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April 12, 2005 ACG File No.: YTG-04-01

Memo To: Hugh Copland, P.Eng. – A/Manager, Type II Sites
Government of Yukon, Department of Energy, Mines, & Resources

Frank Patch – Project Manager, Type II Sites
Government of Yukon, Department of Energy, Mines, & Resources

Dissolved Metal Water Quality Investigation for Galkeno 300 Fugitive Flow, 2004/05

Dear Hugh,

This report is in response to a request for information and data interpretation regarding dissolved metal concentrations – specifically Zn - from the Galkeno 300 Fugitive Flow at Keno Hill. This request was made of ACG by F. Patch of your office in January of this year. Access Consulting Group (ACG) is pleased to provide an interpretation of specific water quality data previously collected by Ewing Transport Ltd. and ACG as part of the Galkeno 300 Fugitive Flow Monitoring Program.

Should you have any questions regarding this report, please feel free to contact D. Cornett or S. Keesey at 668-6463.

Respectfully submitted,
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Reviewed by:

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Background and Introduction

Access Consulting Group (ACG) has been conducting water quality sampling of the Galkeno 300 Fugitive Flow and Receiving Environment on a regular basis as part of their contract with YG for Care and Maintenance of the Keno Hill Property since early 2004. Sampling and analysis on a monthly basis has included dissolved and total metal scans, with reporting and operational decisions focusing on the results for total metals, in particular Zn.

Results for total Zn analysis have been highly variable at most sites between the Galkeno 300 pond decant and where the flow reports to Christal Creek, and are dependant upon a variety of factors both identified and unidentified, such as:

- natural fluctuations in raw adit flow Zn concentrations,
- time since pond clean-out activities,
- seasonal fluctuations,
- natural attenuation and geochemical processes which sequester metals on the Galena Hill slope above the Silver Trail Highway, including those described by D. MacGregor (2002) and others.

This data compilation and interpretation was compiled in an attempt to determine the treatment efficiency for dissolved Zn at the Galkeno 300 (G300) treatment system and to characterize the dissolved Zn concentrations along the G300 fugitive flow path.

Methodology

The investigation utilized a data set of previously collected sampling results where both dissolved and total metals samples were collected at the same time, by the same sampler and were analyzed at the same laboratory. This approach was aimed at reducing sampling and analytical error during the data comparison. These paired values for [dissolved Zn] and [total Zn] were represented as a ***ratio*** – [dissolved Zn] / [total Zn]. The relationship between this ratio, expressed in percent (%) and the following variables was explored by initially plotting the comparative data:

- Total Zn concentration;
- Location of sampling site; and
- Time of year (expressed numerically as Julian Date).

The plotted data was then either analyzed in MS Excel using linear regression and methods from *Elementary Statistics* (Triola,1995) to determine the degree of correlation between the ratio and the variable in question (Figures 3, 4 and 5), or the plots were interpreted visually for trends (Figures 6 and 7). These analyses serve to identify any significant relationships between these variables and the relative distribution of Zn ***in solution*** and ***in suspension*** in the fugitive flow and the receiving waters that the flow reports to.

Results

Tables 1 and 2 display the data set used in this investigation. Table 1 contains data from the sites pertaining directly to the treatment efficiency, and Table 2 show data for the remaining sites in the receiving environment. Mean ratio values are displayed for each sampling location, as is the standard deviation of ratio values for each sampling site. In the complete set of sampling results between February 2004 and February 2005, there were a few instances where the dissolved Zn concentration actually exceeded the result for total Zn at given sites. These results, attributed to either the inherent variability in analytical accuracy with Zn or sample contamination, were excluded from the investigation.

The initial question explored in this investigation was how the treatment system performs with respect to removal of dissolved metals. Using Zn as the indicator parameter, Figures 1 and 2 show the relative distribution of Zn (solution vs. suspension) over the course of the study period in the raw adit flow and in the treatment pond decant flow respectively. Visual comparison of these figures shows not only the greater degree of variation in the total Zn results for the pond decant in Figure 2 (attributed to variability in treatment efficacy), but also the high degree of variation in dissolved Zn levels within the total Zn concentration.

This difference is illustrated numerically in Figure 3, where the mean dissolved/total Zn ratio was charted for each site and variation represented by the standard deviation (SD) is shown. The sample size (n) for each site is included as well. This figure illustrates that for each site included in the investigation, the mean ratio values are in excess of 50%, meaning that the majority of aqueous Zn in the samples collected, independent of site, was ***in solution.*** There is a decrease in the *mean* ratio values between the raw adit flow and the treatment pond decant site, however the high standard deviation value for the latter reflects the aforementioned variation in dissolved Zn concentrations. This reduces confidence in the tempting conclusion that the treatment system consistently reduces the proportion of dissolved Zn in the adit discharge.

Figures 4, 5 and 6 explore the question of how the ratio values relate back to the initial total Zn concentration. Figure 4 shows the plot and regression analysis of the ratio values vs. the total Zn concentration for the entire data set. The trendline for the scatter plot is shown, as is the $\mathbf{R^2}$ value (coefficient of determination) that represents the percentage of variation in the ratio explained by variation in the total Zn concentration. The value of 0.0108 means that only 1.08% of the variation in the ratio value can be attributed to variation in the total Zn concentration (Triola, 1995.) Essentially, the total Zn concentration has no bearing on what proportion of Zn is in solution across the entire data set.

