

MPERG Report 2009-4

**Brewery Creek:
From Assessment and Permitting
Through Production to Post Closure:
A Post Closure Analysis of a
Northern Heap Leach Mine**

By

Access Consulting Group

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Brewery Creek

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2010

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1.0 STUDY PURPOSE

This study was first conceived as an attempt to document the processes undertaken for the Brewery Creek Mine (referred to as Brewery Creek in this report) in the Yukon Territory and provide a description of the lessons learned from this process. The hope is that this report will be used in the future as a tool for regulatory authorities, assessors, resource development companies, and First Nations for analyzing and planning resource development projects. This report provides an analysis of some of the aspects of the first heap leach mine north of 60° from planning through to post-closure monitoring, start to finish by comparing expectations and predictions versus reality and the lessons learned through the entire process.

2.0 PROPERTY HISTORY

Brewery Creek is a closed gold heap leach mine site located 57 km due east of Dawson city in the Yukon Territory, Canada. Access is via the Dempster Highway, and then by Ditch Road and 4WD road to the mine site. The Brewery Creek property was first staked in October 1987. Prior to 1994, when the application for production and water use was first submitted, exploration consisted of 841 reverse circulation and 64 diamond drill exploration holes. Metallurgical testing in 1989 identified significant gold mineralization with extraction potential for bulk tonnage heap leach deposits. In 1994 an application for a class 'A' Water Use License (WUL) was submitted. Mining and construction commenced in 1995. Ore processing employed conventional heap leach technology on run of mine ore, commencing in November 1996. Brewery Creek originally operated under WUL QZ94-003, issued in August 1995 and under Quartz Mining License (QML) A99-001 issued in June 1999. In July 1997 the mine began operating under WUL QZ96-007, created as a result of an amendment application to WUL QZ94-003. Brewery Creek ceased active mining operations in September of 2000 and no additional ore was added to the heap leach after this date. This cessation date was more than 2 years earlier than predicted in the planning and permitting stages, due primarily to depressed gold prices. Active cyanide leaching of the heap leach pad continued until December 2001. Detoxification of the heap leach was completed in the second and third quarters of 2002 with some release of detoxified waters over 2002 and 2003 and regular post closure monitoring.

The production rate was planned at 2 million tonnes of ore per year for 8 years (WULA, p 6-1) but, due to depressed markets and a lower than anticipated recovery rate production ceased after only 5.5 years and a total of 9.5 tonnes of ore.

3.0 ASSESSMENT AND REGULATORY PROCESSES

The assessment and regulatory processes for Brewery Creek were initiated by Loki Gold Corp and culminated in the 1995 issuance of WUL QZ94-003. In 1996 Viceroy Resource Corp (referred to as Viceroy in this report) acquired Loki Gold Corp and Brewery Creek. All licences and permits were then transferred to Viceroy. On March 5, 1997 WUL QZ94-003 was amended as WUL QZ96-007. In March 2005 licences and permits were again transferred, from Viceroy to Alexco Resource Corp (referred to as Alexco in this report) after Alexco purchased the property. Many of the employees of Loki and then Viceroy who were associated with Brewery Creek project remained, providing some continuity as the project progressed.

The assessment process that was undertaken for Brewery Creek was the national environmental assessment legislation at the time: the *Environmental Assessment and Review Process Guidelines Order* (EARP), registered in 1984. IN 1995 EARP was replaced by the *Canadian Environmental Assessment Act* (CEAA). In 2003, with the devolution of federal responsibilities to the Yukon, the federal CEAA was replaced by the territorial *Environmental Assessment Act* (EAA). The EAA has since been replaced by the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA) which came into effect in November 2005.

The initial environmental evaluation investigated and discussed most aspects of the proposed mining process, including design, mitigative measures, and operational and closure requirements. The environmental management plan identified and addressed three mine components: 1) the heap leach pads and plant; 2) the open pits and waste rock piles; and 3) infrastructure.

The main licence required for an operating mine at the time was a Water Use Licence from the Yukon Water Board, an independent administrative tribunal established under the federal *Yukon Waters Act* (previously established under the federal *Northern Inland Waters Act* of 1972, currently under the territorial *Waters Act*). The WUL was initially granted in 1994 (QZ94-003). An amendment was then issued in 1997 as a new licence (QZ96-007) and seven more amendments were issued between 1999 and 2005. Most of these amendments were the result of changes to operational or design aspects at Brewery Creek as a result of changing site and market conditions, discussions with regulatory authorities, and from experience gained during the construction and operation of Brewery Creek. Both the first WUL amendments to WUL QZ96-007 (amendment application QZ98-032), approved in 1999, and seventh (amendment application QZ03-062), approved in 2005, required a screening under the EAA.

An amendment to the federal *Yukon Quartz Mining Act* (YQMA) required that all development and production activities related to quartz mining in the Yukon be carried out in accordance with a

licence and the YQMA and Regulations by June 1999. Viceroy Minerals applied for and in February 1999, received a Quartz Mining Licence (QML A99-001). In 2003, under the devolution of authority from the federal government to the Yukon Government the federal YQMA was replaced by the territorial *Quartz Mining Act*. The QML was amended in April 2004 (amendment 04-001) to remove some of the conditions of the licence and provide more specific guidelines on the reclamation and decommissioning processes.

One current regulatory instrument that was not in place when Brewery Creek was operating but came into effect shortly after is the Metal Mining Effluent Regulations (MMER). These regulations, created as a result of requirements under the *Fisheries Act*, came into effect in June of 2002. This was after Brewery Creek was no longer in operation and thus MMER did not apply but if Brewery Creek had continued operation beyond June 2002 it would have applied. It should be noted that, while the MMER does have specific limits for deleterious substances in mine effluent there are not significant differences between these and the limits imposed under WUL QZ96-007 (see Appendix A). The most significant changes that would have been brought in with the MMER that would have applied to Brewery Creek are in regards to toxicity testing and the Environmental Effects Monitoring (EEM) portion of the MMER (Schedule 5). Much of the MMER requires pre-operational studies to determine baseline biological conditions and subsequent monitoring of “fish population, on fish tissue and on the benthic invertebrate community” (MMER, 14(b)(ii)). These additional studies would have resulted in some additional costs but the impacts to operations are difficult to judge. Even with all of the data from the water quality monitoring programs it is impossible to predict if the mine operations would have contravened the EEM requirements of the MMER and the effluent discharge aspect of the MMER are very similar to those imposed under the WUL.

4.0 MINE DESCRIPTION

Brewery Creek consisted of an open pit gold mining operation that employed a retrieval technique that was new to the Yukon: heap leaching. Gold heap leaching is a process whereby raw ore is piled in large mounds, or “heaps”, and a sodium cyanide solution is sprayed/dripped onto the ore heap. The cyanide solution percolates down through the ore, dissolving the gold into solution. The gold-bearing solution is collected at the base of the heap and transported to a recovery plant where it is processed to extract the gold from solution.

Brewery Creek consisted of 8 shallow, mostly oxidized gold deposits. In 1994 the predicted mineable reserves were 16.7 million tonnes grading 1.4 g/tonne containing a total of 794 000 ounces of gold. The mining was generally standard open pit with some differences as a result of

the rock quality and number of small pits at a distance from the heap leach. Figure 1 shows the general mine site layout.

The mine site consisted of an office/maintenance area, a heap leach pad, eight deposits as ten open pits, a carbon adsorption/desorption/recovery facility (ADR plant), two process ponds sized for the capacity of a 12 hours drain-down of the heap, and an overflow pond sized for the capacity of complete drain down of the heap plus above average precipitation. The original 1994 plan called for 2 overflow ponds to be phased in as the heap increased in size but for various reasons mining ceased early when the heap was at only 70% of the planned size.

The heap leach was chosen as the most economically feasible option for ore processing. Much of the operational feasibility as a cold-climate heap leach was based on the Zortman Landusky Mine in northern Montana. The heap leach pad was designed to be approximately 38 ha in size and contain 15 million tones of ore, with the potential for higher stacking in the latter stages to mine and process the entire 17 million tonne deposit. The heap was designed for 10 distinct cells with 3 lifts per cell to allow for segregation of the ore so that, in the case of liner failure, repairs could be effected without removing the entire heap. Solution was collected and transported from the leach with a collection system of perforated HDPE piping buried in drain rock to HDPE drainage pipes and then transported up to the ADR plant. The solution was processed, removing as much of the gold, and then recycled back into the heap. Double-lined “pregnant” and “barren” ponds were constructed to be used as receiving points for the unprocessed solution from the heap and the processed solution from the processing plant but were bypassed to reduce icing and other winter effects. These two process ponds were used primarily as receiving points for water and solution collected from the leak recovery system in the heap.

The leach pad was constructed in a series of phases: in 1996, 158,000 m² of double lined leach pad was constructed followed by additions of 59,500 m² in 1997, 12,000 m² in 1998, and 82,000 m² in 1999. At the end of 1999 the Brewery Creek heap leach pad consists of 7 individual cells comprising a total liner surface area of approximately 311,000 m². The ultimate design was for ten cells. At the end of 2001 a total of 9.458 million tonnes of ore had been placed in 7 cells on the leach pad. These totals are less than the predicted levels as shown in the Table 1.

Brewery Creek Mine

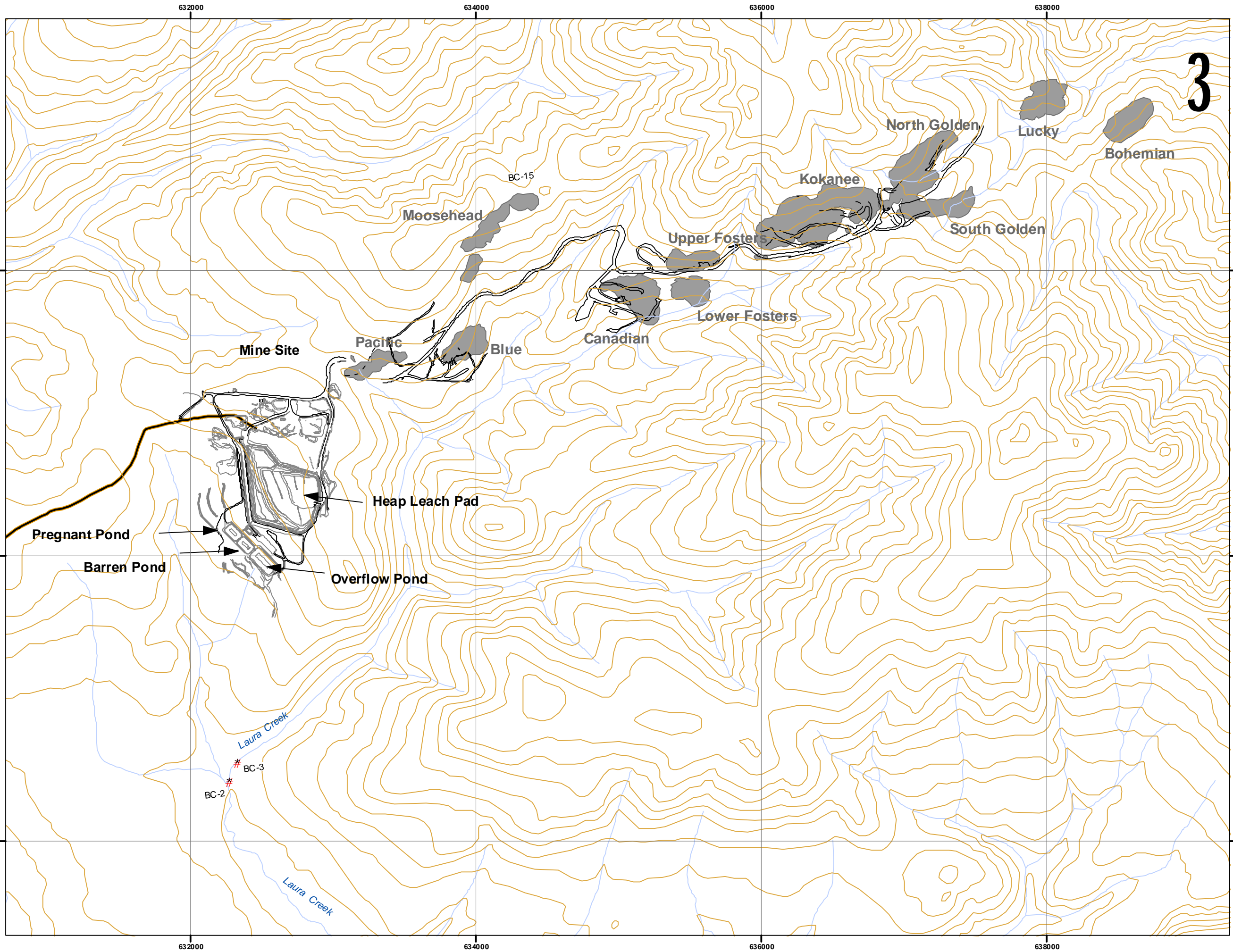
3



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Legend:

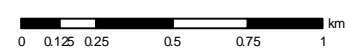
- Main Building
- Water Quality and Sediment Sample Station
- Brewery Creek Mine Access Road
- Secondary Road
- Water Course
- Mined Ore Zone



UTM Zone 7 NAD83
NTS Sheets 116B/01

Brewery Creek Site Overview

Scale: 1:25,000



Drawn by: HD/PI Checked by: PI
Date: May 2009

Our File: D:\Project\AllProjects\ALEX-05-01\GIS\mxd\BrewCreek\KFieldMapSiteOverview.mxd

Table 1. Mine production: predicted versus actual

	Predicted	Actual
Heap leach pad area	38.7	31.1
Number of cells	10	7
Millions of tonnes of ore	15	9.55
Operational lifespan	8	5.5
Gold recovery rate	79%	62%

5.0 MANAGEMENT ISSUES – PREDICTIONS VS. REALITY

5.1 Wildlife Management and Affects

5.1.1 Description

Concerns were raised during the review process that the solution could pose a risk to wildlife as the chemical composition would likely be toxic. Based on recommendations netting covers were added to the process ponds to restrict wildlife access these ponds. Fencing around the entire heap leach to restrict access to the active heap leach areas was also required.

5.1.2 Issues and Lessons Learned

Wildlife incidents were documented in WUL annual reports and indicate that, while there were no significant events there were annual problems with wildlife in the process and overflow ponds. Nearly all of the wildlife fatalities were a result of wildlife, usually foxes, gaining access to the ponds and being unable to escape on the slick HDPE slope. A capture and release program was attempted to save trapped foxes but was unsuccessful. A “fox ladder” was constructed to provide a form of egress for the foxes, although the success of this was not obvious as it was difficult to quantify. The other suspected cause of wildlife fatalities was consumption of pooled process solution soon after application to the heap. This occurred to three birds in one incident. Additional there was a single incident in winter in which a group of caribou were trapped within one of the ponds. A layer of fencing that allowed the caribou to climb the slippery liner and exit the ponds was constructed and there were no fatalities.

Some form of permanent egress for trapped wildlife in lined ponds combined with increased wildlife vigilance and routine inspections of all fencing may reduce these wildlife fatalities in future heap leach operations. The potential problem of bird fatalities due to cyanide solution should be considered for future heap leach operations particularly if a cyanide heap leach mine is to be

constructed in an area of dense avian habitat or migratory route. Methods of scaring birds in during the operation of a heap leach could also be investigated.

5.2 Leach Pad and Pond Design and Leakage Rates

5.2.1 Description

A leak detection and recovery system (LDRS) was designed as part of the liner system for the heap leach and process ponds. A different liner system was designed for each of these uses.

Revised plans for double lined leak detection and recovery systems for the heap leach and process ponds were submitted as a result of the WUL review process. The LDRS for heap leach pad consisted of the following layers:

- a 0.6 to 1 m of crushed ore as a cushion layer;
- a primary composite layer of 40 mil PVC geomembrane and 300mm of compacted silt;
- a geotextile filter and separation layer;
- a LDRS layer of 300mm of gravel; and
- a secondary composite layer of 30 mil PVC and 300mm of compacted silt

An amendment to the WUL in 1999 allowed a change of the design of the top composite layer to a geosynthetic clay liner.

Solution percolating through the stacked ore was collected by a network of pipes on the primary liner of the pad, and gravity flows through double-contained pipes to the Adsorption-Desorption-Recovery (ADR) plant. Conventional carbon adsorption, pressure stripping, electrowinning, and smelting were used to recover the precious metals from solution. The 'barren' solution was then recirculated to the pad.

The process ponds double lined LDRS system of consisting the following:

- a 80 mil HDPE liner;
- a geonet drain; and
- a 40 mil HDPE liner

Low volume leakage was detected with the LDRS throughout the life of the project but from 1998 on a higher than predicted rate of leakage was observed at the pregnant pond due to freshet surface runoff waters short circuiting the liners and entering LDRS from a ditch. This may have been avoidable through additional review of the planning and installation of the liner, but it should

be noted that this water was returned to process and did not cause undue stress to the solution management system. Testing of the water for free cyanide, pH, and conductivity showed that it was not process water. Nonetheless this water had to be treated as process water and temporarily increased the water in the circuit. In a flood event of the magnitude of a 1 in 200 wet year this could have put undue stress on the system as all additional water from the LDRS was recycled as process water. Precipitation tracking throughout the life of the project showed that no significant wet event occurred over the active life of the mine.

There was one notable increase in the leakage rates of the heap leach in 2000 as a result of a broken seal in the upper liner near the overflow pipes and in the leakage rates of the pregnant pond as a result of a broken cable that caused a pump to puncture the upper liner. Both of these incidents and the freshet meltwater inflow resulted in the LDRS flow rates to exceed the allowable levels, but when calculated out the flow rates were always well within allowable levels. This seems to indicate that the leakage rates for the liner were lower than anticipated in the planning process. It appears that the LDRS was successful at capturing most potential leakage water and preventing it entering the natural environment.

5.2.2 Issues and Lessons Learned

The lower than expected emergency storage requirements (see Section 5.1), combined with the lower than estimated total ore mined and a subsequent reduced size of the heap leach (7 cells used as opposed to the originally planned 10) meant that the second overflow pond was not required and thus not constructed.

The heap leach pad was designed for ten discrete cells. This design was intended to allow precise application of solution and to close off cells should a major leak be detected. After four years of operation it was determined that, from an operational point of view, the discrete nature of the cells was not as practical or necessary as first envisioned (Viceroy, 2000 USMP). As there was no need for utilizing the emergency response aspect of the discrete cell construction there was nothing to indicate that this was also less necessary.

5.3 Solution Management

5.3.1 Description

The facilities constructed for gold recovery and solution management at Brewery Creek included a heap leach pad, a leach solution application and collection system, two process ponds, one

overflow pond and a carbon adsorption/desorption/recovery facility (ADR plant). The overflow pond was sized to have capacity for complete draindown of the heap pad plus a 100 snowmelt event. A second overflow pond was to be constructed once the pad size required additional storage space to meet these criteria. WUL QZ96-007 required that Viceroy

“...submit an updated Solution Management Plan to the Board no later than December 31, 1998. The updated plan will include an updated water balance which takes into account the operating experience and climatological data which will have been collected to that time.” (Clause 29)

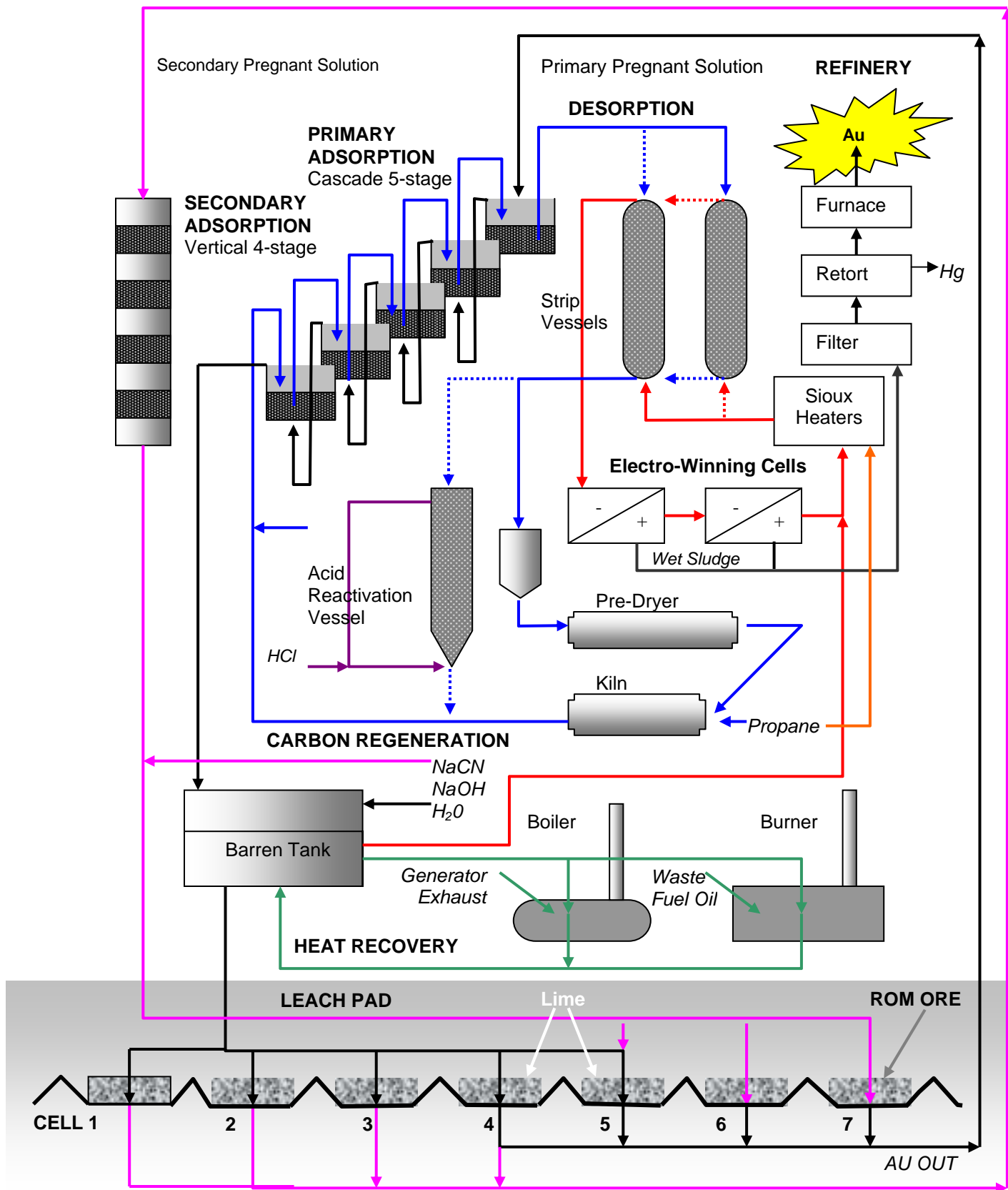
“...design of the second overflow pond must accommodate a consideration of the volume which would be required to contain a complete draindown of the fully developed heap and the run-off from a 100-year snowmelt.” (Clause 21)

The leaching process required application of solution to the heap, collection and transfer of the solution to the ADR plant, then reapplication to the heap leach. The pregnant and barren process ponds were bypassed under normal operations to minimize the potential for freeze-up over winter. In September 1998 a second circuit of pregnant solution was added to the process because recovery rates were slower than expected (300+ days versus the 90 days originally envisaged in Water Licence Application QZ94-003). Because of the slower than expected leaching process recycling of the pregnant solution was required to increase efficiency (see Figure 2).

An updated Solution Management Plan was submitted in December 1998 to satisfy Clause 29 and a revised version was submitted in December 2000. Both of these plans included additional climatological data collected on site that allowed for a more accurate and precise water balance. The additional time also allowed for the incorporation of information learned through 4 years of mine operation.

With more comprehensive precipitation data, reduced production, and an emergency pumping system to displace emergency water volumes plans for the second overflow pond were pushed back and then dropped.

Figure 2 Heap Solution Process Flow Sheet



5.3.2 Issues and Lessons Learned

The initial planning for the project used conservative measures for the precipitation data when planning for the solution management because there was little climatological data available for the actual mine site. This resulted in planning for a second overflow pond that was never required. As a result a number of additional studies, reports, and amendments were required to justify the requested WUL amendment to remove the requirement for the second overflow pond. Stronger, more defensible climate data prior to start up would have provided this information in the initial application and environmental evaluation. It also became clear that continually compiling climate data allows for evolving and adapting management plans to make them more effective and more cost-effective.

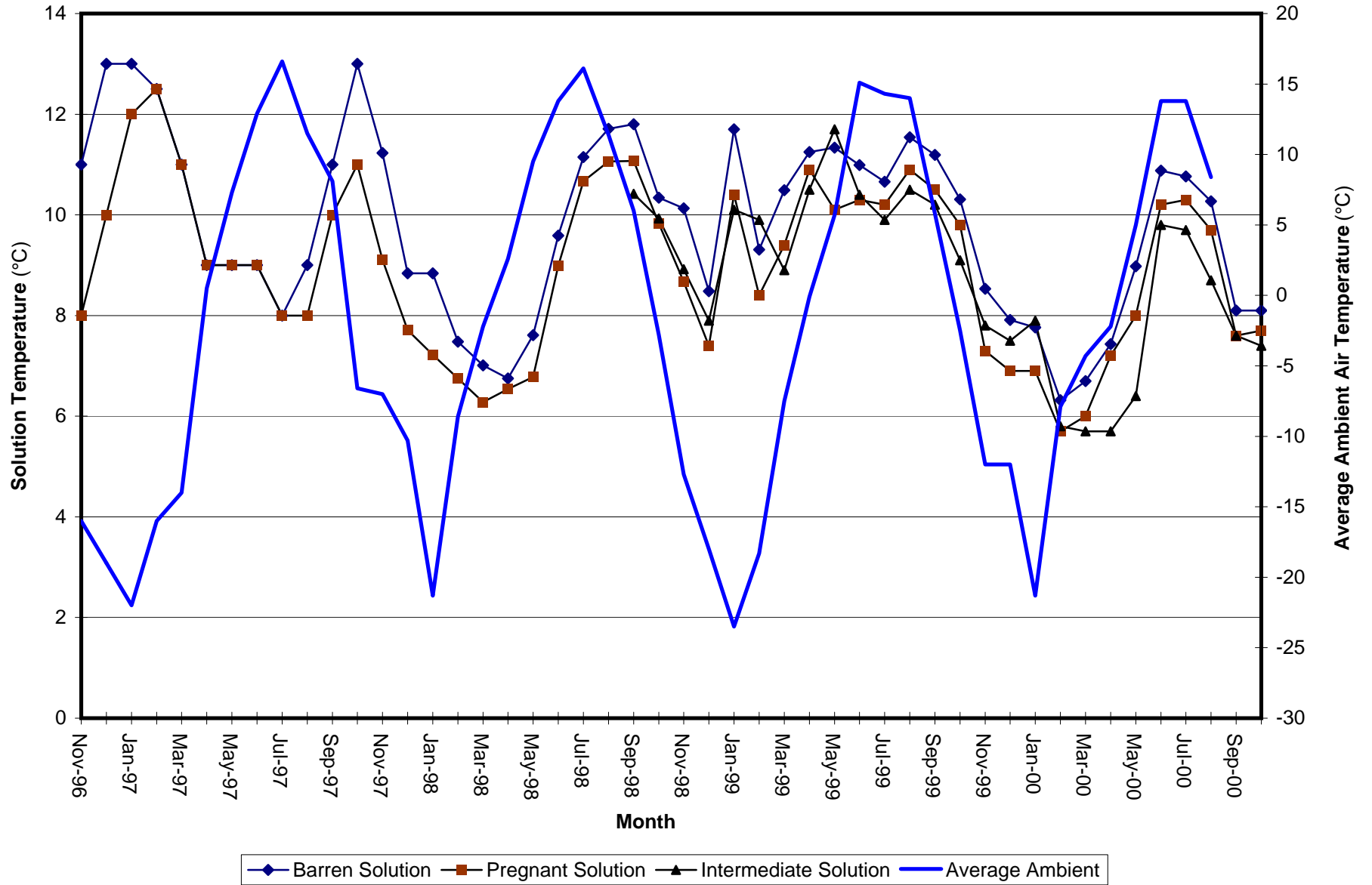
A tracking system for the solution processed through the ADR plant was in place at Brewery Creek but it was noted during the interview process for this report that there was no detailed tracking system for the amounts of solution in the different cells within the heap. While there were no incidents that resulted in emergency release of solution it was stated by a then employee of the regulatory authorities that a more accurate and precise tracking system for solution in process in the heap would be a useful tool in solution management and emergency response had there been a significant release. This would also provide a secondary check should other incidents resulting in a water penetrating or short-circuiting the upper liner (as described in Section 5.2) cause high rates of liquids collected in the leak detection and recovery system.

The reapplication of the pregnant solution to the heap as a second was a result of significantly slower than expected recovery rates. The allowance for additional solution application circuits should be considered when planning a heap leach for this reason.

