5 –Day Lagoon Seepage Testing
Case Studies

Electronic Measurements and Recording

Brett M. Converse Ph.D., P.E.
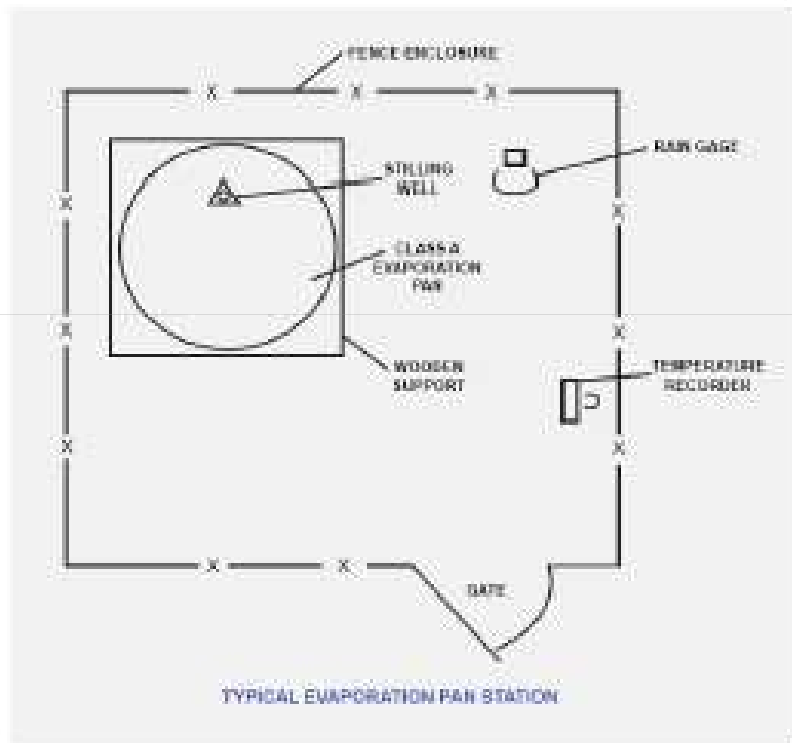bconverse@jub.com

J-U-B ENGINEERS, Inc.

Sandpoint, ID

(208) 265 7281

2009 Annual PNCWA Conference
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Electronic Measurements and Recording

Guidance for Evaluating Wastewater Lagoon Seepage Rates

TYPICAL EVAPORATION PAN STATION

Idaho Department of Environmental Quality
Revised April 2009

Helpful Spreadsheet

DEQ Seepage Calculation Spreadsheet

Welcome to the DEQ Seepage Calculation Spreadsheet.
This spreadsheet is for data input for a lagoon seepage test that has either 15 days of data collected at 3 day intervals or 5 days of data collected at 4 hour intervals.

Note that each worksheet has instructions and data is to be input in yellow cells.
Three worksheet examples are provided.

http://www.deq.state.id.us/water/assist_business/engineers/guidance.cfm

Electronic Measurements and Recording

- **5.5.2 Procedures for using mechanical or electronic measurements and recording for a minimum 5 day test**

- Part 4 (5.5.2-4)

- Liquid surface measuring equipment to measure lagoon surface elevation and evaporation pan surface elevation. In most cases, the equipment to measure these two parameters must be accurate to 0.001 ft. to determine compliance with the rule. Such equipment includes ultrasonic equipment, pressure transducers, and float-operated equipment, each having associated electronic or mechanical recorders to log the data. When using equipment that may be affected by barometric pressure, these effects must be taken into account

Accurate to 0.001 ft.

- 0.001 ft
- 0.012 inches
- Find equipment that has a full scale accuracy of ± 0.1%
- Operating range of 12 inches Maximum

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Equipment

Equipment

- Precipitation gauge
- Air temperature sensor
- Air temperature sensor
- Water temperature sensor
- Wind Speed and Direction sensors
- Liquid level sensor (2) – GeoKon, vibrating wire force transducer for water level monitoring with a full scale sensor range from 0 to 6 inches and an accuracy of ±0.1% of full scale.
- Power supply – 12 V battery.
- Galvanized steel instrumentation tripod.
- Data logger
- Class A evaporation pan with pan stilling well

Case Study One
Wet Well Lagoon

Case Study One
Wet Well Lagoon

Lined	Maximum Operating Depth (ft)	Approximate Volume (gallons)	Area (acres)
Yes	3.5	25,000	0.057
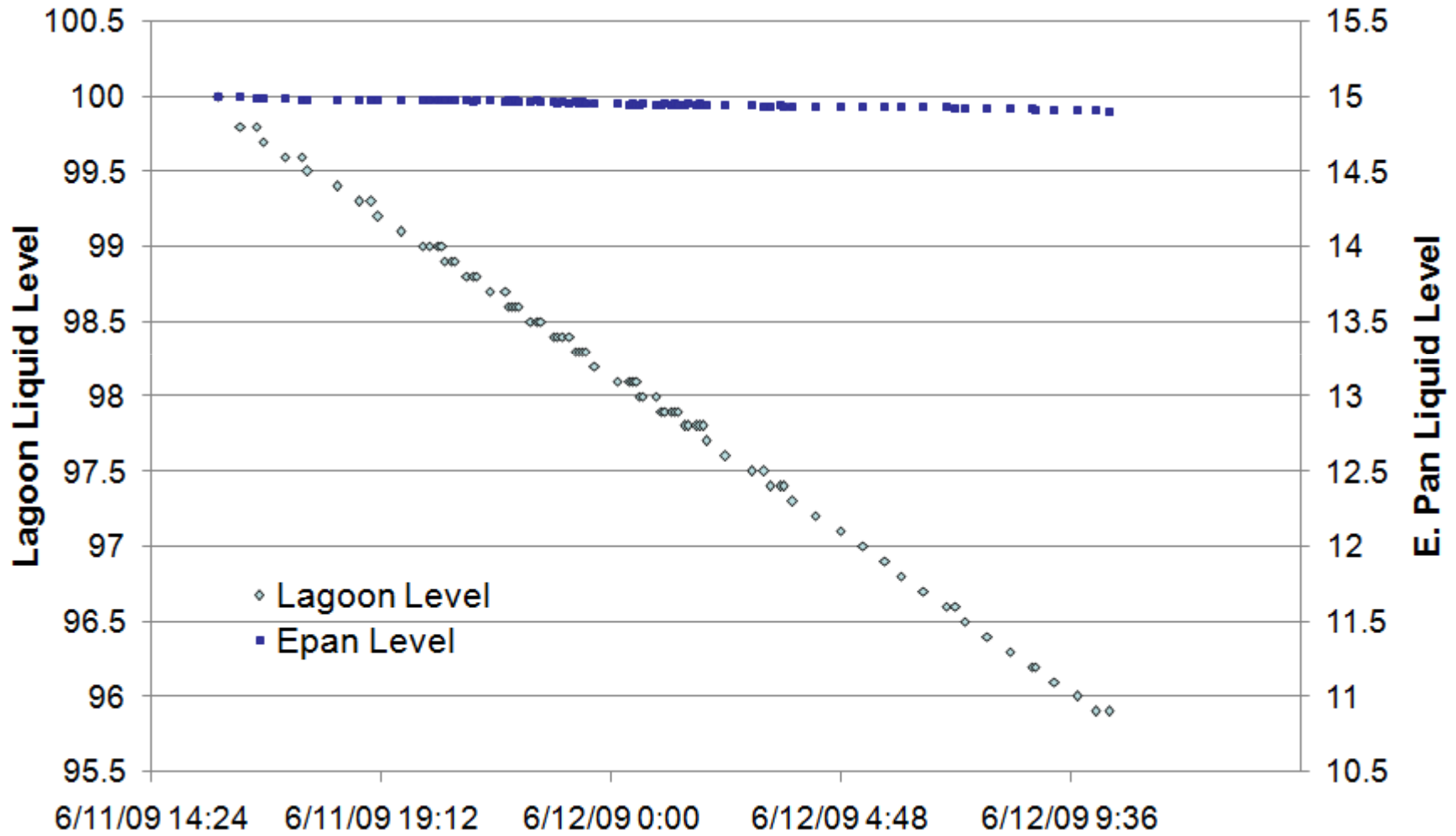
Lesson Learned

- Prior to arriving on site have operators
  - Isolate lagoon for a few days
  - If the lagoon liquid level is dropping
    - More than about 1 inch per day – leaking
    - Very little – better chance of not leaking
- Problems (two sites)
  - Open valve on the pump cooling jacket line.
    - Closed valve, filled lagoon, restarted test
  - Isolation gates did not seal
    - Could not fix leak quickly, job postponed.