Statistically, the square root of the coefficient of determination is ***r*** *(the linear correlation coefficient.)* This value can be compared against established criteria to determine the significance of the relationship. For Figure 4:

$\mathbf{r} = \sqrt{R^2}$ **criteria** (n = 110, 95% confidence) = 0.190

$= \sqrt{0.0108}$

$= 0.104$

r is not ≥ 0.190, therefore:

There is not sufficient evidence to support the claim that there is a linear relationship between the two variables. (Triola, 1995)

Figures 5 and 6 examine this relationship at key sites in the treatment regime and receiving environment. Figure 5 shows that at individual key treatment sites some relationships become evident. The relationships at the pond decant and Culvert 4 are not strong, with the least degree of correlation being observed at the treatment decant site (R^2 = 6.39%.) These two relationships are again statistically insignificant. The raw adit flow returns different results, however. The 48.29% R^2 value for the raw adit flow (r = 0.695) compared against the criteria of 0.666 (n=9, 95% confidence) reveals a negative correlation between the two variables, or as the total Zn concentration increases, the percentage in solution decreases. Approximately half of this relationship can be deemed *cause and effect.*

Figure 6 illustrates similar results in the receiving environment. Of note is that the South McQuesten River background site (KV-1) results analysis showed the greatest percentage of variation in the ratio explained by variation in the total metal results, with the percentage of Zn in solution sharply *decreasing* as total Zn levels rise. This relationship shows a strong and significant negative correlation (r = 0.836, criteria [n = 7, 95% confidence] = 0.754.) Without the influence of current mine water discharge or previous mining activities, this background site sees total metal results rising primarily during spring freshet events when turbidity is high and the majority of metals are bound with particulate metal in suspension. This relationship is not supported at the other sites, with previous mining activities (KV-6 on Christal Creek u/s of Silver Trail - Mackeno tailings) and adit discharge from G300 apparently impacting how these variables relate. Essentially, it cannot be surmised that the relative proportion of dissolved Zn in the G300 flow - from the decant through to the downstream receiving waters - decreases as the total Zn levels increase during periods of treatment inefficacy.

The final Figure 7 shows the ratio values plotted against time of year (converted into Julian Date, i.e. 1-365) for all paired values. Also plotted are the mean ratio values for each sampling event. Statistical variance notwithstanding in this figure, there is a weak trend observable where the mean proportion of Zn in solution is lower, relatively speaking, during the “open” season months (May – August.) This trend is not strong when variation is taken into account, however, and statistically these non-linear trends are difficult to analyze for cause and effect (Triola, 1995.)

Conclusion

Dissolved metal levels in waters associated with the G300 Adit discharge, as represented by Zn, are highly variable both in terms of absolute values and in their proportional representation of total metals concentrations. The percentage of metals (represented by Zn) in solution is most variable in the decant and Culvert 4 sample sets. It could not be determined that seasonal fluctuations have any bearing on the distribution of Zn between dissolved and suspended phases. The proportional contribution of dissolved Zn is negatively correlated to the total Zn concentrations at only two sites: the Galkeno 300 adit discharge, and the background South McQuesten River site. At all other sites, there is no correlation, suggesting that the G300 treatment system is producing a more random and less predictable distribution of metals between the dissolved and suspended phases. Further review of the data set with an improved G300 treatment system may be warranted at a later date.

Table 1. Treatment System Data Table for Dissolved Zinc G300 Investigation - April 1, 2005

Date	Site ID	Location	[Dissolved Zn] ppm	[Total Zn] ppm	Ratio (Diss/Tot)	Mean Ratio	Standard Deviation
19-Feb-04	Raw	G300 Adit - Raw	92.6	144	64.31%	88.46%	0.12
23-Mar-04	Raw	G300 Adit - Raw	132	133	99.25%		
24-Apr-04	Raw	G300 Adit - Raw	108	109	99.08%		
20-May-04	Raw	G300 Adit - Raw	104	105	99.05%		
24-Aug-04	Raw	G300 Adit - Raw	113	128	88.28%		
21-Oct-04	Raw	G300 Adit - Raw	128	140	91.43%		
29-Nov-04	Raw	G300 Adit - Raw	134	169	79.29%		
16-Dec-04	Raw	G300 Adit - Raw	116	149	77.85%		
25-Jan-05	Raw	G300 Adit - Raw	123	126	97.62%		
23-Mar-04	Decant	G300 Pond Decant	69.1	74.8	92.38%	51.21%	0.45
24-Apr-04	Decant	G300 Pond Decant	60.5	61.1	99.02%		
20-May-04	Decant	G300 Pond Decant	8.73	15.4	56.69%		
21-Jul-04	Decant	G300 Pond Decant	23.5	24.7	95.14%		
24-Aug-04	Decant	G300 Pond Decant	0.67	129	0.52%		
21-Sep-04	Decant	G300 Pond Decant	6.99	9.07	77.07%		
21-Oct-04	Decant	G300 Pond Decant	14	16.1	86.96%		
29-Nov-04	Decant	G300 Pond Decant	0.005	0.293	1.71%		
16-Dec-04	Decant	G300 Pond Decant	0.366	14	2.61%		
25-Jan-05	Decant	G300 Pond Decant	0.004	103	0.00%		
19-May-04	Culvert 4 - Hillside	Silver Trail Hwy	14.8	15	98.67%	85.65%	0.41
17-Jun-04	Culvert 4 - Hillside	Silver Trail Hwy	17.4	47.4	36.71%		
24-Aug-04	Culvert 4 - Hillside	Silver Trail Hwy	7.87	65.5	12.02%		
22-Oct-04	Culvert 4 - Hillside	Silver Trail Hwy	2.33	2.72	85.66%		
23-Mar-04	Culvert 4	Silver Trail Hwy	80.6	81.4	99.02%	77.97%	0.25
17-Jun-04	Culvert 4	Silver Trail Hwy	19.4	57.3	33.86%		
22-Oct-04	Culvert 4	Silver Trail Hwy	2.35	2.77	84.84%		
30-Nov-04	Culvert 4	Silver Trail Hwy	1.92	2.22	86.49%		
17-Dec-04	Culvert 4	Silver Trail Hwy	2.03	2.37	85.65%		

Table 2. Receiving Environment Data Table for Dissolved Zinc G300 Investigation - April 1, 2005