One of the concerns over the solution management was how functional a heap leach would be in the cold Yukon winters as maintaining the solution at a high enough temperature to prevent freezing is of paramount importance. Requirements were derived from the initial review process and included temperature monitoring of the heap, solution, and ambient air; installation of heat trace at various key points of the solution transport system; bypassing the process ponds under normal operation; and providing back-up solution pumping systems. The performance of the leaching system in extreme winter conditions exceeded the expectations during the design and permitting stages. Figure 3 illustrates the seasonal change in solution temperature (Viceroy, 2000 USMP). As expected, temperatures increased from the spring months through the fall and then slowly decrease throughout the winter months. Of importance is the solution temperature range in the winter months. Operating experience demonstrated that significantly higher solution

temperatures can be maintained during the winter operating months than had been envisioned during the permitting stages. The significance of this is the greatly reduced risk of loss of solution circulation ability in the winter, which may result in pad draindown until circulation can resume in the following spring. This pad freeze-up scenario was the justification for accepting solution storage criteria of total containment of both a complete pad draindown and a 100-year snowmelt. This scenario is now shown to be significantly less likely than previously hypothesized. (Viceroy, 2000 USMP)

Figure 3: Leach Pad Solution and Ambient Temperatures



5.4 Heap Detoxification

5.4.1 Description

With the cessation of active leaching of a heap leach mine the heap must go through a detoxification process to remove all mobile toxic constituent before it can be considered to be closed. Three general methods for heap detoxification of a heap leach include fresh water rinsing, natural degradation through continued recirculation, cyanide destruction with strong oxidizers such as hydrogen peroxide and detoxification through biological processes. An extensive testing program had been completed at the Brewery Creek site. One of the test programs completed was a large-scale column program (LSC) designed to compare the effectiveness of three detoxification processes, namely; natural degradation, peroxide detoxification and in-situ bacteria detoxification. Based on the results of the large-scale column test program and successful full-scale application at other sites employing heap leach technology, Viceroy selected an in-situ bacteria process for detoxification. In the original application a natural rinsing program was proposed and was expected to require at least 6 months to complete.

With the in-situ bacteria detoxification process, a supply of nutrients consisting of sugars, alcohols, fats and proteins is designed and mixed based on the specific nature and level of contaminants in the Brewery Creek process solution. The liquid supply of nutrients is continuously added to the recirculating heap solution until a pre-determined amount of nutrient addition has been satisfied. The existing strains and cultures of bacteria already present in the process solution and spent ore are used in conjunction with the nutrients supplied to promote the reduction of cyanide and metal-cyanide compounds through bacteria reduction processes.

The Brewery Creek Mine heap leach pad was detoxified in 2002-2003 by using a biological reduction process through the introduction of nutrients into the recirculating solution applied to the leach pad. As part of the Decommissioning and Rec1mnation Plan (DRP) Viceroy proposed and committed to conducting a solids sampling program on the Brewery Creek heap to verify destruction of free cyanide. The primary objective of the heap solids program was to collect and analyze representative samples and determine the level of free cyanide remaining in the heap. Reactive free cyanide is the driving force for instability in the heap. The destruction of reactive free cyanide remaining in the heap is demonstration of the lack of a driving force for remobilization of reduced metals. In addition to free cyanide, moisture, extractable metals and paste pH were analyzed on composite and individual samples.

Initially the water was to be discharged to surface waters (Laura Creek) but due to high levels of ammonia in the water produced during the detoxification process the water was discharged to land. The water quality of the heap effluent met land application discharge quality standards (Criteria 1) within 2 months after treatment with nutrients. This 2 month heap detoxification program took one third the time expected when initially planned and was also substantially quicker than the rinsing method originally proposed. The effluent discharge standards used for direct discharge to the land application area are those established in the *Effluent Treatment and Land Application Water Licence Submission*. In addition, water licence amendment application QZ03-060 was submitted to the YWB in July 2003 to allow direct discharges of treated heap solutions to Laura Creek. Once heap detoxification was complete, the heap recirculating volume was gradually drained down in a controlled manner. One benefit to this method over rinsing was a significant reduction in wash water that would later require treatment.

The 3 lined process ponds, with a total capacity of 150,000 m³, were retained until 2008 as emergency storage capacity until the long-term heap detoxification standard is achieved. The pregnant pond served as the buffer and receiving pond for heap effluent. Most suspended solids in the heap effluent settled in the pregnant pond. Once direct surface water discharge quality was achieved, the pregnant pond was discharged to surface. Once long-term passive release of effluent solution was been met in 2008, the liners were removed from the ponds and the side slopes were scarified and revegetated.

Long-term stability of metal precipitates formed during the heap detoxification program is an issue that was raised during the CEEA review process. Using copper as an example, copper readily forms a sulfide precipitate within initially formed carbonates and within oxygen deprived slime zones. These slime zones were readily forming and visible on the heap 3 weeks after nutrient addition commenced. This same process of forming an initial precipitate, followed by formation of more stable precipitates over time, is the scheme that bacteria use to survive when faced with any other metals such as copper, mercury, arsenic and selenium. Cyanide is first used as a carbon source until the breakdown of cyanide is no longer thermodynamically favorable (too dilute to extract a meaningful amount of energy by volume), and then it becomes an electron acceptor, breaking down to nitrogen forms and ultimately gasifying as carbon dioxide and diatomic nitrogen. As the tracking of the heap effluent demonstrated, WAD cyanide was the first parameter to be substantially reduced during treatment. The stability of each mineral is dependent on both its concentration and any surrounding forces that could act upon it. If there were a large quantity of cyanide stored as complexes within the heap, then a copper carbonate would not be stable in the long-term. As the spikes of cyanide are released by oxidative free

radical attack, the copper carbonate would dissolve. The bioremediation eliminates metal complexes of cyanide that could cause future release.

5.4.2 Issues and Lessons Learned

Initial planning in 1994 called for detoxification of the heap using recycled water for heap detoxification and calcium hypochlorite to treat the wash water (Loki, 1994 WULA). This would have resulted in significant amounts of wash water that would have required treatment prior to discharge. This method also was expected to take longer than the method used and thus would have resulted in a higher cost to undertake. The use of this innovative method for heap detoxification resulted in shorter time frames and reduced costs. Biological reduction has proven to be successful in a cyanide heap leach in northern climates and can be considered with some level of assurance for future applications.

5.5 Heap Leach Soil Cover

5.5.1 Description

The construction of a soil cover followed by revegetation of the detoxified heap was another important aspect of the overall heap closure process. The *September 2001 Decommissioning and Reclamation Plan, Volume II* outlined the design details for the engineered heap soil cover. In 2003, the heap leach pad was recontoured, 80,000 m³ of growth media applied and the area revegetated. The objective of the cover was to reduce the infiltration of precipitation runoff into the heap so that the volume of effluent requiring further passive secondary treatment and/or release to the environment is likewise reduced. Secondly the growth media provides an environment for successful revegetation.

Viceroy retained the services of BGC Engineering to design a soil cover using the known quantities of argillite, sediments and growth media on the leach pad or immediately adjacent to the leach pad. Approximately 80,000 m³ of growth media was hauled and placed on the leach pad over the period of June – August 2003. The growth media was uniformly spread over the entire surface of the heap and resulted in an average thickness of 0.25 meters. This represents all of the available growth media stored adjacent to the heap. All other sources of growth media were utilized in other areas of mine reclamation.

The BGC design for the soil cover over the heap estimated an annual infiltration rate of 24%. The majority of the infiltration was to occur in the spring and early summer months (April – June) and

gradually decreases into the winter months. All of the secondary contingency measures and long-term release volumes had been estimated using a 30% infiltration factor. This provided additional conservatism in the long-term heap management program.

Effluent discharging from the leach pad was then monitored for flow and other chemical constituents. The flow monitoring provided confirmation of the long-term release volumes and infiltration rates which can then be used to assess the performance of the soil cover.

5.5.2 Issues and Lessons Learned

Heap infiltration was calculated using pond volumes and discharge volumes and compared to precipitation values. The following table shows the estimated infiltration through the heap since 2003 when the cover was constructed.

Table 2. Heap cover infiltration rates

Year	Calculated infiltration (%)
2004	21.5
2005	24.1
2006	27.3
2007	27.1

The liners of the ponds were removed in 2008 and thus there are no calculated values for the infiltration rate as the pond volumes could not be measured with any assurance as there would have been infiltration from the ponds. The values for 2005-2007 are above the estimated infiltration rates of 24% but below the 30% contingency factor, indicating the value of using conservative measures during planning and construction.

5.6 Revegetation

5.6.1 Description

Over 180 ha of recontoured slopes were seeded and fertilized in 2002 – 2003. Based on the recommendation of the company’s specialist, the application rate of seed for these programs was 25 kg/ha and 300 kg/ha of fertilizer. This was a decreased application rate from that originally used and was recommended as a means to promote invasion of natural species such as willow.

An assessment of the current status of revegetation at the Brewery Creek Mine must take into account the objectives set out in the 2004 Amendment to the Quartz Mining License. The standards as described in the 2008 Revegetation Assessment (Laberge Environmental) include:

1. Vegetation is self sustaining and comprises native seed mixes.
2. The vegetative cover is capable of self-regeneration without continued dependence on fertilizer or reseeding.
3. The establishment of a vegetative cover with sufficient density and species diversity to stabilize the surface against the effects of long term erosion.
4. The successive vegetation must be similar to naturally occurring habitats in the surrounding area.

Most of the grasses seeded since 2003 are species naturally occurring in the Yukon, but at the time of seeding Yukon-produced seeds were not available in the necessary amounts and seeds were acquired from suppliers in southern Canada, as. Two non-native exceptions were used: Kentucky Bluegrass and Red Fescue. These were used in the Leach Pad Mix to help form a tighter cover. Non-native legumes, white clover and alfalfa, were also used at Brewery Creek to fix nitrogen in the soils. Non-native species were used as the seeds of native species of legumes were not commercially available in large enough quantities at the time of seeding (Laberge Environmental, 2009).

5.6.2 Issues and Lessons Learned

Laberge noted that the vegetative cover appears to be self-regenerating. The long-term sustainability of the seeded species is not intended, as these species should eventually give way to native successional species. At the time of the 2008 Vegetation Assessment many native plant species were observed to be colonizing most reclaimed areas. This includes native willows that were observed in sixteen of 23 areas assessed in 2008. Alaska birch, a native early and mid seral species was observed at 12 sites. The results of the vegetation assessment indicated that the revegetation appears to be successful and regeneration to a climax forest as in adjacent areas will slowly occur if the area is left undisturbed. Natural revegetation at this latitude, particularly on the relatively dry upland slopes such as those at Brewery Creek, is a slow process. Further seeding with grasses will do little to hasten this process, and may even hinder it. Further disturbance to the soil could delay the revegetation process, and the resulting formation of a too dense ground cover may inhibit the colonizing of the area by indigenous species. It was noted that the non-native species used initially in the revegetation process did not fair well and soon died off, to be replaced by species indigenous to the area.

5.7 Receiving Water Quality and Stream Sediment Impacts

5.7.1 Description

Water quality monitoring in the watershed was an important part of the WUL. More than 30 surface water stations were monitored for various parameters and at different intervals depending on the situation at the time; some of these are still monitored. Appendix B shows the water sampling requirements as revised in Amendment 6 in July, 2004. Included in Appendix C are changes of water quality sampling results of key parameters including total suspended solids (TSS), nitrogen species (ammonia), and selected metals at three stations over time. The three stations chosen are the three surface water sampling stations immediately downstream of the heap leach pad. BC-2 is the main receiving watershed (Carolyn Creek) for the heap leach area. BC-3 is in an adjacent watershed (Laura Creek) upstream of the confluence with the Carolyn Creek watershed but downstream of most of the open pit mining areas. BC-1 is downstream of the confluence of these two watersheds.

An additional aspect of water quality is the water in a number of the open pits and surface runoff from the waste rock piles. The waters in some of the pits have shown levels of some contaminants exceeding the CCME guidelines and have failed some toxicity testing. The discussion of these pit waters was not included in the proposed scope of this report and thus a discussion of them has not been included.

A natural forest fire came through the Brewery Creek Mine area in 2004 and burned extremely hot through the Laura Creek watershed. The sampling results for total suspended solids (TSS) are evidence of the influence of the forest fires on water quality in the Laura Creek stations in 2005. TSS at stations BC-1, 2 and 3 are all elevated over historic levels. TSS at BC-1 during 2008 showed significant spikes in the late spring and summer period, consistent with the spring freshet and significantly high precipitation experienced in 2008. The same trends with TSS were exhibited at station BC-2 during 2008. TSS measurements at station BC-3 were consistently low throughout the 2008 period. Ammonia levels at stations BC-1, 2 and 3 were consistently low throughout the year suggesting the effects of the 2004 fire are now negligible.

Arsenic and zinc concentrations at stations BC-1, 2 and 3 are similar to levels experienced in the past several years. No significant trends either up or down appear in any of the stations for the parameters arsenic and zinc. Occasional spikes occur at various stations but these are not associated with any trends.

Copper and lead levels at most stations are within historic levels and there is evidence that past

spikes have diminished.

Also included in Appendix C are the water quality sampling results for the heap effluent over a time period from 2001 when the mine went into closure, until 2008, the most recent available results. These also show a few different trends: ammonia, zinc, and WAD cyanide were strongly downward; arsenic and total cyanide trended less strongly downward, and selenium showed no obvious trend.

Sediment sampling results over time can often show clearer trends as they are less of an instantaneous snapshot of conditions and more accurately reflect an annual trend. The most notable trends were arsenic and mercury in BC-1, BC-2, and BC-3. Interestingly all three stations show obvious upward trends during operation and downward trends post-closure, although spikes in both parameters in 2008 at BC-2 are in opposition to that trend. These parameters show obvious trends that are clearly tied to contaminant increases from operation and reductions post-closure. Not all parameters show the same clear trends but most appear to be trending similarly with nominal peaks in 2001 and gradual decreases or show no discernable increases or decreases that could be tied to events at the mine. BC-2 does show unexpected spikes in 2008 in a few parameters and it will be interesting to see if this is an anomalous sample as the next few years of sampling are added to the data sets.

5.7.2 Issues and Lessons Learned

What needs to be noted from the surface water quality sampling results when shown over the years from preconstruction (1991) through to post closure (2008) are the changes of some of the metals over time, and a return, of many parameters, to preconstruction levels or near preconstruction levels by 2008. This appears to show that there may be more that could be done to prevent contamination of adjacent watersheds, particularly during freshet months but that there is some natural renovation occurring. Likely there is a tipping point where levels of contaminants will damage the ability of the natural environment to respond to contamination by nearby mining but this does not appear to have been reached at Brewery Creek.

5.8 Security costs

5.8.1 Description

Brewery Creek is a mine that has seen a high level of reclamation work done by the operators, particularly when compared to other Yukon mines of that same time period. Some of this can be

attributed to the very high, at the time, bond relative to previous and contemporary projects and some to the will of the company to undertake the reclamation work.

For the time assessors and regulators took a conservative approach to the Brewery Creek project although 15 years later the current assessment requirements would likely be as comprehensive, if not more. This approach was largely because the technology being applied at Brewery Creek was a new to the regulatory and assessment regimes and was unproven in northern climates. This is most apparent when the bonding requirements and the reclamation requirements for Brewery Creek are compared to those of another gold mine in the Yukon, Mt Nansen as operated by BYG Natural Resources Inc. The Mt Nansen mine was a smaller deposit and a smaller proposed mine but the difference in the total bonding is noteworthy. The Mt Nansen mine received its WUL in 1996 and the project required \$974 500 compared to a bond of \$8 709 000 for the Brewery Creek mine. Mt Nansen is currently classified as an Abandoned Type II Mine because, after repeated WUL violations BYG went into receivership and the government took over responsibility for care and maintenance activities. This has resulted in high costs to the federal and territorial governments for the care and maintenance of the Mt Nansen.

While bonding can play an obvious role in the effectiveness of remediation and reclamation work it is also clear that genuine effort by the owner is required. At Brewery Creek the daily operations reflect that genuine effort and respect for the regulatory processes that underpin the decommissioning and reclamation requirements. Additionally decommissioning plans and environmental studies were completed and submitted as required. While there is no method of quantifying the will of the operator it is clear that this is a significant factor in the effectiveness of decommissioning and reclamation.

5.8.2 Issues and Lessons Learned

One of the issues that arose at Brewery Creek was confusion over the repayment of the reclamation bond and how it would be staged. This was due to the relatively rare occurrence, at the time, of actual effective remediation being completed at closed mines. Most mines had been left in a state of perpetual “temporary closure” or had been abandoned altogether. Viceroy and Alexco have made clear efforts to undertake remediation. They have also been required to demonstrate the effectiveness of their reclamation works which has resulted in disagreements with the regulatory agencies as to what is demonstrable effectiveness. A part of the difference of opinion is the due to differing conservative approach to short versus long-term assessments of effectiveness. This is due in large part to ill-defined or undefined measures of effectiveness for reclamation works. What must be taken from this is that there is an obvious need for creating

clear benchmarks for defining effective reclamation prior to the calculating and posting of bonds. This became obvious throughout the closure and reclamation process as some amendments to the WUL included changes to the monitoring requirements and defining detoxification of the heap leach (YWB, 2005). What also became clear is that the relatively high (at the time) security bond for the Brewery Creek Mine became a clear incentive for Viceroy and Alexco to continue with reclamation effective and cost-effective measures to recover the security bond.

Clearly defining methods and benchmarks for assessing effectiveness will aid governments who will ultimately be required to take responsibility for a mine should it be abandoned as has happened in the past, but also to the proponent when they undertake feasibility studies and when they are attempting to recover their bond after undertaking reclamation activities. Some of the reclamation work undertaken at Brewery Creek was unproven in the specific environment at Brewery Creek and the effectiveness resulted in faster remediation than expected. One clear example was the rapid initial detoxification of the heap using a biological degradation process. Using innovative approaches to reclamation allows those doing the reclamation work to prove the effectiveness of a new technique and may result in more rapid repayment of security bonds.

The continued concern over the water quality of some of the pit waters has also been outside of much of the discussion over security bonding and an argument has been made that based on the relative importance of this aspect of environmental liability it has not been properly included within the security bonding assessment. This would also point to the need to improve clear benchmarks for reclamation measures and expectations.

6.0 CONCLUSION

As with any large, long-term operation the process of assessing, planning, operating, and decommissioning the Brewery Creek has provided us with a number of lessons. There appears to be something to be learned for everyone who has been involved in this process, from assessors, regulatory authorities, neighbours, First Nations, and mining companies. Some of the obvious lessons to be learned from Brewery Creek are

- the importance of wildlife control measures and vigilance on the part of staff to reduce opportunities for wildlife conflicts;
- the reduced importance of discrete cells in the heap leach pad from an operation standpoint;
- the value in being adaptable to respond to changes in the operational effectiveness of the planned operations;
- the value in complete climate data prior to the start-up of a mine;

- the effectiveness of biological detoxification of a cyanide heap leach;
- the importance of using native species for reclamation and encouraging natural regeneration;
- the ability of the natural environment to respond to contamination and to renovate itself;
- a need for clearly establishing benchmarks and a schedule for reclamation activities;

These are some of the lessons that can be learned from Brewery Creek, as the first heap leach mine operating north of the 60th parallel.

7.0 REFERENCES

- Access Mining Consultants Ltd. and Withers, S.P., 1999. *Vegetation Characteristics – Bohemian and Big Rock Ore Zones – Brewery Creek Mine.*
- Alexco Resource Corp, 2006. *Brewery Creek Mine 2005 Annual Water Licence Report Yukon Territory.*
- Alexco Resource Corp, 2007. *Brewery Creek Mine 2006 Annual Water Licence Report Yukon Territory.*
- Alexco Resource Corp, 2008. *Brewery Creek Mine 2007 Annual Water Licence Report Yukon Territory.*
- Alexco Resource Corp, 2009. *Brewery Creek Mine 2008 Annual Water Licence Report Yukon Territory.*
- Copeland, H., 2001. *Financial and Other Considerations, Mt. Nansen Mine Case Study.* Indian and Northern Affairs Canada. Presentation to the Orphan Mines Workshop June 26/27.
- Cornett, D. May 2008-2009. Personal interviews
- Laberge Environmental, 2009. *Brewery Creek Mine 2008 Revegetation Assessment.*
- Loki Gold Corporation, 1993. *Brewery Creek Gold Mine Project Overview and Plan for Initial Environmental Evaluation.*
- Loki Gold Corporation, 1994. *Brewery Creek Project Initial Environmental Evaluation, Summary Document and Supporting Documents I, II, III, and IV.*
- Loki Gold Corporation, 1994. *Brewery Creek Water Licence Application, Volumes I, II, and III.*
- Loki Gold Corporation, 1996. *Brewery Creek Mine 1995 Annual Water Licence Report Yukon Territory.*
- Slater, B. May 2009. Personal interview.
- Thrall B., 1999. *Heap Leaching in extreme northern climates – Overview of Brewery Creek Mine, Yukon, Canada.* Mining in the Arctic, Udd & Keen, Balkena Rotterdam ISBN 90 5809 098
- Thrall B. May 2008-May 2009. Personal interviews
- Viceroy Minerals Corp, 1997. *Brewery Creek Mine 1996 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 1998. *Brewery Creek Mine 1997 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 1999. *Brewery Creek Mine 1998 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 2000. *Brewery Creek Mine Updated Solution Management Plan*

- Viceroy Minerals Corp, 2000. *Brewery Creek Mine 1999 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 2001. *Brewery Creek Mine 2000 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 2001. *Brewery Creek Mine September 2001 Decommissioning and Reclamation Plan Volumes I-IV.*
- Viceroy Minerals Corp, 2002. *Brewery Creek Mine 2001 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 2003. *Brewery Creek Mine 2002 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, March 2003. *Mine Decommissioning and Reclamation Plan Volumes I-IV and Executive Summary.*
- Viceroy Minerals Corp, 2004. *Brewery Creek Mine 2003 Annual Water Licence Report Yukon Territory.*
- Viceroy Minerals Corp, 2005. *Brewery Creek Mine 2004 Annual Water Licence Report Yukon Territory.*
- Yukon Government. *Mount Nansen Mine, Fast Facts.* http://www.emr.gov.yk.ca/aam/pdf/mn_background_march2008.pdf , March 2008. accessed January 2009
- Indian and Northern Affairs Canada, December 2003. *Performance Report 2002-2003, Northern Contaminated Sites Program.*
- Yukon Territorial Water Board, 1995. *Yukon Territorial Water Board, Water Use Licence QZ94-003.*
- Yukon Territorial Water Board, 1996. *Yukon Territorial Water Board, Water Use Licence QZ94-004.*
- Yukon Territorial Water Board, 1997. *Yukon Territorial Water Board, Water Use Licence QZ96-007, (Amendment to QZ94-003).*
- Yukon Territorial Water Board, 1999. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ98-032 (Amendment #1).*
- Yukon Territorial Water Board, 1999. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ98-038 (Amendment #2).*
- Yukon Territorial Water Board, 1999. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ99-041 (Amendment #3).*
- Yukon Territorial Water Board, 2002. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ01-050 (Amendment #4).*
- Yukon Territorial Water Board, 2002. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ02-056 (Amendment #5).*

Yukon Territorial Water Board, 2004. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ03-060 (Amendment #6).*

Yukon Territorial Water Board, 2005. *Yukon Territorial Water Board, Water Use Licence QZ96-007, Amendment QZ03-062 (Amendment #7).*

**Brewery Creek - From Assessment and Permitting through
Production to Post Closure:
A Post Closure Analysis of a Northern Heap Leach Mine**

Appendix A

**Brewery Creek Mine Water Use Licence Water Quality Criteria versus the
Metal Mining Effluent Regulations**



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Metal Mining Effluent Regulations (Schedule 4)

Deleterious Substance	Maximum Authorized Monthly Mean Concentration	Maximum Authorized Concentration in a Composite Sample	Maximum Authorized Concentration in a Grab Sample
Arsenic	0.50 mg/L	0.75 mg/L	1.00 mg/L
Copper	0.30 mg/L	0.45 mg/L	0.60 mg/L
Cyanide	1.00 mg/L	1.50 mg/L	2.00 mg/L
Lead	0.20 mg/L	0.30 mg/L	0.40 mg/L
Nickel	0.50 mg/L	0.75 mg/L	1.00 mg/L
Zinc	0.50 mg/L	0.75 mg/L	1.00 mg/L
Total Suspended Solids	15.00 mg/L	22.50 mg/L	30.00 mg/L
Radium 226	0.37 Bq/L	0.74 Bq/L	1.11 Bq/L

WUL QZ96-007

Parameter	Concentration
Weak Acid Dissociable Cyanide	0.25 mg/l
Total Cyanide	2.0 mg/l
Ammonia (as N)	5.0 mg/l
Copper	0.2 mg/l
Arsenic	0.5 mg/l
Antimony	1.0 mg/l
Mercury	0.005 mg/l
Zinc	0.5 mg/l
Selenium	0.25 mg/l
Lead	0.2 mg/l
Aluminum	1.0 mg/l
Bismuth	0.5 mg/l
Cadmium	0.1 mg/l
Chromium	0.5 mg/l
Iron	1.0 mg/l
Manganese	2.0 mg/l
Molybdenum	0.5 mg/l
Nickel	0.5 mg/l
Silver	0.1 mg/l
pH	6.0 to 9.5 pH units
Suspended Solids	50 mg/l

WUL QZ96-007 Amendment 6 (Application QZ03-060)

Parameter	Concentration
Weak Acid Dissociable Cyanide	0.25 mg/l
Total Cyanide	2.0 mg/l
Ammonia (as N)	5.0 mg/l
Copper	0.2 mg/l
Arsenic	0.5 mg/l
Antimony	1.0 mg/l
Mercury	0.005 mg/l
Zinc	0.5 mg/l
Selenium	0.05 mg/l
Lead	0.2 mg/l
Aluminum	1.0 mg/l
Bismuth	0.5 mg/l
Cadmium	0.1 mg/l
Chromium	0.5 mg/l
Iron	1.0 mg/l
Manganese	2.0 mg/l
Molybdenum	0.5 mg/l
Nickel	0.5 mg/l
Silver	0.1 mg/l
pH	6.0 to 9.5 pH units
Suspended Solids	50 mg/l

**Brewery Creek - From Assessment and Permitting through
Production to Post Closure:
A Post Closure Analysis of a Northern Heap Leach Mine**

Appendix B

Water Sampling Requirements



QZ96-007 - Amendment #6 (Application QZ03-060)

**SCHEDULE A - CORRECTED - JULY 5, 2004
MONITORING STATIONS**

Station	Description	UTM Coordinates (Zone 7)	
		Northing (m)	Easting (m)
BC-01, H5, W5, B3	Laura Ck., 50 m u/s from Ditch Road	7,099,630	634,420
BC-02, H15, W15	Carolyn Ck. u/s from Laura Ck.	7,101,970	633,250
BC-03, 2, W4B	Laura Ck. above Carolyn Ck.	7,102,570	632,345
BC-04, H13, W13, B7	Lucky Ck. d/s from Lucky Pit	7,107,640	639,180
BC-05	Pacific Ck. u/s from confl. with Lee Ck.	7,103,130	627,610
BC-06, K1, W9, B5	South Klondike d/s from confl. with Lee Ck.	7,097,460	627,400
BC-07	Canadian Waste Dump	7,105,520	634,890
BC-08	Canadian Pit and Dump (scrap plastic pipe location)	7,105,610	635,350
BC-09	Fosters Pit and Dump (Upper)		
BC-10	Kokanee Pit and Dump	7,105,760	635,620
BC-11	Blue Waste Dump	7,105,050	633,740
BC-12	Blue Pit	7,105,420	634,090
BC-13	Moosehead West Waste Dump	7,106,120	634,150
BC-14	Moosehead East Waste Dump		
BC-15	Moosehead Pit discharge	7,106,430	634,420
BC-16	Pacific Gulch - 300m above Laura	7,105,140	633,350
BC-17	Golden Pit and Dump	7,106,510	637,560
BC-18S	Lucky Pit and Dump - south end	7,107,220	638,180
BC-18N	Lucky Pit and Dump - north end	7,107,410	638,160
BC-19	Piezometer RC94-843	7,103,750	632,290
BC-20	Piezometer RC94-844	7,104,710	632,070
BC-21	Piezometer RC95-1354	7,105,070	632,740
BC-22	Piezometer RC95-1357	7,104,000	632,066
BC-23	Piezometer RC95-1370	7,103,410	632,500
BC-24	Piezometer RC95-1400	7,104,630	631,920
BC-25	Piezometer RC96-1608	7,104,000	632,215
BC-26	Piezometer RC97-2024	7,107,120	638,320
BC-27	Piezometer RC97-2026	7,106,550	637,380
BC-28	Overflow pond decant	7,103,800	632,540
BC-29	Pad leak detection and recovery system		
BC-30	Pond leak detection and recovery system		
BC-39	Laura Creek in the side channel of the South Klondike River	7,098,230	631,340
H2, W2, B2	Golden Creek above confluence with S. Klondike		
H3, W3	Laura Creek below exploration camp		
H6, W6A, B6	Lee Creek above Pacific Creek		
H7, W7, B1	Lee Creek at Ditch Road		
He, W14	Pacific Creek below heap leach pad		
H16, W16	Golden Creek above confluence with Lucky Creek		
H17, W5A	Laura Creek at Ditch Road		
K4, W8, B4	S. Klondike upstream from confluence with Golden Creek		