Lagoon and E-pan Liquid Level
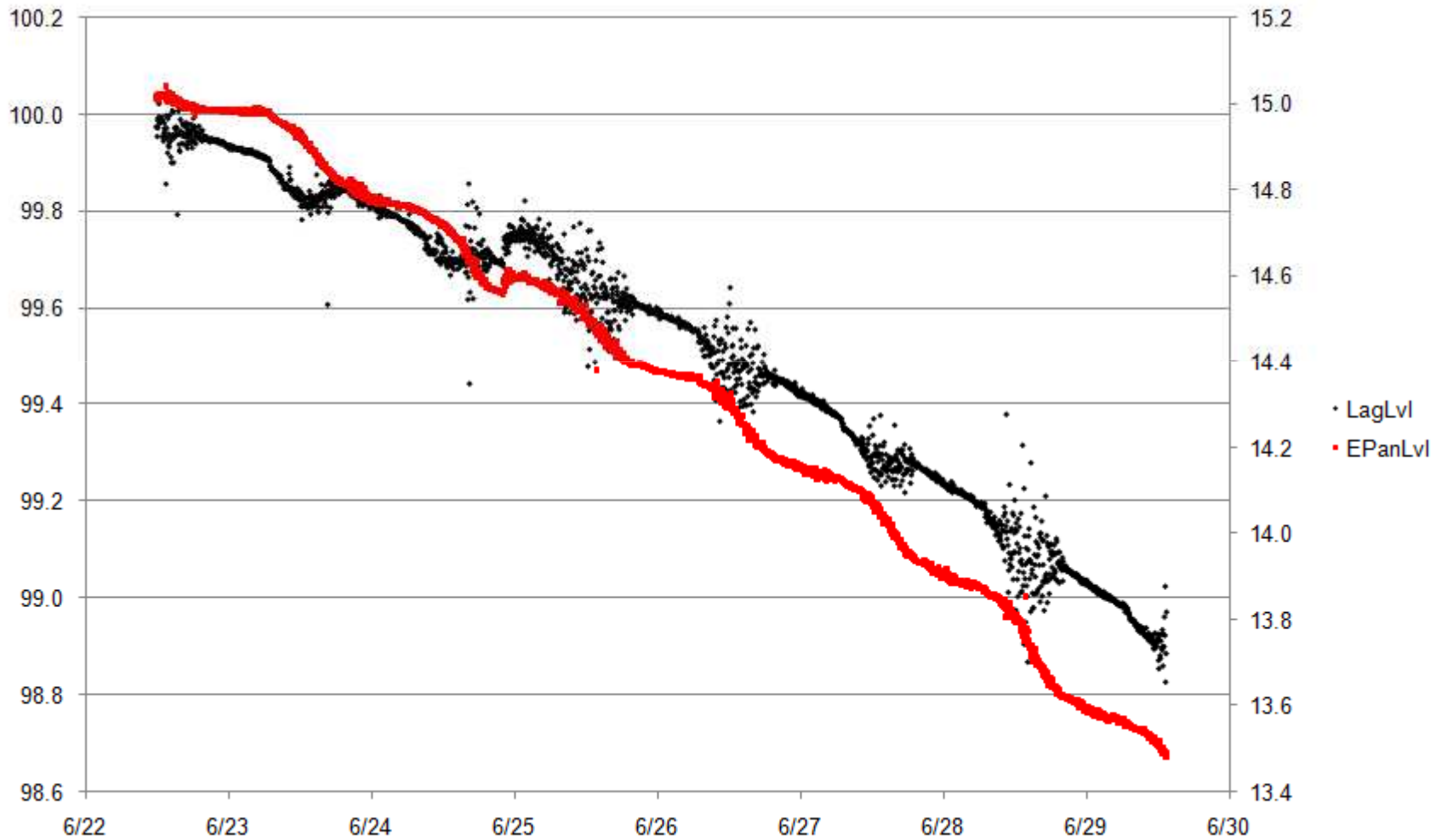
E-pan Liquid Level
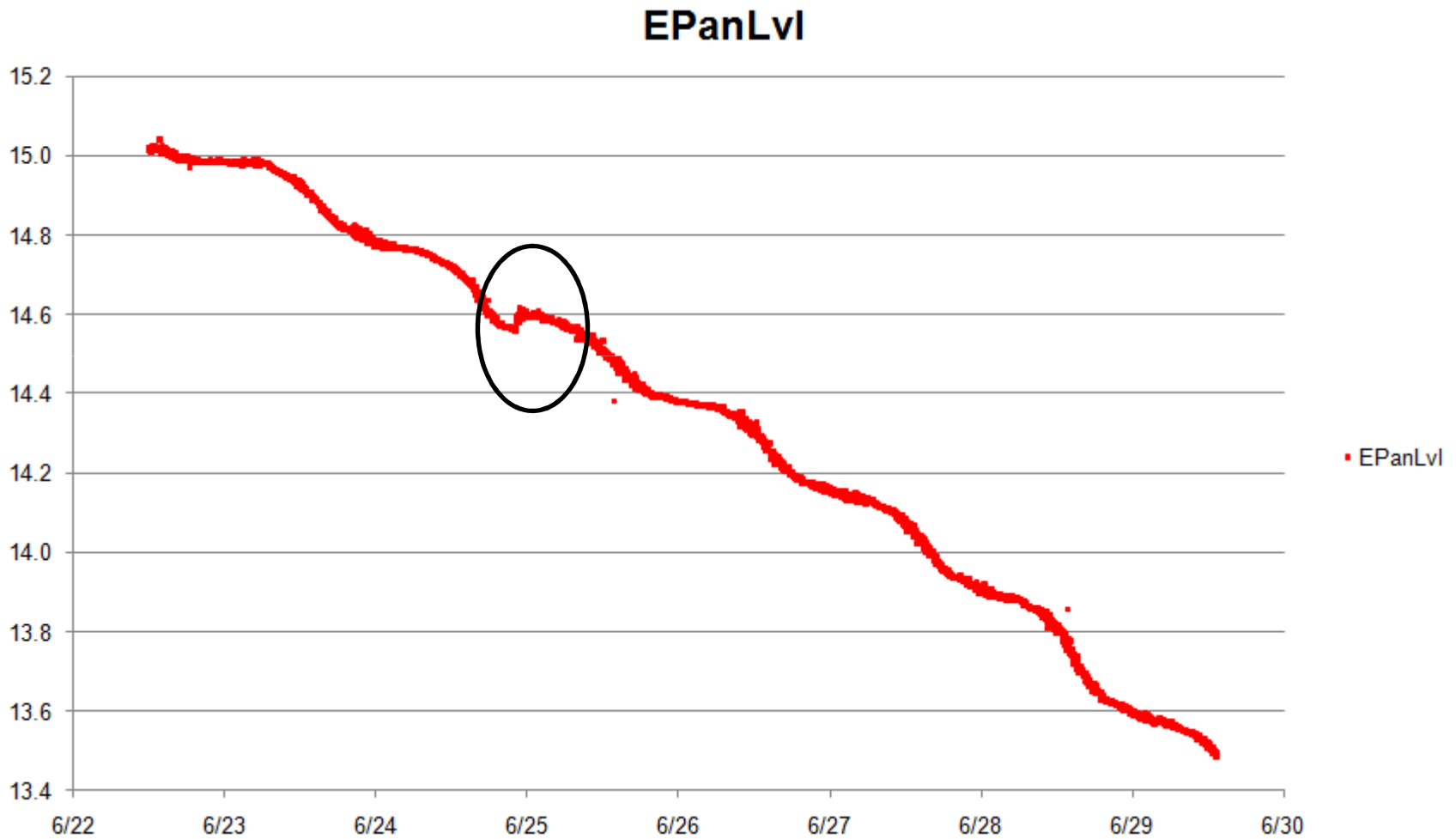
E-pan and Rain
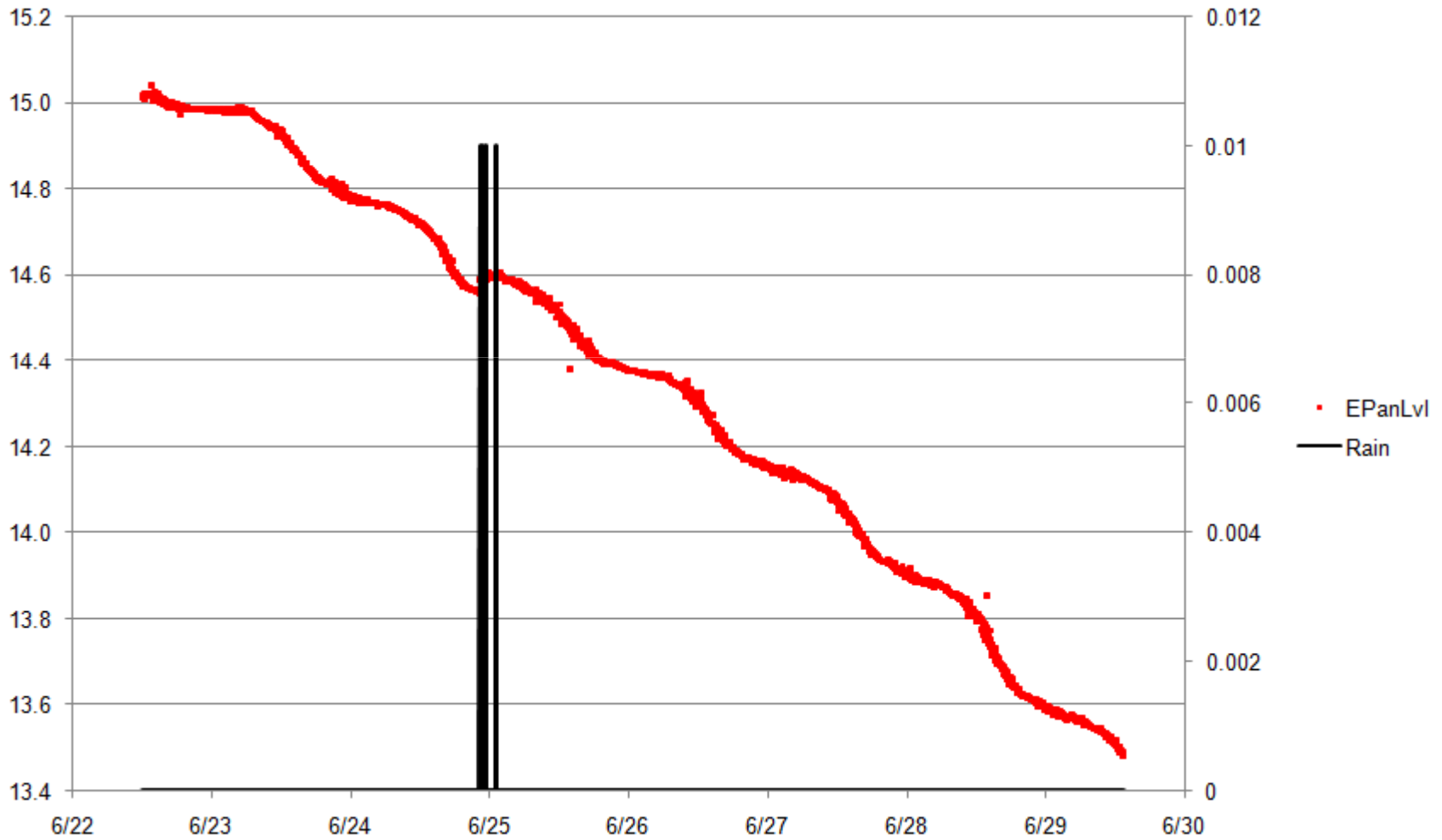
E-pan and Temperature
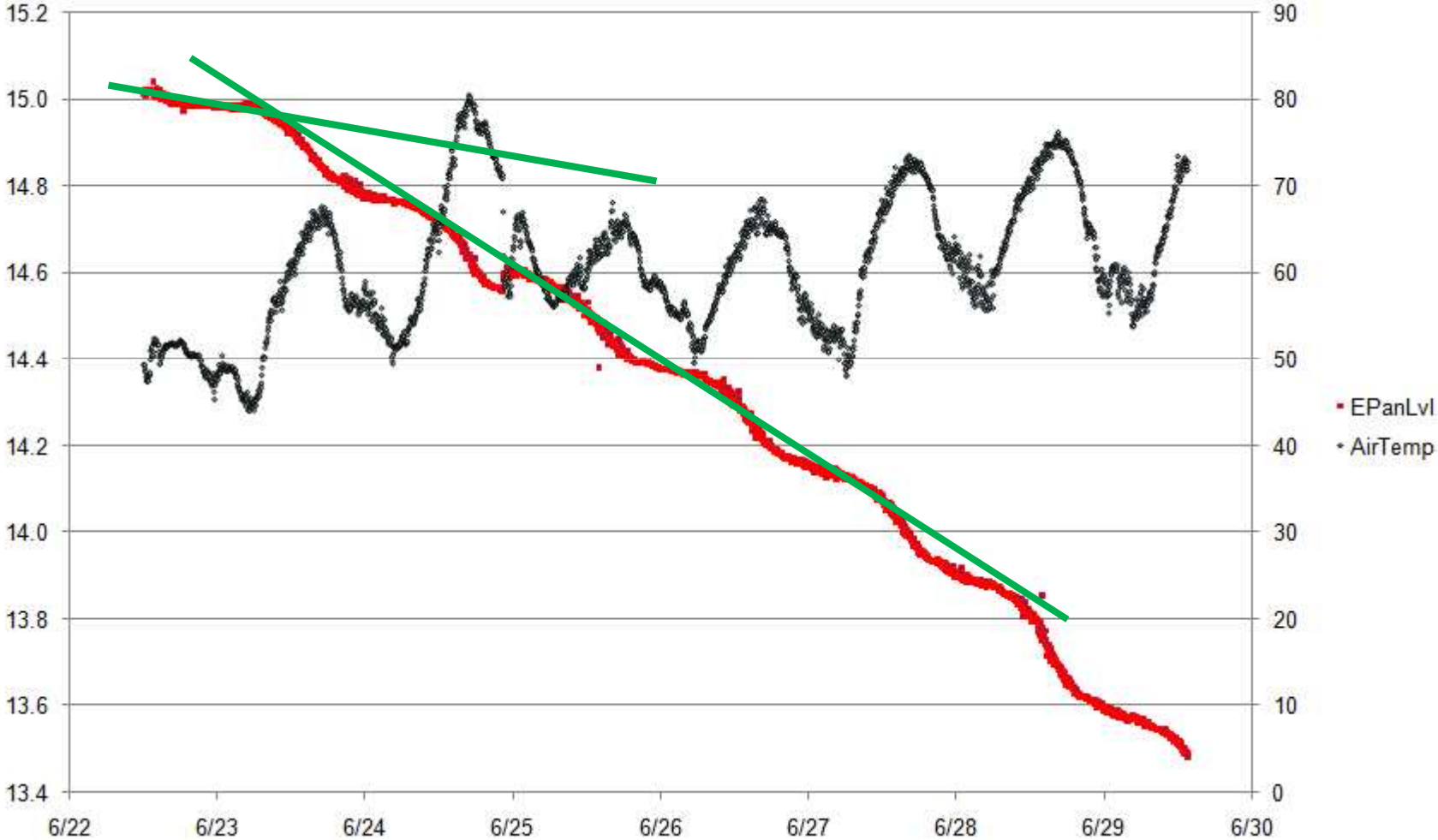
Lagoon Liquid Level
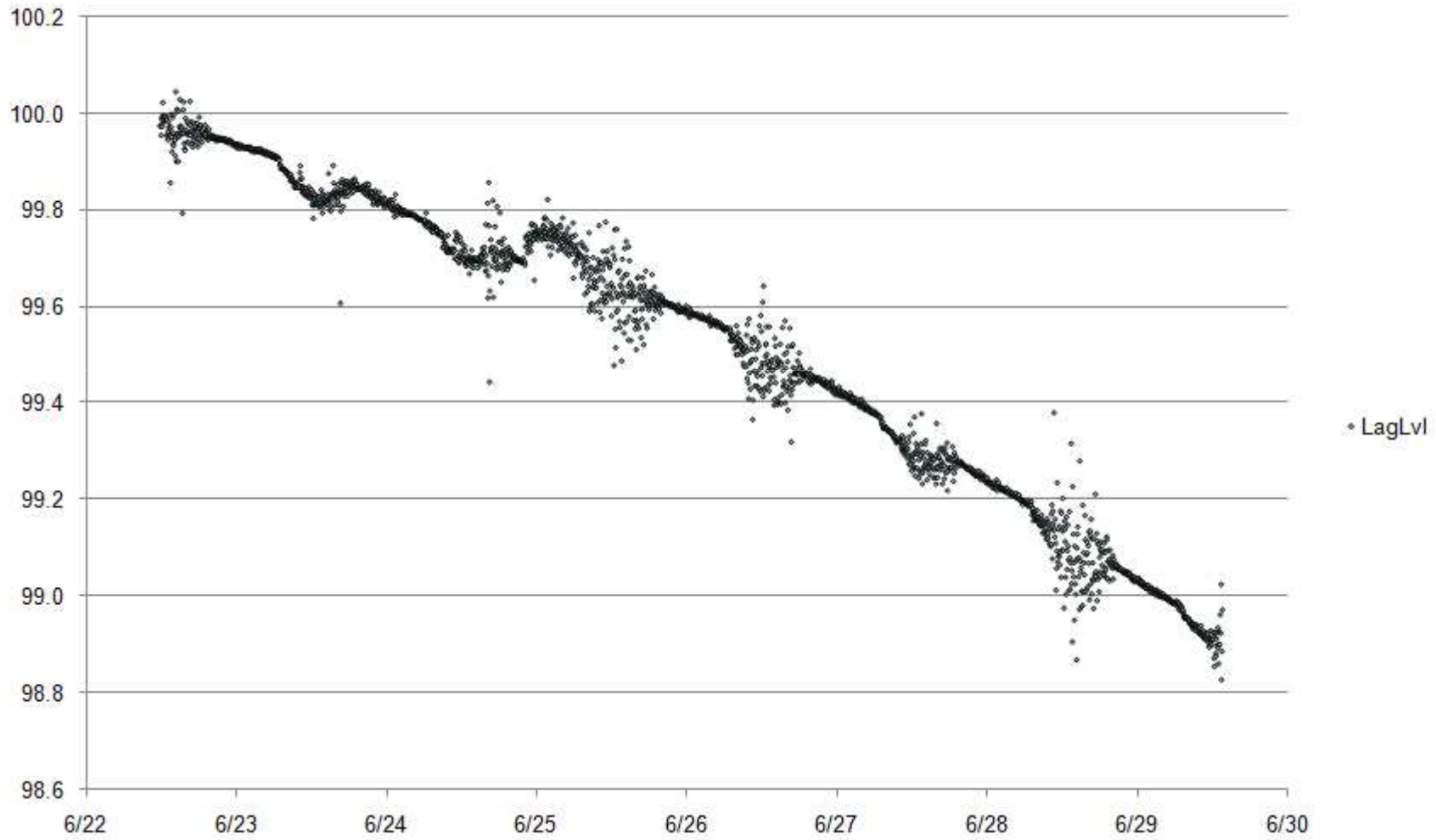
Wind Scatter
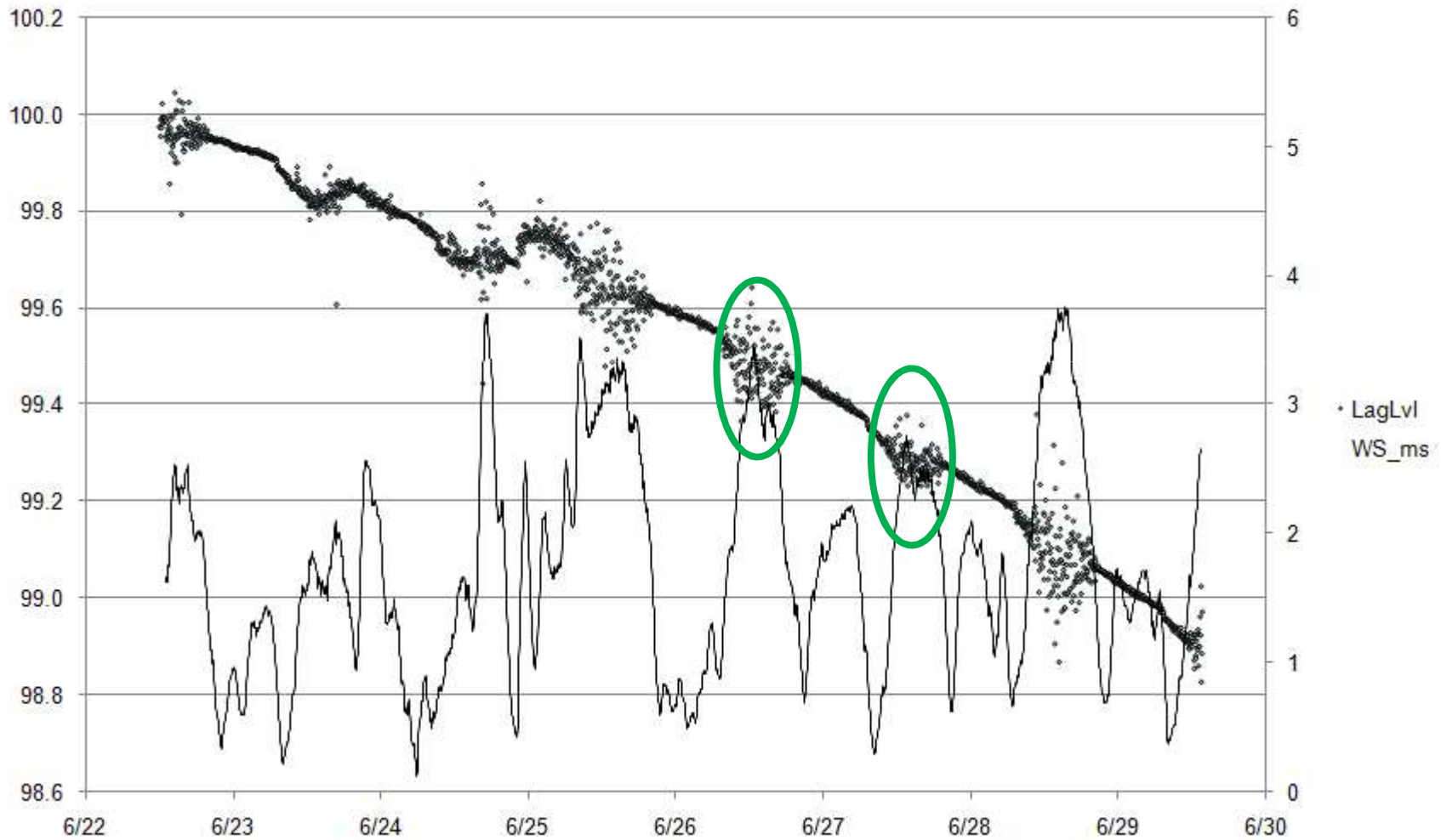
Wind Scatter
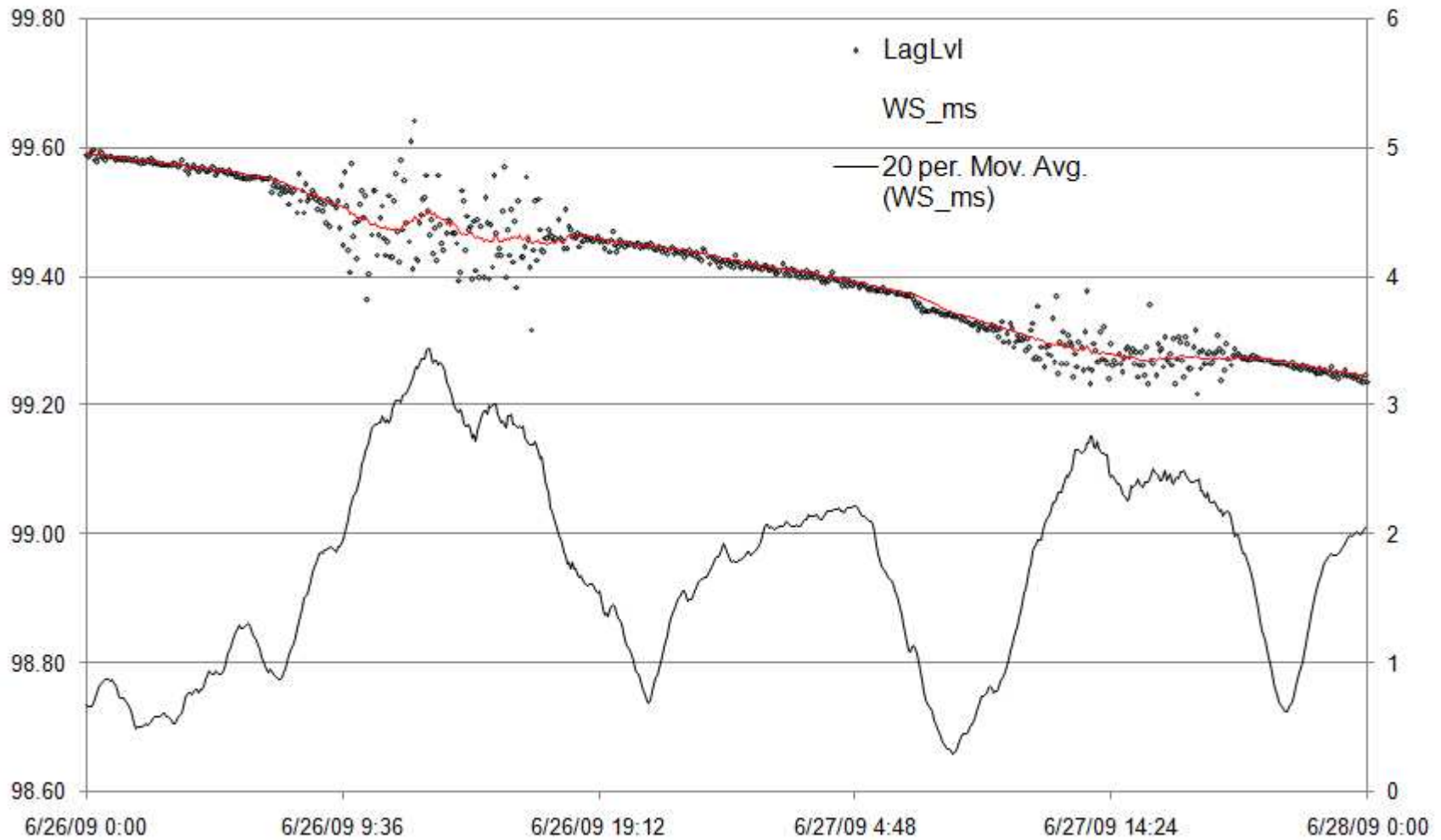
Lagoon Liquid Level and Rain
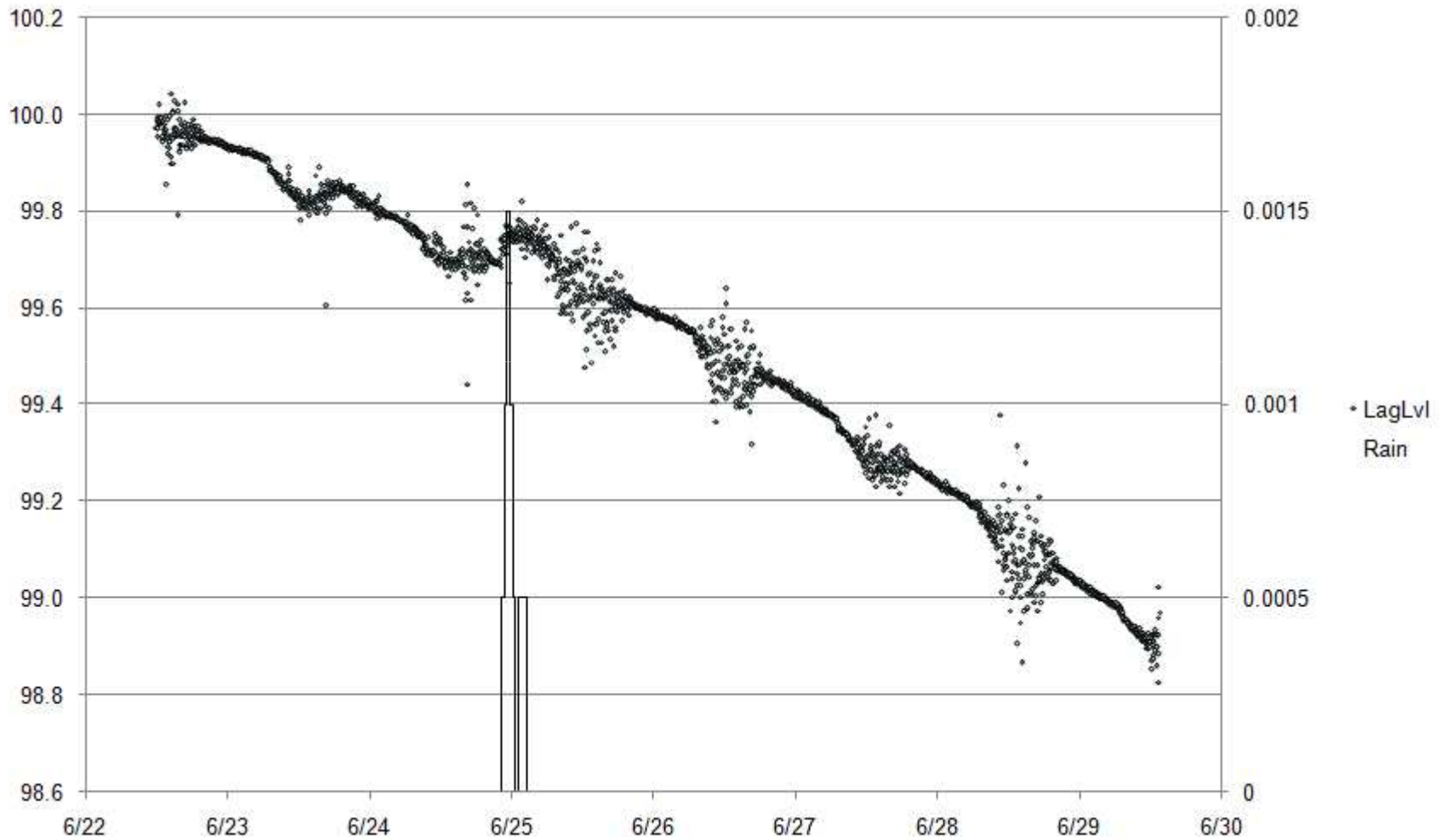
Log Data Every 4 Minutes

