SPRING RIVER METALS TMDL EVALUATION

HYDROLOGY OVER 2002-2007

Flow conditions within the TMDL assessment area for Spring River metals are determined through three USGS gaging stations; Shoal Creek above Joplin, Missouri; Spring River near Waco, Missouri and Spring River near Quapaw, Oklahoma (Figure 1). The former two stations measure flow entering the TMDL assessment unit, while the Quapaw station monitors flows leaving the subwatershed. Flows have been continuously measured at Waco, Joplin and Quapaw since 1924, 1941, and 1939, respectively.

Flows emanating above Waco comprise 47% of the flow measured at Quapaw, while 19% of the Quapaw flow comes from Shoal Creek above Joplin. These flow proportions are comparable to the percentage of Quapaw drainage area measured near Waco (46%) and above Joplin (17%). Baseflow makes up 57% of the total flow seen at Quapaw. Flows at Waco are similarly composed of baseflow (51%). However, Shoal Creek has a much greater proportion of its streamflow as baseflow (73%), likely due to the fractured Mississippian limestone within its drainage area, allowing a higher proportion of rainfall to infiltrate and re-emerge through seeps and springs to Shoal Creek. Flows at Quapaw are tightly correlated with flows near Waco (Pearson correlation coefficient = 0.94); but less so with Shoal Creek (r = 0.78).

Flows at Quapaw ranged from 90 cfs to 93,500 cfs over 2002 – 2007. Generally, flows during this recent period were lower than normal. Nonetheless, streamflow was always gaining between Waco and Quapaw (Figure 2). The period 2002-2007 had about 75% of the flow seen during 1970-2001 (Figure 3). Monthly flows on Spring River at Quapaw and Waco and Shoal Creek above Joplin were lower for 2002-2007 for 8, 9 and 10 months, respectively, than long term averages. Flows were especially smaller (15-37%) during October and November in the recent period.

Analysis of annual 60-day low flows and 30-day high flows at Quapaw indicates the recent 2002-2007 evaluation period was in the midst of a drying trend, noted by a decrease in runoff and slight downturn in baseflows (Figures 4 & 5). The 60-day low flows for 2006-2007 were the lowest in the past 40 years, approaching the 10-year recurrence low flow of 125 cfs. Conversely, while 2002 had the highest 30-day average flow since 1995, streamflow that year as well as subsequent years were far below the high values seen over the 1993-1995 period. LOWESS analysis suggests the high flows of the early 1990's forced a rising trend, but flows have continuously fallen off since 1995.

The recent losing trend in streamflow is reflective of dryer climatic conditions. Double mass analysis, as described in Lindsay, Kohler and Paulhus (1975,pg 81), comparing accumulated flows since 1941 at Waco and Shoal Creek against those at Quapaw indicates no deviations in the flow pattern over time (Figure 6). This suggests little

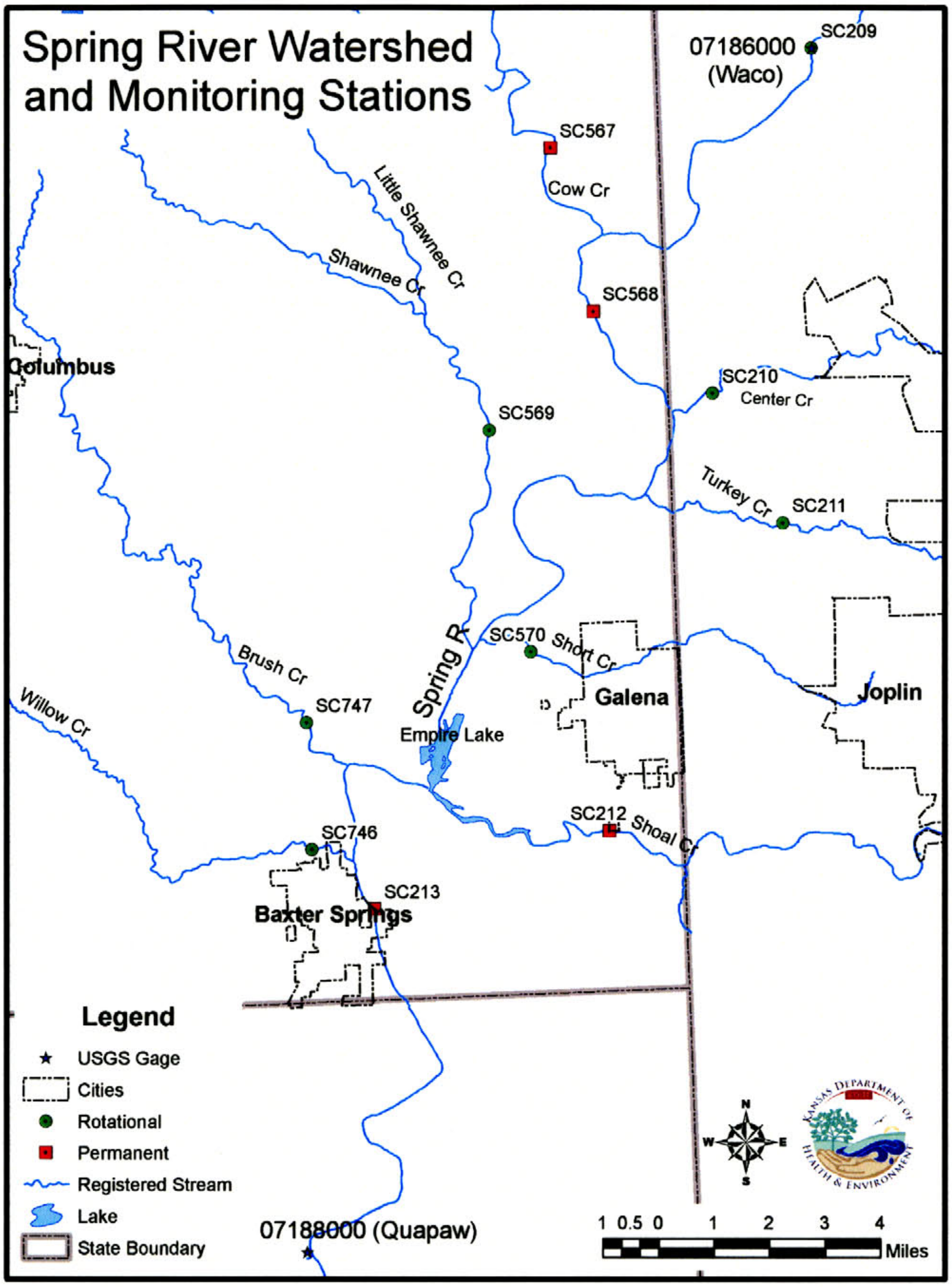

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Figure 1. The Spring River TMDL Assessment Area