Date	Site ID	Location	[Dissolved Zn] ppm	[Total Zn] ppm	Ratio (Diss/Tot)	Mean Ratio	Standard Deviation
19-Feb-04	KV6	Christal Cr. - u/s Silver Trail	0.154	0.164	93.90%	92.86%	0.06
23-Mar-04	KV6	Christal Cr. - u/s Silver Trail	0.175	0.177	98.87%		
24-Apr-04	KV6	Christal Cr. - u/s Silver Trail	0.169	0.171	98.83%		
19-May-04	KV6	Christal Cr. - u/s Silver Trail	0.13	0.164	79.27%		
16-Jun-04	KV6	Christal Cr. - u/s Silver Trail	0.346	0.35	98.86%		
21-Jul-04	KV6	Christal Cr. - u/s Silver Trail	0.664	0.678	97.94%		
24-Aug-04	KV6	Christal Cr. - u/s Silver Trail	0.343	0.396	86.62%		
22-Oct-04	KV6	Christal Cr. - u/s Silver Trail	0.245	0.27	90.74%		
17-Dec-04	KV6	Christal Cr. - u/s Silver Trail	0.214	0.237	90.30%		
25-Jan-05	KV6	Christal Cr. - u/s Silver Trail	0.153	0.164	93.29%		
19-Feb-04	Site A	Christal Cr - u/s G300 influence	5.17	5.41	95.56%	88.31%	0.18
23-Mar-04	Site A	Christal Cr - u/s G300 influence	4.35	4.400	98.86%		
24-Apr-04	Site A	Christal Cr - u/s G300 influence	2.21	2.24	98.66%		
19-May-04	Site A	Christal Cr - u/s G300 influence	0.109	0.284	38.38%		
16-Jun-04	Site A	Christal Cr - u/s G300 influence	0.276	0.279	98.92%		
21-Jul-04	Site A	Christal Cr - u/s G300 influence	0.506	0.536	94.40%		
21-Sep-04	Site A	Christal Cr - u/s G300 influence	0.234	0.245	95.51%		
22-Oct-04	Site A	Christal Cr - u/s G300 influence	0.218	0.25	87.20%		
29-Nov-04	Site A	Christal Cr - u/s G300 influence	0.216	0.243	88.89%		
25-Jan-05	Site A	Christal Cr - u/s G300 influence	0.156	0.18	86.67%		
19-Feb-04	Site C	Culvert 5 Flow before Christal Cr	22.4	22.8	98.25%	92.19%	0.10
23-Mar-04	Site C	Culvert 5 Flow before Christal Cr	30.9	31.2	99.04%		
24-Apr-04	Site C	Culvert 5 Flow before Christal Cr	33.8	34.1	99.12%		
19-May-04	Site C	Culvert 5 Flow before Christal Cr	2.22	2.9	76.55%		
16-Jun-04	Site C	Culvert 5 Flow before Christal Cr	3.75	3.8	98.68%		
17-Dec-04	Site C	Culvert 5 Flow before Christal Cr	3.39	4.16	81.49%		
19-Feb-04	Site D	Christal Cr d/s G300 influence	4.63	4.68	98.93%	80.57%	0.25
23-Mar-04	Site D	Christal Cr d/s G300 influence	5.73	5.79	98.96%		
24-Apr-04	Site D	Christal Cr d/s G300 influence	4.66	4.71	98.94%		
19-May-04	Site D	Christal Cr d/s G300 influence	0.342	0.65	52.62%		
16-Jun-04	Site D	Christal Cr d/s G300 influence	1.99	6.54	30.43%		
21-Jul-04	Site D	Christal Cr d/s G300 influence	1.26	1.33	94.74%		
24-Aug-04	Site D	Christal Cr d/s G300 influence	1.67	3.97	42.07%		
21-Sep-04	Site D	Christal Cr d/s G300 influence	0.53	0.538	98.51%		
22-Oct-04	Site D	Christal Cr d/s G300 influence	0.512	0.553	92.59%		
29-Nov-04	Site D	Christal Cr d/s G300 influence	0.371	0.389	95.37%		
17-Dec-04	Site D	Christal Cr d/s G300 influence	0.322	0.427	75.41%		
25-Jan-05	Site D	Christal Cr d/s G300 influence	0.219	0.248	88.31%		

Table 2. Receiving Environment Data Table for Dissolved Zinc G300 Investigation - April 1, 2005