QZ03-062

EXHIBIT 7.7.1

Sharon L. Coyle
July 5, 2004

SCHEDULE B - CORRECTED JULY 5, 2004
MONITORING SCHEDULE

Monitoring Station																															
	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	39
Parameter																															
Flow	M	M	C	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	M	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	C	D	D	M
pH (field)	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	D		M
pH (laboratory)	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q			M	
Conductivity (field)	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	D	D	D	M
Conductivity (lab)	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q			M	
Temperature (field)	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M													M	
Turbidity	M	M	M	M/Q	M/Q	Q																									
Salinity	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q			M	
Dissolved solids	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q			M	
Suspended solids	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M											W		M		
Fluoride	M	M	M	M/Q	M/Q	Q												Q	Q	Q	Q	Q	Q	Q	Q	Q					
Phosphate	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q			M	
Ammonia	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	W		M	
Nitrate	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q			M	
Total cyanide	M	M				Q												Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	W	M	M	
Free cyanide	M	M				Q												Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	W	M	M	
Trace metals	M	M	M	M/Q	M/Q	Q	M	M	M	M	M	M	M	M	M	M	M	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	W		M	
DO assay																											W				
LEGEND																															
= Daily while discharging																- ICP metals to include Ca, Mg, Na, K, Cu, As, Sb, Hg, Zn, Se, Pb, Al, Bi, Cd, Cr, Fe, Mn, Mo, Ni, Ag and S.															
= Monthly when flowing																- All stations are total metals except the ground water wells which are dissolved metals															
Q = quarterly when not active/monthly during active mining																- BC-18 includes BC-18S and BC-18N															
= Quarterly																- Samples BC-7 through BC-18 weekly if licence limits exceeded															
= Continuous																															
= static water elevation																															

U703-062

EXHIBIT 7.7.1

Sharon L. Boyle
 July 5, 2004

**Brewery Creek - From Assessment and Permitting through
Production to Post Closure:
A Post Closure Analysis of a Northern Heap Leach Mine**