Figure 2: Spring River Streamflows 2002-2007

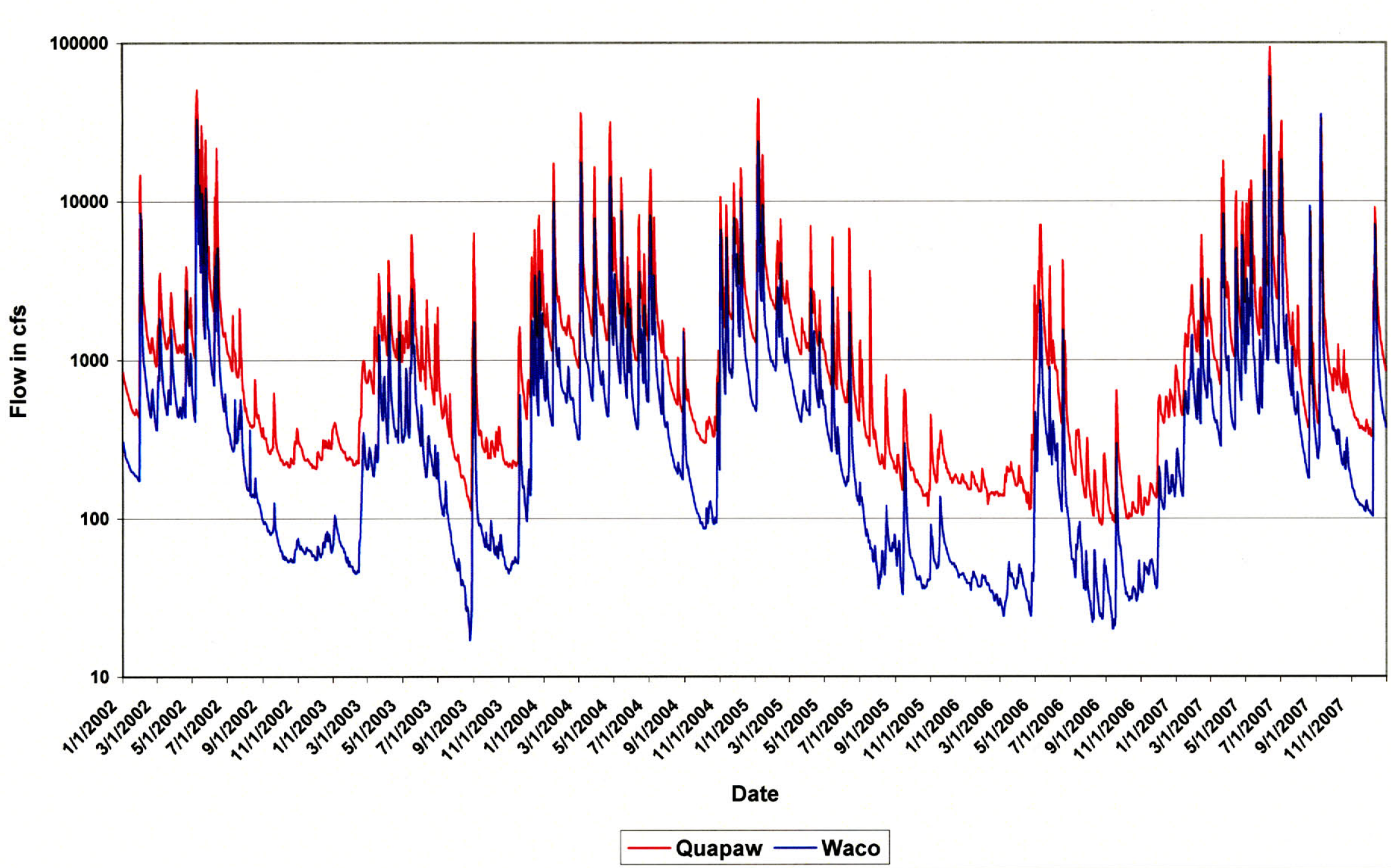


Figure 3: Spring River & Shoal Creek Flow Duration Comparison

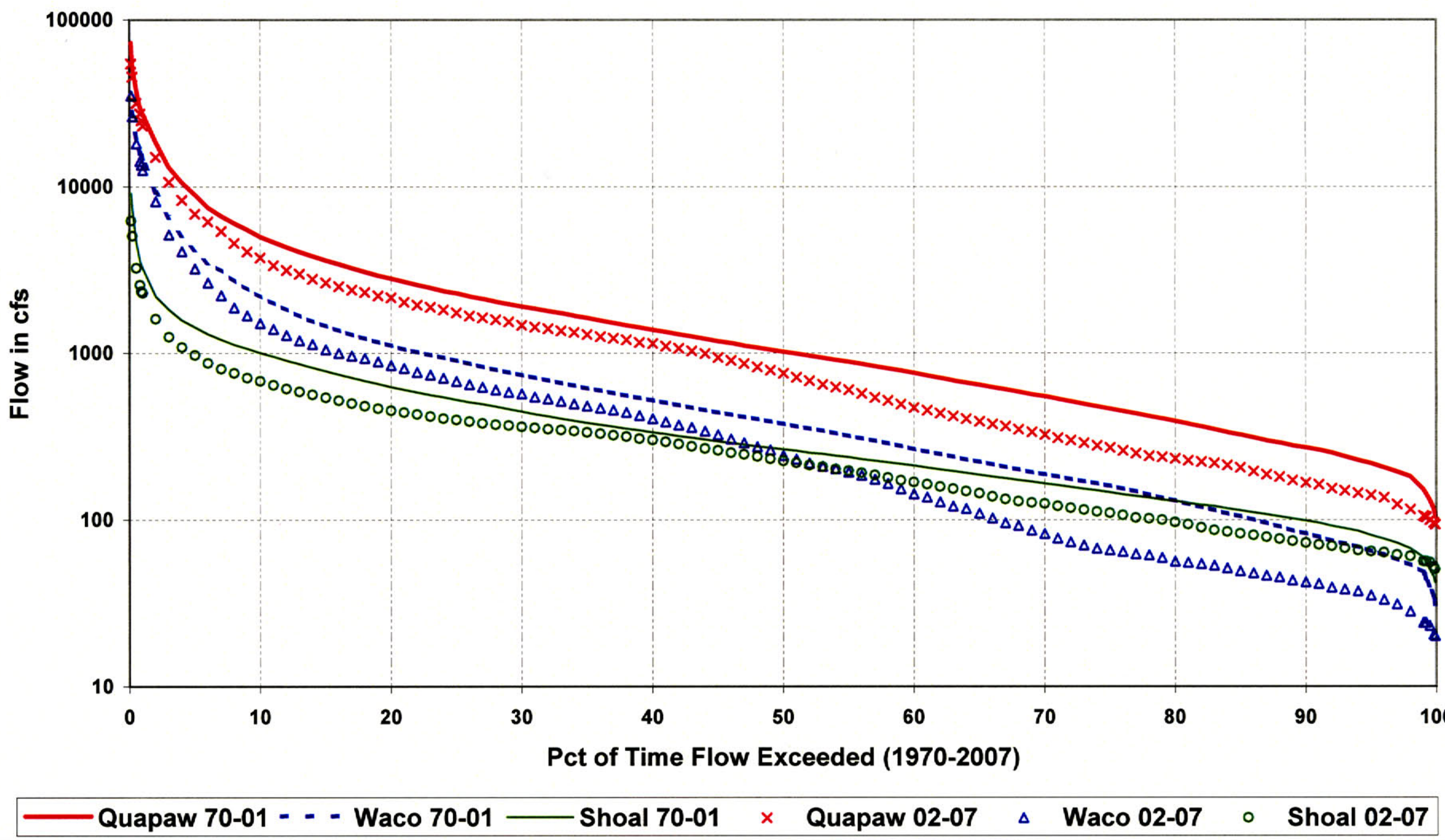


Figure 4: LOWESS Curve of 60-Day Low Flows on Spring River

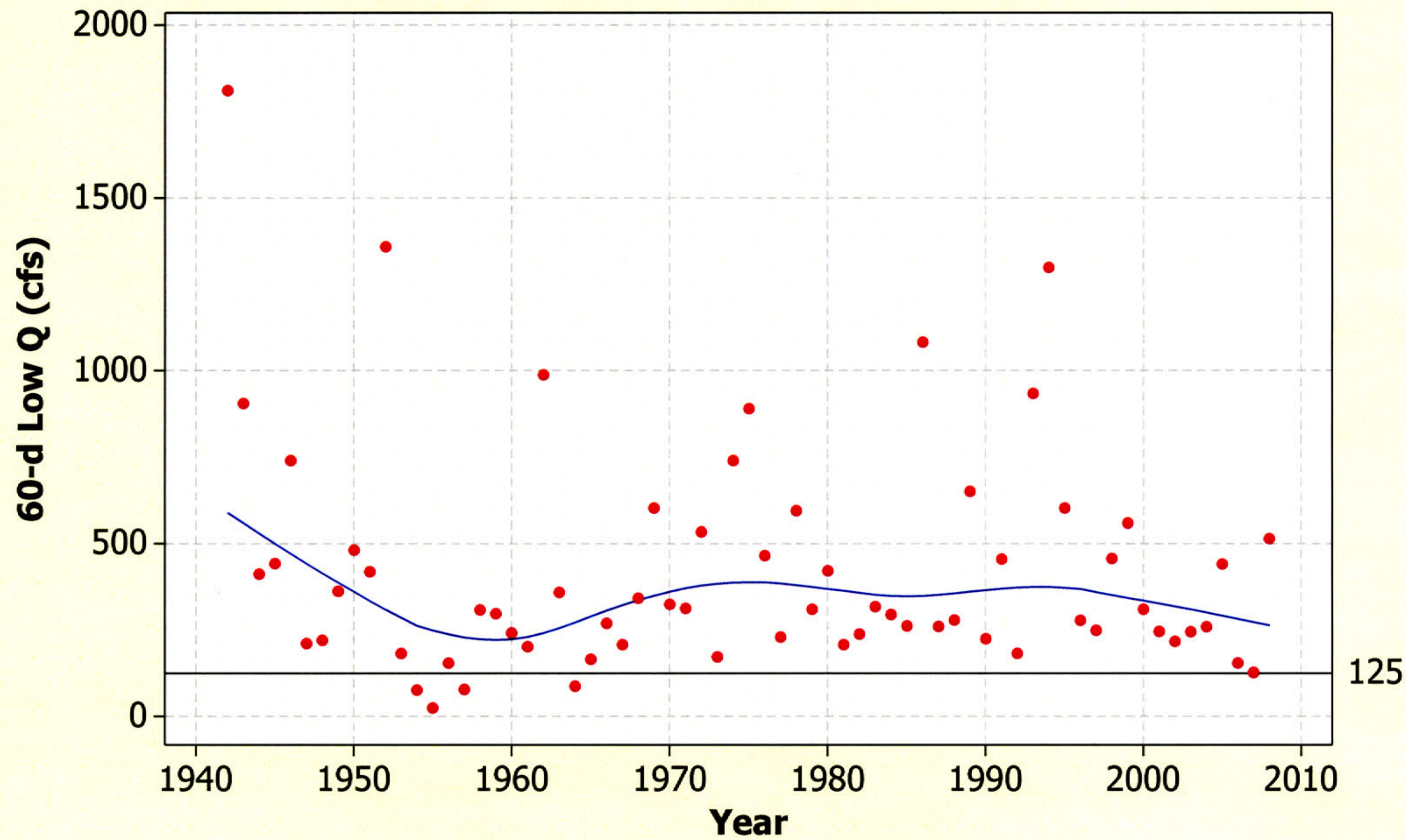


Figure 5: LOWESS Curve of 30-Day High Flows on Spring River

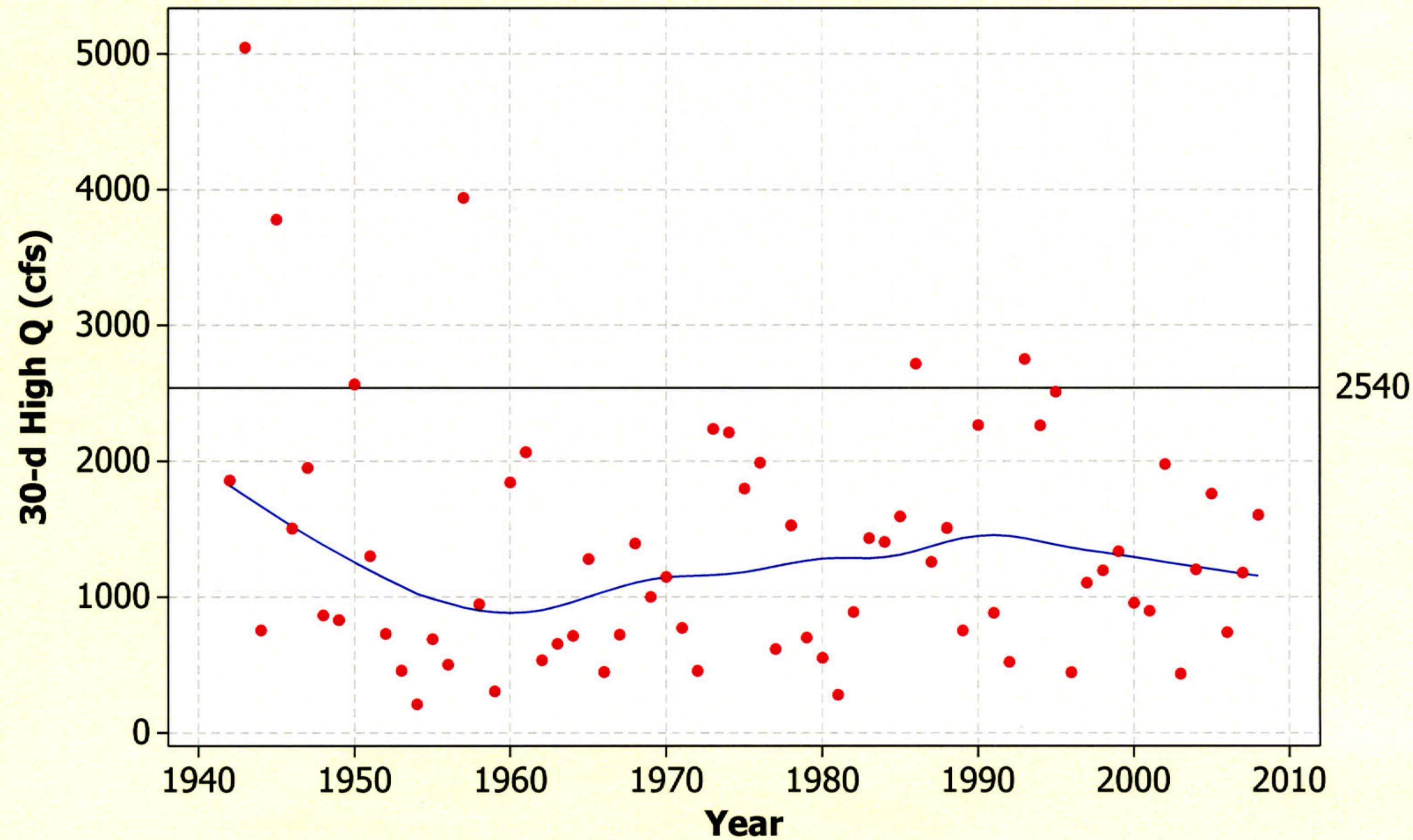
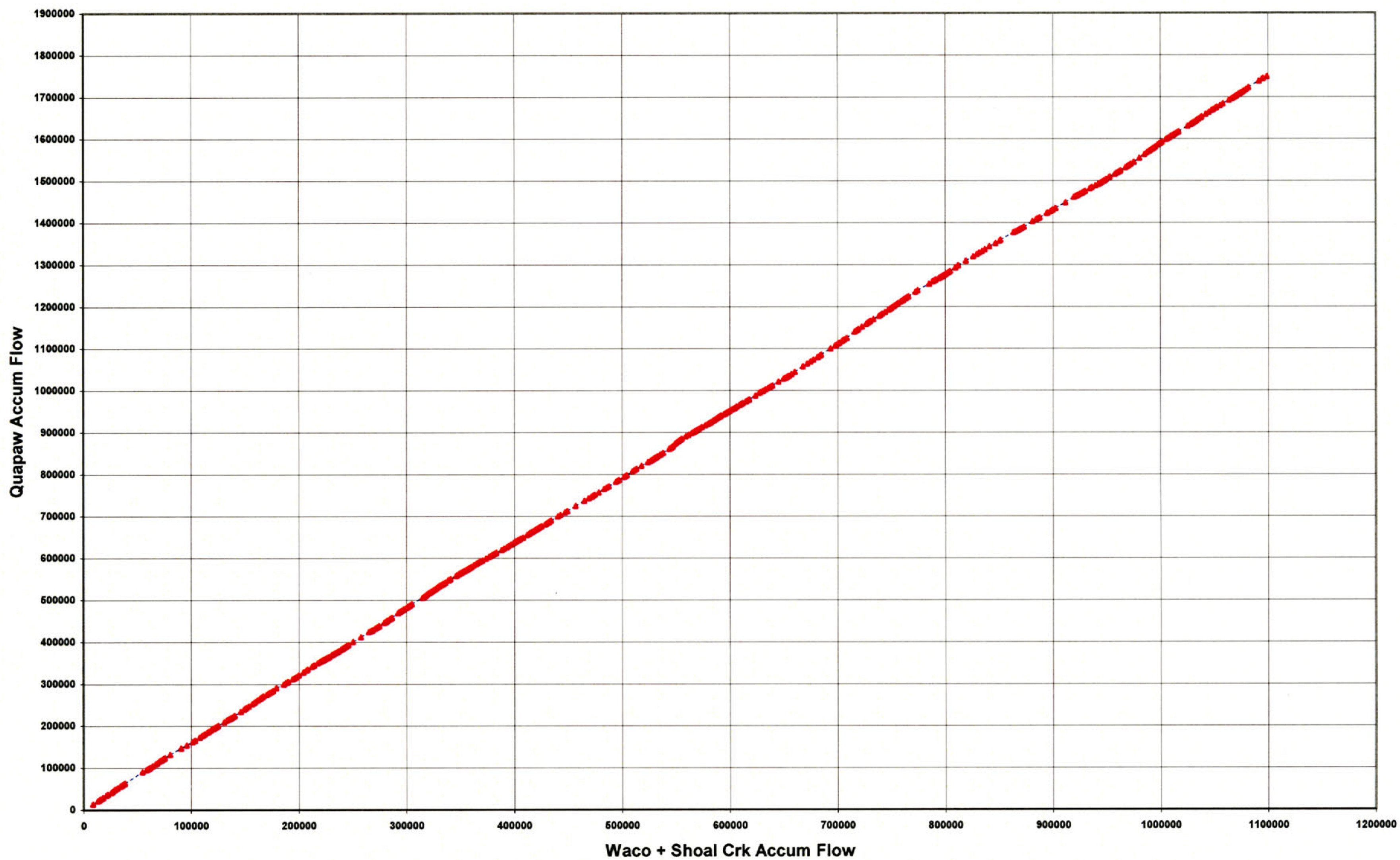


Figure 6: Spring River Double Mass Curve



alteration to the flow regime by impoundments, diversions or discharges has occurred in the drainage to a degree that would influence the flow records in the watershed.

Similarly, a double mass curve of accumulated precipitation in Southeast Kansas and accumulated flow measured at Quapaw did not show deviations from a constant trend line over 1940-2007.

Examination of water use reports filed with the State for 2006, indicate little water use made from diversions from Spring River or its tributaries, except on the lower reaches by Empire Electric and Baxter Springs. Little irrigation of crops occurred that year, despite the extreme dryness. Kansas Farm Facts indicates that no corn is irrigated in Cherokee County while the Division of Water Resources indicates 222 acre-feet of water irrigated 460 acres in all of Cherokee County, including both the Spring and Neosho River drainages. Therefore, consumptive use through evapo-transpiration of irrigation water is not a significant factor in streamflow patterns along Spring River. The dam at Empire Lake impounds a shallow body of water fed by Spring River and Shoal Creek, but its lack of significant storage means it merely detains flows, but does little to divert and store them and alter the historic hydrograph.

Because of its high proportion of baseflow, Shoal Creek tends to sustain lower flows better than the upper Spring River monitored near Waco. This is also reflected in the more gradual recessions of flow after flood peaks on Shoal Creek. The relative flow conditions during samplings at Quapaw (Baxter Springs), Waco (Crestline) and Shoal Creek (Galena) were within 10 percentile points 29 times out of 36 during 2002 through 2007 (Figure 7). Six of the seven samplings with divergent flow conditions registered contrasts between Shoal Creek and the Spring River near Waco. Four of those resulted from the more gradual, sustained flow recession of high flows along Shoal Creek in the days prior to sampling while flows seen near Waco decreased rapidly. In the other two cases, localized rain generated runoff above Waco but not along Shoal Creek. The gradual flow recession on Shoal Creek also resulted in a divergent condition between Quapaw and Shoal Creek. Flows along the Spring River near Waco and at Quapaw were within seven percentile points during 2002 – 2007, verifying the strong correlation in flow between the two stations.

Samplings occurred under all flow conditions over 2002 – 2007 (Figure 8). A general pattern appears in the sampling record of Quapaw/Baxter Springs. Samples with lower metal concentrations or sufficient hardness to maintain non-toxic conditions occurred generally during baseflow or the recession portions of the hydrograph. Samples with metal criteria exceedances typically occurred at or near peak flows or on the rising limb of hydrographs. Clearly, water quality is influenced by the timing, sequence and magnitude of runoff events.

Among the tributaries sampled in 2002 and 2006, no flow situations were recorded on Shawnee, Brush and Willow Creeks. However, the remaining tributaries, Center, Turkey and Short Creeks had flow each time they were visited.

Figure 7: Relative Flow Percentiles for Spring River and Shoal Creek during Samplings over 2002-2007

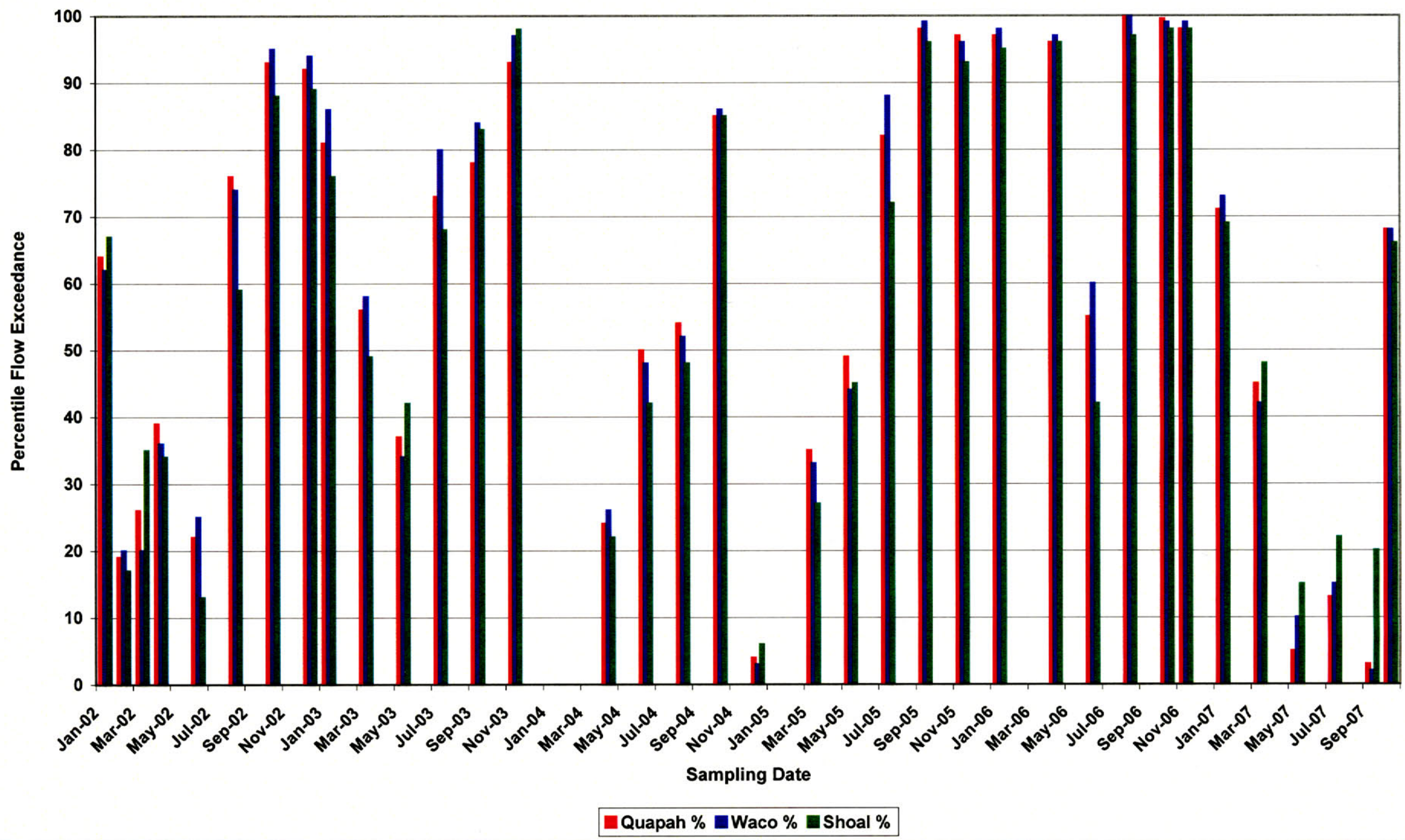
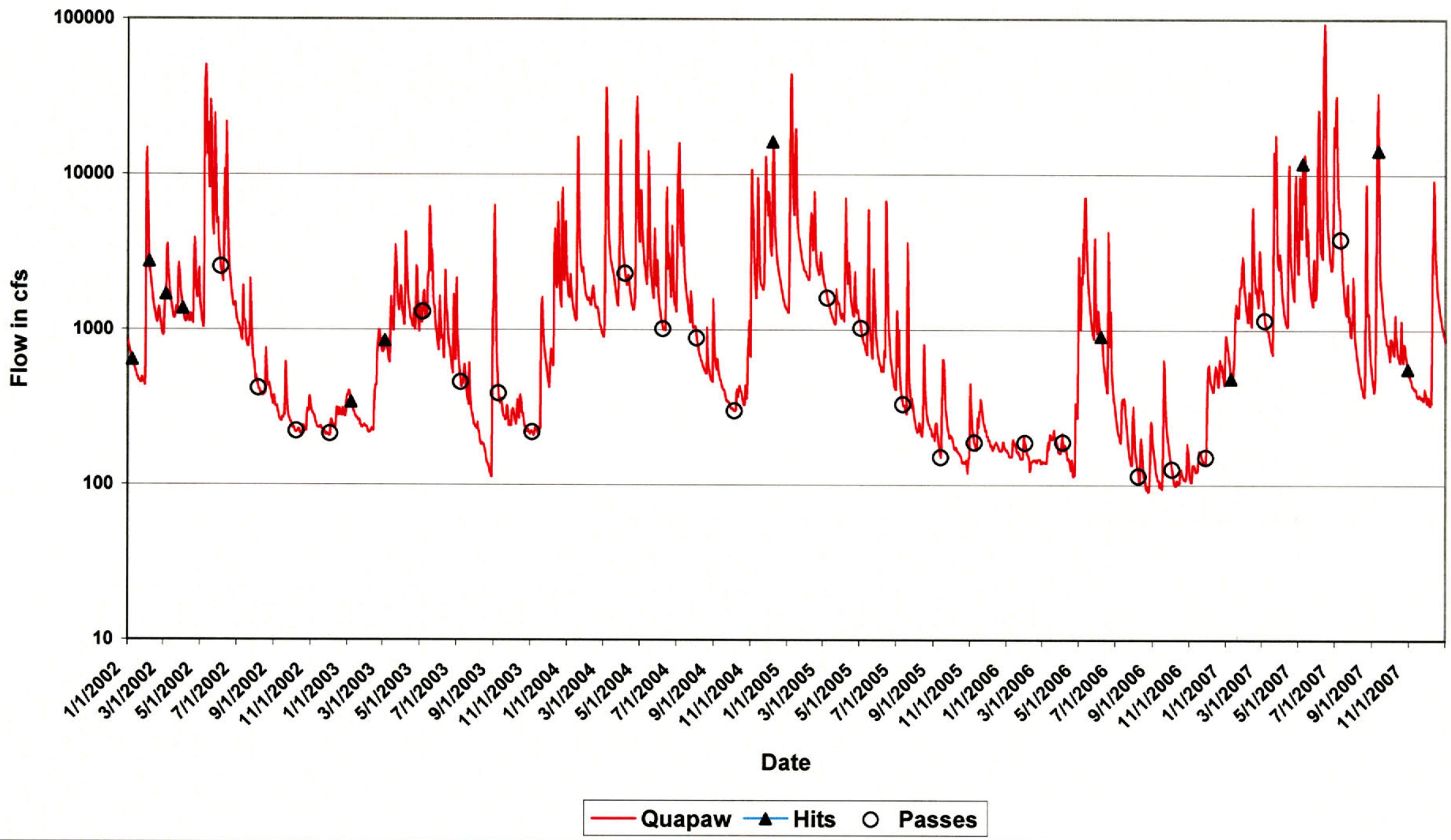


Figure 8: Spring River-Quapaw Conditions At Samplings in 2002-2007



HARDNESS RELATIONS

Kansas criteria for acute and chronic concentrations of metals are based on the ambient hardness of the water body. The applicable equations for lead and zinc are:

(1) Chronic lead criteria (ug/l) = exp(1.273*ln(hardness)-4.705)
(2) Acute lead criteria (ug/l) = exp(1.273*ln(hardness)-1.460)
(3) Acute & chronic zinc criteria (ug/l) = exp(.8473*ln(hardness)+0.884)

There is an inverse relationship between hardness and metal toxicity, therefore, as hardness increases, the permissible metal criterion also increases. Acute and chronic criteria for lead and zinc increase by 853-fold and 89-fold, respectively, with an order of magnitude increase in total hardness (calcium and magnesium carbonate concentrations). The criteria values approximately double with each 50 mg/l incremental increase within the typical range of hardness found in streams (100-300 mg/l).

Additionally, as shown in Figure 9, there is an inverse relationship between streamflow and hardness, i.e.; high flows exceeded a small percentage of time have low hardness. Low flows are derived chiefly from baseflow discharged from underlying ground water with a high mineral content. Conversely, high flows stem from runoff from precipitation events and are marked with a notable softness relative to carbonate minerals. Therefore, higher flows are more prone to metal toxicity while baseflows have some buffering capacity. Although a greater proportion of Shoal Creek streamflow comes from baseflows discharged through limestone formations, Shoal Creek is actually softer than the Spring River at Baxter Springs. This could possibly be due to the short residence time of infiltrated precipitation within the fractured limestone formations above Joplin. As a rule, Mississippian limestones do not yield much water unless they are fractured, creating pathways for rapid infiltration of rainfall into the ground and into the stream.

Examination of the distribution of hardness concentrations over flow conditions at Baxter Springs (Figure 10) indicates that most compliant situations with metal criteria occur at lower flows with a high exceedance percentile. Water quality standard violations occur generally at higher flows, although there is a band of violations occurring between median flow (50% exceedance) and 80% exceedance, despite above-average hardness levels. Ambient levels of total recoverable lead and zinc were sufficiently elevated under those conditions to create the violations. Once hardness falls below 150 mg/l, there is high probability of a violation to occur, typically at higher flows.

The following table indicates the average total hardness concentrations at high, normal and low flow conditions at the three major stream stations along Spring River and Shoal Creek. Spring River tends to be harder than Shoal Creek, except under high flows, when the watershed appears to reflect uniform conditions. The hardest water tends to be on the Spring River at the upper reaches of the TMDL assessment area, perhaps influenced by Cow Creek and its high levels of hardness.

