Water Supply and Hydrology Study

For the

MCCULLOCH RESERVOIR WATER SUPPLY AREA

(Year 1 - 2003 Report)

Prepared for the
SOUTH EAST KELOWNA IRRIGATION DISTRICT
Kelowna, BC

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1.0 INTRODUCTION

In 1979 the Ministry of Environment completed a report titled *Report on South East Kelowna Irrigation District Water Supply Hydrology* and in 1984 a letter update to the 1979 report was completed. A key recommendation from this report was that hydrometric data collection should continue for the SEKID system and that the annual supply capabilities of the system should be re-evaluated in 7 – 10 years.

It has been 19 years since that comprehensive water supply study was completed, so it is timely to confirm what the hydrologic characteristics of the supply area are today based on actual flow data and to compare this information to the hydrology that was reported in 1979. With increasing demands for water and the potential that climate change and land use change (changes in vegetative cover due to forestry activities) may be affecting runoff, it is important that the District has a clear understanding of the current water supply situation.

At the request of the South East Kelowna Irrigation District, Dobson Engineering Ltd. initiated a water supply study for the McCulloch Reservoir water supply area.

2.0 PROJECT DESCRIPTION

Water Survey of Canada (WSC) operated hydrometric stations at several locations in the water supply area over the period 1973 to 1984 including station 08NM210 - *Pooley Creek Above Pooley Ditch*, and station 08NM212 - *Stirling Creek Diversion to McCulloch Reservoir*. Unfortunately the Pooley Creek station was discontinued in 1979 and the Stirling Creek station in 1984. Based on the 1979 Ministry of Environment report, Pooley Creek contributes the largest proportion of run-off to the McCulloch reservoir, and nearly 40% of the mean annual runoff for the Hydraulic drainage area was derived from the areas draining to both the Pooley Creek and Stirling Creek diversions. Based on this information, the first priority was to re-establish these two hydrometric stations. Additional hydrometric stations are proposed to quantify the water yield from both Canyon Creek and upper Hydraulic Creek supply areas.

The purpose of re-establishing the hydrometric gauging stations is to provide the District with current data on the spring, summer and fall runoff that is the source of supply to the storage reservoirs. This data will be used to compute unit area runoff values that will be compared to those values computed in the previous reports. It is important for the District to know if these unit runoff values have changed. If they have changed then they may impact the ability of the District to meet its supply obligations in the future. Accurate estimates of unit runoff values will require several years of data. Because of the importance of this data, one of the objectives of the project is identify which stations are of greatest value and what are the best locations for the stations to meet the District's needs.

2.1 Project Activities

The completion dates for the various project activities are outlined in Table 1 below.

Table 1 – Project Activities

Dates	Activity
May 16, 2003	Field review to determine stream gauging locations
July 28-29, 2003	Install Pooley Creek stilling well
Aug. 19, 2003	Install steel shelter at Pooley Creek and calculate stream flow
Sept. 30, 2003	Install instrumentation at Pooley Creek and calculate stream flow
Oct. 14, 2003	Install instrumentation on Stirling Creek and calculate stream flow
Oct. 20, 2003	Calculate stream flows and ensure site operation
Oct. 28, 2003	Survey channels and calculate stream flow
Nov. 10, 2003	Remove instrumentation from service for winter

The stilling well at the Pooley Creek site had been damaged and past flood events washed the structure downstream from its original location. In late July, the structure was salvaged, repaired and re-installed near the original location, upstream from the diversion.

Installation of the level sensors and data loggers was planned for early summer 2003, however equipment delivery delays, the back country travel ban imposed by the Ministry of Forests and fire fighting activities all combined to delay the installations. Permanent survey benchmarks were established to enable elevation references for water levels.

Four discharge and stage measurements were completed for each station. This data was used to develop an initial stage discharge curve for each site. (Refer to Appendix A for detailed stage and discharge data). The equipment was removed from service on November 10, 2003 to prevent damage from freezing conditions.

2.2 Equipment Design

The stations are designed to record water levels, which is converted to discharge data using the stage discharge curve. The stage discharge curve for each site must be established by measuring the discharge over a range of water levels. Discharge [Q] (m^3/s) is calculated by measuring water velocity [V] (m/s) multiplied by channel cross sectional area [A] (m^2). The discharge and corresponding water levels are graphed to determine the relationship between stage and discharge. From this graph, water levels can be converted to discharge values. A minimum of three points is required to establish this relationship, however better accuracy is obtained with more points to plot the curve. The equipment used at each site is listed in Table 2 and the technical specifications for this equipment is found in Appendix B.

Table 2 – Sites and Equipment

Site	Water Level Sensor	Water Level Data Logger
Pooley Creek	OTT Thalimedes float operated shaft encoder and data logger	OTT Thalimedes float operated shaft encoder and data logger
Stirling Ditch	Stevens Pressure Transducer	Campbell Scientific CR510 Data Logger

The velocity measurements (used to calculate discharge) were made using a Marsh McBirney Flow Mate Model 2000 flowmeter (refer to Appendix B for equipment specifications). The equipment at the Pooley station is owned by SEKID, the remaining equipment is on loan.

2.3 Quality Assurance and Quality Control

This project follows standards outlined by the Resource Inventory Standards Committee (RISC) in the Manual of Standard Operating Procedures for Hydrometric Surveys in British Columbia. The accuracy of the flow meter was confirmed by taking velocity measurements in a uniform open concrete channel and comparing them with the values obtained using the floating object method of estimating stream velocity, as well as the Manning Equation for that channel.

3.0 RESULTS

Continuous water level data was collected from September 30, 2003 to November 10, 2003 at Pooley Creek and from October 14, 2003 to November 10, 2003 at Stirling Creek. Observations made during site visits in July and August determined that although there were minor flows at the diversions, the flows were lost to evaporation (and minor infiltration/ditch losses) and were not supplying any water to the McCulloch Reservoir.

During the summer of 2003, the Okanagan experienced a drought period and there was no appreciable precipitation from mid July through September. Environment Canada data indicates that in 2003, the Southern BC Mountains Region experienced the 4th driest summer since 1948. Continuous water level data was not collected at Pooley Creek or Stirling Creek during the summer months, however because of the drought conditions it is likely that the two basins provided no water to the McCulloch Reservoir from mid July through September. There were several significant rainstorms during October, which resulted in increased stream flows. The data from Environment Canada indicates that in 2003, the Southern BC Mountains Region experienced the 11th wettest autumn since 1948.

The dates on which discharge measurements were completed are listed in Table 3 and a comparison of the historic WSC data with the 2003 data is in Table 4.