Date	Site ID	Location	[Dissolved Zn] ppm	[Total Zn] ppm	Ratio (Diss/Tot)	Mean Ratio	Standard Deviation
19-Feb-04	KV7	Christal Cr - @ Hanson Rd	2.1	2.14	98.13%	82.87%	0.30
23-Mar-04	KV7	Christal Cr - @ Hanson Rd	2.53	2.560	98.83%		
24-Apr-04	KV7	Christal Cr - @ Hanson Rd	2.13	2.16	98.61%		
19-May-04	KV7	Christal Cr - @ Hanson Rd	0.001	0.759	0.13%		
15-Jun-04	KV7	Christal Cr - @ Hanson Rd	1	2.28	43.86%		
20-Jul-04	KV7	Christal Cr - @ Hanson Rd	0.373	0.392	95.15%		
24-Aug-04	KV7	Christal Cr - @ Hanson Rd	1.29	1.31	98.47%		
21-Sep-04	KV7	Christal Cr - @ Hanson Rd	0.349	0.387	90.18%		
21-Oct-04	KV7	Christal Cr - @ Hanson Rd	0.608	0.635	95.75%		
29-Nov-04	KV7	Christal Cr - @ Hanson Rd	0.282	0.291	96.91%		
17-Dec-04	KV7	Christal Cr - @ Hanson Rd	0.25	0.275	90.91%		
25-Jan-05	KV7	Christal Cr - @ Hanson Rd	0.189	0.216	87.50%		
23-Mar-04	KV8	Christal Cr @ mouth	1.89	1.910	98.95%	84.57%	0.17
24-Apr-04	KV8	Christal Cr @ mouth	1.84	1.86	98.92%		
19-May-04	KV8	Christal Cr @ mouth	0.472	0.684	69.01%		
15-Jun-04	KV8	Christal Cr @ mouth	0.768	1.47	52.24%		
20-Jul-04	KV8	Christal Cr @ mouth	0.221	0.322	68.63%		
21-Sep-04	KV8	Christal Cr @ mouth	0.383	0.398	96.23%		
21-Oct-04	KV8	Christal Cr @ mouth	0.586	0.614	95.44%		
29-Nov-04	KV8	Christal Cr @ mouth	0.357	0.385	92.73%		
17-Dec-04	KV8	Christal Cr @ mouth	0.322	0.362	88.95%		
23-Mar-04	KV1	S.McQ River - background	0.026	0.027	96.30%	65.38%	0.26
19-May-04	KV1	S.McQ River - background	0.009	0.058	15.52%		
20-Jul-04	KV1	S.McQ River - background	0.015	0.03	50.00%		
21-Sep-04	KV1	S.McQ River - background	0.015	0.02	75.00%		
21-Oct-04	KV1	S.McQ River - background	0.01	0.013	76.92%		
17-Dec-04	KV1	S.McQ River - background	0.021	0.031	67.74%		
25-Jan-05	KV1	S.McQ River - background	0.016	0.021	76.19%		
19-Feb-04	KV2	S.McQ River - Pumphouse	0.139	0.142	97.89%	79.55%	0.23
23-Mar-04	KV2	S.McQ River - Pumphouse	0.204	0.206	99.03%		
24-Apr-04	KV2	S.McQ River - Pumphouse	0.115	0.116	99.14%		
19-May-04	KV2	S.McQ River - Pumphouse	0.084	0.158	53.16%		
15-Jun-04	KV2	S.McQ River - Pumphouse	0.036	0.059	61.02%		
20-Jul-04	KV2	S.McQ River - Pumphouse	0.012	0.04	30.00%		
21-Sep-04	KV2	S.McQ River - Pumphouse	0.03	0.038	78.95%		
21-Oct-04	KV2	S.McQ River - Pumphouse	0.021	0.029	72.41%		
29-Nov-04	KV2	S.McQ River - Pumphouse	0.037	0.038	97.37%		
17-Dec-04	KV2	S.McQ River - Pumphouse	0.042	0.046	91.30%		
25-Jan-05	KV2	S.McQ River - Pumphouse	0.036	0.038	94.74%		
20-May-04	KV5	S.McQ River - d/s Flat Creek	0.037	0.063	58.73%	64.97%	0.21
14-Jun-04	KV5	S.McQ River - d/s Flat Creek	0.028	0.051	54.90%		
22-Sep-04	KV5	S.McQ River - d/s Flat Creek	0.02	0.025	80.00%		
30-Nov-04	KV5	S.McQ River - d/s Flat Creek	0.014	0.036	38.89%		
25-Jan-05	KV5	S.McQ River - d/s Flat Creek	0.024	0.026	92.31%		

Figure 1. Total and Dissolved Zn Concentrations in G300 Raw Adit Water Samples

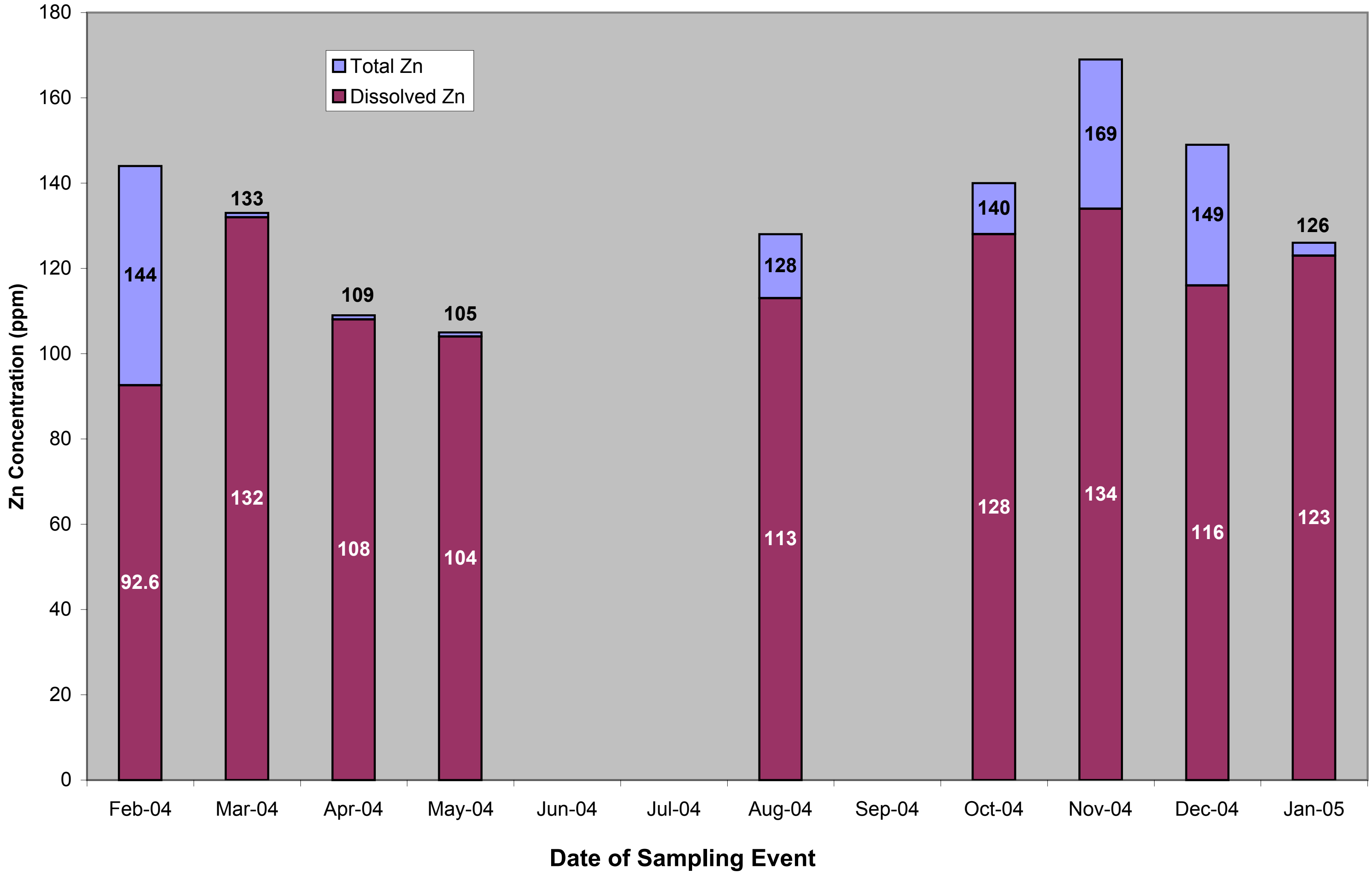


Figure 2. Total and Dissolved Zn Concentrations in G300 Treated Decant Water Samples