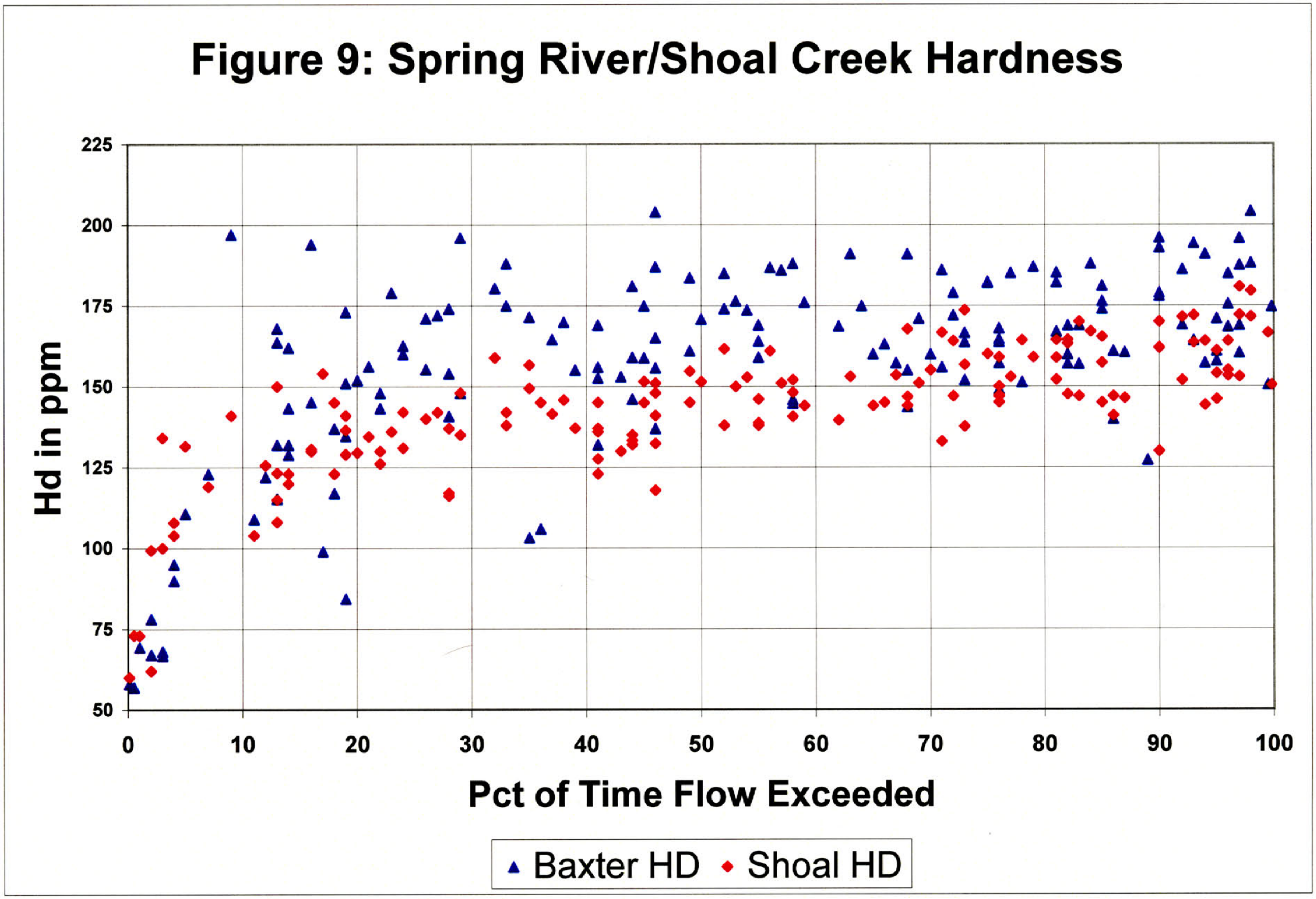
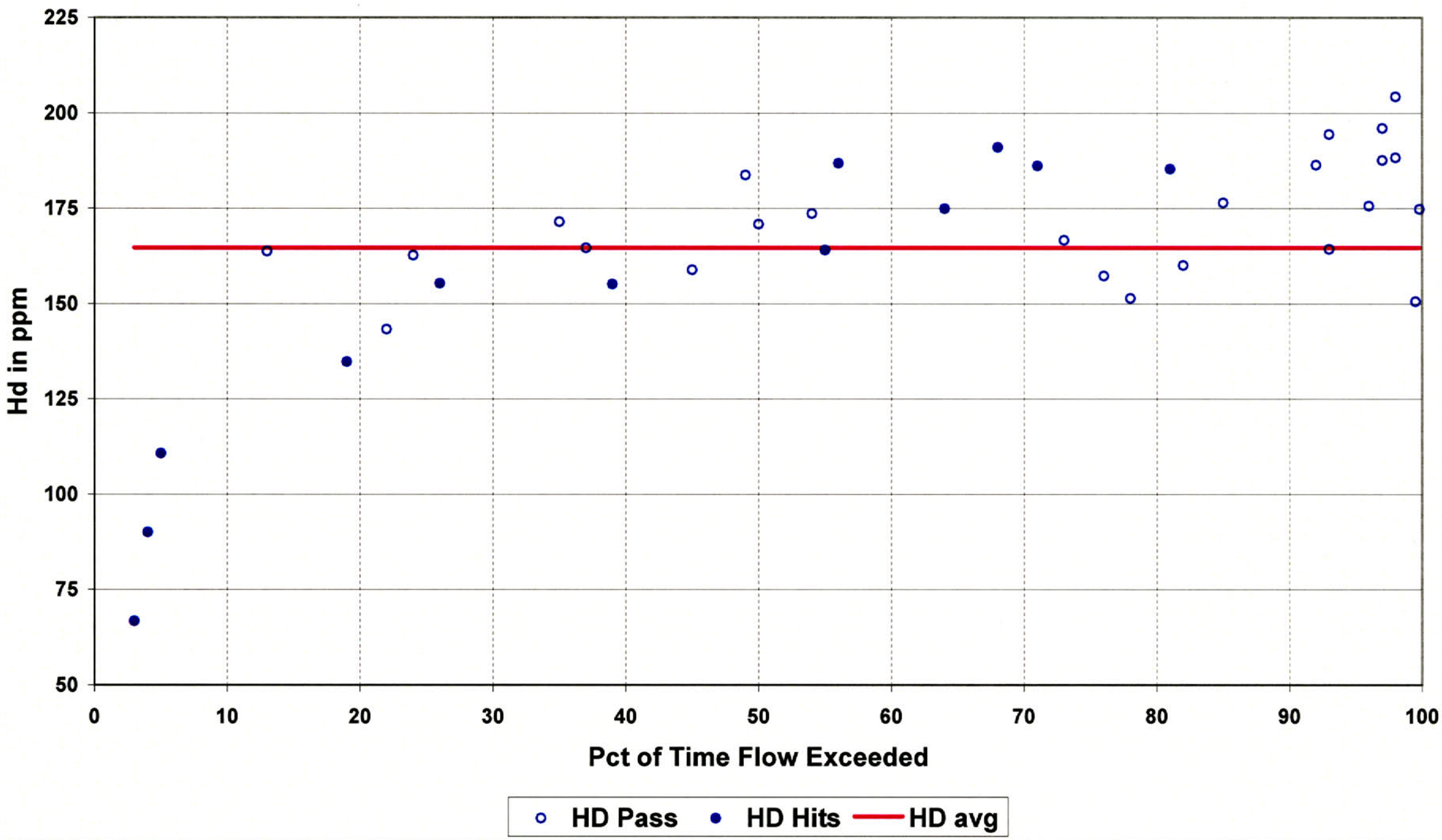


Figure 9: Spring River/Shoal Creek Hardness
Hd in ppm
225
200
175
150
125
100
75
50
0
10
20
30
40
50
60
70
80
90
100
Pct of Time Flow Exceeded
Baxter HD
Shoal HD

Figure 10: Spring River @ Baxter Sprgs - Hardness & Flow Condition



Station	High Flow	Normal Flow	Low Flow
Shoal Creek	128 mg/l	151 mg/l	165 mg/l
Spring River nr Baxter Springs	128 mg/l	170 mg/l	177 mg/l
Spring River nr Crestline	128 mg/l	174 mg/l	187 mg/l

A LOWESS curve was applied to the long term record of total hardness values over the range of flow conditions that were sampled on Spring River and Shoal Creek (Figure 11). In both cases, there was a gradual decrease in hardness from very low flows to mean daily flow, approximately at the 25% exceedance point. Once flows exceeded this level, hardness values dropped rapidly.

The next table indicates the average total hardness on the tributary stations in 2002 and 2006. Because of the limited datasets, there was not much coverage of all flow conditions, so normal flows were pooled with higher flows, while the pervasive drier flows were similarly combined.

Tributary	High/Normal Flows	Low/Very Low Flows
Center Creek	163 mg/l	186 mg/l
Turkey Creek	203 mg/l	221 mg/l
Short Creek	169 mg/l	274 mg/l
Willow Creek	267 mg/l	922 mg/l
Brush Creek	84 mg/l	170 mg/l
Shawnee Creek	79 mg/l	84 mg/l

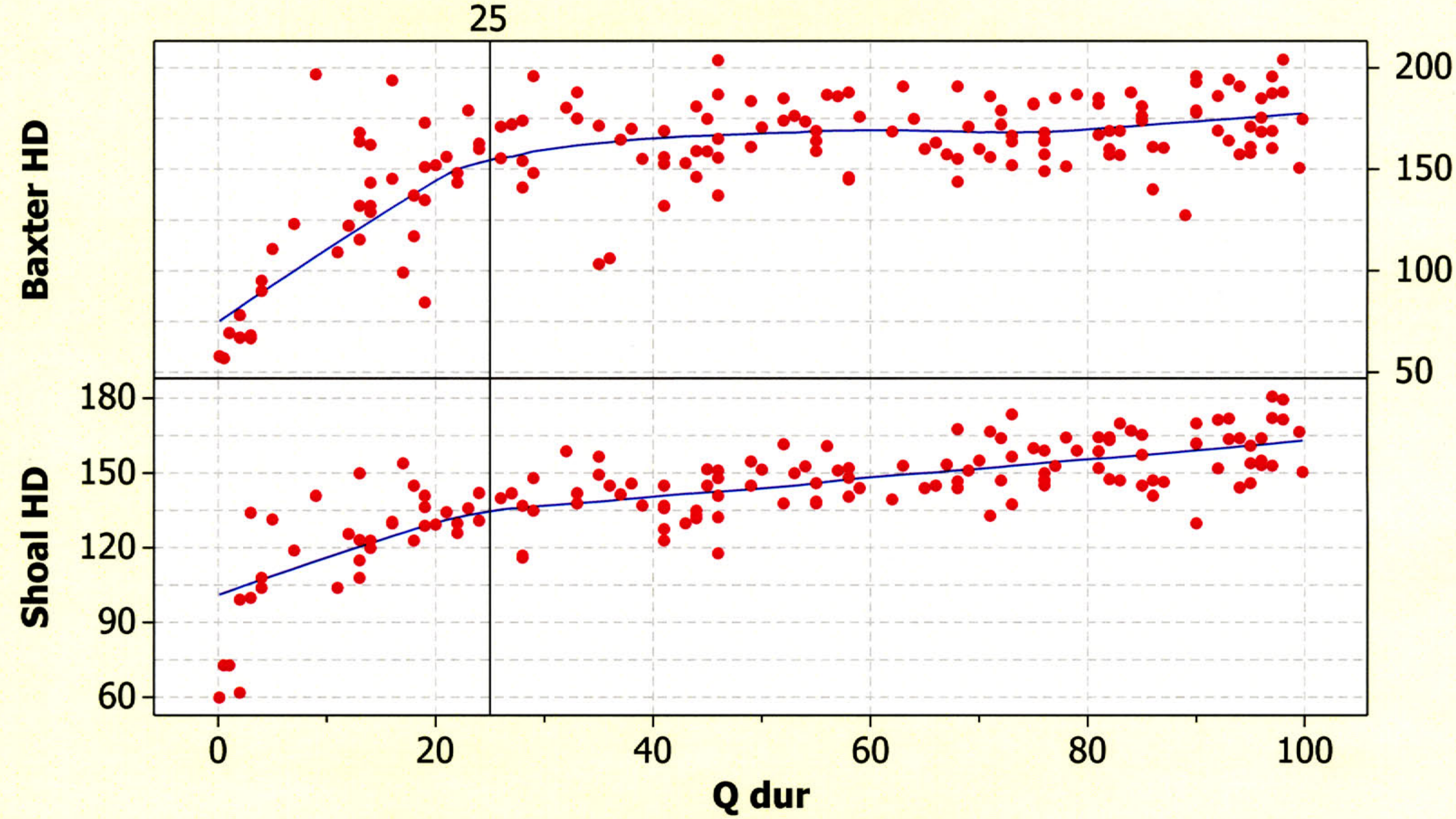
With the exception of Brush and Shawnee Creeks, the tributaries tend to have higher levels of hardness than the major streams, Spring River and Shoal Creek. This may reflect smaller flows, longer residence times with the underlying geology and a higher proportion of ground water contributions from seeps as well as discharges from mine shafts. The four streams with the highest hardness levels also have the highest metal concentrations and are prone to water quality standards violations. Brush and Shawnee Creek are vulnerable because of their low hardness, but their frequency of violations is relatively low because of the limited mining areas within their drainages west of the Spring River.

TOTAL SUSPENDED SOLIDS RELATIONS

Counter to the relationships between hardness and streamflow, total suspended solids (TSS), an estimate of the sediment moving through the stream system, is directly related to the magnitude of streamflow encountered during sampling (Figure 12). The relationship, although noisy, shows a definite upturn in TSS concentrations once flows surpass the 25th percentile value. A LOWESS curve indicates a point of inflection around the 25% exceedance flow for both the lower Spring River at Baxter Springs and Shoal Creek (Figure 13). There is a surprising uniformity in TSS values at normal or lower flows. From the samples taken from 2002-2007, the following tables indicate the average TSS values for the three large stream stations and the individual tributaries.

Figure 11: Hardness on Spring River and Shoal Creek

As function of flow condition



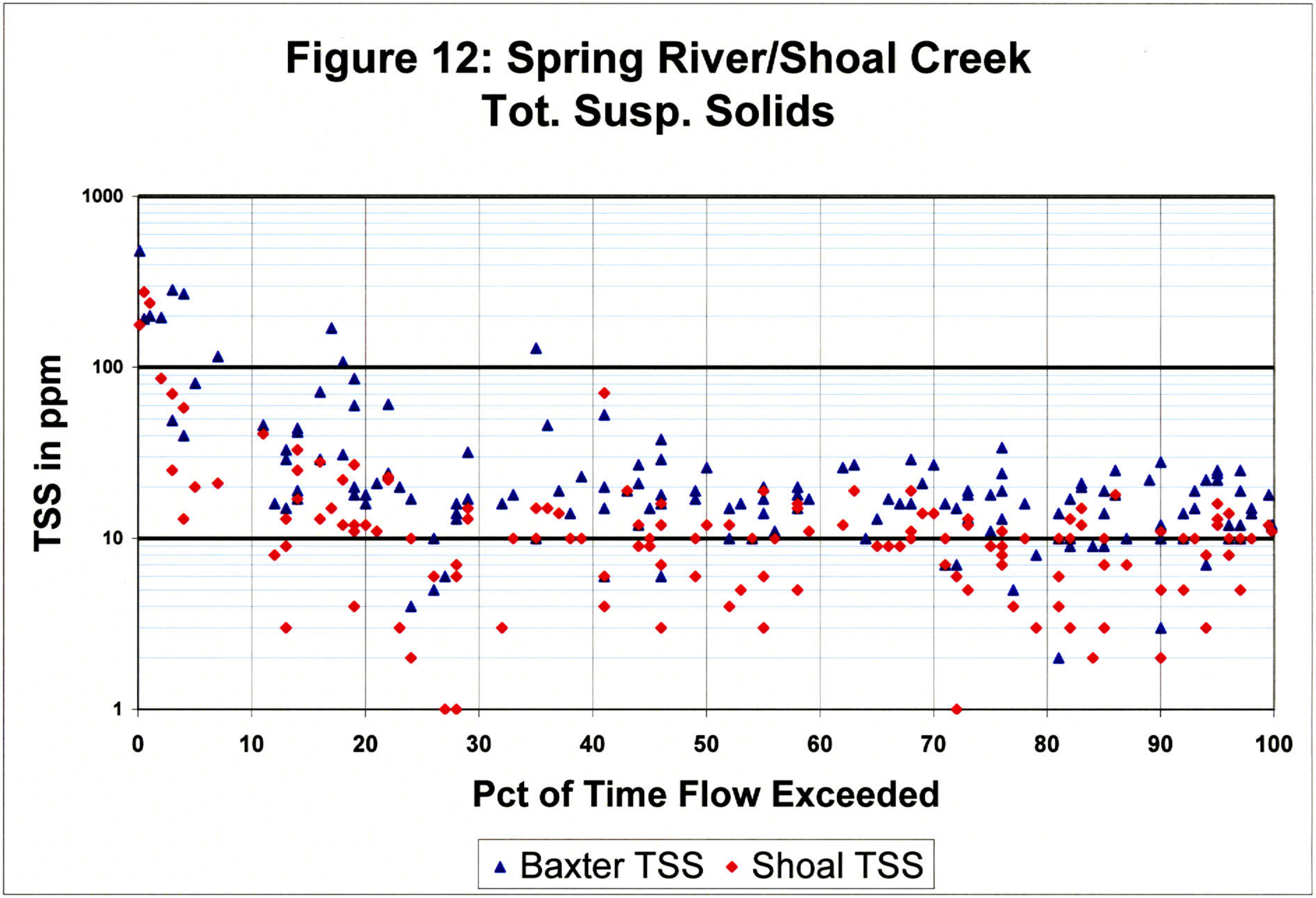
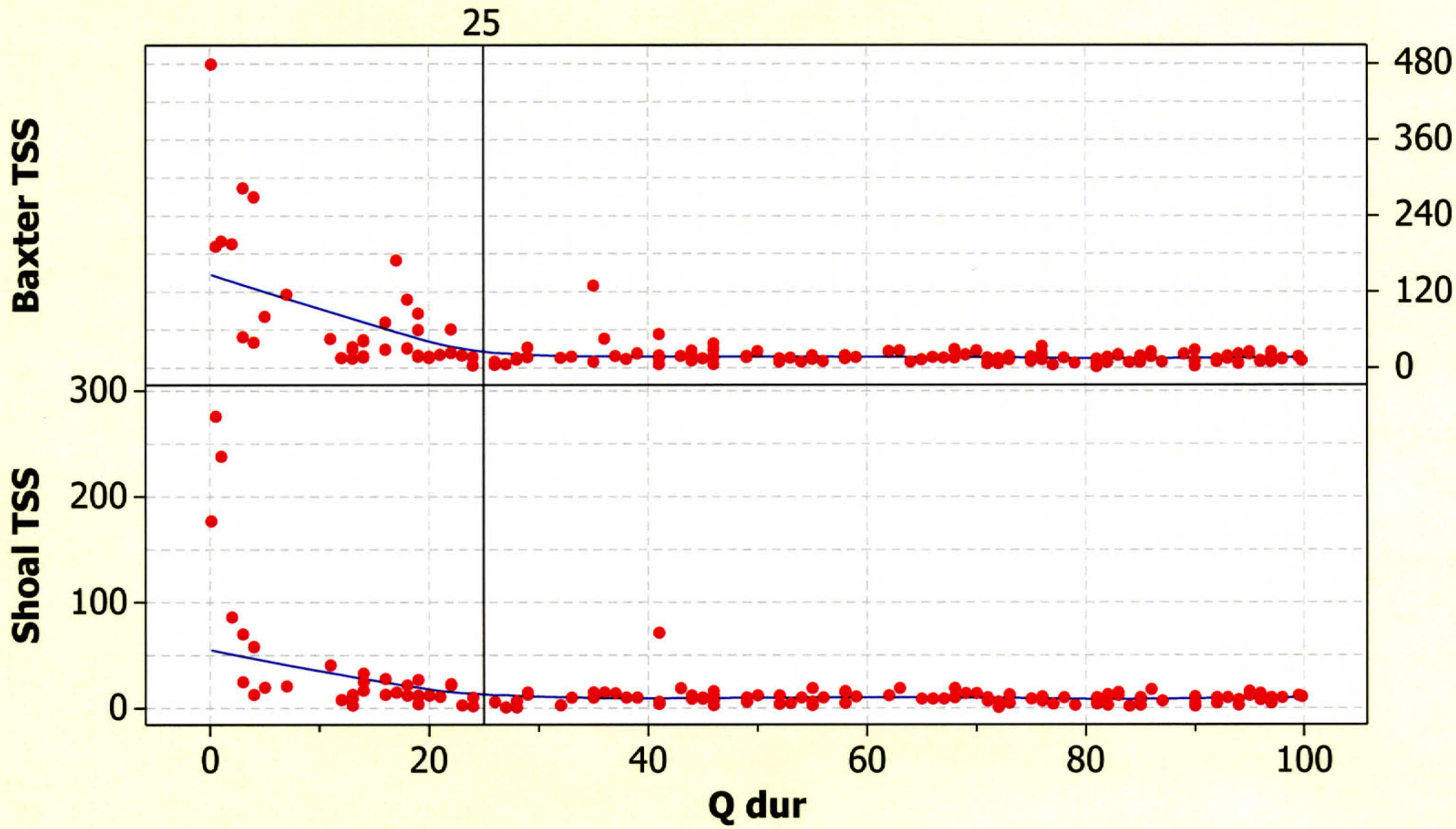


Figure 12: Spring River/Shoal Creek
Tot. Susp. Solids
TSS in ppm
1000
100
10
1
0
10
20
30
40
50
60
70
80
90
100
Pct of Time Flow Exceeded
Baxter TSS
Shoal TSS

Figure 13: Total Susp Solids on Spring River and Shoal Creek

As function of flow condition



Stream	Very Low Flow	Low Flow	Normal Flow	High Flow	Very High Flow
Spring R @ Baxter Springs	14 mg/l	13 mg/l	15 mg/l	17 mg/l	133 mg/l
Spring R nr Crestline	15 mg/l	15 mg/l	23 mg/l	21 mg/l	92 mg/l
Shoal Creek	10 mg/l	11 mg/l	12 mg/l	14 mg/l	34 mg/l

Stream	High to Normal Flows	Low to Very Low Flows
Center Creek	14 mg/l	10 mg/l
Turkey Creek	9 mg/l	10 mg/l
Short Creek	13 mg/l	10 mg/l
Willow Creek	52 mg/l	45 mg/l
Brush Creek	10 mg/l	10 mg/l
Shawnee Creek	10 mg/l	10 mg/l

Clearly, Spring River has a higher sediment load than Shoal Creek. TSS concentrations are generally low except at very high flows. The period 2002-2007 was dryer than normal, so TSS levels would be expected to be low, overall. Because of the pervasive dry conditions in 2006, most of the tributaries show very low TSS averages as well. The exception is Willow Creek, which only has three samples taken between June and October of 2006, but had higher than normal TSS concentrations each time.

Total suspended solids are an important parameter because Kansas water quality standards use total recoverable forms of metals, both suspended and dissolved. Many metals may attach themselves to sediment or suspended organic material, which also contributes to the TSS measurement. Figure 14 shows the relationship between TSS and lead and zinc at Baxter Springs and on Shoal Creek. Lead seems to show a more direct relationship with TSS than zinc. This is particularly true on the Spring River where there are a number of elevated zinc samples below TSS concentrations of 20 mg/l. Additional scatter among the data might occur if more samples are included. Previous studies by USGS indicated that almost all ambient lead was in the suspended form, while a high proportion of zinc was dissolved

The following table shows the Pearson correlation coefficients between TSS, lead and zinc for the lower Spring River and for Shoal Creek.

