.2 km, Table Mountain (7B) 272.0 km, Manner's Creek (8A) 557.8 km, Mackenzie Hwy. (10A) 588.3 km and Petitot River (5B) 783.3 km]. These changes are briefly summarised in **Table S.W.2.1** and reviewed in greater detail in **Table S.W.2.2. Table S.W.2.2** also includes descriptive comments on the thermal trends during shutdown and after start-up. **(NOTE: Wrigley South 351.5 km** was added during **S.W.4** after request from the scientific authority. Not all analyses in this task include **Wrigley South** although the site may be included in certain figures, depending on shutdown dates.)

Plots of temperature fluctuations with distance from Pump Station 1 for shutdowns occurring in winter and summer at each of the six sites are

shown in **Appendix S.W.2.1a.** Histograms of the data used in **Appendix S.W.2.1a** with indications of increases and/or decreases in temperature are given in **Appendix S.W.2.1b.** Equilibrium temperatures with distance from Pump Station 1 during each of the fourteen shutdowns at the six sites were plotted and are given in **Appendix S.W.2.2.** Increasing and/or decreasing conditions were detected and included in the latter Tables and Appendices.

S.W. 2.3 Thermal Responses as a Result of Shutdown

Changes in temperature response along the pipeline were examined for each shutdown. Mean daily pipe temperatures for the period 1-week prior to shutdown to 1-week after start-up for eight (8) significant shutdowns (4 in winter and 4 in summer) at the six sites are provided in **Appendix S.W.2.3a.** These eight particular shutdowns were selected mainly because of their length of time and not their uninterrupted record of pipe temperature data. Many logger and/or battery failures unfortunately occurred prior to significant shutdowns (e.g. on four occasions at PS1; twice at 8A; once at 3A). Nonetheless, thermal trends can be detected from most installations and shutdown effects are apparent at pump stations. Shutdown effects were not readily discernible at other sites along the pipeline route since temperature fluctuations during shutdowns were not greater than 1.3 °C in winter and 2 °C in summer for all six sites.

As requested by the scientific authority following submission of this task, plots of pipe temperature at 1 and 3-hr intervals for **three (3)** specific shutdowns (namely, August 18, 1987 [121hrs]; February 28, 1989 [25.5hrs]; August 12, 1990 [85hrs]) were generated and are shown in **Appendix S.W.2.3b.**

Plots of changes in pipe temperature amplitude with distance from Pump Station 1 at each site 1-week prior to winter shutdowns and 1-week after winter start-ups are shown in **Appendix S.W.2.4.**

S.W. 2.4 Summary

As requested in **Statement of Work 2 (S.W. 2)**, the effect of shutdown and start-up on pipe temperatures were investigated using 1-hr and 3-hr pipe logger data. A total of fourteen (14) shutdowns were examined between the period of August 1987 and August 1990. Eight (8) shutdowns were selected in summer and six (6) in winter.

The change in pipe temperature following shutdown and start-up, the amplitude 1-week before and after shutdown, equilibrium temperatures during shutdown, and the time required to reach equilibrium with the surrounding ground material were examined. Any changes in equilibrium temperature were also noted. In addition, changes in thermal response along the pipeline route as a result of shutdowns were investigated and

any peculiar patterns in change of amplitude were accounted. The length of a shutdown and the distance affected along the pipeline from pump stations revealed relationships that were, in certain cases, unanticipated.

Sufficient information was gathered in **S.W. 2** to proceed to **Statement of Work 3.**

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REPORT ON STATEMENT OF WORK 3 (S.W. 3)

S.W. 3.1 Introduction

Mean daily and mean monthly pipe temperature data for the **six (6)** recommended sites for the time period since installation to September 1990 were plotted. As requested in **S.W. 3**, preliminary statistical analyses were conducted on the data. In addition, gaps in the data record were identified for each site where applicable. **(NOTE: Wrigley South 351.5 km** was added during **S.W.4** after request from the scientific authority. Not all analyses in this task include **Wrigley South** although the site is included in all figures.)

S.W. 3.2 Analyses and Work Performed

Mean daily and mean monthly graphs for each of the **seven (7)** recommended sites [Pump Station 1 (PS1) 0.02 km, Great Bear River (3A) 79.2 km, Table Mountain (7B) 272.0 km, Wrigley South 351.5 km, Manner's Creek (8A) 557.8 km, Mackenzie Hwy. (10A) 588.3 km and Petitot River N. (5B) 783.3 km] were produced. Individual plots of mean, maximum and minimum daily pipe temperatures for each site are shown in **Appendix S.W.3.1a.** Significant shutdowns from **Statement of Work 2 (S.W.2)** were also identified on the plots. Compiled or single plots of the data used in **Appendix S.W.3.1a** are given in **Appendix S.W.3.1b.**

Plots of mean, maximum and minimum monthly pipe temperatures are shown in **Appendix S.W.3.2.** These latter monthly pipe temperature values, their time of occurrence and the standard deviation about the monthly means are summarised in **Tables S.W.3.1** to **S.W.3.6.** Gaps in the data record for each site (excluding Wrigley South) are listed in **Table S.W.3.7.**

S.W. 3.3 Summary

As requested in **Statement of Work 3 (S.W. 3)**, mean daily and mean monthly graphs for all pipe temperature stations (for the time period

since installation to September 1990) were generated and plotted. The mean, maximum and minimum temperatures recorded each month and their time of occurrence were derived from the data and the standard deviation about the monthly means were calculated. Lastly, gaps in the data record were identified, however interpolations were not performed since gaps were considered too significant and long-lasting (i.e. greater than two months) in most cases.

* * *

REPORT ON STATEMENT OF WORK 4 (S.W. 4)

S.W. 4.1 Introduction

As continuity of data records permitted, running mean annual plots for the **six (6) initial** recommended sites were generated. At least 12 months of data is required for analyses to be performed.

S.W. 4.2 Analyses and Work Performed

Four sites required interpolation of data points because of logger failure, namely Pump Station 1 (PS1), Great Bear River (3A), Manner's Creek (8A) and Table Mountain (7B). However, only PS1, 3A and 8A had practical gaps to interpolate while 7B had a longer data gap (42 weeks). A cubic spline interpolation method was used on these three sites. It provided excellent data in replacement of the short data gaps.

For continuum in the "NWZ - Pipe and Ground Thermal Data Project", running mean annual temperatures were derived using the same technique as Riseborough et al. (1988, p. 20). The running mean for Pump Station 1 (PS1), Great Bear River (3A), Table Mountain (7B), Manner's Creek (8A), Mackenzie Hwy. (10A) and Petitot River N. (5B) are shown in **Appendix S.W.4.1.** Wrigley South was not included since at least 1-yr of data is needed for the analysis.

S.W. 4.3 Summary

As requested in **Statement of Work 4 (S.W. 4)**, running mean annual pipe temperatures for six sites were plotted. Interpolation of data was necessary for three sites prior to producing the running mean annual temperatures.

* * *

RECOMMENDATIONS

In order to make the AG-CAN dataset more accessible and manipulative, all files should be managed as: (1) yearly data instead of Brancker datalogger extension formats; and (2) presented as column formatted ASCII data instead of LOTUS 1-2-3 format. This would greatly improve the handling of the dataset, the readability of the data and allow the user to analyze and manipulate the data to his/her liking and not be restricted by software.

Lastly, this project would greatly benefit from a continuation of the present analyses on all remaining sites along the pipeline route. Such an initiative would reinforce the trends detected during shutdown and after start-up. In addition, correlations between mean monthly flow data and mean monthly pipe temperatures and mean monthly outgoing temperatures for each site along the pipeline route may reveal trends not observed previously. Similar objectives should be considered for the monitoring stations along the eventual pipeline route between Norman Wells and the Beaufort Sea coast.

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TABLE S.W.1.1

PRELIMINARY LISTING OF
LENGTH AND TIME OF PROMINENT SHUTDOWNS
AT PUMP STATION 1
FOR THE PERIOD BETWEEN SEPTEMBER 1988 AND SEPTEMBER 1990.

con't TABLE S.W.1

Month & Year	Day	Length of Shutdown (hrs)	Shutdown of Interest	Shutdown Selected
Dec. 89	4	1.6		
	5	4.9	*	
	12	2.8		
	13	2.2		
	14	1.3		
Jan. 90	16	2.7		
	24	3.3		
	27	3.5	*	
Feb. 90	14	3.7	*	
Mar. 90	1	4.2	*	√
	17	3.0		
Apr. 90	4	6.6	*	√
	25	2.2		
May 90	22	0.4		
	16	1.8	*	
Jun. 90	27	3.0	*	
Jul. 90	6	3.1	*	
	12	1.2		
Aug. 90	9	12.1		
	12	24.0	*	√
	13	24.0	*	√
	14	24.0	*	√
	15	12.0	*	√
	20	3.2		
Sept. 90	---------- data not available ----------			

KEY

?	length of shutdown unknown.
◘	IPL flow data was not available during the selection.
*	shutdowns that may show effects of pipe temperature.
√	shutdowns selected for S.W.1 / S.W.2 and showing significant changes in pipe temperature.

TABLE S.W.1: Prominent Shutdowns at Pump Station 1

Month & Year	Day	Length of Shutdown (hrs)	Shutdown of Interest	Shutdown Selected
Sept. 88	6	?□		
	10	?□		
	20	?□		
	23-25	?□		
	27-28	?□		
Oct. 88	17	?□		
	25-26	?□		
	31	?□		
Nov. 88	29-30	?□		
Dec. 88	1-2	?□		
	26	?□		
Jan. 89	17	?		
	21	?		
	25	7.1		
	28-29	?		
	31	12.0	*	
Feb. 89	28	?	*	
Mar. 89	1-2	?	*	
	11	?		
	20	?		
Apr. 89	1	3.0		
	18	8.0		
May 89	18	?		
Jun. 89	2	?		
	10	?		
	23	23.0	*	
	26-30	?		
Jul. 89	4	?		
	15-16	?		
	21	?		
Aug. 89	3	3.7		
	19	1.8		
	23	9.4	*	√
Sept. 89	3	3.6		
	6	7.4		
	15	14.9	*	
	17	10.1		
	19	3.8		
Oct. 89	6	5.7	*	
	30	1.5		
Nov. 89	17	3.5		
	18	4.7	*	

TABLE S.W.2.1

BRIEF SUMMARY OF TEMPERATURES 1-WEEK BEFORE, AFTER AND DURING SHUTDOWN FOR 14 SHUTDOWNS BETWEEN AUGUST 1987 AND AUGUST 1990.

Date of Shutdown	No. of Shutdown Hours	Dates 1-week prior & after Shutdown	Range in Temperature (°C)			
			Fluctuation during Shutdown	Amplitude 1-week before Shutdown	Amplitude 1-week after Startup	Equilibrium Temperature
88.04.22	15	88.04.15-88.04.29	0.0-0.3	0.0-1.8	0.0-1.8	-1.6 to 2.7
88.10.19	9	88.10.12-88.10.26	0.0-0.6	0.5-2.1	0.4-3.0	-1.6 to 6.7
89.01.31	12.5	89.01.24-89.02.07	0.0-0.6	0.2-2.7	0.0-3.0	-2.8 to 0.6
89.02.28-89.03.01	25.5	89.02.21-89.03.08	0.0-0.7	0.0-1.8	0.1-3.4	-2.2 to 2.1
89.04.18-89.04.19	11.75	89.04.11-89.04.26	0.0-1.3	0.0-2.5	0.0-1.3	-2.2 to 1.5
89.10.06	5.7	89.09.29-89.10.13	0.0-1.0	0.4-1.2	0.4-1.3	-1.5 to 8.0
90.03.01	4.1	90.02.22-90.03.08	0.1-0.5	0.0-1.1	0.1-0.9	-2.3 to 2.2
90.04.04-90.04.05	6.6	90.03.28-90.04.12	0.0-0.5	0.0-1.2	0.0-0.9	-2.2 to 2.2
87.08.18-87.08.23	121	87.08.17-87.08.30	0.1-2.0	-	0.4-1.6	3.6 to 9.3
88.05.25-88.05.27	41	88.05.18-88.06.03	0.0-0.9	0.0-1.9	0.1-2.6	-1.2 to 3.4
89.06.02	2	89.05.26-89.06.09	0.0-0.3	0.1-1.4	0.1-2.4	-1.7 to 3.1
89.06.10	0.2	89.06.03-89.06.17	0.0-0.1	0.1-2.4	0.1-2.1	-1.3 to 4.3
89.08.23	9.5	89.08.16-89.08.30	0.1-1.3	0.3-1.5	0.3-1.2	-1.2 to 11.4
90.08.12-90.08.15	85	90.08.05-90.08.22	0.7-1.3	0.1-1.1	0.5-2.3	4.8 to 7.1

TABLE S.W.2.2

DETAILED SUMMARY OF TEMPERATURES AT SIX SITES 1-WEEK BEFORE, AFTER AND DURING SHUTDOWN FOR 14 SHUTDOWNS BETWEEN AUGUST 1987 AND AUGUST 1990.

Site Name & Date	Temperature Fluctuations (°C) during Shutdown	Amplitude(°C) 1-week before Shutdown	Amplitude(°C) 1-week after Startup	Length of time (hr) required to reach Equilibrium	Equilibrium Temperature (°C)	Comments
PS1 A	0.3 +	1.8	1.8	12	-1.6 ↑↓	-rapid cooldown after startup & fluctuations thereafter -inc./dec./inc. in temperature during shutdown
3A A	0.0	1.1	0.6	*	-0.9 ↑	-no effect after startup -slight inc. in temperature during shutdown
7B A	0.1 +	0.1	0.1	*	-0.3	-little to no effect after startup -very slight inc. in temp. during shutdown & dec. occasionally
8A A	0.0	0.0	0.0	*	0.0	-no effect during shutdown and after startup
10A A	0.3 -	0.8	0.7	1 or 32 ?	2.7	-a dec. of 0.7 on the day after startup -slight dec. in temperature during shutdown
5B A	0.0	0.1	0.1	*	0.3	-no effect during shutdown and after startup
PS1 B	0.5 +/-	2.1	3.0	6	-1.6 ↑↓	-sharp inc. in temp. followed by sharp dec. & inc. after startup -fluctuating inc. & dec. in temperature during shutdown
3A B	0.4 -	0.6	0.4	4	-0.5 ↓	-increase in temperature after startup until return to equilibrium -gradual dec. in temperature during shutdown
7B B	0.0	0.6	0.5	*	1.2	-slight dec. in temperature after startup -no effect during shutdown
8A B	0.6 -	0.6	0.6	7	4.7 ↓	-slight inc. in temperature after startup until return to equilibrium -decrease in temperature during shutdown
10A B	0.4 -	0.9	1.9	5	6.7	-slight inc. in temperature after startup until return to equilibrium -decrease in temperature during shutdown
5B B	0.2 -	0.5	0.6	*	3.8 ↓	-no effect after startup -very slight dec. in temperature during shutdown
PS1 C	0.2 -	2.7	3.3	12	-2.8 ↓	-rapid dec. in temp. after startup & inc. temp. to equilibrium -decrease in temperature during shutdown
3A C	0.6 -	0.7	0.7	3 - 4	-2.1 ↓	-no effect after startup -decrease in temperature during shutdown
7B C	0.0	0.2	0.0	*	-0.5	-no effect during shutdown and after startup
8A C	0.3 -	0.2	0.3	≈ 6	0.6 ↓	-increase in temp. after startup until return to equilibrium -very slight decrease in temperature during shutdown
10A C	0.5 -	0.6	0.8	≈ 16	2.4	-slight inc. in temp. after startup until return to equilibrium -decrease in temperature during shutdown
5B C	0.0	0.2	0.0	*	0.4	-no effect during shutdown and after startup
PS1 D	0.2 -	1.8	3.4	20	-2.2 ↓	-sharp dec. in temp. after startup until return to equilibrium -very slight decrease in temperature during shutdown
3A D	0.4 -	0.3	0.4	16	-1.9 ↓	-v. slight inc. in temp. after startup until return to equilibrium -very slight decrease in temperature during shutdown
7B D	0.0	0.0	0.1	6	-0.5	-very slight dec. in temp. after startup until return to equilibrium -no effect during shutdown
8A D	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
10A D	0.7 +/-	0.4	1.6	≈ 33	2.1 ↓	-dec. in temp. long after startup until return to equilibrium -slight inc. followed by gradual dec. in temperature during shutdown
5B D	0.2 -	0.0	0.1	≈ 35	0.3 ↓	-stable temp. followed by inc. temp. after startup -very slight dec. in temperature during shutdown
PS1 E	1.3 +/-	2.5	1.3	10	-2.2 ↑	-decrease in temp. after startup until return to equilibrium -warm temperatures followed by dec. in temp. during shutdown
3A E	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
7B E	0.0	0.0	0.0	*	-0.8	-no effect during shutdown and after startup
8A E	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
10A E	0.4 -	1.6	0.7	7	1.5 ↓	-inc. in temp. after startup until return to equilibrium -dec. in temperature during shutdown
5B E	0.1 -	0.0	0.1	4	0.0 ↓	-rapid return to equilibrium after startup -very slight dec. in temperature during shutdown

* not apparent ↑↓ increase/decrease in equilibrium temperatures ND no data available +/- increase/decrease in temperature during shutdown

KEY	Date & Time of Shutdown	# of Shutdown hours
A	88.04.22(00:00-15:09)	15
B	88.10.19(08:03-17:09)	9
C	89.01.31(01:46-14:20)	12.5
D	89.02.28(15:46) - 89.03.01(17:21)	25.5
E	89.04.18(21:53) - 19 (09:32)	11.75

Site Name & Date	Temperature Fluctuations (°C) during Shutdown	Amplitude(°C) 1-week before Shutdown	Amplitude(°C) 1-week after Startup	Length of time (hr) required to reach Equilibrium	Equilibrium Temperature (°C)	Comments
PS1 F	0.6 -	1.0	1.3	≈ 12	-1.5 ↑	-dec./slight inc. in temp. after startup until return to equilibriu -slight dec. in temperature during shutdown
3A F	0.5 -	1.2	0.5	≈ 6	1.2 ↓	-inc. in temp. after startup until return to equilibrium -dec. in temperature during shutdown
7B F	0.0	0.5	0.6	1 - 3	2.7 ↓	-no effect during shutdown and after startup
8A F	0.3 -	0.5	0.6	7 - 10	6.0 ↓	-inc. in temp. after startup until return to equilibrium -dec. in temperature during shutdown
10A F	1.0 -	1.2	1.2	≈ 30	7.9 ↓	-inc. in temp. after startup until return to equilibrium -dec. in temperature during shutdown
5B F	0.1 -	0.4	0.4	*	4.2 ↓	-no effect after startup -slight dec. in temperature during shutdown
PS1 G	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
3A G	0.3 -	0.2	0.1	1 - 3	-2.3 ↓	-no effect after startup -dec. in temperature during shutdown
7B G	0.1 -	0.2	0.1	3 - 6	-0.7 ↑	-no effect after startup -very slight dec. in temperature during shutdown
8A G	0.1 -	0.1	0.1	1 - 3	0.3 ↓	-no effect after startup -very slight dec. in temperature during shutdown
10A G	0.5 -	0.1	0.9	9 - 12	2.2 ↓	-dec./sharp inc. in temp. after startup until return to equilibriu -sharp decrease in temperature during shutdown
5B G	0.1 -	0.0	0.1	1 - 3	-0.3 ↓	-no effect after startup -very slight dec. in temperature during shutdown
PS1 H	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
3A H	0.1 -	0.3	0.2	1 - 3	-2.2 ↓	-no effect after startup -slight decrease in temperature during shutdown
7B H	0.0	0.0	0.0	*	-0.8	-no effect during shutdown and after startup
8A H	0.1 +/-	0.2	0.2	7 - 9	0.2 ↑↓	-increase in temp. after startup until return to equilibrium -increase and decrease in temperature during shutdown
10A H	0.5 -	1.2	0.9	≈ 38	2.2 ↓	-temp. fluctuations after startup until return to equilibrium -decrease in temperature during shutdown
5B H	0.1 +	0.0	0.0	*	-0.5	-no effect after startup -very slight inc. in temperature during shutdown
PS1 I	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
3A I	1.3 -	ND	0.6	5 - 11	5.1 ↓	-inc. in temp. after startup until return to equilibrium -decrease in temperature during shutdown
7B I	0.1 +/-	ND	0.4	4	3.6 ↑↓	-slight dec./inc. in temp. after startup until return to equilibriu -no effect during shutdown
8A I	1.0 -	ND	1.4	≈ 13	5.7? ↑↓	-inc. in temperature after startup -decrease in temperature during shutdown
10A I	0.6 -	ND	1.5	≈ 12	9.3? ↓	-inc. in temp. after startup until return to equilibrium -decrease in temperature during shutdown
5B I	2.0 -	ND	1.6	≈ 24	5.1? ↓	-increase in temp. after startup until return to equilibrium -decrease in temperature during shutdown
PS1 J	0.9 +	1.9	2.6	≈ 12	-1.2 ↑	-sharp dec. in temp. after startup / inc. until return to equilibriu -increase in temperature during shutdown
3A J	0.1	0.1	0.1	*	-0.4	-no effect during shutdown and after startup
7B J	0.0	0.0	0.1	*	-0.2	-no effect during shutdown and after startup
8A J	0.6 -/+	1.2	0.7	≈ 10	1.2 ↓↑	-dec. in temp. after startup until return to equilibrium then inc. -dec./inc./dec./inc. in temperature during shutdown
10A J	0.5 -	0.5	2.0	29	3.4 ↓	-slight dec. & inc. in temp. after startup until return to equilibriu -dec. in temperature during shutdown
5B J	0.3 -	0.4	1.2	34	1.0 ↓	-slight dec. & inc. in temp. after startup until return to equilibriu -decrease in temperature during shutdown

* not apparent ↑↓ increase/decrease in equilibrium temperatures ND no data available +/- increase/decrease in temperature during shutdown

KEY	Date & Time of Shutdown	# of Shutdown hours
F	89.10.03(12:48-18:30)	5.7
G	90.03.01(13:01-17:12)	4.1
H	90.04.04(23:00) - 05 (06:15)	6.6
I	87.08.18(04:08) - 23 (04:58)	121
J	88.05.25(09:15) - 27 (02:20)	41

Site Name & Date	Temperature Fluctuations (°C) during Shutdown	Amplitude(°C) 1-week before Shutdown	Amplitude(°C) 1-week after Startup	Length of time (hr) required to reach Equilibrium	Equilibrium Temperature (°C)	Comments
PS1 K	0.1 -	1.4	2.4	*	-1.7 ↓	-no effect after startup -very slight decrease in temperature during shutdown
3A K	0.0	0.1	0.1	*	-1.1	-no effect during shutdown and after startup
7B K	0.0	0.1	0.1	*	-0.5	-no effect during shutdown and after startup
8A K	0.3 -	0.7	1.0	4	1.4 ↓	-no effect after startup -slight decrease in temperature during shutdown
10A K	0.2 -	0.9	1.5	5	3.1 ↓	-rapid inc. in temp. after startup until return to equilibrium -very slight decrease in temperature during shutdown
5B K	0.1 -	0.6	1.1	2	1.4 ↓	-no effect after startup -very slight decrease in temperature during shutdown
PS1 L	0.0	2.4	2.1	2 - 3	-1.3 ↓	-rapid inc. in temp. after startup until return to equilibrium -no effect during shutdown
3A L	0.0	0.2	0.3	2	-0.9	-slight dec. in temp. after startup until return to equilibrium -no effect during shutdown
7B L	0.0	0.1	0.1	*	-0.5	-no effect during shutdown and after startup
8A L	0.1 -	1.2	1.4	3	2.6 ↓	-no effect after startup -very slight dec. in temperature during shutdown
10A L	0.1 -	1.7	1.5	1 - 2	4.3	-no effect after startup -very slight decrease in temperature during shutdown
5B L	0.0	1.1	1.0	*	2.4	-no effect during shutdown and after startup
PS1 M	1.3 +/-	1.2	1.2	1 or 10 ?	-1.2 ↓	-slight inc./dec. in temp. after startup until return to equilibrium -increase and decrease in temperature during shutdown
3A M	0.3 -	0.8	0.4	1 - 3	5.5 ↓	-very slight dec. in temp. after startup until return to equilibrium -slight decrease in temperature during shutdown
7B M	0.1 -	0.3	0.7	2	6.8 ↑	-very slight dec. in temp. after startup until return to equilibrium -very slight increase in temperature during shutdown
8A M	0.6 -	0.3	0.6	≈ 17	9.5 ↓	-increase in temp. after startup until return to equilibrium -decrease in temperature during shutdown
10A M	0.8 -	1.5	1.0	≈ 9	11.4 ↓	-dec./inc. in temp. after startup until return to equilibrium -slight decrease in temperature during shutdown
5B M	0.3 -	0.4	0.3	7 or 11 ?	7.2 ↓	-slight inc. after startup until return to equilibrium -slight decrease in temperature during shutdown
PS1 N	ND	ND	ND	ND	ND	-DEFECTIVE -- BATTERY FAILURE ON LOGGER SYSTEM
3A N	1.3 -	0.5	0.5	47	4.8 ↓	-inc. in temp. after startup until return to equilibrium -decrease in temperature during shutdown
7B N	0.8 +	0.2	0.6	≈ 11	7.1 ↑	-decrease in temp. after startup until return to equilibrium -slight increase in temperature during shutdown
8A N	1.2 -	0.5	0.7	≈ 10	8.8 ↓	-increase in temp. after startup until return to equilibrium -decrease in temperature during shutdown
10A N	0.8 -	1.1	2.3	≈ 9 - 10	8.3 ↓	-inc. in temp. after startup until return to equilibrium -decrease in temperature during shutdown
5B N	0.7 -	0.1	0.8	≈ 28	5.3 ↓	-gradual inc. in temp. after startup until return to equilibrium -decrease in temperature during shutdown

* not apparent ↑↓ increase/decrease in equilibrium temperatures ND no data available +/- increase/decrease in temperature during shutdown

KEY	Date & Time of Shutdown	# of Shutdown hours
K	89.06.02(20:37-22:46)	2
L	89.06.10(17:28-17:41)	0.2
M	89.08.23(14:24-23:50)	9.5
N	90.08.12(06:09) - 15 (19:02)	85

TABLE S.W.3.1

**SUMMARY OF MEAN,
MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES,
THEIR TIME OF OCCURRENCE
AND THE STANDARD DEVIATION ABOUT THE MONTHLY MEANS
AT PUMP STATION 1 (PS1)
BETWEEN DECEMBER 1987 AND OCTOBER 1989.**

Month & Year	Monthly Pipe Temperature (°C)							
	Maximum [Date & Time]*			Minimum [Date & Time]*			Mean	Standard Deviation
08.87	ND			ND			ND	ND
09.87	ND			ND			ND	ND
10.87	ND			ND			ND	ND
11.87	ND			ND			ND	ND
12.87	0.3	19	(05:00)	-3.1	18	(14:00)	ID	ID
01.88	1.5	16	(20:00)	-4.4	16	(13:00)	-2.0	0.2904
02.88	0.0	17	(07:00)	-3.2	13	(11:00)	-1.8	0.1880
03.88	0.0	30	(19:00)	-3.6	28	(11:00)	-2.5	ID
04.88	-0.2	15	(06:00)	-2.6	03	(14:00)	-1.6	0.2029
05.88	-0.1	29	(07:00)	-2.9	27	(20:00)	-1.2	0.2182
06.88	0.9	19	(08:00)	-2.7	14	(21:00)	-0.9	0.1802
07.88	1.8	07	(07:00)	-1.5	05	(16:00)	-0.6	0.1563
08.88	-0.2	02	(23:00)	-1.7	16	(01:00)	-0.7	0.1777
09.88	-0.3	11	(10:00)	-3.2	28	(19:00)	-1.3	0.2918
10.88	-0.4	15	(09:00)	-3.6	25	(15:00)	-1.6	0.2867
11.88	-0.3	28	(10:00)	-4.0	30	(16:00)	-1.7	0.2825
12.88	-0.6	09	(02:00)	-3.3	29	(09:00)	-1.9	0.3411
01.89	-0.6	09	(01:00)	-4.2	25	(20:00)	-2.4	0.3826
02.89	-0.4	25	(17:00)	-3.3	29	(09:00)	-1.8	0.2512
03.89	-0.8	03	(24:00)	-4.2	01	(23:00)	-2.1	0.2649
04.89	-0.5	18	(22:00)	-3.3	01	(21:00)	-1.8	0.3153
05.89	-0.9	21	(02:00)	-2.4	03	(13:00)	-1.5	0.1669
06.89	-0.5	05	(11:00)	-3.1	16	(24:00)	-1.7	0.3469
07.89	-0.5	15	(15:00)	-2.5	31	(10:00)	-1.3	0.2538
08.89	-0.6	01	(13:00)	-2.6	01	(06:00)	-1.1	0.1513
09.89	-0.6	06	(14:00)	-3.3	18	(9 → 12)	-1.4	0.2898
10.89	-0.6	03	(18 → 21)	-2.4	23	(3 → 6)	ID	ID
11.89 to 09.90	ND			ND			ND	ND

* Date & time of occurrence (hrs) (MST)
ND No data as a result of logger system failure
ID Incomplete &/or noncontinuous data

Table SW3.1 Maximum, minimum, mean and standard deviation of monthly pipe temperature at Pump Station 1 (PS1) [Site No. 50].