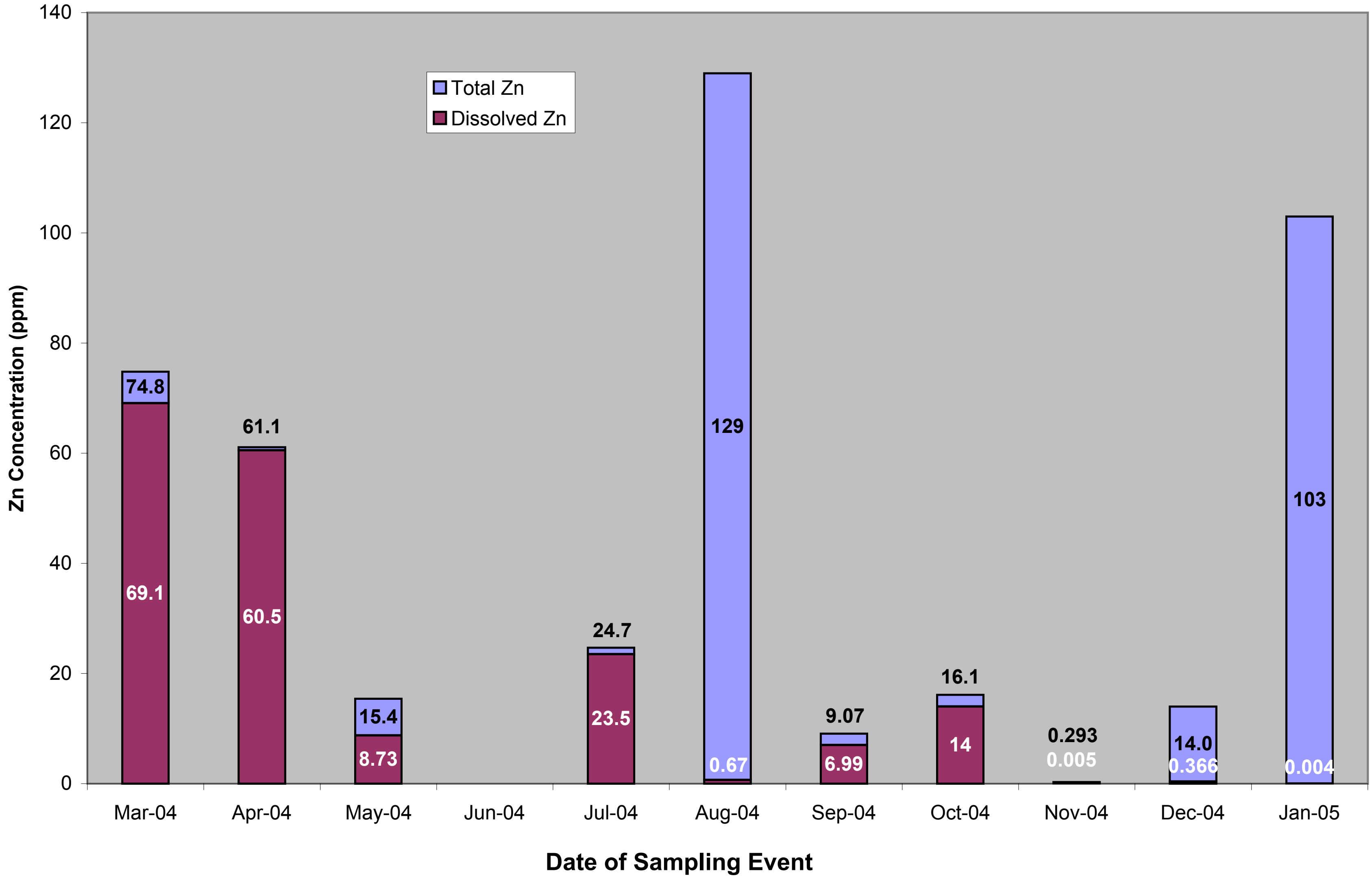


Figure 3. Mean and Variance for Dissolved/Total Zn Ratio by Site

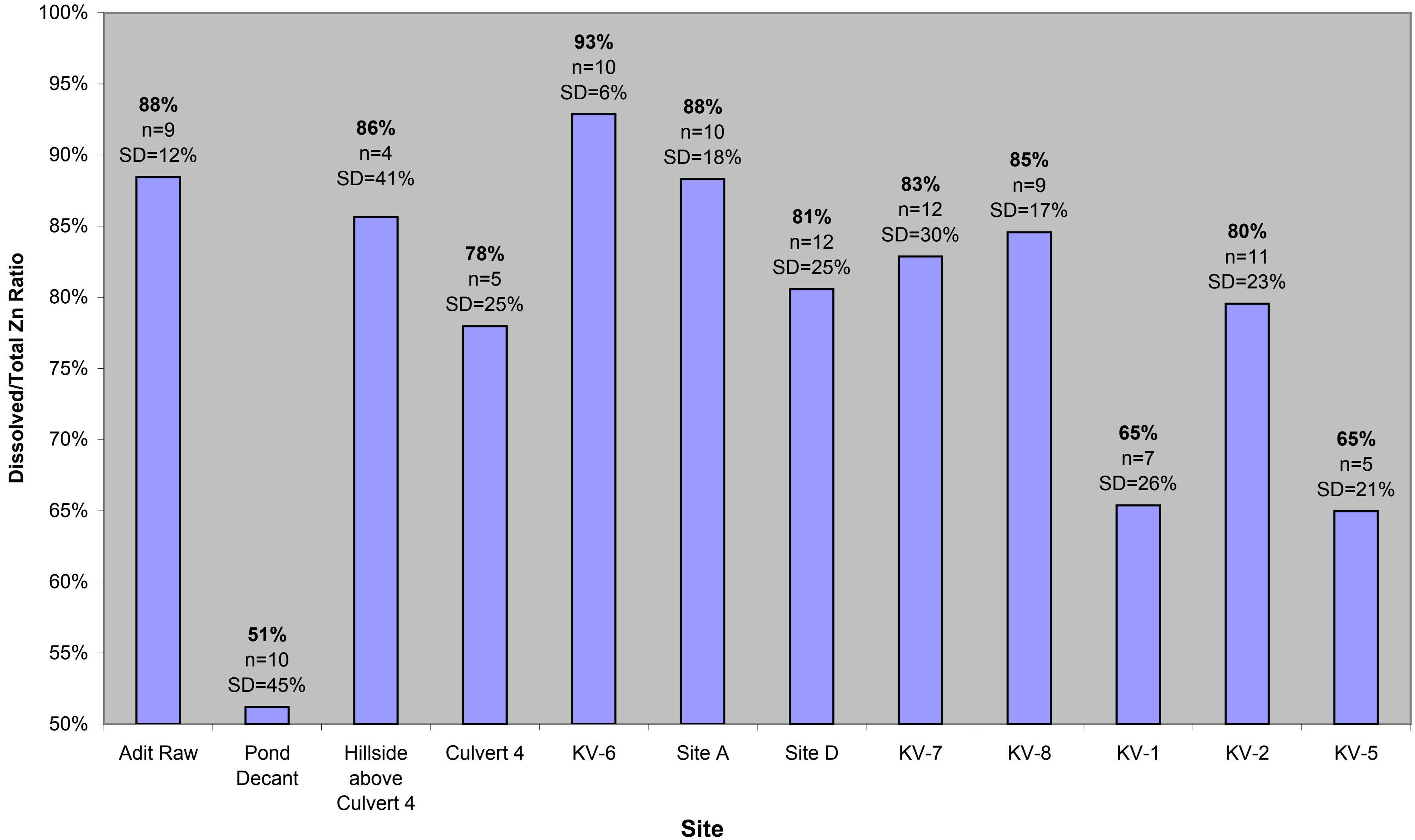