Station	Lead	Zinc
Baxter Springs	0.983	0.504
Shoal Creek	0.860	0.811

Lead has the stronger linear relationship with TSS, especially on the Spring River. Zinc on Shoal Creek is only slightly less related to TSS, but is significantly less related at Baxter Springs. Lead might be more tightly attached to suspended material, including organic material. Correlations between lead, zinc and total organic carbon are not significantly different from zero along Shoal Creek, but are significant for lead at Baxter Springs ($r = 0.60$). There appears to be different relationships among the parameters on the lower Spring River than on Shoal Creek. One significant difference between the two

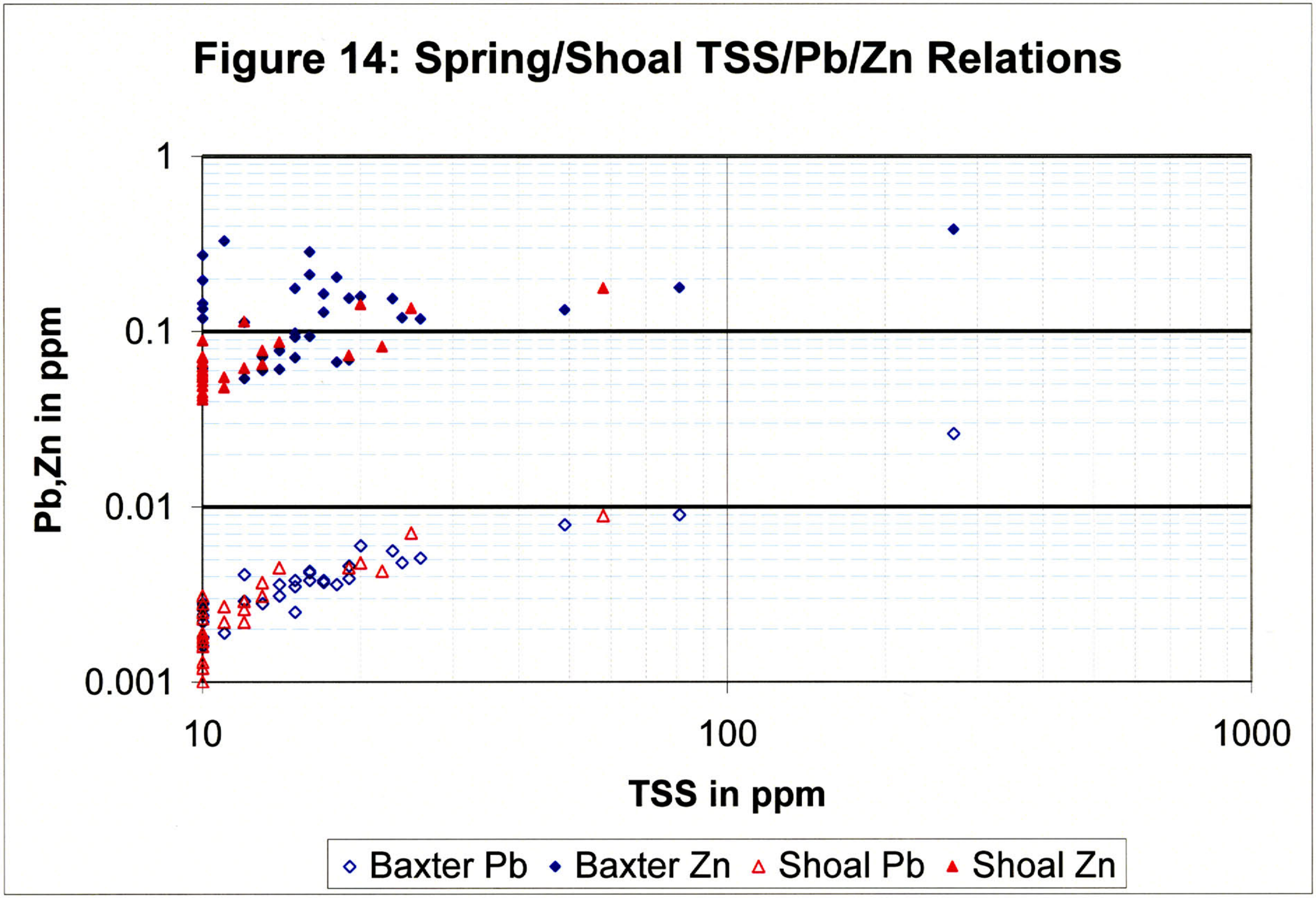


Figure 14: Spring/Shoal TSS/Pb/Zn Relations
1
0.1
0.01
0.001
Pb,Zn in ppm
10
100
1000
TSS in ppm
Baxter Pb
Baxter Zn
Shoal Pb
Shoal Zn

stream systems is the presence of Empire Lake above the Baxter Springs station. It is possible the shallow lake serves as a sink and re-supply source for material and metals, especially at high flows. USGS has noted high levels of lead and zinc in the sediments of Empire Lake.

The distribution of TSS concentrations between samples that are compliant with water quality criteria for metals and those that exceed the applicable criteria is shown in Figure 15. There is little relationship across the flow spectrum, until one surpasses the upper decile flow exceeded 10% of the time. Those samples had significantly higher TSS and metal concentrations. The remaining metal criteria exceedances were distributed across the lower flows, with the exception of no exceedances once flows fell below the 82nd percentile value. Some of these exceedances and compliant conditions might be due to the accompanying hardness measured at the time of samples.

A LOWESS curve of TSS versus hardness on the lower Spring River shows a rapid decline in hardness as initially low TSS conditions begin to increase up to 25-30 ppm (Figure 16). After TSS levels surpass 30 mg/l, the rate of hardness decrease begins to moderate. The relationship is noisy throughout the range of TSS concentrations, but there is strong negative correlation between TSS and hardness at both Baxter Springs (r = - .71) and Shoal Creek (r = -.65). A curvilinear relationship is probably more accurate in describing how TSS and hardness relate to one another. Once TSS levels rise above 50 mg/l, hardness becomes depressed by the associated high flow/runoff conditions transporting suspended solids.

LEAD RELATIONS

Lead concentrations were largely compliant with the applicable water quality criteria on the main rivers. Figure 17 shows the annual average concentrations of lead at the three large stream stations along with a "control" station on Cow Creek above the confluence of Spring River north of Crestline. There is some relationship with average annual flow conditions; the two years with the largest lead concentrations, 2004 and 2007, also had the highest mean annual flows. Lead concentrations for the other four years are fairly constant. 2006 was very dry, with flows 50-75% of those of the next driest year, 2003. Yet, the lowest concentrations were seen in the third driest year, 2005. Individual source contributions that vary with time might be as important as hydrology in determining low flow lead concentrations.

Baxter Springs had the highest concentrations of lead with five samples over 5 ppb (Figure 18). Those five samples exceeded the chronic criteria for lead and occurred during some of the highest flows sampled at Baxter Springs (Figure 19). Samples exceeding lead criteria at Crestline and Shoal Creek coincided with the three highest Baxter Springs concentrations as well as the three highest flows seen on the streams over 2002-2007. No violations occurred at lower flows

On the tributaries, Center and Turkey Creeks had higher lead concentrations during 2006 than 2002, despite the lower annual flows seen in 2006 (Figure 20). Willow and Center Creeks had the highest concentrations of lead overall. Conversely, Shawnee and Brush