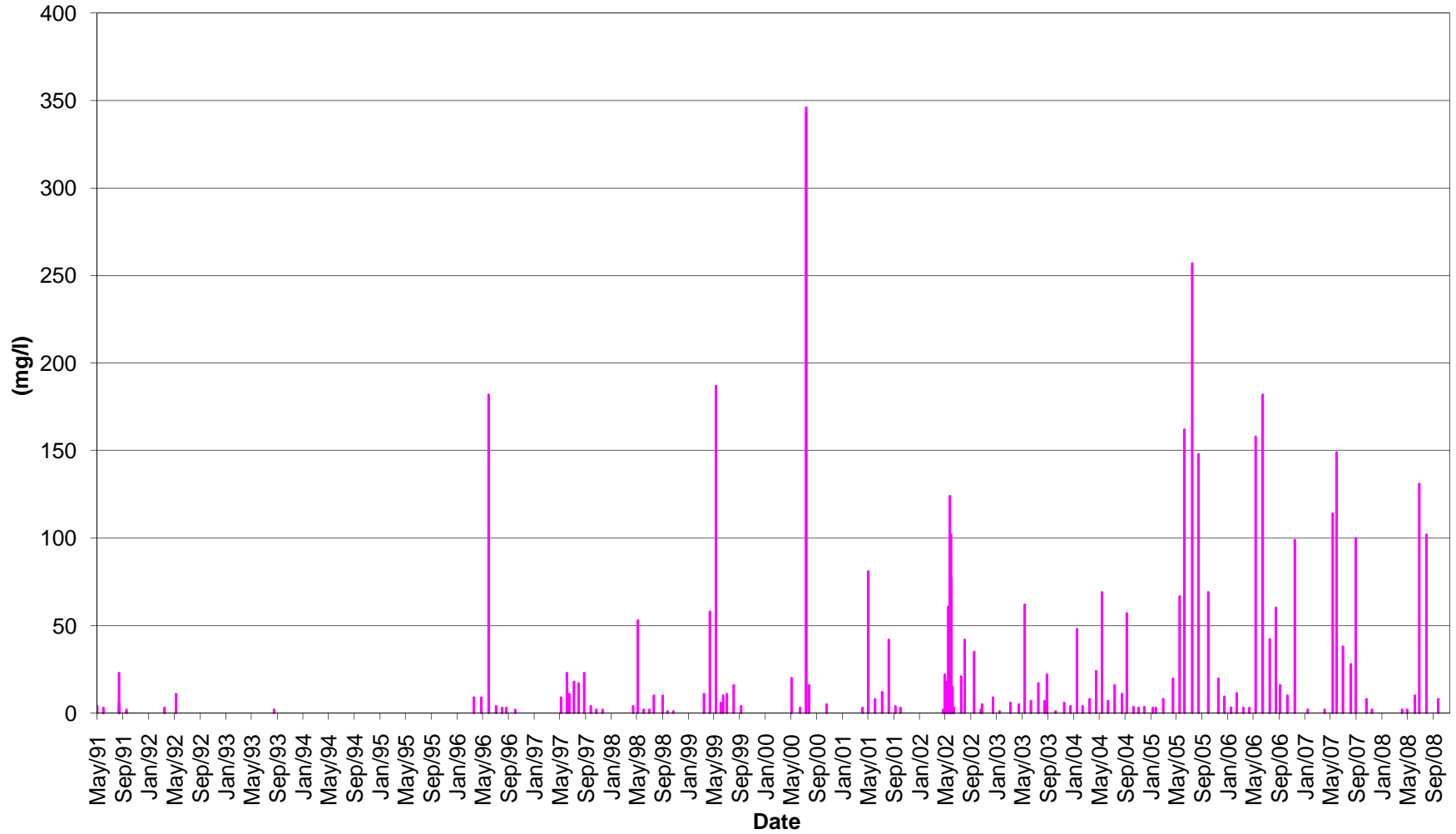
Appendix C

Water Quality Sampling Results Over Time



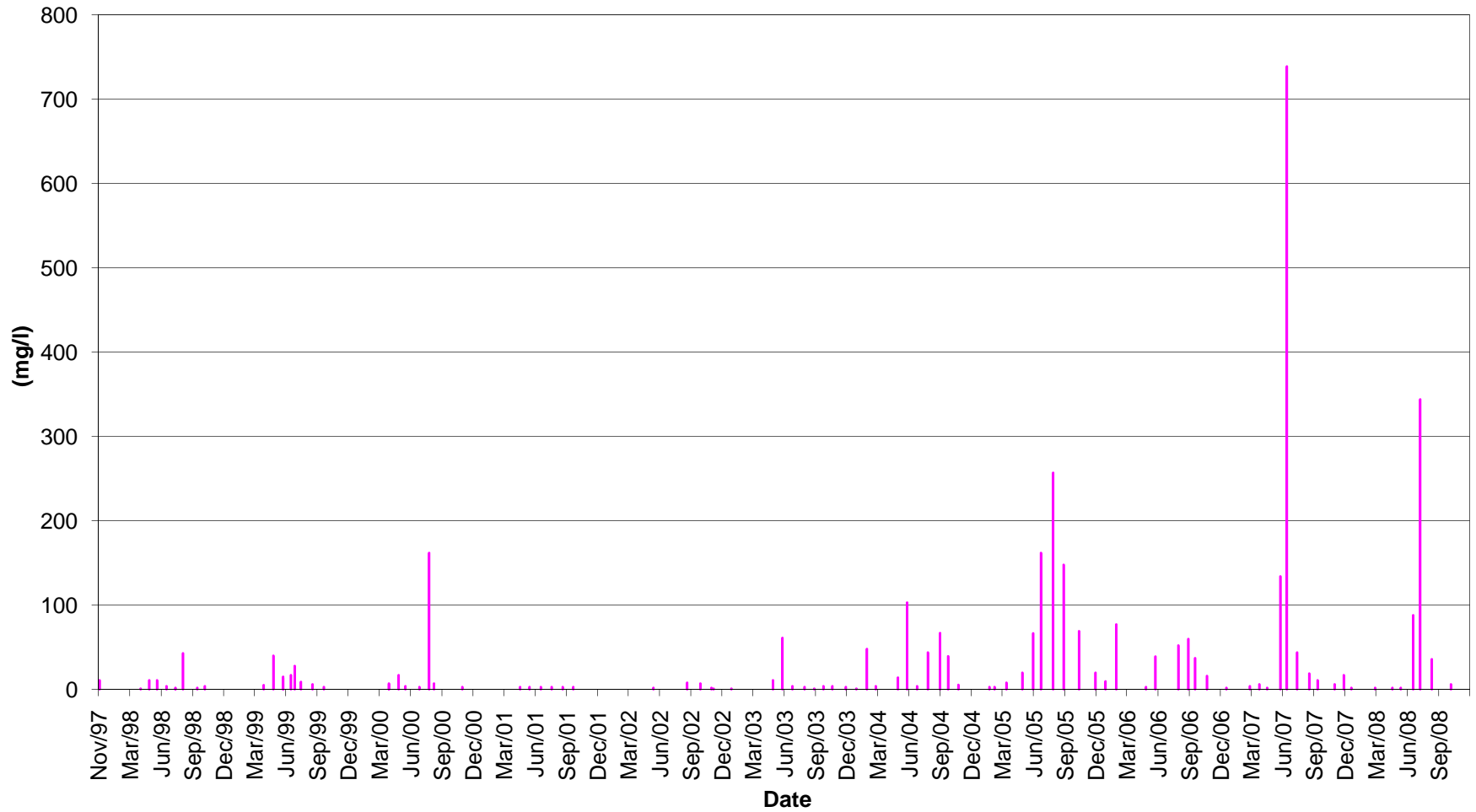
ACCESS
CONSULTING GROUP

BC-01: Laura Creek 50m above Ditch Road



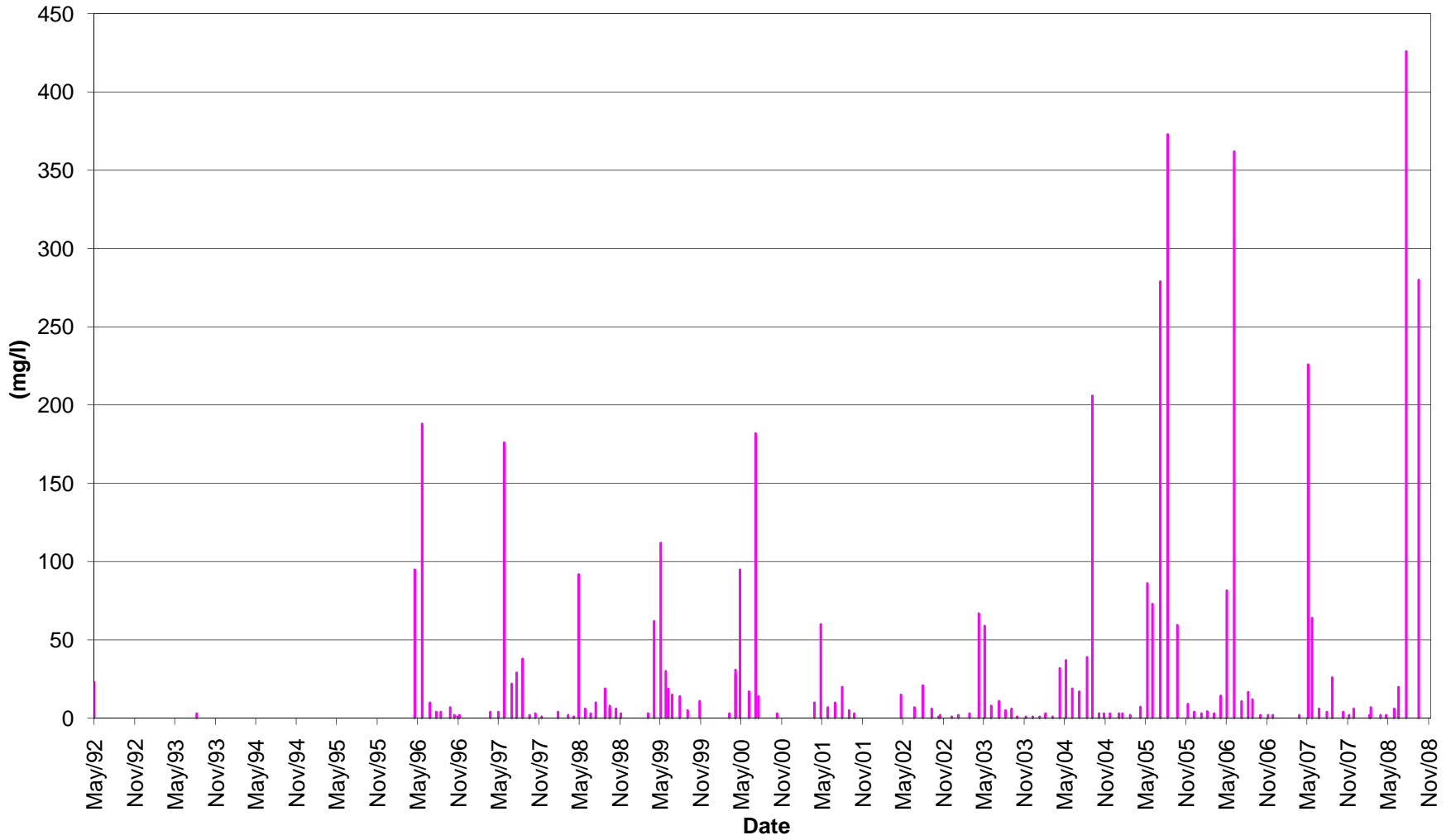
■ TSS

BC-02: Carolyn Creek u/s from Laura Creek



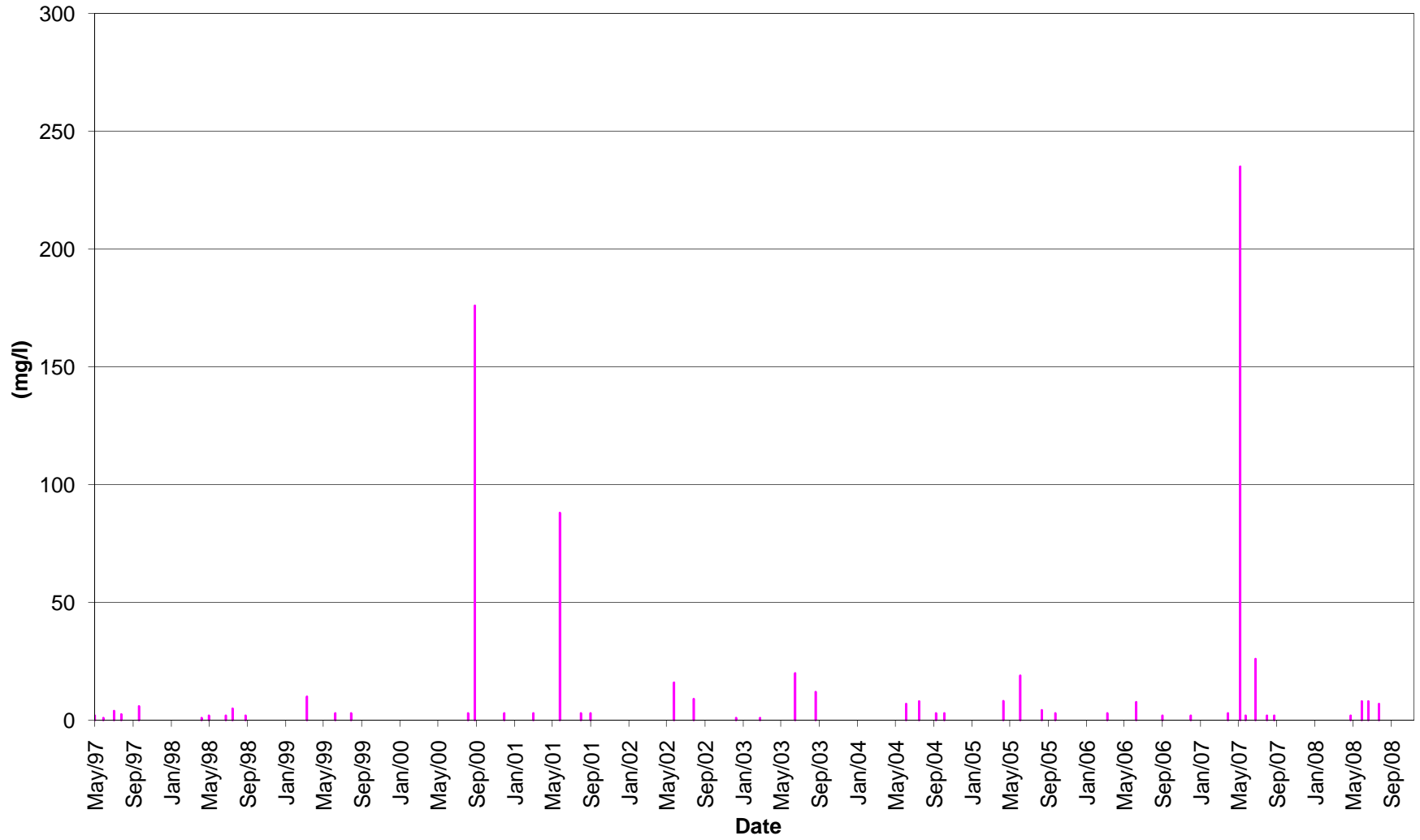
■ TSS

BC-03: Laura Creek Above Carolyn Creek



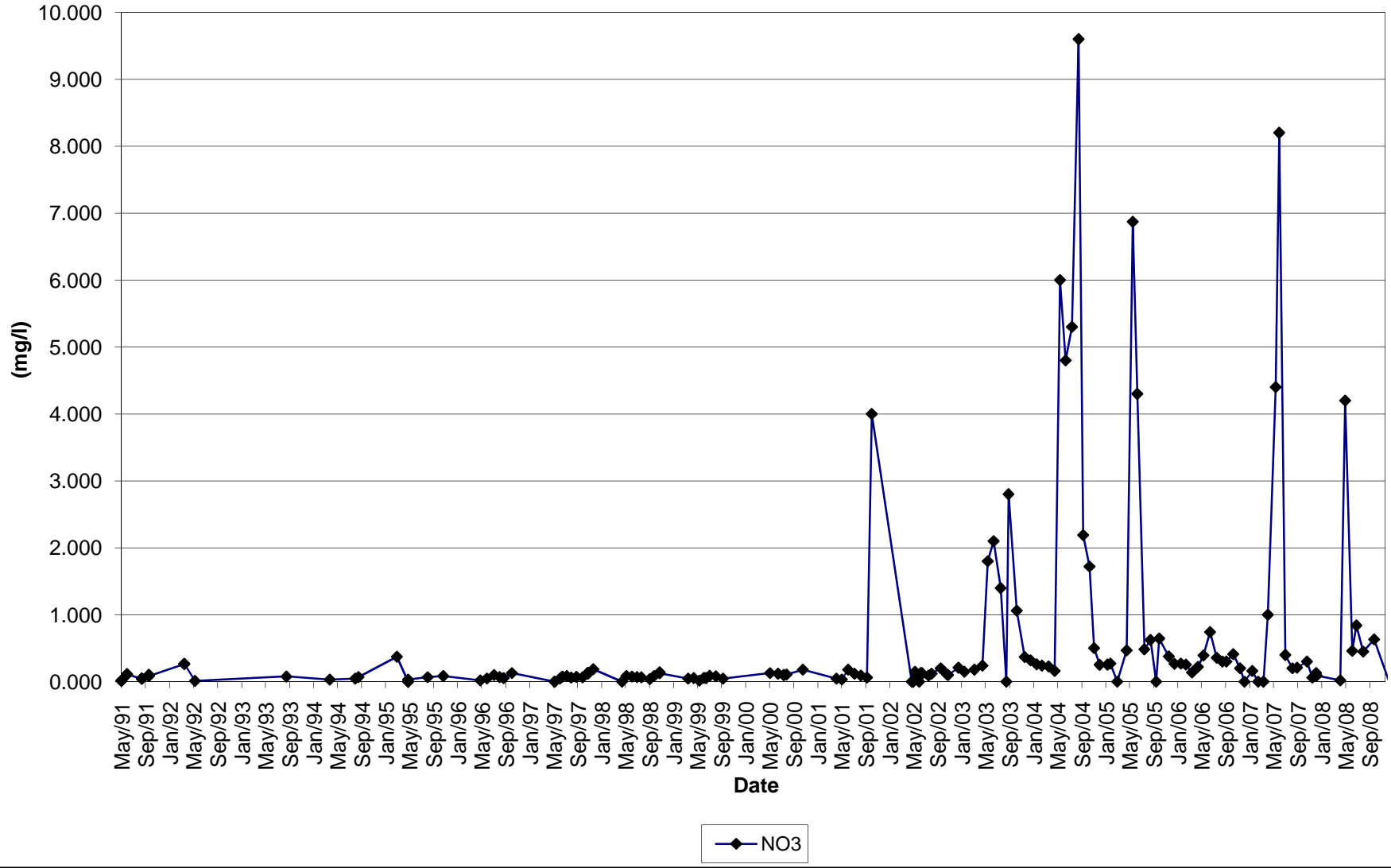
■ TSS

BC-39: Laura Creek at confluence with S. Klondike

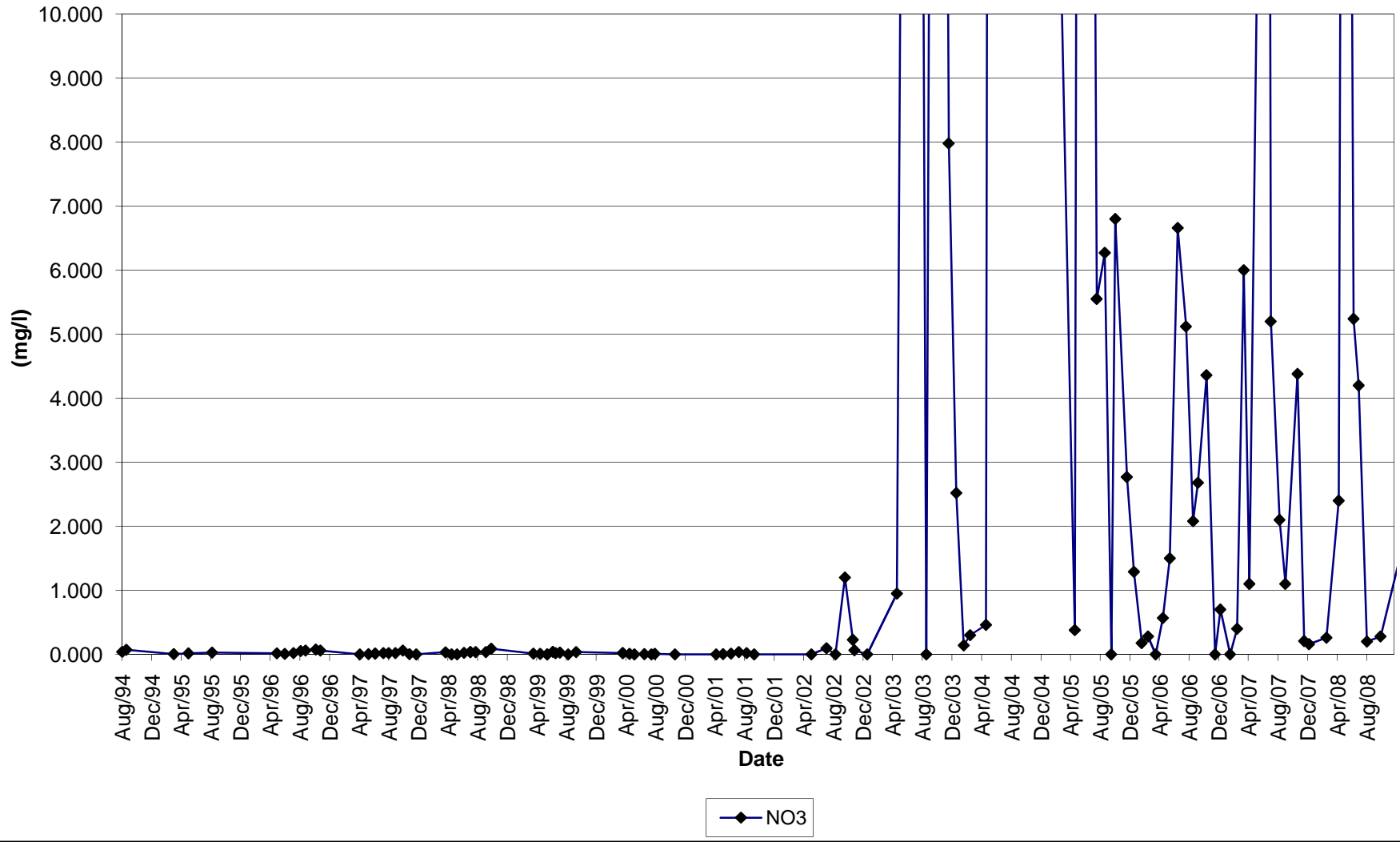


TSS

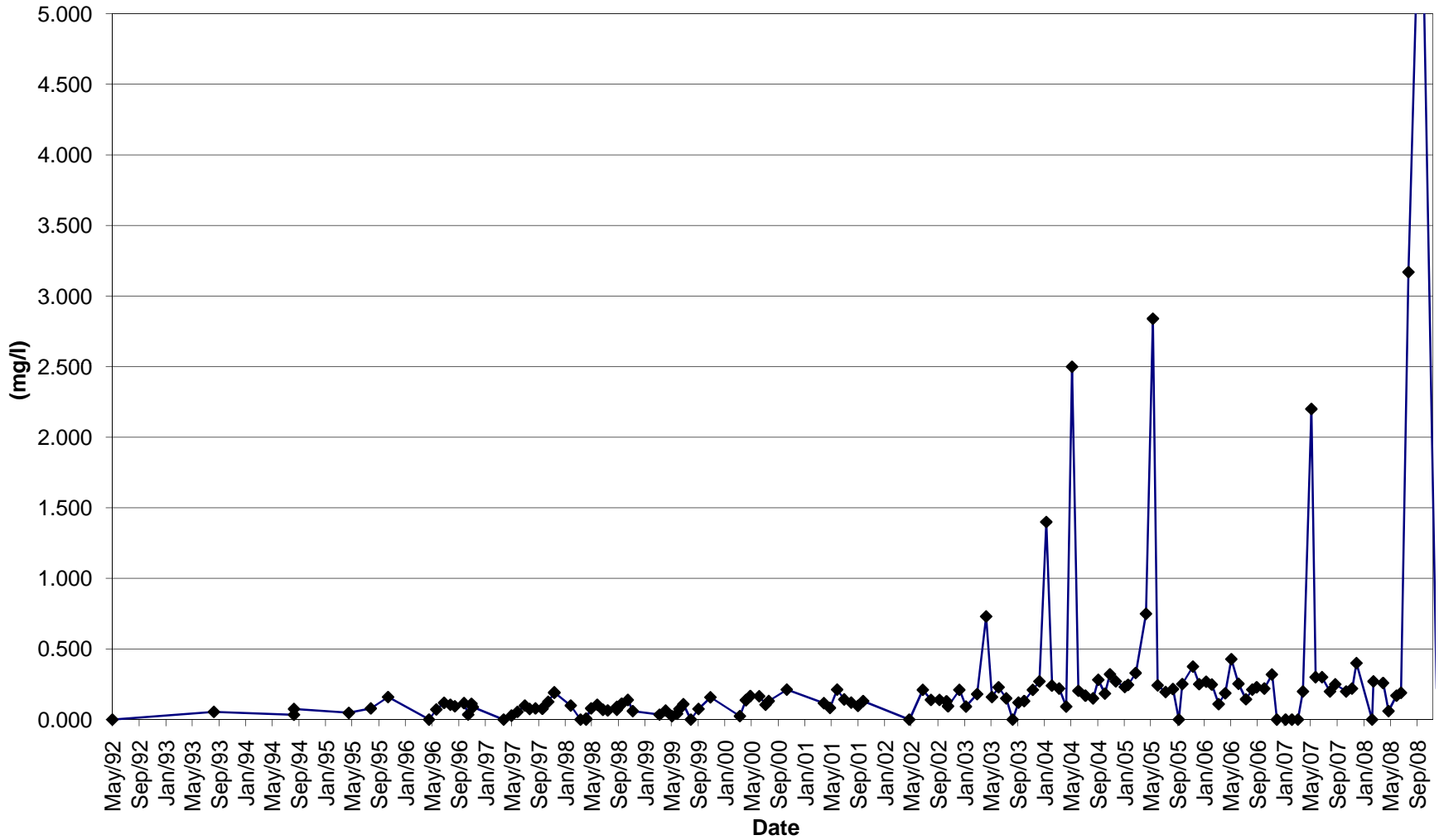
BC-01: Laura Creek 50m above Ditch Road



BC-02: Carolyn Creek upstream from Laura Creek

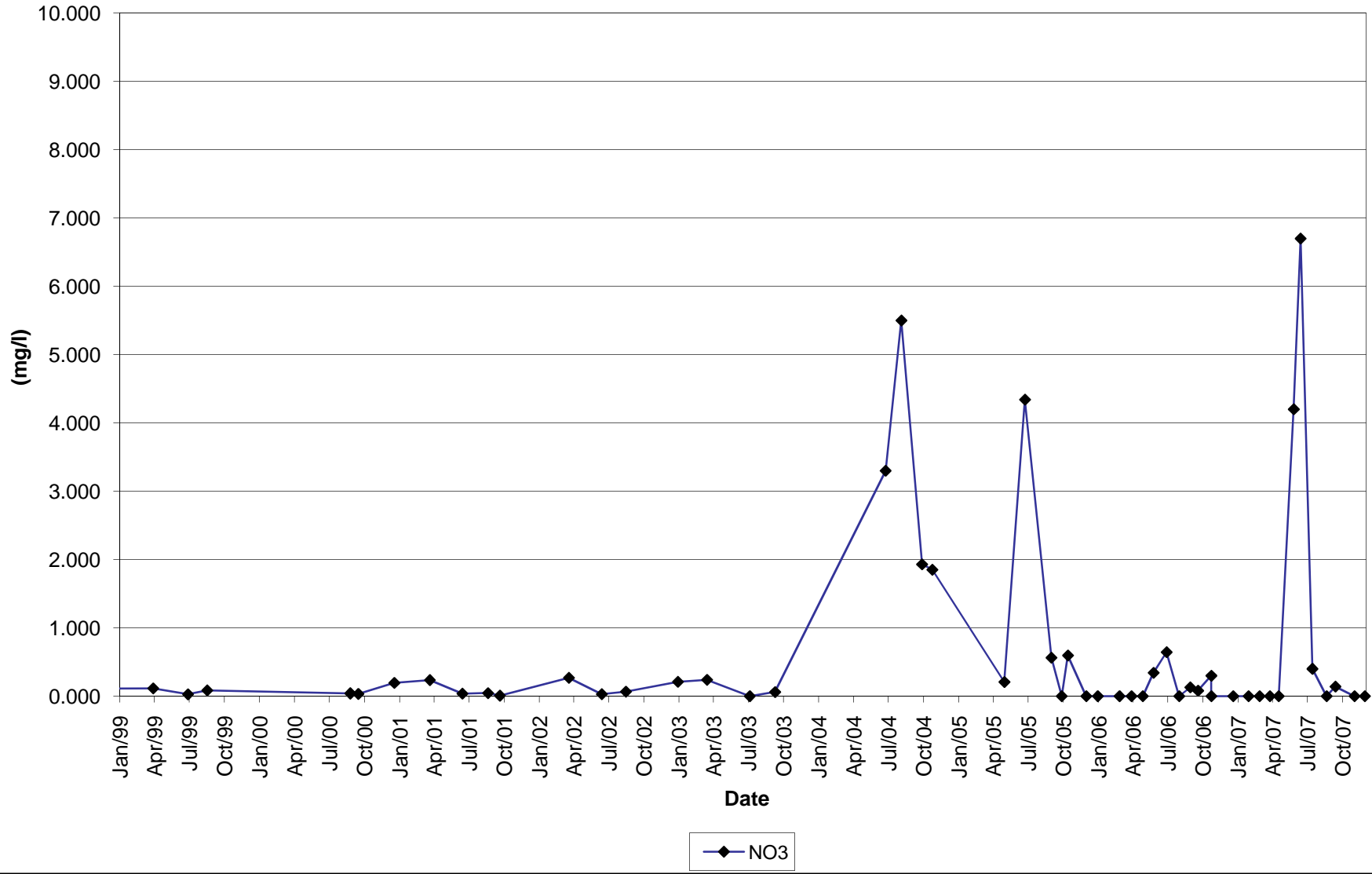


BC-03: Laura Creek Above Carolyn Creek

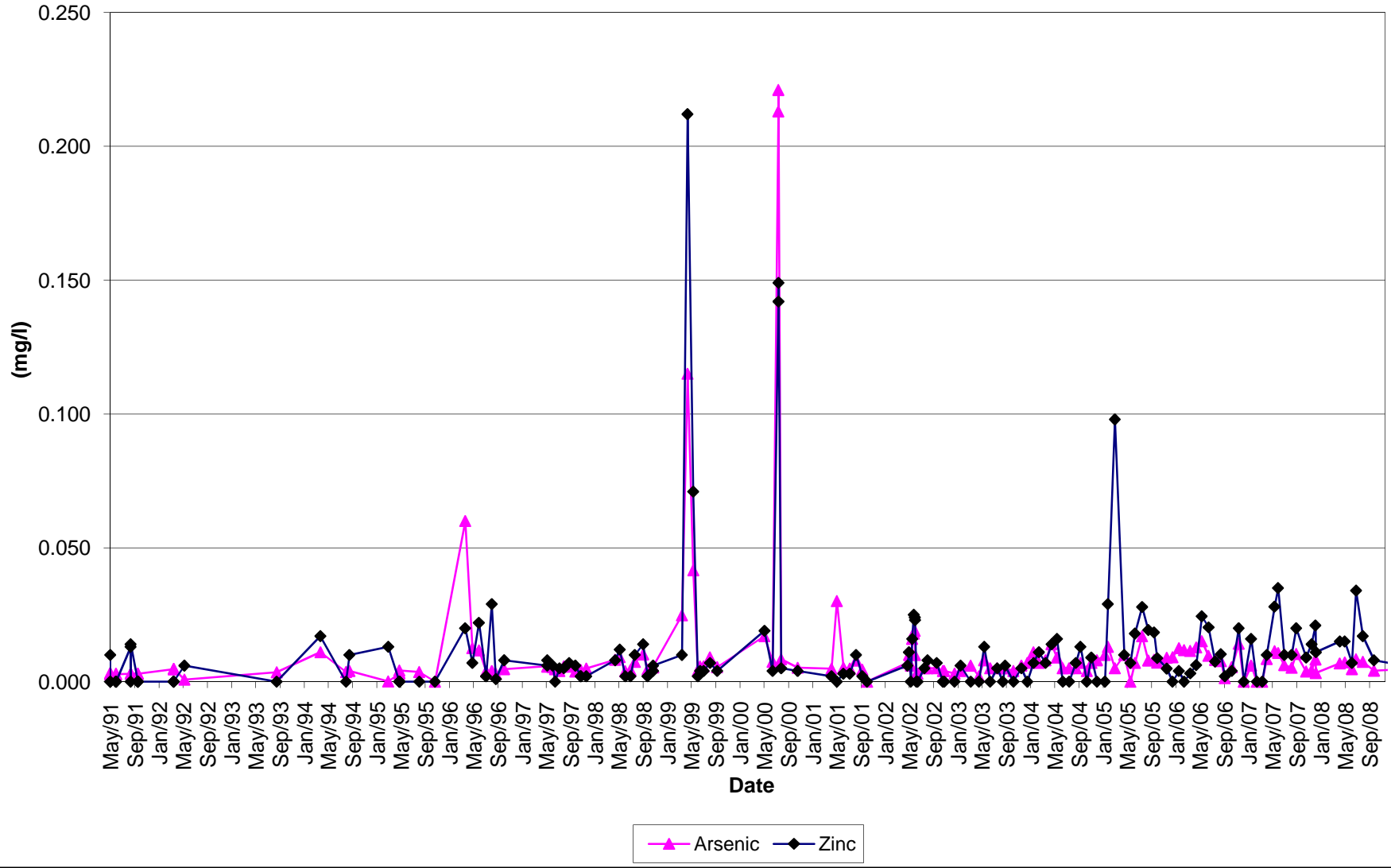


◆ NO3

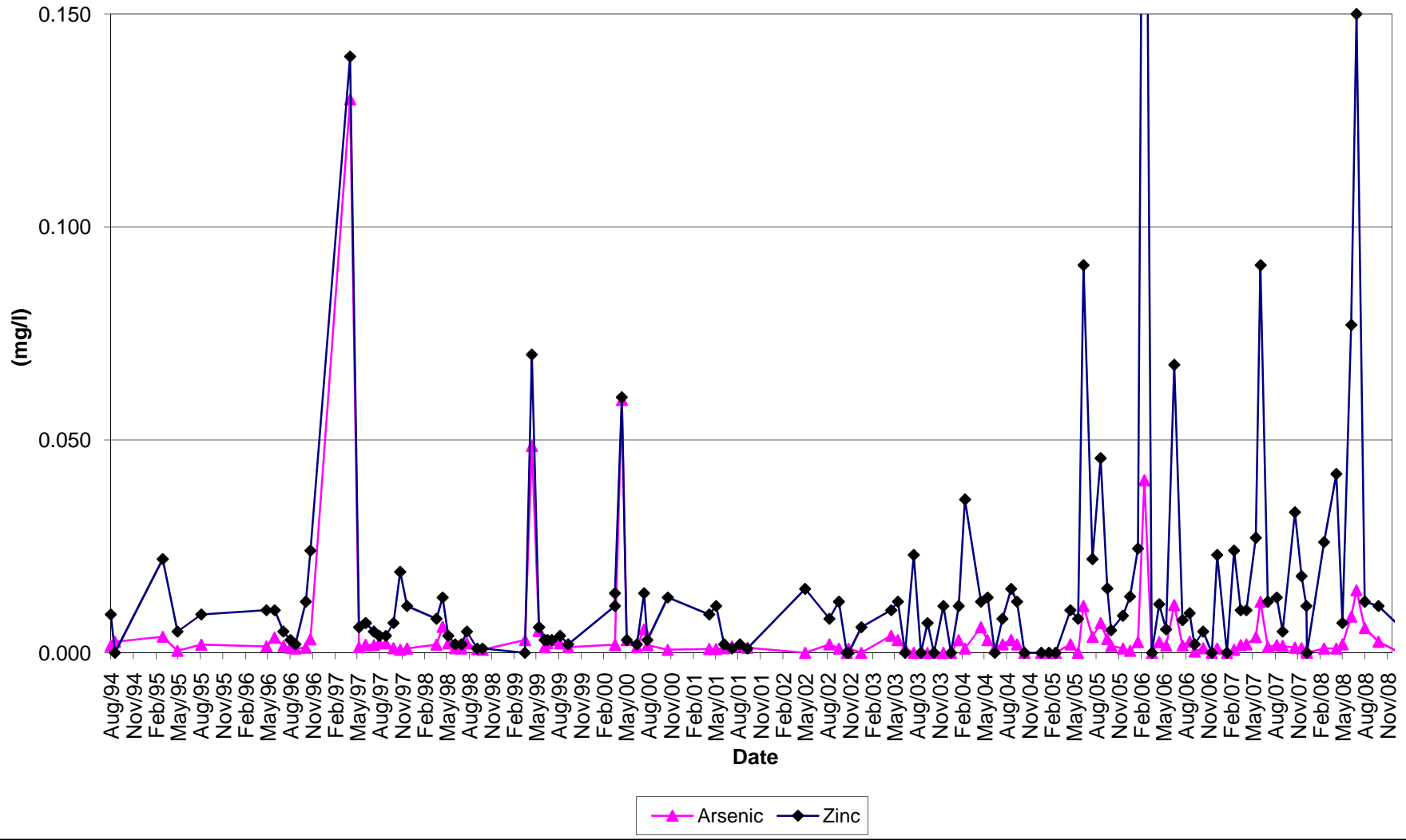
BC-39: Laura Creek at confluence with S. Klondike



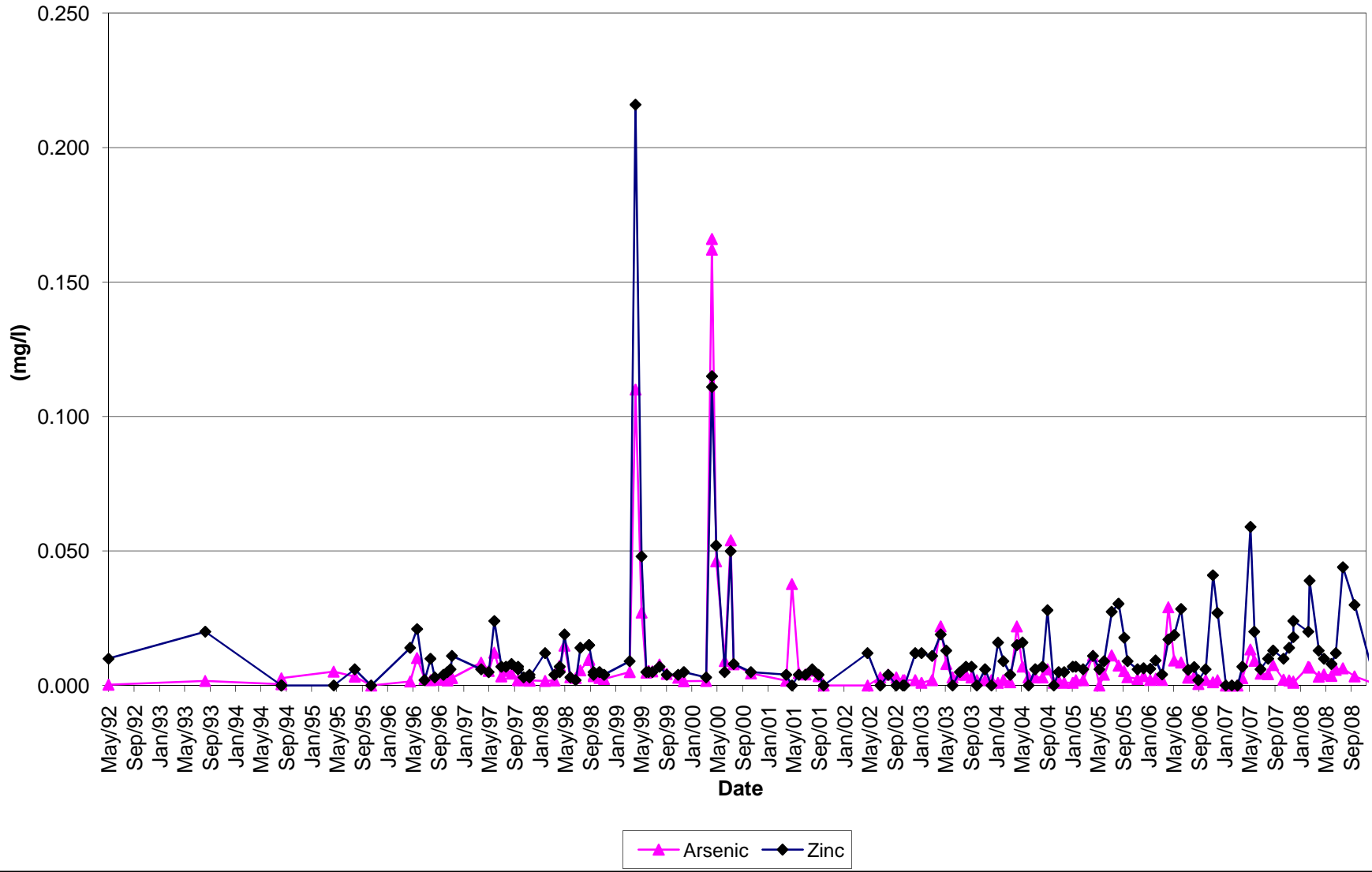
BC-01: Laura Creek 50m above Ditch Road



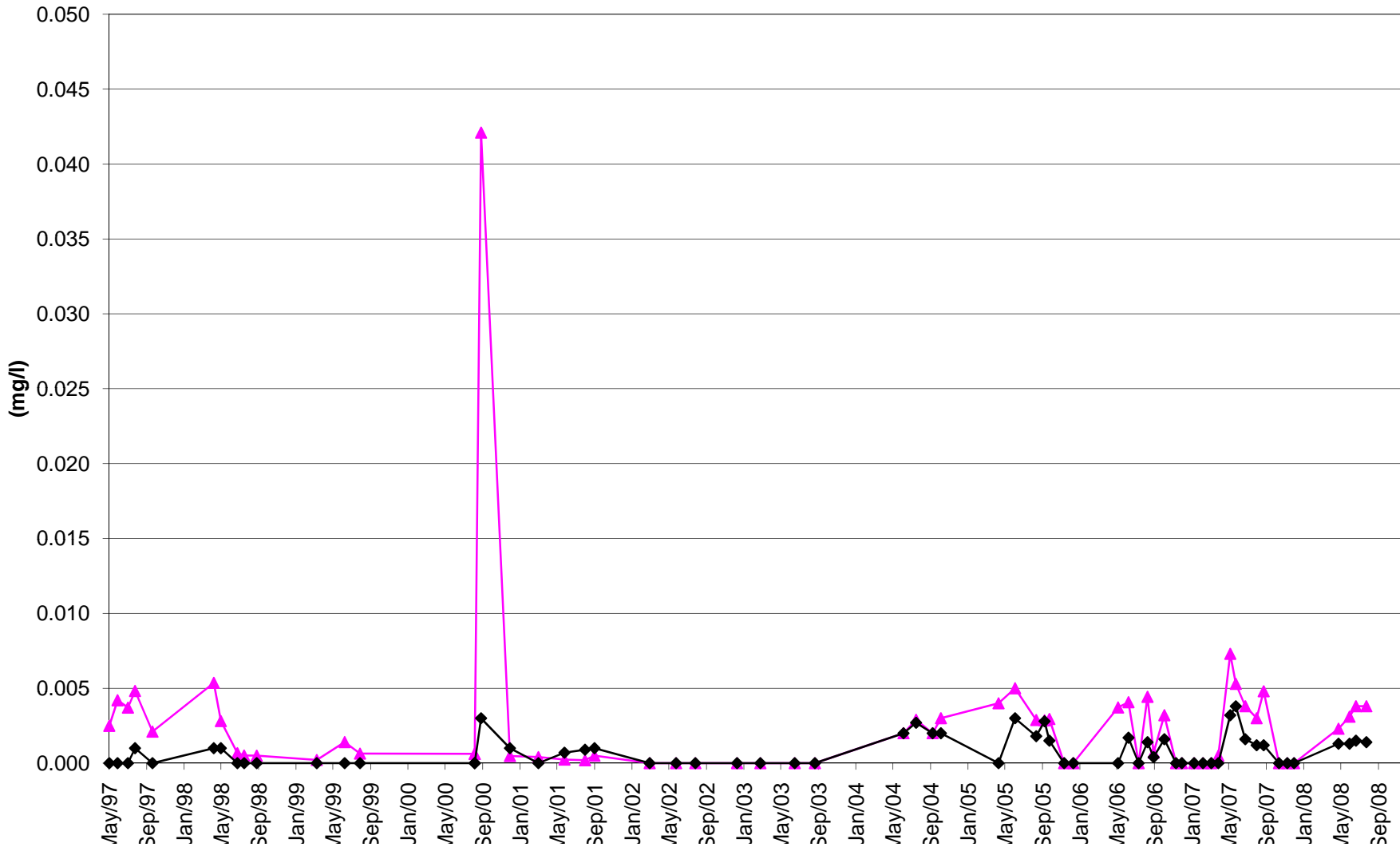
BC-02: Carolyn Creek u/s from Laura Creek



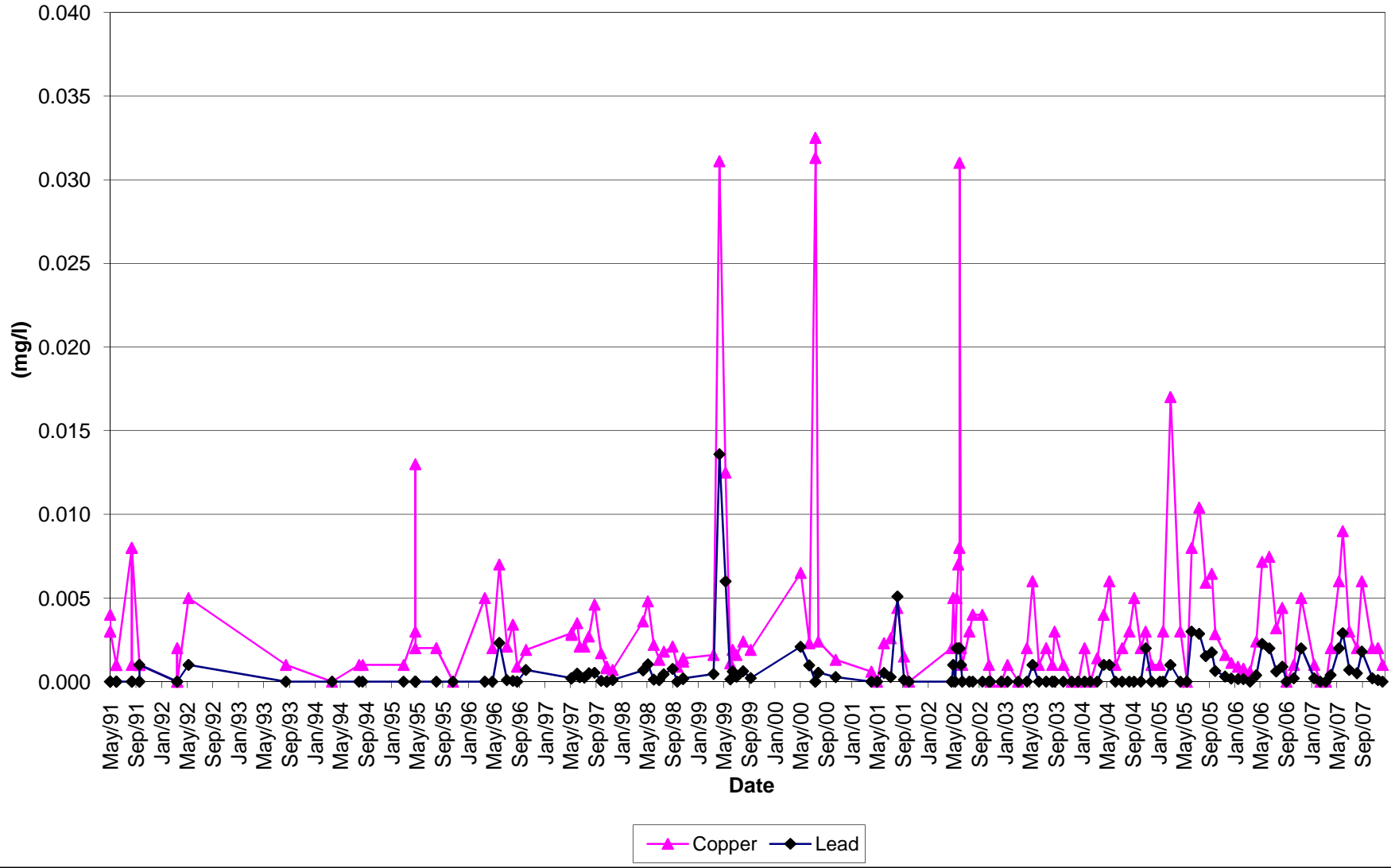
BC-03: Laura Creek Above Carolyn Creek



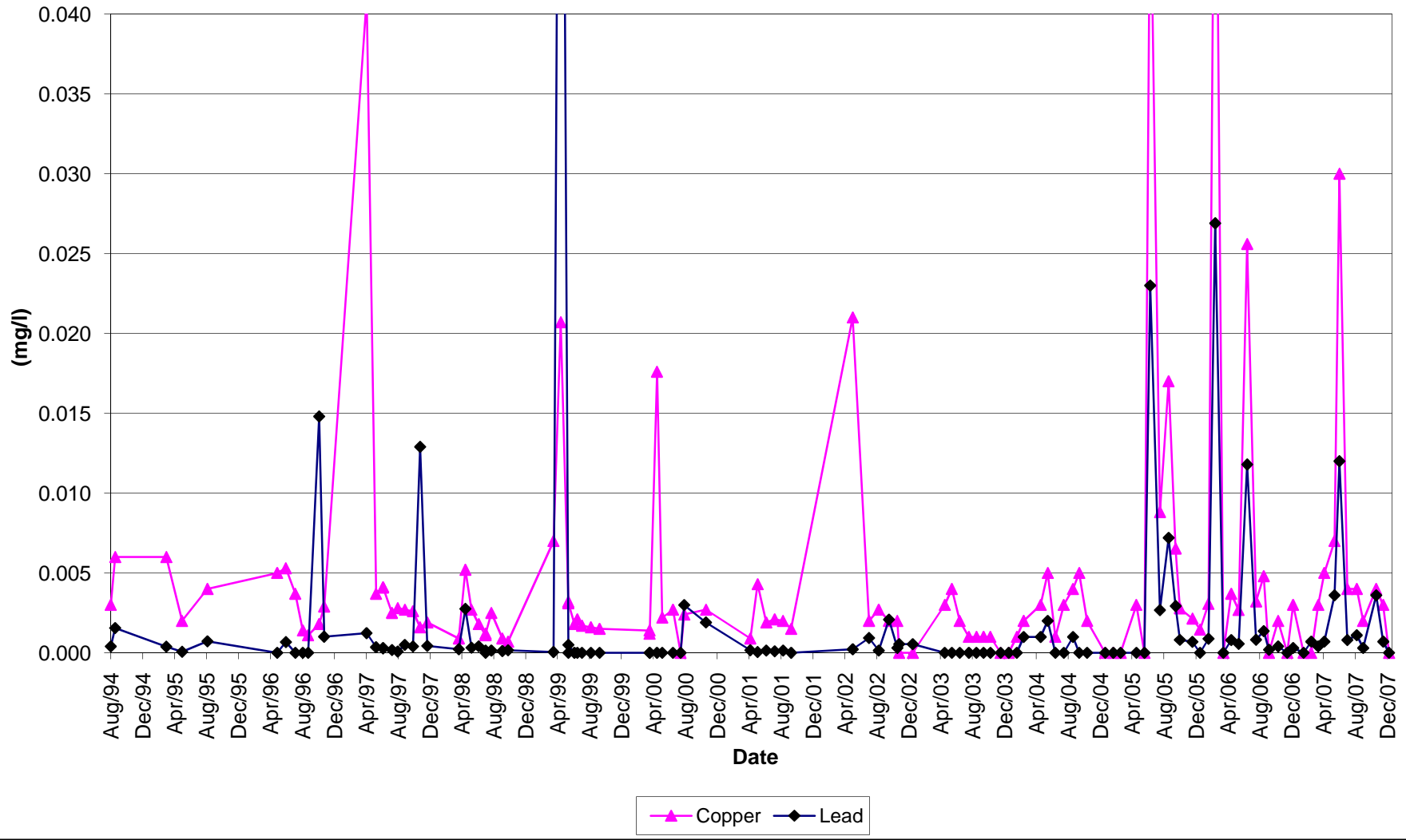
BC-39: Laura Creek in the side channel of the S. Klondike River