TIMESTAMP			LagLvl	EPanLvl	Rain_inches	AirTemp1	WS_ms
7/22/2009 9:20	0		100.0023	15.00048		72.18518	0
7/22/2009 9:24	1		100.004	14.99946		72.1157	0.453125
7/22/2009 9:28	2		100.0042	14.99858		72.673142	0.25625
7/22/2009 9:32	3		100.0104	14.9975		72.514994	0.24375
7/22/2009 9:36	4		100.0156	14.99736		72.045392	0.596875
7/22/2009 9:40	5		100.0098	14.99532		72.044672	0.4375
7/22/2009 9:44	6		100.0177	14.99545		72.04424	0.765625
7/22/2009 9:48	7		100.0165	14.99386		72.244562	0.740625
7/22/2009 9:52	8		100.0296	14.99301		72.75956	0.334375
7/22/2009 9:56	9		100.0165	14.99229		74.120036	0
7/22/2009 10:00	10		100.0325	14.99156		73.391216	0.475
7/22/2009 10:04	11		100.0335	14.99073		74.234462	0.4125

4-Hour Time Step Data Averaged

TIMESTAMP		LagLvl	EPanLvl	Rain_inches	AirTemp1	WS_ms
7/22/2009 9:20	0	100.0023	15.00048		72.18518	0
7/22/2009 9:24	1	100.004	14.99946		72.1157	0.453125
7/22/2009 9:28	2	100.0042	14.99858		72.673142	0.25625
7/22/2009 9:32	3	100.0104	14.9975		72.514994	0.24375
7/22/2009 9:36	4	100.0156	14.99736		72.045392	0.596875
7/22/2009 9:40	5	100.0098	14.99532		72.044672	0.4375
7/22/2009 9:44	6	100.0177	14.99545		72.04424	0.765625
7/22/2009 9:48	7	100.0165	14.99386		72.244562	0.740625
7/22/2009 9:52	8	100.0296	14.99301		72.75956	0.334375
7/22/2009 9:56	9	100.0165	14.99229		74.120036	0
7/22/2009 10:00	10	100.0325	14.99156		73.391216	0.475
7/22/2009 10:04	11	100.0335	14.99073		74.234462	0.4125
7/22/2009 10:08	12	100.0378	14.98955		75.97409	0
7/22/2009 10:12	13	100.0433	14.98877		75.436088	0.34375
7/22/2009 10:16	14	100.047	14.98782		76.848116	0
7/22/2009 10:20	15	100.0527	14.98706		75.506018	0.5
7/22/2009 10:24	16	100.0521	14.9865		75.833366	0.575
7/22/2009 10:28	17	100.05	14.98598		76.44524	0.403125
7/22/2009 10:32	18	100.0604	14.98455		76.943318	0.253125
7/22/2009 10:36	19	100.0618	14.98371		76.44524	0.528125
7/22/2009 10:40	20	100.0685	14.98295		76.49249	0.478125
7/22/2009 10:44	21	100.0653	14.98218		77.181656	0.309375
7/22/2009 10:48	22	100.0529	14.98095		79.020986	0
7/22/2009 10:52	23	100.0485	14.98047		79.538054	0
7/22/2009 10:56	24	100.0615	14.97862		78.095228	0.634375
7/22/2009 11:00	25	100.0579	14.97851		78.071	0.784375
7/22/2009 11:04	26	100.0628	14.97819		77.733176	0.6625
7/22/2009 11:08	27	100.0671	14.97694		78.898442	0
7/22/2009 11:12	28	100.0751	14.97659		79.389914	0.534375
7/22/2009 11:16	29	100.0762	14.97916		78.971936	1.03125
7/22/2009 11:20	30	100.089	14.97603		79.934666	0.528125
7/22/2009 11:24	31	100.0944	14.97475		80.208716	0.615625
7/22/2009 11:28	32	100.0919	14.97187		79.637	0.7125
7/22/2009 11:32	33	100.0942	14.97335		80.936672	0.303125
7/22/2009 11:36	34	100.1036	14.96842		80.8862	0.8375
7/22/2009 11:40	35	100.1	14.97124		80.735072	0.865625
7/22/2009 11:44	36	100.1091	14.96965		81.341744	0.59375
7/22/2009 11:48	37	100.1134	14.96897		82.365566	0.4
7/22/2009 11:52	38	100.1072	14.967		82.857578	0.70625
7/22/2009 11:56	39	100.123	14.9657		82.339736	0.80625
7/22/2009 12:00	40	100.1262	14.9633		82.93559	1.090625
7/22/2009 12:04	41	100.1238	14.963		83.196338	1.1125
7/22/2009 12:08	42	100.122	14.96343		84.516512	0.34375
7/22/2009 12:12	43	100.1302	14.96265		84.569918	0.459375
7/22/2009 12:16	44	100.1394	14.96132		84.757118	0.746875
7/22/2009 12:20	45	100.1489	14.96027		85.322084	0.38125
7/22/2009 12:24	46	100.1441	14.95881		86.330138	0.34375
7/22/2009 12:28	47	100.1564	14.95984		85.755992	0.771875
7/22/2009 12:32	48	100.149	14.95733		85.647236	0.815625
7/22/2009 12:36	49	100.156	14.95713		85.919522	0.56875
7/22/2009 12:40	50	100.1654	14.95592		87.076328	0.25625
7/22/2009 12:44	51	100.1687	14.95317		86.79893	0.90625
7/22/2009 12:48	52	100.177	14.9549		86.743562	1.259375
7/22/2009 12:52	53	100.1705	14.95389		86.495216	0.98125
7/22/2009 12:56	54	100.1666	14.95193		87.550826	0.85
7/22/2009 13:00	55	100.1639	14.95112		87.578906	0.959375
7/22/2009 13:04	56	100.1936	14.94853		88.029122	1.690625
7/22/2009 13:08	57	100.1832	14.94874		88.968398	0.434375
7/22/2009 13:12	58	100.1931	14.94755		89.689928	0.56875
7/22/2009 13:16	59	100.213	14.94514		90.039398	0.721875
7/22/2009 13:20	60	100.1854	14.94672		90.332186	2.35