Figure 15: Spring River - Baxter Springs TSS & Flow Condition

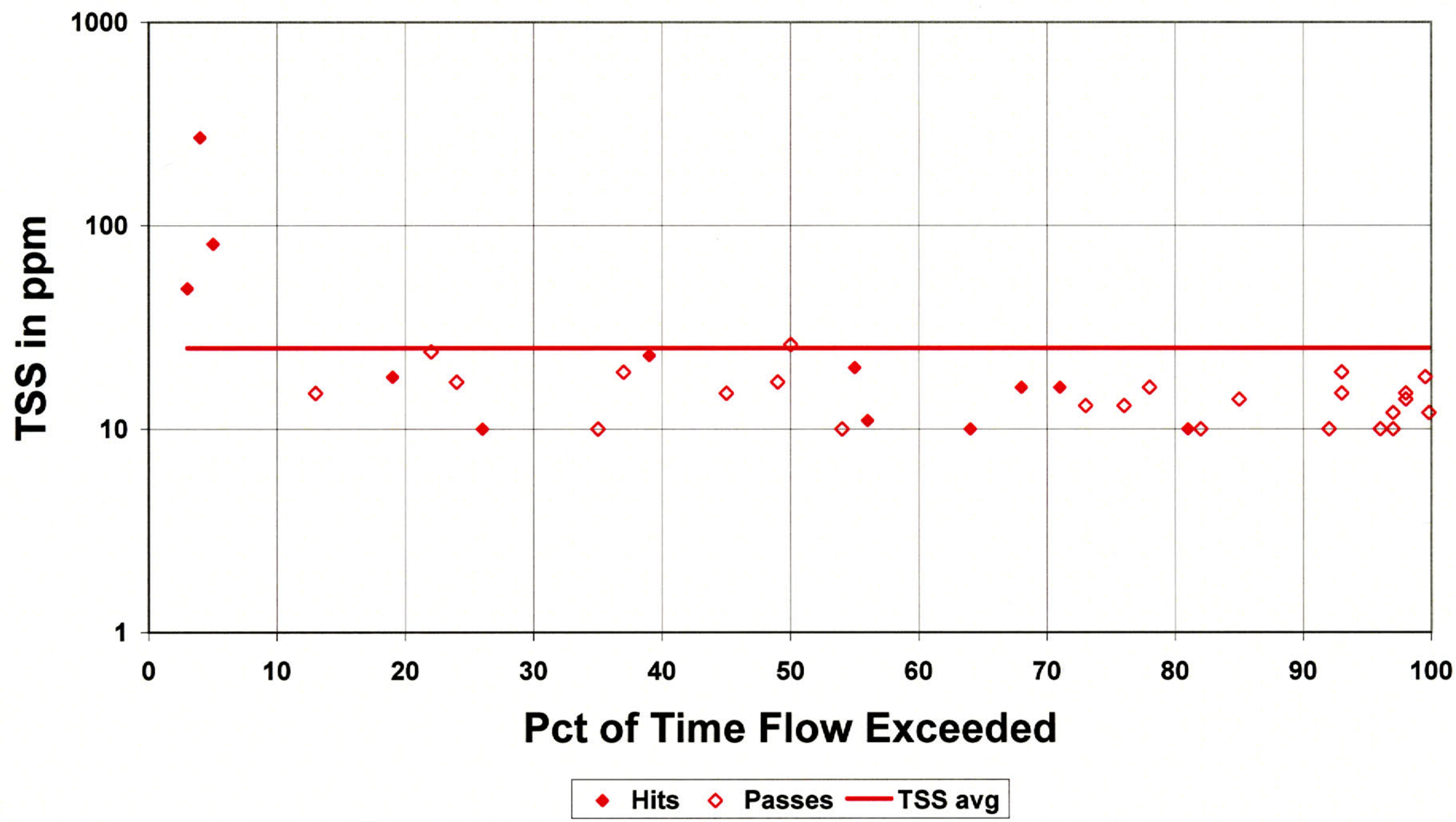


Figure 16: Total Hardness vs. Total Susp Solids

on Spring River @ Baxter Springs

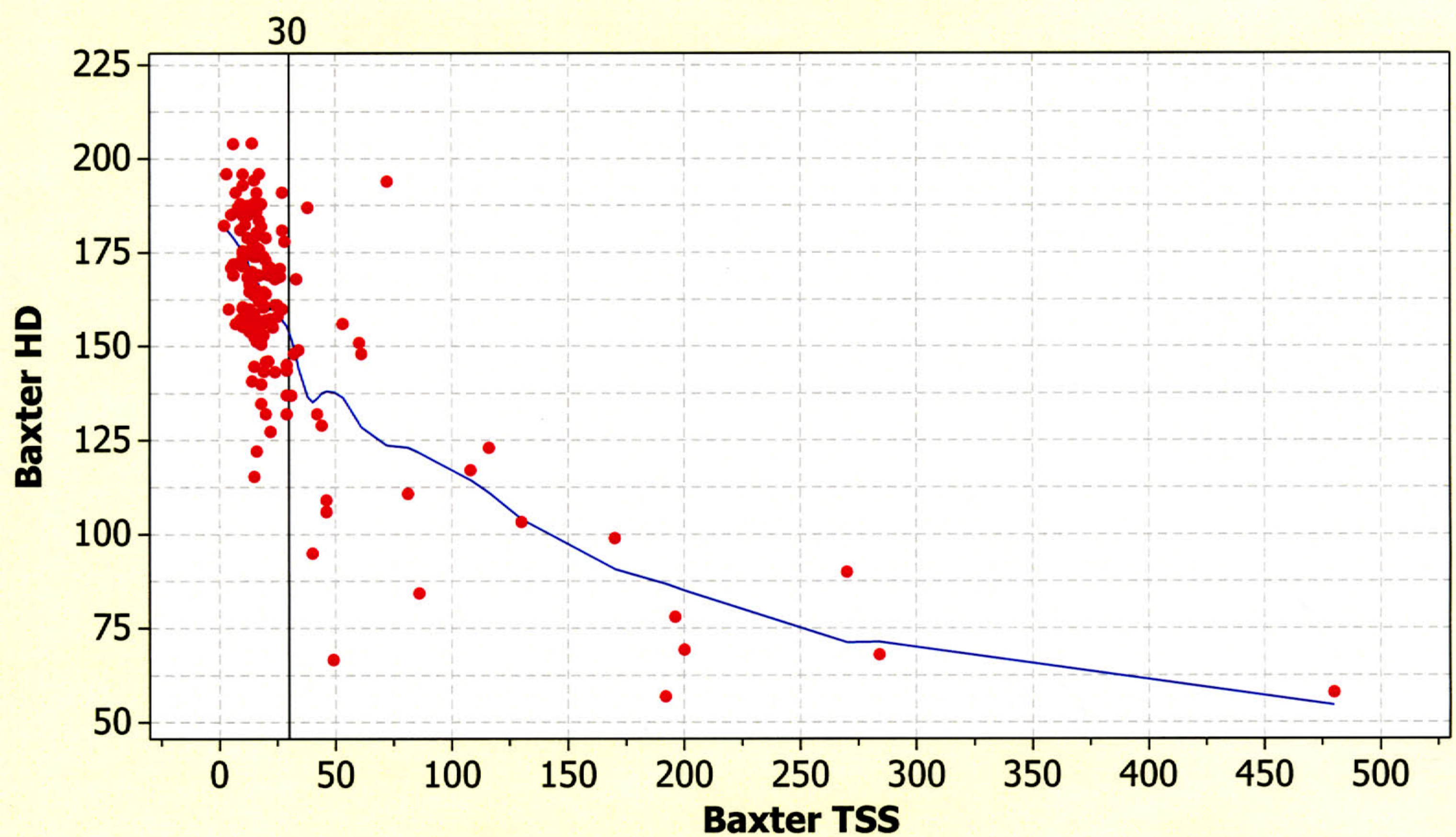


Figure 17: Annual Average Lead Concentrations

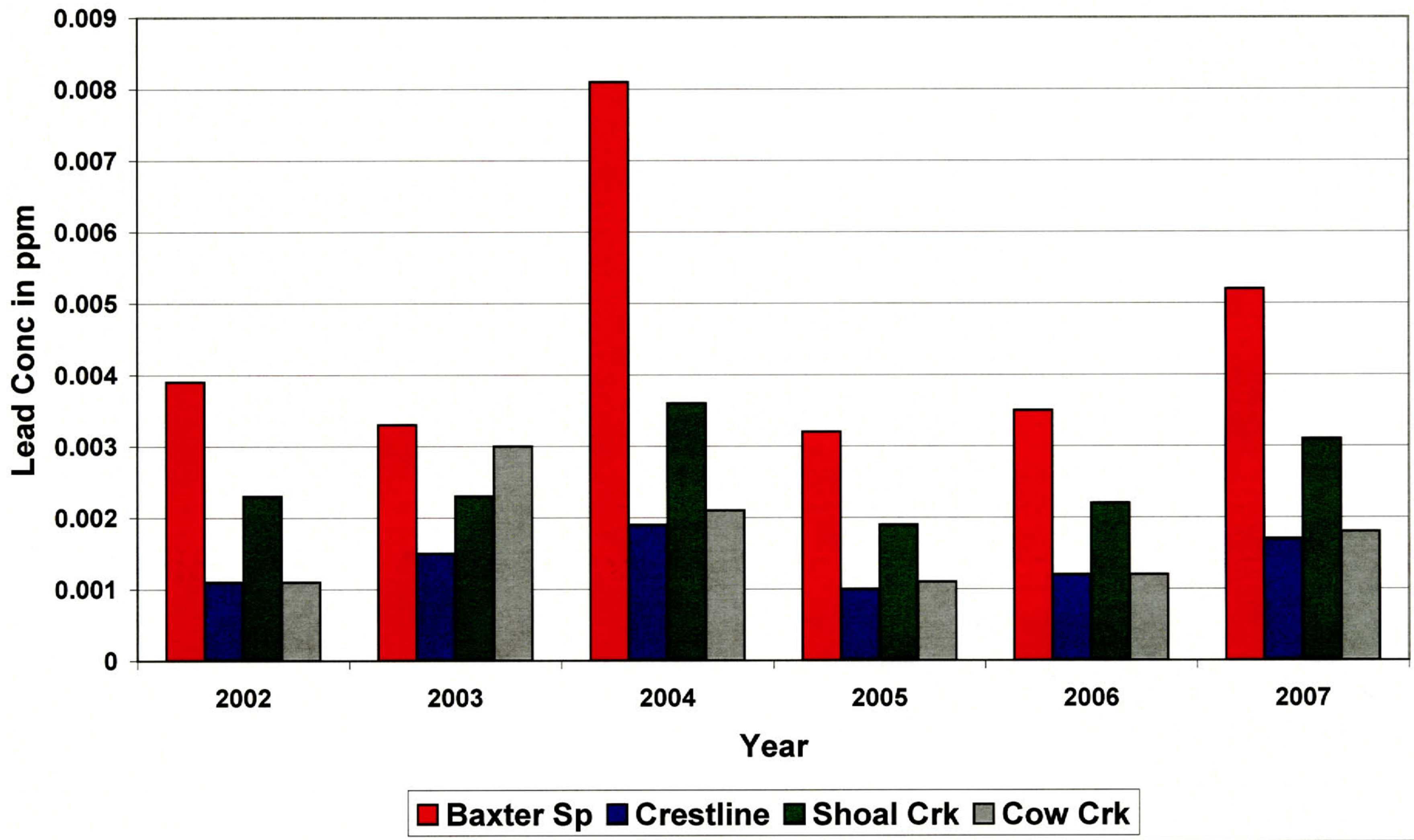


Figure 18: Spring R & Shoal Crk Lead Concentrations

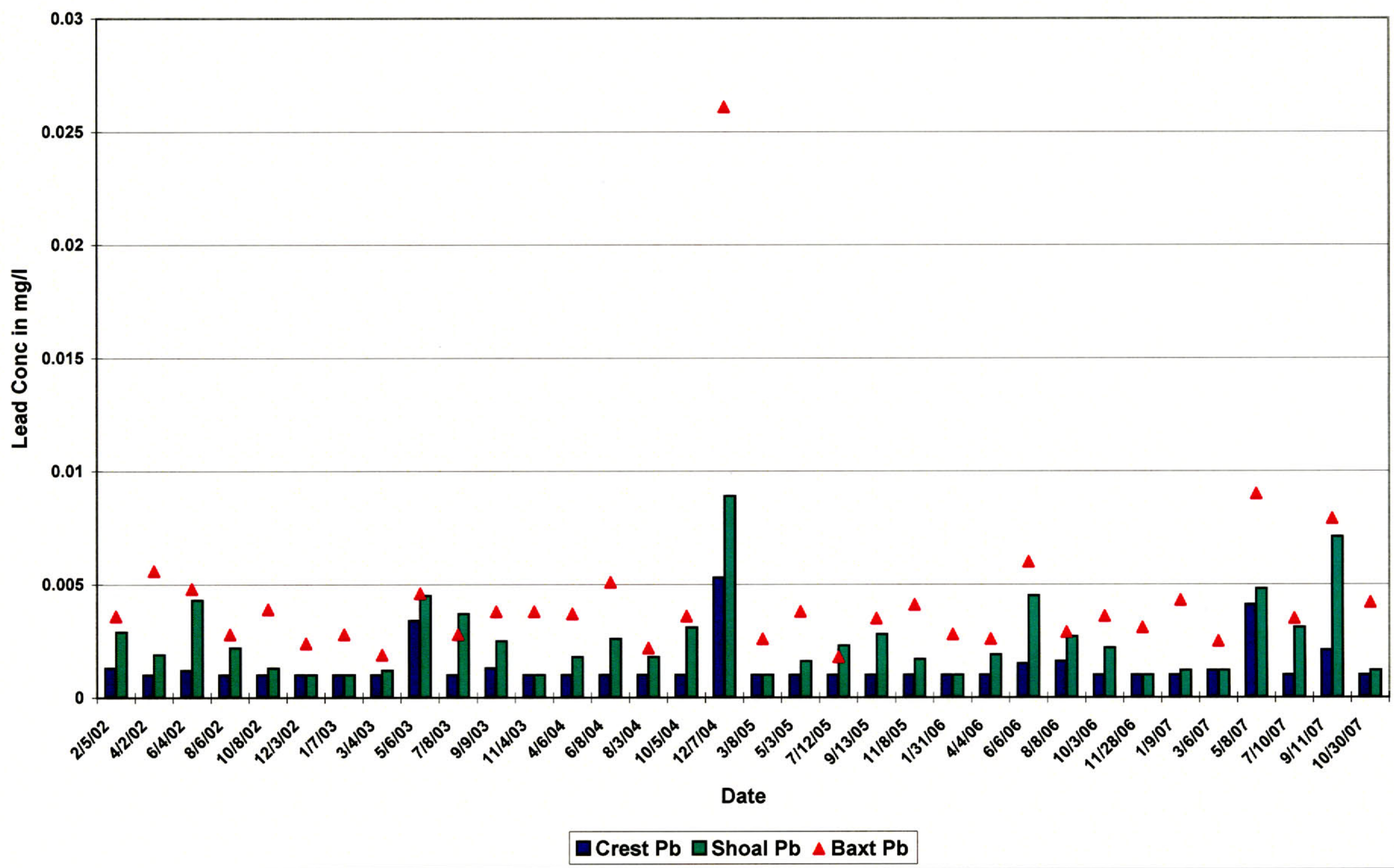


Figure 19: 2002-2007 Flows and Lead at Baxter Springs

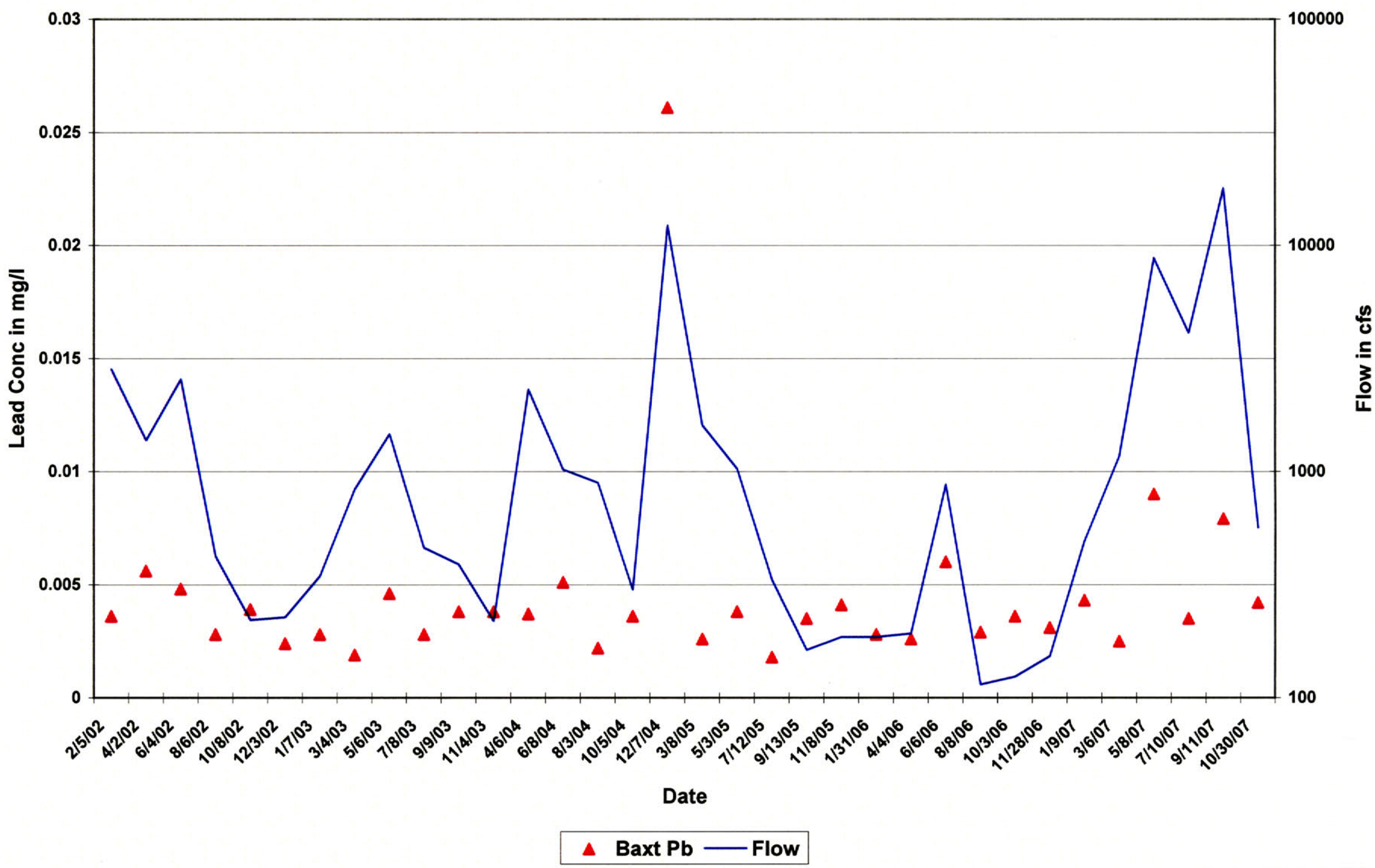
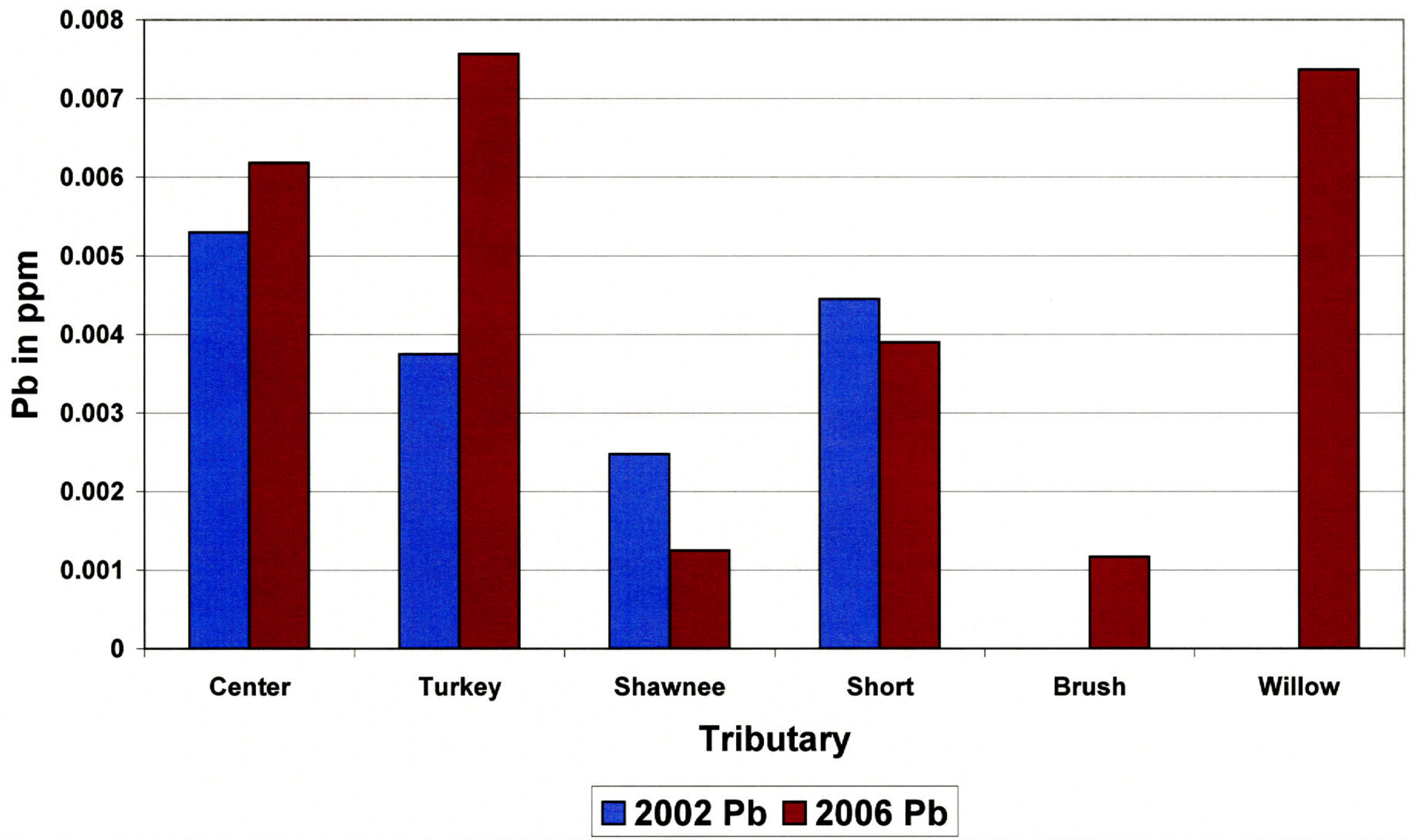


Figure 20: Spring River Tributary Lead



Creeks had the lowest lead concentrations. Samples taken at higher flows had higher lead, particularly on Willow, Center, Turkey and Short Creeks, where all exceeded 5 ppb of lead on average (Figure 21). Samples at lower flows typically were below the associated lead criteria.

The following table indicates average lead concentrations by station and flow condition. With only two years of sampling, several flow conditions on certain streams were not available for sampling.

Station	Very High Flow	High Flow	Normal Flow	Dry Flow	Very Dry Flow
Baxter Springs	143 ppb	34 ppb	37 ppb	31 ppb	33 ppb
Crestline	38 ppb	11 ppb	13 ppb	10 ppb	11 ppb
Shoal Creek	69 ppb	30 ppb	22 ppb	23 ppb	17 ppb
Center Creek	-------	89 ppb	76 ppb	54 ppb	44 ppb
Turkey Creek	-------	54 ppb	80 ppb	28 ppb	55 ppb
Short Creek	-------	61 ppb	67 ppb	37 ppb	30 ppb
Shawnee Creek	-------	32 ppb	18 ppb	15 ppb	10 ppb
Brush Creek	-------	--------	10 ppb	--------	13 ppb
Willow Creek	-------	--------	198 ppb	--------	12 ppb
Overall	73 ppb	34 ppb	33 ppb	22 ppb	26 ppb

Generally, very high flow conditions resulted in the highest concentrations on the major rivers. Center, Turkey, Short and Willow Creeks were elevated in lead under most monitored flow conditions. The large values seen under very dry conditions on Center and Turkey Creeks might result from seeps from previously mined areas or capture of some bed sediment with high lead content. USGS found high lead concentrations in the sediments of Turkey Creek and the Spring River immediately below the confluence with Center Creek. Higher flow conditions may put lead attached to sediments and organic material back into suspension or they may result in situations where larger portions of the watershed are contributing loads to the streams.

Violations of water quality standards at Baxter Springs resulted from higher flows, greater concentrations and lower hardness (Figure 22). Under very high flow conditions, lead concentrations far exceeded the target values set by the 2005 TMDL. The other two exceedances were close to target values and were only slightly higher than the calculated criteria during those normal flows. All compliant samples were below TMDL targets for the various flow conditions. Some of the lead occurring during very high flows may be resuspension and transport of sediments in Empire Lake, which were tended to have higher lead content than the streams.

Center Creek had high exceedances associated with higher flows (Figure 23). Violations at very low flows were near TMDL target values and were attributed to lower hardness levels at the time. Turkey Creek had two exceedances at normal and very low flows,

Figure 21: Spring River Tributary Lead

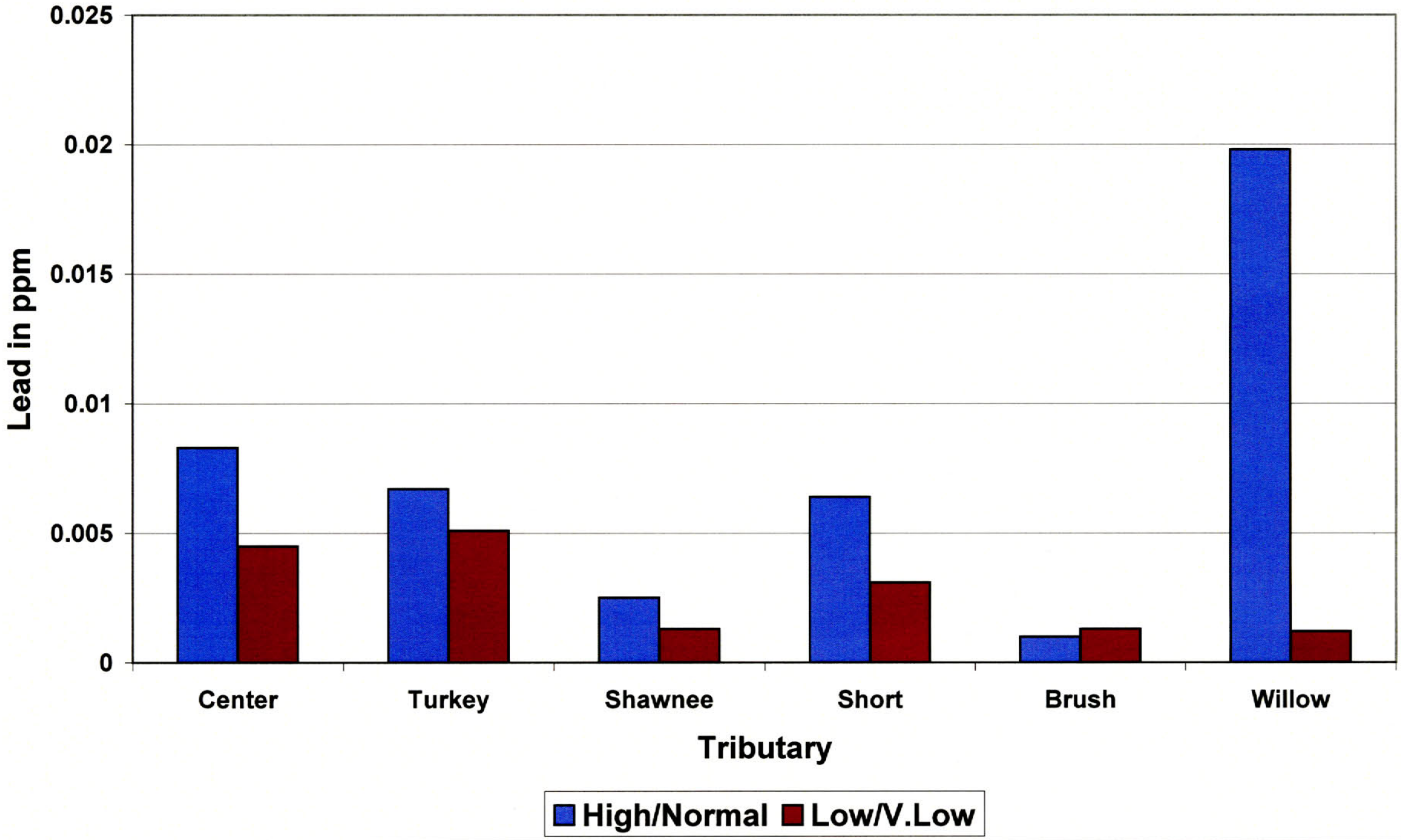


Figure 22: Baxter Springs Lead Conditions

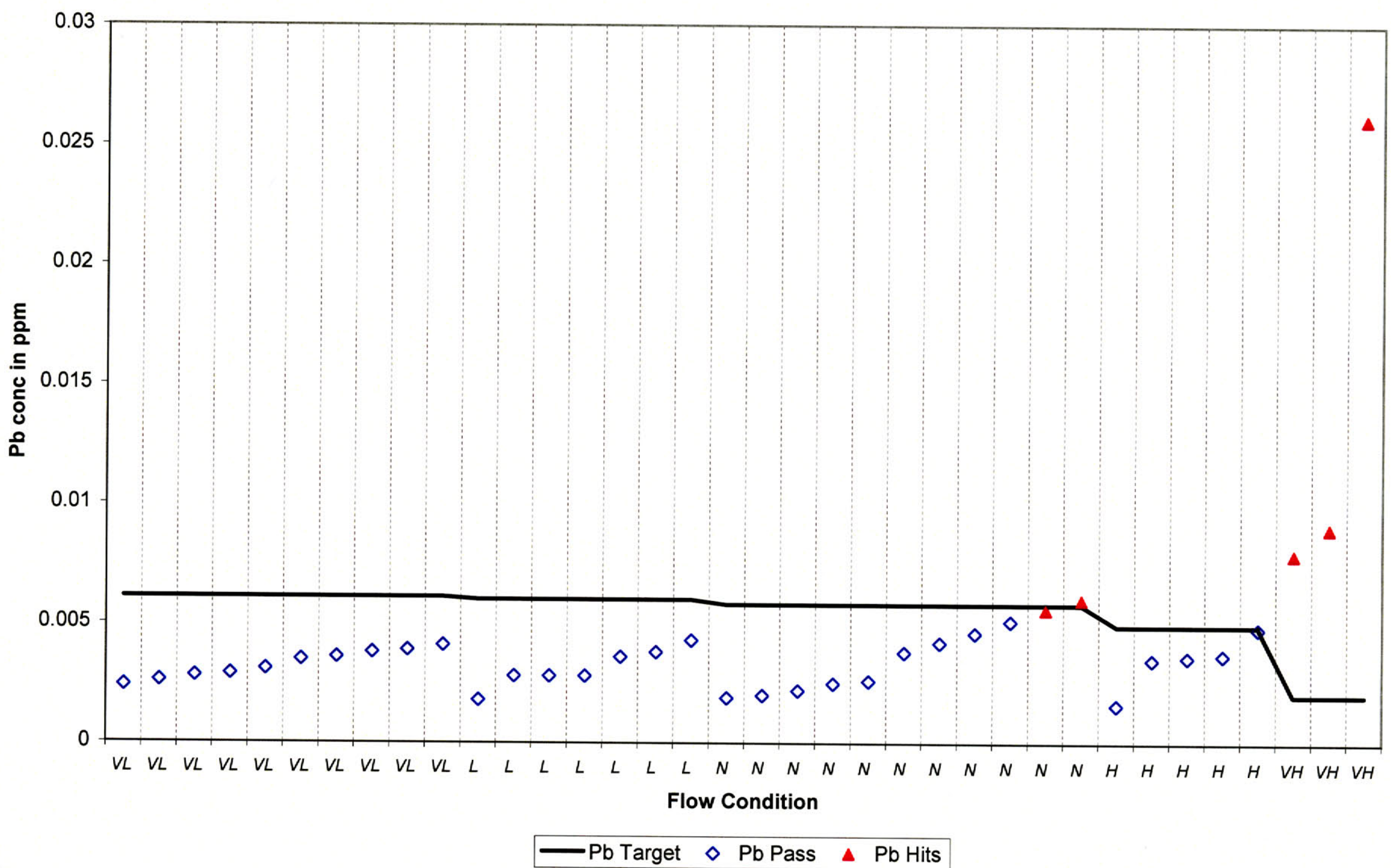
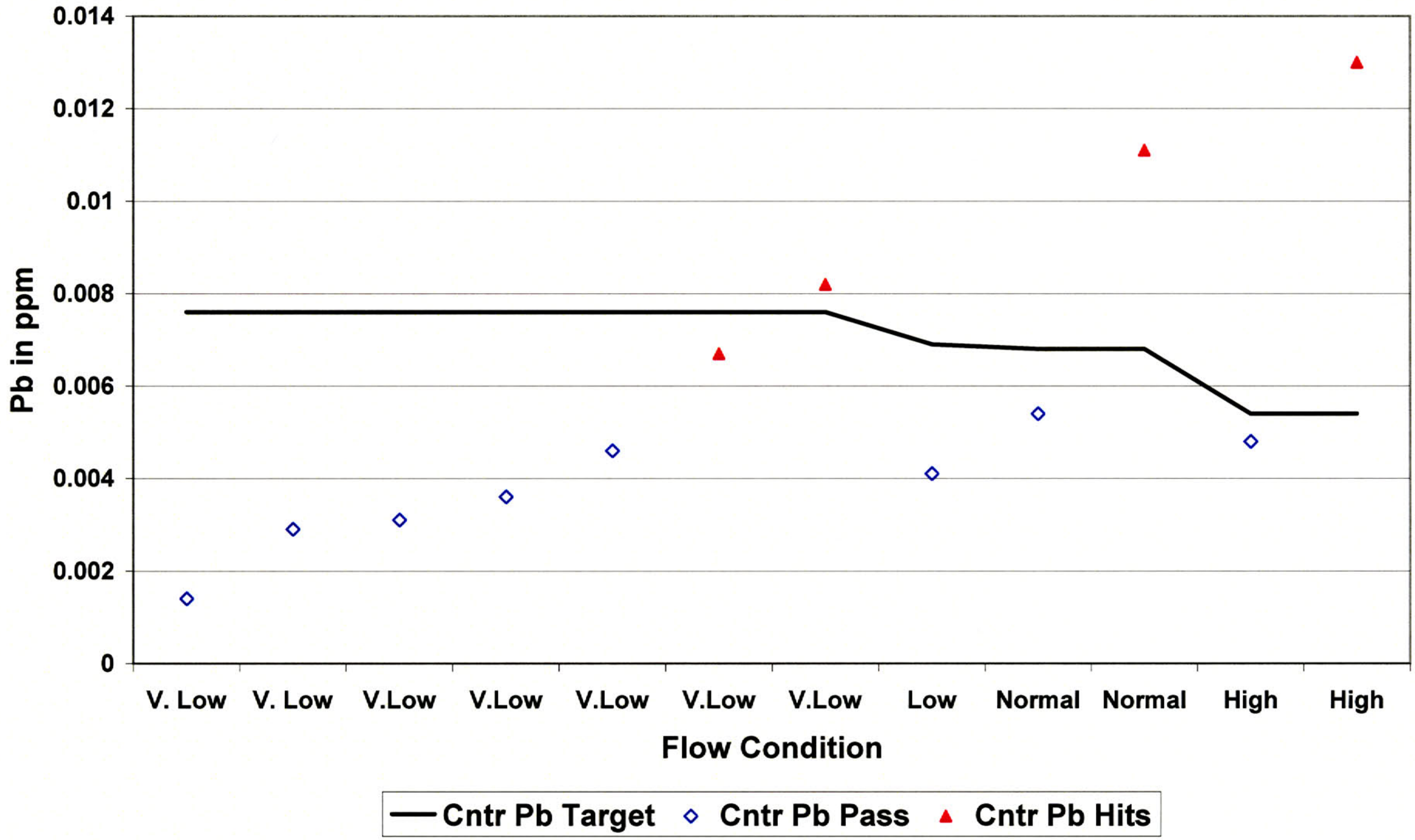


Figure 23: Center Creek Lead



suggesting that some incidental loading might have occurred from seeps or the bed sediment (Figure 24). All other samples were below TMDL targets. Short Creek had low lead levels under very low flow conditions, well below the TMDL targets (Figure 25). Two samples at normal to high flows exceeded the TMDL target, but because of higher ambient hardness, did not violate criteria. The highest flow situation resulted in the only hit for lead on Short Creek.