Table 3 – Stage and Discharge Measurements

Date	Pooley Creek		Stirling Creek	
	Stage (m)	Discharge (m^3/s)	Stage (m)	Discharge (m^3/s)
Aug. 9, 2003	0.000	0.0038	N/A	0.0006
Sept. 30, 2003	0.001	0.0044	N/A	N/A
Oct. 14, 2003	N/A	N/A	0.263	0.0026
Oct. 20, 2003	0.137	0.0874	0.309	0.0281
Oct. 28, 2003	0.104	0.0431	0.286	0.0115

Table 4 – Mean Monthly Discharge (WSC Data vs 2003 Data)

Data	Mean Monthly Discharge (m^3/s)						
	Apr.	May	June	July	Aug.	Sept.	Oct.
2003 Pooley	-	-	-	-	-	-	0.025
WSC Pooley	-	0.957	0.868	0.123	0.016	0.063	0.018
2003 Stirling	-	-	-	-	-	-	*0.021
WSC Stirling	0.041	0.356	0.148	0.012	0.003	0	0

*This value is based on data collected from Oct 14 to Oct 31, and may be an overestimate of the true average monthly discharge.

3.1 Pooley Creek

Very low flow was observed in Pooley Creek during the site installation in July and during subsequent visits in August and September. During these periods the diverted flow from Pooley Creek was lost along the diversion ditch, primarily due to evaporation. Although there are likely minor infiltration losses along the ditch, these are considered negligible, as the ditch is constructed in areas with relatively impervious soil.

Flows less than approximately 0.0044 m^3/s (4.4 l/s, or 0.31 ac. ft/day) did not reach the McCulloch Reservoir during the hot summer months. Flows exceeding this value likely reach the reservoir, however it is not known what proportion of these flows are lost to evaporation. Because the air temperature is much lower in October than during the summer months the evaporation losses are assumed to be negligible and the discharge recorded at the station during the cooler fall period is assumed to reach the McCulloch Reservoir.

The October 2003 mean monthly discharge for Pooley Creek is 0.025 m^3/s compared to the WSC mean monthly discharge of 0.018 m^3/s (based on data collected in 1973,1974,1976-1979). The total monthly discharge from Pooley Creek for October 2003 is approximately 65 742 m^3 or 53.3 ac ft (based on mean daily discharges summed for the month, assuming no losses). At this time this data is only relevant for the period that it was collected. It will form part of the archived data that will be used in the future to define the current trends in runoff. However, this data is very valuable since 2003 was a record year from a hydrologic perspective due to extremely low precipitation. Refer to Appendix A for additional details.

3.2 Stirling Creek

Similar to Pooley Creek, very low flows were also observed in Stirling Creek during the summer months, and it is likely that flows from mid July through September did not reach the McCulloch Reservoir. Flows less than 0.0026 m^3/s (2.6 l/s, or 0.18 ac ft/day) are lost to evaporation during the hot summer months. During October, it is assumed that evaporation losses are negligible, and the October flows reached the McCulloch Reservoir.

The mean discharge for Stirling Creek (based on data collected from October 14-31) is 0.021 m^3/s compared to the WSC mean monthly discharge of 0 m^3/s (based on data collected in 1977-1979 and 1984). The total discharge from Stirling Creek during the period October 14-31, 2003 is approximately 31 952 m^3 or 25.9 ac ft (based on mean daily discharges summed for the month, assuming no losses). As with the Pooley Creek data, this data is only relevant for the period that it was collected, but will from part of the data archive to be used in the future to define the current runoff trends. Please refer to Appendix A for additional details.

4.0 CONCLUSIONS

- Prior to the undertaking of this project, the last hydrology and water supply study for the McCulloch Reservoir water supply area was completed in 1979. The runoff conditions of the water supply area may have changed since 1979 due to climate change and changes in forest cover in the upper watershed.

- The previous hydrology study suggests that the Pooley and Stirling diversions supply nearly 40% of the mean annual run-off to the McCulloch Reservoir. The WSC hydrometric stations on Pooley Creek and the Stirling Ditch (lower Stirling Creek) were re-established and water level and stream discharge data were collected during the fall of 2003. No additional stations were established in 2003.

- The Okanagan experienced drought conditions during the summer of 2003. Because precipitation was negligible and air temperatures were very high from mid-July through September 2003, stream flows in Pooley Creek and Stirling Creek were negligible during this time. However, there were significant rainstorms and cooler air temperatures in October, which resulted in increased stream flows. Environment Canada reports that the 2003 summer was the 4th driest and the 2003 autumn was the 11th wettest on record for the Southern BC Mountains region.

- During the hot summer months (mid-July through September 2003), neither the Pooley diversion nor the Stirling diversion were supplying water to the McCulloch Reservoir. For the Pooley diversion, summer flows less than 0.0044 m^3/s (0.31 ac ft/day) did not reach the McCulloch Reservoir. For the Stirling diversion, summer flows less than 0.0026 m^3/s (0.18 ac ft/day) did not reach the reservoir (most likely due to evaporation losses along the diversion ditches).

- The rains in October, combined with reduced evaporation losses resulted in increased stream flow at both diversions and water was supplied to the reservoir from early October through early November. Because of the reduced evaporation rates during the cooler months, it is assumed that the discharge recorded at the diversions reached the reservoir with negligible losses.

- The water yield from the Pooley diversion to the McCulloch Reservoir (October 1-31, 2003) was approximately 62 910 m^3 (51 ac ft), and the yield from the Stirling diversion (October 14-31, 2003) was approximately 32 070 m^3 (26 ac ft).

5.0 RECOMMENDATIONS

- Continue to collect and analyze hydrometric data at the Pooley Creek and Stirling ditch diversions to develop a current database that can be used to define the hydrology of these areas.
- Install a staff gauge at the Stirling Ditch station to confirm datalogger readings during routine site visits.
- Conduct flow measurements on the ditches downstream from the points of diversion, in addition to those at the gauging stations, to determine the extent of the water losses in the ditches during the summer period. Compare daily reservoir level data and reservoir outflow data with the inflow data from the stations to better understand the current water supply conditions.
- Sites for new hydrometric stations should be located in 2004 in Canyon Creek and upper Hydraulic Creek and stations should be established to determine the water yields for these two supply areas.
- Dedicate specific staff to be trained to take over the routine operations of the gauging station network or arrange to have the network managed under contract. The success of this project depends upon the commitment of the staff time or resources to maintain the stations and collect the additional field data.
- Purchase additional equipment to replace that on loan and that required for any new stations.