TABLE S.W.3.2

**SUMMARY OF MEAN,
MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES,
THEIR TIME OF OCCURRENCE
AND THE STANDARD DEVIATION ABOUT THE MONTHLY MEANS
AT GREAT BEAR RIVER (3A)
BETWEEN AUGUST 1987 AND SEPTEMBER 1990.**

Month & Year	Monthly Pipe Temperature (°C)							
	Maximum [Date & Time]*			Minimum [Date & Time]*			Mean	Standard Deviation
08.87	5.4	23	(19:00)	3.8	22	(22:00)	ID	ID
09.87	4.8	01	(01:00)	2.6	30	(10:00)	3.8	0.5577
10.87	2.7	01	(01:00)	0.6	29	(10:00)	1.4	0.6661
11.87	0.6	01	(01:00)	0.1	20	(16:00)	0.3	0.1365
12.87	0.1	01	(01:00)	-0.2	10	(12:00)	0.0	0.0498
01.88	0.0	01	(01:00)	-1.7	31	(19:00)	-0.6	0.4826
02.88	-1.7	01	(01:00)	-3.6	17	(06:00)	-2.8	0.5301
03.88	-1.7	15	(19:00)	-2.6	31	(12:00)	-2.1	0.2446
04.88	-0.3	28	(02:00)	-2.5	01	(18:00)	-1.5	0.7006
05.88	-0.3	29	(13:00)	-0.5	01	(01:00)	-0.4	0.0418
06.88	2.4	30	(11:00)	-0.4	01	(01:00)	0.6	0.8443
07.88	5.4	31	(06:00)	2.3	02	(17:00)	4.1	1.0599
08.88	5.8	22	(06:00)	5.2	06	(22:00)	5.5	0.1590
09.88	5.5	01	(15:00)	1.4	28	(12:00)	3.3	1.2160
10.88	1.5	01	(01:00)	-0.1	30	(22:00)	0.7	0.5095
11.88	-0.1	01	(01:00)	-0.8	29	(13:00)	-0.4	0.1398
12.88	-0.5	02	(14:00)	-0.9	31	(16:00)	-0.7	0.0856
01.89	-0.8	01	(01:00)	-2.6	25	(16:00)	-1.4	0.4855
02.89	-1.6	13	(15:00)	-2.2	01	(01:00)	-1.8	0.2069
03.89	-1.9	02	(10:00)	-2.6	12	(14:00)	-2.3	0.1936
04.89		ND			ND		ND	ND
05.89		ND			ND		ND	ND
06.89	0.9	30	(23:00)	-1.1	01	(01:00)	-0.6	0.5673
07.89	5.3	01	(08:00)	0.9	01	(01:00)	3.4	1.4905
08.89	6.6	14	(14:00)	5.1	01	(01:00)	5.9	0.4640
09.89	5.2	01	(01:00)	1.9	27	(3 → 6)	3.8	1.2268
10.89	1.9	01	(01:00)	-0.8	31	(3 → 6)	0.4	0.7504
11.89	-0.6	01	(01:00)	-1.2	17	(16 → 18)	-1.0	0.1776
12.89	-1.2	01	(01:00)	-1.5	29	(1 → 3)	-1.4	0.0711
01.90	-1.4	01	(01:00)	-1.7	01	(4 → 6)	-1.6	0.0573
02.90	-1.7	01	(01:00)	-2.4	25	(9 → 12)	-2.0	0.2113
03.90	-2.3	01	(01:00)	-2.7	17	(18 → 21)	-2.4	0.0589
04.90	-1.9	21	(16:00)	-2.3	01	(01:00)	-2.0	0.1181
05.90	-1.7	31	(16:00)	-1.9	01	(01:00)	-1.8	0.0423
06.90	0.2	30	(22 → 24)	-1.8	01	(3 → 6)	-1.2	0.5876
07.90	4.6	31	(16:00)	0.2	01	(01:00)	2.9	1.3541
08.90	5.1	16	(9 → 12)	3.7	15	(18 → 20)	4.5	0.3149
09.90	3.8	01	(01:00)	1.8	11	(22 → 24)	-1.4	0.2898

* Date & time of occurrence (hrs) (MST)
ND No data as a result of logger system failure
ID Incomplete &/or noncontinuous data

Table SW3.2 Maximum, minimum, mean and standard deviation of monthly pipe temperature at Great Bear River (3A) [Site No. 51].

TABLE S.W.3.3

**SUMMARY OF MEAN,
MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES,
THEIR TIME OF OCCURRENCE
AND THE STANDARD DEVIATION ABOUT THE MONTHLY MEANS
AT TABLE MOUNTAIN (7B)
BETWEEN AUGUST 1987 AND SEPTEMBER 1990.**

Month & Year	Monthly Pipe Temperature (°C)							
	Maximum [Date & Time]*			Minimum [Date & Time] *			Mean	Standard Deviation
08.87	3.9	17	(01:00)	3.4	17	(14:00)	3.7	ID
09.87	3.7	01	(01:00)	2.3	30	ID	3.1	0.3288
10.87	2.3	01	(01:00)		ND		ND	ND
11.87		ND			ND		ND	ND
12.87		ND			ND		ND	ND
01.88		ND			ND		ND	ND
02.88		ND			ND		ND	ND
03.88		ND			ND		ND	ND
04.88		ND			ND		ND	ND
05.88		ND			ND		ND	ND
06.88	1.7	30	(22:00)	-0.2	01	(01:00)	0.2	0.5313
07.88	5.1	24	(06:00)	1.6	01	(01:00)	3.5	1.1234
08.88	5.6	31	(14:00)	5.0	01	(01:00)	5.3	0.1294
09.88	5.6	01	(11:00)	2.2	30	(18:00)	4.1	1.1740
10.88	2.2	01	(01:00)	0.6	28	(19:00)	1.4	0.4951
11.88	0.6	01	(01:00)	0.0	24	(05:00)	0.2	0.1572
12.88	0.0	01	(01:00)	-0.3	27	(17:00)	-0.1	0.0785
01.89	-0.2	01	(04:00)	-0.5	28	(04:00)	-0.3	0.0794
02.89	-0.5	01	(01:00)	-0.5	01	(01:00)	-0.5	0.0000
03.89	-0.5	01	(01:00)	-0.8	31	(11:00)	-0.6	0.0723
04.89	-0.6	29	(18:00)	-0.9	06	(05:00)	-0.8	0.0596
05.89	-0.5	26	(09:00)	-0.8	02	(05:00)	-0.6	0.1934
06.89	0.5	01	(01:00)	-0.6	01	(01:00)	-0.4	0.2358
07.89	5.7	29	(16:00)	0.4	01	(01:00)	3.4	1.7539
08.89	7.1	20	(05:00)	5.6	01	(01:00)	6.5	0.4353
09.89	6.1	01	(01:00)	3.1	30	(21 → 22)	4.9	1.0116
10.89	3.1	01	(01:00)	0.7	30	(21 → 22)	1.8	0.7388
11.89	0.7	01	(01:00)	-0.2	27	(9 → 10)	0.2	0.2581
12.89	-0.2	01	(01:00)	-0.5	28	(21 → 22)	-0.3	0.0863
01.90	-0.4	01	(12 → 13)	-0.5	01	(01:00)	-0.5	0.0296
02.90	-0.5	01	(01:00)	-0.8	28	(3 → 4)	-0.6	0.0457
03.90	-0.6	01	(6 → 7)	-0.8	02	(15 → 16)	-0.8	0.0296
04.90	-0.7	30	(3 → 4)	-0.8	01	(01:00)	-0.8	0.0000
05.90	-0.5	08	(18 → 19)	-0.8	01	(01:00)	-0.8	0.0468
06.90	2.9	30	ID	-0.7	01	(01:00)	0.8	1.1722
07.90	6.5	30	ID	2.9	01	ID	5.0	1.0990
08.90	7.3	14	ID	6.0	31	ID	6.6	0.2549
09.90	6.0	01	ID	4.4	14	ID	5.2	ID

* Date & time of occurrence (hrs) (MST)
ND No data as a result of logger system failure
ID Incomplete &/or noncontinuous data

Table SW3.3 Maximum, minimum, mean and standard deviation of monthly pipe temperature at Table Mountain (7B) [Site No. 57].

TABLE S.W.3.4

SUMMARY OF MEAN, MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES, THEIR TIME OF OCCURRENCE AND THE STANDARD DEVIATION ABOUT THE MONTHLY MEANS AT MANNER'S CREEK (8A) BETWEEN AUGUST 1987 AND SEPTEMBER 1990.

Month & Year	Monthly Pipe Temperature (°C)									
	Maximum [Date & Time]*			Minimum [Date & Time]*			Mean	Standard Deviation
08.87	6.4	28	(02:00)	3.8	22	(22:00)	5.1	ID
09.87	6.3	01	(01:00)	5.1	30	(19:00)	5.8	0.2822
10.87	5.1	01	(01:00)	4.0	07	(19:00)	4.8	ID
11.87		ND			ND		ND	ND
12.87		ND			ND		ND	ND
01.88		ND			ND		ND	ND
02.88		ND			ND		ND	ND
03.88		ND			ND		ND	ND
04.88		ND			ND		ND	ND
05.88		ND			ND		ND	ND
06.88	5.4	30	(19:00)	0.9	01	(01:00)	3.0	1.3429
07.88		ID		5.5	01	(01:00)	6.3	ID
08.88		ND			ND		ND	ND
09.88		ND		5.9	28	(14:00)	7.0	ID
10.88	6.0	01	(01:00)	3.5	31	(16:00)	4.8	0.7308
11.88	3.6	01	(16:00)	1.9	29	(13:00)	2.7	0.4042
12.88	2.0	01	(01:00)	1.1	31	(14:00)	1.5	0.2662
01.89	1.2	01	(01:00)	0.3	31	(15:00)	1.0	0.1910
02.89	0.6	01	(12:00)	0.4	01	(01:00)	0.5	ID
03.89		ND			ND		ND	ND
04.89		ND			ND		ND	ND
05.89		ND			ND		ND	ND
06.89	5.4	29	(23:00)	1.1	01	(01:00)	3.4	1.3527
07.89	8.4	27	(16:00)	5.4	01	(01:00)	7.0	0.9689
08.89	9.7	20	(04:00)	8.1	03	(11:00)	9.1	0.4333
09.89	9.0	01	(01:00)	6.4	30	(21→22)	7.9	0.8018
10.89	6.4	01	(01:00)	3.6	31	(3→4)	5.1	0.8422
11.89	3.6	01	(01:00)	2.1	30	(6→7)	2.8	0.4316
12.89	2.1	01	(01:00)	1.2	31	(12→13)	1.7	0.2366
01.90	1.2	01	(01:00)	0.7	27	(9→10)	1.0	0.1606
02.90	0.8	03	(21→22)	0.3	22	(01:00)	0.5	0.1318
03.90	0.3	01	(01:00)	0.1	15	(12→13)	0.2	0.0498
04.90	0.4	15	(15→16)	0.1	02	(18→19)	0.2	0.0300
05.90	1.5	30	(21→22)	0.2	01	(3→4)	0.6	0.3564
06.90	5.6	30	(15→16)	1.7	01	(01:00)	3.6	1.1226
07.90	8.5	30	(3→4)	5.6	01	(01:00)	7.2	0.8644
08.90	9.2	17	(15→16)	7.6	15	(9→10)	8.8	0.3694
09.90	8.7	01	(01:00)	7.3	11	(21→22)	8.0	ID

* Date & time of occurrence (hrs) (MST)
ND No data as a result of logger system failure
ID Incomplete &/or noncontinuous data

Table SW3.4 Maximum, minimum, mean and standard deviation of monthly pipe temperature at Manner's Creek (8A) [Site No. 68].

TABLE S.W.3.5

SUMMARY OF MEAN, MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES, THEIR TIME OF OCCURRENCE AND THE STANDARD DEVIATION ABOUT THE MONTHLY MEANS AT MACKENZIE HWY. (10A) BETWEEN AUGUST 1987 AND SEPTEMBER 1990.

Month & Year	Monthly Pipe Temperature (°C)					
	Maximum [Date & Time]*			Minimum [Date & Time] *		
						Mean	Standard Deviation
08.87	9.4	23	(19:00)	7.9	28 (11:00)	ID	ID
09.87	9.3	01	(01:00)	6.8	28 (12:00)	8.8	0.3290
10.87	8.1	01	(01:00)	5.7	31 (03:00)	6.9	0.7228
11.87	5.7	01	(01:00)	3.9	30 (18:00)	4.8	0.4581
12.87	4.2	02	(23:00)	3.5	22 (17:00)	3.9	0.1253
01.88	4.3	13	(01:00)	2.2	26 (12:00)	3.4	0.1954
02.88	3.2	01	(10:00)	1.2	18 (09:00)	2.9	0.2345
03.88	3.1	01	(15:00)	0.6	28 (06:00)	2.5	0.6369
04.88	2.8	05	(17:00)	2.0	01 (20:00)	2.7	0.1176
05.88	3.9	31	(20:00)	2.2	01 (07:00)	3.0	0.3632
06.88	8.5	29	(08:00)	3.8	01 (02:00)	6.3	1.3051
07.88	10.9	24	(20:00)	7.2	06 (21:00)	9.6	0.9519
08.88	11.1	22	(15:00)	10.4	07 (21:00)	10.9	0.1123
09.88	11.1	01	(16:00)	8.1	28 (13:00)	9.1	0.9444
10.88	8.2	01	(03:00)	4.8	26 (17:00)	6.9	0.8612
11.88	5.5	01	(01:00)	3.3	26 (18:00)	4.7	0.4688
12.88	4.0	01	(21:00)	2.4	08 (20:00)	3.3	0.2745
01.89	3.1	01	(01:00)	1.5	24 (19:00)	2.7	0.2243
02.89	2.5	02	(07:00)	1.5	18 (16:00)	2.2	0.1047
03.89	2.1	04	(16:00)	0.5	05 (11:00)	1.8	0.1490
04.89	1.8	01	(01:00)	0.2	17 (08:00)	1.5	0.1335
05.89	2.8	30	(08:00)	1.0	11 (08:00)	2.1	0.3403
06.89	6.7	25	(21:00)	2.7	02 (11:00)	5.2	1.2286
07.89	10.6	29	(08:00)	6.4	06 (01:00)	8.4	1.2045
08.89	11.6	22	(12:00)	8.8	03 (11:00)	10.5	0.8281
09.89	11.0	01	(01:00)	7.8	13 (9 → 13)	9.3	0.7322
10.89	8.4	01	(01:00)	4.7	31 (12 → 15)	7.0	0.7836
11.89	5.6	01	(01:00)	3.0	27 (12 → 14)	4.5	0.6265
12.89	4.1	01	(01:00)	2.4	05 (15 → 17)	3.3	0.3013
01.90	3.3	01	(01:00)	1.2	31 (21 → 22)	2.6	0.4585
02.90	2.5	11	(11 → 12)	0.2	20 (15 → 16)	1.7	0.5026
03.90	2.4	03	(15 → 16)	1.4	25 (18 → 19)	2.2	0.0983
04.90	2.3	04	(18 → 19)	-0.5	17 (6 → 7)	1.9	0.3461
05.90	3.7	31	(22:00)	-0.2	01 (01:00)	2.0	0.7861
06.90	7.1	29	(22:00)	2.8	01 (9 → 10)	5.0	1.1020
07.90	9.6	31	(16:00)	6.2	12 (18 → 19)	8.0	0.8687
08.90	10.7	24	(18 → 19)	7.5	15 (18 → 19)	9.2	0.8937
09.90	8.6	01	(01:00)	7.3	16 (18 → 19)	8.0	ID

* Date & time of occurrence (hrs) (MST)
ND No data as a result of logger system failure
ID Incomplete &/or noncontinuous data

Table SW3.5 Maximum, minimum, mean and standard deviation of monthly pipe temperature at Mackenzie Hwy. (10A)[Site No. 67].

TABLE S.W.3.6

**SUMMARY OF MEAN,
MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES,
THEIR TIME OF OCCURRENCE
AND THE STANDARD DEVIATION ABOUT THE MONTHLY MEANS
AT PETITOT RIVER N. (5B)
BETWEEN AUGUST 1987 AND SEPTEMBER 1990.**

Month & Year	Monthly Pipe Temperature (°C)							
	Maximum [Date & Time]*			Minimum [Date & Time]*			Mean	Standard Deviation
08.87	5.9	18	(01:00)	3.9	23	(03:00)	ID	ID
09.87	5.7	01	(01:00)	4.6	30	(07:00)	5.2	0.3015
10.87	4.6	01	(01:00)	2.4	31	(15:00)	3.5	0.6489
11.87	2.4	01	(01:00)	1.4	28	(20:00)	1.8	0.2918
12.87	1.4	01	(01:00)	1.0	26	(19:00)	1.2	0.1289
01.88	1.0	01	(01:00)	0.7	24	(03:00)	0.8	0.0883
02.88	0.7	01	(01:00)	0.4	25	(22:00)	0.6	0.0738
03.88	0.5	01	(01:00)	0.2	30	(22:00)	0.4	0.0908
04.88	0.4	19	(03:00)	0.3	01	(01:00)	0.3	0.0340
05.88	1.4	30	(12:00)	0.3	01	(01:00)	0.6	0.3077
06.88	4.6	29	(14:00)	1.4	01	(01:00)	3.1	0.9534
07.88	6.5	31	(07:00)	4.7	01	(01:00)	5.6	0.5782
08.88	7.0	31	(10:00)	6.4	01	(24:00)	6.7	0.1493
09.88	7.0	01	(01:00)	4.8	30	(09:00)	6.3	0.7053
10.88	4.8	01	(01:00)	2.8	31	(05:00)	3.9	0.5839
11.88	2.8	01	(01:00)	1.5	29	(14:00)	2.1	0.3625
12.88	1.5	01	(01:00)	0.9	30	(06:00)	1.2	0.1791
01.89	0.9	01	(01:00)	0.4	31	(04:00)	0.7	0.1313
02.89	0.4	01	(01:00)	0.3	13	(22:00)	0.3	0.0500
03.89	0.3	01	(01:00)	0.1	01	(17:00)	0.1	0.0438
04.89	0.1	01	(01:00)	-0.1	19	(06:00)	0.0	0.0179
05.89	1.1	30	(19:00)	0.0	01	(01:00)	0.4	0.3583
06.89	4.9	30	(06:00)	1.2	01	(01:00)	3.0	0.9966
07.89	6.4	29	(06:00)	4.4	01	(01:00)	5.4	0.6349
08.89	7.4	21	(19:00)	6.4	01	(01:00)	6.9	0.3087
09.89	6.9	01	(01:00)	4.6	30	(1 → 3)	5.9	0.7098
10.89	4.6	01	(01:00)	2.4	30	(10 → 13)	3.5	0.6660
11.89	2.4	01	(01:00)	1.1	28	(7 → 9)	1.7	0.3774
12.89	1.1	01	(01:00)	0.4	28	(13 → 15)	0.7	0.1958
01.90	0.4	01	(01:00)	0.0	24	(13 → 16)	0.2	0.1367
02.90	0.0	01	(01:00)	-0.3	19	(10 → 13)	-0.2	0.0886
03.90	-0.3	01	(01:00)	-0.5	15	(7 → 10)	-0.4	0.0770
04.90	-0.5	01	(01:00)	-0.6	05	(1 → 4)	-0.6	0.0400
05.90	0.7	31	(16 → 19)	-0.6	02	(10 → 13)	-0.3	0.3218
06.90	3.3	29	(13 → 16)	0.7	01	(01:00)	2.0	0.7642
07.90	5.2	31	(7 → 10)	3.3	01	(01:00)	4.3	0.5556
08.90	5.6	22	(16 → 19)	4.6	15	(16 → 19)	5.3	0.2101
09.90	5.3	01	(01:00)	4.6	15	(01:00)	5.0	ID

* Date & time of occurrence (hrs) (MST)
ND No data as a result of logger system failure
ID Incomplete &/or noncontinuous data

Table SW3.6 Maximum, minimum, mean and standard deviation of monthly pipe temperature at Petitot River N. (5B) [Site No. 64].

TABLE S.W.3.7

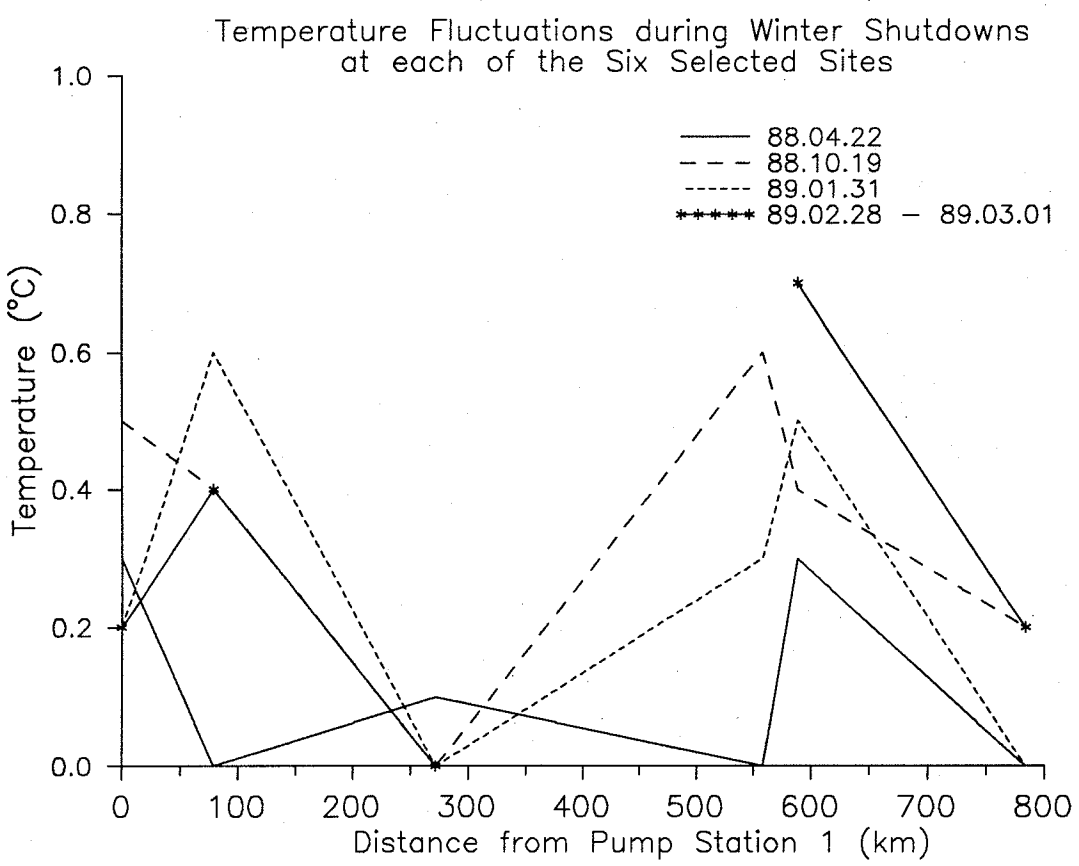
SUMMARY OF GAPS IN PIPE TEMPERATURE DATA RECORD FOR EACH OF THE SIX RECOMMENDED SITES ALONG THE NORMAN WELLS PIPELINE.

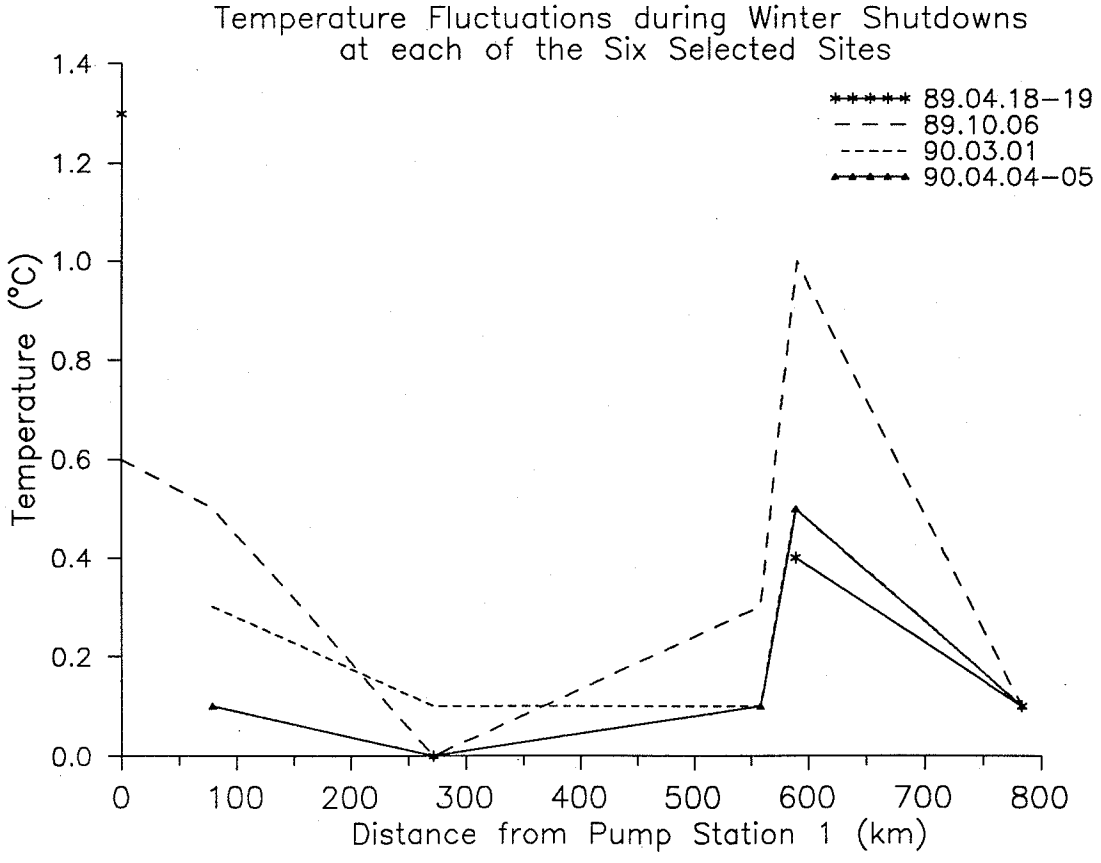
Site	Data Gaps	
	Daily (d.mth.yr)	Monthly (mth.yr)
Pump Station 1 (PS1)	01.03.88→16.03.88	12.87 03.88 01.89 10.89
Great Bear River (3A)	01.04.89→21.05.89	08.87 04 & 05.89 09.90
Table Mountain (7B)	08.10.87→25.05.88 15.09.88→17.09.88	08.87 10.87→05.88 09.88 09.90
Manner's Creek (8A)	09.10.87→28.05.88 10.07.88→15.09.88 16.02.89→23.05.89	08.87 10.87→05.88 07→09.88 02→05.88 09.90
Mackenzie Hwy. (10A)	-	08.87 09.90
Petitot River N. (5B)	-	08.87 09.90

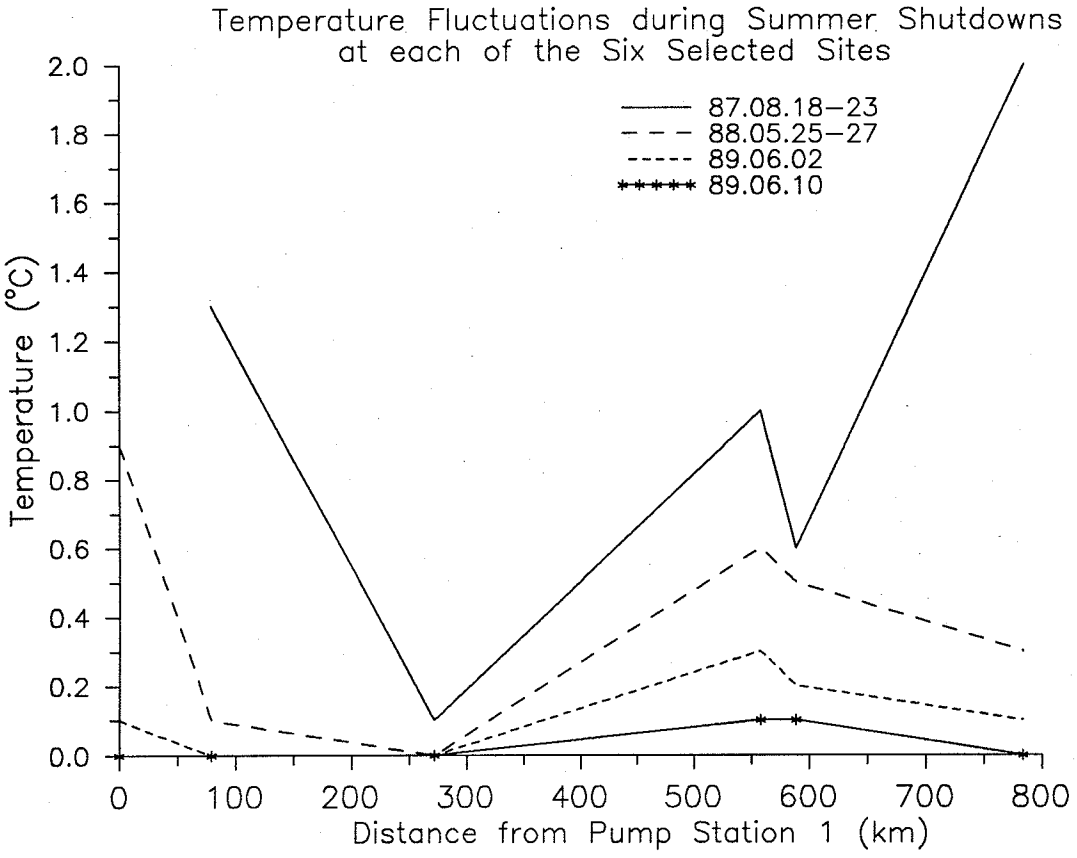
Table SW3.7 Summary of gaps in pipe temperature data record for each site.

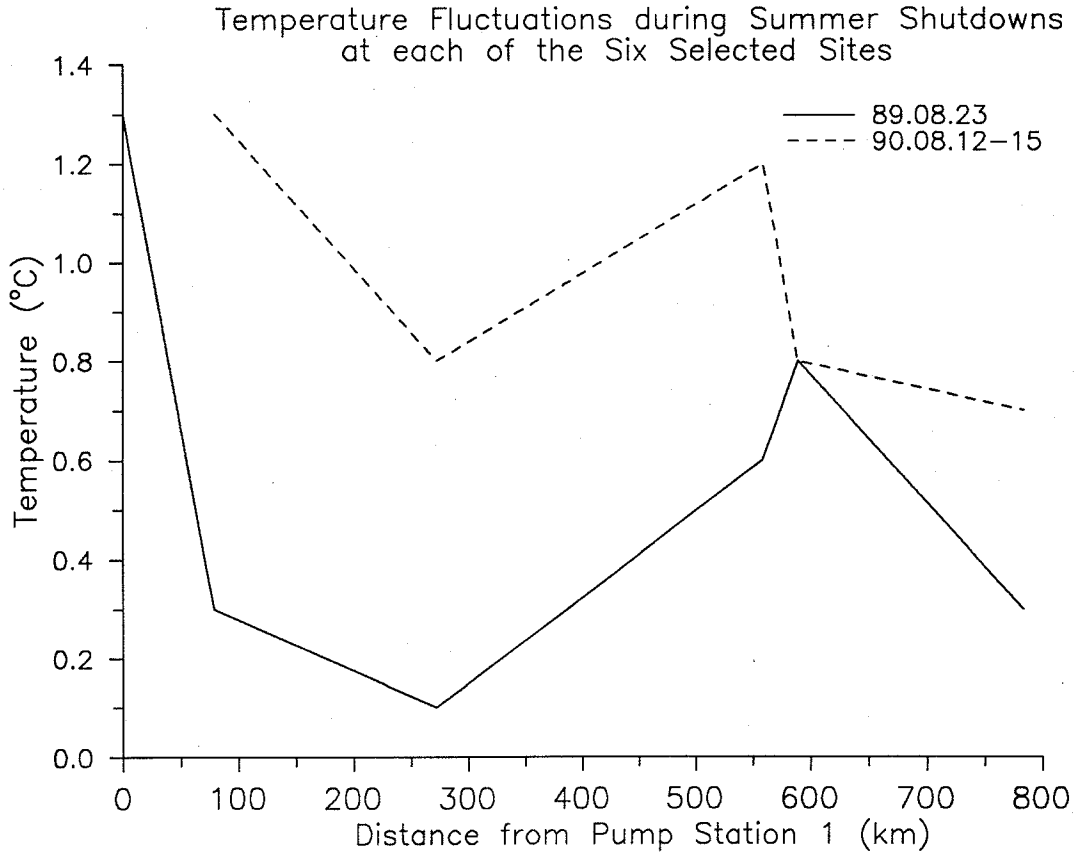
APPENDIX S.W.2.1a

PLOTS OF TEMPERATURE FLUCTUATIONS WITH DISTANCE FROM PUMP STATION 1 DURING WINTER AND SUMMER SHUTDOWNS AT SITES ALONG THE NORMAN WELLS PIPELINE.