The TMDL target values seem to continue to be reasonable and achievable on the streams. While violations were noted at the highest flows, no acute criteria were surpassed for lead at any of the stations. The highest flows pose the greatest challenge because of enhanced loading from the watershed, re-suspension of lead-laden bed sediments and lowering of ambient hardness levels in the stream water.

ZINC RELATIONS

The outlet station at Baxter Springs has a higher frequency of zinc exceedances than it did for lead. Looking at Figure 26, zinc levels at Baxter Springs far exceed those on Shoal Creek or upstream at Crestline. While Baxter Springs has 10 exceedances of the zinc criteria, Shoal Creek only has one and Crestline has none. The relationship between zinc and flow is muddled. While some of the large values for zinc at Baxter Springs coincide with peaks in flow (Figure 27), some increases in zinc occur during steady baseflow periods. The two largest Shoal Creek yearly average zinc concentrations occur in the two years of highest annual streamflow: 2004 and 2007 (Figure 28). However at Baxter Springs, while 2007 and 2004 also make up two of the highest zinc levels, there is the anomaly of 2003, a dry year, having the second highest average zinc concentration. The other low flow years of 2005 and 2006 had lower zinc levels at Baxter Springs and on Shoal Creek. Average zinc concentrations at Crestline are fairly level, generally near or below 20 ppb.

Figure 26 shows the individual sample zinc concentrations for the three main stream stations over 2002-2007. Two samples, both exceedances, at Baxter Springs were left off since there was no concurrent sampling at Crestline or Shoal Creek. Seven of the eight displayed exceedances for Baxter Springs had zinc levels over 175 ppb. The March 2007 sample also exceeded 175 ppb, but had a higher hardness level and was thus compliant with the criterion. The September 2007 sample was an exceedance at 133 ppb, but also had very low hardness (67 mg/l). Shoal Creek's solo exceedance occurred on December 7, 2004, which was the highest flow event sampled in the past six years. This date also marked the highest zinc concentration sampled at Baxter Springs as well as the highest lead levels sampled at Baxter Springs, Crestline and Shoal Creek.

The following table indicates the zinc concentrations seen at the monitoring stations over various flow conditions in 2002-2007. It is clear that the elevated zinc levels seen at Baxter Springs emanate from the tributary streams, regardless of flow conditions. Shoal Creek, Shawnee Creek and Brush Creek and the upper Spring River have low zinc concentrations in the water column. Center, Turkey, Short and Willow are potentially major contributors to Spring River. The high concentrations at low flows may indicate that seeps and minehole discharges might be loading zinc into the streams.

Figure 24: Turkey Creek Lead

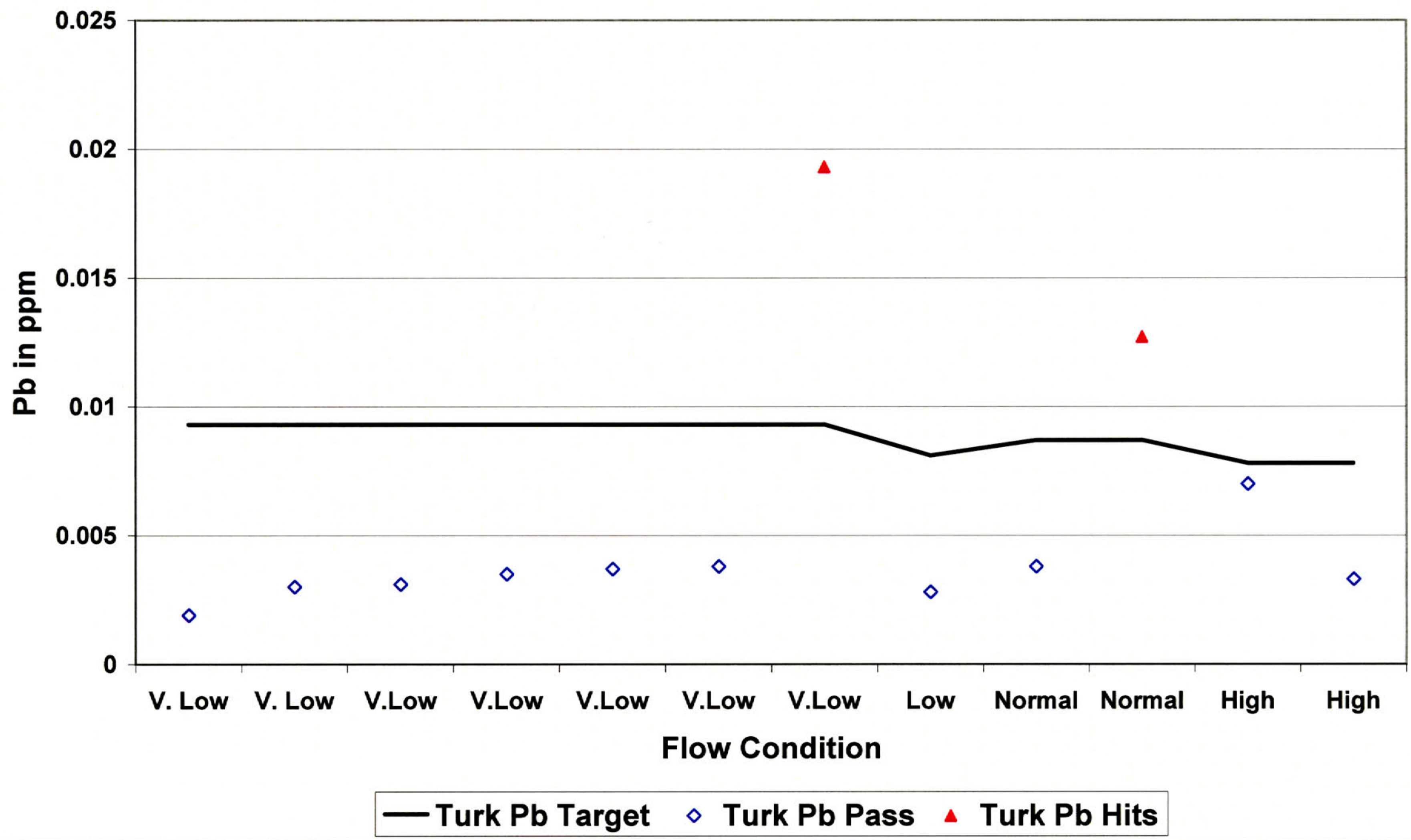


Figure 25: Short Creek Lead

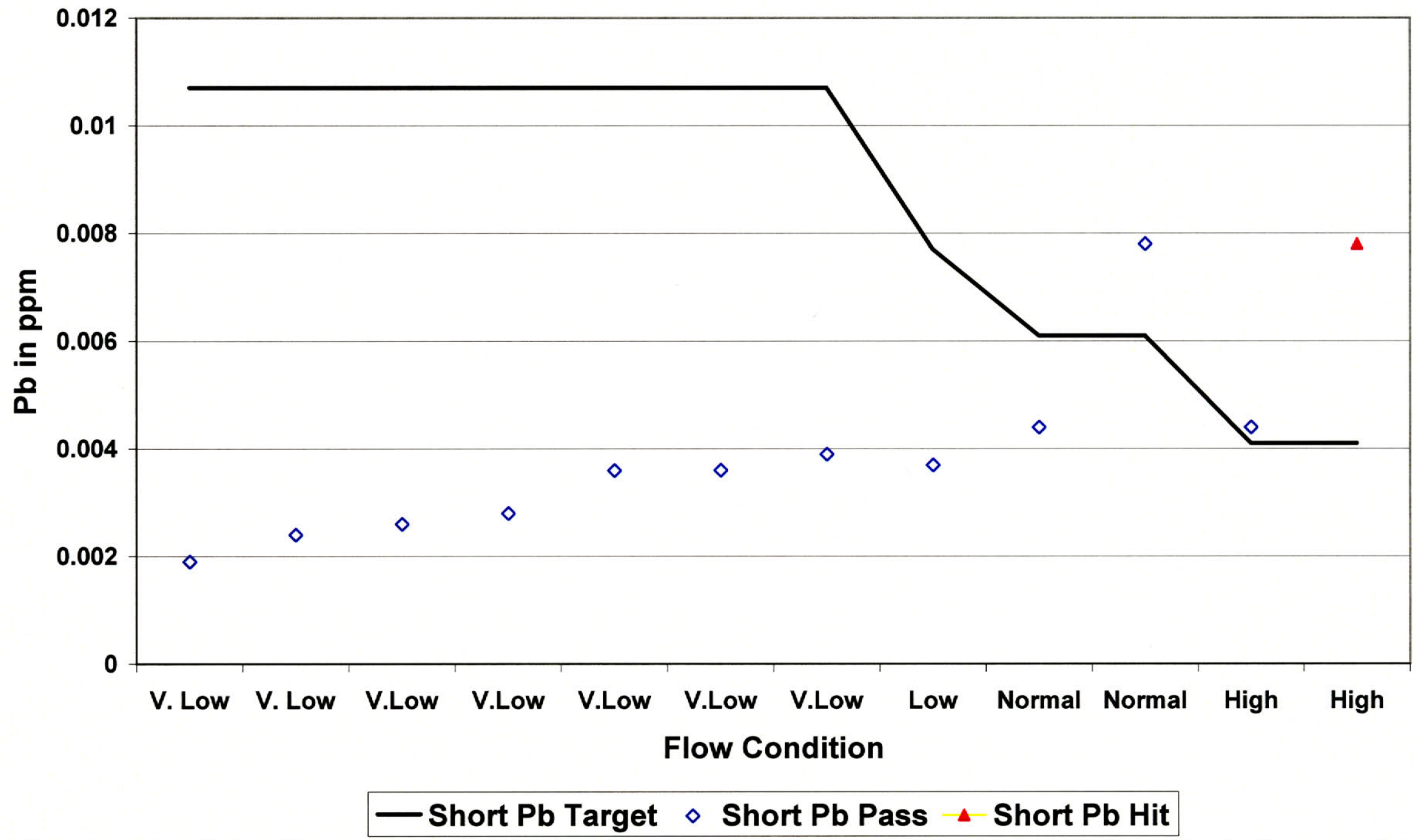


Figure 26: Spring R & Shoal Crk Zinc Concentrations

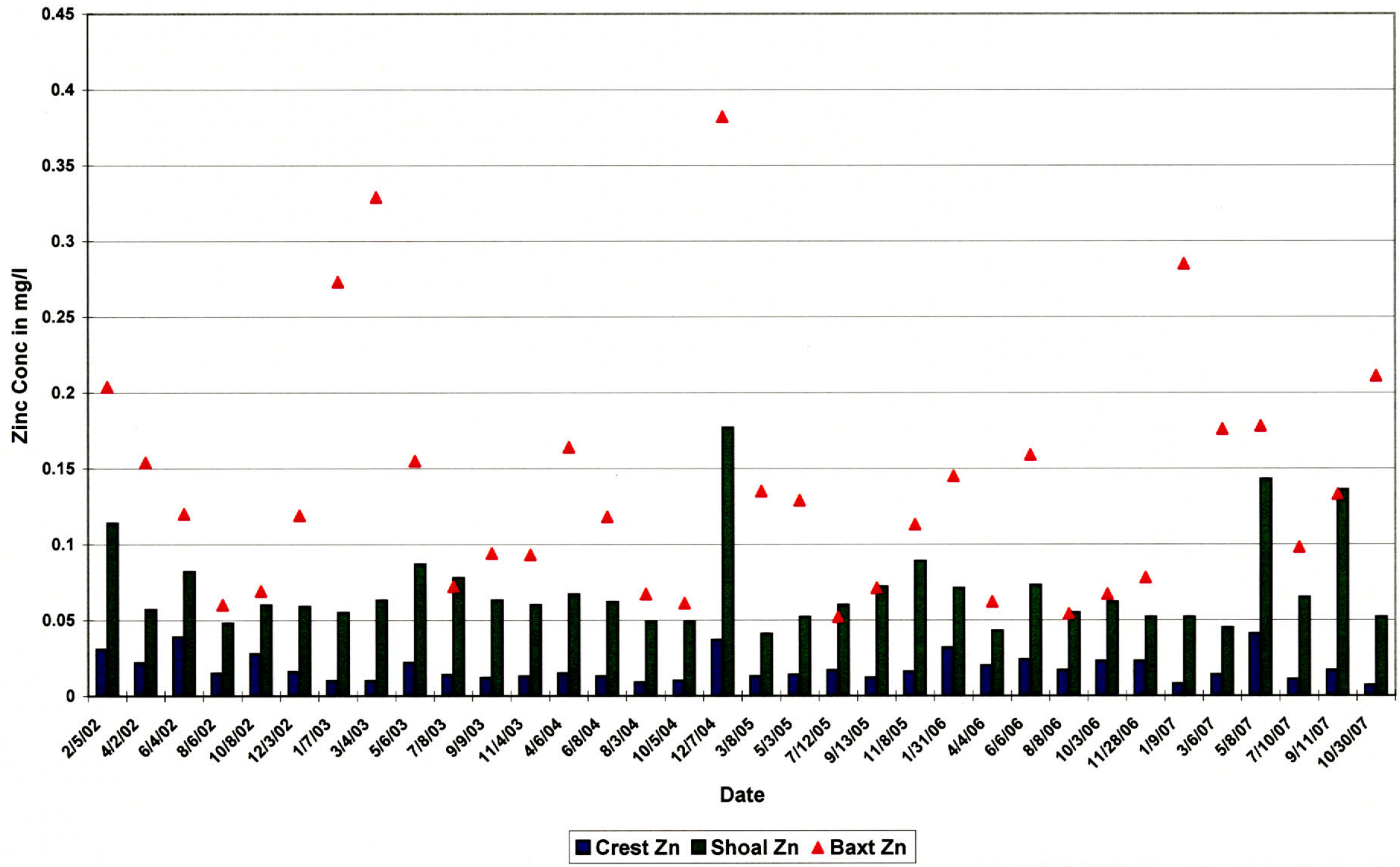
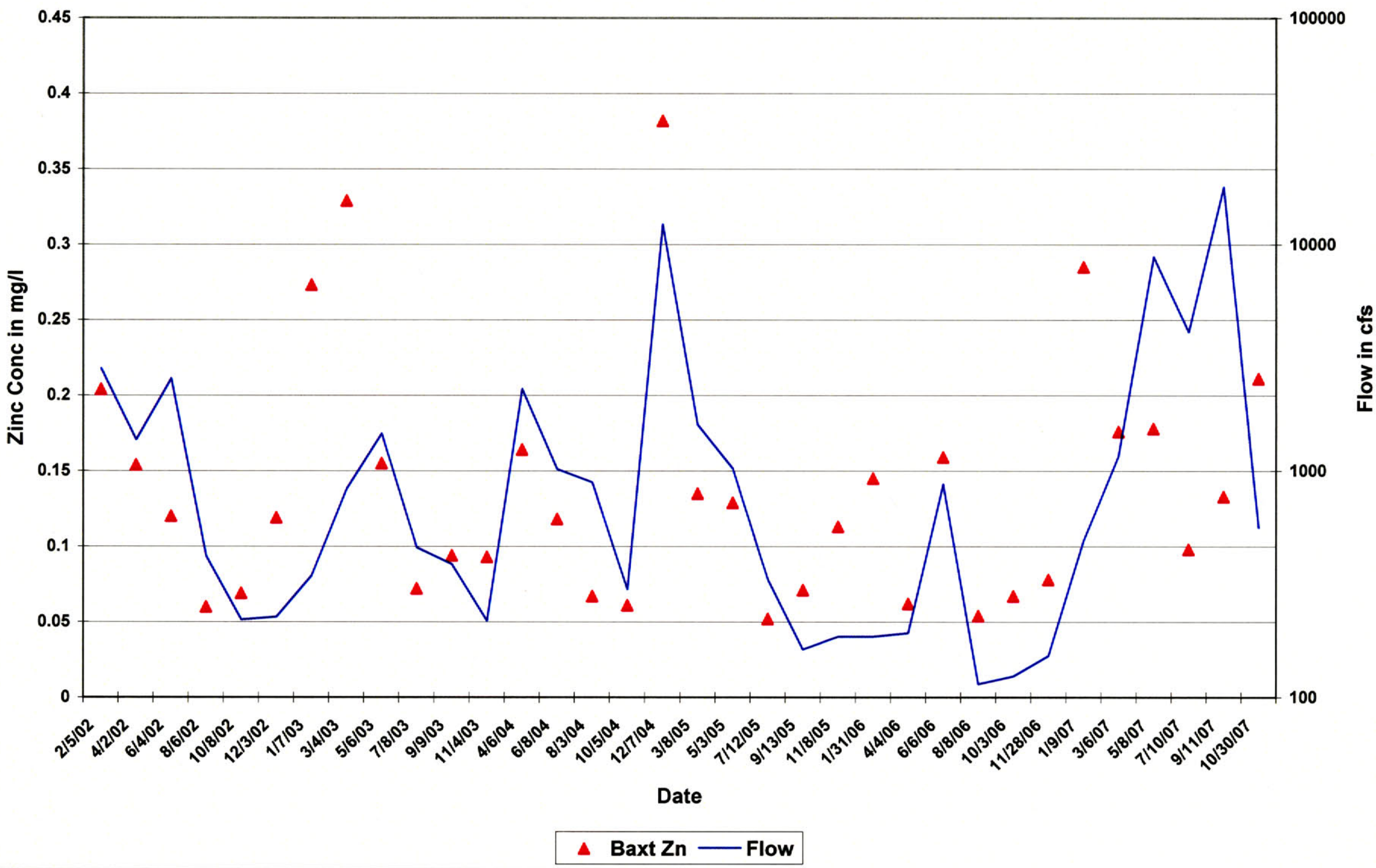