Averaged

4-Hour Time Step
20 Points Averaged (80 Minutes)

TIMESTAMP		LagLvl	EPanLvl	Rain_inches	AirTemp1	WS_ms
7/22/2009 9:20	0	100.0023	15.00048		72.18518	0
7/22/2009 9:24	1	100.004	14.99946		72.1157	0.453125
7/22/2009 9:28	2	100.0042	14.99858		72.673142	0.25625
7/22/2009 9:32	3	100.0104	14.9975		72.514994	0.24375
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7/22/2009 9:40	5	100.0098	14.99532		72.044672	0.4375
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7/22/2009 9:56	9	100.0165	14.99229		74.120036	0
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7/22/2009 10:04	11	100.0335	14.99073		74.234462	0.4125
7/22/2009 10:08	12	100.0378	14.98955		75.97409	0
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7/22/2009 10:16	14	100.047	14.98782		76.848116	0
7/22/2009 10:20	15	100.0527	14.98706		75.506018	0.5
7/22/2009 10:24	16	100.0521	14.9865		75.833366	0.575
7/22/2009 10:28	17	100.05	14.98598		76.44524	0.403125
7/22/2009 10:32	18	100.0604	14.98455		76.943318	0.253125
7/22/2009 10:36	19	100.0618	14.98371		76.44524	0.528125
7/22/2009 10:40	20	100.0685	14.98295		76.49249	0.478125
7/22/2009 10:44	21	100.0653	14.98218		77.181656	0.309375
7/22/2009 10:48	22	100.0529	14.98095		79.020986	0
7/22/2009 10:52	23	100.0485	14.98047		79.538054	0
7/22/2009 10:56	24	100.0615	14.97862		78.095228	0.634375
7/22/2009 11:00	25	100.0579	14.97851		78.071	0.784375
7/22/2009 11:04	26	100.0628	14.97819		77.733176	0.6625
7/22/2009 11:08	27	100.0671	14.97694		78.898442	0
7/22/2009 11:12	28	100.0751	14.97659		79.389914	0.534375
7/22/2009 11:16	29	100.0762	14.97916		78.971936	1.03125
7/22/2009 11:20	30	100.089	14.97603		79.934666	0.528125
7/22/2009 11:24	31	100.0944	14.97475		80.208716	0.615625
7/22/2009 11:28	32	100.0919	14.97187		79.637	0.7125
7/22/2009 11:32	33	100.0942	14.97335		80.936672	0.303125
7/22/2009 11:36	34	100.1036	14.96842		80.8862	0.8375
7/22/2009 11:40	35	100.1	14.97124		80.735072	0.865625
7/22/2009 11:44	36	100.1091	14.96965		81.341744	0.59375
7/22/2009 11:48	37	100.1134	14.96897		82.365566	0.4
7/22/2009 11:52	38	100.1072	14.967		82.857578	0.70625
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7/22/2009 12:00	40	100.1262	14.9633		82.93559	1.090625
7/22/2009 12:04	41	100.1238	14.963		83.196338	1.1125
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7/22/2009 12:12	43	100.1302	14.96265		84.569918	0.459375
7/22/2009 12:16	44	100.1394	14.96132		84.757118	0.746875
7/22/2009 12:20	45	100.1489	14.96027		85.322084	0.38125
7/22/2009 12:24	46	100.1441	14.95881		86.330138	0.34375
7/22/2009 12:28	47	100.1564	14.95984		85.755992	0.771875
7/22/2009 12:32	48	100.149	14.95733		85.647236	0.815625
7/22/2009 12:36	49	100.156	14.95713		85.919522	0.56875
7/22/2009 12:40	50	100.1654	14.95592		87.076328	0.25625
7/22/2009 12:44	51	100.1687	14.95317		86.79893	0.90625
7/22/2009 12:48	52	100.177	14.9549		86.743562	1.259375
7/22/2009 12:52	53	100.1705	14.95389		86.495216	0.98125
7/22/2009 12:56	54	100.1666	14.95193		87.550826	0.85
7/22/2009 13:00	55	100.1639	14.95112		87.578906	0.959375
7/22/2009 13:04	56	100.1936	14.94853		88.029122	1.690625
7/22/2009 13:08	57	100.1832	14.94874		88.968398	0.434375
7/22/2009 13:12	58	100.1931	14.94755		89.689928	0.56875
7/22/2009 13:16	59	100.213	14.94514		90.039398	0.721875
7/22/2009 13:20	60	100.1854	14.94672		90.332186	2.35

Averaged

DEQ Spreadsheet

Lagoon seepage rate calculations to customize for testing data collected at more than 4 hour intervals

Owner/Facility/HOA/Permittee:	
Responsible P.E. or P. G. :	Brett M. Converse Ph.D., P.E.
Phone Number:	208 265 7281
Name of Lagoon:	Irrigaion Pump Station Wet Well Lagoon
Test Start Date:	June 22, 2009
Test Start Time:	7:56 PM
Equipment used for lagoon:	GeoKon

Equipment Accuracy:	0.1	%FS	0.5	Range (ft)	0.006	Inches

Equipment used for pan: GeoKon

Equipment Accuracy:	0.1	%FS	0.5	Range (ft)	0.006	Inches

Equipment used for precipitation:	Campbell Scientific	Equipment Accuracy:	0.010	Inches
Equipment used for flow in to lagoon:		Equipment Accuracy:		
Equipment used for flow out of lagoon:		Equipment Accuracy:		

Definitions: (Refer to guidance for additional information)

E_{S0} : lagoon surface elevation at start of test for new time increment (units: inches)

E_{SN}: lagoon surface elevation at day n (units:inches)

ES: lagoon surface elevation change (units:inches)

P: see pan coefficient worksheet for table and temperature range

$E_{pan\,0}$: evap pan surface elevation start of test for new time increment (units:inches)

$E_{pan\,n}$: evap pan surface elevation day n (units:inches)

$ES = Es0 - Esn$

n: time in days

S_{r1}: seepage rate (units: inches/day)

$S_{R1} = (ES - I_L - Q + precipitation)/n = inches\ day$

I_L: net lagoon evaporation (units:inches)

$I_L = P*(precipitation + E_{PAN\,0} - E_{PAN\,n})*C$

Air Temperature: *median* over test interval

Sample Event Number	4 hour averages	Seepage	Seepage Error	E_{S0}	E_{SN}	ES	ES Error	I_L	$I_{L\ Error}$	n	Test time	Air temp	P
	Time	inches	+/- inches	inches	inches	inches	+/- inches	inches	+/- in	days		°F	coefficent
Step →					99.963								
1	6/22/09 19:56	-0.013332	0.011	99.963	99.959	0.004	0.008	0.017	0.007	0.16667		51.69	0.805
2	6/22/09 23:56	0.010170	0.011	99.959	99.944	0.015	0.008	0.005	0.007	0.16667		48.41	0.832

DEQ Spreadsheet

Lagoon seepage rate calculations to customize for testing data collected at more than 4 hour intervals

Owner/Facility/HOA/Permittee:	
Responsible P.E. or P. G. :	Brett M. Converse Ph.D., P.E.
Phone Number:	208 265 7281
Name of Lagoon:	Irrigaion Pump Station Wet Well Lagoon
Test Start Date:	June 22, 2009
Test Start Time:	7:56 PM
Equipment used for lagoon:	GeoKon
Equipment Accuracy:	0.1 %FS 0.5 Range (ft) 0.006 Inches
Equipment used for pan:	GeoKon
Equipment Accuracy:	0.1 %FS 0.5 Range (ft) 0.006 Inches
Equipment used for precipitation:	Campbell Scientific Equipment Accuracy: 0.010 Inches
Equipment used for flow in to lagoon:	Equipment Accuracy:
Equipment used for flow out of lagoon:	Equipment Accuracy:

Definitions: (Refer to guidance for additional information)
E_{S0}: lagoon surface elevation at start of test for new time increment (units: inches)
E_{SN}: lagoon surface elevation at day n (units inches)
ES: lagoon surface elevation change (units inches)
P: see pan coefficient worksheet for table and temperature range
$E_{pan 0}$: evap pan surface elevation start of test for new time increment (units inches)
$E_{pan n}$: evap pan surface elevation day n (units inches)

$ES = Es0-Esn$

n: time in days
S_{rt}: seepage rate (units: inches/day)
$S_{R1} = (ES-I_L-Q+precipitation)/n = inches\ day$
I_L: net lagoon evaporation (units inches)
$I_L = P * (precipitation + E_{pan0} - E_{pan,n}) * C$
Air Temperature: median over test interval

Instructions
1. Enter information in all fields in yellow.
2. See the previous worksheets for details.
3. The cells are not locked in this worksheet and rows may be added to accommodate additional testing intervals.

Note that equipment error calculations are based on the Propagation of Uncertainty.
Sampling Error: the standard error of the sample standard deviation
Sampling Error = (standard deviation)/(n^0.5)
Equipment Error: Evap. Error = (%FS/100 * Range) *12inches/ft
$Q = ((effluent flow-influent flow (gallons)*ft3*12in) / (lagoon surface area ft2 *7.48 gal *ft)$

Sample Event Number	4 hour averages	Seepage	Seepage Error	E_{S0}	E_{SN}	ES	ES Error	I_L	I_L Error	n	Test time	Air temp	P	$E_{pan 0}$	$E_{pan n}$	Epan	Epan error	Precipitation	Q	Effluent Q	Influent Q	Lagoon SA	C: precip factor	S_{rt}
	Time	inches	+/- inches	inches	inches	inches	+/- inches	inches	+/- in	days		°F	coefficient	inches	inches	inches	+/- in	inches	inches	gallons	gallons	ft2	see note	inches/day
Step →																								
1	6/22/09 19:56	-0.013332	0.011	99.963	99.959	0.004	0.008	0.017	0.007	0.16667		51.69	0.805	15.012	14.990	0.022	0.008	0.00	0.000	0	0	1	1.00	-0.0800
2	6/22/09 23:56	0.010170	0.011	99.959	99.944	0.015	0.008	0.005	0.007	0.16667		48.41	0.832	14.990	14.984	0.006	0.008	0.00	0.000	0	0	1	1.00	0.0610
3	6/23/09 3:56	0.014085	0.011	99.944	99.927	0.017	0.008	0.003	0.007	0.16667		48.67	0.832	14.984	14.980	0.003	0.008	0.00	0.000	0	0	1	1.00	0.0845
4	6/23/09 7:56	0.016841	0.011	99.927	99.907	0.020	0.008	0.003	0.007	0.16667		45.50	0.860	14.980	14.975	0.004	0.008	0.00	0.000	0	0	1	1.00	0.1010
5	6/23/09 11:56	0.030014	0.011	99.906598	99.85313	0.053	0.008485	0.023	0.00635	0.16667		57.00	0.749	14.9763	14.9450	0.031	0.008	0.00	0.000	0	0	1	1.00	0.1801
6	6/23/09 15:56	-0.004090	0.010	99.863	99.822	0.032	0.008	0.036	0.006	0.16667		63.70	0.693	14.945	14.894	0.051	0.008	0.00	0.000	0	0	1	1.00	-0.0245
7	6/23/09 19:56	-0.059646	0.010	99.822	99.838	-0.016	0.008	0.043	0.006	0.16667		65.62	0.674	14.894	14.829	0.064	0.008	0.00	0.000	0	0	1	1.00	-0.3579
8	6/23/09 23:56	-0.017353	0.011	99.838	99.830	0.008	0.008	0.026	0.006	0.16667		56.61	0.758	14.829	14.795	0.034	0.008	0.00	0.000	0	0	1	1.00	-0.1041
9	6/24/09 3:56	0.009474	0.011	99.830	99.801	0.029	0.008	0.019	0.007	0.16667		54.56	0.776	14.795	14.771	0.025	0.008	0.00	0.000	0	0	1	1.00	0.0568
10	6/24/09 7:56	0.017039	0.011	99.801	99.776	0.025	0.008	0.008	0.007	0.16667		52.05	0.795	14.771	14.760	0.011	0.008	0.00	0.000	0	0	1	1.00	0.1022
11	6/24/09 11:56	0.027690	0.010	99.776	99.730	0.045	0.008	0.018	0.006	0.16667		61.73	0.712	14.760	14.735	0.025	0.008	0.00	0.000	0	0	1	1.00	0.1661
12	6/24/09 15:56	0.005285	0.010	99.730	99.699	0.031	0.008	0.026	0.006	0.16667		72.51	0.609	14.735	14.692	0.043	0.008	0.00	0.000	0	0	1	1.00	0.0317
13	6/24/09 19:56	-0.054140	0.010	99.699	99.705	-0.006	0.008	0.048	0.005	0.16667		77.39	0.563	14.692	14.608	0.085	0.008	0.00	0.000	0	0	1	1.00	-0.3248
14	6/24/09 23:56	-0.016218	0.010	99.705	99.715	-0.010	0.008	0.037	0.005	0.16667		71.35	0.619	14.608	14.579	0.029	0.008	0.00	0.000	0	0	1	1.00	-0.0973
15	6/25/09 3:56	-0.022330	0.010	99.715	99.751	-0.036	0.008	-0.004	0.005	0.16667		63.77	0.693	14.579	14.594	-0.015	0.008	0.01	0.000	0	0	1	1.00	-0.1340
16	6/25/09 7:56	0.016657	0.011	99.751	99.716	0.034	0.008	0.018	0.006	0.16667		57.25	0.749	14.594	14.570	0.024	0.008	0.00	0.000	0	0	1	1.00	0.0999
17	6/25/09 12:00	0.031970	0.011	99.716	99.657	0.059	0.008	0.027	0.006	0.16944		59.13	0.730	14.570	14.533	0.037	0.008	0.00	0.000	0	0	1	1.00	0.1887
18	6/25/09 15:56	-0.004875	0.010	99.657	99.622	0.035	0.008	0.040	0.006	0.16389		62.58	0.702	14.533	14.476	0.057	0.008	0.00	0.000	0	0	1	1.00	-0.0297
19	6/25/09 19:56	-0.028569	0.010	99.622	99.609	0.013	0.008	0.041	0.006	0.16667		64.80	0.683	14.476	14.415	0.061	0.008	0.00	0.000	0	0	1	1.00	-0.1714
20	6/25/09 23:56	-0.011885	0.011	99.609	99.600	0.009	0.008	0.021	0.007	0.16667		58.98	0.739	14.415	14.387	0.028	0.008	0.00	0.000	0	0	1	1.00	-0.0713
21	6/26/09 3:56	0.009219	0.011	99.600	99.580	0.021	0.008	0.011	0.007	0.16667		55.79	0.767	14.387	14.372	0.015	0.008	0.00	0.000	0	0	1	1.00	0.0553
22	6/26/09 7:56	0.017580	0.011	99.580	99.553	0.027	0.008	0.009	0.007	0.16667		52.52	0.795	14.372	14.361	0.011	0.008	0.00	0.000	0	0	1	1.00	0.1055
23	6/26/09 11:56	0.034042	0.011	99.553	99.495	0.058	0.008	0.024	0.006	0.16667		58.51	0.739	14.361	14.329	0.032	0.008	0.00	0.000	0	0	1	1.00	0.2043
24	6/26/09 15:56	-0.020162	0.010	99.495	99.473	0.022	0.008	0.043	0.006	0.16667		64.77	0.683	14.329	14.267	0.062	0.008	0.00	0.000	0	0	1	1.00	-0.1210
25	6/26/09 19:56	-0.030694	0.010	99.473	99.457	0.016	0.008	0.046	0.006	0.16667		65.09	0.674	14.267	14.198	0.069	0.008	0.00	0.000	0	0	1	1.00	-0.1842
26	6/26/09 23:56	-0.006873	0.011	99.457	99.440	0.017	0.008	0.023	0.007	0.16667		58.28	0.739	14.198	14.165	0.033	0.008	0.00	0.000	0	0	1	1.00	-0.0412
27	6/27/09 3:56	0.013396	0.011	99.440	99.410	0.020	0.008	0.016	0.007	0.16667		53.26	0.786	14.165	14.144	0.021	0.008	0.00	0.000	0	0	1	1.00	0.0804
28	6/27/09 7:56	0.023141	0.011	99.410	99.374	0.036	0.008	0.013	0.007	0.16667		52.11	0.795	14.144	14.128	0.016	0.008	0.00	0.000	0	0	1	1.00	0.1388
29	6/27/09 11:56	0.034863	0.010	99.374	99.318	0.056	0.008	0.022	0.006	0.16667		62.72	0.702	14.128	14.098	0.029	0.008	0.00	0.000	0	0	1	1.00	0.2092
30	6/27/09 15:56	0.000258	0.010	99.318	99.281	0.037	0.008	0.037	0.005	0.16667		70.56	0.628	14.098	14.039	0.058	0.008	0.00	0.000	0	0	1	1.00	0.0016
		0.024601																						
						0.682		0.701		5.00		60	0.721			0.972		0.04				1.00		0.0042