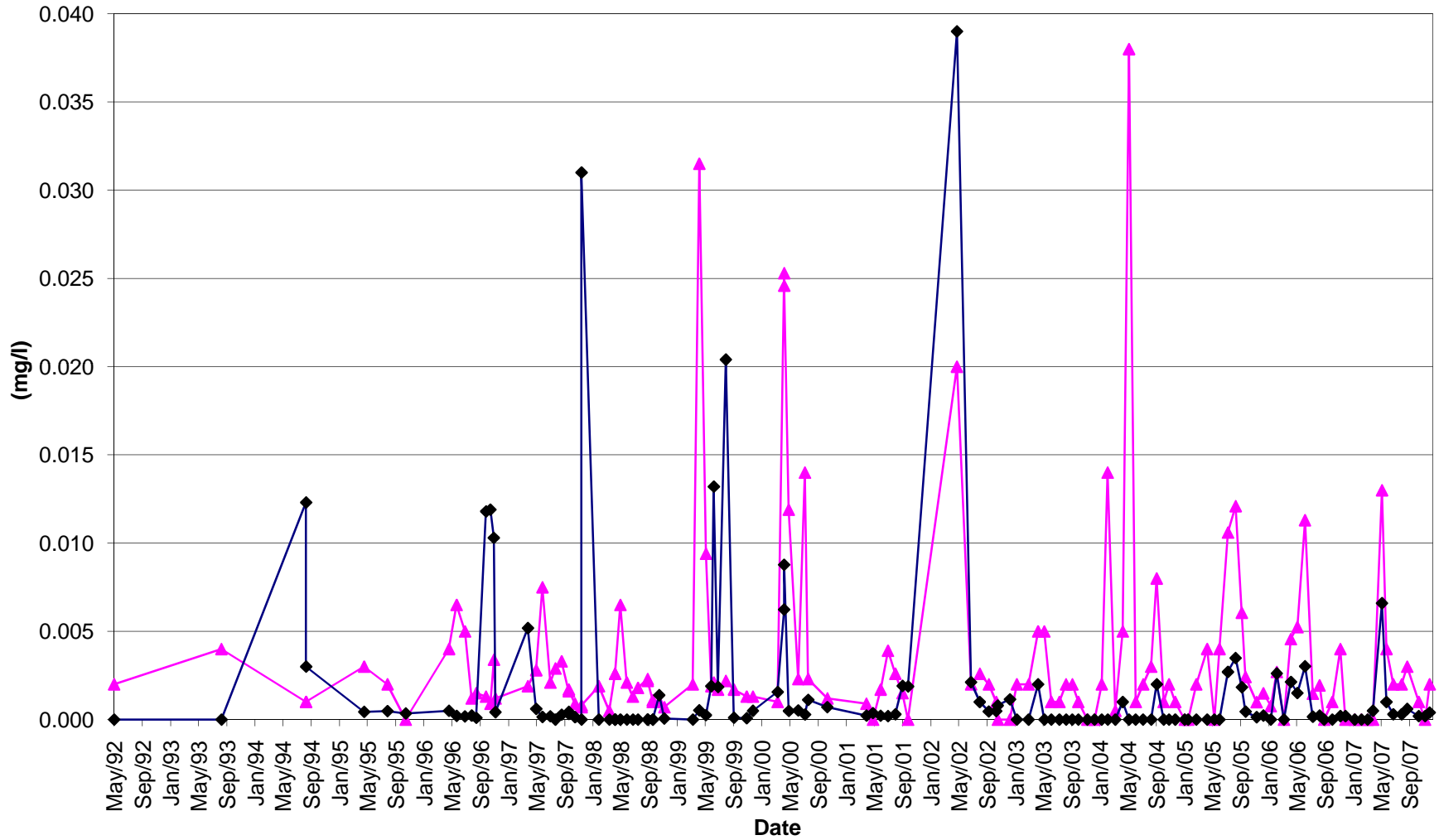
BC-01: Laura Creek 50m above Ditch Road



BC-02: Carolyn Creek u/s from Laura Creek

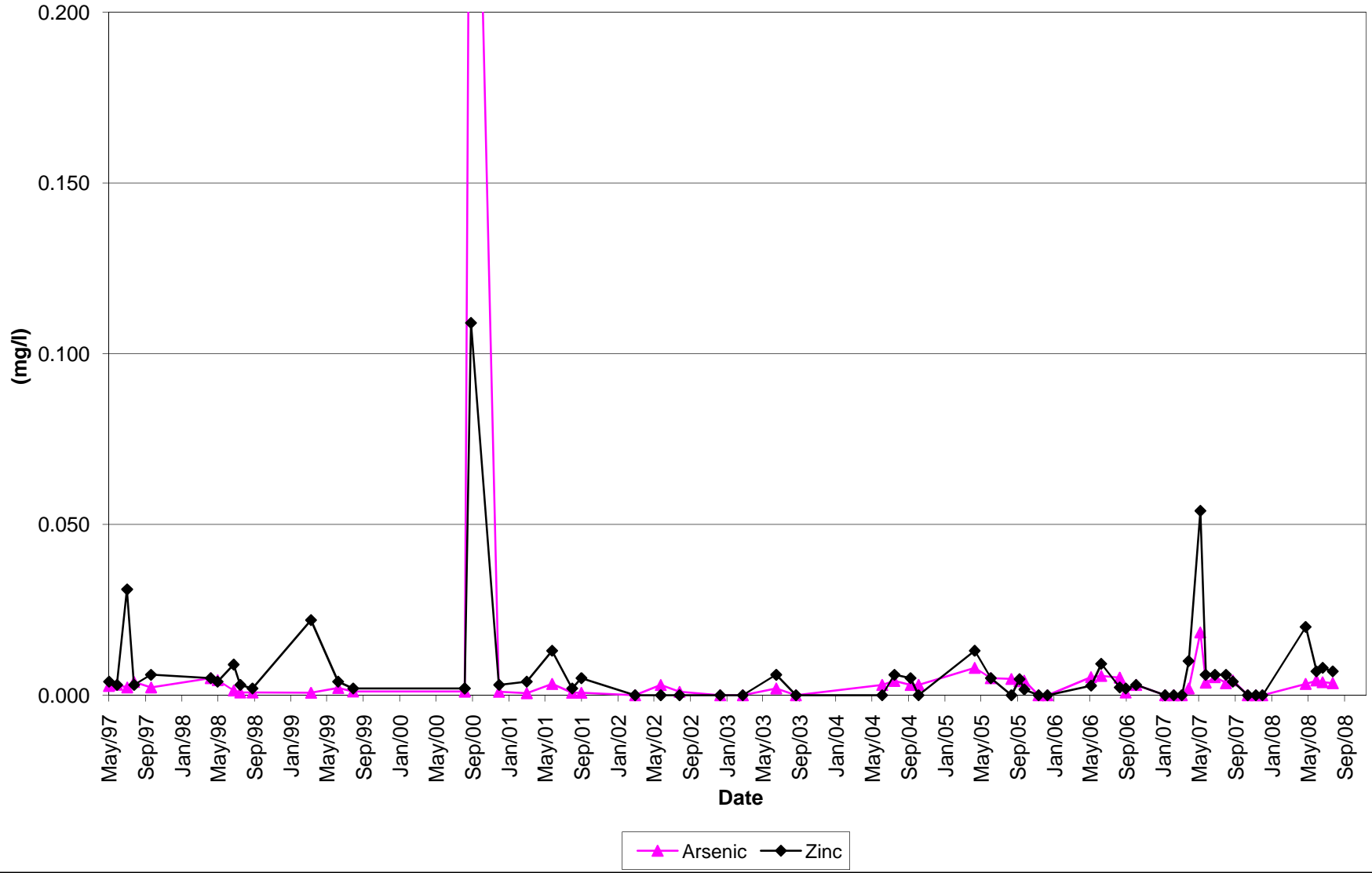


BC-03: Laura Creek Above Carolyn Creek

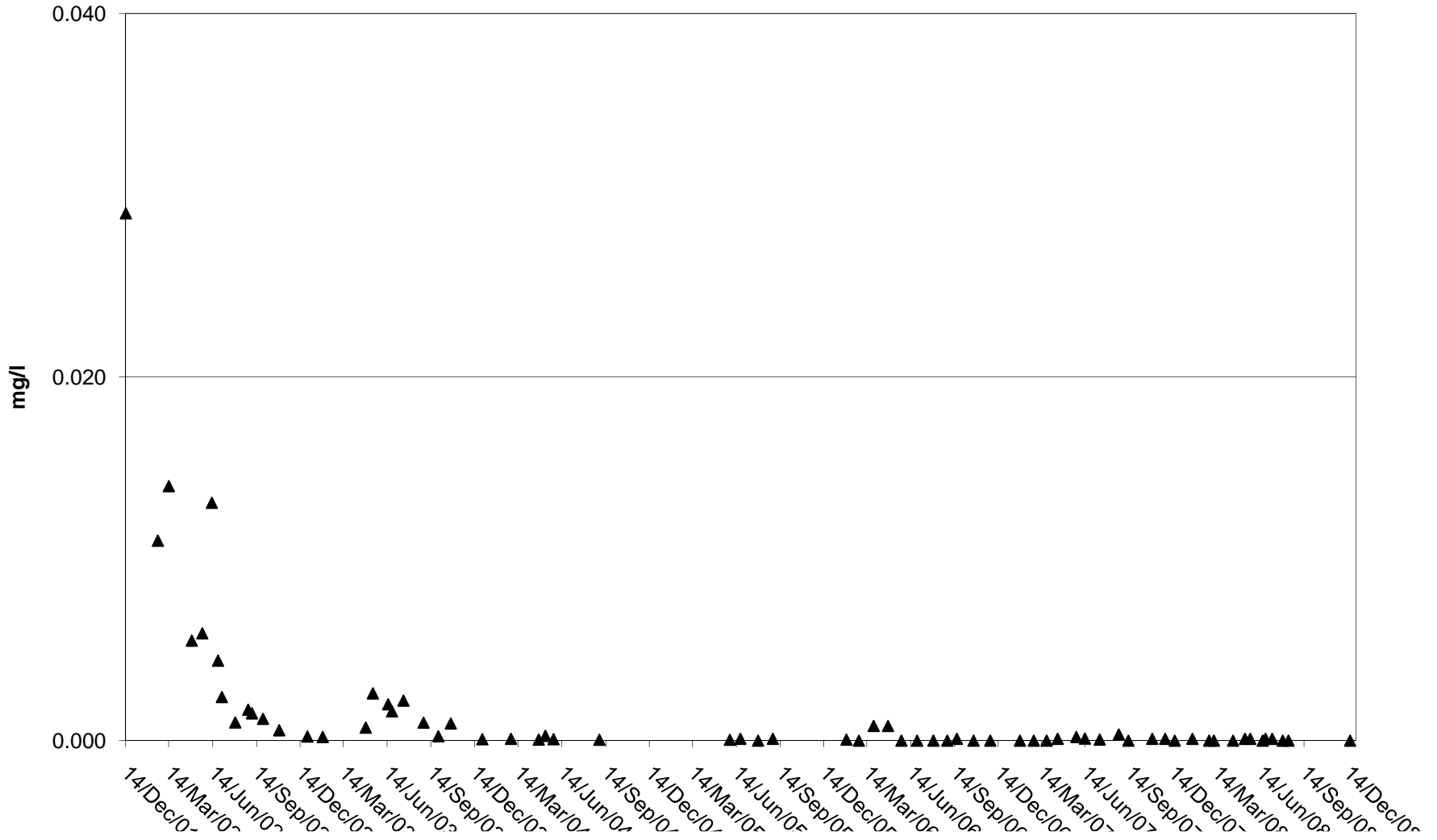


—▲— Copper —◆— Lead

BC-39: Laura Creek at confluence with S. Klondike

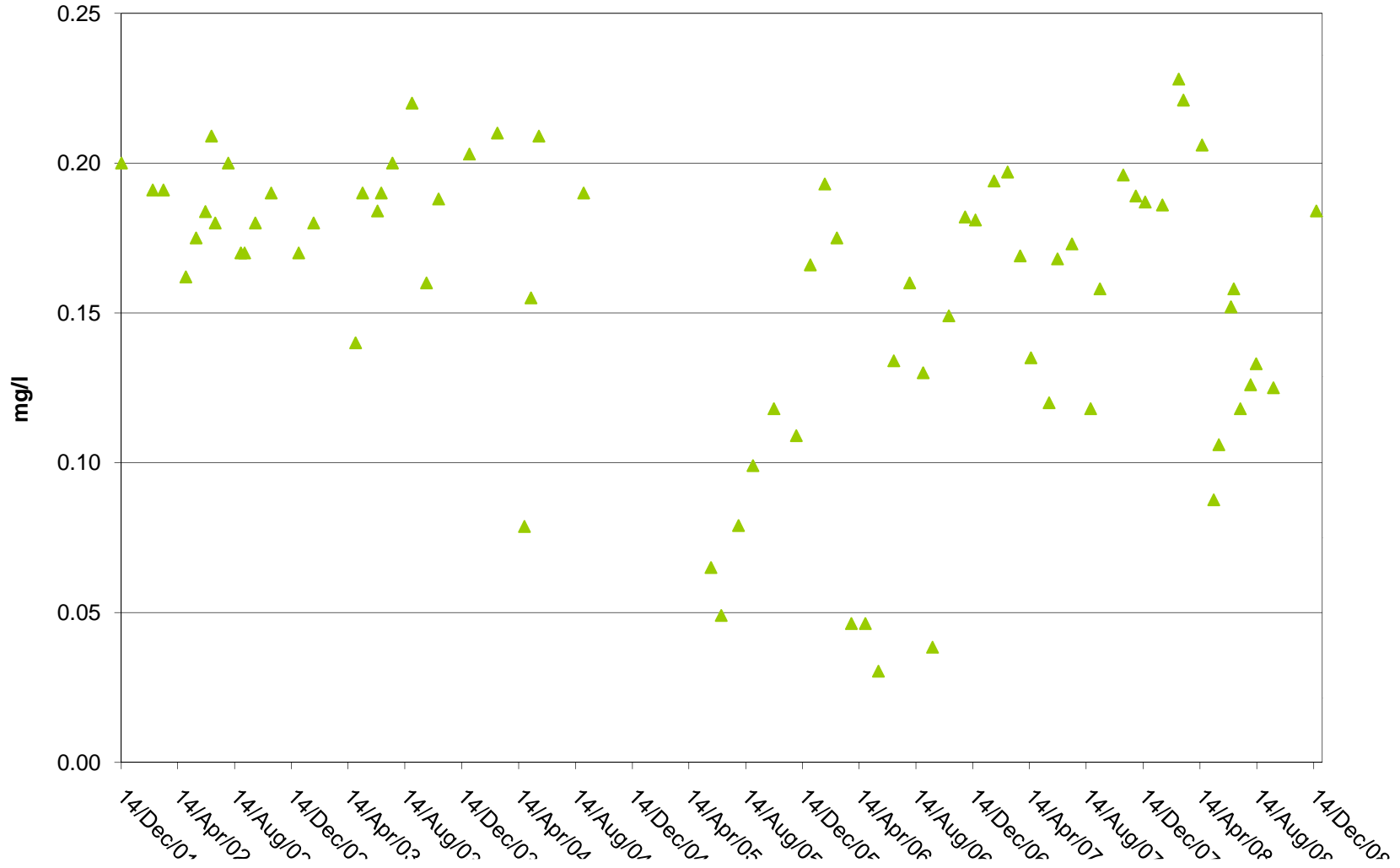


BC 28a (Heap Effluent)
Mercury



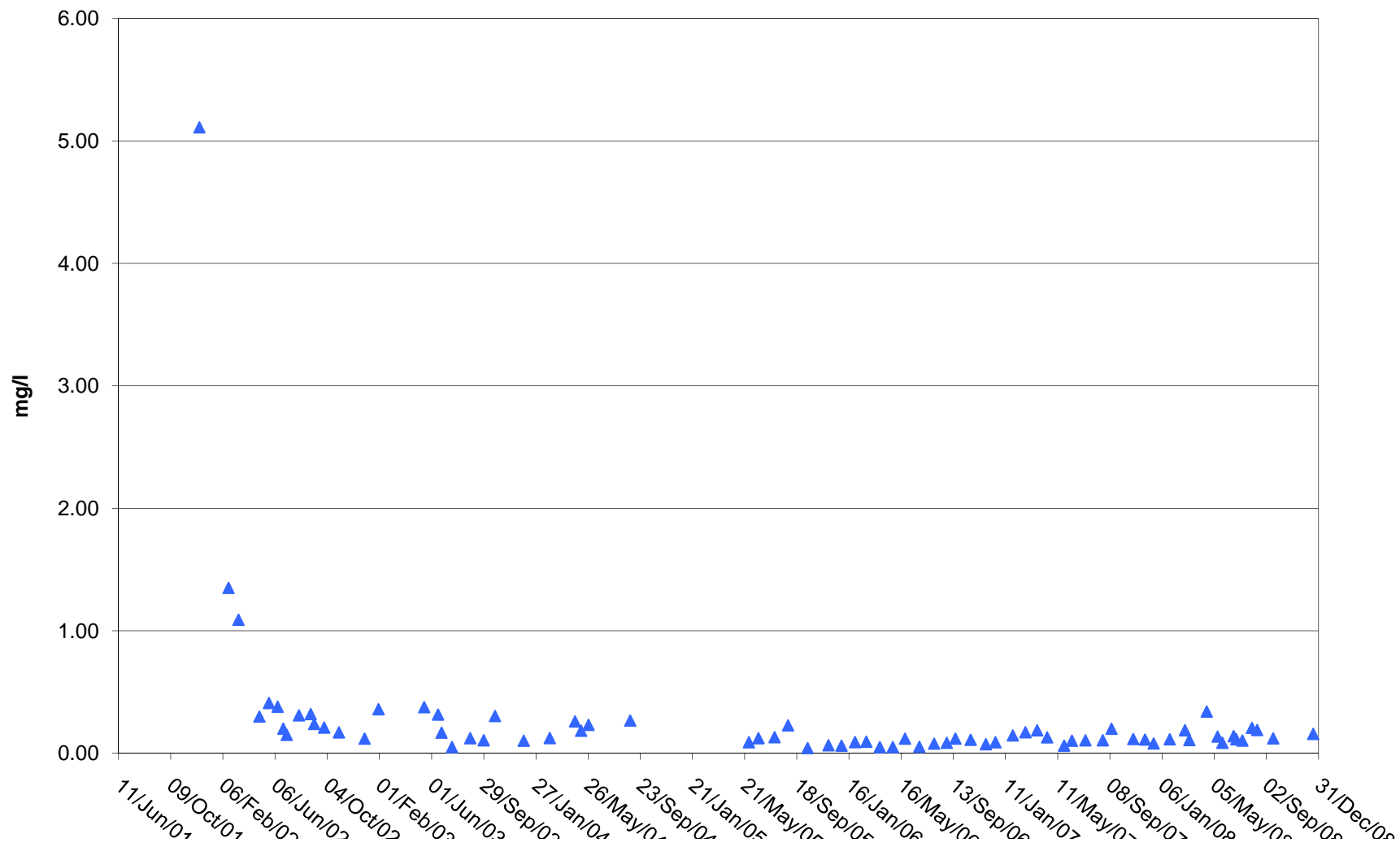
Brewery Creek Mine

BC-28a (Heap Effluent)
Selenium



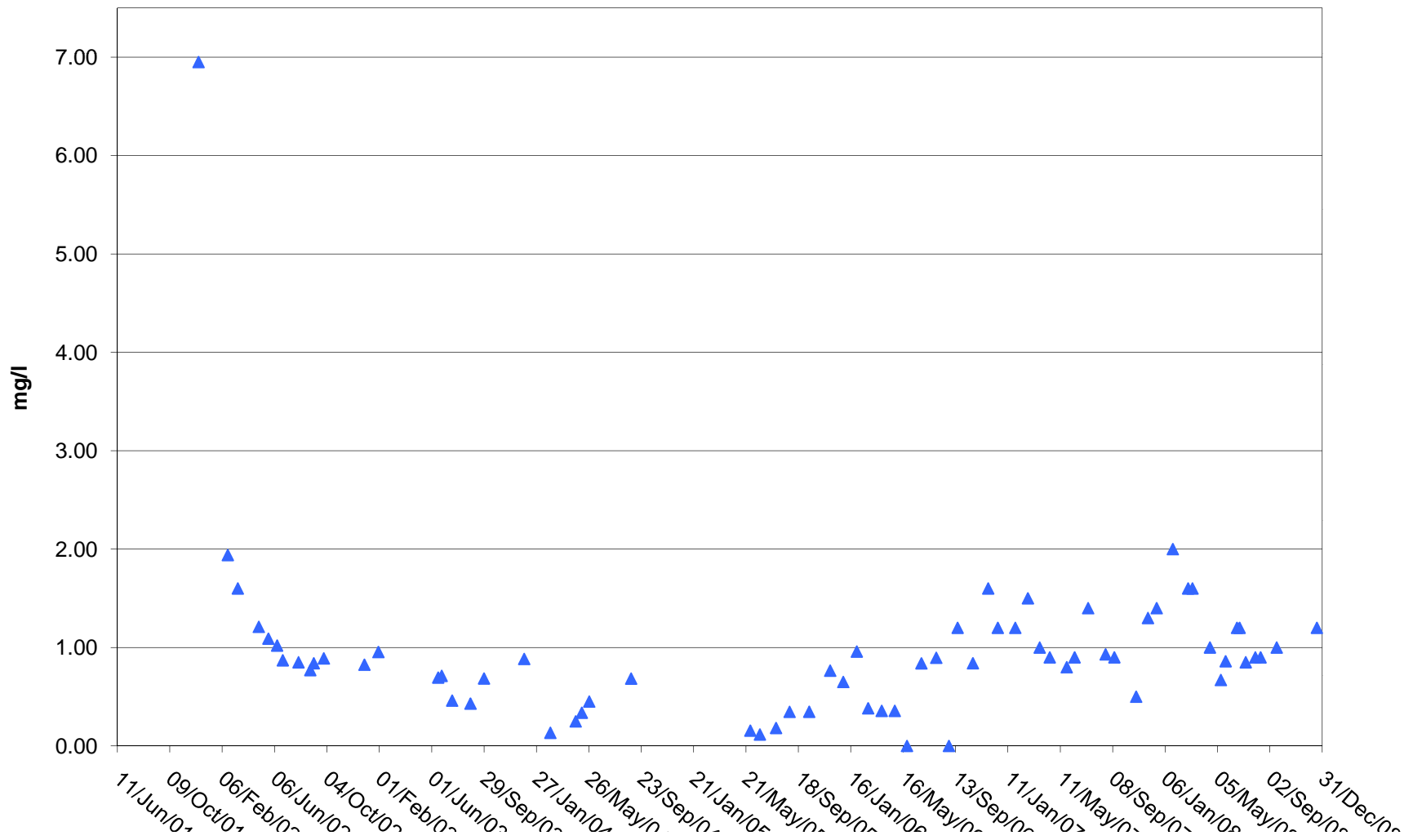
Brewery Creek Mine

BC-28a (Heap Effluent)
WAD Cyanide



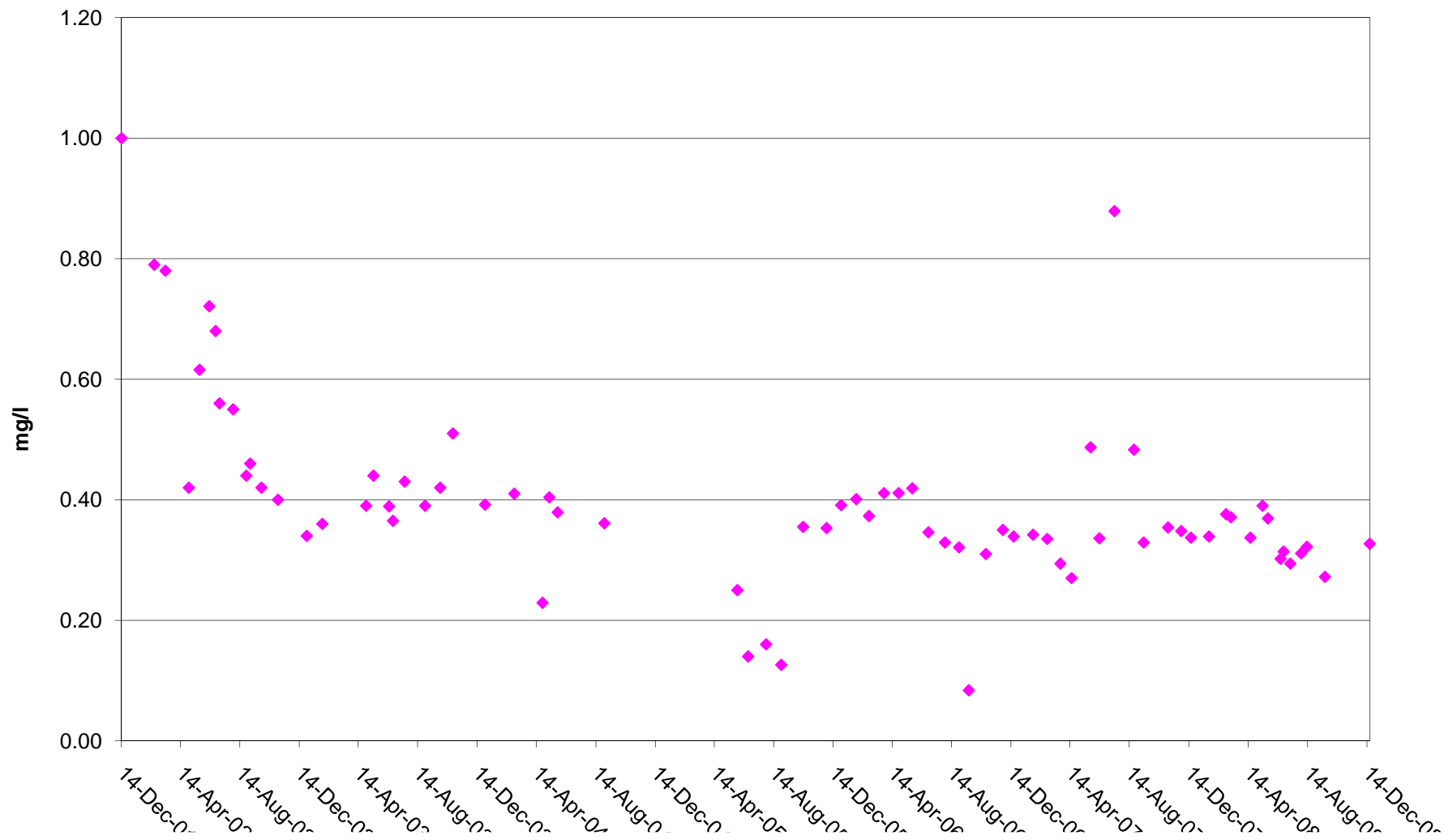
Brewery Creek Mine

BC-28a (Heap Effluent)
Total Cyanide



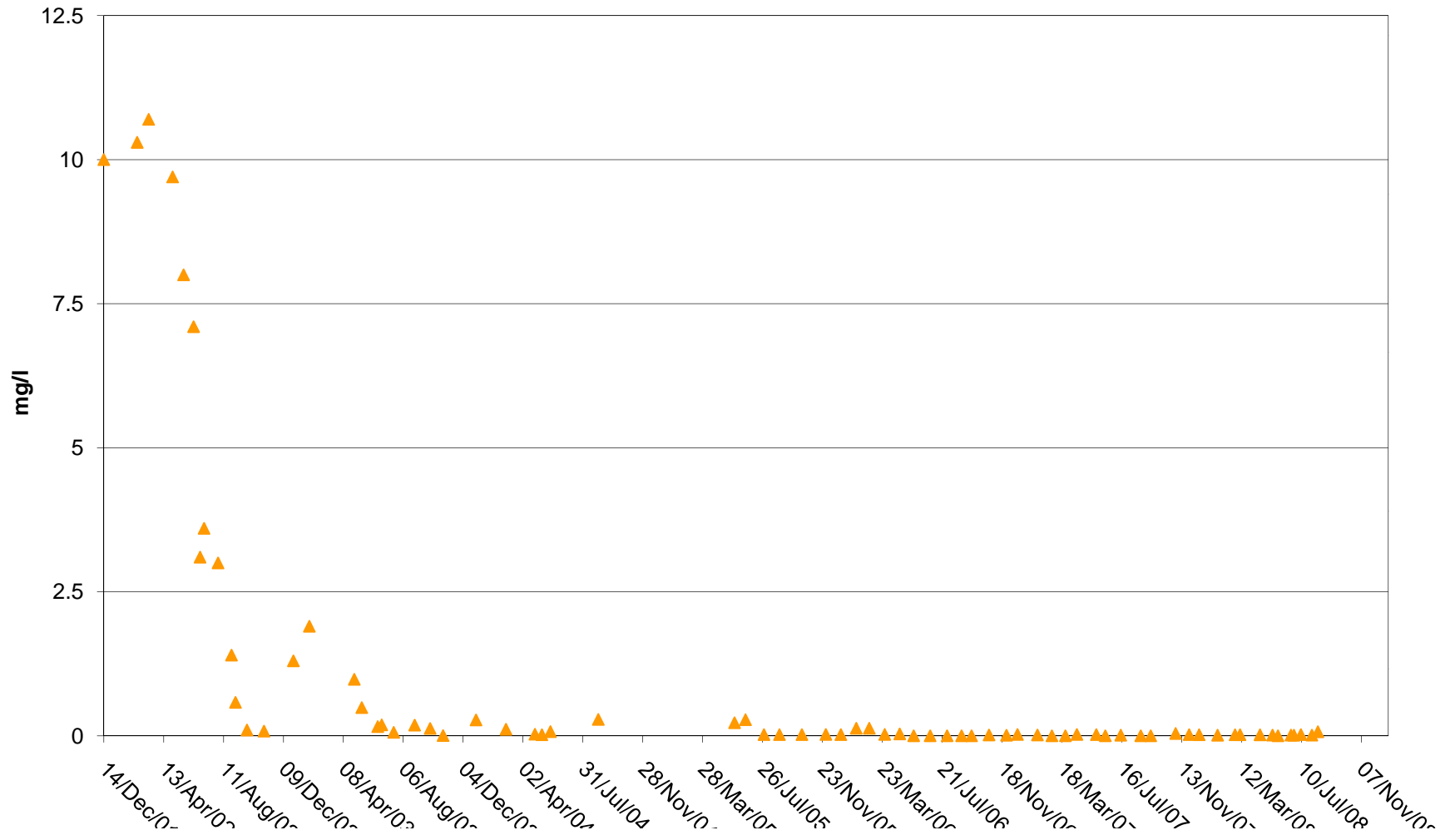
Brewery Creek Mine

BC-28a (Heap Effluent)
Arsenic

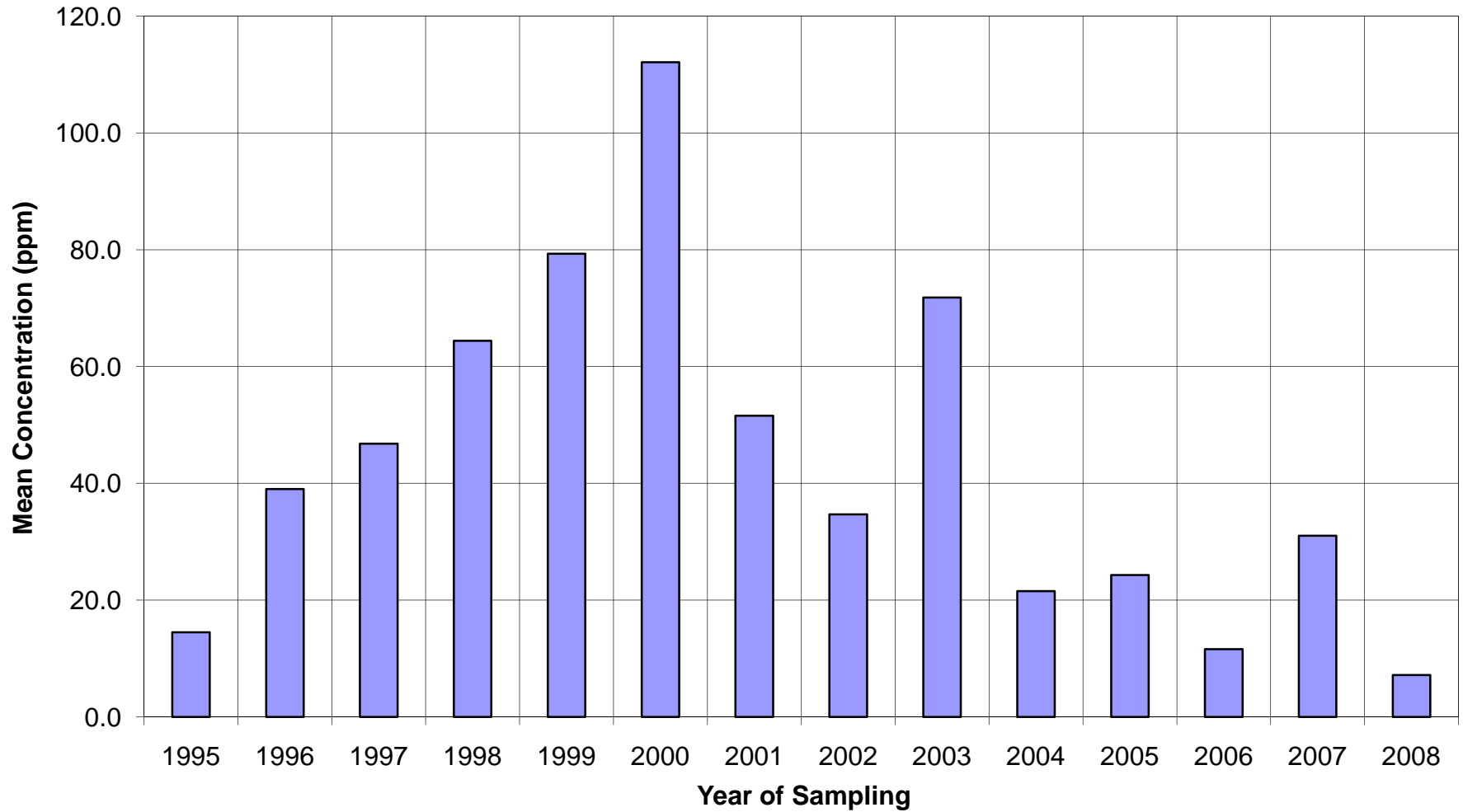