Temperature Fluctuations during Winter Shutdowns
at each of the Six Selected Sites
88.04.22
88.10.19
89.01.31
89.02.28 – 89.03.01
Temperature (°C)
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)


Temperature Fluctuations during Winter Shutdowns
at each of the Six Selected Sites
89.04.18–19
89.10.06
90.03.01
90.04.04–05
Temperature (°C)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

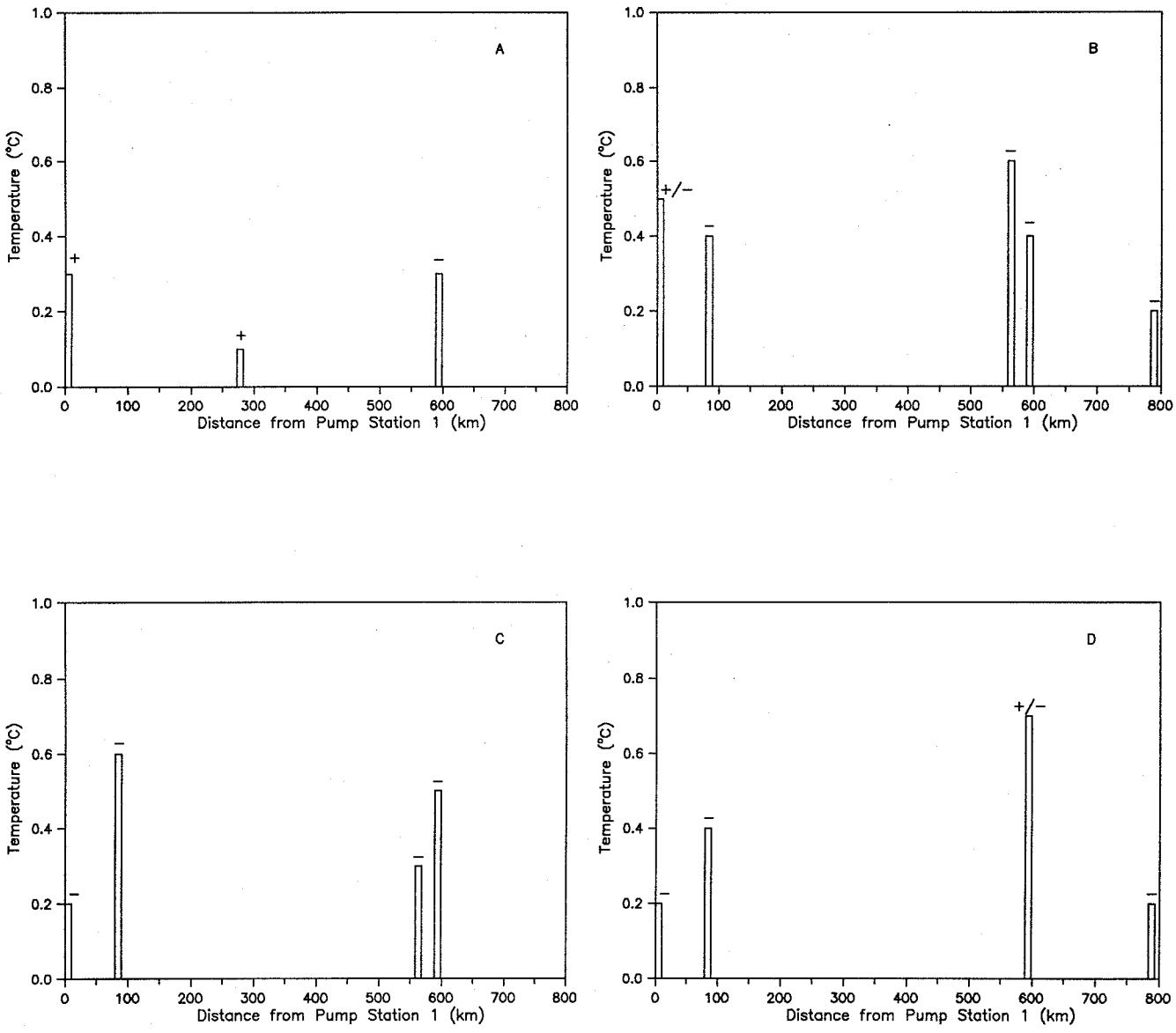

Temperature Fluctuations during Summer Shutdowns
at each of the Six Selected Sites
87.08.18–23
88.05.25–27
89.06.02
89.06.10
Temperature (°C)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

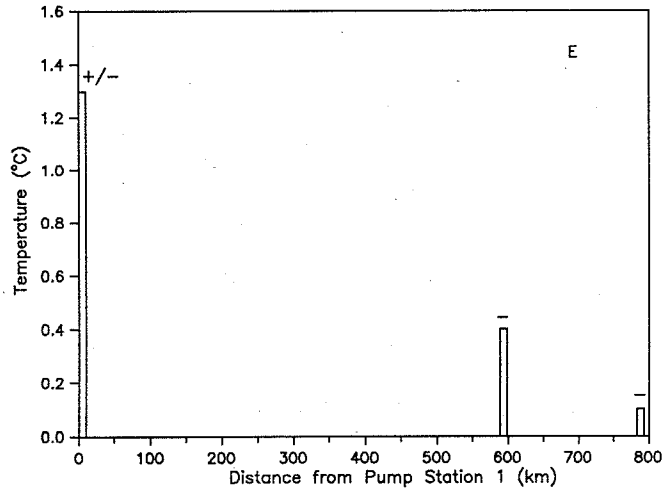

Temperature Fluctuations during Summer Shutdowns
at each of the Six Selected Sites
89.08.23
90.08.12–15
Temperature (°C)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

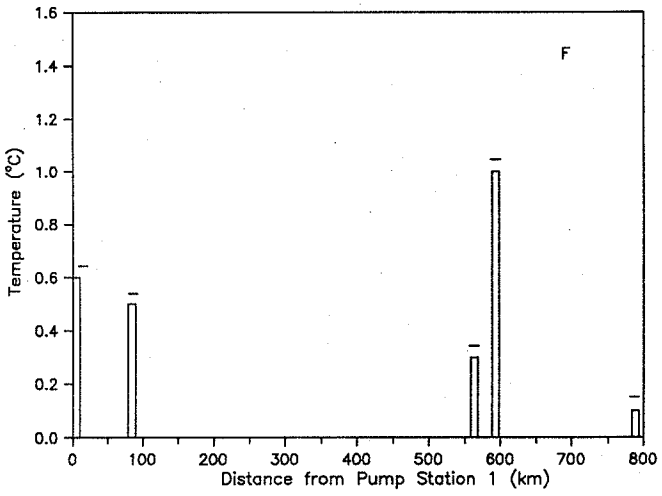
APPENDIX S.W.2.1b

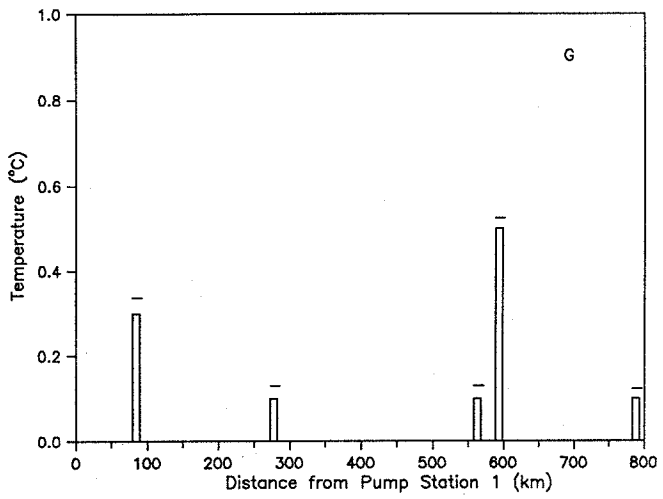
HISTOGRAMS OF TEMPERATURE FLUCTUATIONS WITH DISTANCE FROM PUMP STATION 1 DURING WINTER AND SUMMER SHUTDOWNS AT SITES ALONG THE NORMAN WELLS PIPELINE.

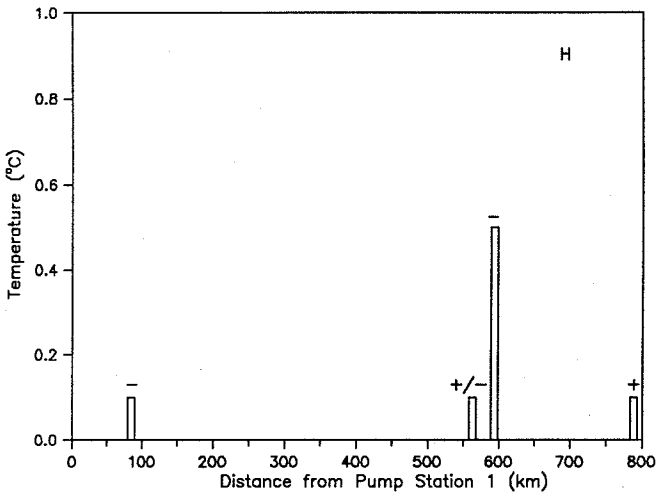
note: -Letters in top right of each figure correspond to the key in Table S.W.2.2.
-Plus & minus signs (i.e. +/-) correspond to increase/decrease in temperature during shutdown.

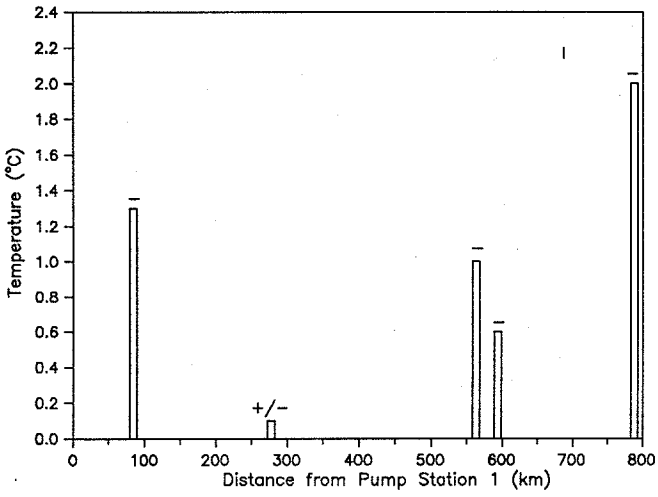

A
B
C
D
Temperature (°C)
Distance from Pump Station 1 (km)
0.0
0.2
0.4
0.6
0.8
1.0
0
100
200
300
400
500
600
700
800
+
−
+/−

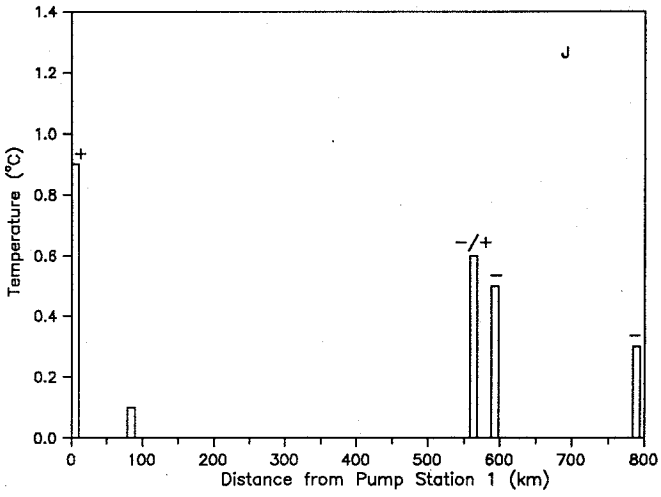

E
+/-
Temperature (°C)
Distance from Pump Station 1 (km)

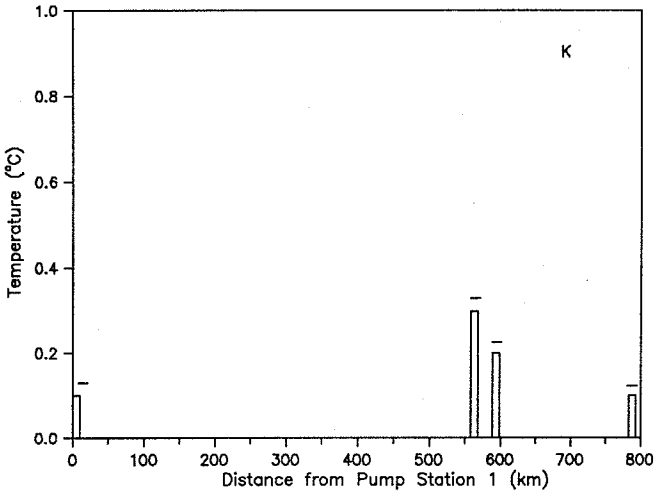

F
Temperature (°C)
Distance from Pump Station 1 (km)

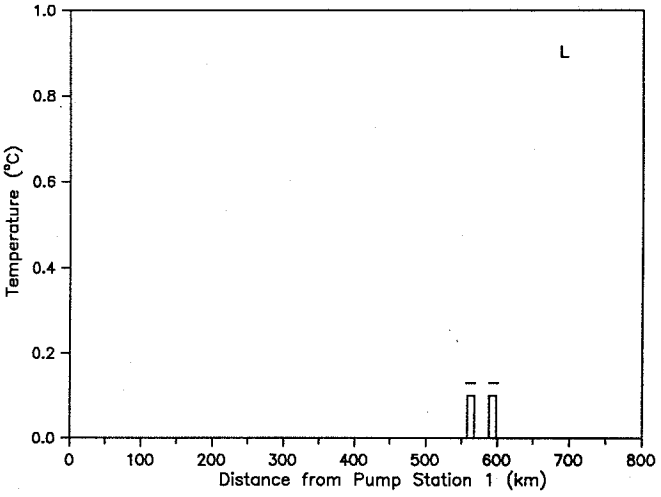

G
Temperature (°C)
Distance from Pump Station 1 (km)

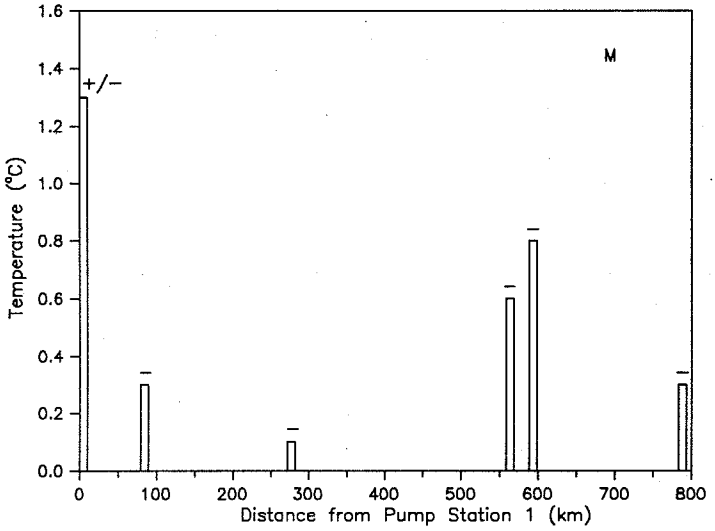

H
+/-
+
Temperature (°C)
Distance from Pump Station 1 (km)

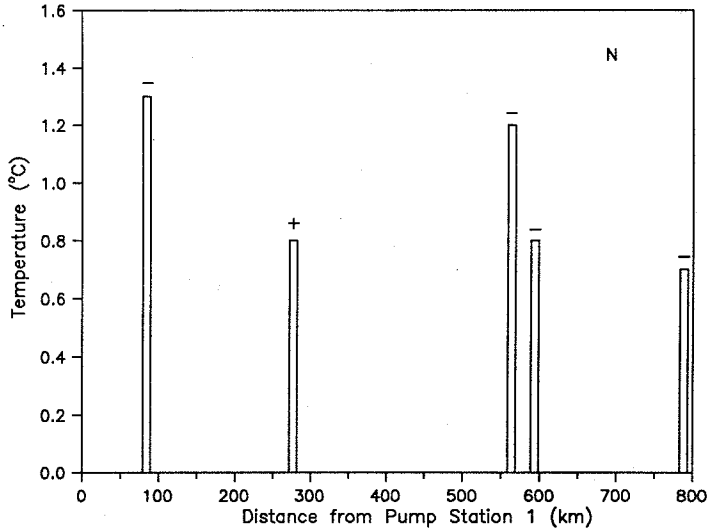

I
Temperature (°C)
Distance from Pump Station 1 (km)
+/−


J
Temperature (°C)
Distance from Pump Station 1 (km)
−/+


K
Temperature (°C)
Distance from Pump Station 1 (km)

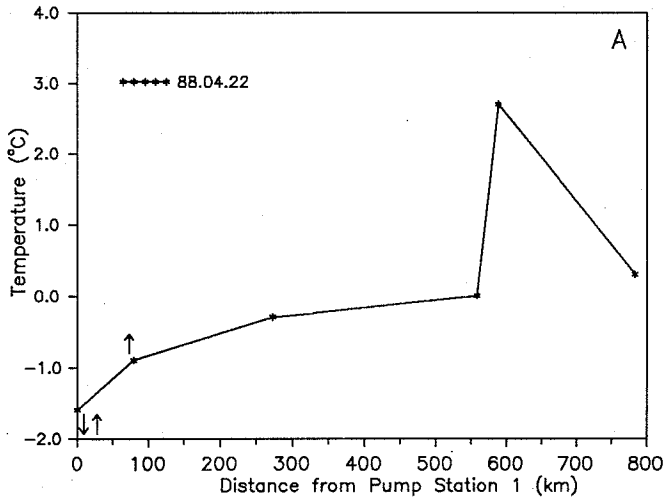

L
Temperature (°C)
Distance from Pump Station 1 (km)

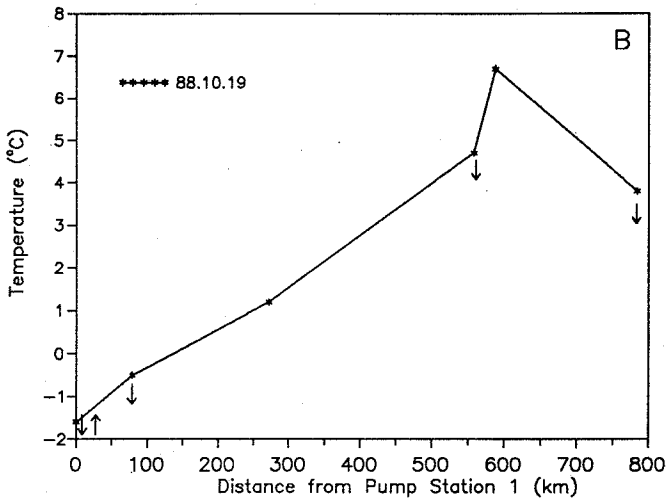

M
+/−
Temperature (°C)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

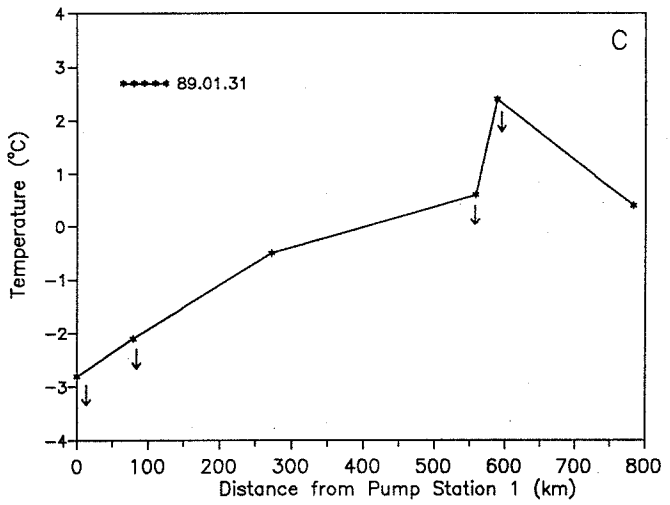

N
Temperature (°C)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

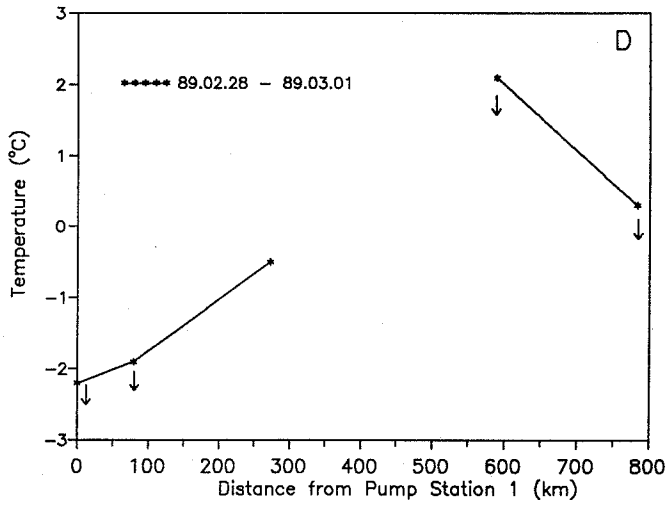
APPENDIX S.W.2.2

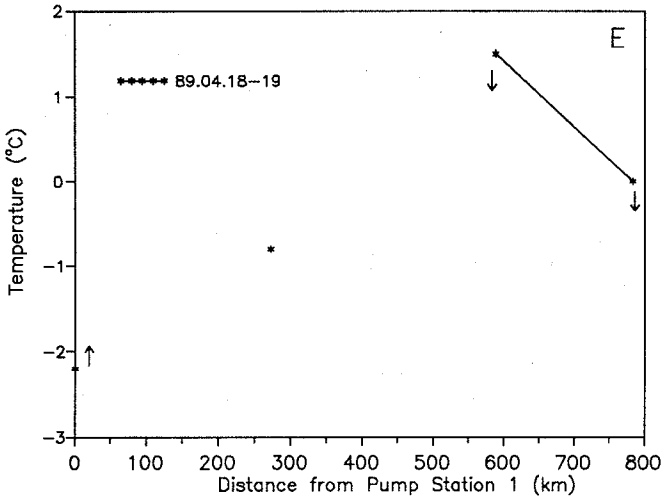
PLOTS OF EQUILIBRIUM TEMPERATURES WITH DISTANCE FROM PUMP STATION 1 AND INDICATION OF INCREASING (↑) OR DECREASING (↓) TEMPERATURES DURING EACH SHUTDOWN AT SIX SITES ALONG THE NORMAN WELLS PIPELINE .

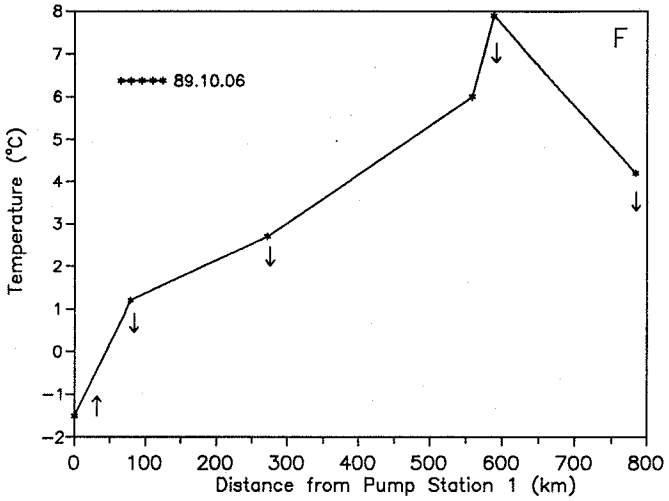

A
88.04.22
Temperature (°C)
Distance from Pump Station 1 (km)

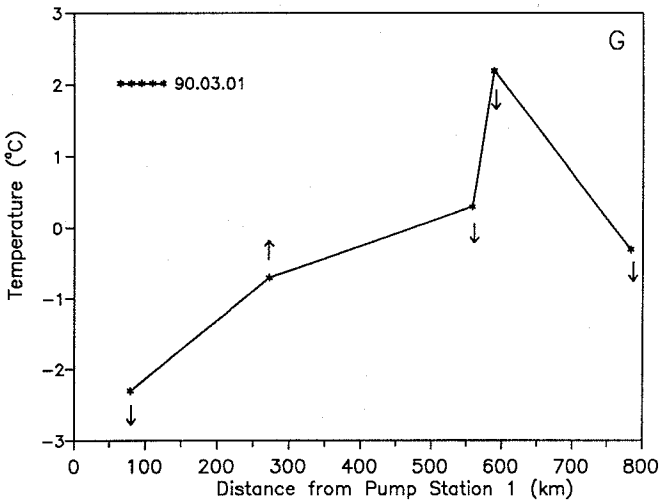

B
88.10.19
Temperature (°C)
Distance from Pump Station 1 (km)

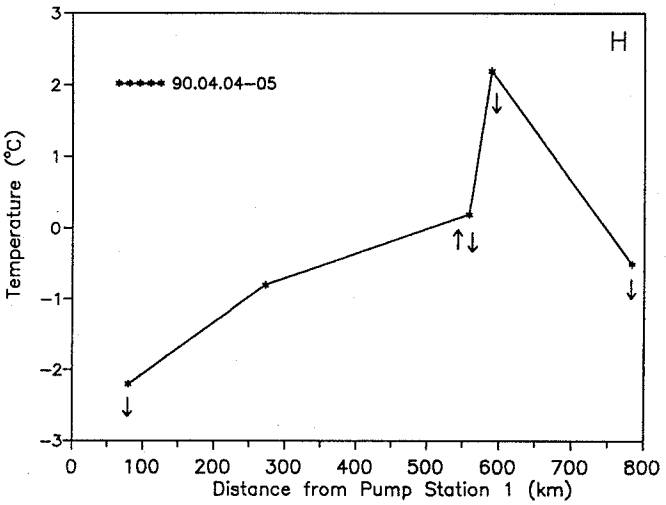

C
89.01.31
Temperature (°C)
Distance from Pump Station 1 (km)

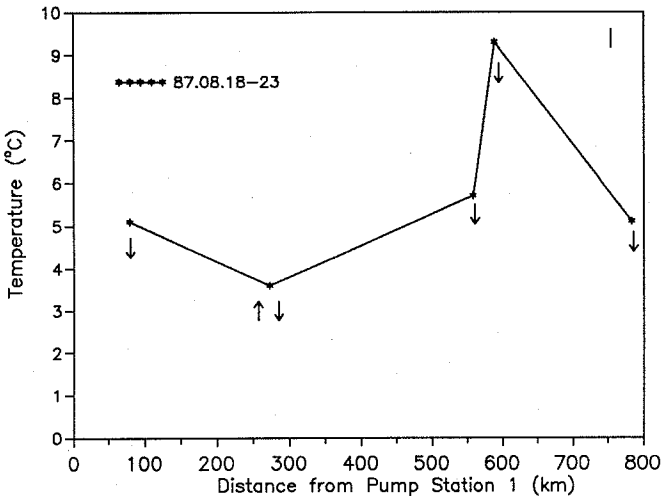

D
89.02.28 – 89.03.01
Temperature (°C)
Distance from Pump Station 1 (km)

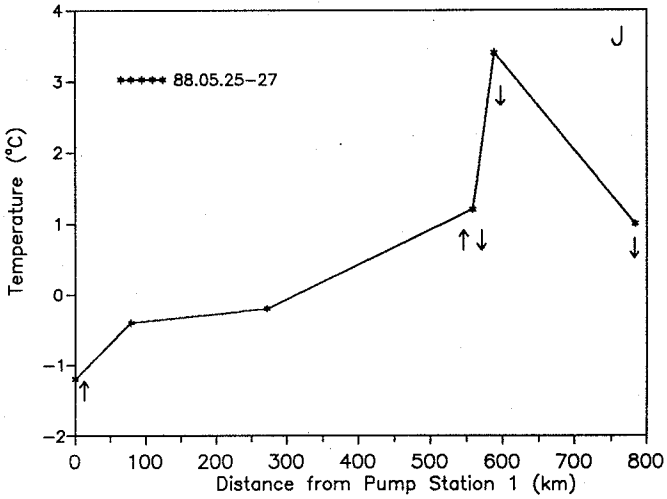

E
***** 89.04.18--19
Temperature (°C)
Distance from Pump Station 1 (km)

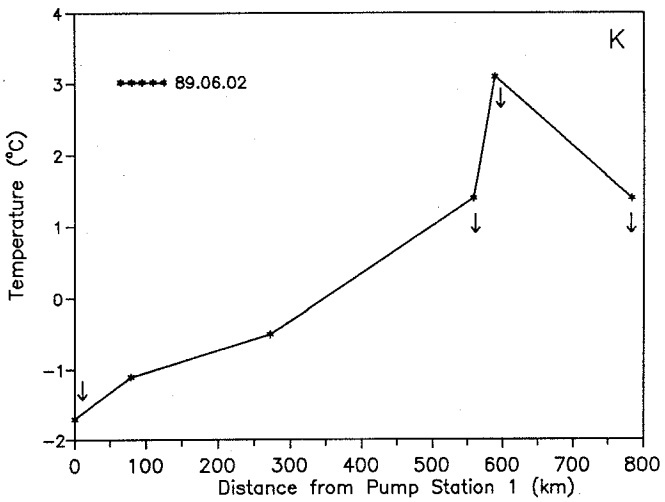

F
***** 89.10.06
Temperature (°C)
Distance from Pump Station 1 (km)

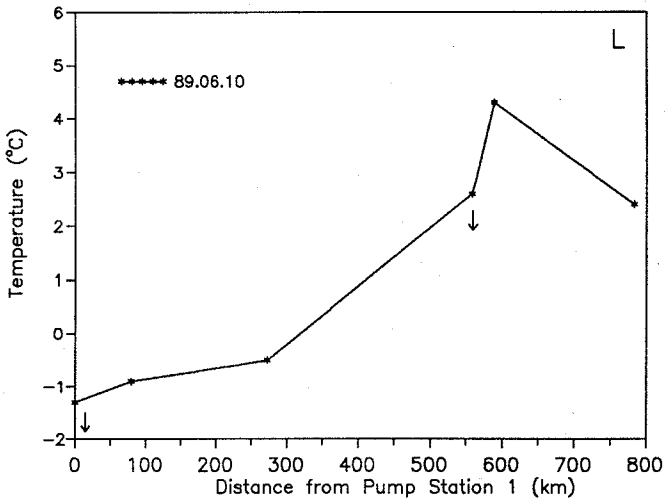

G
***** 90.03.01
Temperature (°C)
Distance from Pump Station 1 (km)

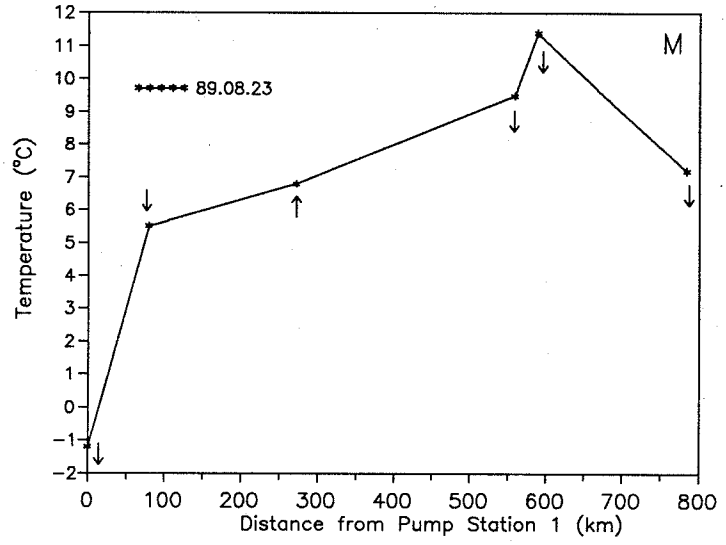

H
***** 90.04.04--05
Temperature (°C)
Distance from Pump Station 1 (km)