Average of Median

4-Minute Median = 60.2344

Hour Period	S_{rt}	S_{rt} Equipment Error	S_{rt} Sampling Error	Worst Case	Best Case	Testing Day
	in/day	+/- in/day	+/- in/day	in/day	in/day	
1-24	0.054	0.011	0.0380	0.0645	0.0428	1
25-48	-0.018	0.011	0.0773	-0.0070	-0.0280	2
49-72	-0.049	0.010	0.0741	-0.0387	-0.0592	3
73-96	0.000	0.011	0.0592	0.0108	-0.0103	4
97-120	0.034	0.010	0.0572	0.0446	0.0236	5
Total Day 5	-0.0015	0.0105	0.0490	-0.0121	
Average	0.0043	0.0105	0.0265	0.0404	-0.0327	

The leakage rate for lagoons constructed after April 15, 2007 shall be no more than (0.125) inches (1/8 inch) per day and for existing lagoons constructed prior to April 15, 2007 shall be no more than (0.25) inches (1/4 inch) per day.

Comparison of ES and Evaporation in Pan

Seepage (S_{R1})
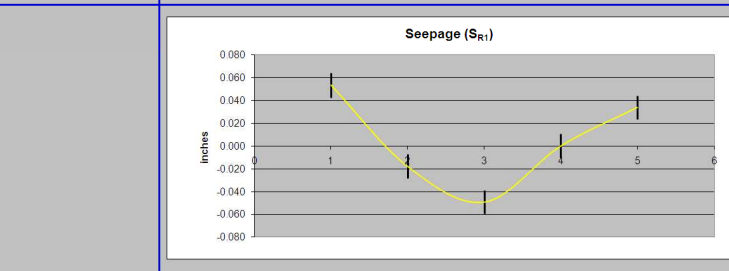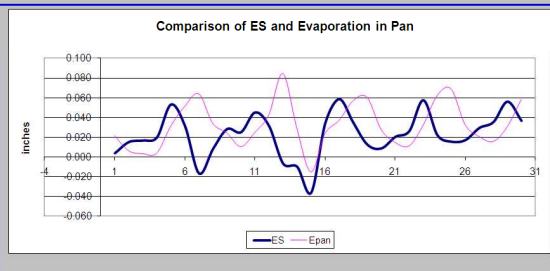
Result – From DEQ Spreadsheet

Hour Period	S_{r1}	S_{r1} Equipment Error	S_{r1} Sampling Error	Worst Case	Best Case
	in/day	+/- in/day	+/- in/day	in/day	in/day
1-24	0.054	0.011	0.0380	0.0645	0.0428
25-48	-0.018	0.010	0.0773	-0.0070	-0.0280
49-72	-0.049	0.010	0.0741	-0.0387	-0.0592
73-96	0.000	0.011	0.0592	0.0108	-0.0103
97-120	0.034	0.010	0.0572	0.0446	0.0236

Total Day 5	**-0.0015**	0.0105		0.0090	-0.0121
Average	**0.0043**	0.0105	0.0269	0.0417	-0.0331

Case Study Two
4-Cell Lagoon Wastewater Treatment

Case Study Two

	Depth (ft)	Volume (gallons)	Area (acres)
Pond 1	7	2,156,000	1.03
Pond 2	3.33	3,344,000	2.827
Pond 3	3.75	964,000	1.013
Pond 4	3.75	982,000	0.979

Issues

- The lagoons are treating flows near capacity
- Fear of permit violations
- Lagoons can not be isolated
- Lagoons can not be taken off line
- Lagoon 1 will continue aeration

- Therefore
- Seepage test all four lagoons at the same time while on line
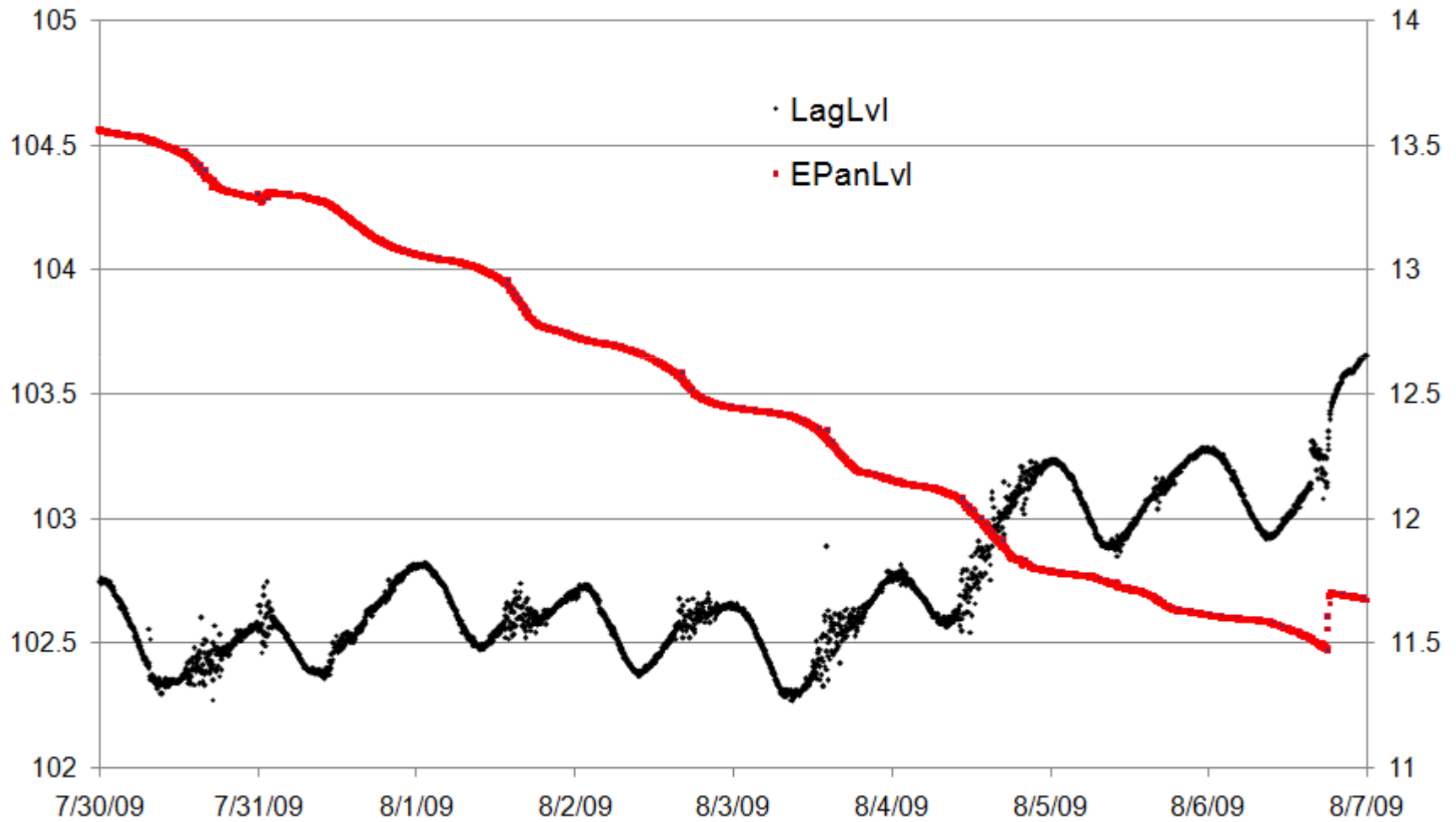
Risk

- Explain risks associated with on-line and multi cell test
- Might not pass and not know if one lagoon was leaking a lot or all of them a bit
- Not pass due to issues other than leaking (test equipment not able to resolve flow issues)
- Lagoon would have to operate consistently throughout test
- Other unknowns

Client Willing to Take Risk

- Forged ahead with a plan
- Submitted seepage testing procedure to DEQ for approval
- Install inlet and outlet flow meters
- Received DEQ approval of procedure
- Set up equipment and began collecting data

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First 8 Days

First 8 Days

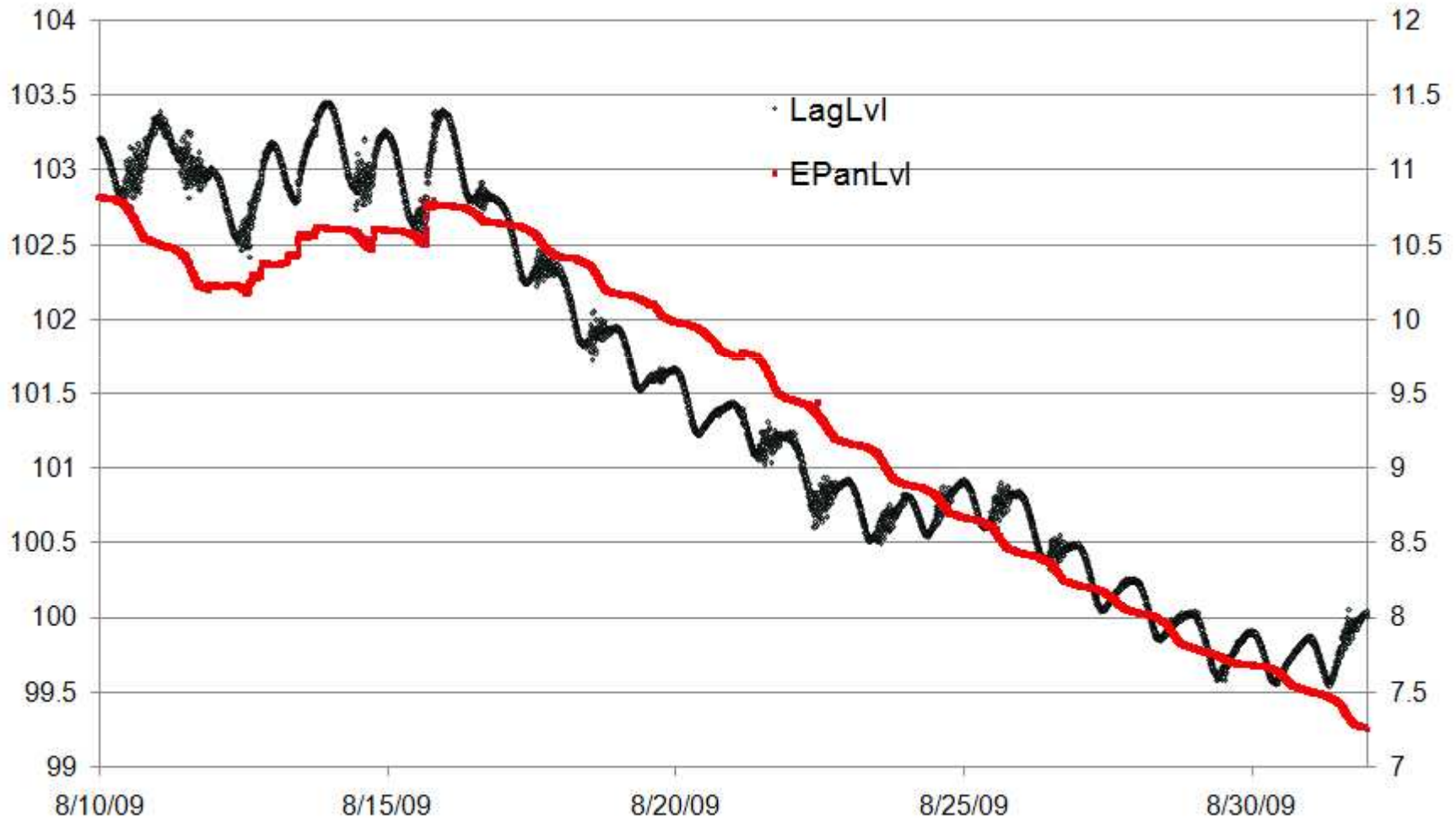| 24-Hour Period	S_{r1} in/day	S_{r1} Equipment Error +/- in/day	S_{r1} Sampling Error +/- in/day	Worst Case in/day	Best Case in/day	Testing Day
1	0.3001	0.0102	0.1918	0.3103	0.2900	1
2	0.1985	0.0102	0.1748	0.2087	0.1884	2
3	0.1897	0.0100	0.1589	0.1998	0.1797	3
4	0.0710	0.0101	0.1523	0.0811	0.0608	4
5	0.0051	0.0101	0.2048	0.0152	-0.0050	5
6	-0.2171	0.0101	0.1907	-0.2069	-0.2272	6
7	0.0396	0.0103	0.1620	0.0498	0.0293	7
8	0.0322	0.0104	0.1787	0.0426	0.0219	8
Total Day 5	0.0622	0.0102		0.0723	0.0520	
Average	0.0774	0.0102	0.0617	0.1493	0.0055	