Figure 4. G300 Dissolved/Total Zn Ratio vs. Total Zn Concentration

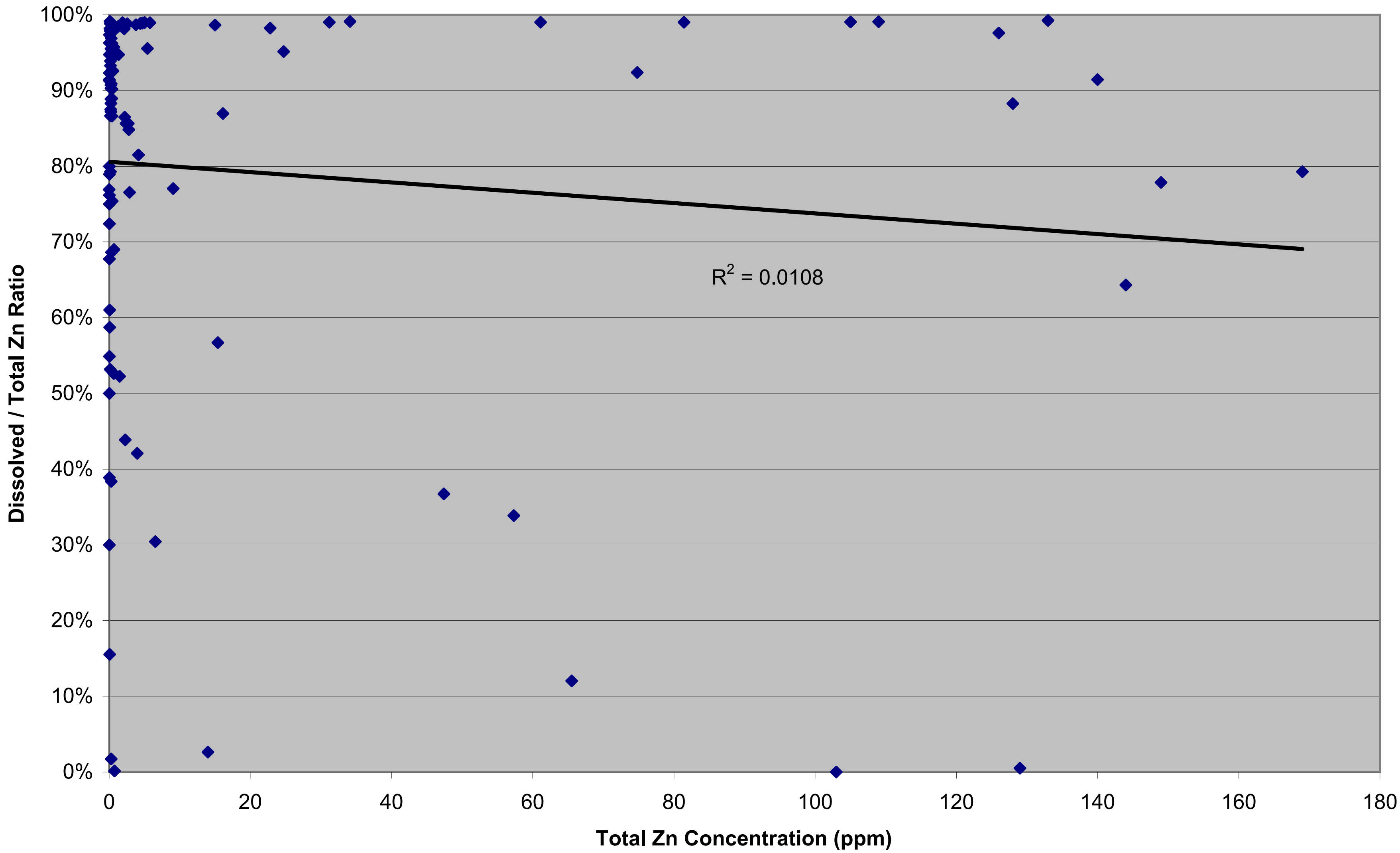


Figure 5. G300 Dissolved Total Zn Ratio vs. Total Zn For Treatment System Sampling Sites