Figure 27: 2002-2007 Flows and Zinc at Baxter Springs



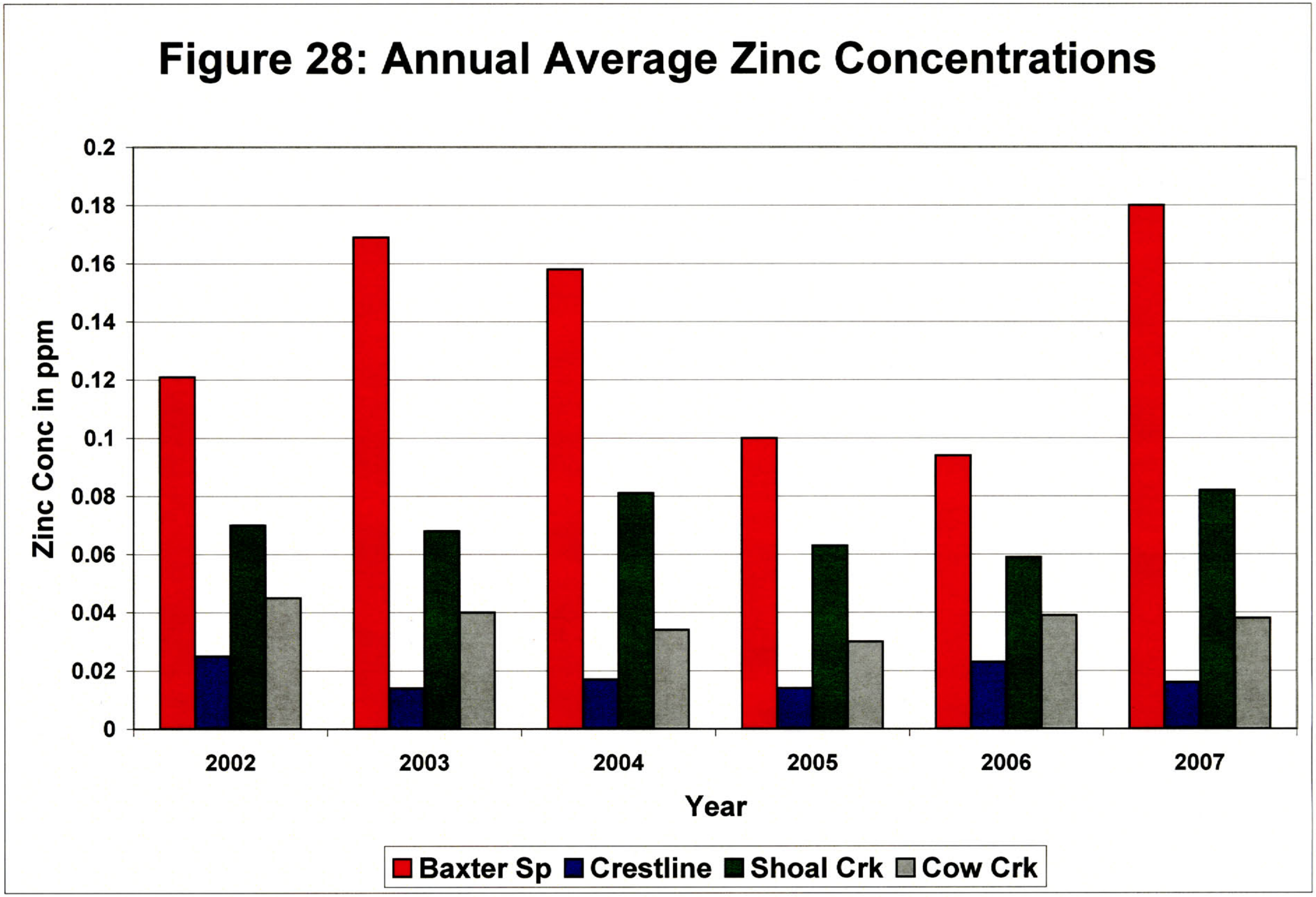


Figure 28: Annual Average Zinc Concentrations
Zinc Conc in ppm
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2002
2003
2004
2005
2006
2007
Year
Baxter Sp
Crestline
Shoal Crk
Cow Crk

Station	Very High Flows	High Flows	Normal Flows	Low Flows	Very Low Flows
Baxter Springs	231 ppb	156 ppb	168 ppb	128 ppb	87 ppb
Crestline	32 ppb	24 ppb	15 ppb	12 ppb	21 ppb
Shoal Creek	152 ppb	82 ppb	58 ppb	58 ppb	62 ppb
Center Creek	---------	311 ppb	304 ppb	161 ppb	193 ppb
Turkey Creek	---------	506 ppb	359 ppb	306 ppb	326 ppb
Short Creek	---------	5060 ppb	5518 ppb	5389 ppb	10,538 ppb
Willow Creek	---------	-----------	603 ppb	-----------	5974 ppb
Shawnee Creek	---------	46 ppb	25 ppb	16 ppb	11 ppb
Brush Creek	---------	-----------	9 ppb	-----------	7 ppb
Overall	118 ppb	529 ppb	325 ppb	247 ppb	1407 ppb

On the tributaries, there was little difference in zinc levels between 2002 and 2006 (Figure 29). Shawnee and Brush Creeks are consistently lower in zinc than the other four monitored tributaries. There also is very little difference in zinc levels between flow conditions (Figure 30). This might indicate that zinc is delivered to streams through constant source loading, including mine shaft discharges and seeps. Lead appears to be more runoff-related and tied to TSS levels. As seen previously by USGS, zinc has a higher propensity to be a dissolved form, although streambed sediments are also enriched with zinc.

Zinc levels that comply or exceed applicable zinc criteria are consistent with the zinc concentration targets established by the 2005 TMDL (Figures 31-34). This would imply that zinc exceedances are a result of actual excessive loading of zinc more so than episodic low hardness periods.

In summary, zinc appears to be caused by local sources consistently discharging to the stream systems, whereas lead may be transported from outer regions along with sediment and perhaps re-suspension of silt deposits in Empire Lake.

CADMIUM RELATIONS

Cadmium detections are chiefly restricted to Center, Turkey and Short Creeks. Three samples taken from Baxter Springs exceeded chronic criteria under low, normal and very high flows. Shoal Creek and Crestline had no exceedances, just as Shawnee and Brush Creeks had no detectable cadmium. Willow Creek had one exceedance among its three samples collected in 2006.

Center Creek had five exceedances distributed across low to high flows (Figure 35). Samples taken at very low flows did not exceed the detection limits, although those limits were greater than the chronic criteria. Turkey and Short Creek had exceedances in all twelve of their samples taken in 2002 and 2006 (Figures 36-37). Short Creek consistently had elevated levels of cadmium in its water column, approximately ten times

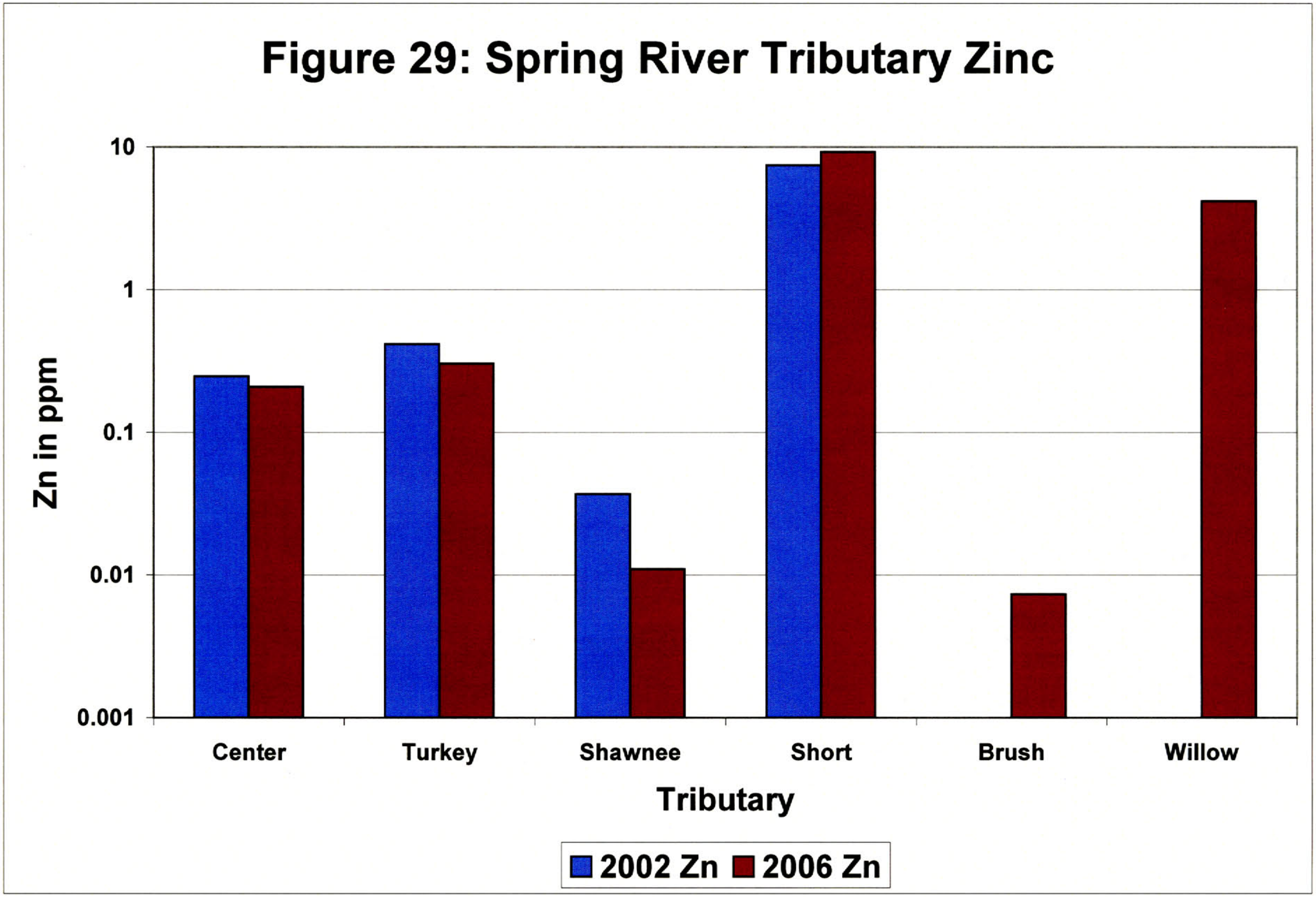
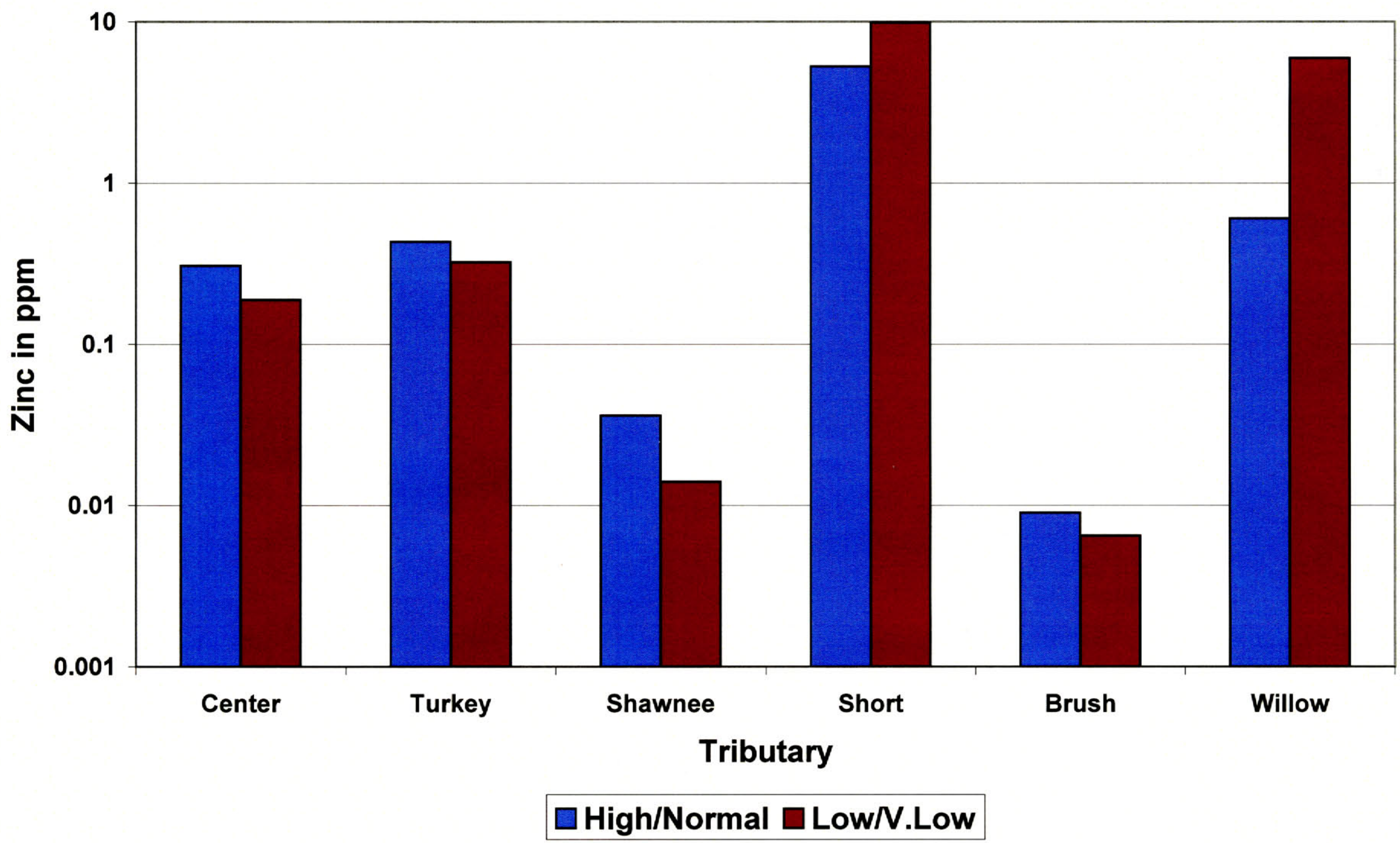


Figure 29: Spring River Tributary Zinc
10
1
0.1
0.01
0.001
Zn in ppm
Center
Turkey
Shawnee
Short
Brush
Willow
Tributary
2002 Zn
2006 Zn

Figure 30: Spring River Tributary Zinc



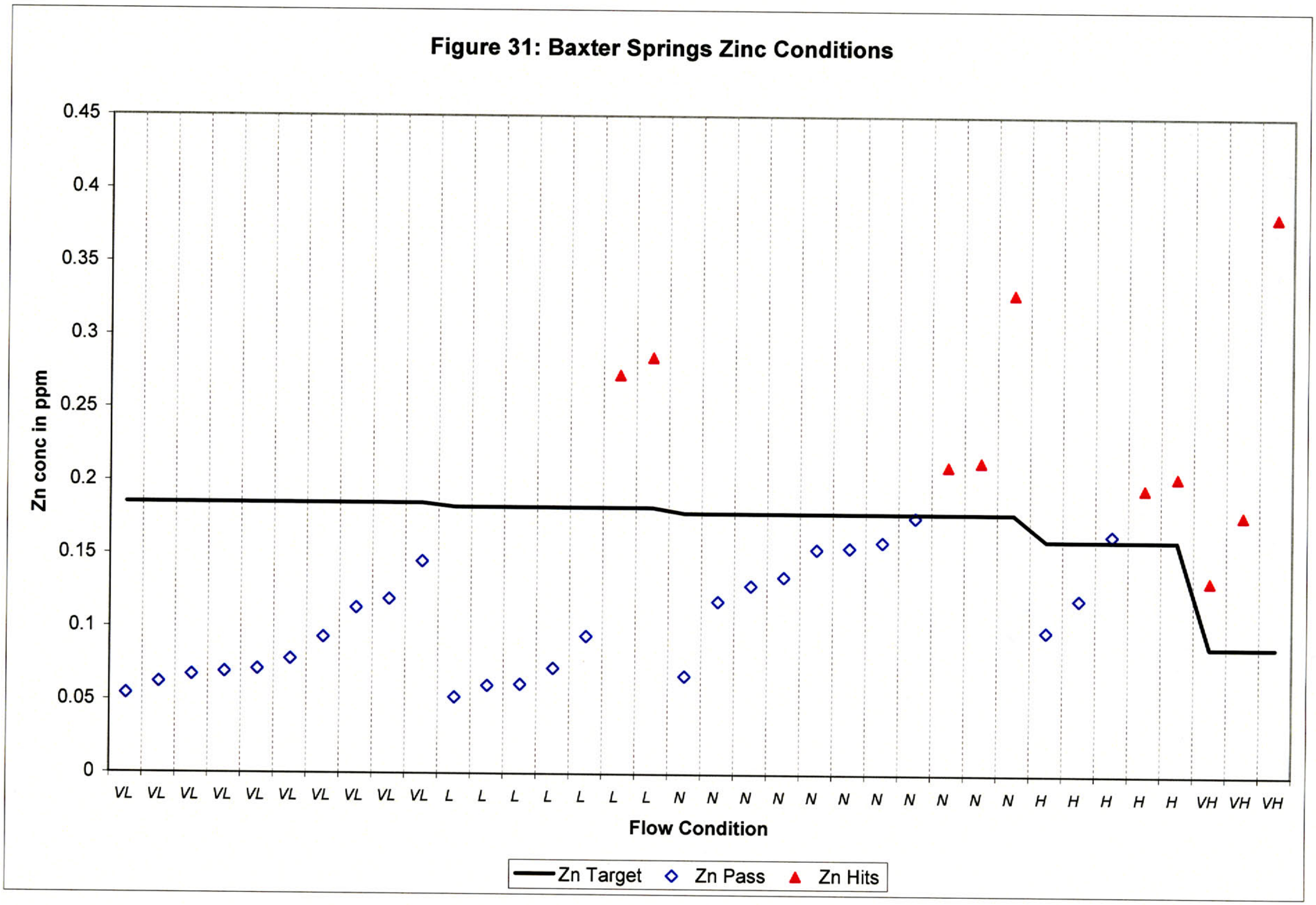


Figure 31: Baxter Springs Zinc Conditions
Zn conc in ppm
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
VL VL VL VL VL VL VL VL VL VL L L L L L L L N N N N N N N N N N N H H H H H VH VH VH
Flow Condition
Zn Target
Zn Pass
Zn Hits