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APPENDIX A

2003 Data

Pooley Creek Discharge Estimate (Sept. 30. 2003)

Surface Velocity measurement flow calculations
Stream/Flume width - 20 cm
Stream/Flume depth - 4 cm deep
Length - 95 cm
Surface Velocity of floating object over 95 cm length

Run	Time (s)	Velocity (m/s)	Area (m2)	Discharge (m3/s)
run 1	1.6	0.594	0.008	0.0048
run 2	1.9	0.500	0.008	0.0040
run 3	1.64	0.579	0.008	0.0046
run 4	1.75	0.543	0.008	0.0043
run 5	1.64	0.579	0.008	0.0046
run 6	1.8	0.528	0.008	0.0042
run 7	1.83	0.519	0.008	0.0042
run 8	1.63	0.583	0.008	0.0047
run 9	1.6	0.594	0.008	0.0048
run 10	1.7	0.559	0.008	0.0045
Average	**1.709**	**0.558**	**0.008**	**0.0045**

Stirling Creek Discharge Estimate (Oct. 14, 2003)

Surface Velocity measurement flow calculations
Stream/Flume width - 21.5 cm
Stream/Flume depth - 4.2 cm deep
Length - 50 cm
Surface Velocity of floating object over 50 cm length

Run	Time (s)	Velocity (m/s)	Area (m2)	Discharge (m3/s)
run 1	1.48	0.338	0.00903	0.0031
run 2	1.5	0.333	0.00903	0.0030
run 3	1.43	0.350	0.00903	0.0032
run 4	1.27	0.394	0.00903	0.0036
run 5	1.37	0.365	0.00903	0.0033
run 6	1.42	0.352	0.00903	0.0032
run 7	1.35	0.370	0.00903	0.0033
run 8	1.45	0.345	0.00903	0.0031
run 9	1.37	0.365	0.00903	0.0033
run 10	1.41	0.355	0.00903	0.0032
Average	**1.405**	**0.357**	**0.009**	**0.0026**

The stream flow on these dates was too low to use the flowmeter.
Rocks were placed to confine flow to a small regular shaped flume.
Surface velocity was measured using a stopwatch and small pieces
of styrofoam.

Pooley Creek Discharge Measurements/Calculations Oct. 20, 2003

Oct 20 2003 at approximately 4:30 DST at Pooley Creek.

Used 0.6 depth for flow meter. Used cross section at gabion wall downstream from stilling well.

Stilling Well = 0.136-0.137 m deep at 4:30 DST
Staff Gauge = .138+/- m at 4:30 DST

Pooley Creek Diversion at Gabion Basket downstream from stilling well.

Station	(m) Water Depth	(m) width at depth	(m2) Flow Area	(m/s) velocity	(m3/s) Q
0.1	0.24	0.05	0.012	0.14	0.00168
0.2	0.26	0.1	0.026	0.32	0.00832
0.3	0.24	0.1	0.024	0.35	0.0084
0.4	0.19	0.1	0.019	0.32	0.00608
0.5	0.22	0.1	0.022	0.35	0.0077
0.6	0.23	0.1	0.023	0.3	0.0069
0.7	0.22	0.1	0.022	0.31	0.00682
0.8	0.22	0.1	0.022	0.3	0.0066
0.9	0.21	0.1	0.021	0.18	0.00378
1	0.22	0.1	0.022	0.22	0.00484
1.1	0.2	0.1	0.02	0.17	0.0034
1.2	0.18	0.1	0.018	0.24	0.00432
1.3	0.14	0.1	0.014	0.31	0.00434
1.4	0.14	0.1	0.014	0.32	0.00448
1.5	0.11	0.1	0.011	0.24	0.00264
1.6	0.13	0.1	0.013	0.11	0.00143
1.7	0.17	0.1	0.017	0.12	0.00204
1.8	0.18	0.1	0.018	0.16	0.00288
1.85	0.18	0.05	0.009	0.08	0.00072
			Total Discharge		**0.0874**

Liters/second	87.4
US Gal/second	23.08
US Gal/minute	1384.85
ft3/second	3.09
ft3/day	266577.19
Acre Feet/day	6.12
Average Depth	0.194

Stirling Creek Discharge Measurements/Calculations Oct. 20, 2003

Oct 20 2003 at approximately 5:30 DST at Stirling Creek.

Used 0.6 depth for flow meter. Used cross section at 3 m downstream from stilling well.

Stilling Well = refer to data logger at 5:30 DST
No Staff Gauge in place = at 5:30 DST

Stirling Creek Ditch.

Station	(m) Water Depth	(m) width at depth	(m2) Flow Area	(m/s) velocity	(m3/s) Q
0.4	0.08	0.1	0.008	0.08	0.00064
0.5	0.09	0.1	0.009	0.02	0.00018
0.6	0.1	0.1	0.01	0.13	0.0013
0.7	0.1	0.1	0.01	0.12	0.0012
0.8	0.12	0.1	0.012	0.18	0.00216
0.9	0.12	0.1	0.012	0.23	0.00276
1	0.14	0.1	0.014	0.27	0.00378
1.1	0.12	0.1	0.012	0.25	0.003
1.2	0.11	0.1	0.011	0.27	0.00297
1.3	0.14	0.1	0.014	0.23	0.00322
1.4	0.13	0.1	0.013	0.11	0.00143
1.5	0.11	0.1	0.011	0.1	0.0011
1.6	0.1	0.1	0.01	0.17	0.0017
1.7	0.1	0.1	0.01	0.12	0.0012
1.8	0.07	0.1	0.007	0.12	0.00084
1.9	0.06	0.1	0.006	0.08	0.00048
2	0.07	0.1	0.007	0.02	0.00014
2.1	0.06	0.1	0.006	0	0
2.2	0.06	0.1	0.006	0	0
			Total Discharge		**0.0281**

Liters/second	28.1	0.08
US Gal/second	7.42	
US Gal/minute	445.40	
ft3/second	0.99	
ft3/day	85736.74	
Acre Feet/day	1.97	
Average Depth	0.099	

Pooley Creek Discharge Measurements/Calculations Oct. 28, 2003

Oct 28 2003 at approximately 2:30 PST at Pooley Creek.

Used 0.6 depth for flow meter. Used cross section at gabion wall downstream from stilling well.

Stilling Well = 0.104 m deep at 2:30 PST
Staff Gauge = .106 m at 2:30 PST

Pooley Creek Diversion at Gabion Basket downstream from stilling well.

Station	(m) Water Depth	(m) width at depth	(m2) Flow Area	(m/s) velocity	(m3/s) Q
0.1	0.21	0.05	0.0105	0.14	0.00147
0.2	0.21	0.1	0.021	0.2	0.0042
0.3	0.21	0.1	0.021	0.19	0.00399
0.4	0.18	0.1	0.018	0.14	0.00252
0.5	0.18	0.1	0.018	0.21	0.00378
0.6	0.18	0.1	0.018	0.19	0.00342
0.7	0.18	0.1	0.018	0.16	0.00288
0.8	0.16	0.1	0.016	0.21	0.00336
0.9	0.14	0.1	0.014	0.18	0.00252
1	0.13	0.1	0.013	0.21	0.00273
1.1	0.11	0.1	0.011	0.16	0.00176
1.2	0.16	0.1	0.016	0.16	0.00256
1.3	0.13	0.1	0.013	0.2	0.0026
1.4	0.1	0.1	0.01	0.2	0.002
1.5	0.1	0.1	0.01	0.14	0.0014
1.6	0.1	0.1	0.01	0.09	0.0009
1.7	0.14	0.1	0.014	0.04	0.00056
1.8	0.14	0.1	0.014	0.02	0.00028
1.85	0.14	0.05	0.007	0.02	0.00014
			Total Discharge		**0.0431**

Liters/second	43.1	0.114444
US Gal/second	11.3779225	
US Gal/minute	682.6753498	
ft3/second	1.52097398	
ft3/day	131412.1519	
Acre Feet/day	3.016602217	
Average Depth	0.153	

Stirling Creek Discharge Measurements/Calculations Oct. 28, 2003

Oct 28 2003 at approximately 12:30 DST at Stirling Creek.