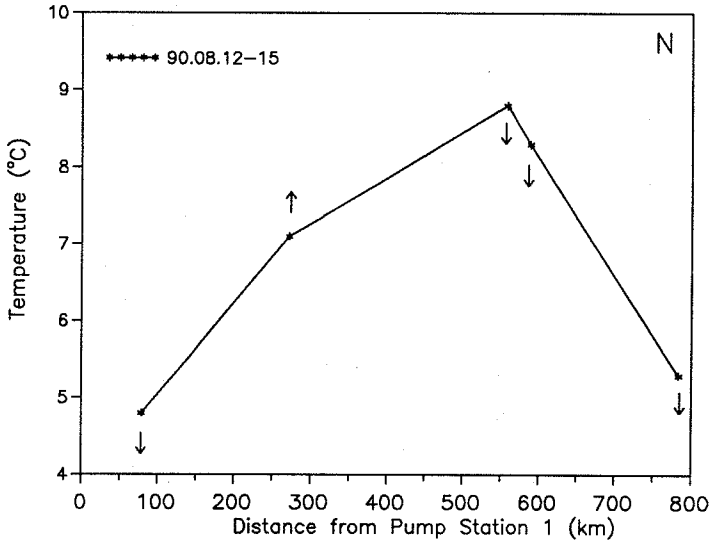

I
87.08.18–23
Temperature (°C)
Distance from Pump Station 1 (km)


J
88.05.25–27
Temperature (°C)
Distance from Pump Station 1 (km)


K
89.06.02
Temperature (°C)
Distance from Pump Station 1 (km)

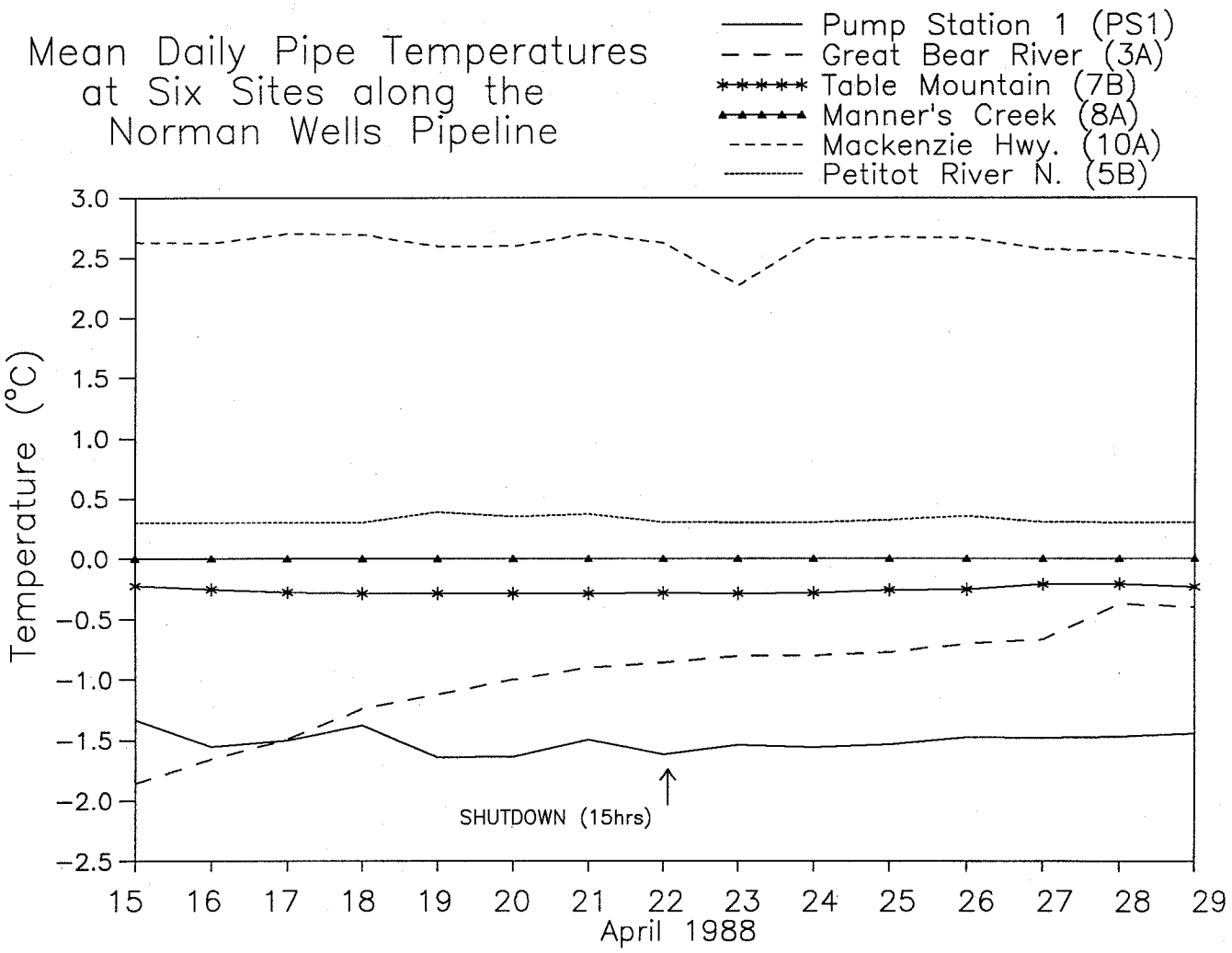

L
89.06.10
Temperature (°C)
Distance from Pump Station 1 (km)

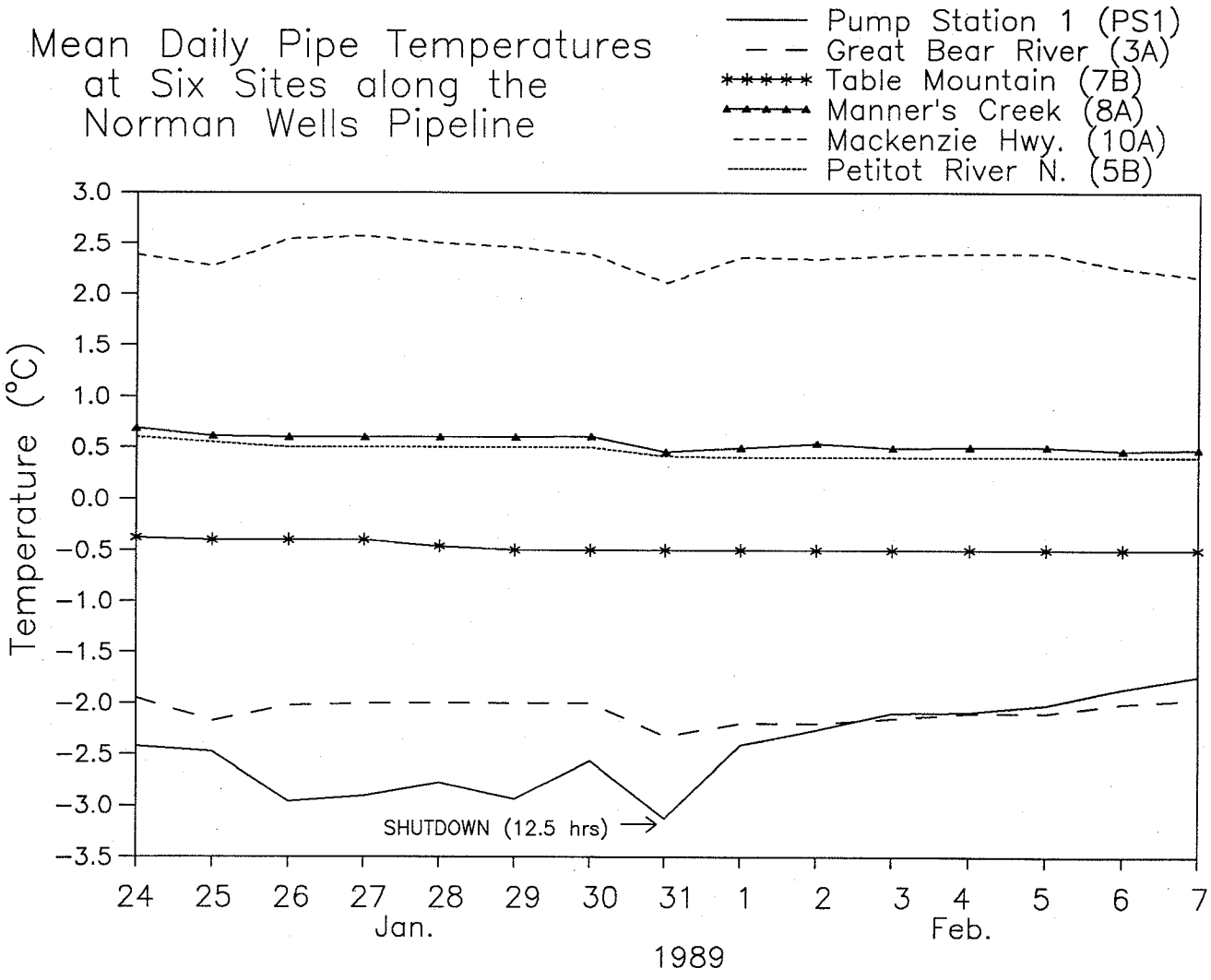

M
***** 89.08.23
Temperature (°C)
Distance from Pump Station 1 (km)

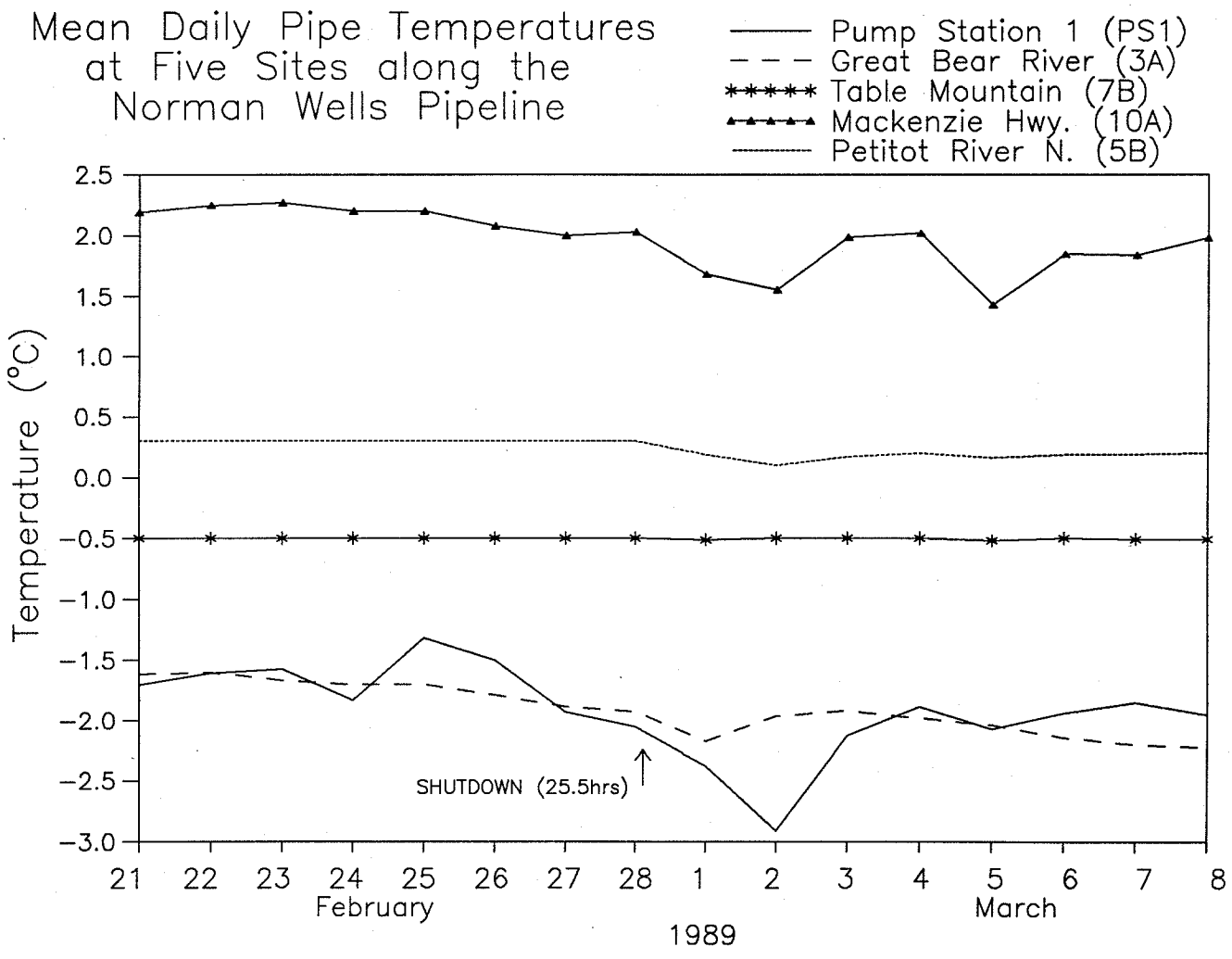

N
***** 90.08.12–15
Temperature (°C)
Distance from Pump Station 1 (km)

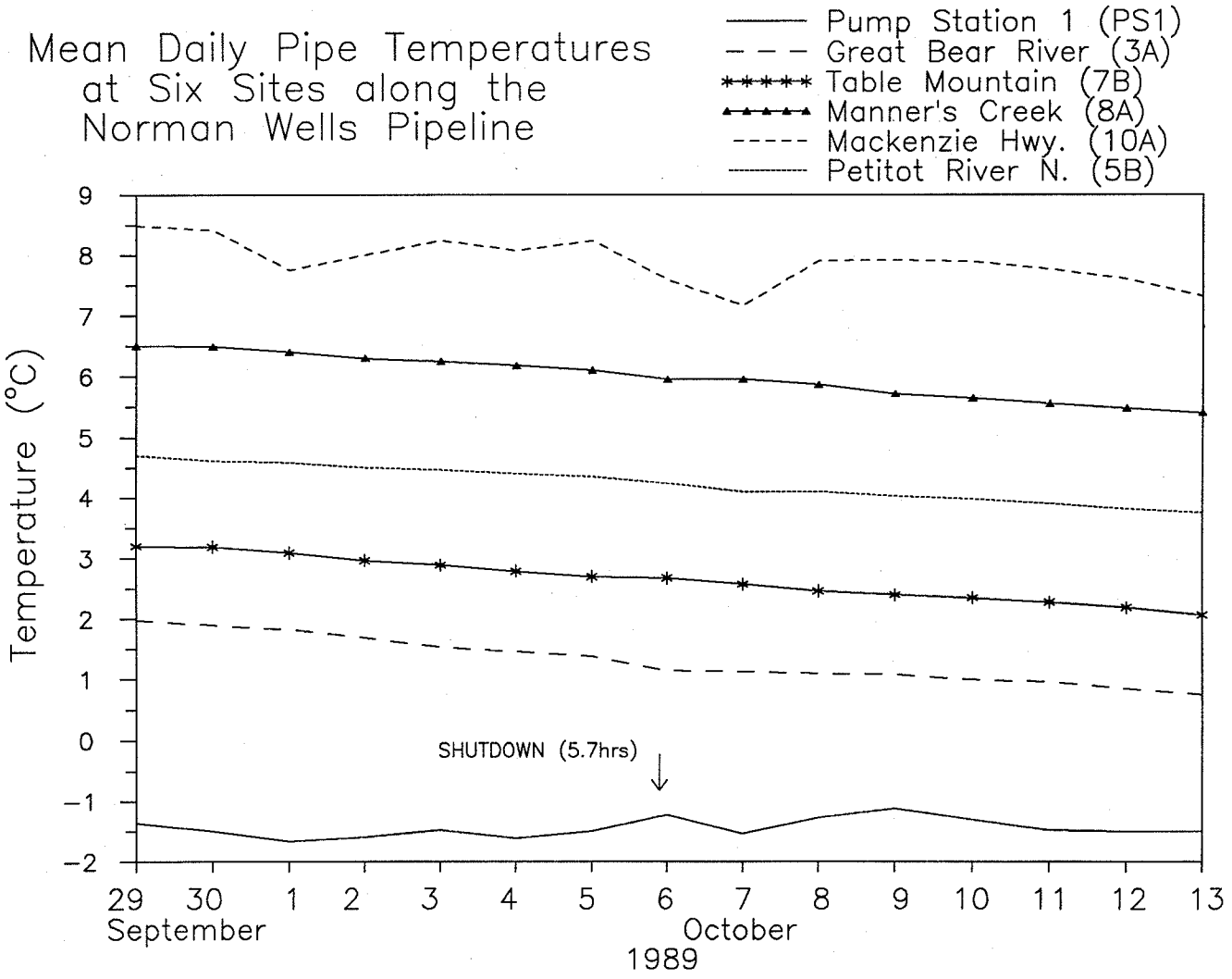
APPENDIX S.W.2.3a

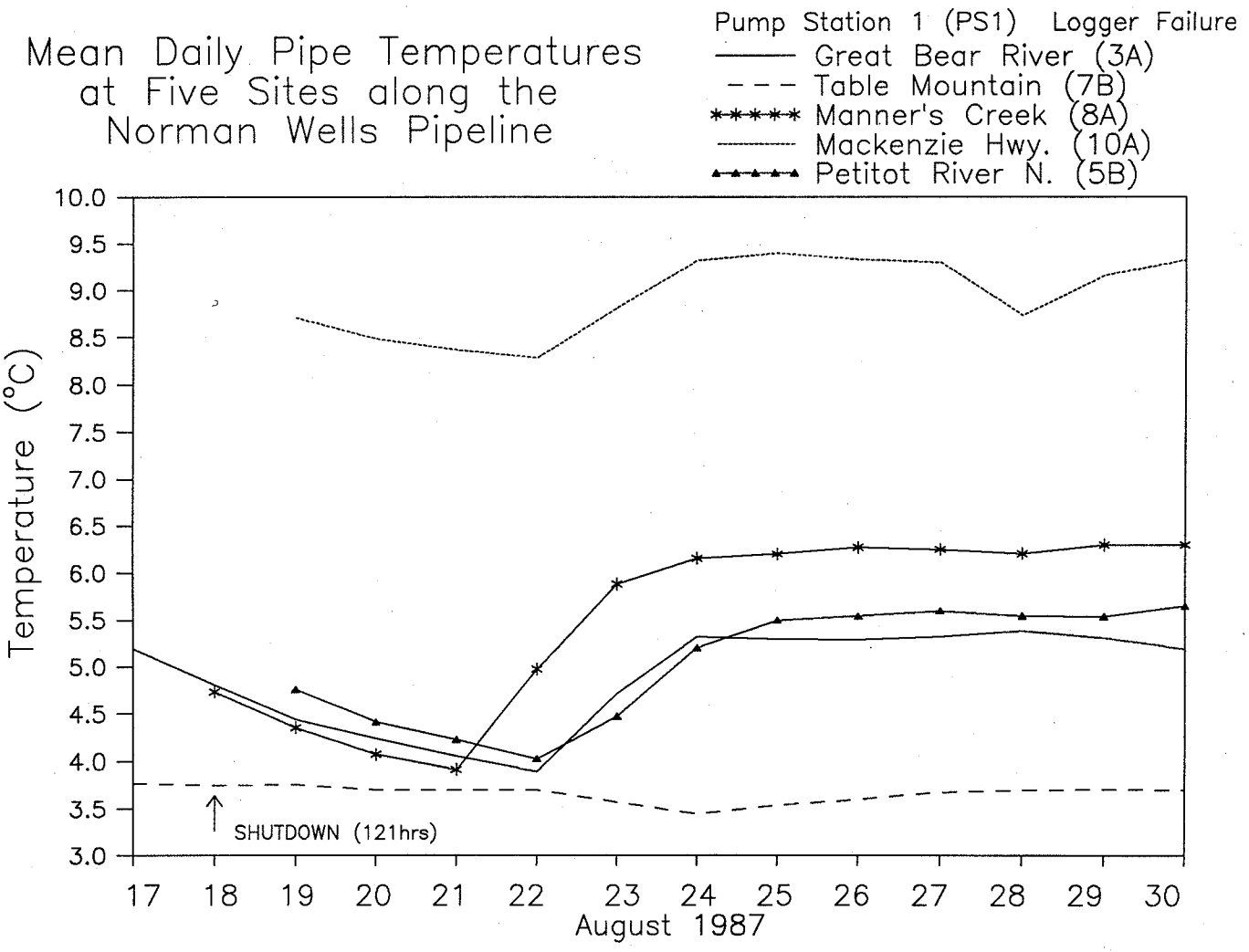
PLOTS OF MEAN DAILY PIPE TEMPERATURES FOR EIGHT (8) SIGNIFICANT SHUTDOWNS AT SITES ALONG THE NORMAN WELLS PIPELINE .

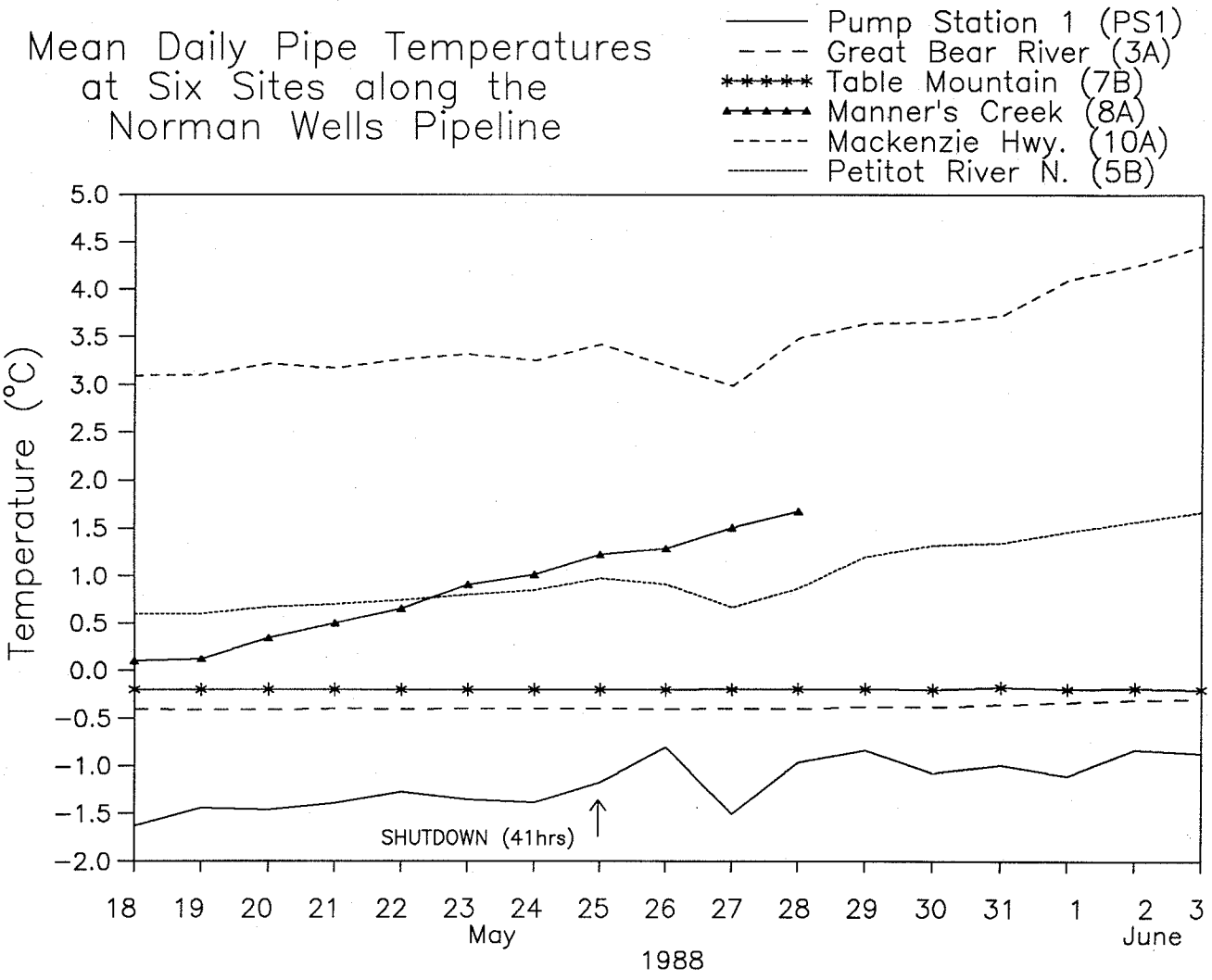

Mean Daily Pipe Temperatures
at Six Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1)
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
SHUTDOWN (15hrs)
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
April 1988

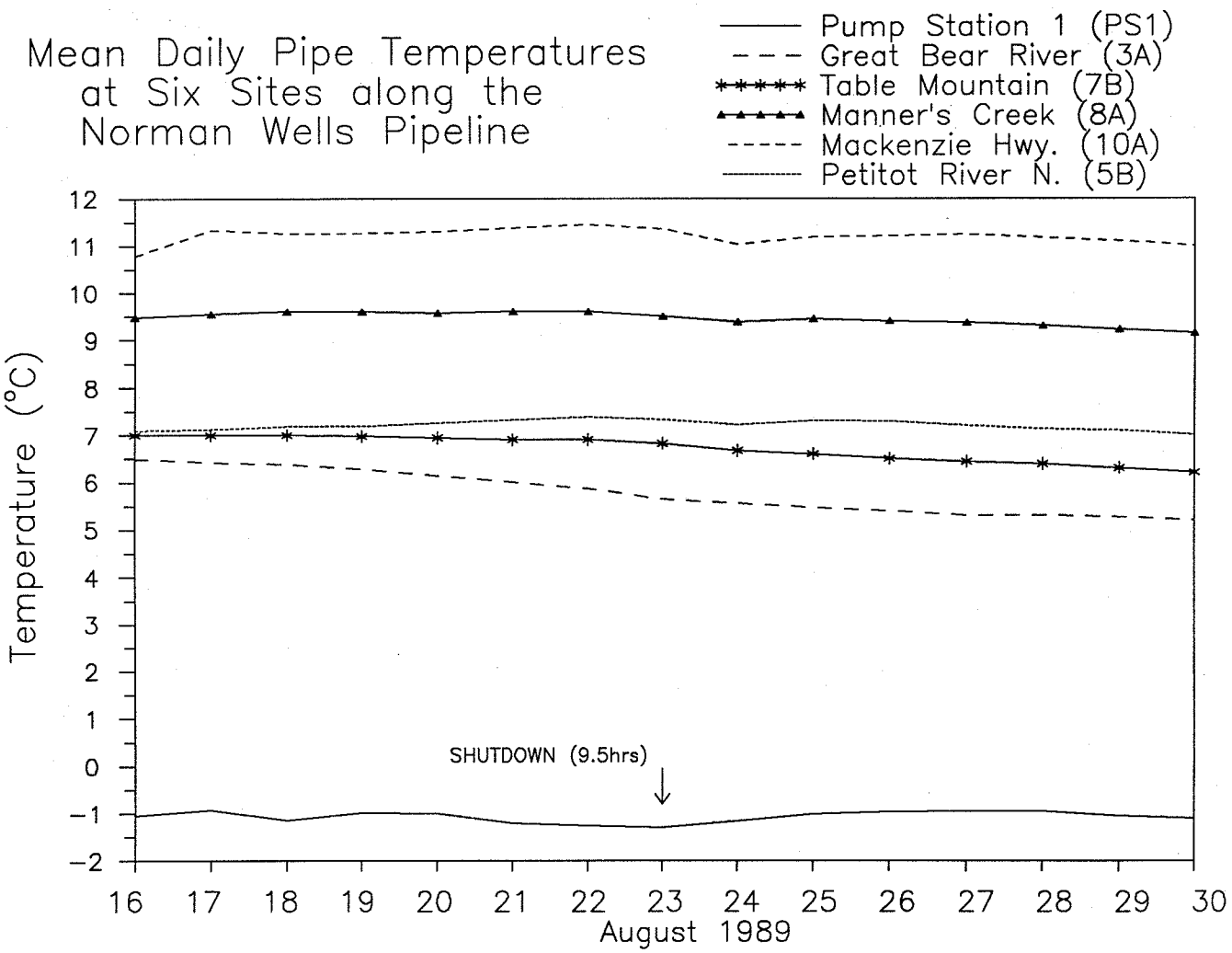

Mean Daily Pipe Temperatures
at Six Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1)
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
−3.5
SHUTDOWN (12.5 hrs)
24 25 26 27 28 29 30 31 1 2 3 4 5 6 7
Jan.
Feb.
1989

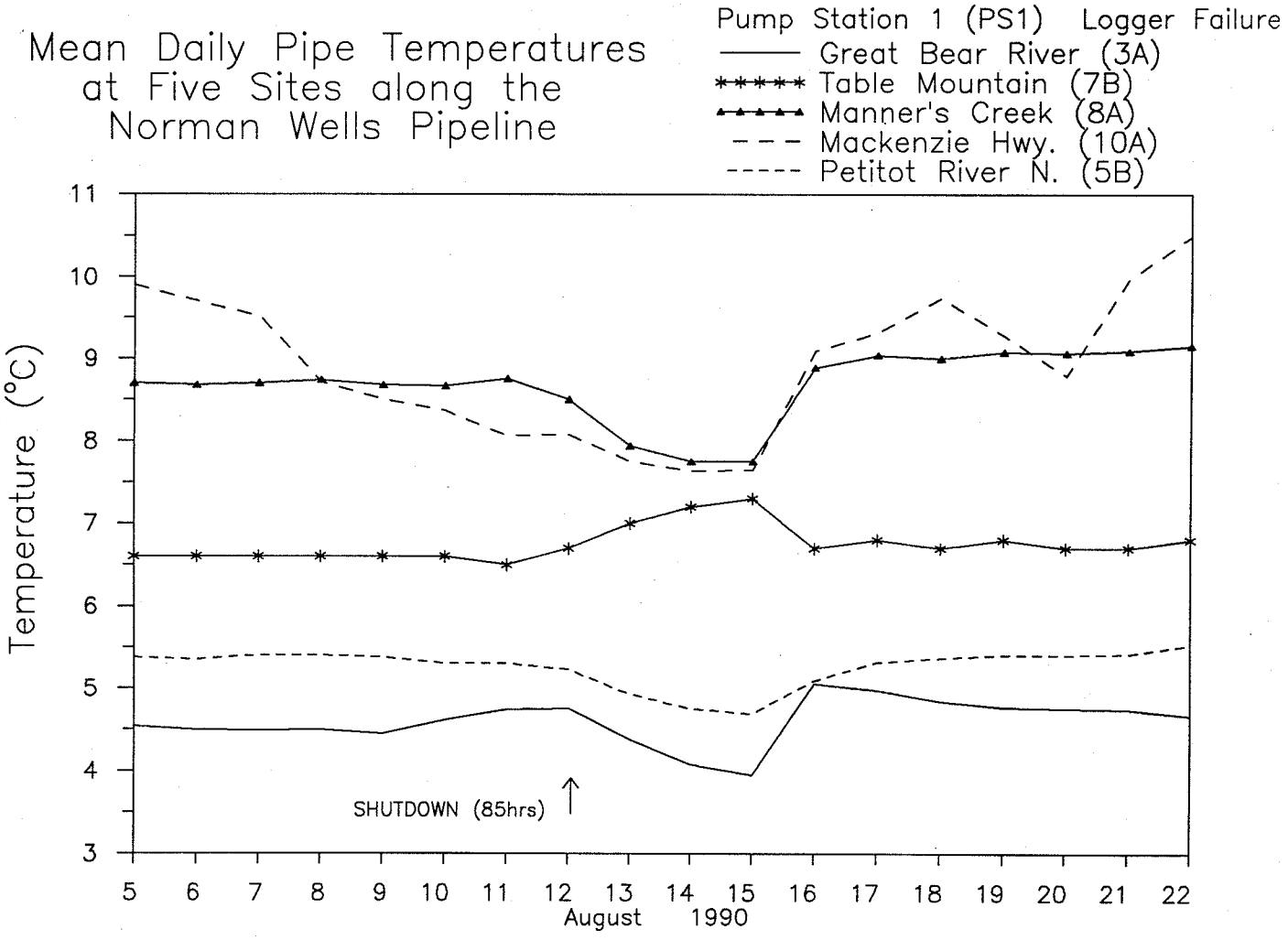

Mean Daily Pipe Temperatures
at Five Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1)
Great Bear River (3A)
Table Mountain (7B)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
SHUTDOWN (25.5hrs)
21 22 23 24 25 26 27 28 1 2 3 4 5 6 7 8
February
March
1989