First 8 Days
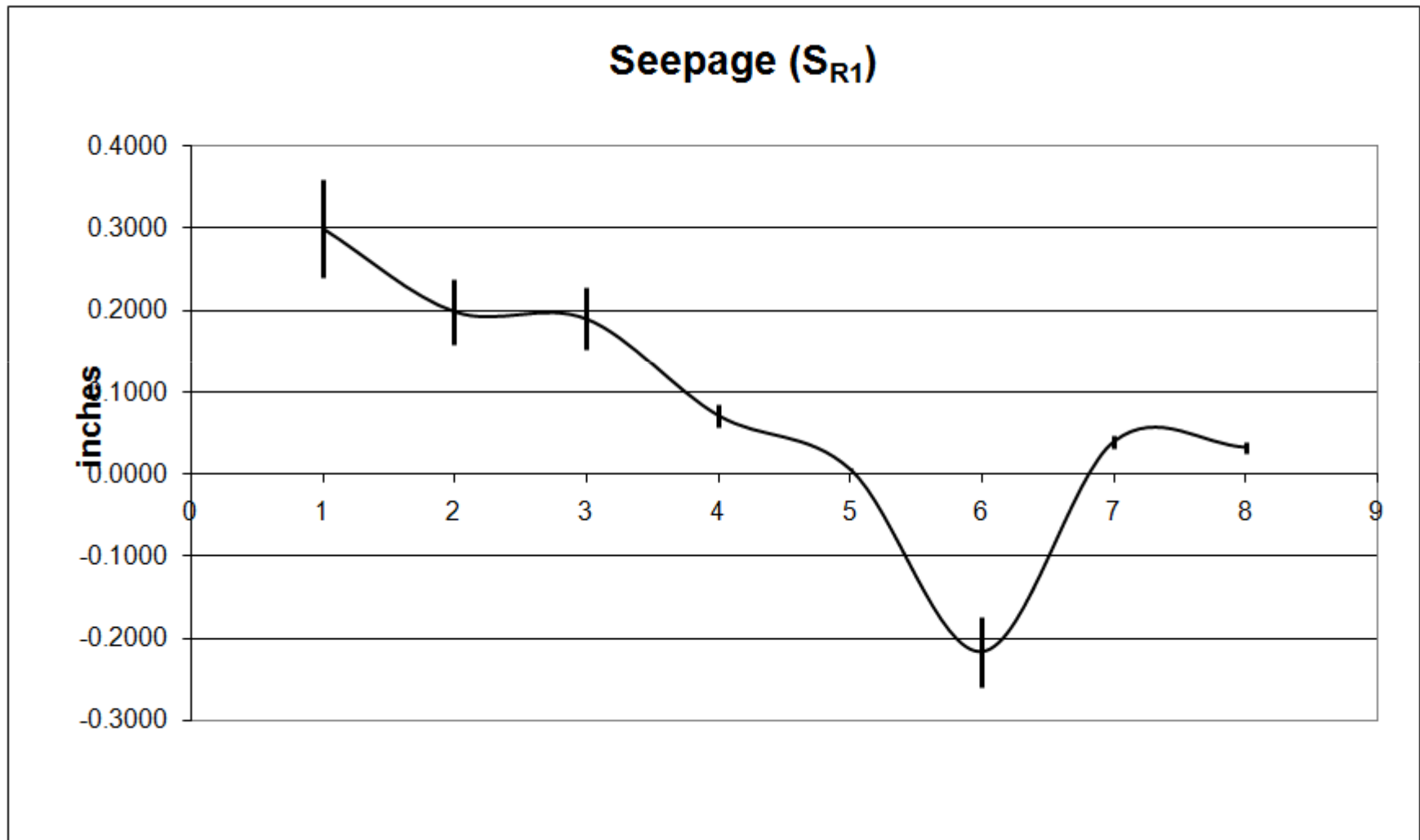
First 8 Days
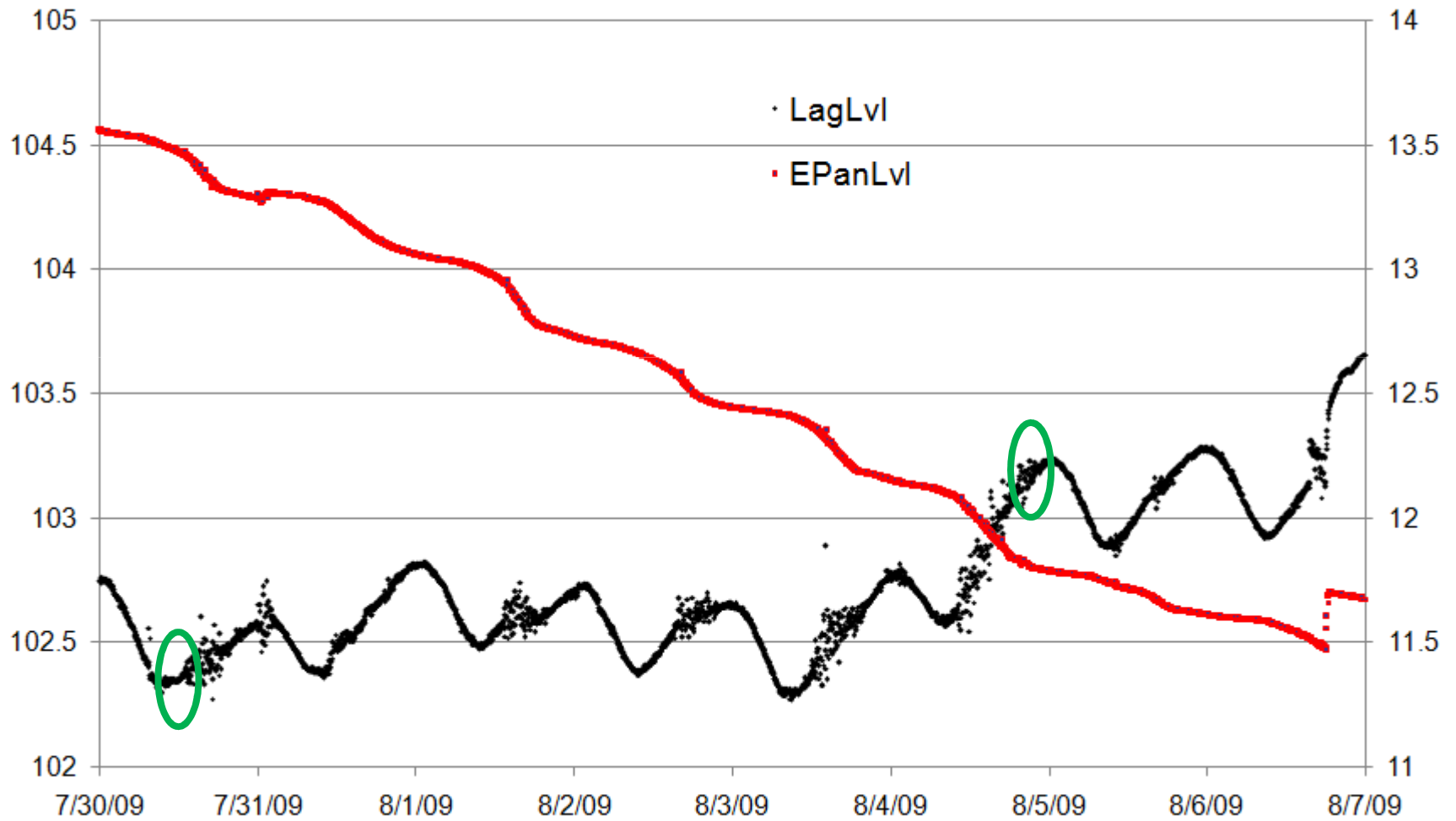
Now What

- Learned the procedure is risky
- Averaging period near peak with scatter
- Collect more data to allow a longer averaging period

- Flow meter partially plug on the 7th and not operational until the 10th.
- Cleared obstruction from Weir (pond 3 and 4)

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# Another 20 Days

20 Days

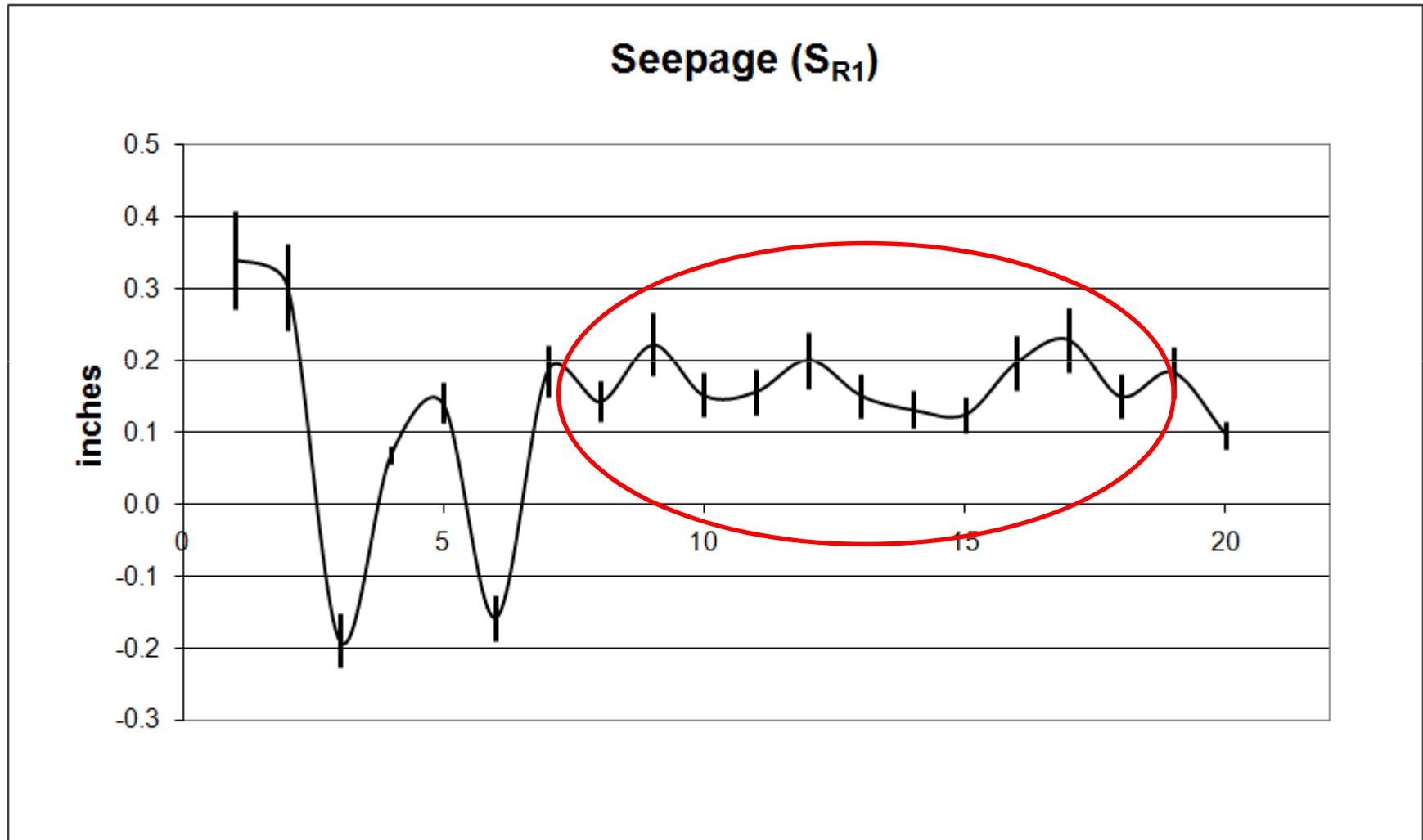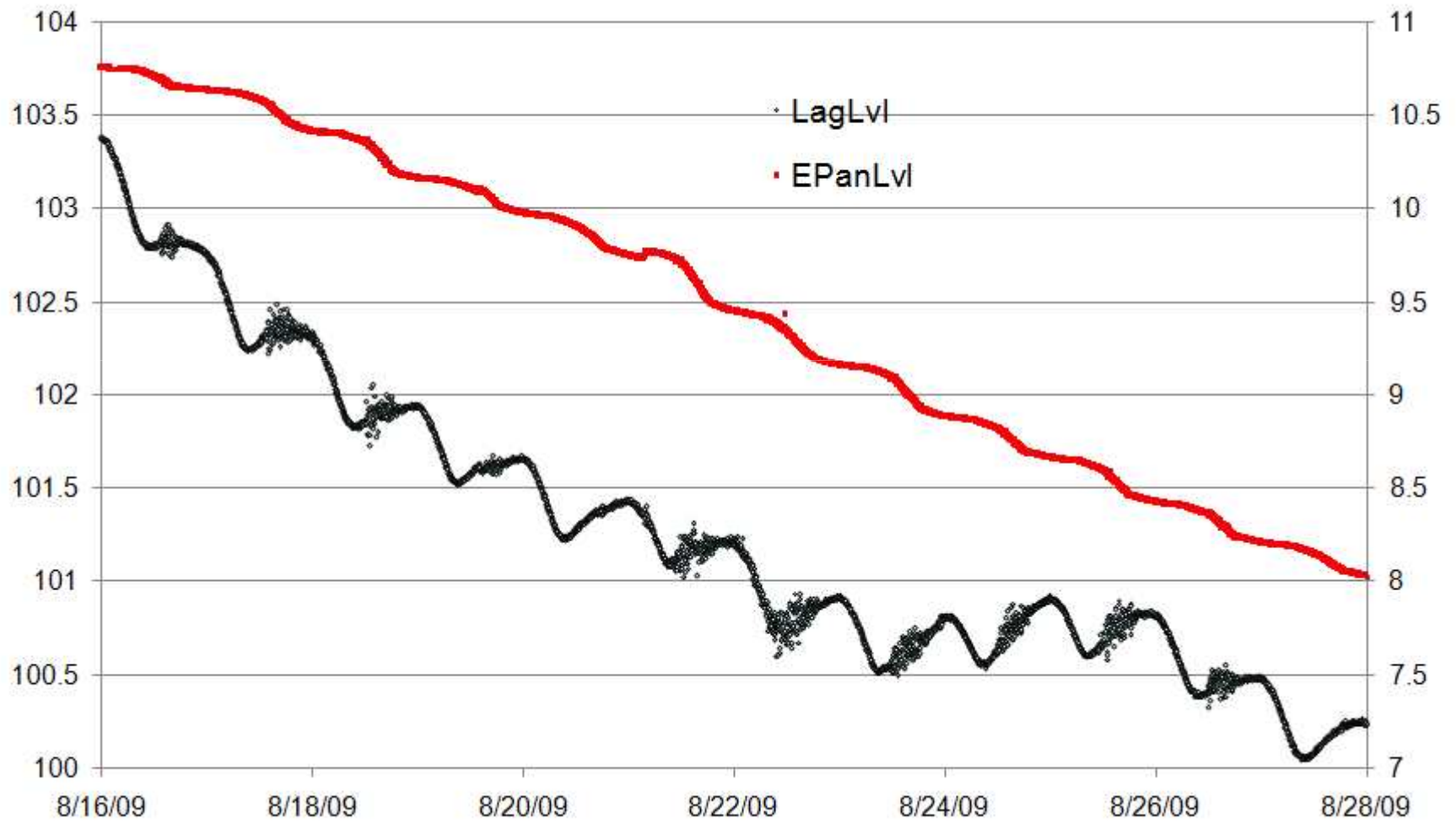|	24-Hour Period	S_{r1} in/day	S_{r1} Equipment Error +/- in/day	S_{r1} Sampling Error +/- in/day	Worst Case in/day	Best Case in/day
8/10/09 21:58	1	0.3400	0.0103	0.2663	0.3503	0.3297
8/11/09 21:58	2	0.3025	0.0106	0.1648	0.3131	0.2919
8/12/09 21:58	3	-0.1898	0.0108	0.2672	-0.1791	-0.2006
8/13/09 21:58	4	0.0677	0.0108	0.1950	0.0785	0.0569
8/14/09 21:58	5	0.1401	0.0110	0.2107	0.1511	0.1291
8/15/09 21:58	6	-0.1590	0.0108	0.3408	-0.1482	-0.1697
8/16/09 21:58	7	0.1852	0.0106	0.1825	0.1959	0.1746
8/17/09 21:58	8	0.1423	0.0103	0.1540	0.1526	0.1321
8/18/09 21:58	9	0.2220	0.0103	0.1352	0.2323	0.2117
8/19/09 21:58	10	0.1515	0.0102	0.1526	0.1617	0.1413
8/20/09 21:58	11	0.1558	0.0101	0.1227	0.1660	0.1457
8/21/09 21:58	12	0.2005	0.0103	0.1479	0.2107	0.1902
8/22/09 21:58	13	0.1500	0.0105	0.1229	0.1605	0.1395
8/23/09 21:58	14	0.1314	0.0103	0.1352	0.1417	0.1211
8/24/09 21:58	15	0.1241	0.0106	0.1409	0.1347	0.1136
8/25/09 21:58	16	0.1958	0.0104	0.1395	0.2062	0.1853
8/26/09 21:58	17	0.2289	0.0105	0.1592	0.2394	0.2184
8/27/09 21:58	18	0.1496	0.0104	0.1248	0.1601	0.1392
8/28/09 21:58	19	0.1830	0.0103	0.1603	0.1933	0.1726
8/29/09 21:58	20	0.0952	0.0104	0.1383	0.1056	0.0848
Total Day 5		0.1246	0.0106		0.1352	0.1139
Average		0.1408	0.0105	0.0585	0.2098	0.0719