Brewery Creek Mine

BC-28a (Heap Effluent)
Ammonia

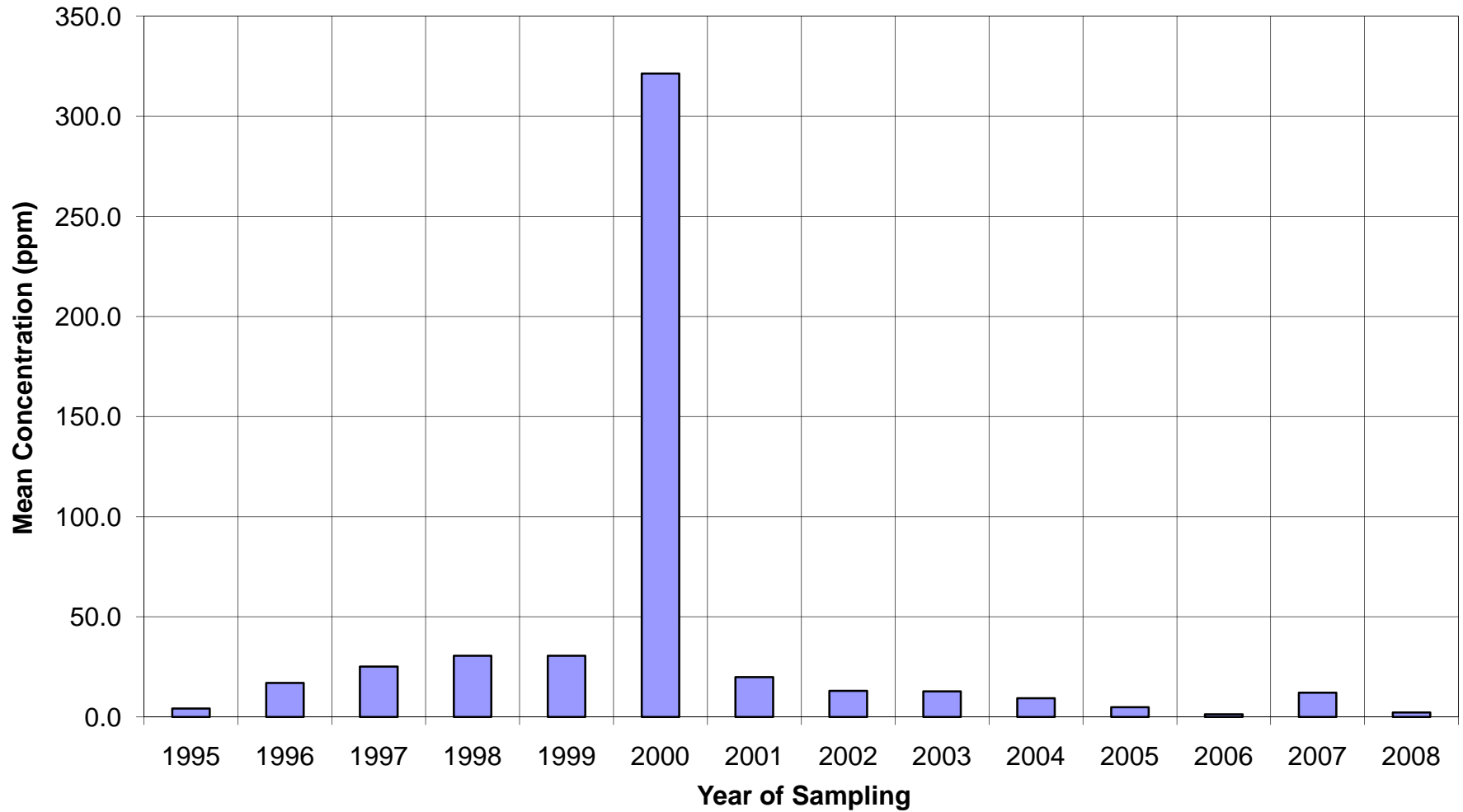


Stream Sediment Site W04B - Arsenic (As)
BC-03: Laura Creek Above Carolyn Creek



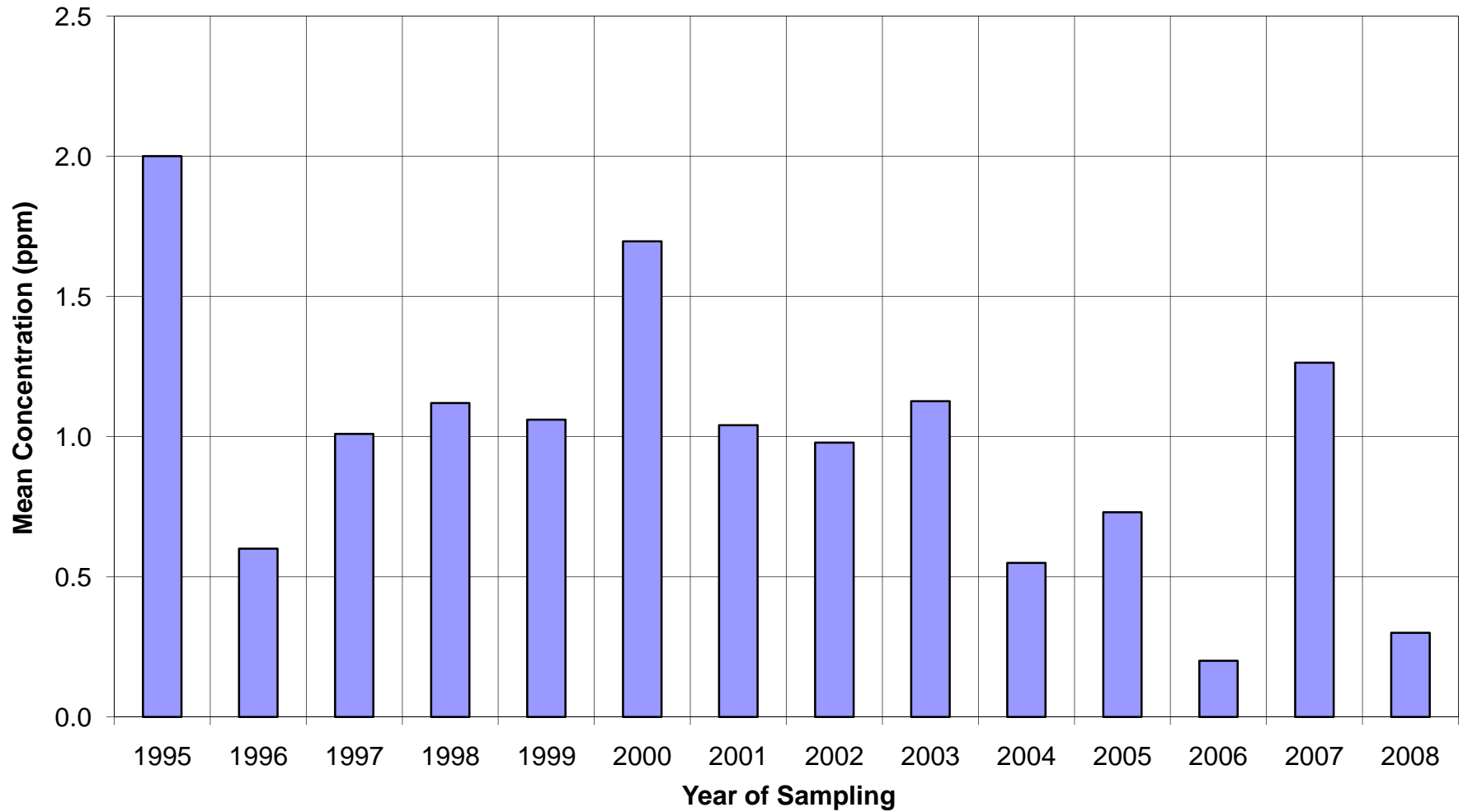
■ As

**Stream Sediment Site W04B - Antimony (Sb)
BC-03: Laura Creek Above Carolyn Creek**



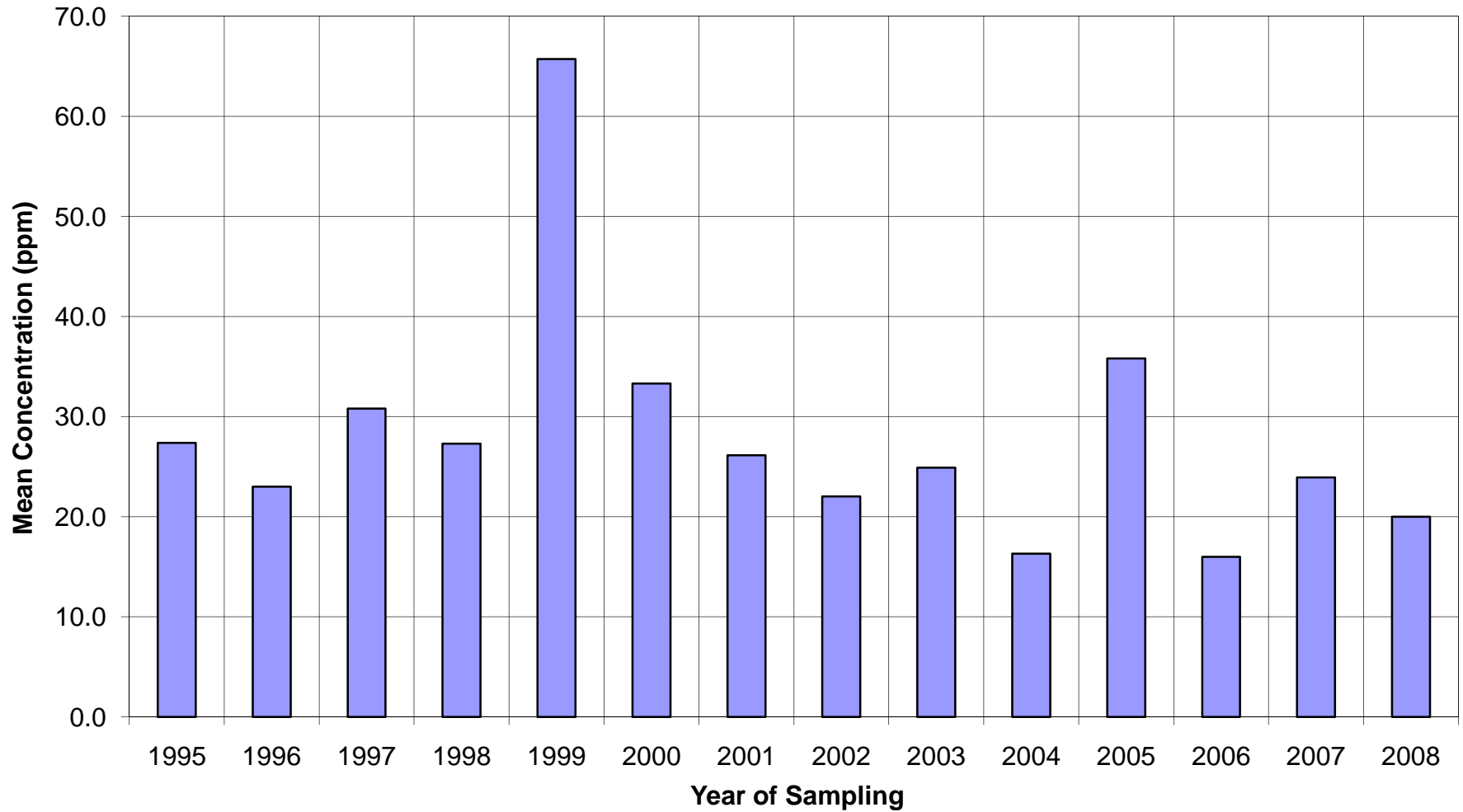
■ Sb

**Stream Sediment Site W04B - Cadmium (Cd)
BC-03: Laura Creek Above Carolyn Creek**



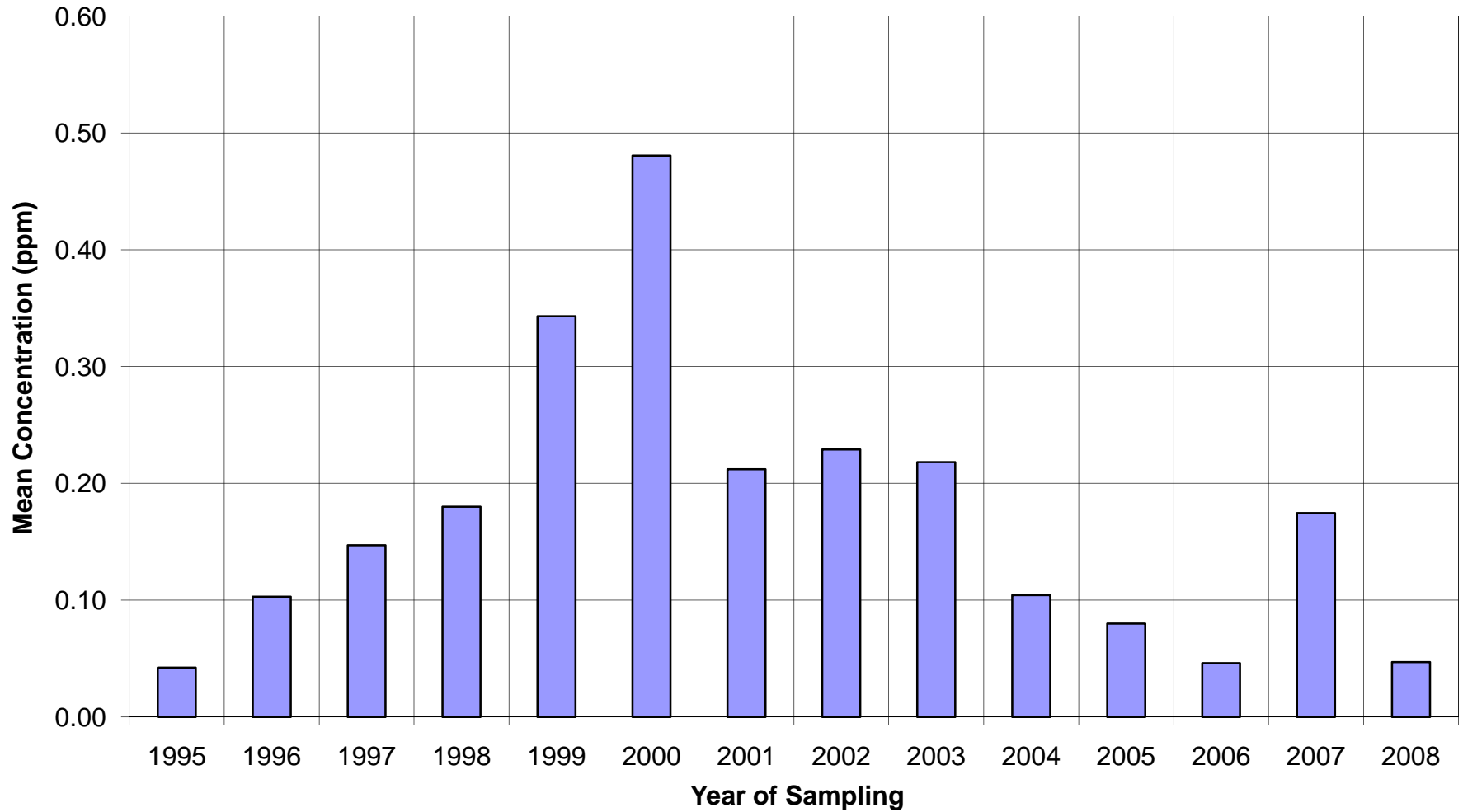
■ Cd

**Stream Sediment Site W04B - Copper (Cu)
BC-03: Laura Creek Above Carolyn Creek**



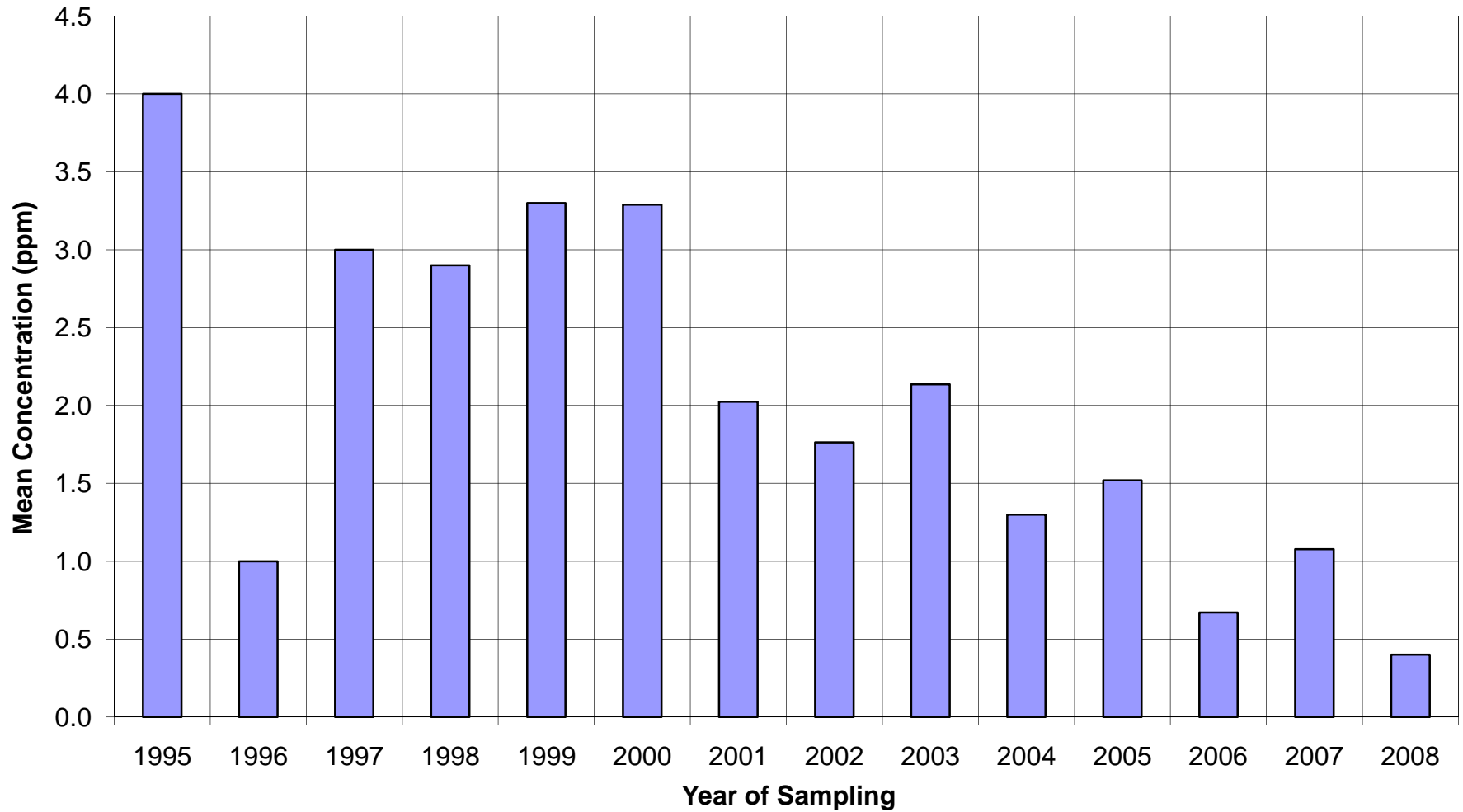
■ Cu

**Stream Sediment Site W04B - Mercury (Hg)
BC-03: Laura Creek Above Carolyn Creek**



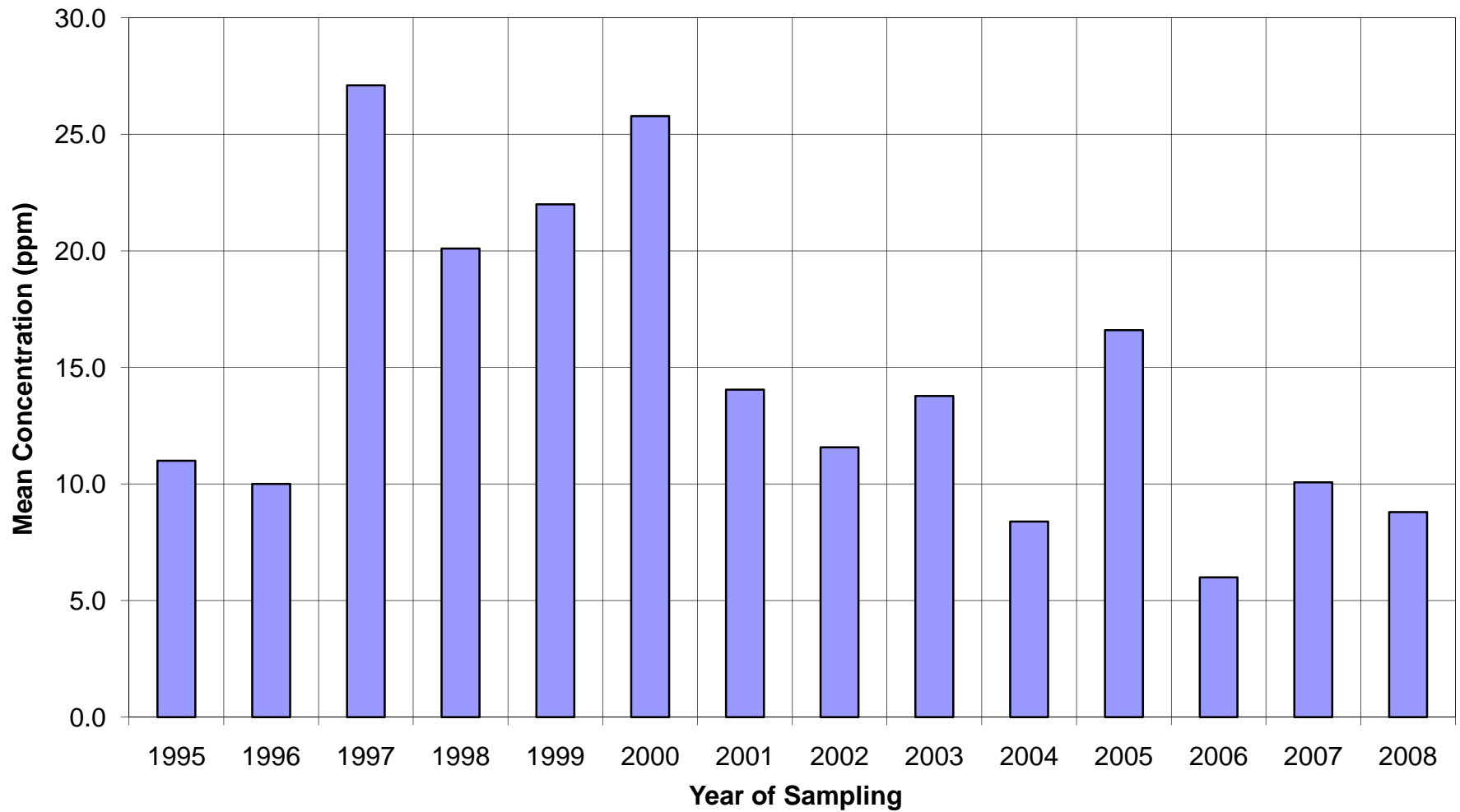
■ Hg

Stream Sediment Site W04B - Molybdenum (Mo)
BC-03: Laura Creek Above Carolyn Creek