Mean Daily Pipe Temperatures
at Six Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1)
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
9
8
7
6
5
4
3
2
1
0
−1
−2
SHUTDOWN (5.7hrs)
29 30 1 2 3 4 5 6 7 8 9 10 11 12 13
September
October
1989


Mean Daily Pipe Temperatures
at Five Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1) Logger Failure
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
SHUTDOWN (121hrs)
17
18
19
20
21
22
23
24
25
26
27
28
29
30
August 1987


Mean Daily Pipe Temperatures
at Six Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1)
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
SHUTDOWN (41hrs)
18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3
May
June
1988

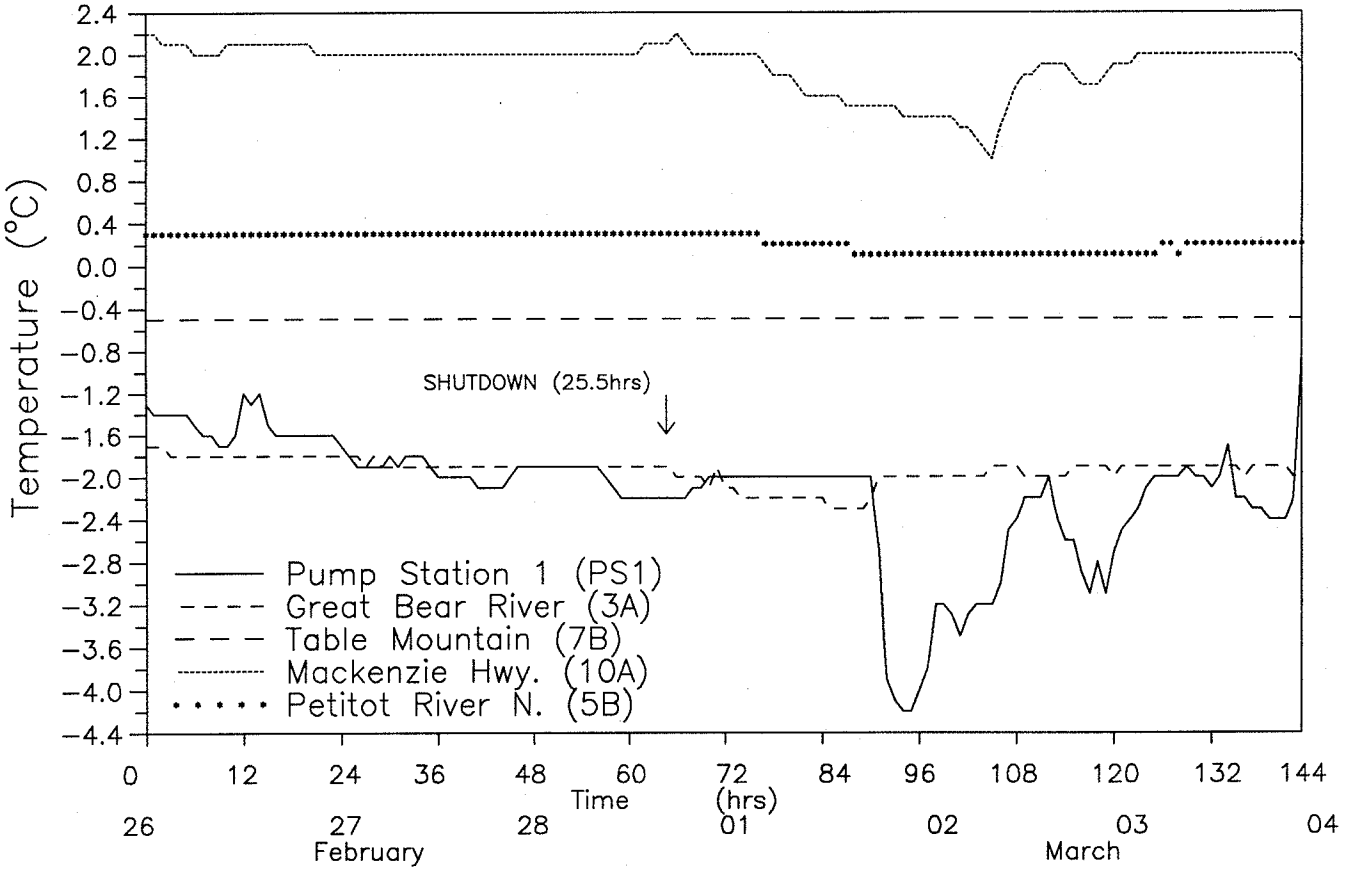

Mean Daily Pipe Temperatures
at Six Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1)
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
SHUTDOWN (9.5hrs)
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
August 1989


Mean Daily Pipe Temperatures
at Five Sites along the
Norman Wells Pipeline
Pump Station 1 (PS1) Logger Failure
Great Bear River (3A)
Table Mountain (7B)
Manner's Creek (8A)
Mackenzie Hwy. (10A)
Petitot River N. (5B)
Temperature (°C)
11
10
9
8
7
6
5
4
3
SHUTDOWN (85hrs)
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
August 1990

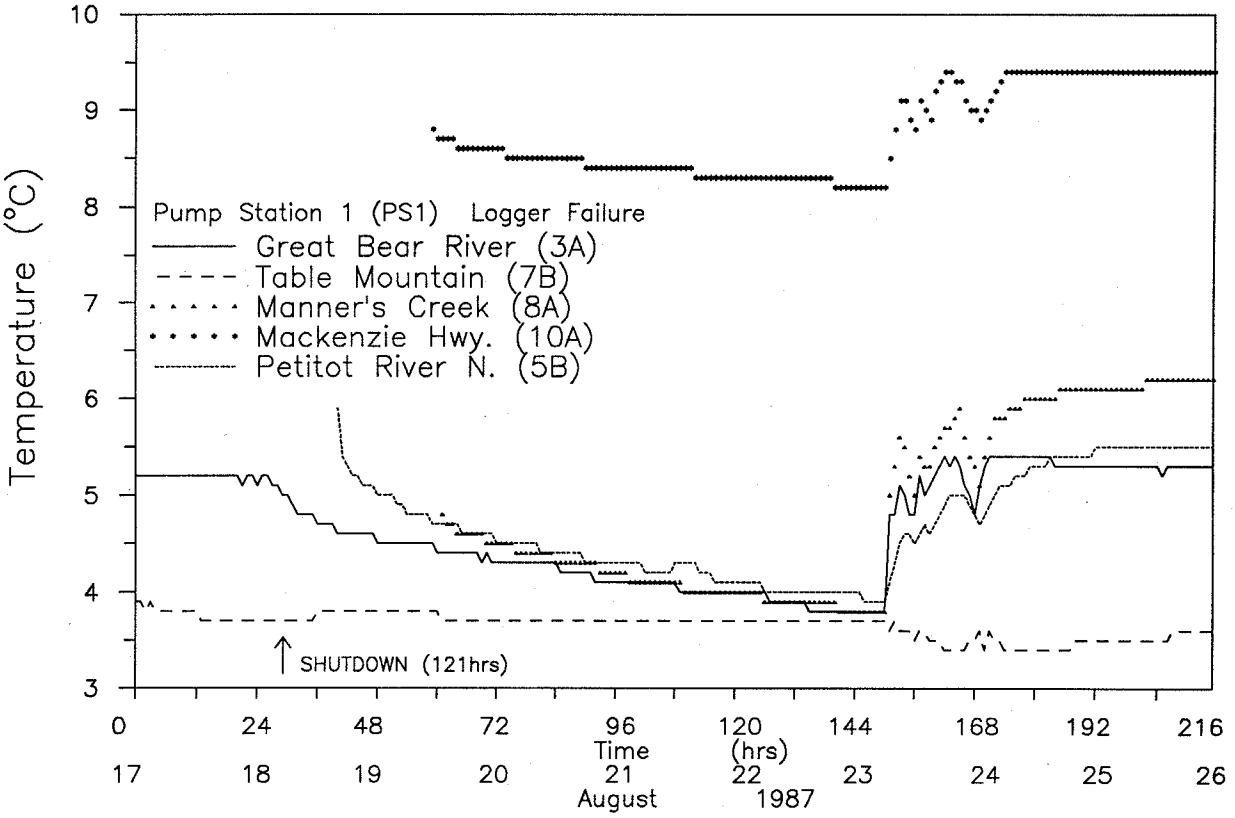
APPENDIX S.W.2.3b

PLOTS OF PIPE TEMPERATURES AT 1 & 3-HR INTERVALS FOR SITES WITH SIGNIFICANT SHUTDOWNS.

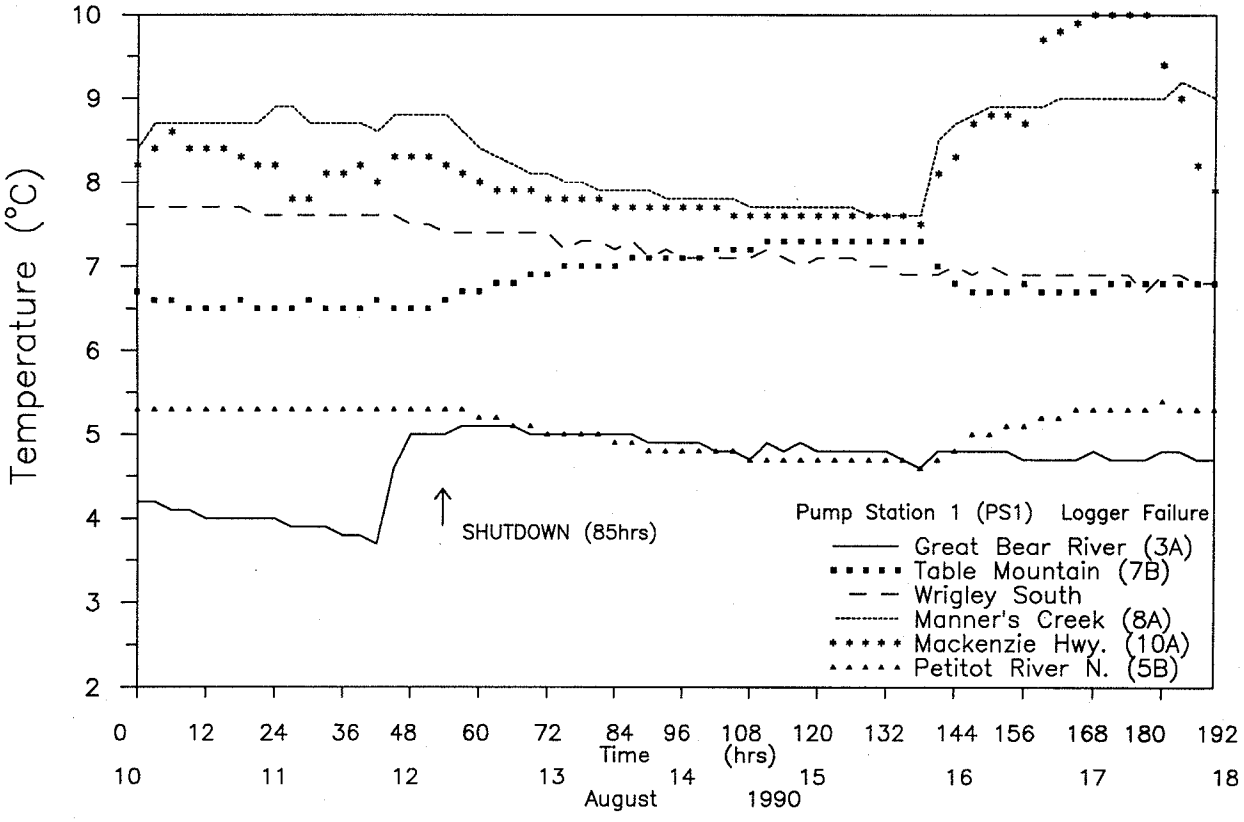
Pipe Temperatures at 1–hour Intervals for Five Sites along the Norman Wells Pipeline between February 26 & March 4, 1989



Pipe Temperatures at 1–hour Intervals for Five Sites
along the Norman Wells Pipeline
between August 17 & 26, 1987



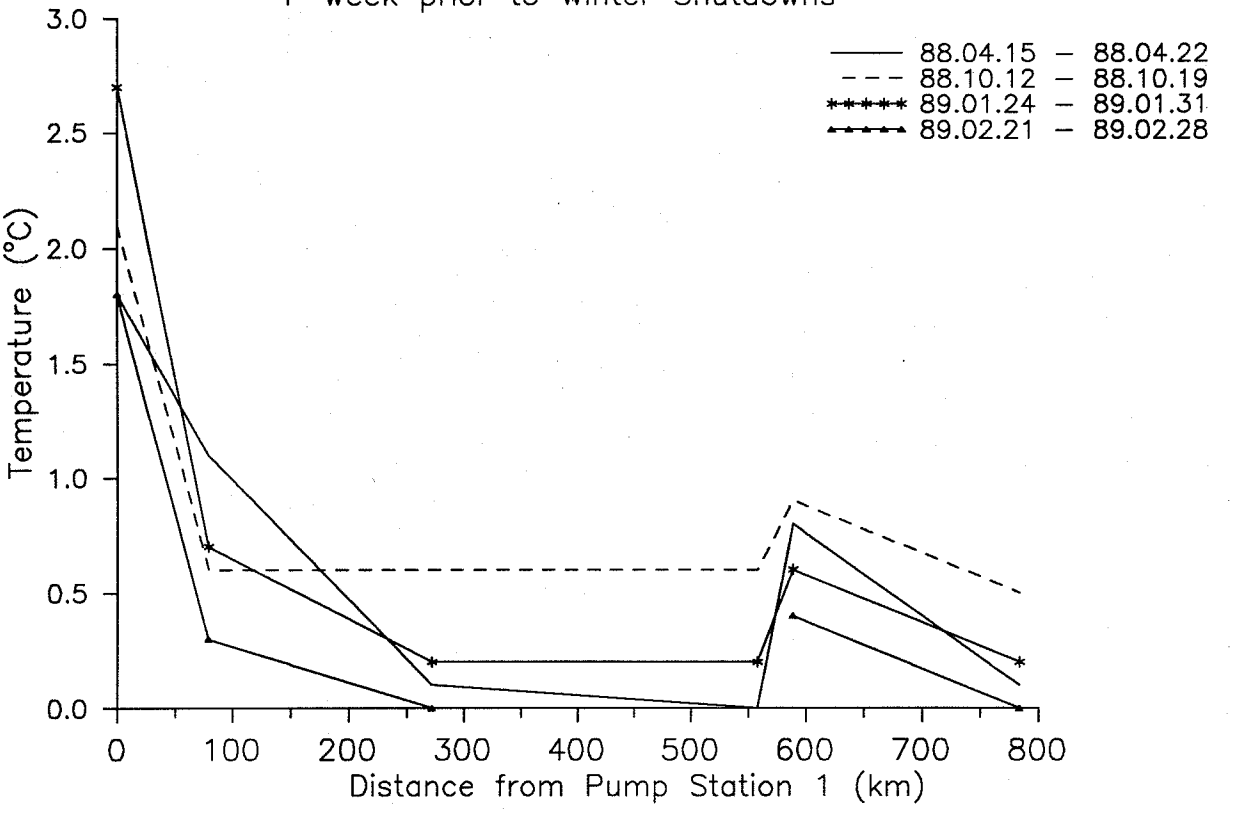
Pipe Temperatures at 3–hour Intervals for Six Sites along the Norman Wells Pipeline between August 10 & 18, 1990



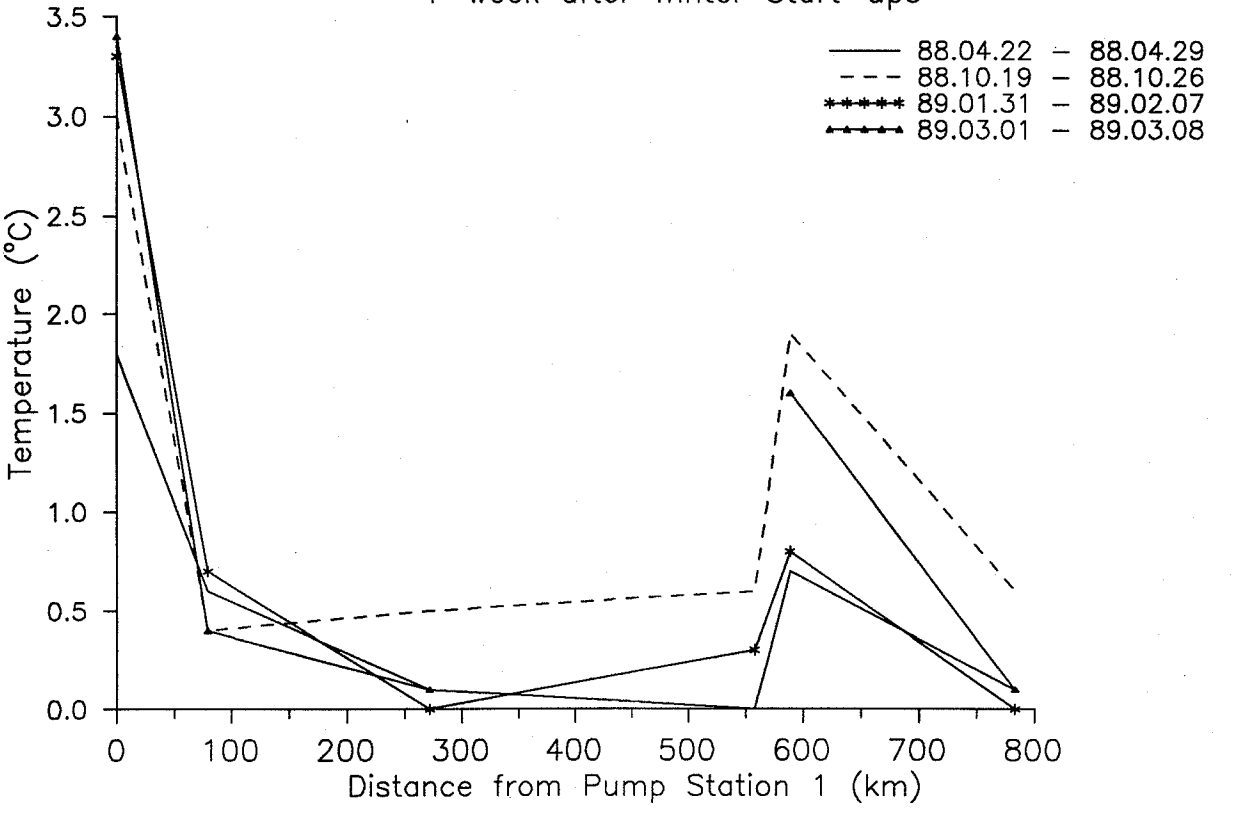
APPENDIX S.W.2.4

PLOTS OF CHANGES IN PIPE TEMPERATURE AMPLITUDE WITH DISTANCE FROM PUMP STATION 1 AT EACH SITE 1-WEEK PRIOR TO WINTER SHUTDOWNS AND 1-WEEK AFTER WINTER STARTUPS.

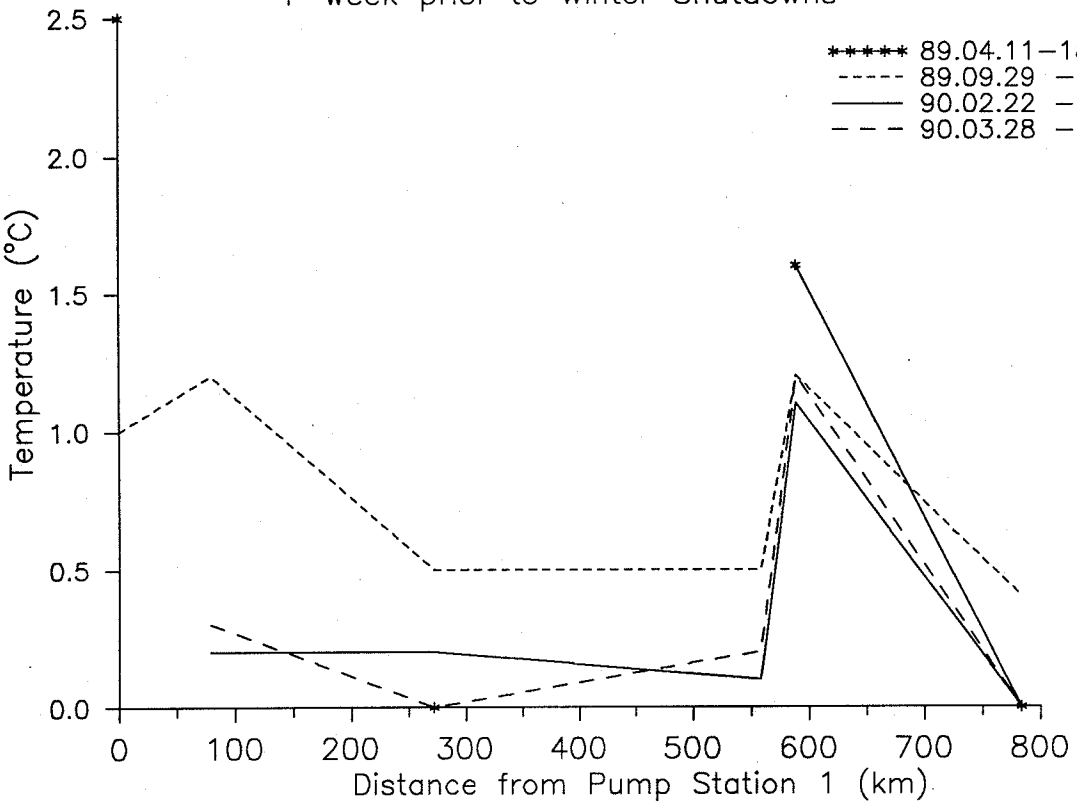
Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1–week prior to Winter Shutdowns



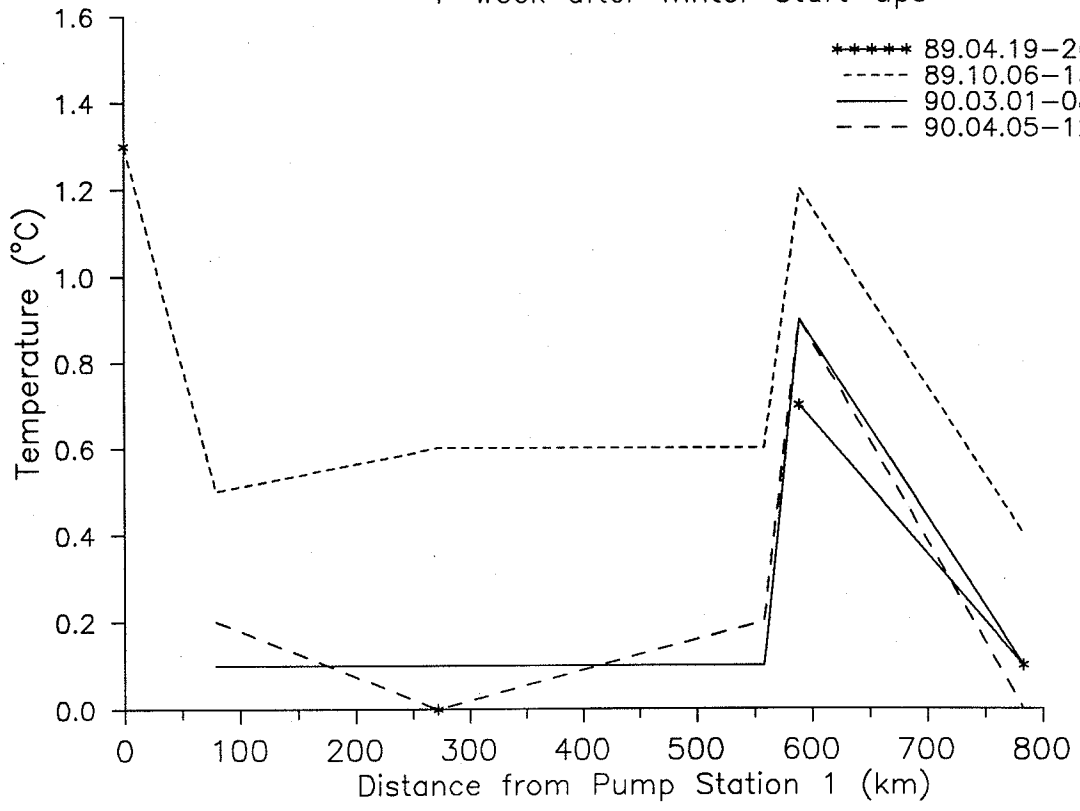
Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1–week after Winter Start–ups



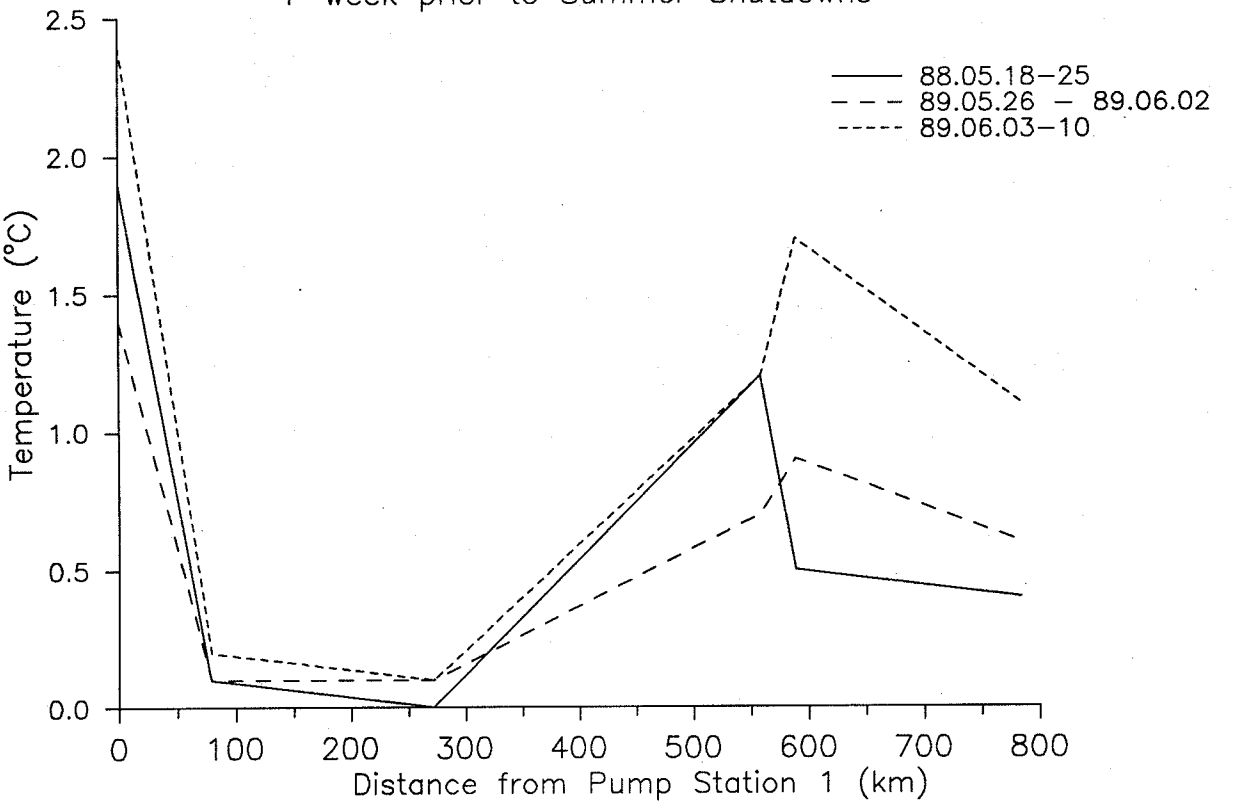
Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1-week prior to Winter Shutdowns



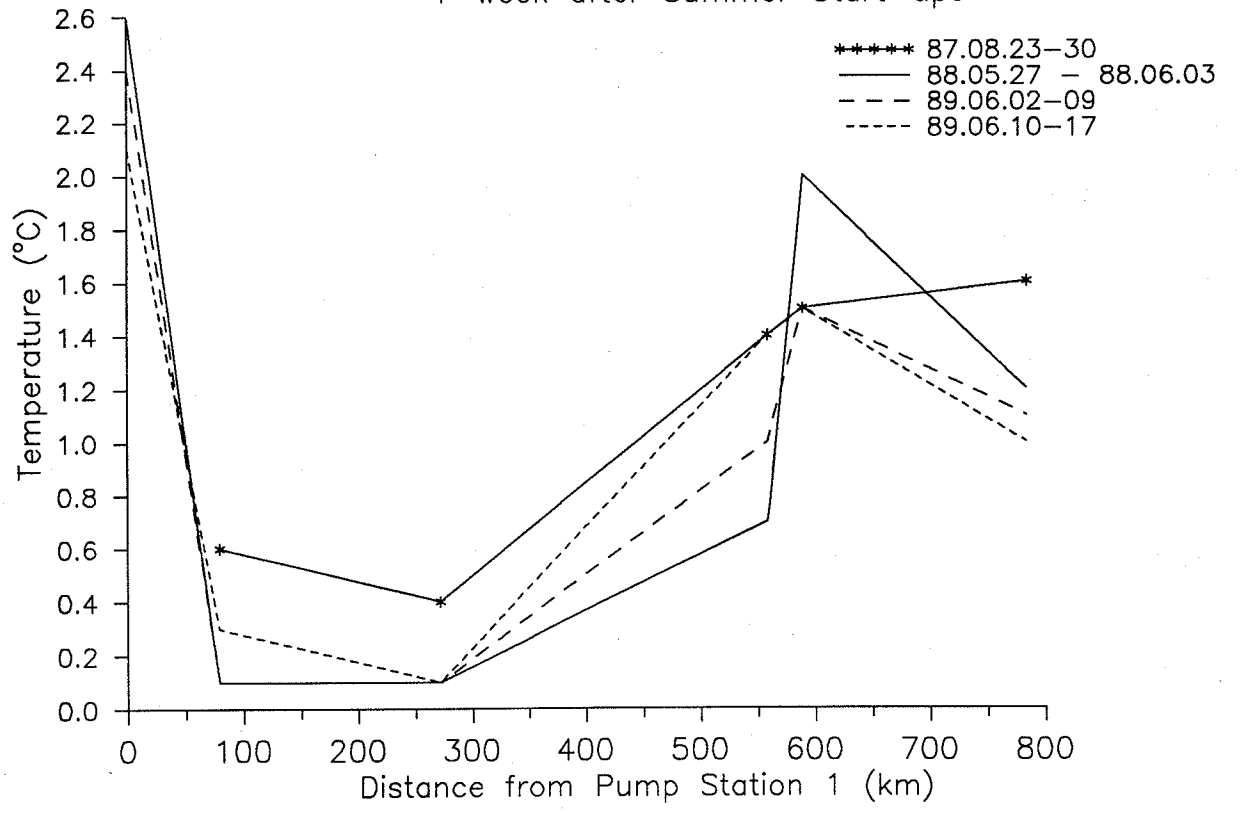
Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1-week after Winter Start-ups