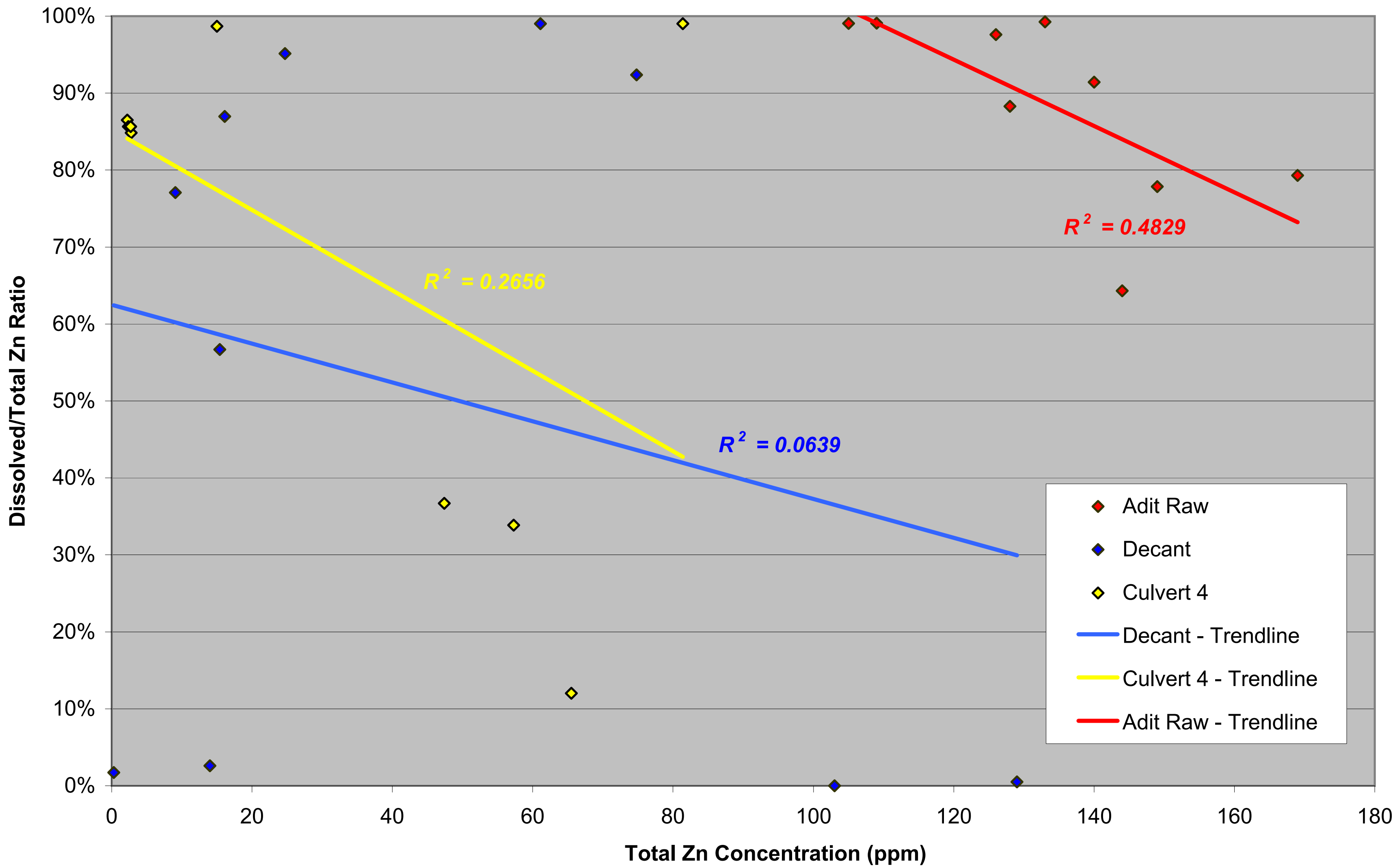


Figure 6. G300 Dissolved Total Zn Ratio vs. Total Zn For Receiving Waters Sampling Sites