20 Days
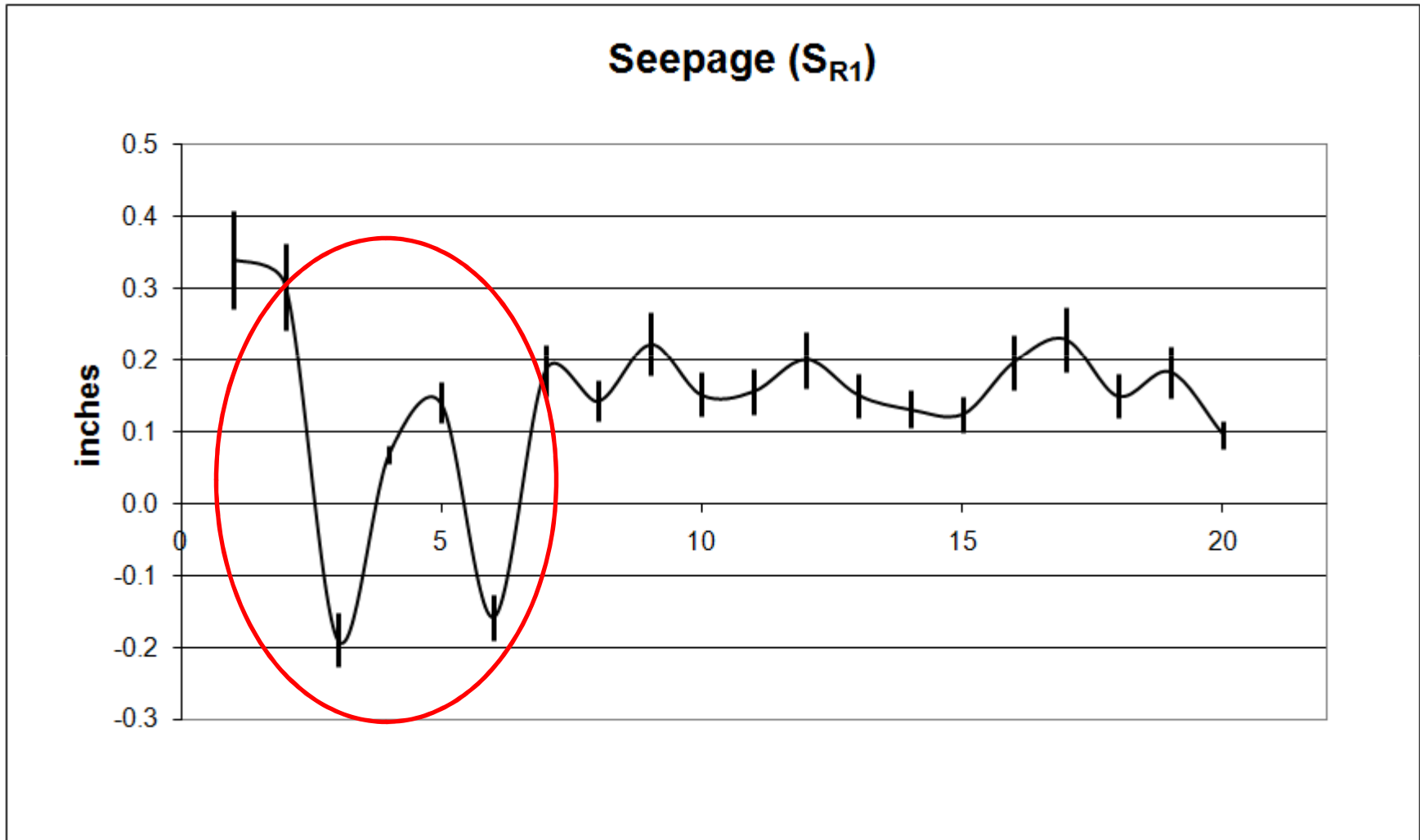
Another 20 Days
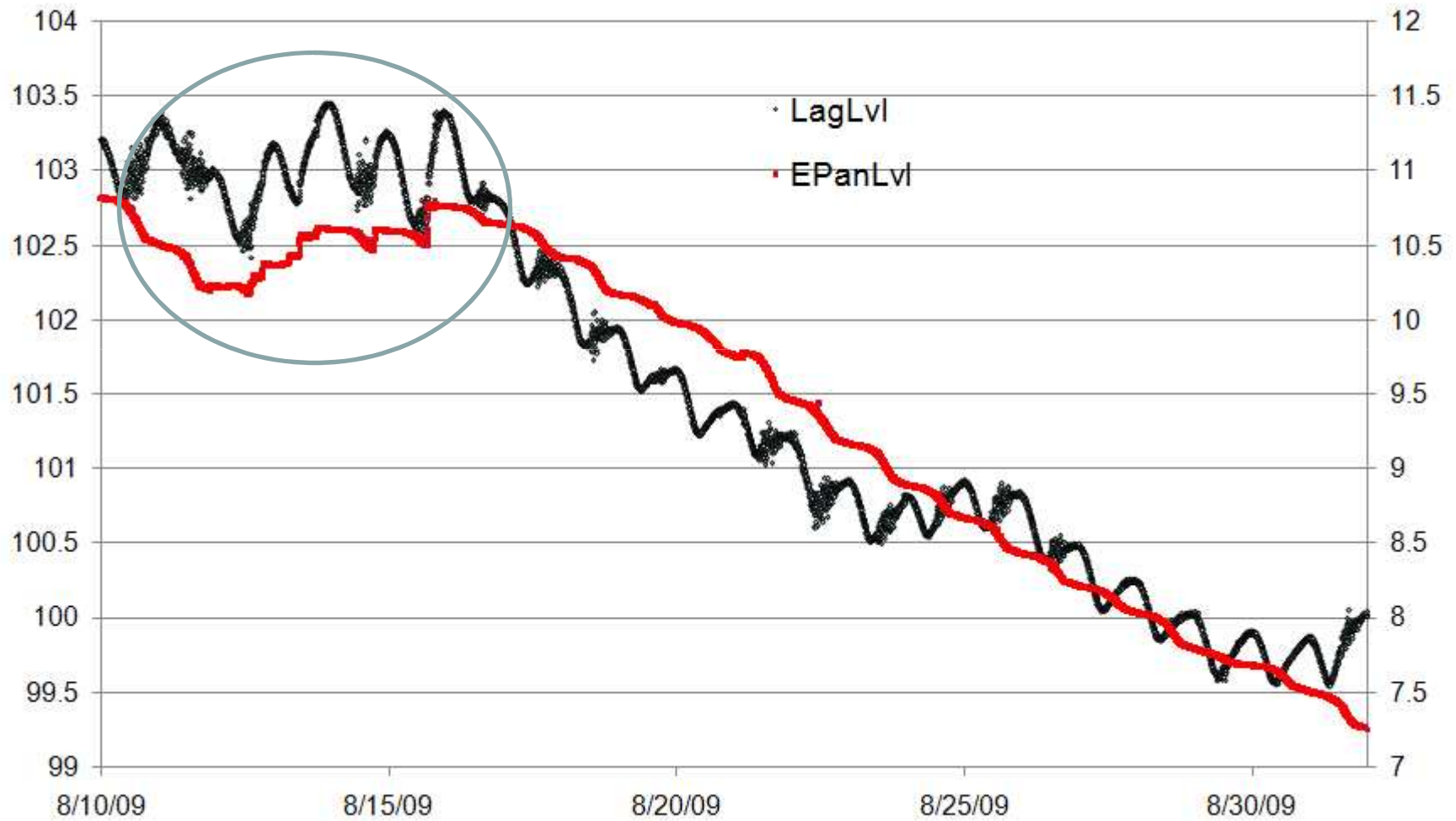
20 Days

13 day Sub Set

13 Day Sub Set

	24-Hour Period	S_{r1}	S_{r1} Equipment Error	S_{r1} Sampling Error	Worst Case	Best Case
		in/day	+/- in/day	+/- in/day	in/day	in/day
8/16/09 19:58	1	0.1592	0.0103	0.1315	0.1695	0.1489
8/17/09 19:58	2	0.1563	0.0103	0.1340	0.1665	0.1460
8/18/09 19:58	3	0.2051	0.0103	0.1414	0.2154	0.1948
8/19/09 19:58	4	0.1546	0.0102	0.1542	0.1648	0.1443
8/20/09 19:58	5	0.1752	0.0101	0.1293	0.1853	0.1651
8/21/09 19:58	6	0.2002	0.0102	0.1564	0.2104	0.1900
8/22/09 19:58	7	0.1266	0.0105	0.1405	0.1371	0.1161
8/23/09 19:58	8	0.1398	0.0103	0.1414	0.1502	0.1295
8/24/09 19:58	9	0.1193	0.0106	0.1591	0.1299	0.1087
8/25/09 19:58	10	0.1922	0.0104	0.1253	0.2026	0.1817
8/26/09 19:58	11	0.2426	0.0105	0.1342	0.2532	0.2321
8/27/09 19:58	12	0.1499	0.0105	0.1336	0.1603	0.1394
8/28/09 19:58	13	0.2014	0.0103	0.1578	0.2117	0.1912
Total Day 5		0.1551	0.0103		0.1654	0.1448
Average		0.1710	0.0104	0.0375	0.2188	0.1231