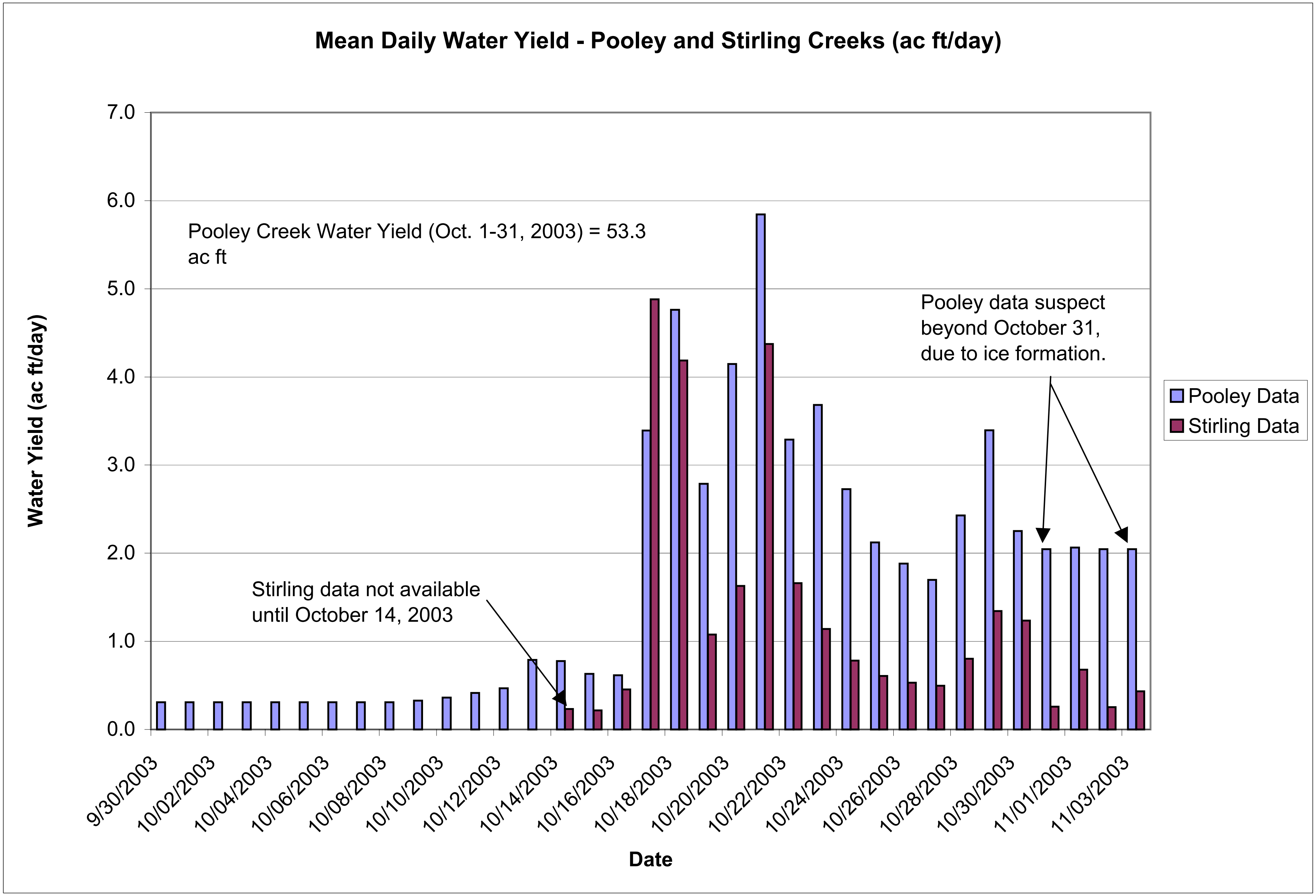
Used 0.6 depth for flow meter. Used cross section at 3 m downstream from stilling well.

Stilling Well = 0.286 m at 12:30 DST
No Staff Gauge in place

Stirling Creek Ditch.

Station	(m) Water Depth	(m) width at depth	(m2) Flow Area	(m/s) velocity	(m3/s) Q
0.4	0.08	0.1	0.008	0	0
0.5	0.07	0.1	0.007	0.01	0.00007
0.6	0.07	0.1	0.007	0.08	0.00056
0.7	0.09	0.1	0.009	0.05	0.00045
0.8	0.1	0.1	0.01	0.13	0.0013
0.9	0.08	0.1	0.008	0.13	0.00104
1	0.1	0.1	0.01	0.2	0.002
1.1	0.1	0.1	0.01	0.16	0.0016
1.2	0.08	0.1	0.008	0.14	0.00112
1.3	0.1	0.1	0.01	0.12	0.0012
1.4	0.08	0.1	0.008	0.1	0.0008
1.5	0.07	0.1	0.007	0.06	0.00042
1.6	0.08	0.1	0.008	0.06	0.00048
1.7	0.075	0.1	0.0075	0.04	0.0003
1.8	0.04	0.1	0.004	0.03	0.00012
1.9	0.04	0.1	0.004	0.01	0.00004
2	0.05	0.1	0.005	0	0
2.1	0.02	0.1	0.002	0	0
2.2	0.02	0.1	0.002	0	0
			Total Discharge		**0.0115**

Liters/second	11.5	0.033333
US Gal/second	3.0379872	
US Gal/minute	182.279232	
ft3/second	0.406111	
ft3/day	35087.9904	
Acre Feet/day	0.805454504	
Average Depth	0.071	