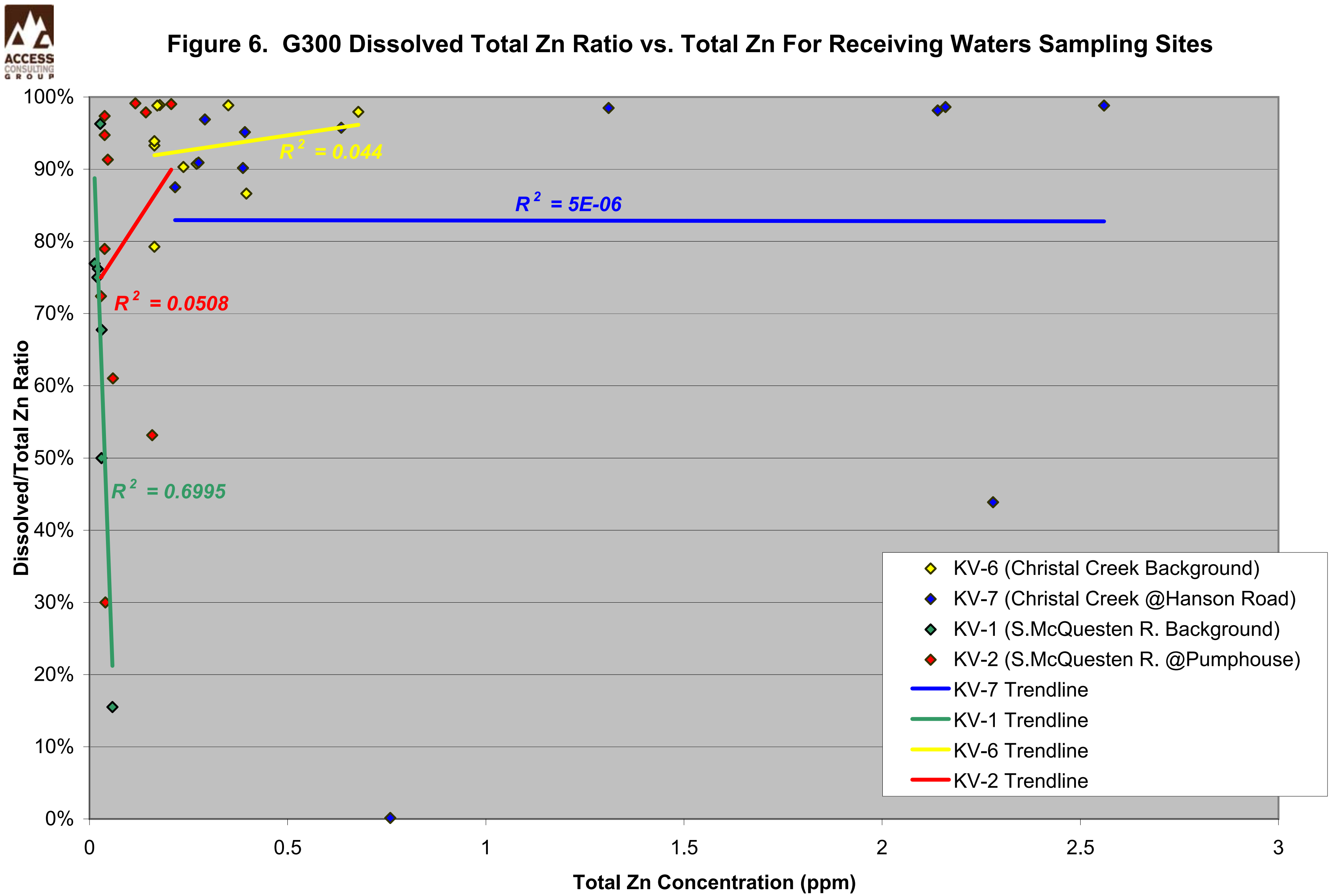
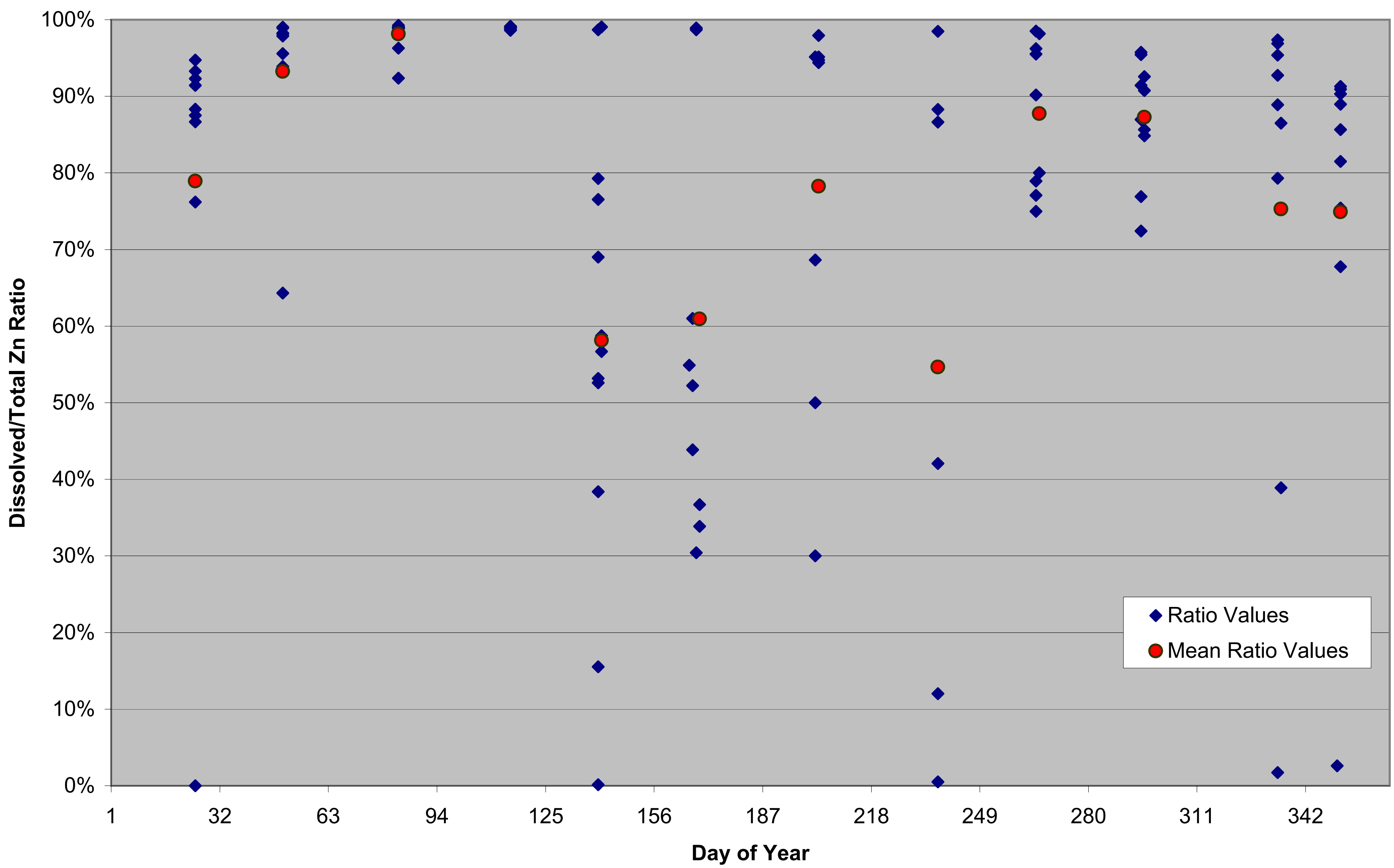


Figure 7. G300 Dissolved/Total Zn Ratio vs. Day of Year



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