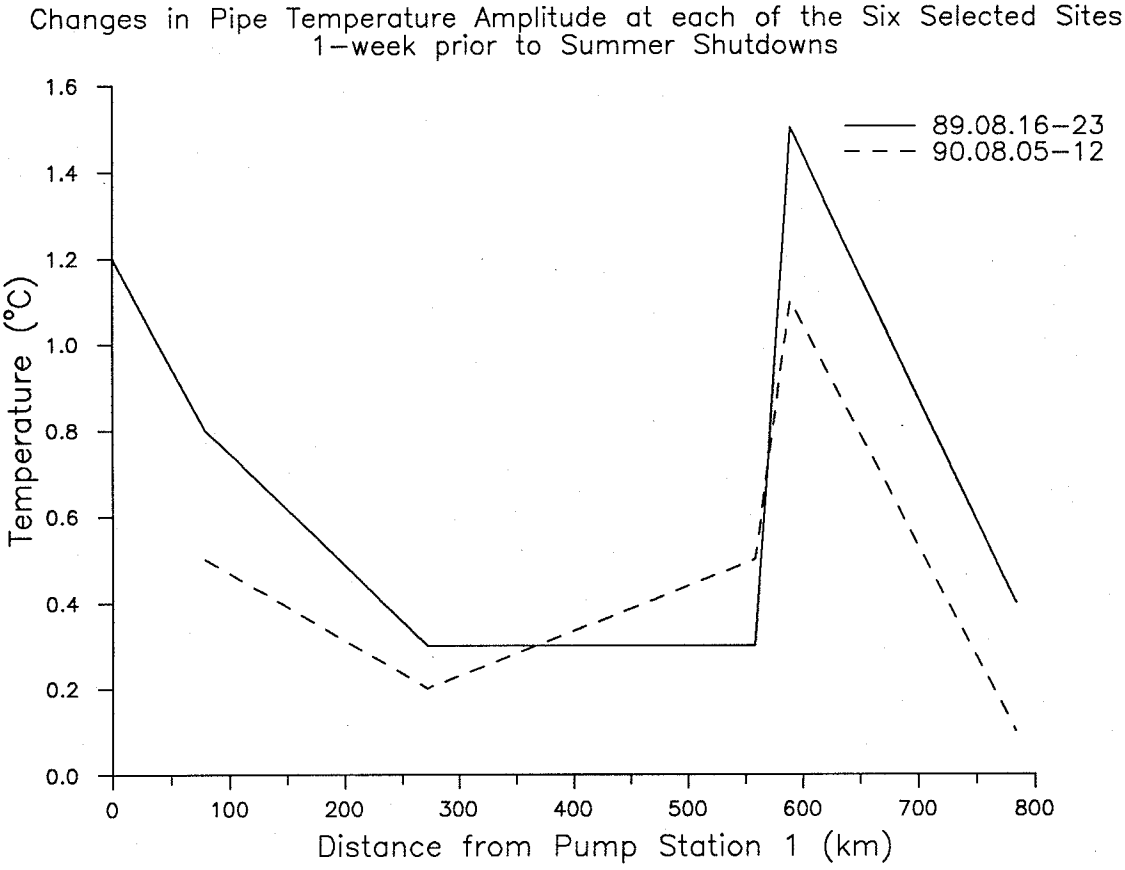


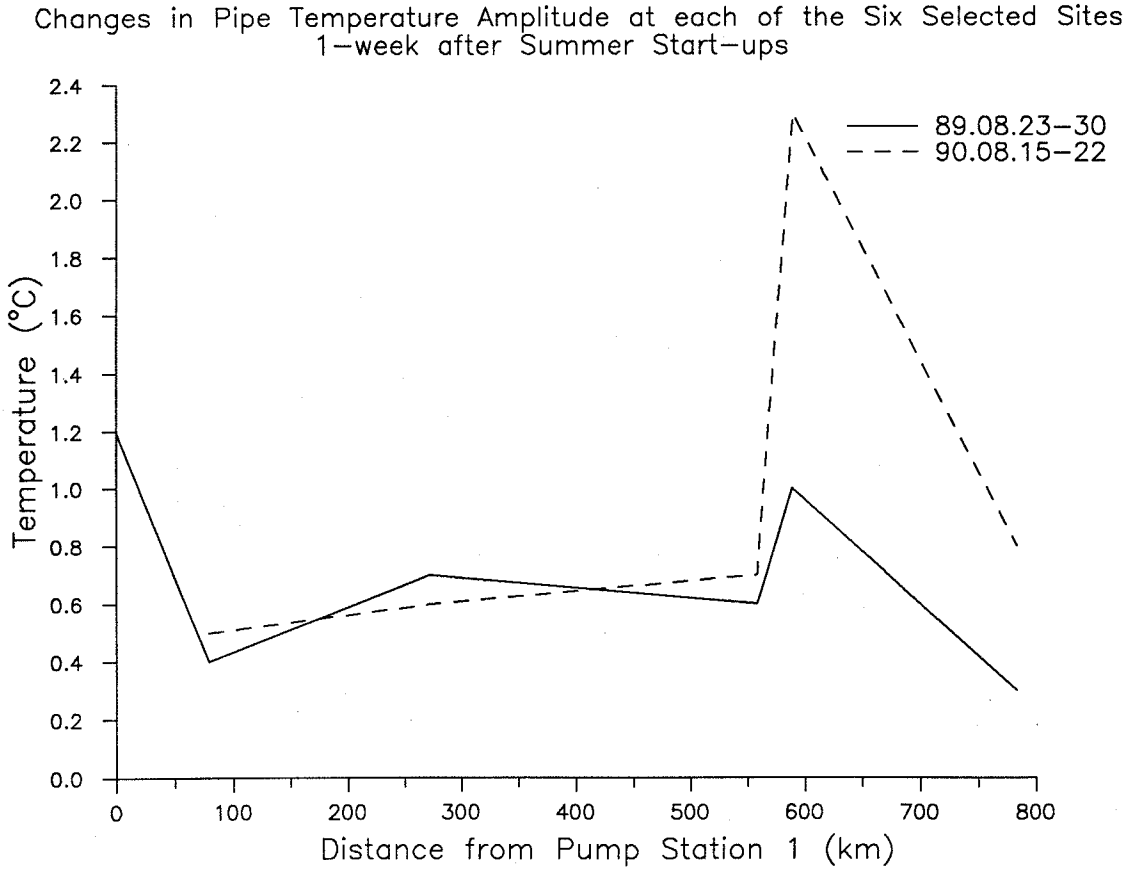
Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1-week prior to Summer Shutdowns



Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1-week after Summer Start-ups

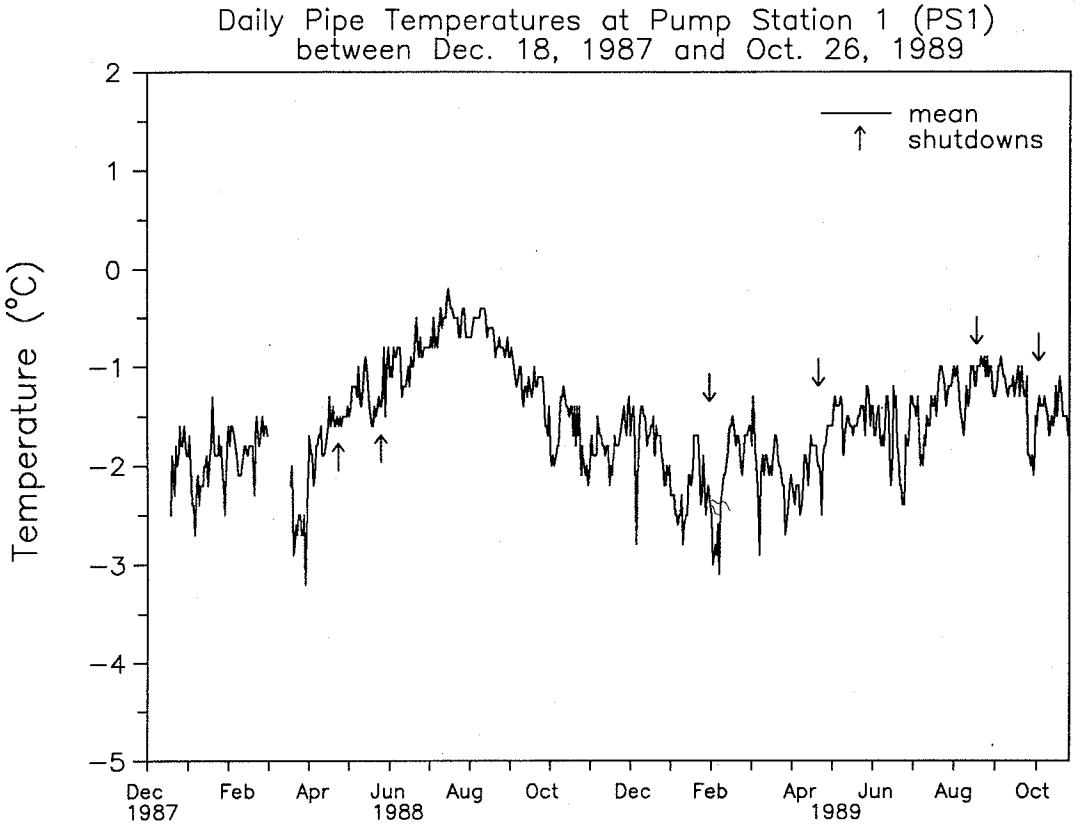


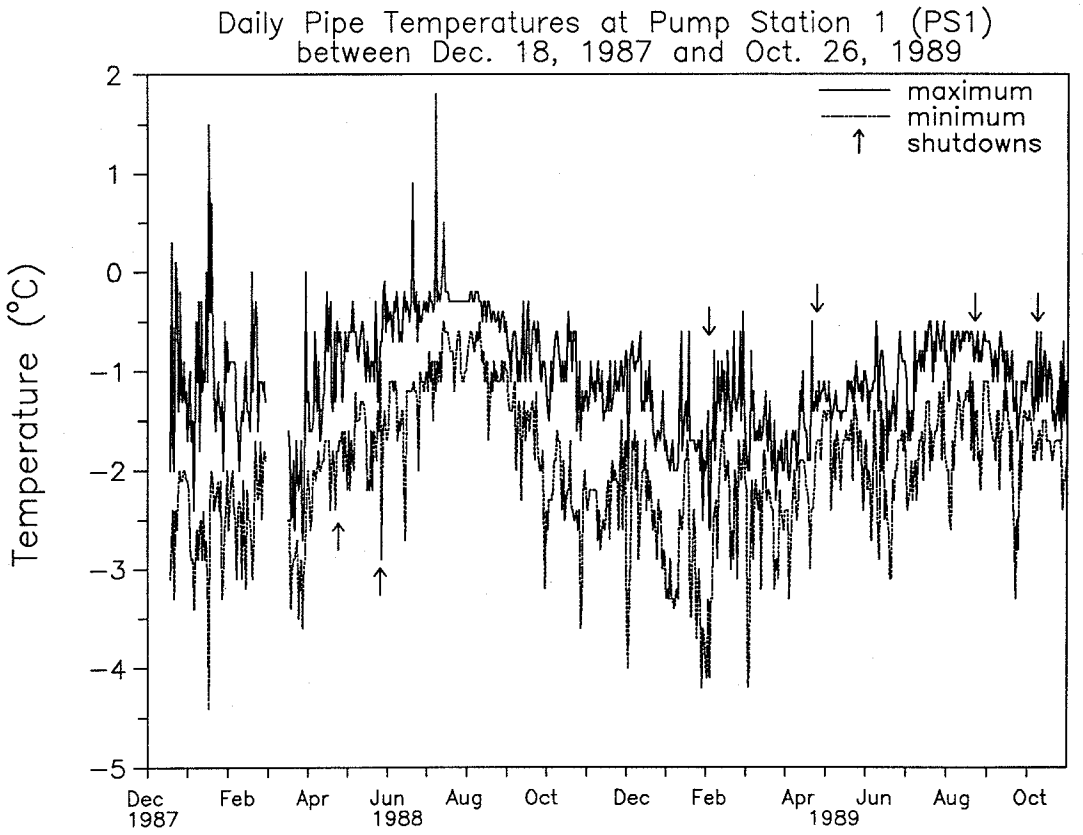

Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1-week prior to Summer Shutdowns
89.08.16-23
90.08.05-12
Temperature (°C)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

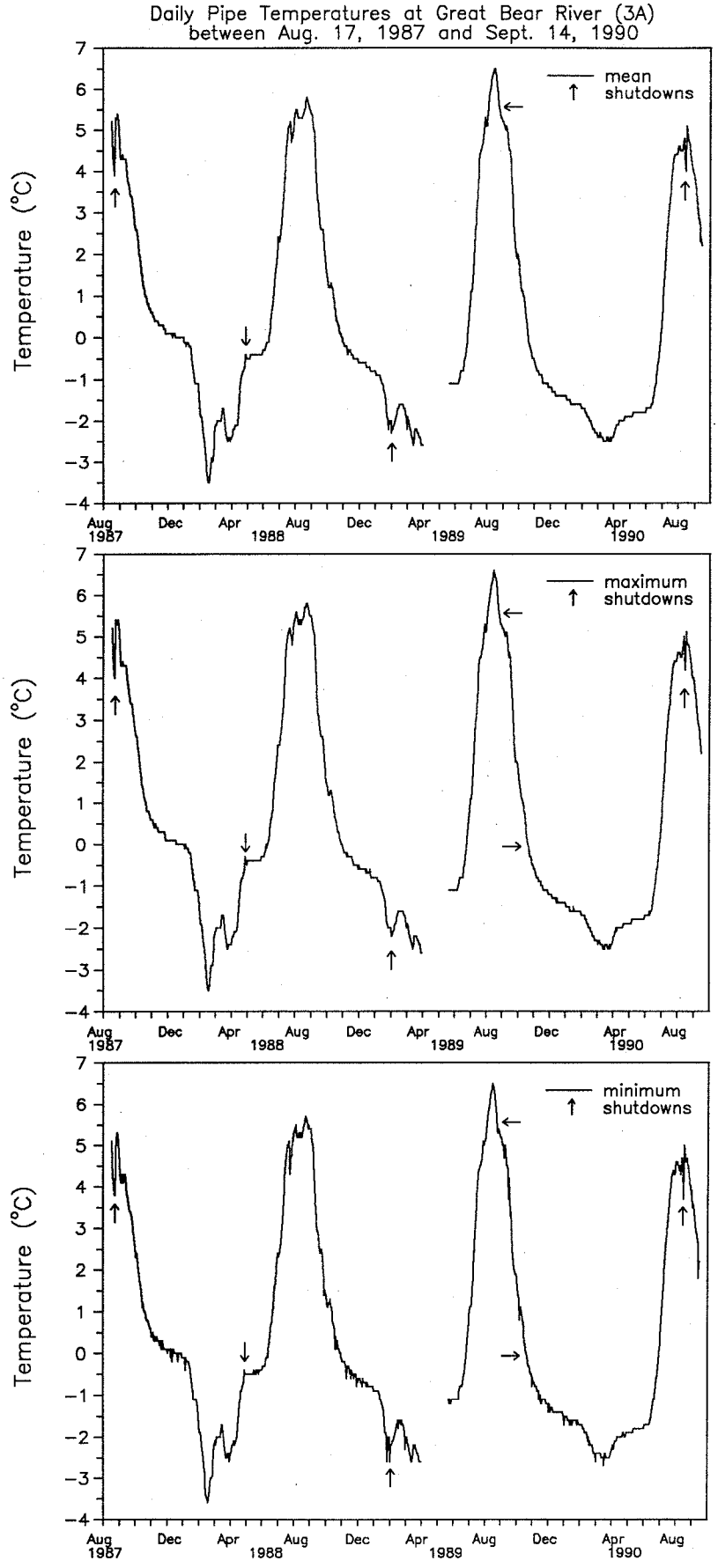

Changes in Pipe Temperature Amplitude at each of the Six Selected Sites
1-week after Summer Start-ups
89.08.23-30
90.08.15-22
Temperature (°C)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
800
Distance from Pump Station 1 (km)

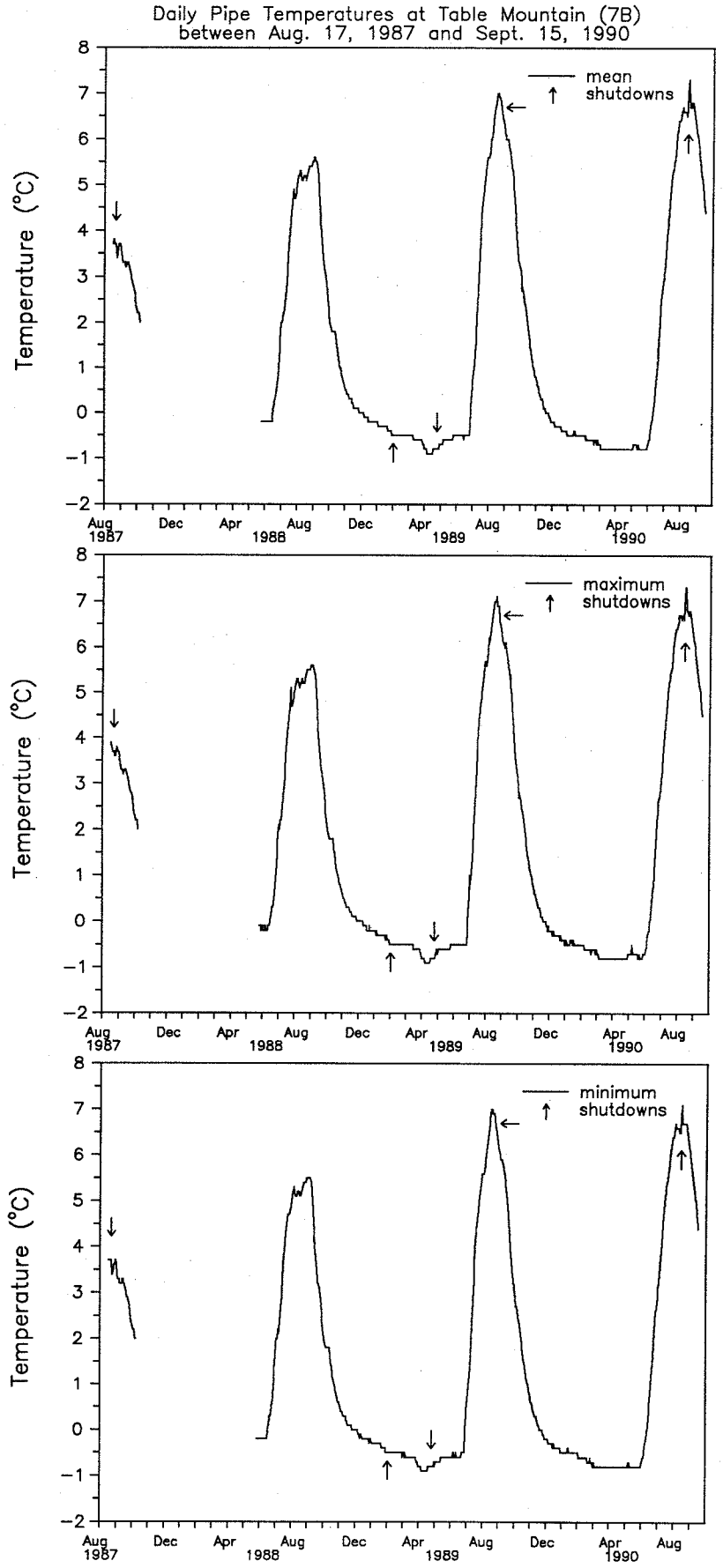
APPENDIX S.W.3.1a

INDIVIDUAL PLOTS OF MEAN, MAXIMUM AND MINIMUM DAILY PIPE TEMPERATURES AT SEVEN SITES ALONG THE NORMAN WELLS PIPELINE.

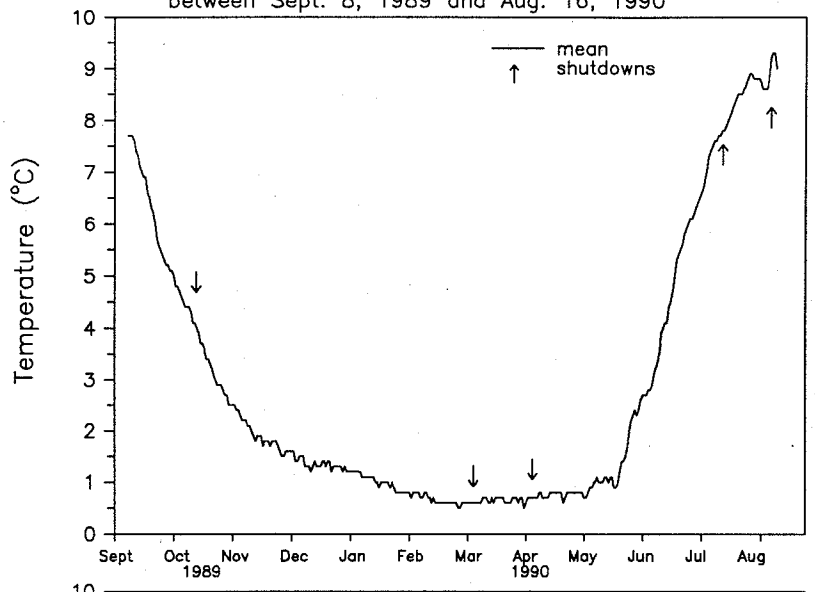

Daily Pipe Temperatures at Pump Station 1 (PS1)
between Dec. 18, 1987 and Oct. 26, 1989
mean
shutdowns
Temperature (°C)
2
1
0
−1
−2
−3
−4
−5
Dec
1987
Feb
Apr
Jun
1988
Aug
Oct
Dec
Feb
Apr
1989
Jun
Aug
Oct

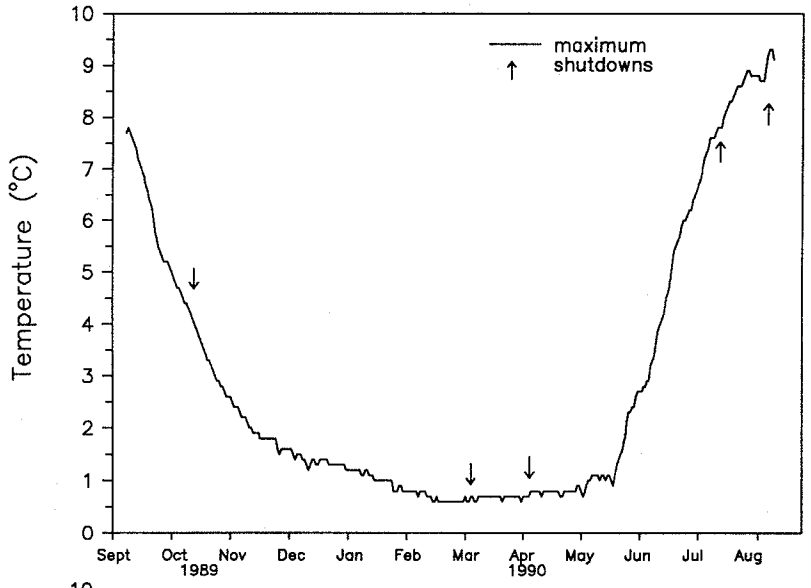

Daily Pipe Temperatures at Pump Station 1 (PS1)
between Dec. 18, 1987 and Oct. 26, 1989
maximum
minimum
shutdowns
Temperature (°C)
2
1
0
−1
−2
−3
−4
−5
Dec
1987
Feb
Apr
Jun
1988
Aug
Oct
Dec
Feb
Apr
1989
Jun
Aug
Oct

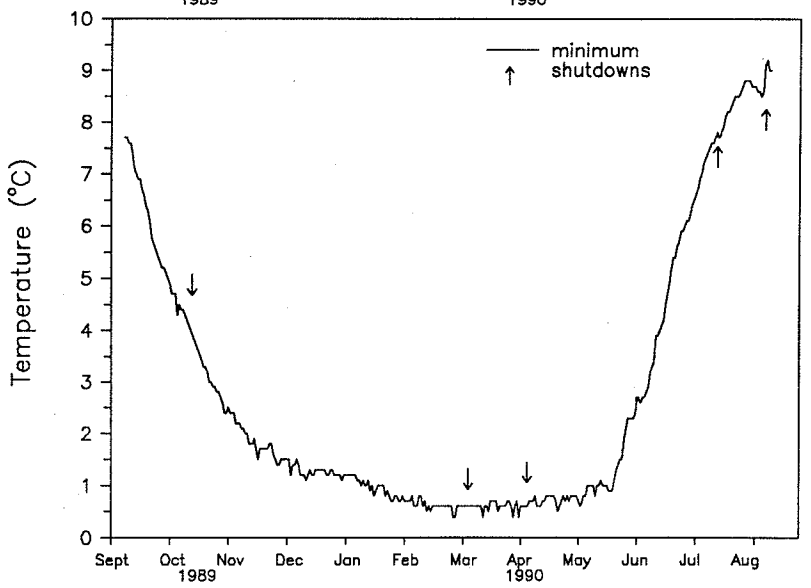

Daily Pipe Temperatures at Great Bear River (3A)
between Aug. 17, 1987 and Sept. 14, 1990
Temperature (°C)
mean
shutdowns
maximum
shutdowns
minimum
shutdowns
7
6
5
4
3
2
1
0
−1
−2
−3
−4
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug

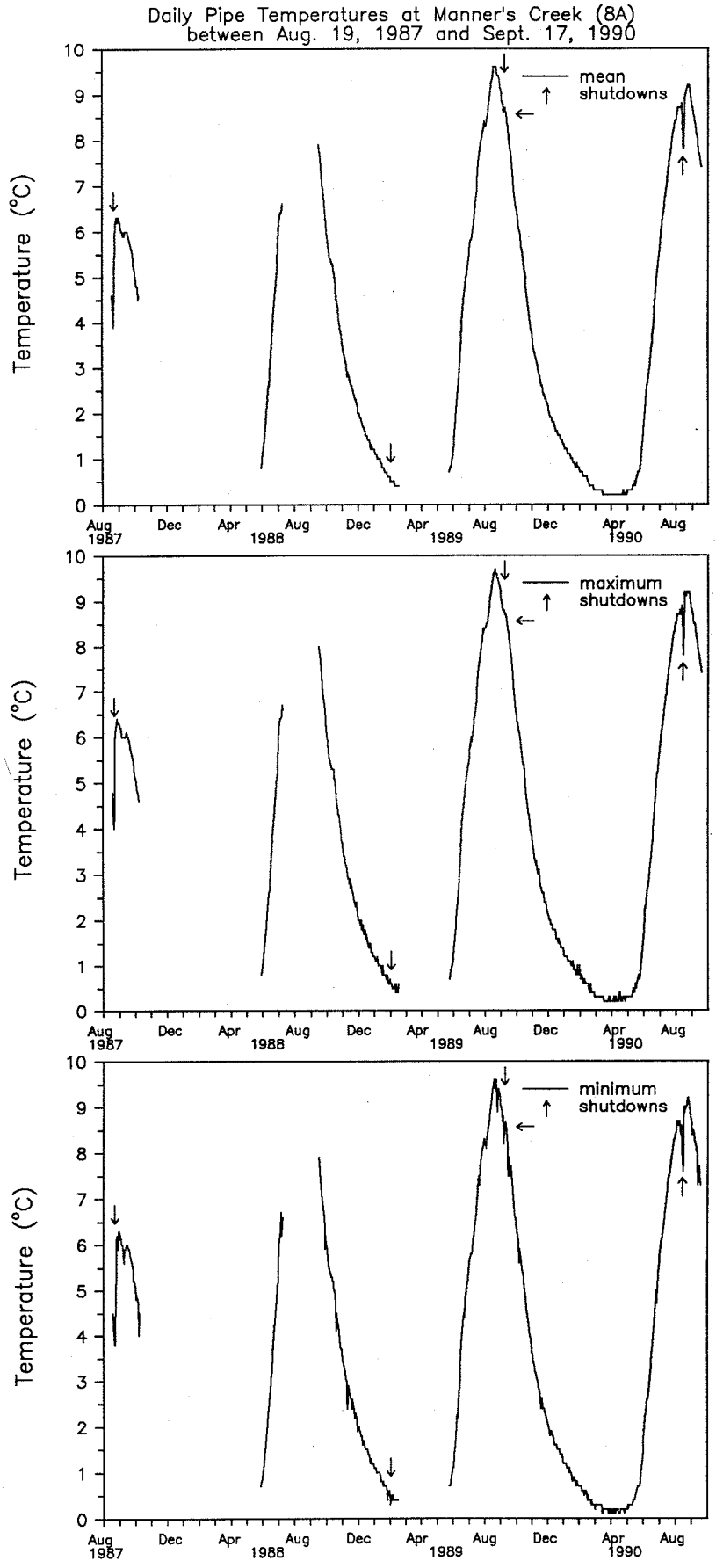

Daily Pipe Temperatures at Table Mountain (7B)
between Aug. 17, 1987 and Sept. 15, 1990
Temperature (°C)
mean
shutdowns
maximum
shutdowns
minimum
shutdowns
8
7
6
5
4
3
2
1
0
−1
−2
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
Aug
1989
Dec
Apr
1990
Aug

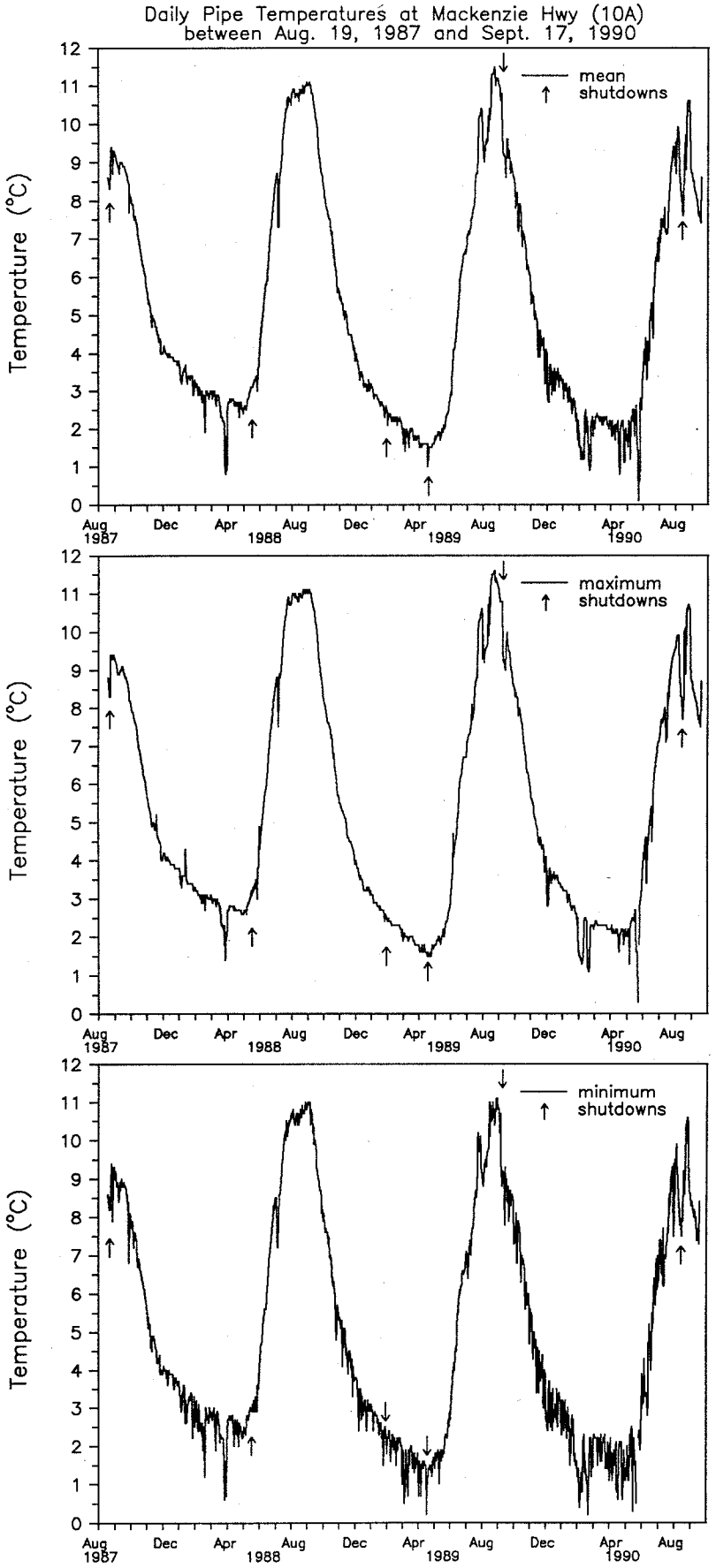
Daily Pipe Temperatures at Wrigley South
between Sept. 8, 1989 and Aug. 16, 1990