13 Day Sub Set

Seepage (SR1) in/day with 20% error Bar
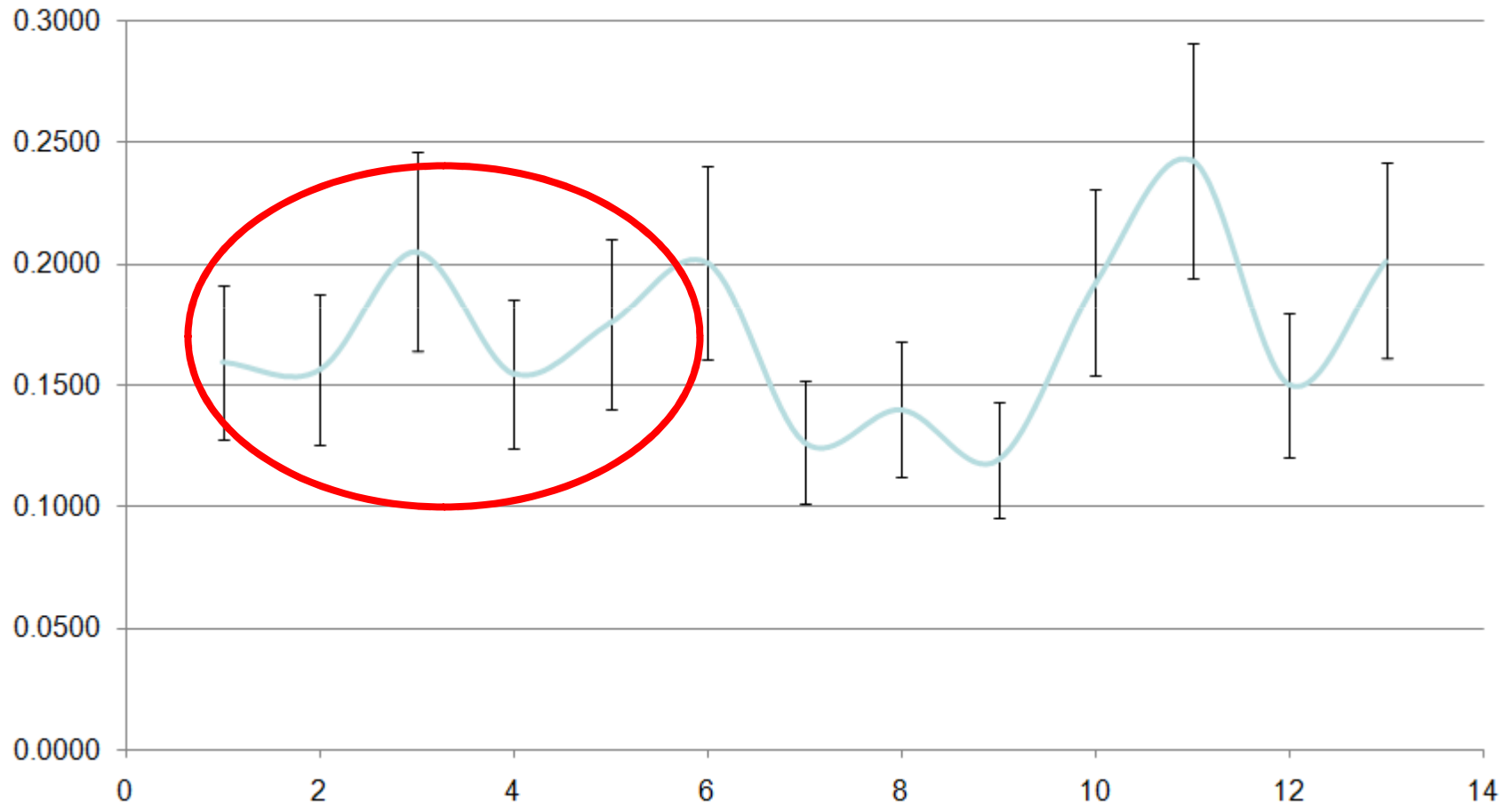
96 Hour Averaging Period

	96-Hour Period	S_{r1} in/day	S_{r1} Equipment Error +/- in/day	S_{r1} Sampling Error +/- in/day	Worst Case in/day	Best Case in/day
8/10/09 21:58	1	0.1301	0.0103	0.2663	0.1404	0.1198
8/14/09 21:58	2	0.0772	0.0106	0.1648	0.0878	0.0666
8/18/09 21:58	3	0.1824	0.0108	0.2672	0.1932	0.1717
8/22/09 21:58	4	0.1503	0.0108	0.1950	0.1611	0.1395
8/26/09 21:58	5	0.1642	0.0110	0.2107	0.1752	0.1532
Total Day 5		0.1246	0.0107		0.1353	0.1139
Average		0.1408	0.0105	0.0585	0.2098	0.0719

96 Hour Averaging Period

Seepage (S_{R1}) 96 Hour Averaging Period
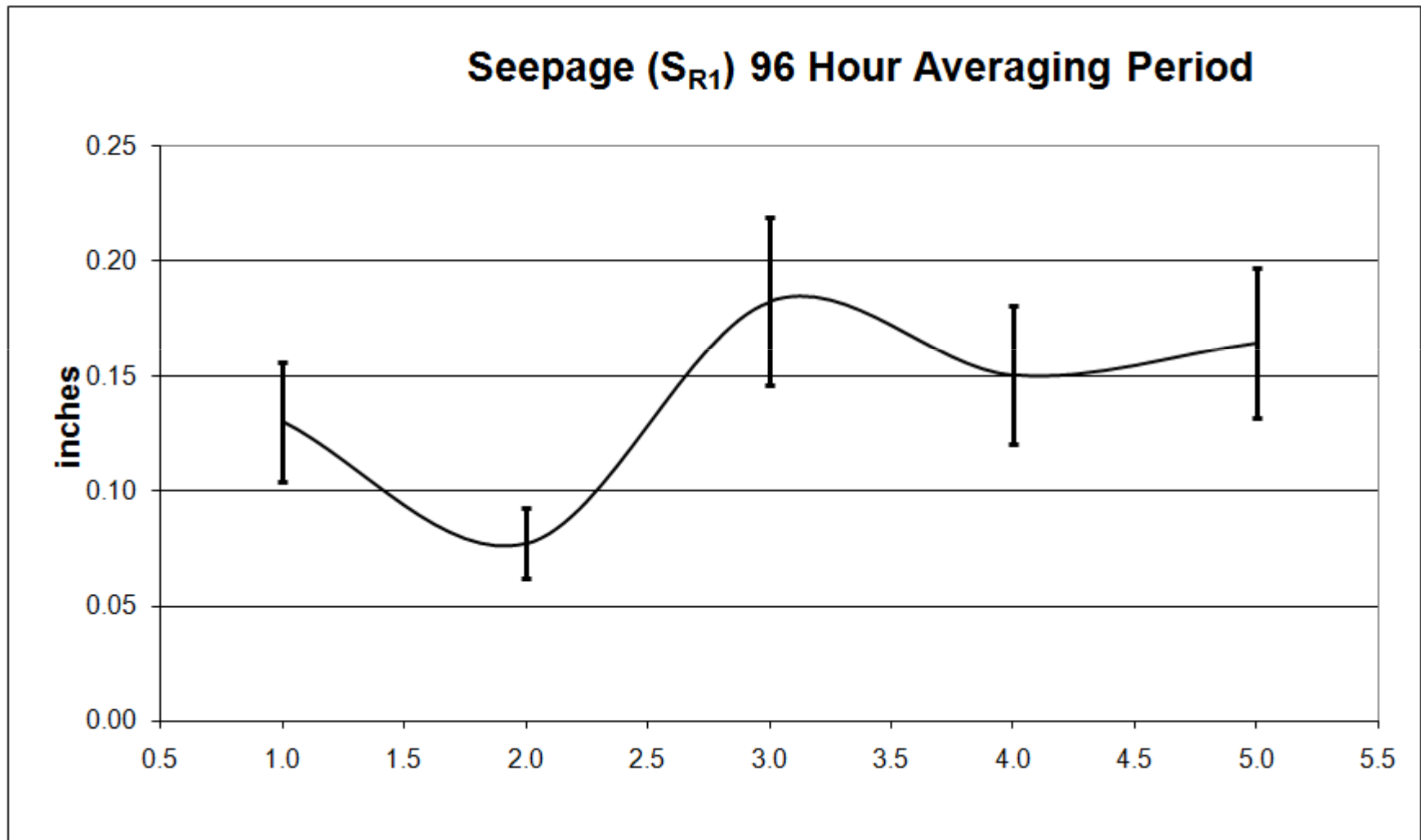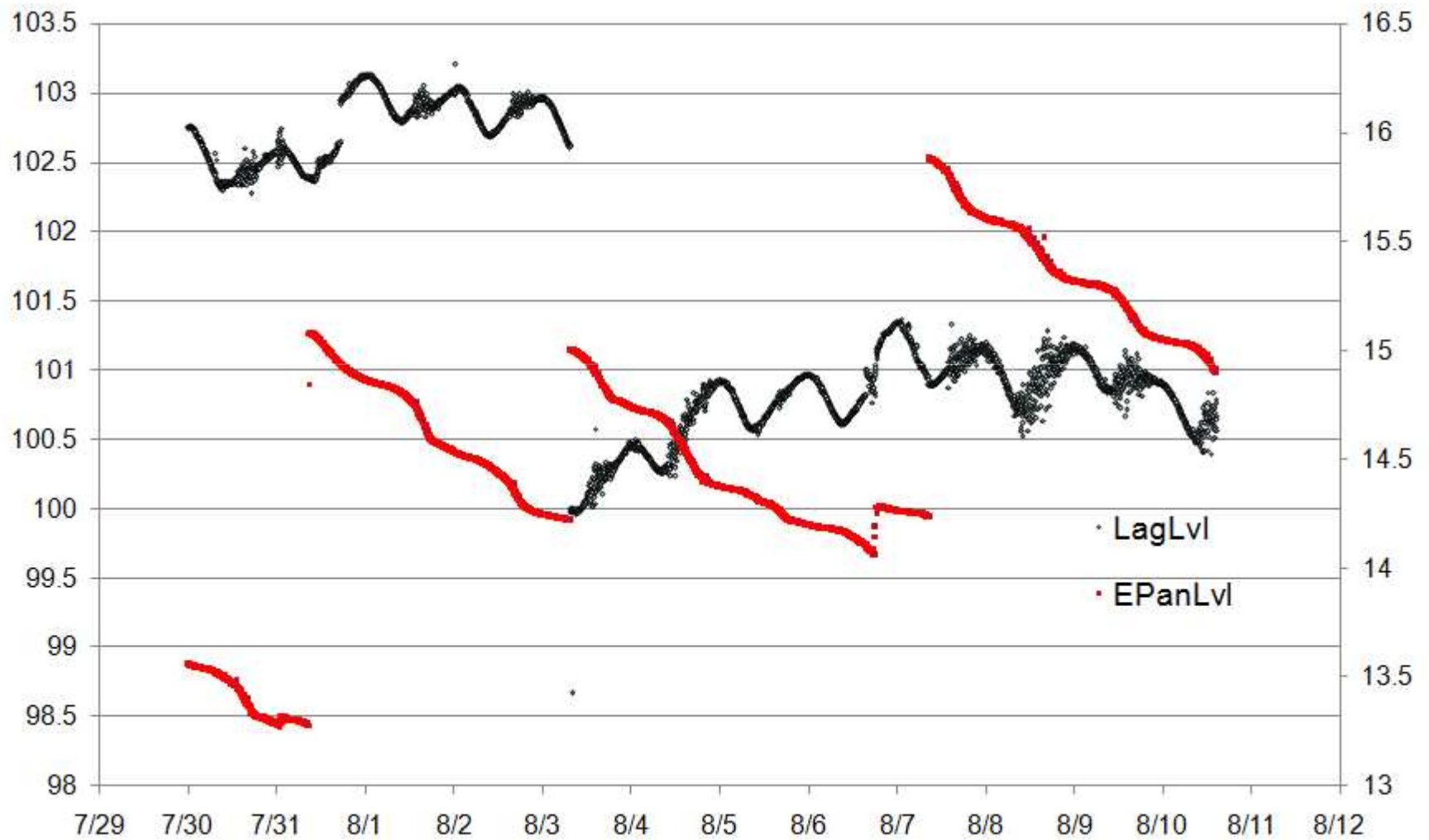
Raw Data

Math – Error Propagation

$$R = X + Y - Z$$

$$\delta R \approx \delta X + \delta Y + \delta Z$$

$$\delta R = \sqrt{(\delta X)^2 + (\delta Y)^2 + (\delta Z)^2}$$

$$R = X^n$$

$$\delta R = |n| \cdot \frac{\delta X}{|X|} \cdot |R|$$

$$R = \frac{X \cdot Y}{Z}$$

$$\frac{\delta R}{|R|} \approx \frac{\delta X}{|X|} + \frac{\delta Y}{|Y|} + \frac{\delta Z}{|Z|}$$

$$\delta R = |R| \cdot \sqrt{\left(\frac{\delta X}{X}\right)^2 + \left(\frac{\delta Y}{Y}\right)^2 + \left(\frac{\delta Z}{Z}\right)^2}$$

$$R = c \cdot X$$

$$\delta R = |c| \cdot \delta X$$

$$R = R(X, Y, \ldots)$$

$$\delta R = \sqrt{\left(\frac{\partial R}{\partial X} \cdot \delta X\right)^2 + \left(\frac{\partial R}{\partial Y} \cdot \delta Y\right)^2 + \ldots}$$

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Math

Seepage/time
Ave of 6 4-hr time steps

Fully Propagated Error

STDEV(6,4-hr)/ Count

	24-Hour Period	S_{r1}	S_{r1} Equipment Error	S_{r1} Sampling Error	Worst Case	Best Case
		in/day	+/- in/day	+/- in/day	in/day	in/day
8/16/09 19:58	1	0.1592	0.0103	0.1315	0.1695	0.1489
8/17/09 19:58	2	0.1563	0.0103	0.1340	0.1665	0.1460
8/18/09 19:58	3	0.2051	0.0103	0.1414	0.2154	0.1948
8/19/09 19:58	4	0.1546	0.0102	0.1542	0.1648	0.1443
8/20/09 19:58	5	0.1752	0.0101	0.1293	0.1853	0.1651
8/21/09 19:58	6	0.2002	0.0102	0.1564	0.2104	0.1900
8/22/09 19:58	7	0.1266	0.0105	0.1405	0.1371	0.1161
8/23/09 19:58	8	0.1398	0.0103	0.1414	0.1502	0.1295
8/24/09 19:58	9	0.1193	0.0106	0.1501	0.1299	0.1087
8/25/09 19:58	10	0.1922	0.0104	0.1253	0.2026	0.1817
8/26/09 19:58	11	0.2426	0.0105	0.1342	0.2532	0.2321
8/27/09 19:58	12	0.1499	0.0105	0.1336	0.1603	0.1394
8/28/09 19:58	13	0.2014	0.0103	0.1578	0.2117	0.1912
Total Day 13		0.1551	0.0103		0.1654	0.1448
Average		0.1710	0.0104	0.0375	0.2188	0.1231

Uses End Result

Average of 4-hr Time Step