Mean Daily Water Yield - Pooley and Stirling Creeks (ac ft/day)
Water Yield (ac ft/day)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Pooley Creek Water Yield (Oct. 1-31, 2003) = 53.3 ac ft
Pooley data suspect beyond October 31, due to ice formation.
Stirling data not available until October 14, 2003
Pooley Data
Stirling Data
9/30/2003
10/02/2003
10/04/2003
10/06/2003
10/08/2003
10/10/2003
10/12/2003
10/14/2003
10/16/2003
10/18/2003
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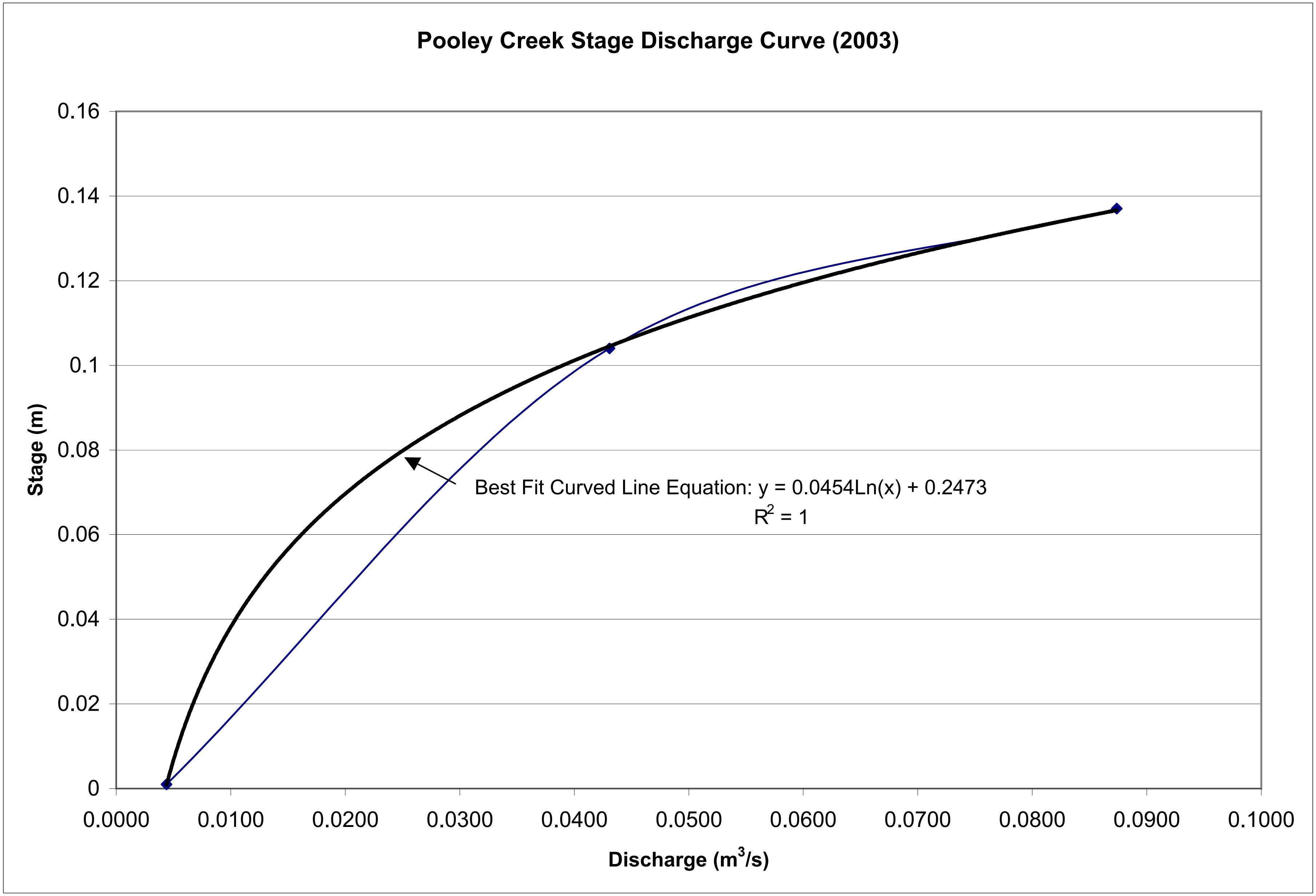
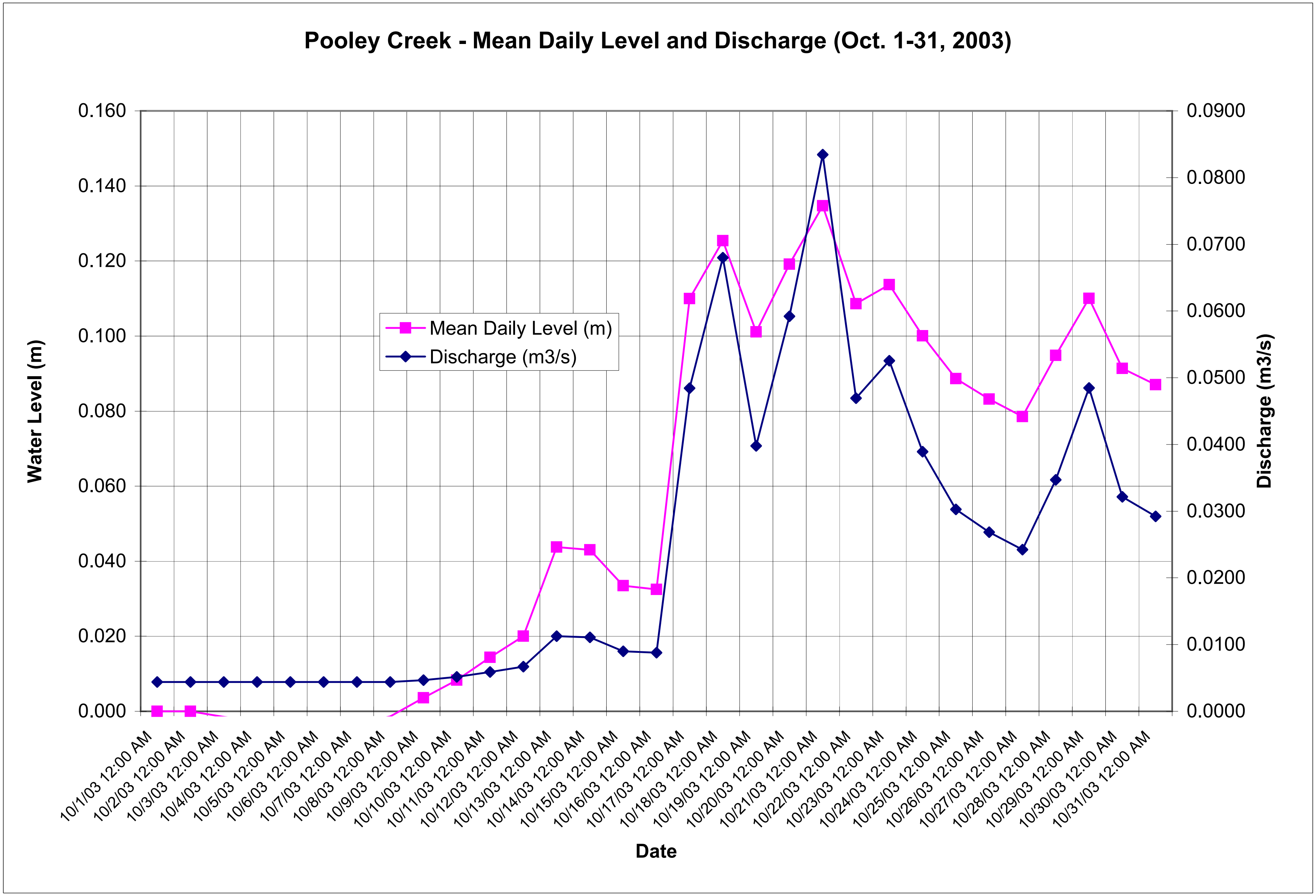
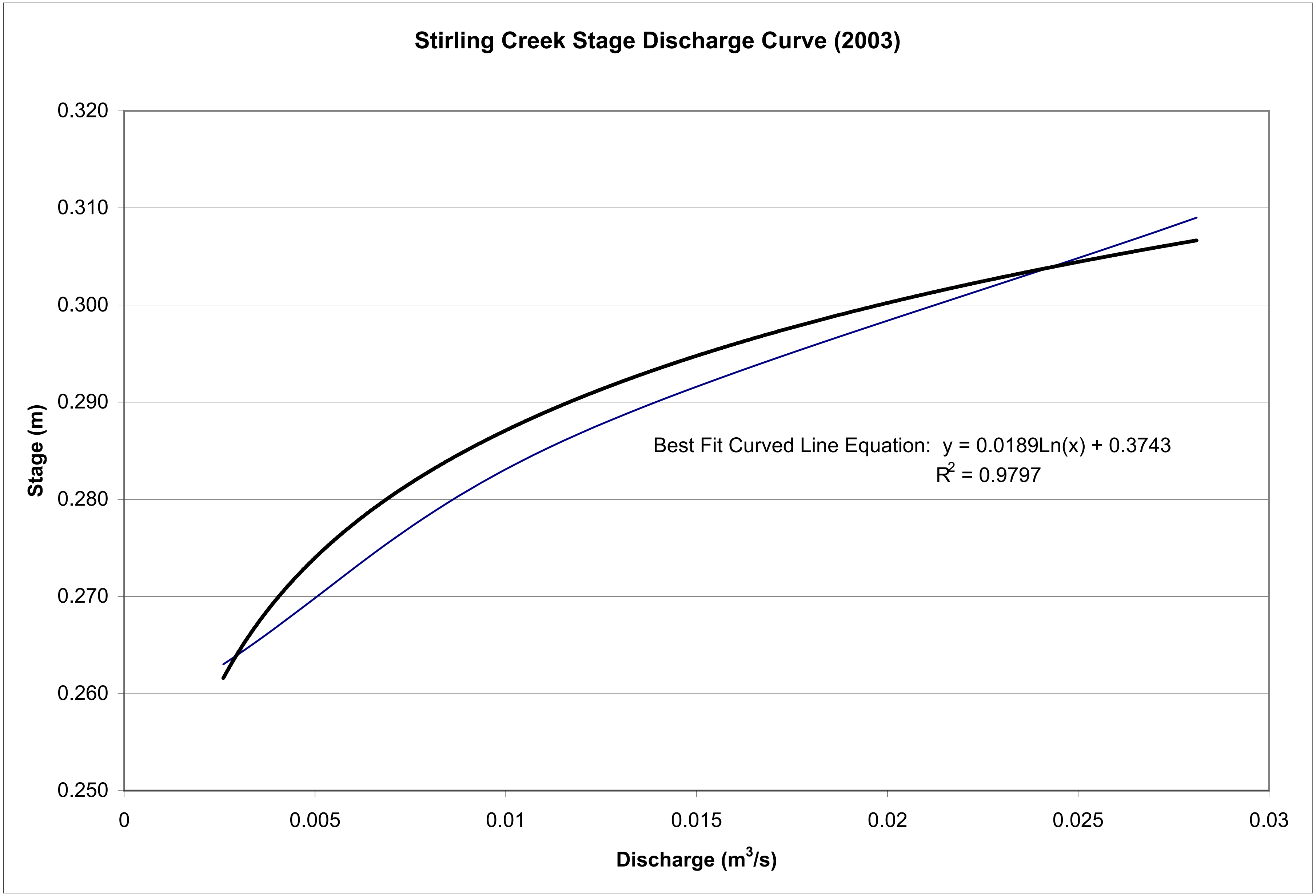
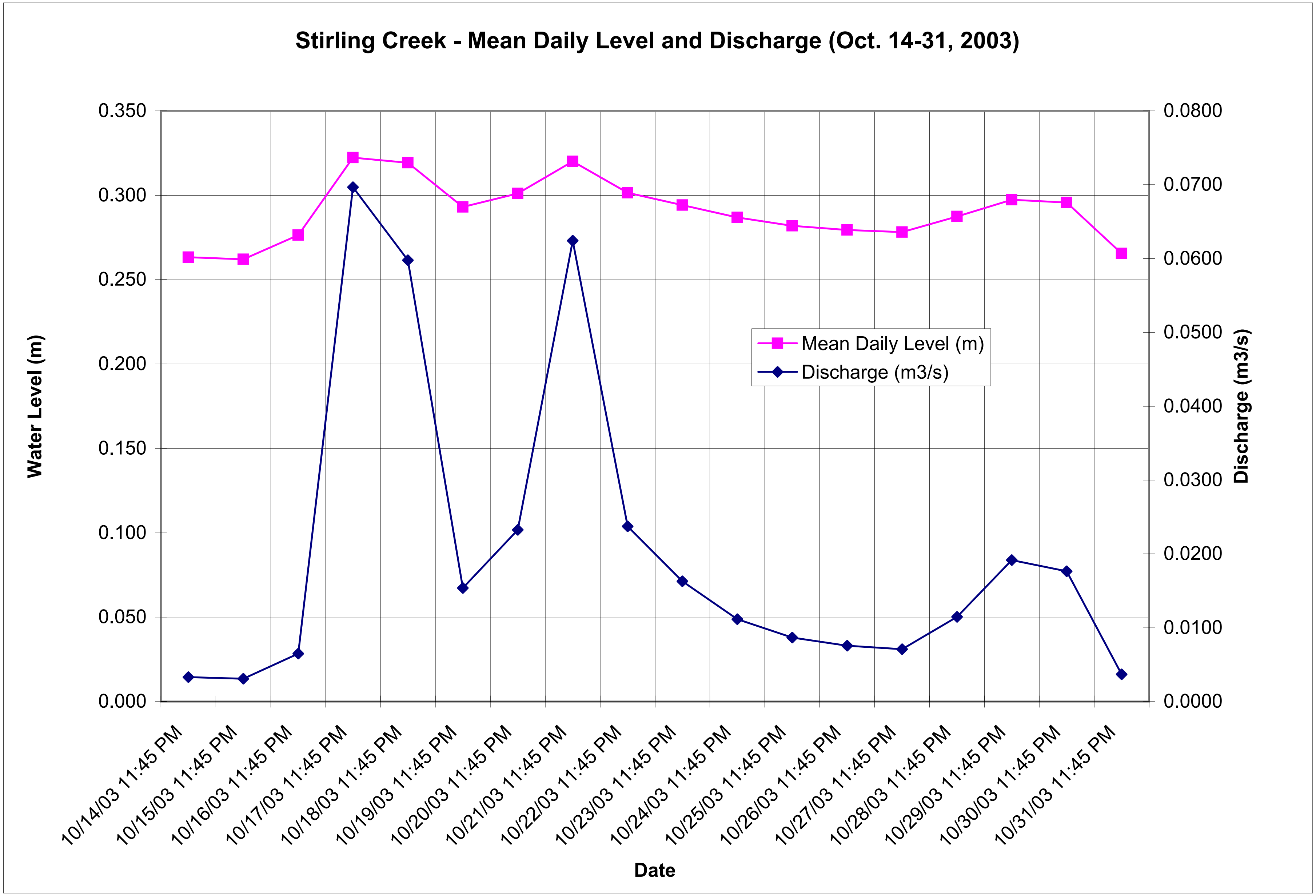
11/01/2003
11/03/2003
Date