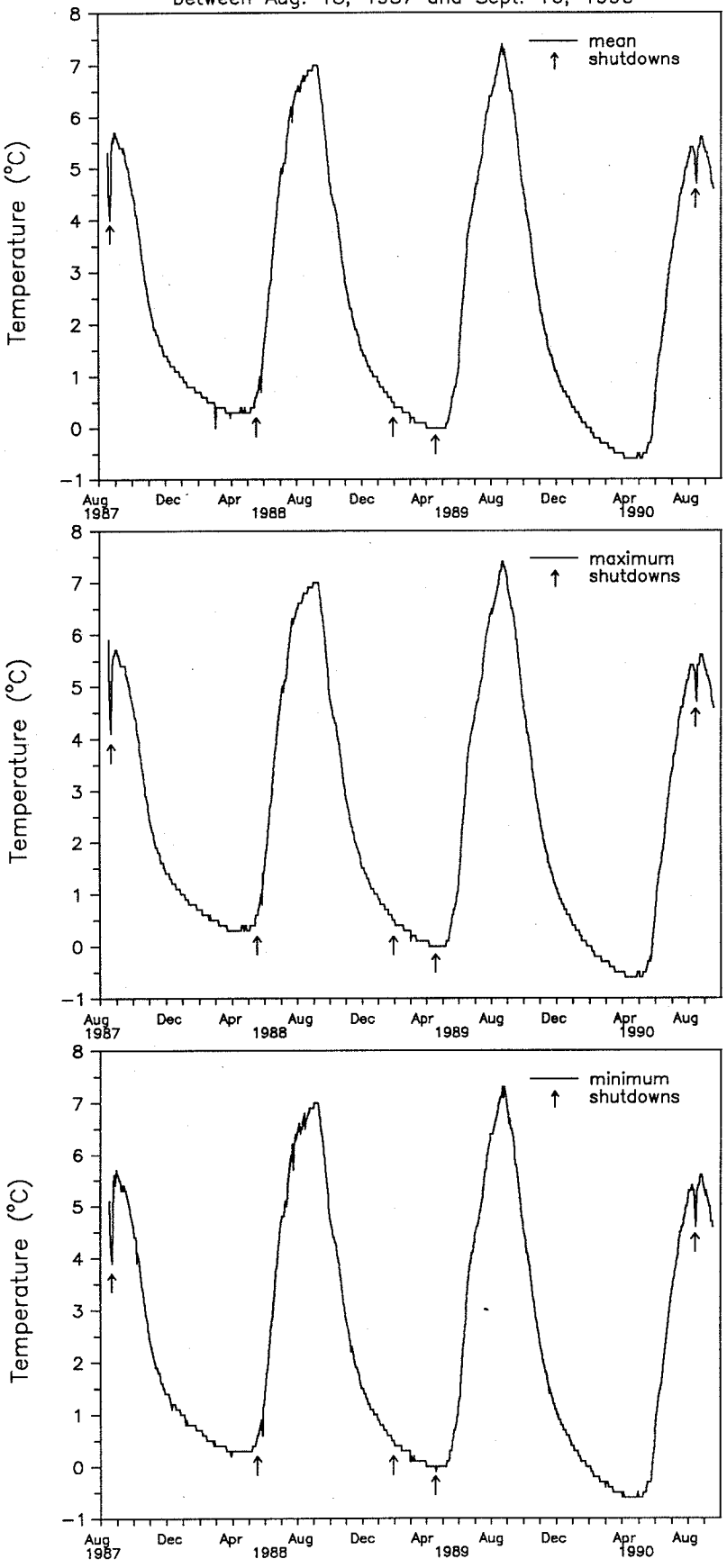





Daily Pipe Temperatures at Manner's Creek (8A)
between Aug. 19, 1987 and Sept. 17, 1990
Temperature (°C)
mean
shutdowns
maximum
shutdowns
minimum
shutdowns
0
1
2
3
4
5
6
7
8
9
10
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug

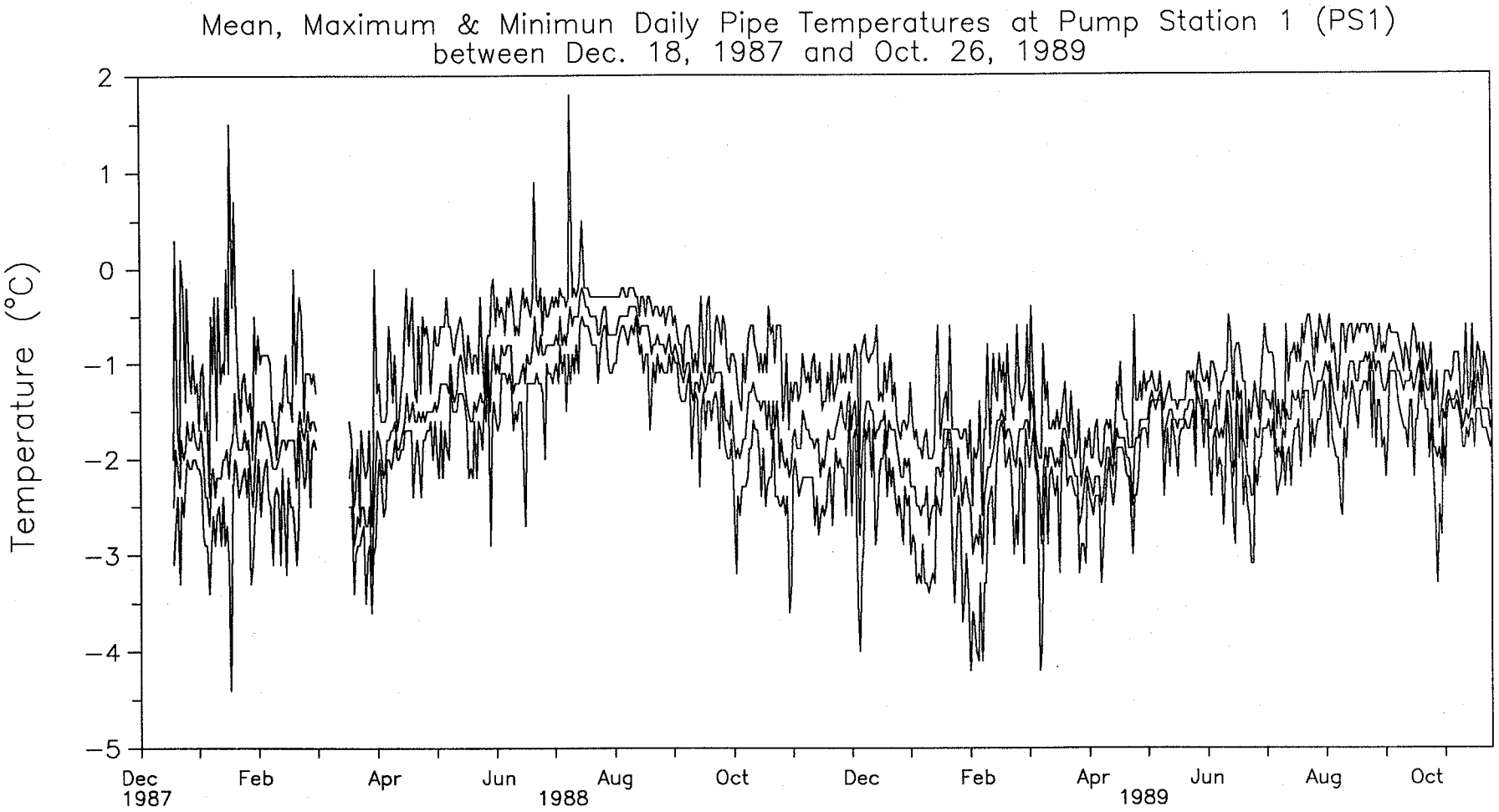

Daily Pipe Temperatures at Mackenzie Hwy (10A)
between Aug. 19, 1987 and Sept. 17, 1990
Temperature (°C)
mean
shutdowns
maximum
shutdowns
minimum
shutdowns
0
1
2
3
4
5
6
7
8
9
10
11
12
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug

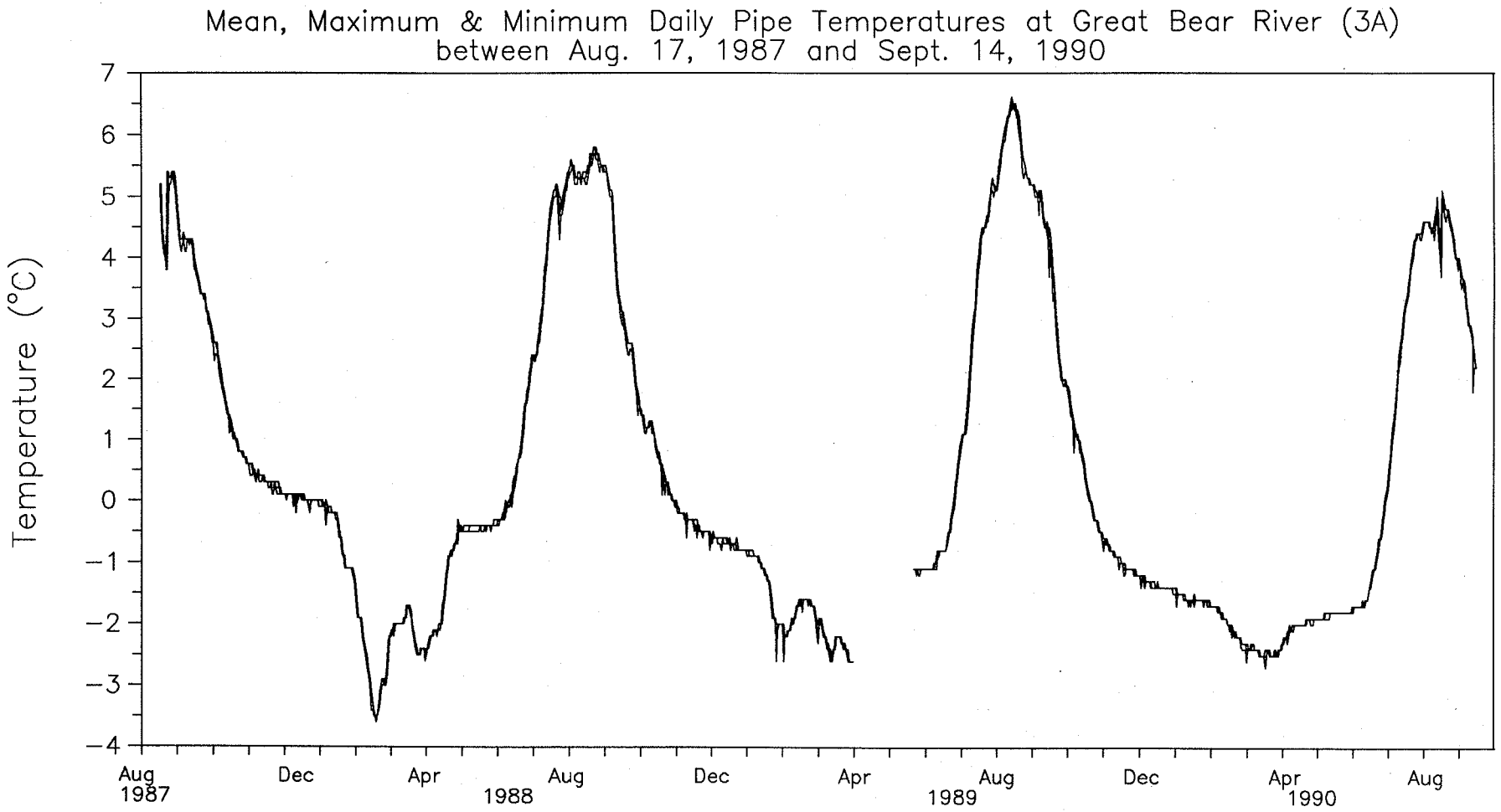
Daily Pipe Temperatures at Petitot River N. (5B)
between Aug. 18, 1987 and Sept. 16, 1990



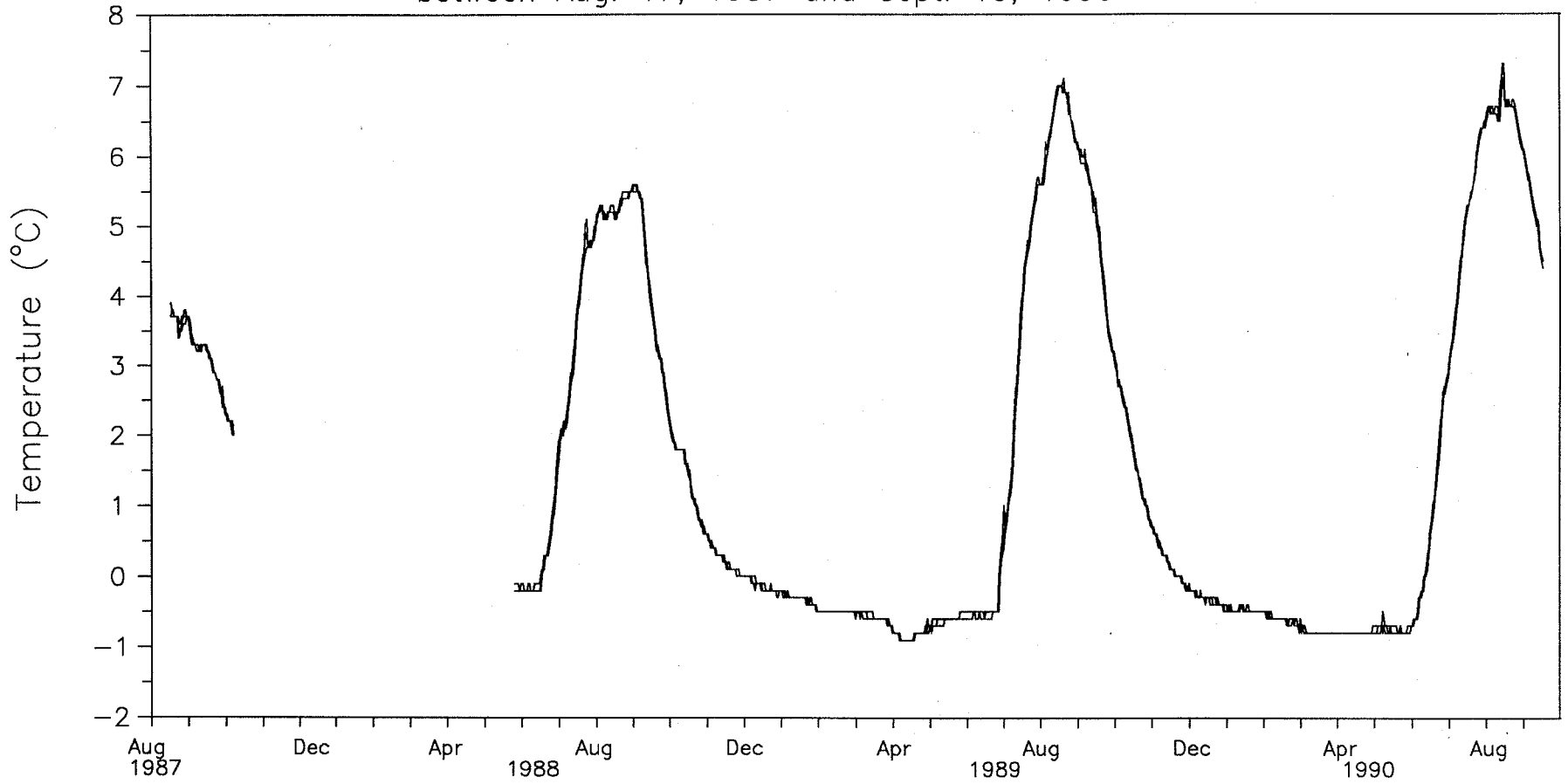
APPENDIX S.W.3.1b

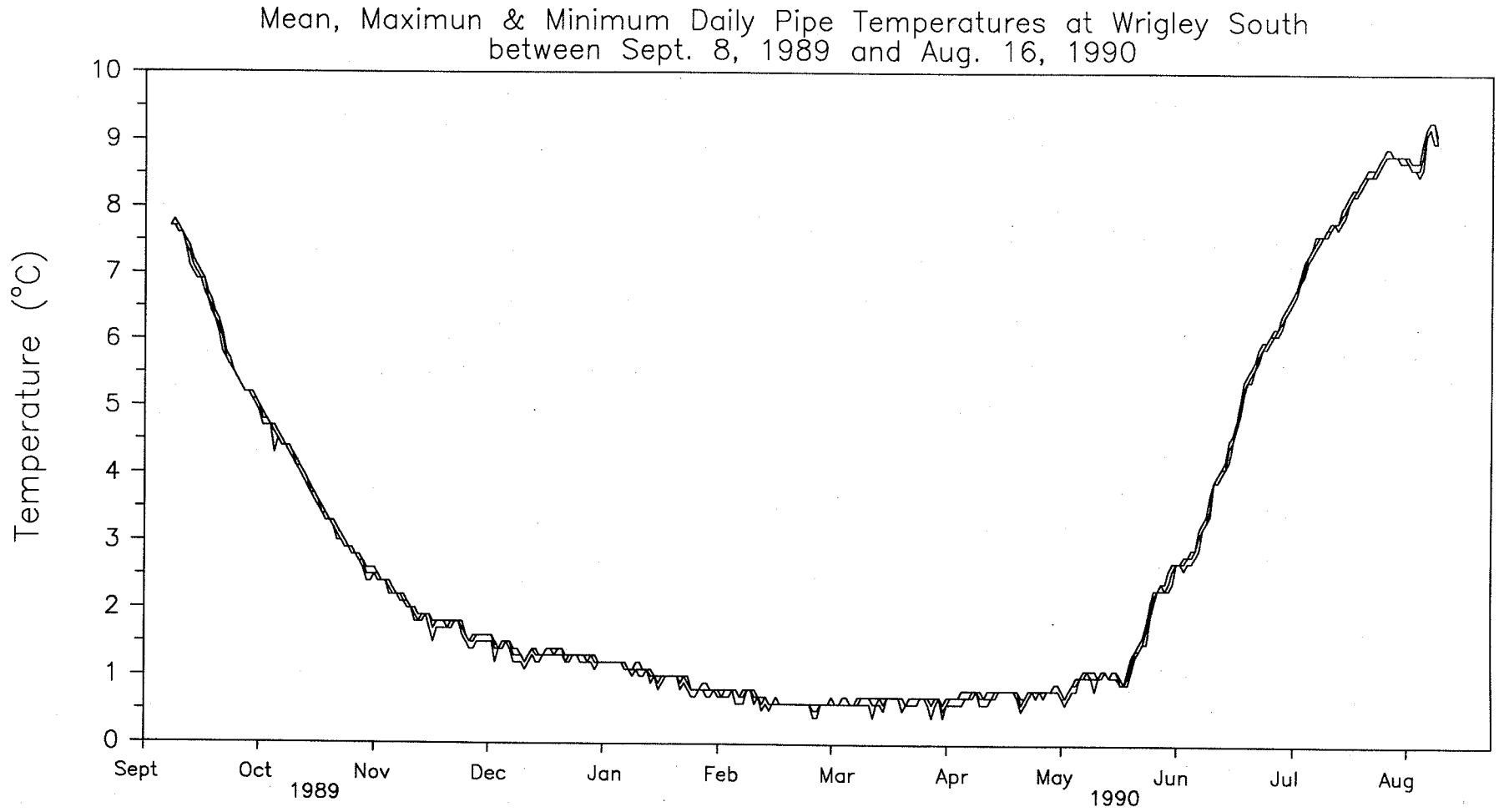
SINGLE PLOTS OF MEAN, MAXIMUM AND MINIMUM DAILY PIPE TEMPERATURES AT SEVEN SITES ALONG THE NORMAN WELLS PIPELINE.

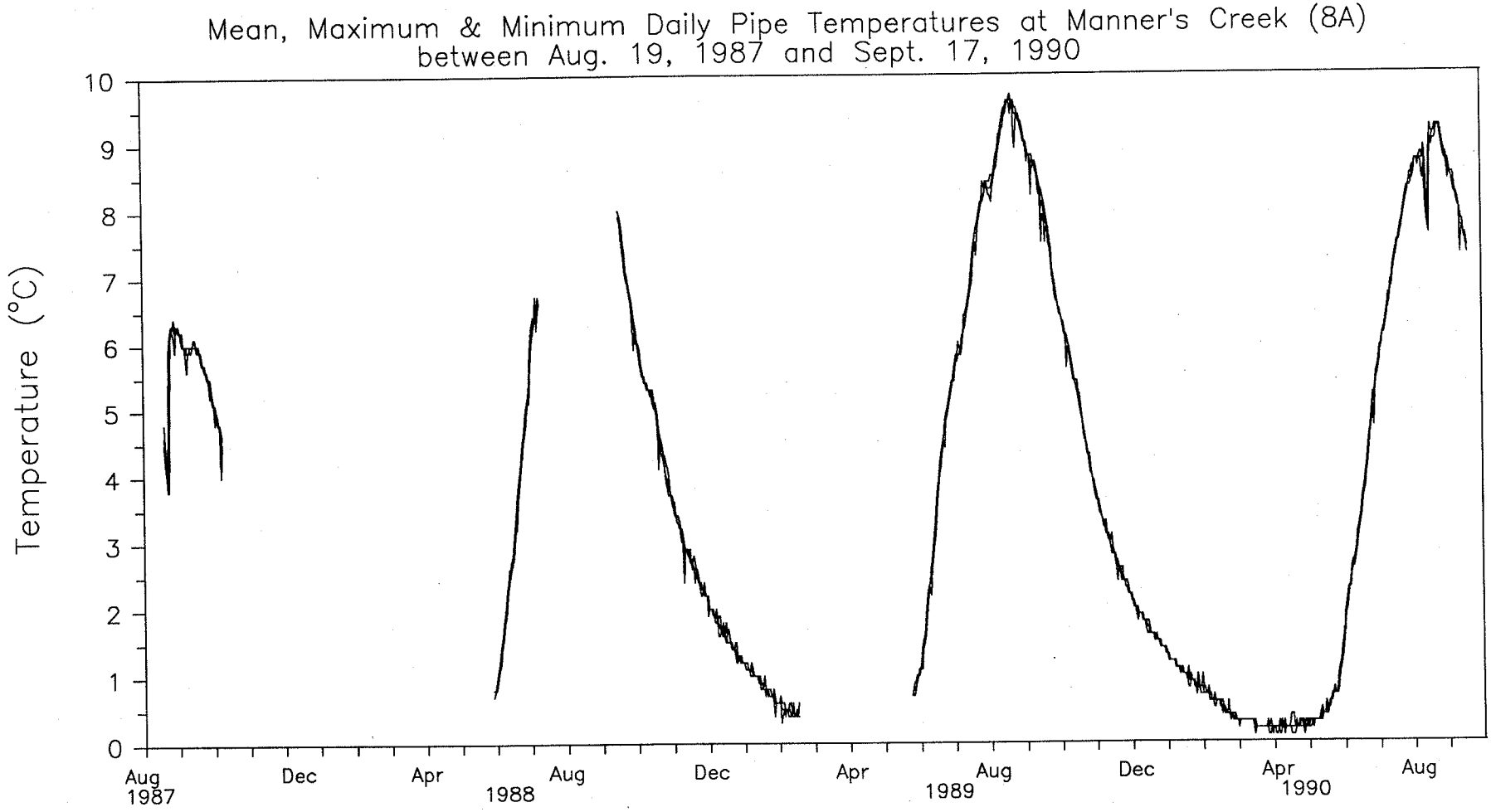

Mean, Maximum & Minimun Daily Pipe Temperatures at Pump Station 1 (PS1)
between Dec. 18, 1987 and Oct. 26, 1989
Temperature (°C)
2
1
0
−1
−2
−3
−4
−5
Dec
1987
Feb
Apr
Jun
Aug
1988
Oct
Dec
Feb
Apr
1989
Jun
Aug
Oct

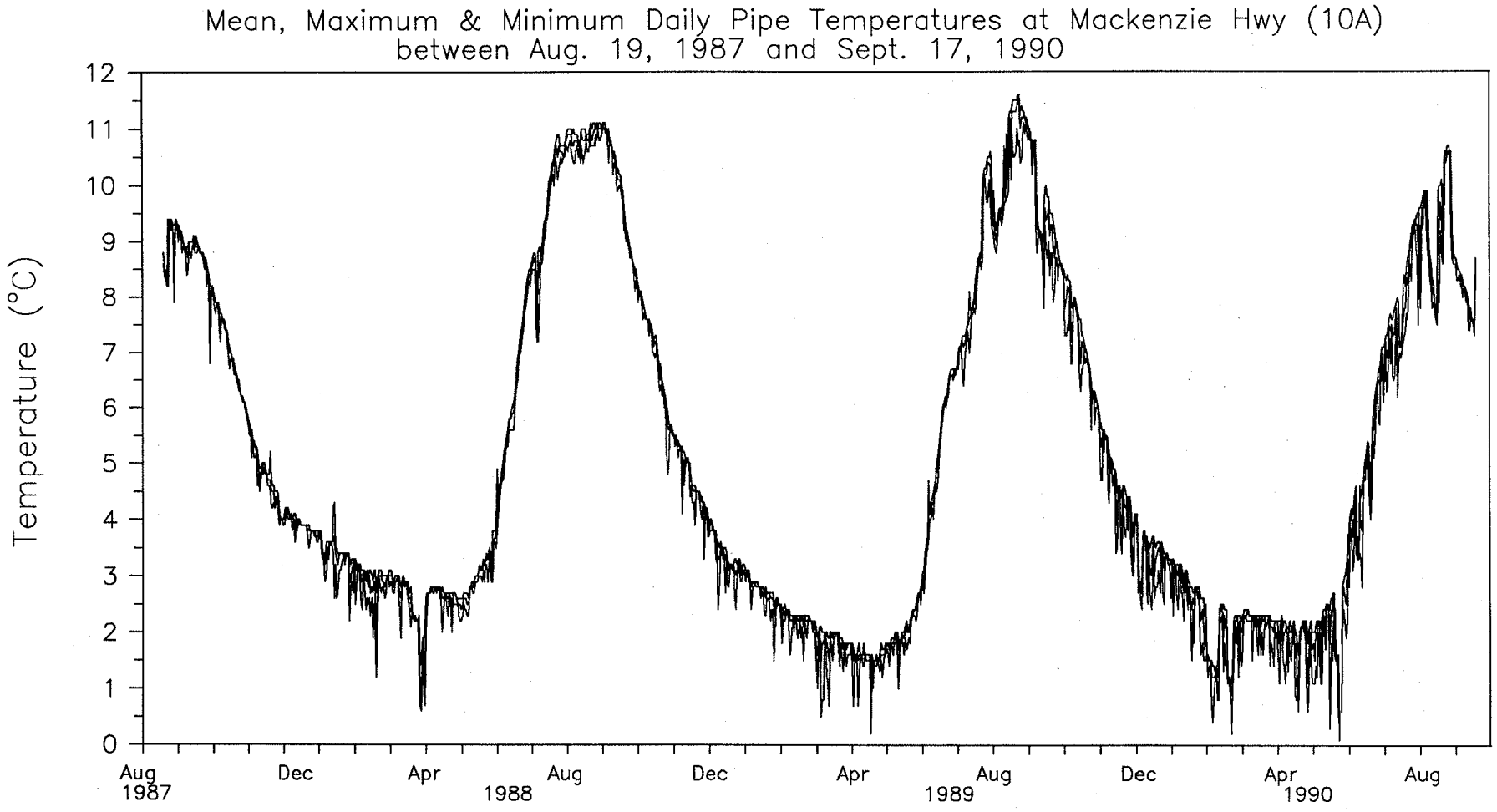

Mean, Maximum & Minimum Daily Pipe Temperatures at Great Bear River (3A)
between Aug. 17, 1987 and Sept. 14, 1990
Temperature (°C)
7
6
5
4
3
2
1
0
−1
−2
−3
−4
Aug
1987
Dec
Apr
1988
Aug
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug

Mean, Maximum & Minimum Daily Pipe Temperatures at Table Mountain (7B)
between Aug. 17, 1987 and Sept. 15, 1990