Figure 32: Center Creek Zinc

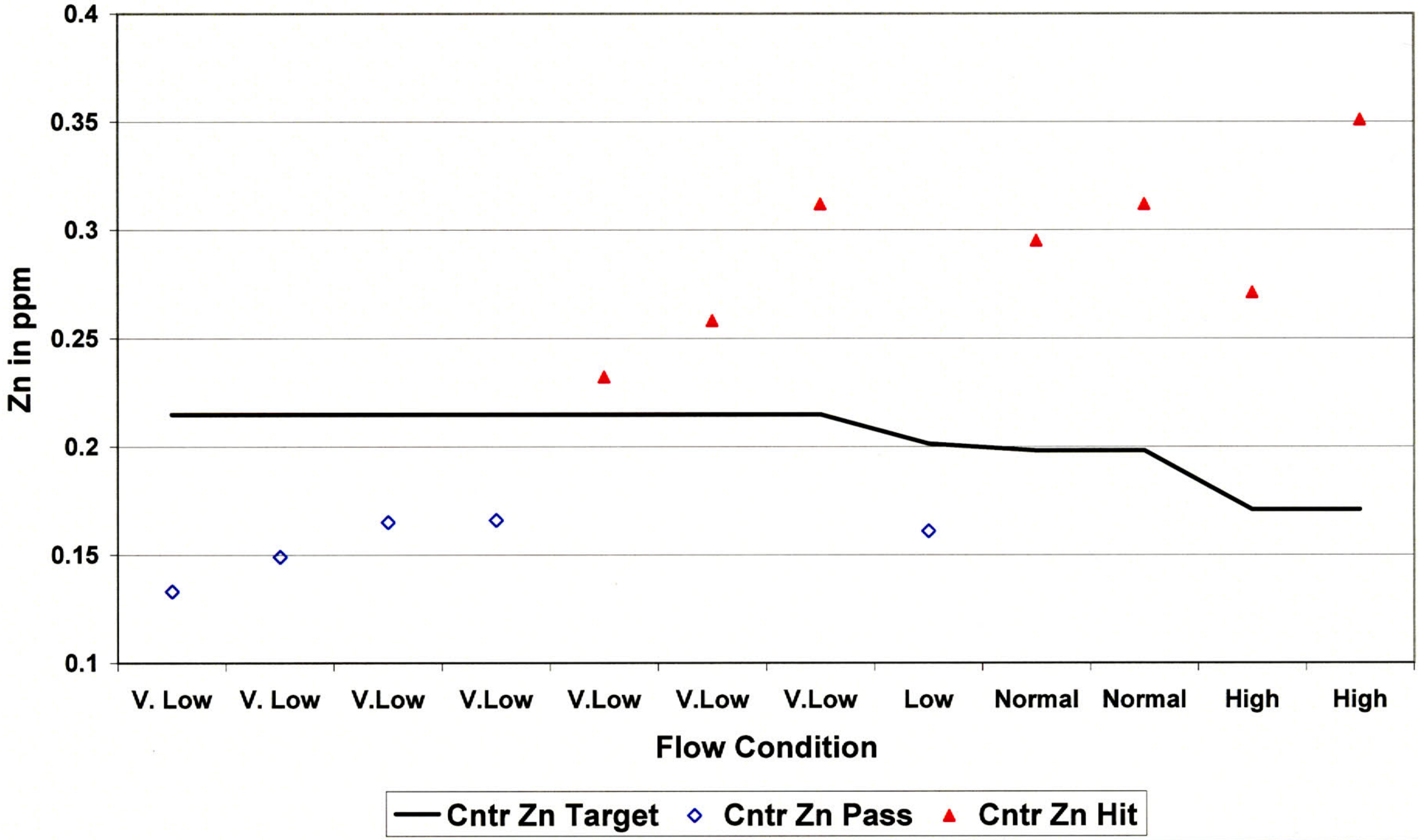


Figure 33: Turkey Creek Zinc

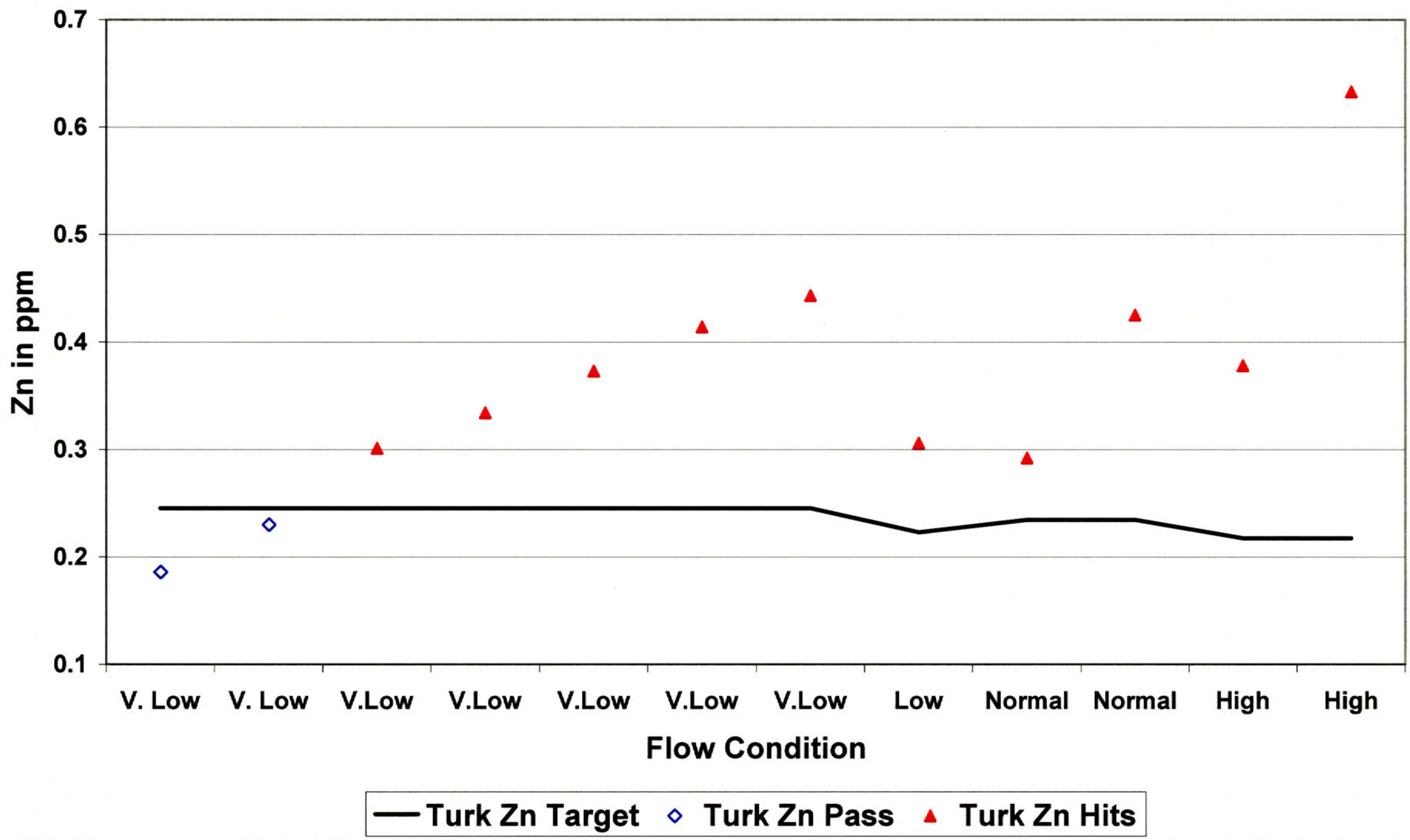


Figure 34: Short Creek Zinc

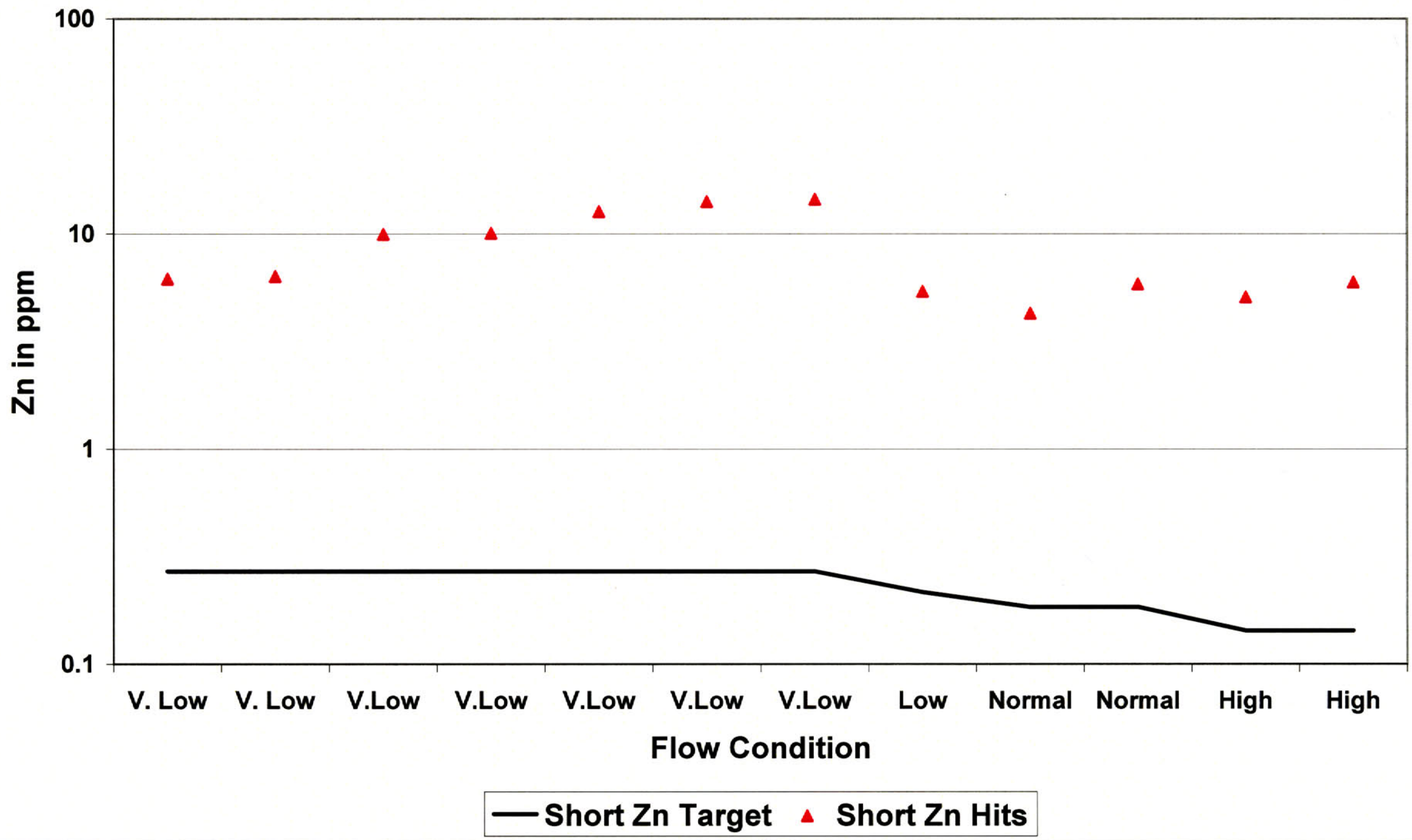


Figure 35: Center Creek Cadmium

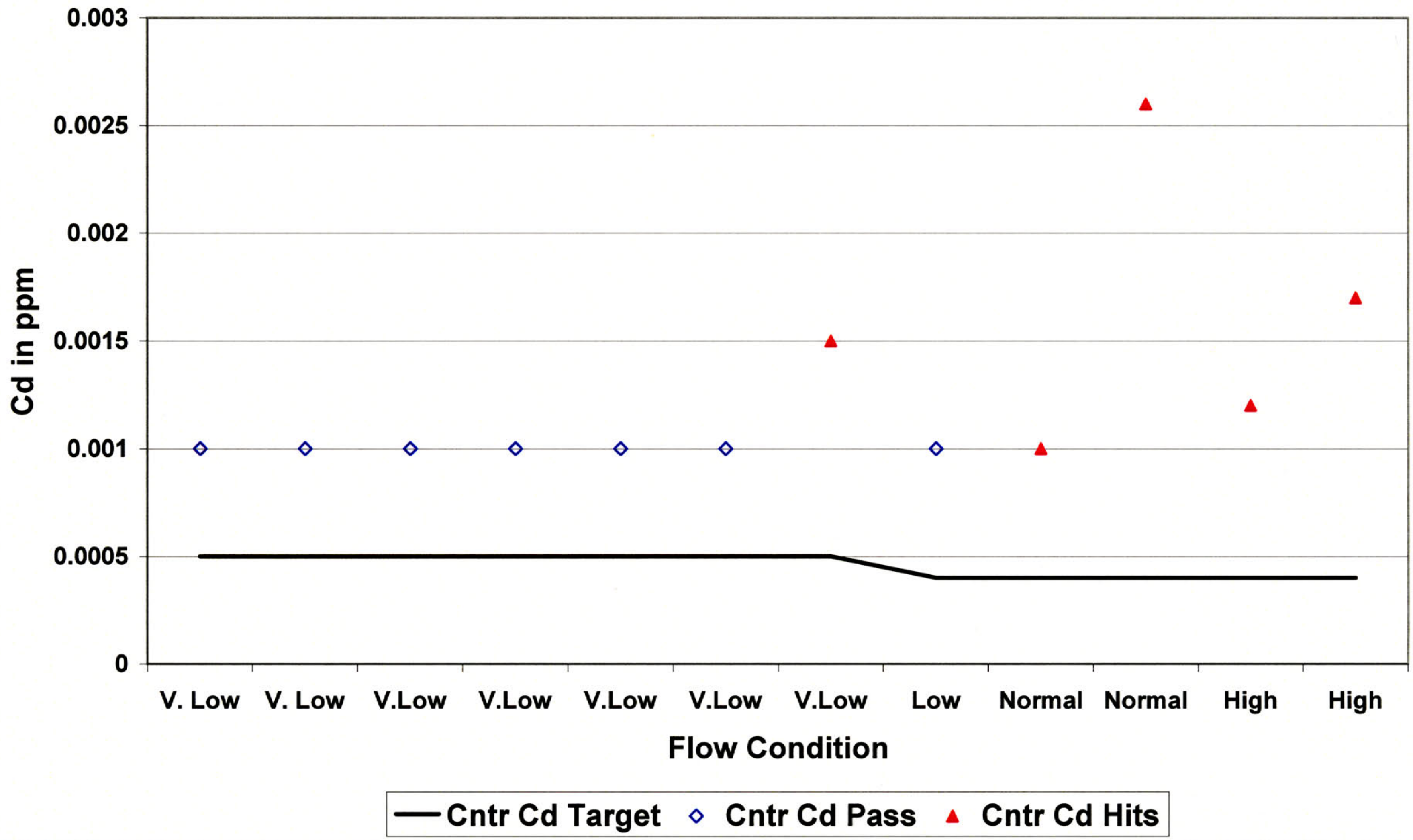


Figure 36: Turkey Creek Cadmium

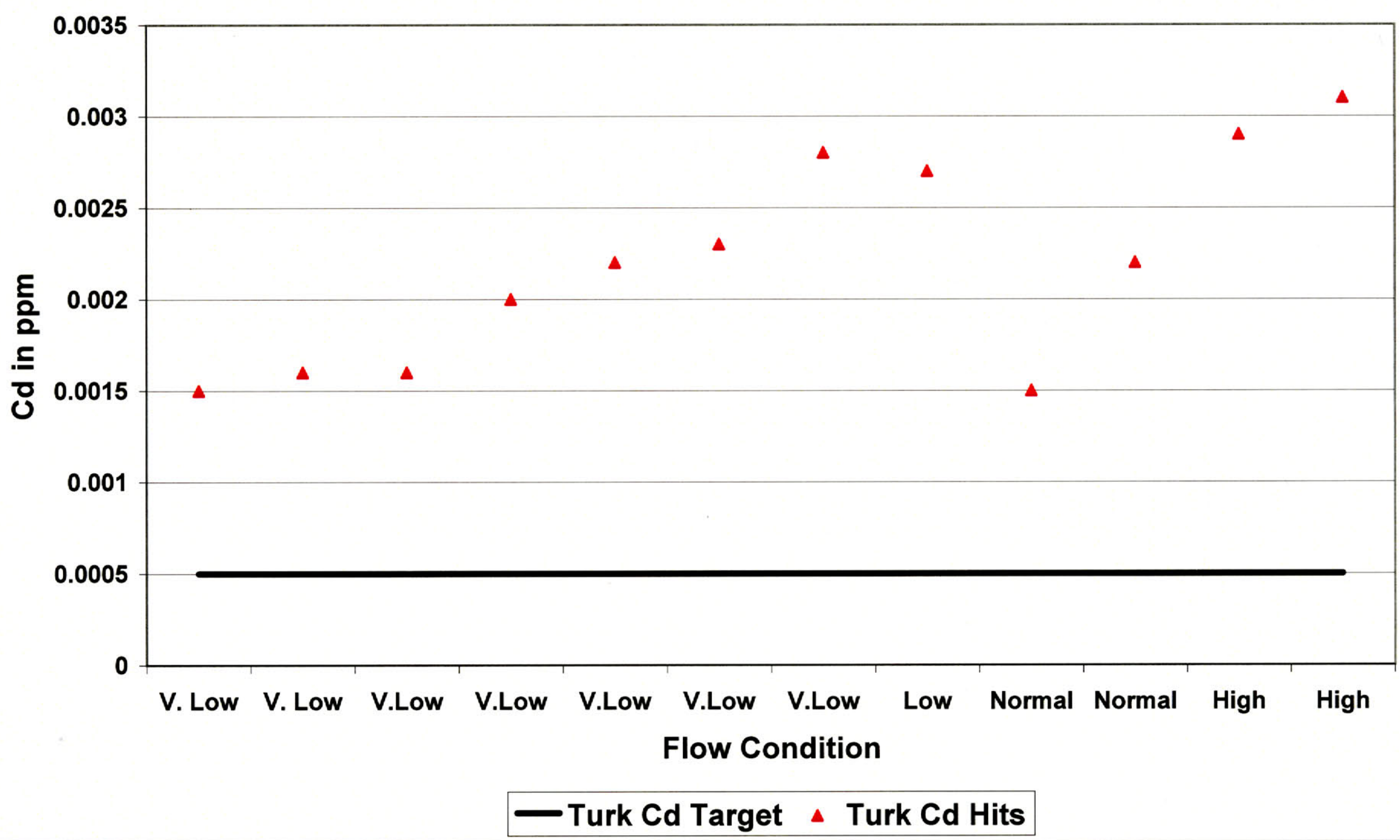
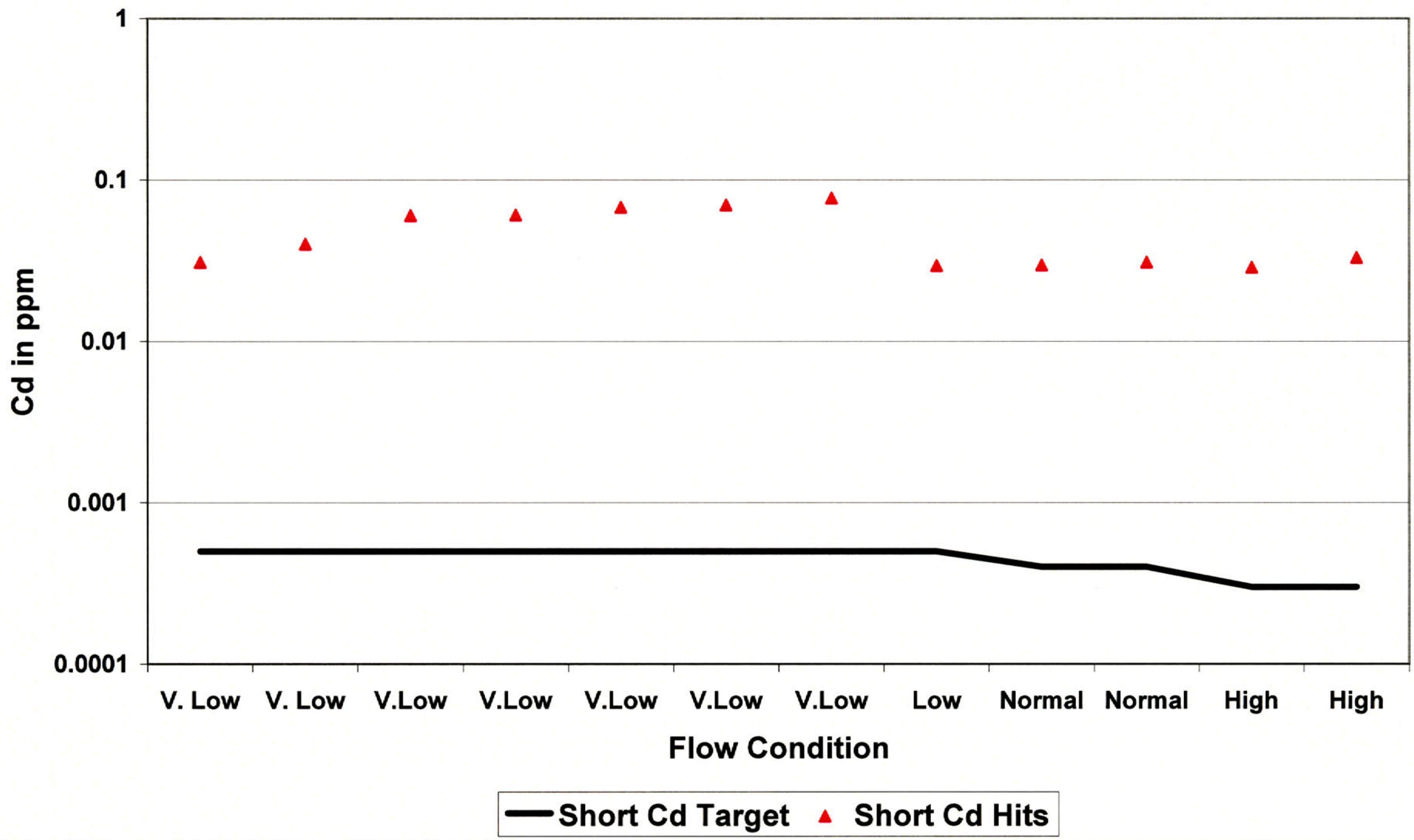


Figure 37: Short Creek Cadmium



that found on Turkey Creek. Because the acute criteria are the same as the chronic criteria, the exceedances of zinc are more toxic to the aquatic life in the Spring River watershed.

Cadmium might be coming from the same sources as the zinc given the persistent exceedances across flow conditions and the coincidental levels of zinc seen on Turkey and Short Creeks. Cadmium behaves comparably with zinc because of their proximity to one another on the periodic chart of elements.

POINT SOURCE CONTRIBUTIONS

Four facilities discharge into the Spring River, one, Columbus, discharges to Brush Creek and one, Galena, discharges to a tributary that enters the Spring River. While monitoring records are sketchy, it would appear that the major facility; Empire Electric, with up to 97 MGD of discharge averages about 200 ppb of zinc and 7 ppb of lead in its wastewater. The water it diverts for cooling averaged about 150 ppb zinc and less than 5 ppb lead. Some concentrating via evaporation might occur before the once-through cooling water returns to the river. Up to 1.24 MGD of water is discharged by Galena, Baxter Springs and the Cherokee County Sewer District #1. No metal monitoring data exist for Baxter Springs, Galena averages 250 ug/l zinc and 175 ug/l lead, although that value came from just two large samples, most of the samples were below detection limits for lead.

The 2005 TMDL did not set wasteload allocations for these discharges pending further data collection to see if they had high concentrations of zinc and lead in their wastewater. Because of the small design flow of the dischargers (< 2 cfs) and their zinc and lead concentrations near the target values for those metals at low flows set by the TMDL, these facilities are deemed not to be significant potential polluters of Spring River.

The major discharger, Empire Electric, also appears to discharge near target values and is only using river water for cooling, so is not inputting additional metal loads into the wastewater. Therefore, there is no apparent need to establish wasteload allocations yet for this facility either.

Instead, some enhanced monitoring would go far in establishing the true impact of these dischargers. In particular, a year of monthly sampling at Empire and Baxter Springs would identify any potential loading issues with the two largest dischargers to the Spring River.

SUMMARY

The conditions over 2002-2007 appear to align well with the expectations of the 2005 TMDL. The tributary contributions continue to load metals into the Spring River and high flow conditions continue to represent the period of greatest stress on the river system. The next evaluation in 2013 should concentrate on the impacts of high flows on re-suspension of Empire Lake sediment deposits and any impacts from point source discharges. As of now, no revisions to the 2005 TMDL are seen as necessary. The next evaluation should occur in 2013 in concert with the third round of TMDLs in the Neosho Basin and in anticipation of possible delistings in the 2014 303d list.

May 30, 2008

Spring + tribs – 8-9 station

2002 – 2007 drier than 1970 - 2001

Flows stable in watershed

Sampling – violations tend to be w/ higher flows

Pb – sediment / Zn – not as much

Pb – Center Cr. Clean
Shoal mostly clean

Elevated @ Baxter ~~@ [illegible]~~ –

Center
Turkey
Short
Willow

High flow impact

Zinc – more prevalent @ Baxter + Shoal

Some seepage impairment along w/ high flows

Pt Sources → need monitoring

Grand Lake influence