Pooley Creek Stage Discharge Curve (2003)
Stage (m)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Discharge (m^3/s)
0.0000
0.0100
0.0200
0.0300
0.0400
0.0500
0.0600
0.0700
0.0800
0.0900
0.1000
Best Fit Curved Line Equation: y = 0.0454Ln(x) + 0.2473
$R^2 = 1$



Pooley Creek - Mean Daily Level and Discharge (Oct. 1-31, 2003)
Water Level (m)
Discharge (m3/s)
Date
Mean Daily Level (m)
Discharge (m3/s)
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
10/1/03 12:00 AM
10/2/03 12:00 AM
10/3/03 12:00 AM
10/4/03 12:00 AM
10/5/03 12:00 AM
10/6/03 12:00 AM
10/7/03 12:00 AM
10/8/03 12:00 AM
10/9/03 12:00 AM
10/10/03 12:00 AM
10/11/03 12:00 AM
10/12/03 12:00 AM
10/13/03 12:00 AM
10/14/03 12:00 AM
10/15/03 12:00 AM
10/16/03 12:00 AM
10/17/03 12:00 AM
10/18/03 12:00 AM
10/19/03 12:00 AM
10/20/03 12:00 AM
10/21/03 12:00 AM
10/22/03 12:00 AM
10/23/03 12:00 AM
10/24/03 12:00 AM
10/25/03 12:00 AM
10/26/03 12:00 AM
10/27/03 12:00 AM
10/28/03 12:00 AM
10/29/03 12:00 AM
10/30/03 12:00 AM
10/31/03 12:00 AM


Stirling Creek Stage Discharge Curve (2003)
Stage (m)
0.320
0.310
0.300
0.290
0.280
0.270
0.260
0.250
0
0.005
0.01
0.015
0.02
0.025
0.03
Discharge (m3/s)
Best Fit Curved Line Equation: y = 0.0189Ln(x) + 0.3743
R2 = 0.9797


Stirling Creek - Mean Daily Level and Discharge (Oct. 14-31, 2003)
Water Level (m)
Discharge (m3/s)
Date
Mean Daily Level (m)
Discharge (m3/s)
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.0000
0.0100
0.0200
0.0300
0.0400
0.0500
0.0600
0.0700
0.0800
10/14/03 11:45 PM
10/15/03 11:45 PM
10/16/03 11:45 PM
10/17/03 11:45 PM
10/18/03 11:45 PM
10/19/03 11:45 PM
10/20/03 11:45 PM
10/21/03 11:45 PM
10/22/03 11:45 PM
10/23/03 11:45 PM
10/24/03 11:45 PM
10/25/03 11:45 PM
10/26/03 11:45 PM
10/27/03 11:45 PM
10/28/03 11:45 PM
10/29/03 11:45 PM
10/30/03 11:45 PM
10/31/03 11:45 PM

APPENDIX B

Equipment Specifications

Equipment Specifications – Marsh McBirney Flow Mate Model 2000 Flow Meter

Velocity Measurement
Method (Electromagnetic)
Zero Stability (+/- 0.05 ft/sec)
Accuracy (+/- 2% of reading + zero stability)
Range (-0.5 to +19.99 ft/sec, -0.15 to +6 m/s)

Power Requirements
Batteries (2 D-Cells)

Battery Life Continuous ON hours
Alkaline (25-30 hours)
NiCad (10-15 hours/charge)
External Power Supply (Optional)
120V, 1W or 220V, 1W

Water Resistant Electronic Case
Submersible one Foot for 30 Seconds

Outputs
3.5 Digit
Signal Output Connector (Optional)
Analog 0.1V = 1 ft/sec or 1 m/s
2V = Full Scale

Materials
Sensor (Polyurethane)
Cable (Polyurethane Jacket)
Electronic Case (High Impact Molded Plastic)

Weight
3 lb 9 oz with case and 20 ft of cable
2 lb 10 oz without sensor and cable

Temperature
Open-Channel-Velocity-Sensor (0°C - 72°C)
Full Pipe Sensor (0°C - 72°C at 250 psi)
Electronics (0°C - 50°C)

OTT Thalimedes Float Operated Shaft Encoder - Technical Data

Measurement range switch-selectable	±19.999 m	±199.99 m	±199.99ft
Resolution	0.001 m	0.01 m	0.01 ft
Maximum measuring error	±0.002 m ± 1 digit	±0.002 m ±1 digit	±0.0066 ft ±1 digit

Data Logger Unit	
Display	LCD 1 single-line, 4.5 places, characters 12 mm high
Measured value memory	approximately 30 000 measured values (EEPROM)
Sample interval/Storage interval	1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30 min 1, 2, 3, 4, 6, 8, 12, 24 h 0 = Off
Interfaces	RS 232 C + infrared (IrDa)
Power Supply	1 x 1.5 V C-cells (LR 14 C AM 2) alkaline type (exclusively battery powered)
Dimensions L x diameter	244 mm x 47 mm
Weight including battery	0.320 kg
Casing	Plastic
Degree of protection	IP 68
Temperature range	-20°C to +70°C
Encoder Unit	
Circumference of pulley	200.0 mm
Standard float cable	1 mm ∅ other diameters can be graduated; e.g. 0.6 mm float cable ∅ - set float pulley circumference to 198.7 mm
Dimensions L x W x H	82 mm x 82 mm x 34 mm
Weight	0.140 kg
Casing	Plastic
Degree of protection	IP 54
Temperature range	-20°C to +70°C
Transducer cable	
Length	1 m
EMC limit values	
-Resistance to electrostatic discharge (ESD)	complies with EN 61000-4-2 degree of severity 2 (4 kV contact discharge)
-Resistance to electromagnetic fields	complies with EN 61000-4-3 degree of severity 3 (10 V/m)
-Resistance to transient fields (burst)	complies with EN 61000-4-4 special degree of severity (4 kV)
-Resistance to surge	complies with EN 61000-4-5 degree of severity 2 (1 kV)
-Line-borne and radiated interference	complies with EN 55022 Class B

Campbell Scientific Model CR 510 Data Logger - Technical Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years**.**

PROGRAM EXECUTION RATE

System tasks initiated in sync with real-time up
to 64 Hz. One measurement with data transfer is
possible at this rate without interruption.