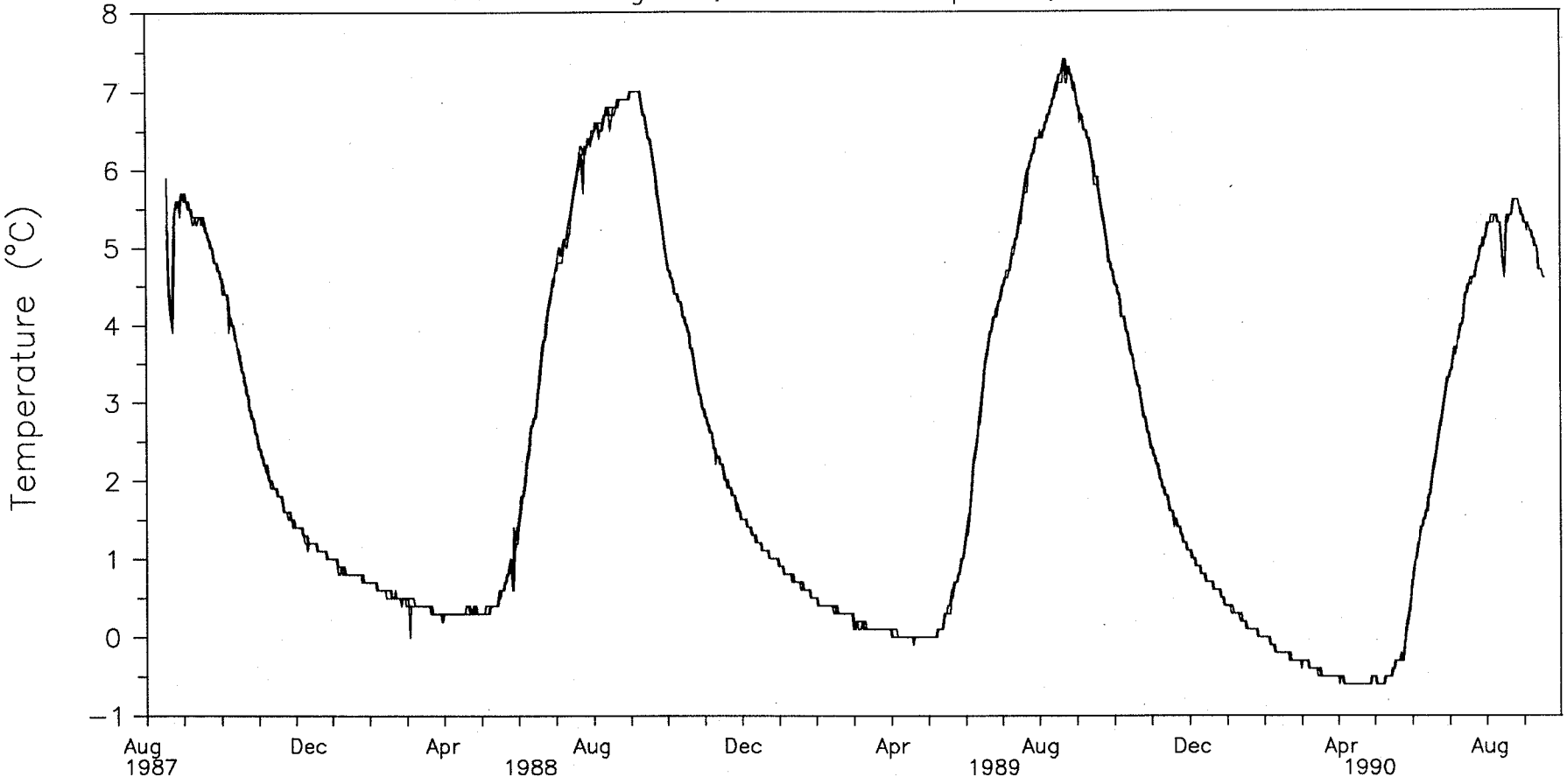



Mean, Maximun & Minimum Daily Pipe Temperatures at Wrigley South
between Sept. 8, 1989 and Aug. 16, 1990
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1989
1990


Mean, Maximum & Minimum Daily Pipe Temperatures at Manner's Creek (8A)
between Aug. 19, 1987 and Sept. 17, 1990
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
Aug
1987
Dec
Apr
1988
Aug
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug

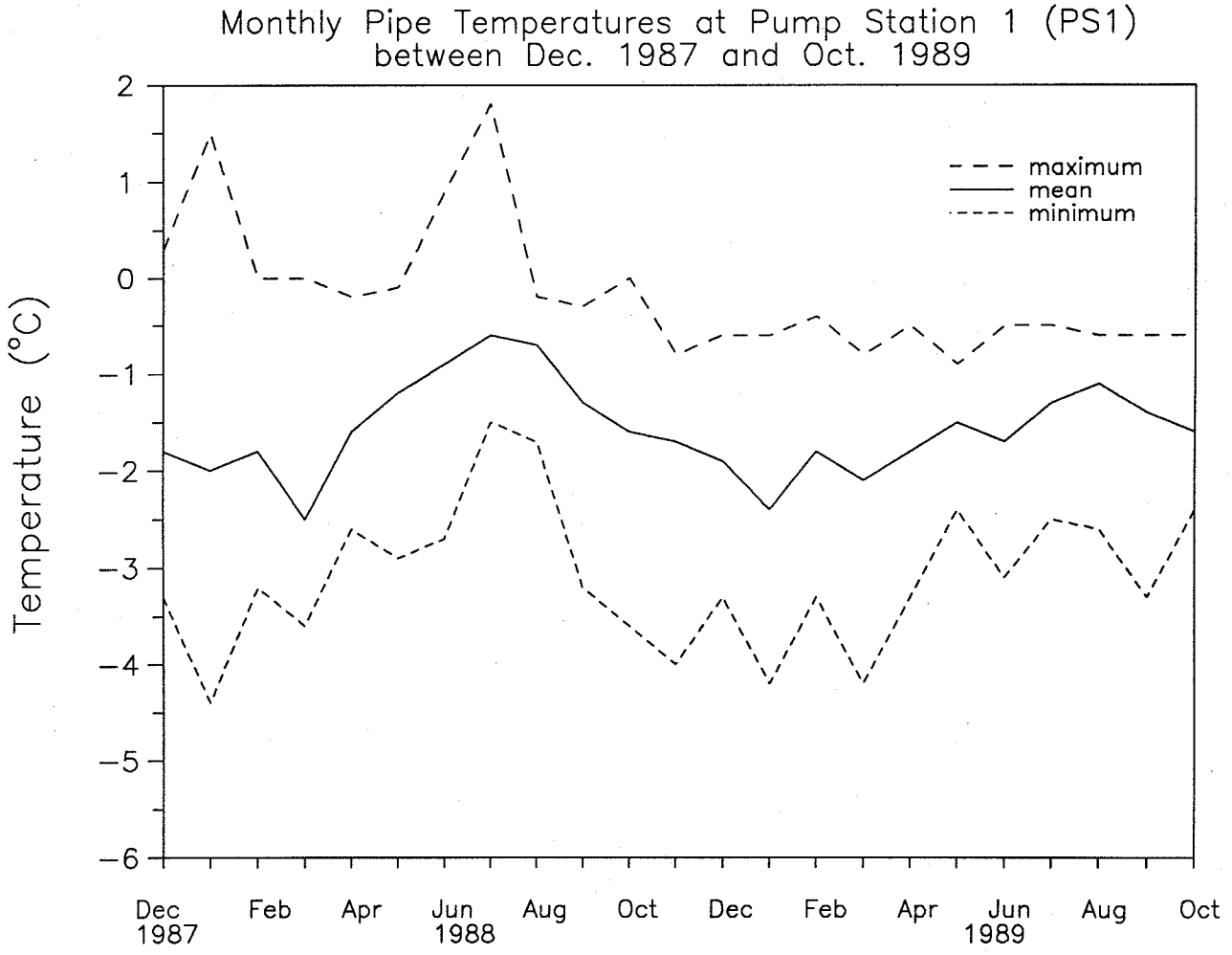

Mean, Maximum & Minimum Daily Pipe Temperatures at Mackenzie Hwy (10A)
between Aug. 19, 1987 and Sept. 17, 1990
Temperature (°C)
12
11
10
9
8
7
6
5
4
3
2
1
0
Aug
1987
Dec
Apr
1988
Aug
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug

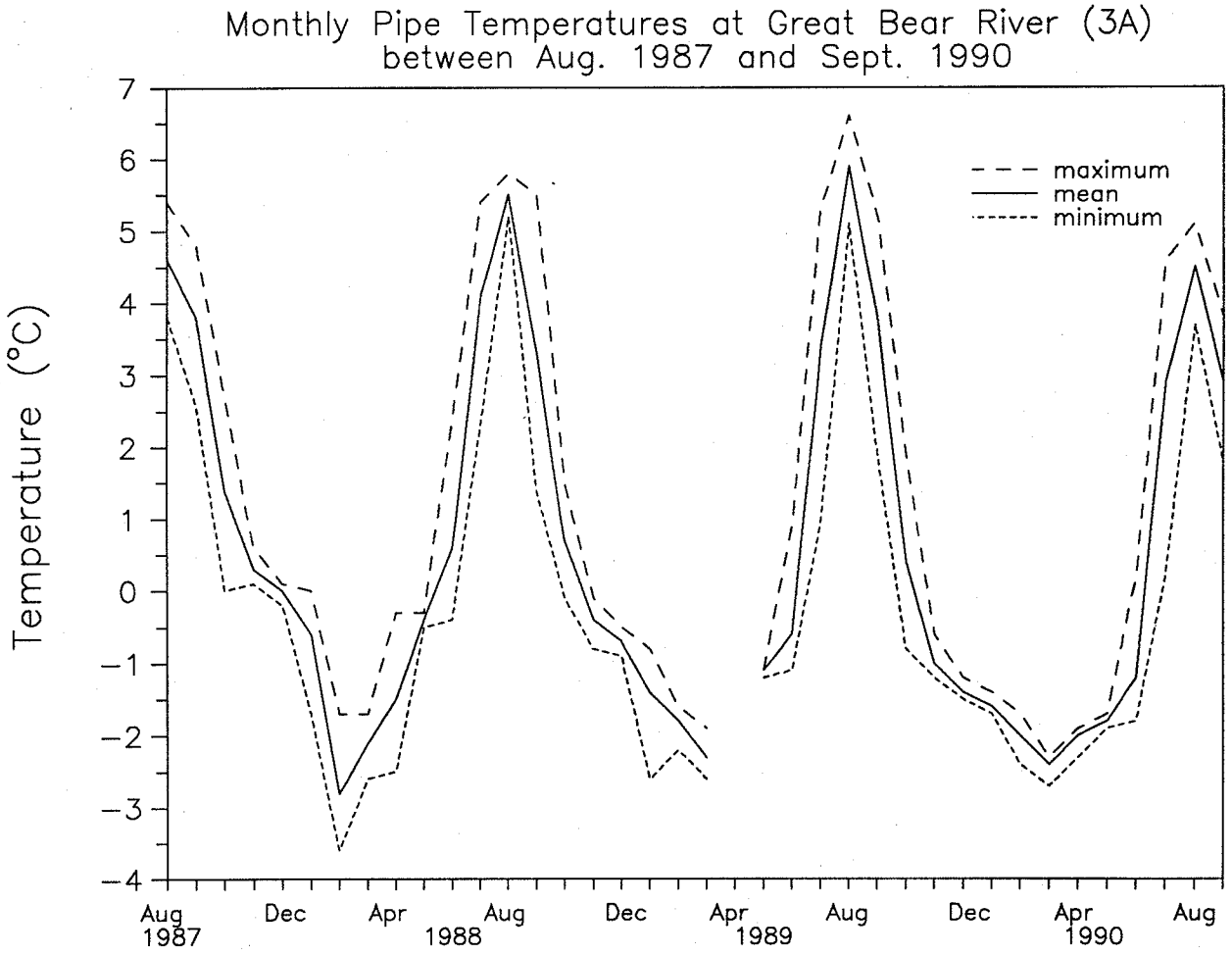
Mean, Maximum & Minimum Daily Pipe Temperatures at Petitot River N. (5B)
between Aug. 18, 1987 and Sept. 16, 1990

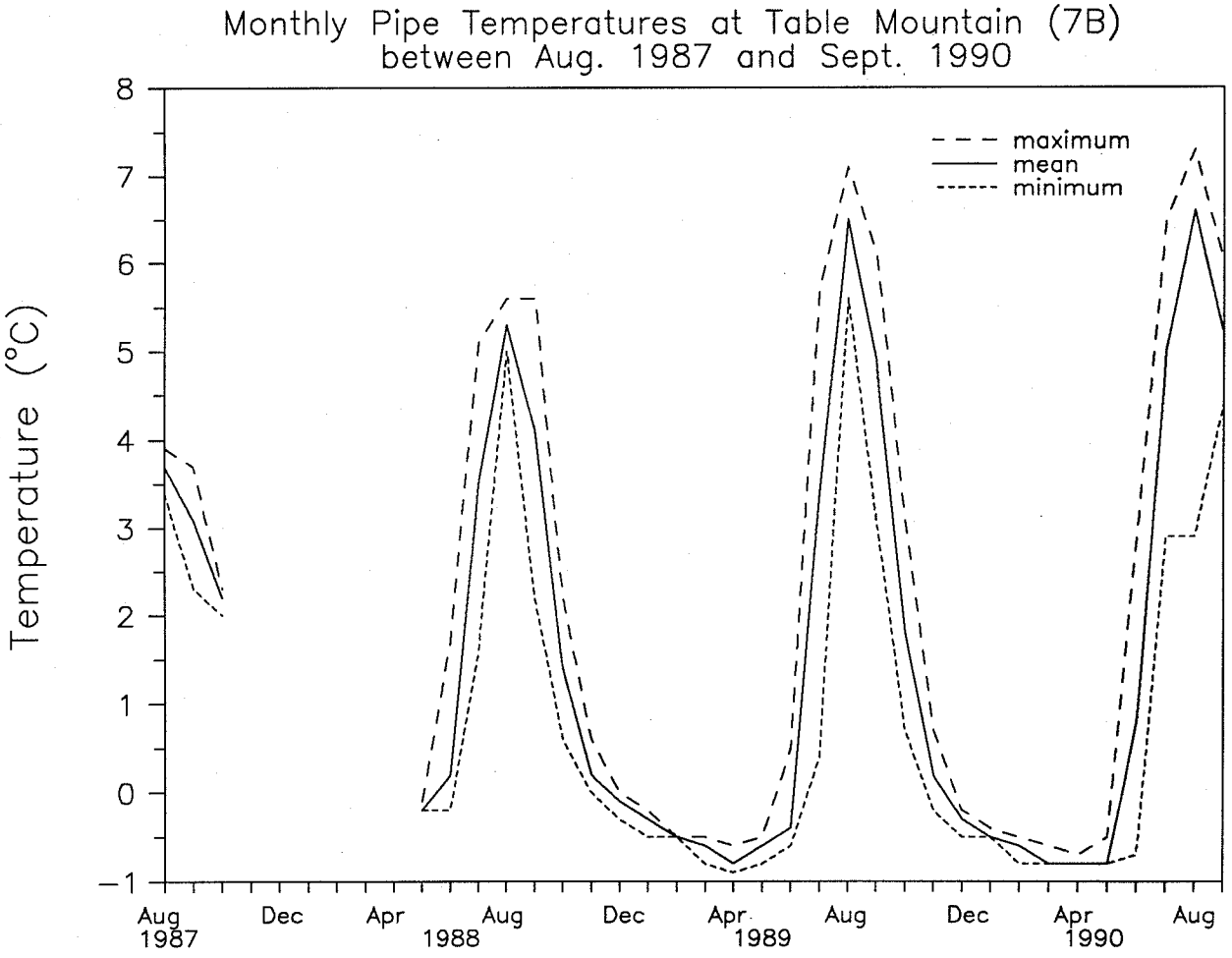


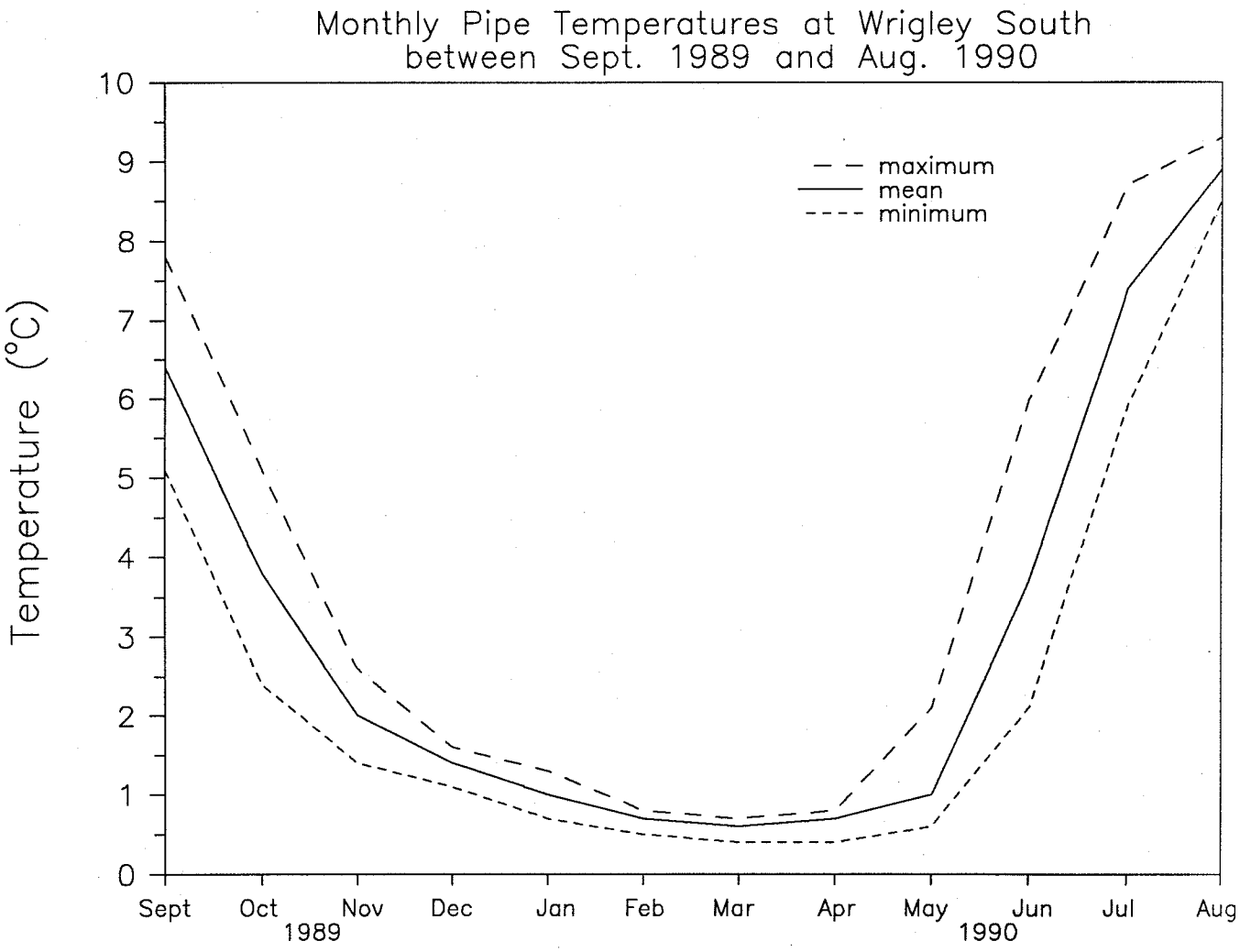
APPENDIX S.W.3.2

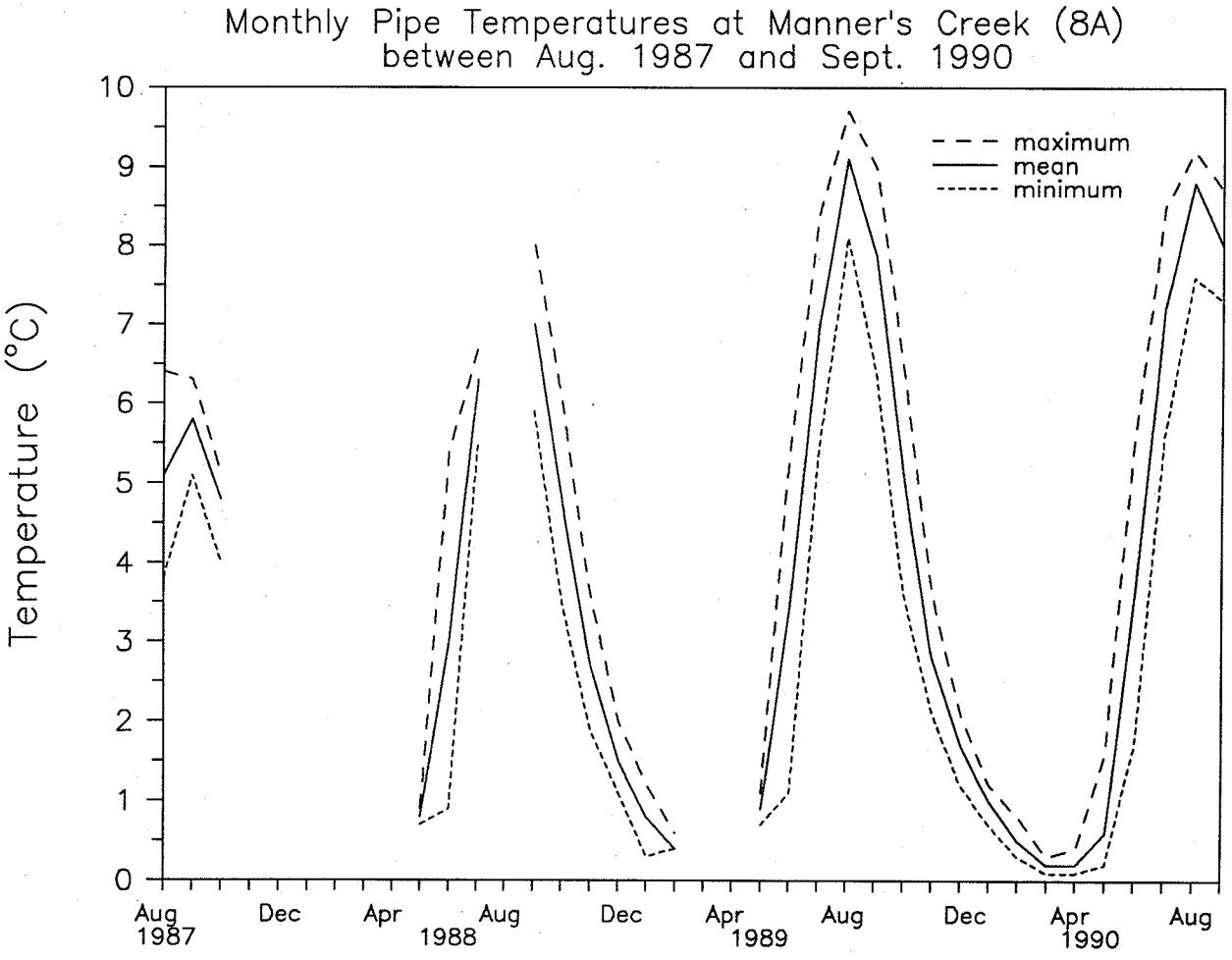
PLOTS OF MEAN, MAXIMUM AND MINIMUM MONTHLY PIPE TEMPERATURES AT EACH OF THE SEVEN SITES ALONG THE NORMAN WELLS PIPELINE.

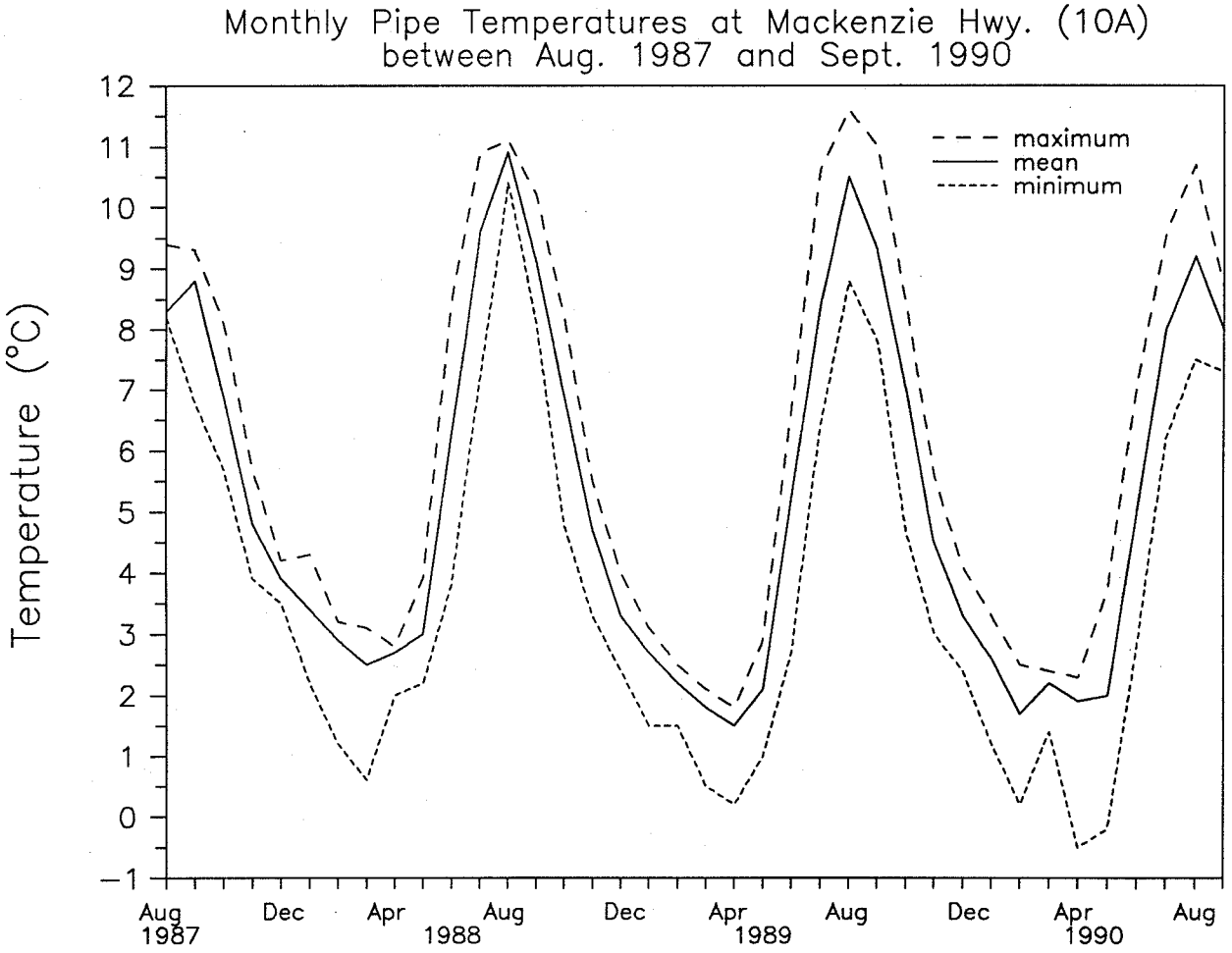

Monthly Pipe Temperatures at Pump Station 1 (PS1)
between Dec. 1987 and Oct. 1989
Temperature (°C)
2
1
0
−1
−2
−3
−4
−5
−6
maximum
mean
minimum
Dec
1987
Feb
Apr
Jun
1988
Aug
Oct
Dec
Feb
Apr
Jun
1989
Aug
Oct

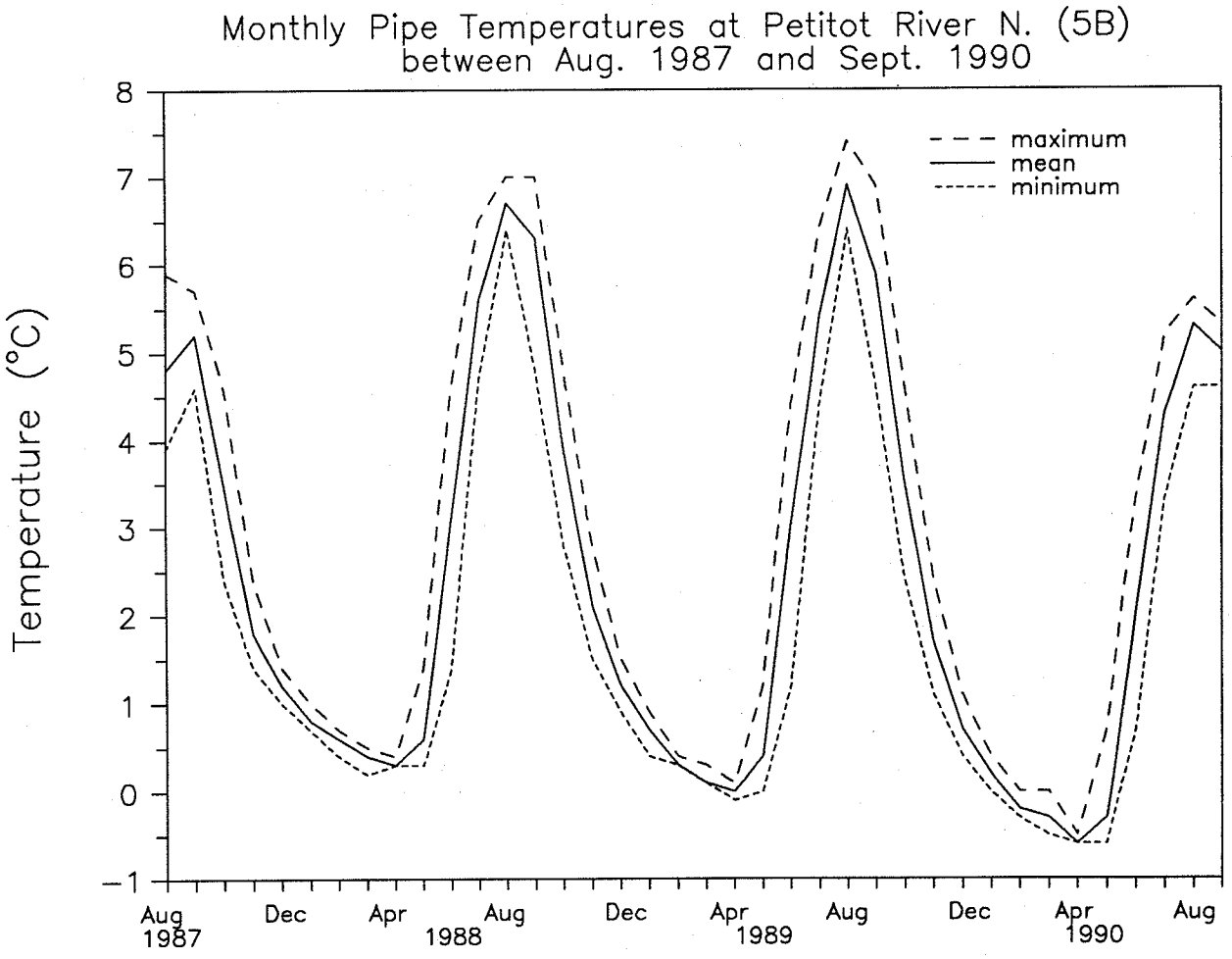

Monthly Pipe Temperatures at Great Bear River (3A)
between Aug. 1987 and Sept. 1990
Temperature (°C)
7
6
5
4
3
2
1
0
−1
−2
−3
−4
maximum
mean
minimum
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug


Monthly Pipe Temperatures at Table Mountain (7B)
between Aug. 1987 and Sept. 1990
Temperature (°C)
8
7
6
5
4
3
2
1
0
−1
maximum
mean
minimum
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug


Monthly Pipe Temperatures at Wrigley South
between Sept. 1989 and Aug. 1990
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
maximum
mean
minimum
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1989
1990


Monthly Pipe Temperatures at Manner's Creek (8A)
between Aug. 1987 and Sept. 1990
Temperature (°C)
10
9
8
7
6
5
4
3
2
1
0
maximum
mean
minimum
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
1989
Aug
Dec
Apr
1990
Aug


Monthly Pipe Temperatures at Mackenzie Hwy. (10A)
between Aug. 1987 and Sept. 1990
Temperature (°C)
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
maximum
mean
minimum
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
Aug
1989
Dec
Apr
Aug
1990


Monthly Pipe Temperatures at Petitot River N. (5B)
between Aug. 1987 and Sept. 1990
Temperature (°C)
8
7
6
5
4
3
2
1
0
−1
maximum
mean
minimum
Aug
1987
Dec
Apr
Aug
1988
Dec
Apr
Aug
1989
Dec
Apr
1990
Aug

APPENDIX S.W.4.1

PLOT OF RUNNING MEAN PIPE TEMPERATURES FOR SIX SITES ALONG THE NORMAN WELLS PIPELINE.

Running Mean Pipe Temperature for Six Sites along the Norman Wells Pipeline.