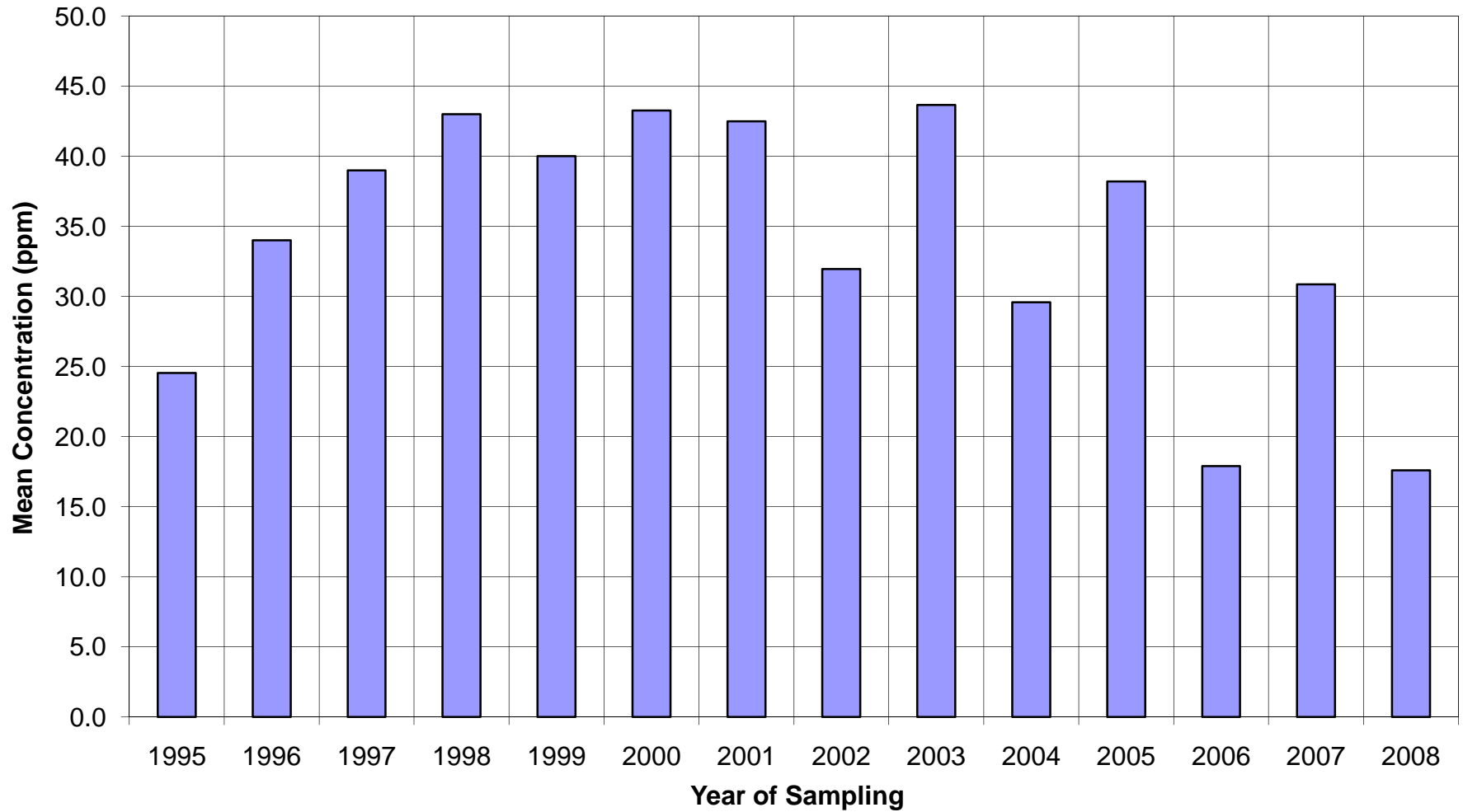
Mo

**Stream Sediment Site W04B - Lead (Pb)
BC-03: Laura Creek Above Carolyn Creek**



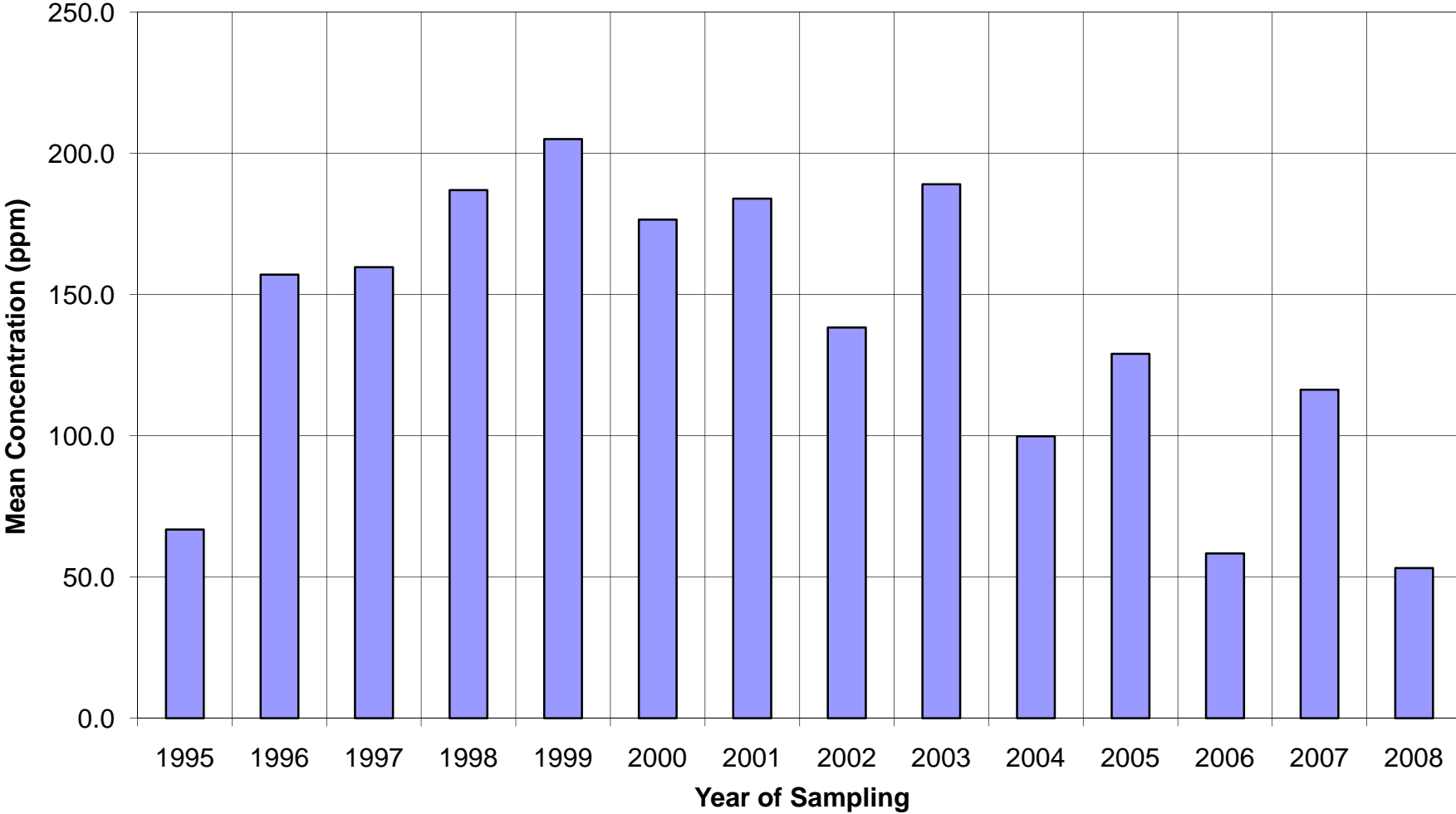
■ Pb

**Stream Sediment Site W04B - Nickel (Ni)
BC-03: Laura Creek Above Carolyn Creek**



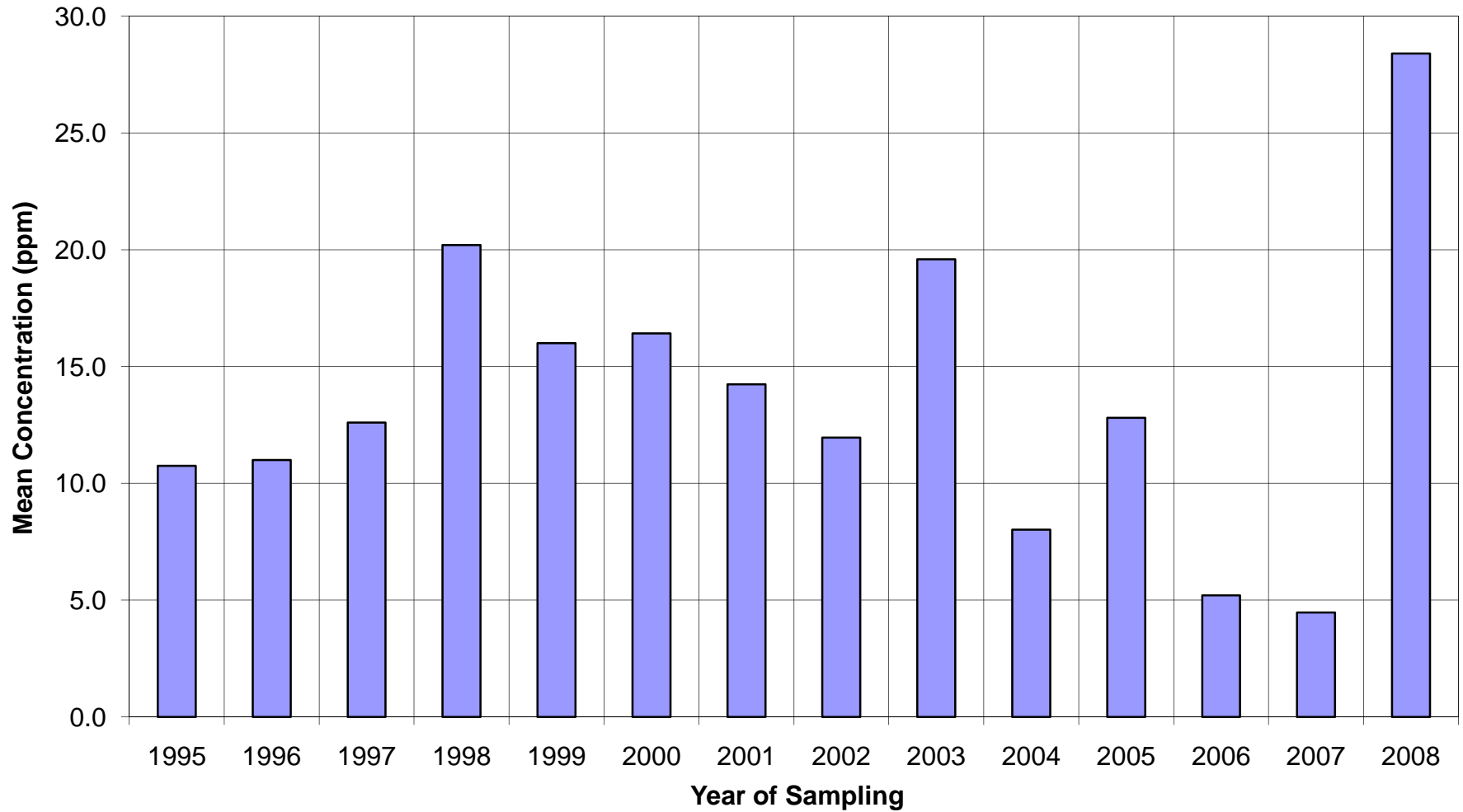
■ Ni

**Stream Sediment Site W04B - Zinc (Zn)
BC-03: Laura Creek Above Carolyn Creek**



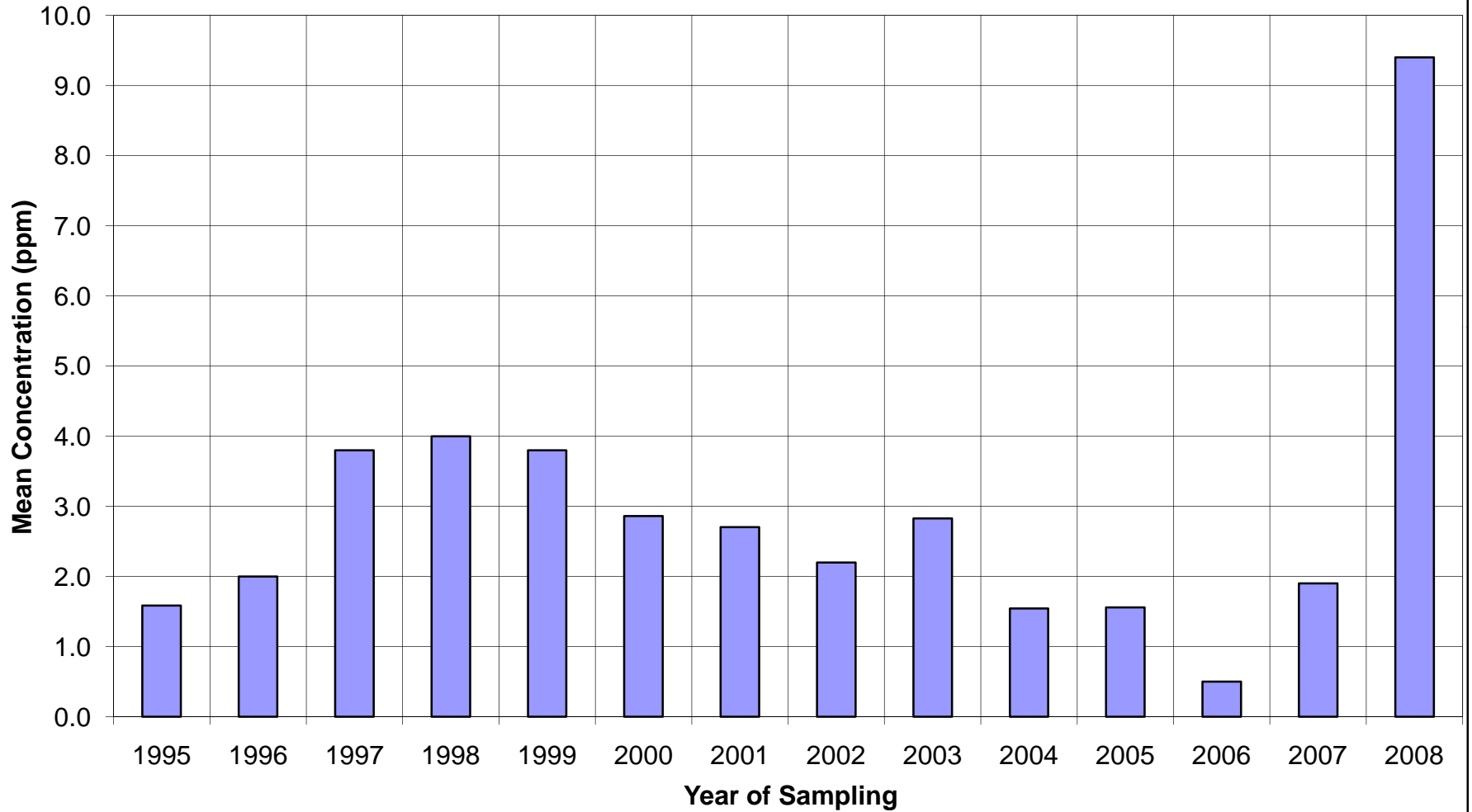
■ Zn

**Stream Sediment Site W15 - Arsenic (As)
BC-02: Carolyn Creek upstream from Laura Creek**



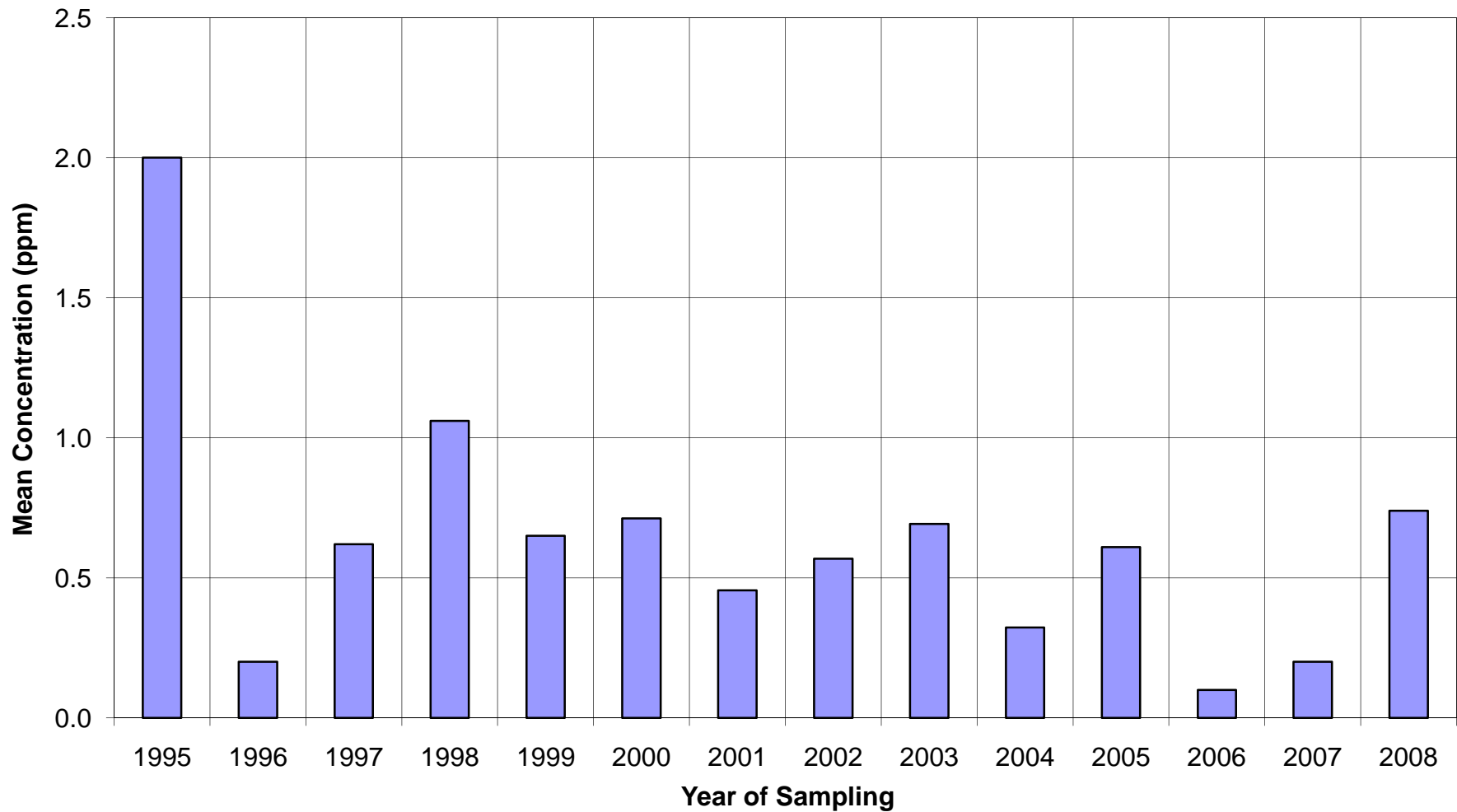
■ As

**Stream Sediment Site W15 - Antimony (Sb)
BC-02: Carolyn Creek upstream from Laura Creek**



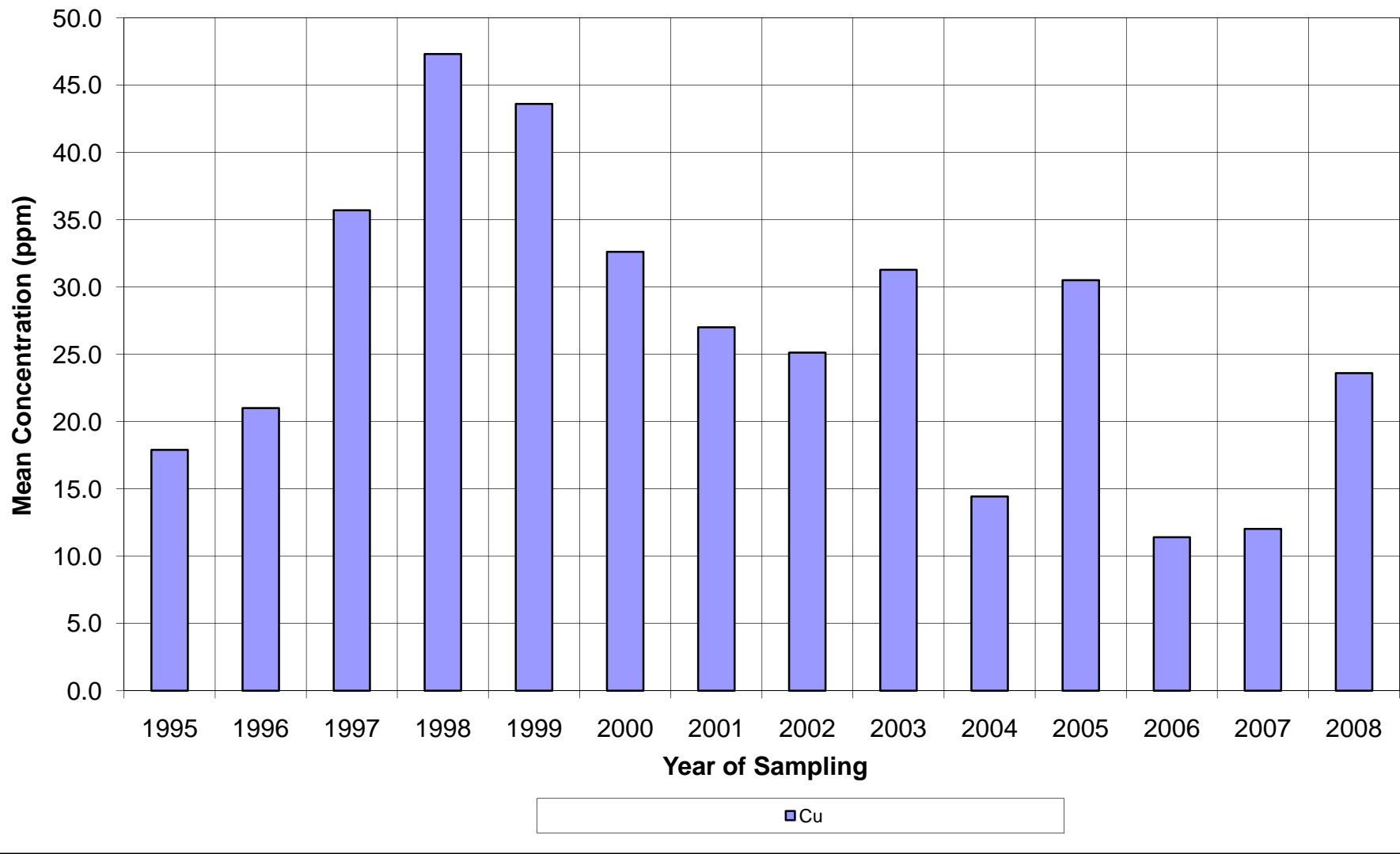
■ Sb

**Stream Sediment Site W15 - Cadmium (Cd)
BC-02: Carolyn Creek upstream from Laura Creek**

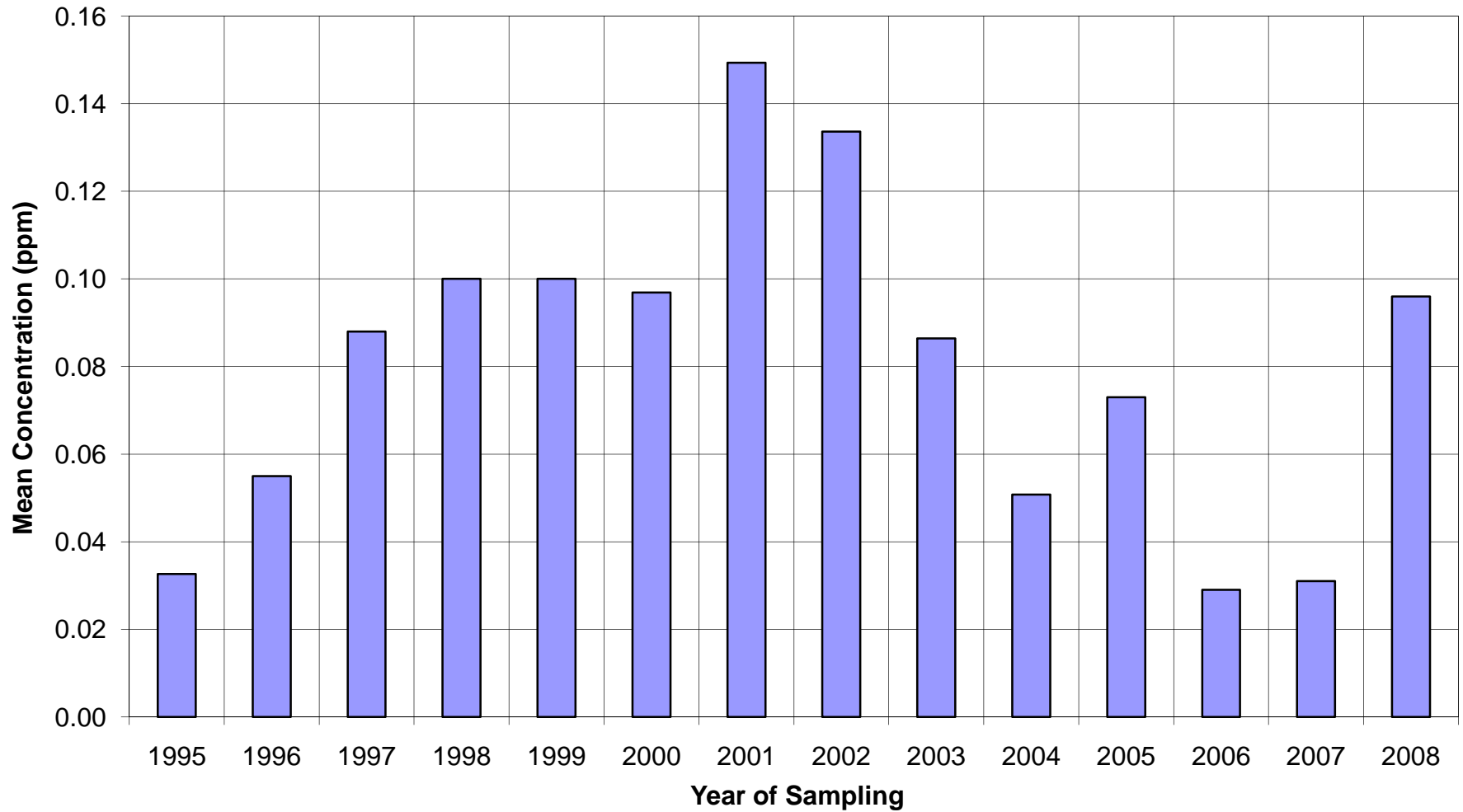


■ Cd

**Stream Sediment Site W15 - Copper (Cu)
BC-02: Carolyn Creek upstream from Laura Creek**

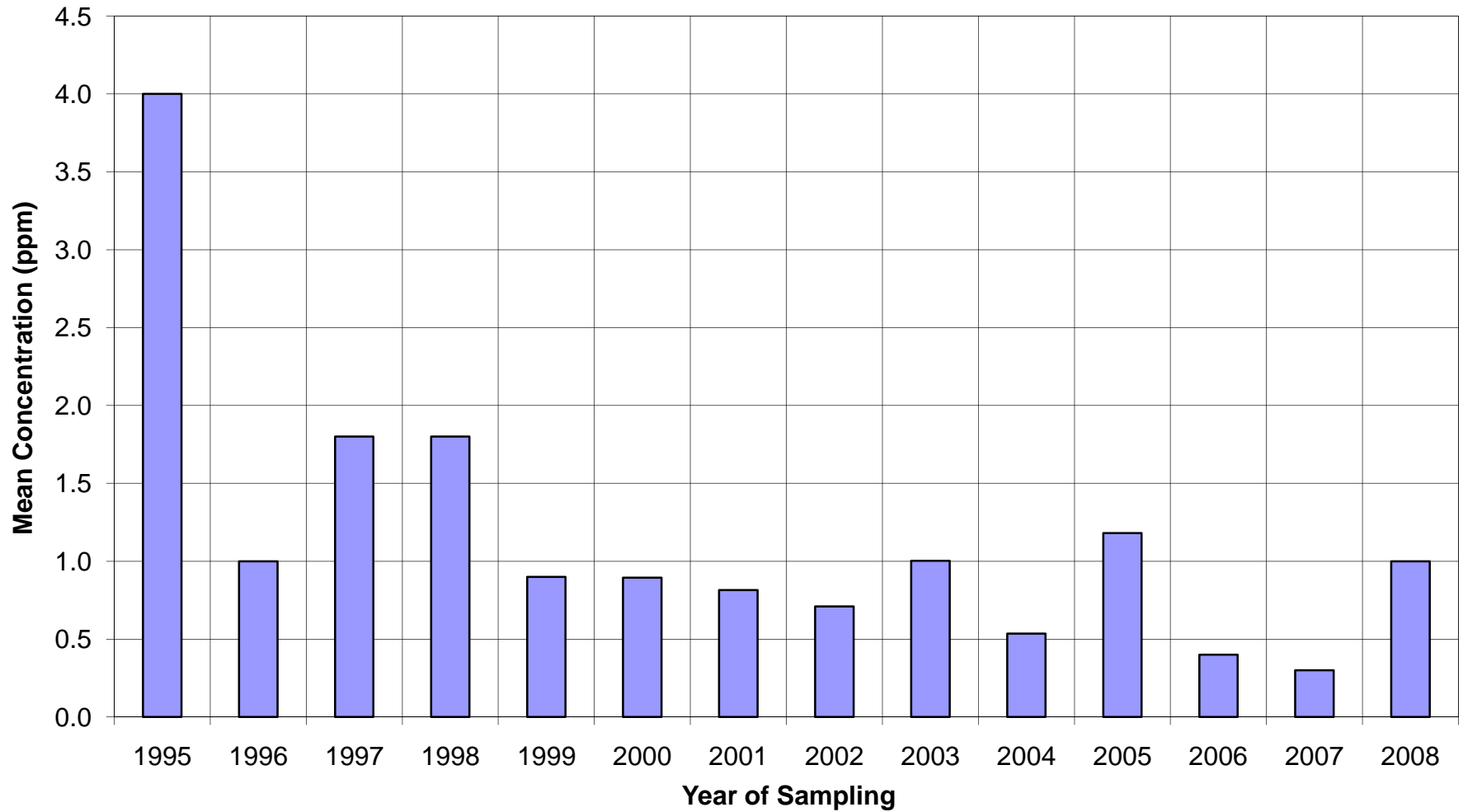


**Stream Sediment Site W15 - Mercury (Hg)
BC-02: Carolyn Creek upstream from Laura Creek**