ANALOG INPUTS

NUMBER OF CHANNELS: 2 differential or 4
single-ended, individually configured.
RANGE AND RESOLUTION:
Full Scale Resolution (μV)

Input Range (mV)	Differential	Single-Ended
±2500	333	666
±250	33.3	66.6
±25	3.33	6.66
±7.5	1.00	2.00
±2.5	0.33	0.66

INPUT SAMPLE RATES: Includes the measurement time and conversion to engineering units. The fast and slow measurements integrate the signal for 0.25 and 2.72 ms, respectively. Differential measurements incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors.
Fast differential voltage: 4.2 ms
Slow differential voltage: 9.2 ms
Differential with 60 Hz rejection: 25.9 ms
ACCURACY: ±0.1% of FSR (-25° to 50°C); ±0.05% of FSR (0° to 40°C);
e.g., ±0.1% FSR = ±5.0 mV for ±2500 mV range
INPUT NOISE VOLTAGE (for ±2.5 mV range):
Fast differential: 0.82 μV rms
Slow differential: 0.25 μV rms
Differential with
60 Hz rejection: 0.18 μV rms
COMMON MODE RANGE: ±2.5 V
DC COMMON MODE REJECTION: > 140 dB
NORMAL MODE REJECTION: 70 dB (60 Hz with slow differential measurement)
INPUT CURRENT: ±9 nA maximum
INPUT RESISTANCE: 20 Gohms typical

ANALOG OUTPUTS

DESCRIPTION: 2 switched excitations, active only during measurement, one at a time.
RANGE: ±2.5 V
RESOLUTION: 0.67 mV
ACCURACY: ±2.5 mV (0° to 40°C); ±5 mV (-25° to 50°C)
CURRENT SOURCING: 25 mA
CURRENT SINKING: 25 mA
FREQUENCY SWEEP FUNCTION: The switched outputs provide a programmable swept frequency, 0 to 2.5 V square wave for exciting vibrating wire transducers.

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR510 provides
ratiometric bridge measurements of 4- and 6-wire full bridge, and 2-, 3-, and 4-wire half bridges. Precise dual polarity excitation using any of the switched outputs eliminates dc errors. Conductivity measurements use a dual polarity 0.75 ms excitation to minimize polarization errors.
ACCURACY: ±0.02% of FSR plus bridge errors.

PERIOD AVERAGING MEASUREMENTS

DEFINITION: The average period for a single cycle is determined by measuring the duration of a specified number of cycles. Any of the 4 single-ended analog input channels can be used. Signal attentuation and ac coupling is typically required.
INPUT FREQUENCY RANGE:
Signal peak-to-peak1 Min. Max

Min.	Max.	Pulse w.	Freq.2
500 mV	5.0 V	2.5 μs	200 kHz
10 mV	2.0 V	10 μs	50 kHz
5 mV	2.0 V	62 μs	8 kHz
2 mV	2.0 V	100 μs	5 kHz

RESOLUTION: 35 ns divided by the number of cycles measured
ACCURACY: ±0.03% of reading
TIME REQUIRED FOR MEASUREMENT: Signal period multiplied by the number of cycles measured plus 1.5 cycles + 2 ms.

PULSE COUNTERS

NUMBER OF CHANNELS: 2 eight-bit or 1 sixteenbit; software selectable as switch closure, high frequency pulse, or low-level ac modes. An additional channel (C2/P3) can be software configured to read switch closures at rates up to 40 Hz.
MAXIMUM COUNT RATE: 16 kHz, eight-bit counter; 400 kHz, sixteen-bit counter. Channels are scanned at 8 or 64 Hz (software selectable).
SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Maximum Bounce Time: 1 ms open without being counted
HIGH FREQUENCY PULSE MODE:
Minimum Pulse Width: 1.2 μs
Maximum Input Frequency: 400 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V at low frequencies. Larger input transitions are required at high frequencies because of input filter with 1.2 μs time constant. Signals up to 400 kHz will be counted if centered around +2.5 V with deviations = ± 2.5 V for = 1.2 μs.
LOW LEVEL AC MODE:
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs.)
Input Hysteresis: 14 mV
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

(Sine wave mV rms)*	Range (Hz)
20	1 to 1000
200	0.5 to 10,000
1000	0.3 to 16,000

*16-bit config. or 64 Hz scan req'd for freq. > 2048 Hz

DIGITAL I/O PORTS

DESCRIPTION: Port C1 is software selectable as a binary input, control output, or as an SDI-12 port.
Port C2/P3 is input only and can be software configured as an SDI-12 port, a binary input, or as a switch closure counter (40 Hz max).
OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low < 0.1 V

OUTPUT RESISTANCE: 500 ohms

INPUT STATE: high 3.0 to 5.5 V; low -0.5 to 0.8 V

INPUT RESISTANCE: 100 kohms

SDI-12 INTERFACE STANDARD

DESCRIPTION: Digital I/O Ports C1-C2 support SDI-12 asynchronous communication; up to ten SDI-12 sensors can be connected to each port. Meets SDI-12 standard Version 1.2 for datalogger and sensor modes.

EMI and ESD PROTECTION

The CR510 is encased in metal and incorporates EMI filtering on all inputs and outputs. Gas discharge tubes provide robust ESD protection on all terminal block inputs and outputs. The following European standards apply.
EMC tested and conforms to BS EN61326:1998.
Details of performance criteria applied are available upon request.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303.
PROGRAM STORAGE: Up to 16 kbytes for active program; additional 16 kbytes for alternate programs. Operating system stored in 128 kbytes Flash memory.
DATA STORAGE: 128 kbytes SRAM standard (approximately 62,000 values). Additional 2 Mbytes Flash available as an option.
OPTIONAL KEYBOARD DISPLAY: 8 digit LCD (0.5" digits).
PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, card storage module, and RS-232 adapter.
BAUD RATES: Selectable at 300, 1200, and 9600, 76,800 for certain synchronous devices. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).
CLOCK ACCURACY: ±1 minute per month

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc
TYPICAL CURRENT DRAIN: 1.3 mA quiescent, 13 mA during processing, and 46 mA during analog measurement.
BATTERIES: Any 12 V battery can be connected as a primary power source. Several power supply options are available from Campbell Scientific.
The model CR2430 lithium battery for clock and SRAM backup has a capacity of 270 mAhr.

PHYSICAL SPECIFICATIONS

SIZE: 8.4" x 1.5" x 3.9" (21.3 cm x 3.8 cm x 9.9 cm). Additional clearance required for serial cable and sensor leads.
WEIGHT: 15 oz. (425 g)

WARRANTY

Three years against defects in materials and workmanship.