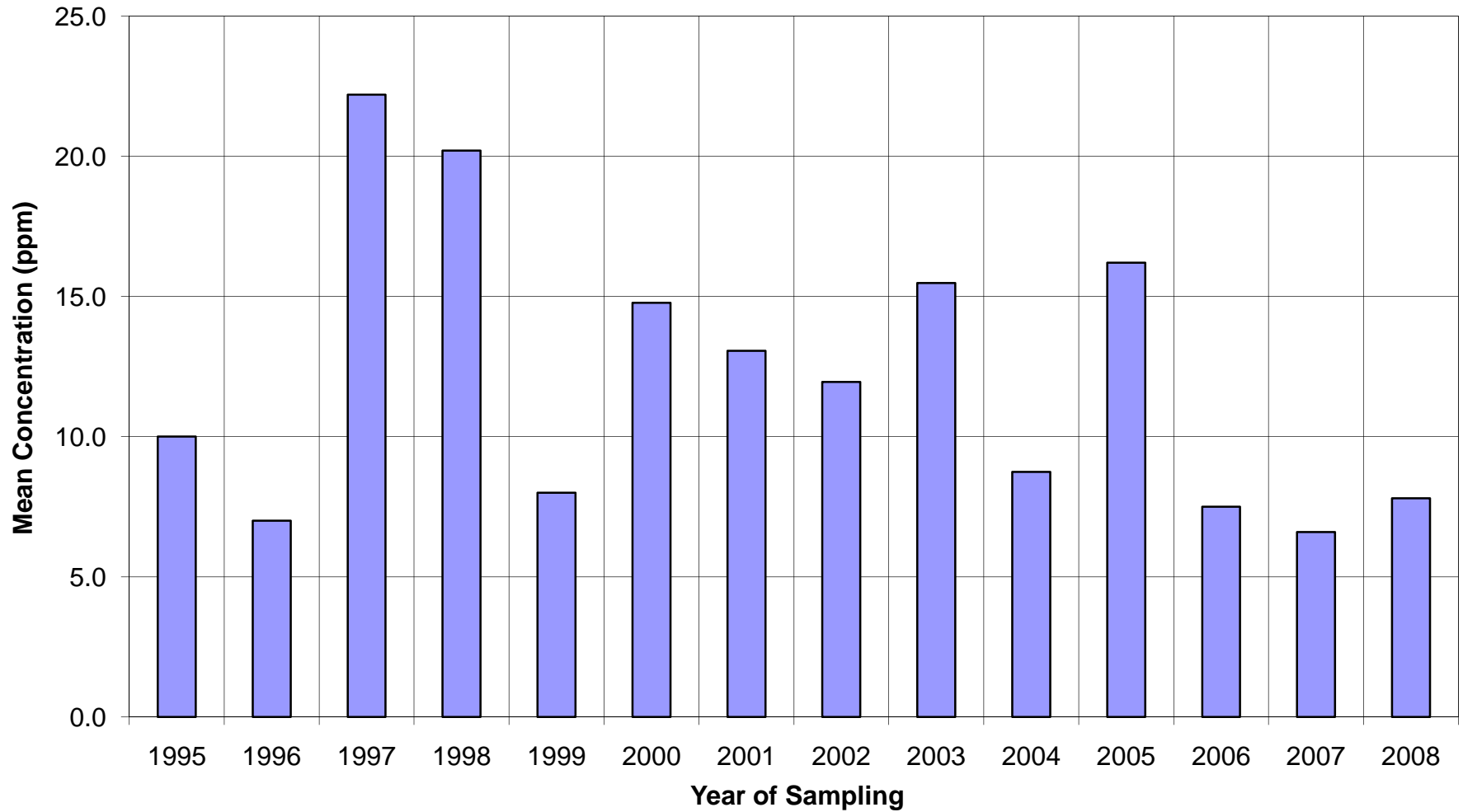
■ Hg

**Stream Sediment Site W15 - Molybdenum (Mo)
BC-02: Carolyn Creek upstream from Laura Creek**



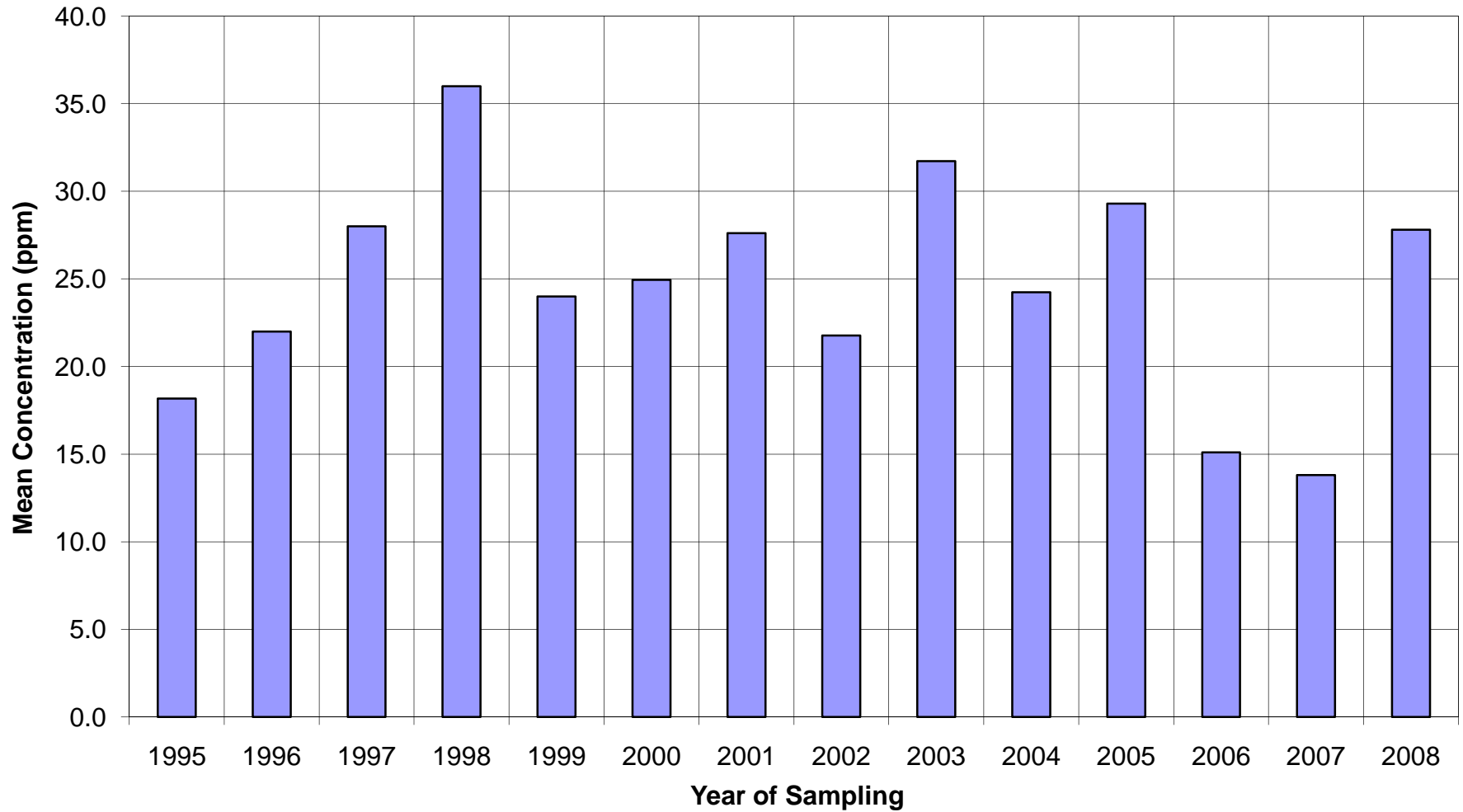
Mo

**Stream Sediment Site W15 - Lead (Pb)
BC-02: Carolyn Creek upstream from Laura Creek**



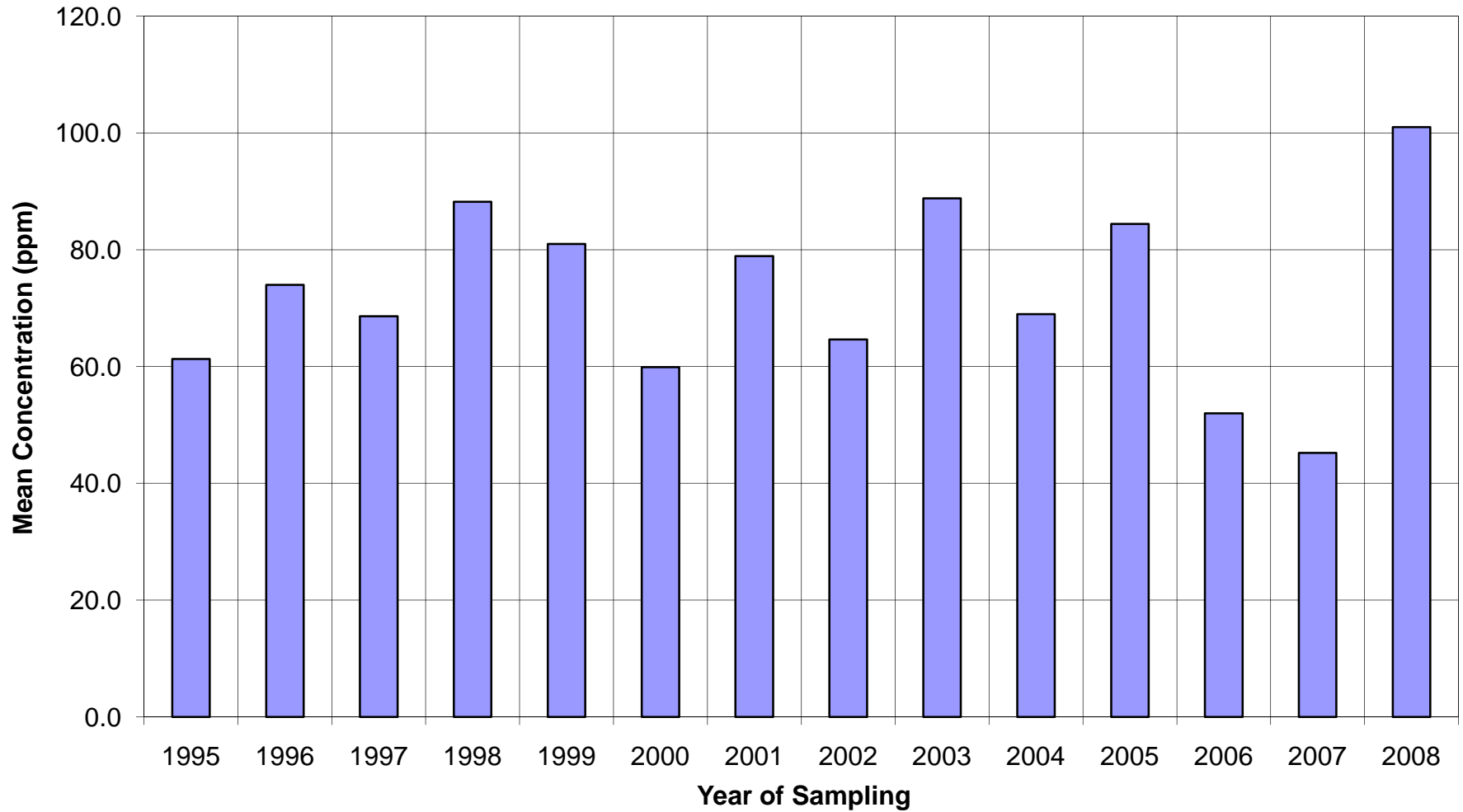
■ Pb

**Stream Sediment Site W15 - Nickel (Ni)
BC-02: Carolyn Creek upstream from Laura Creek**



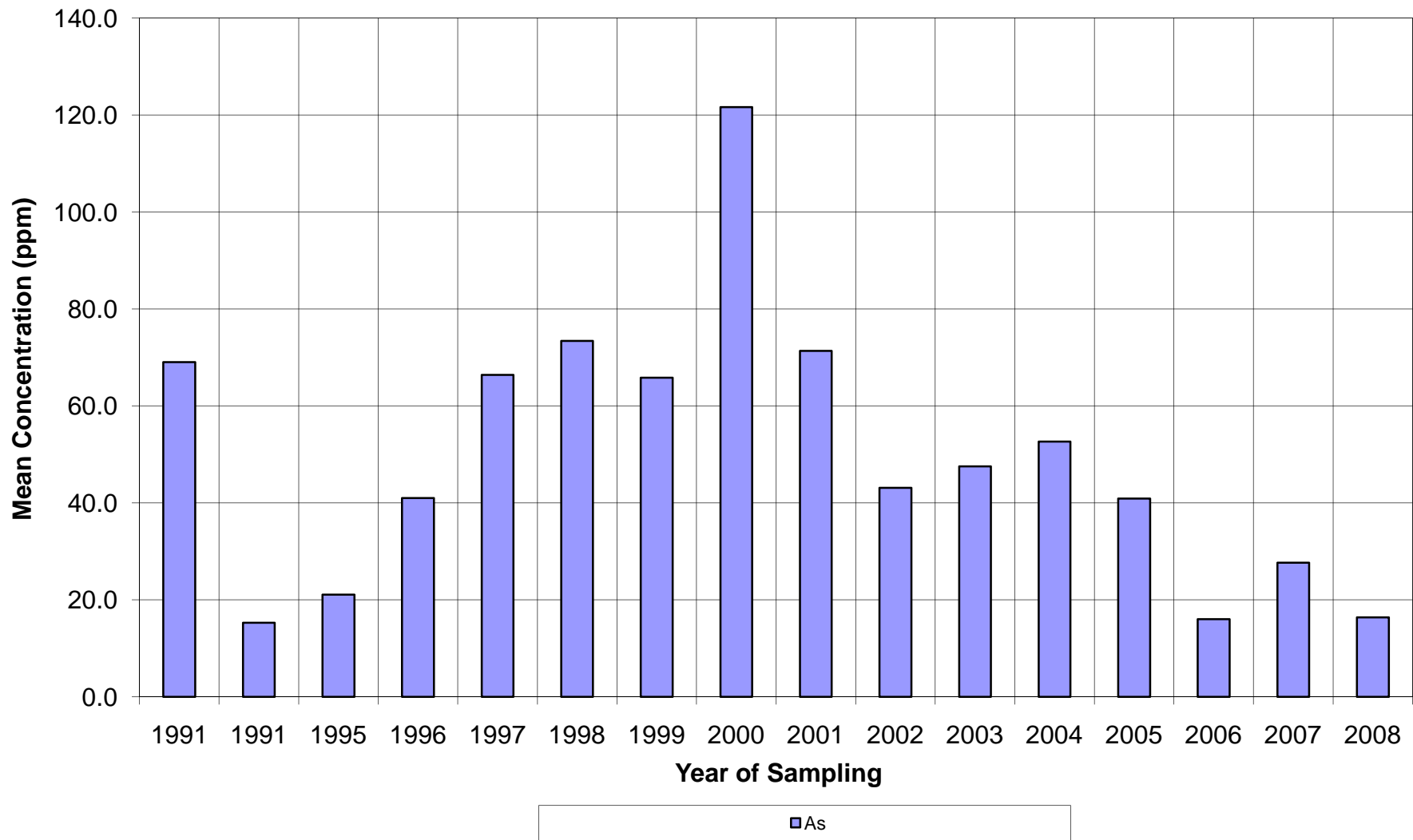
■ Ni

**Stream Sediment Site W15 - Zinc (Zn)
BC-02: Carolyn Creek upstream from Laura Creek**

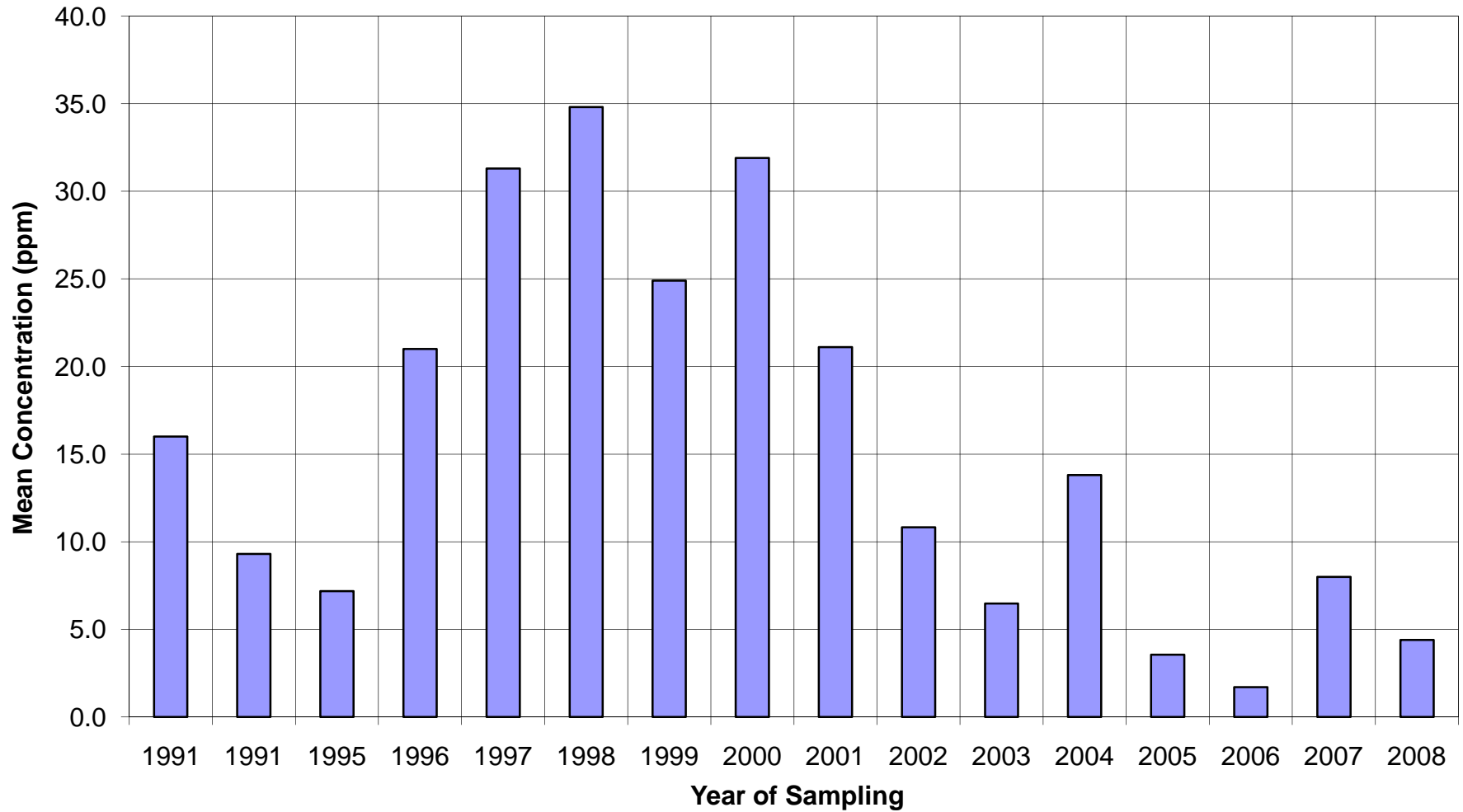


■ Zn

Stream Sediment Site W05 - Arsenic (As)
BC-1: Laura Creek 50m above the Ditch Road

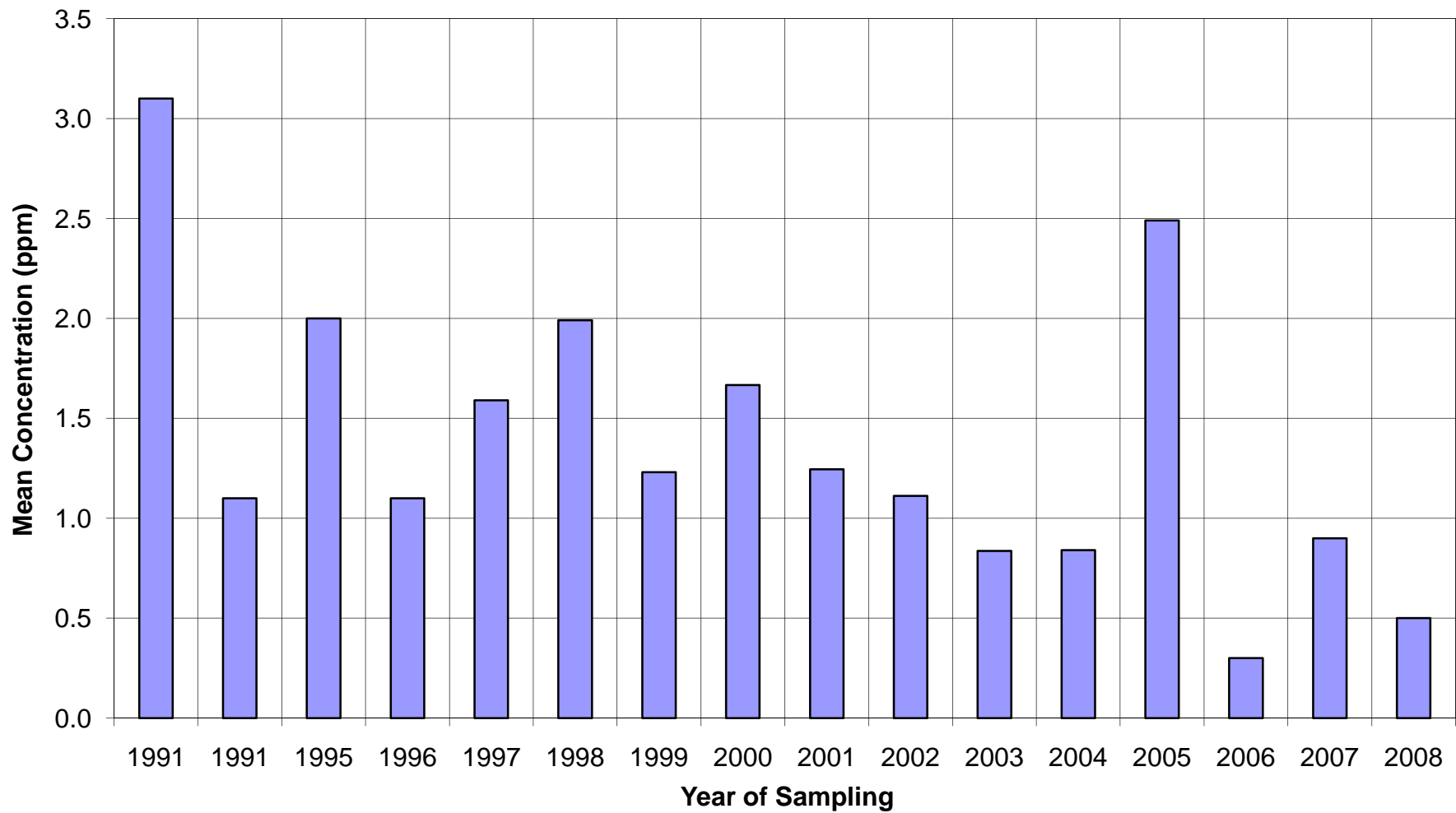


**Stream Sediment Site W05 - Antimony (Sb)
BC-1: Laura Creek 50m above the Ditch Road**



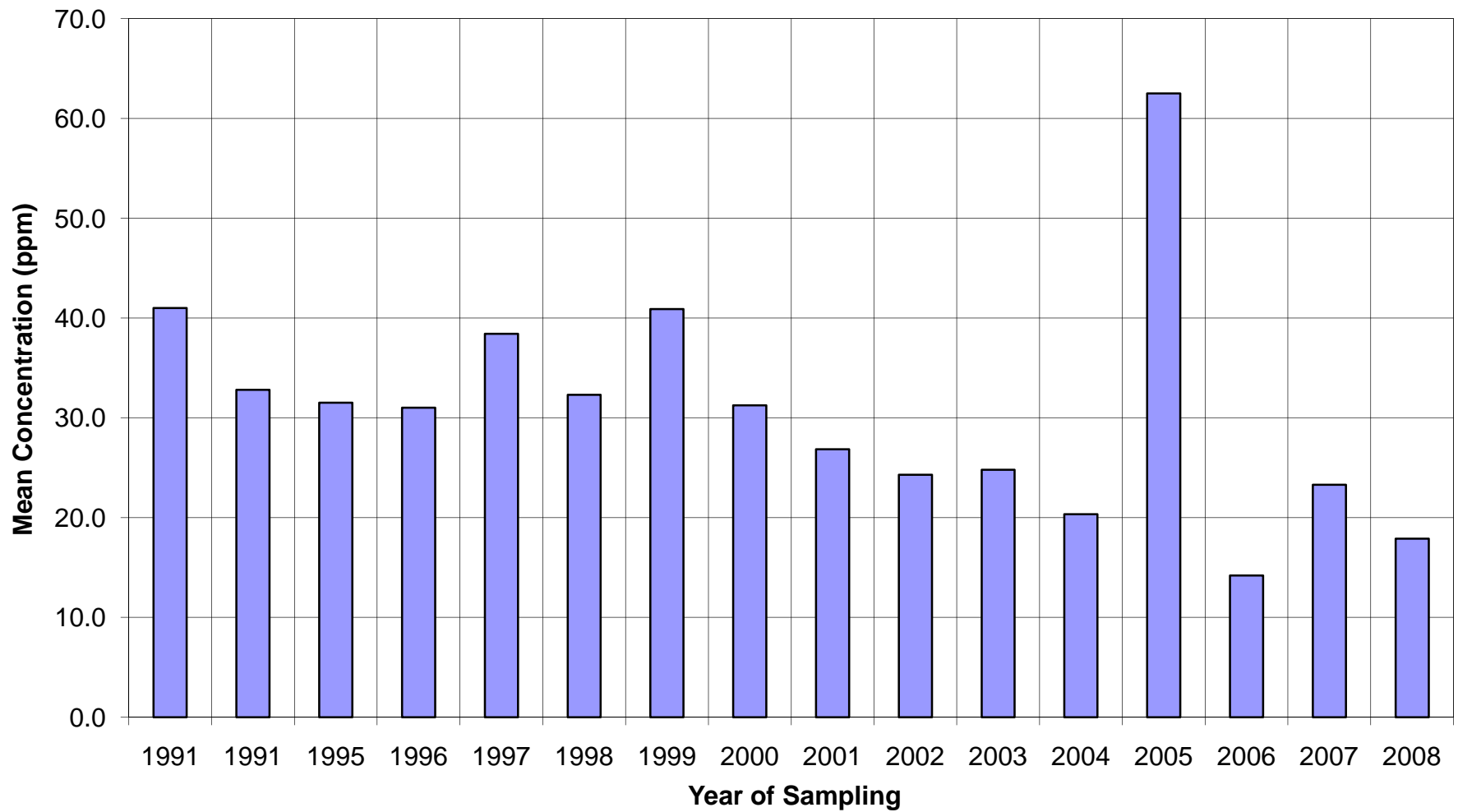
■ Sb

**Stream Sediment Site W05 - Cadmium (Cd)
BC-1: Laura Creek 50m above the Ditch Road**



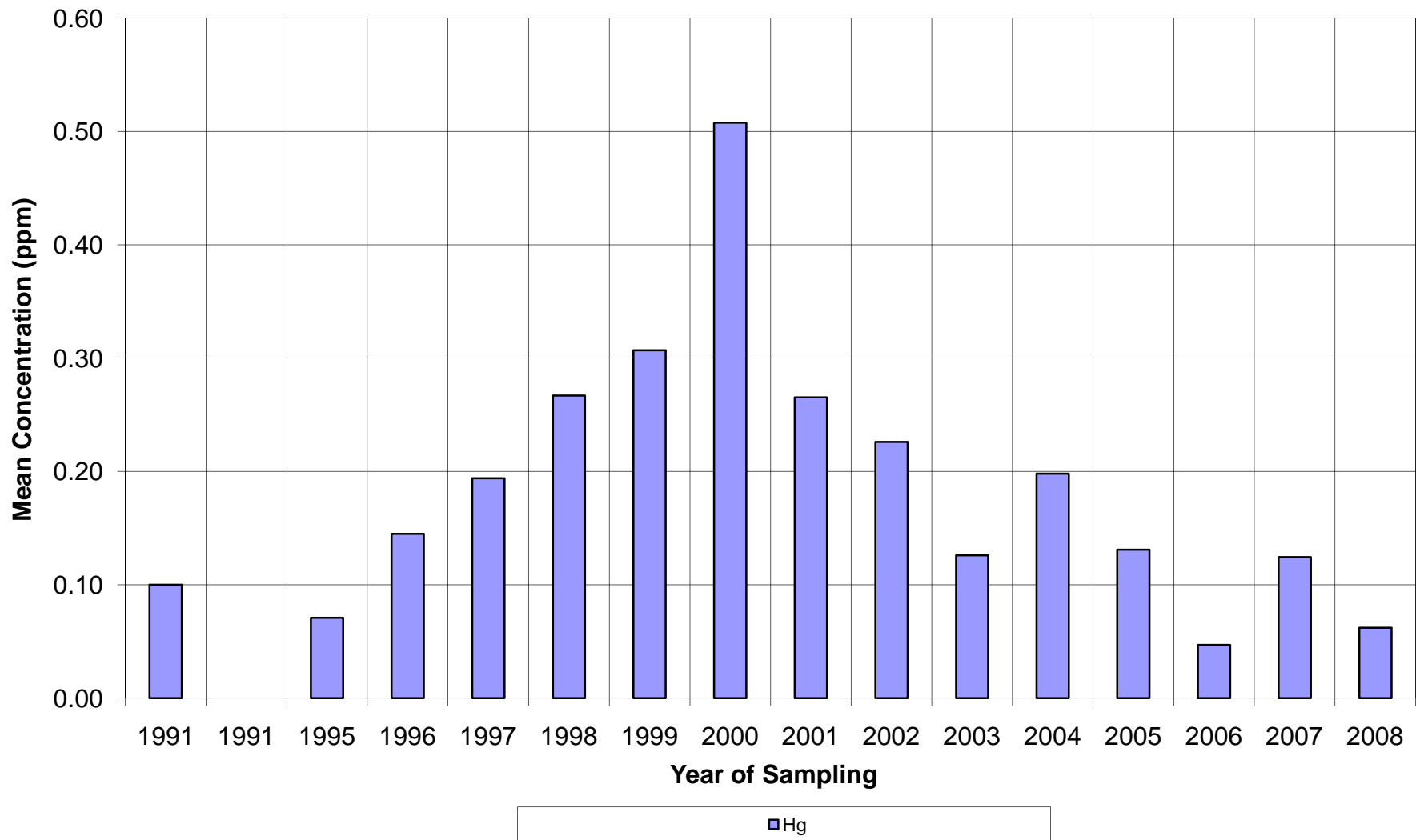
■ Cd

**Stream Sediment Site W05 - Copper (Cu)
BC-1: Laura Creek 50m above the Ditch Road**

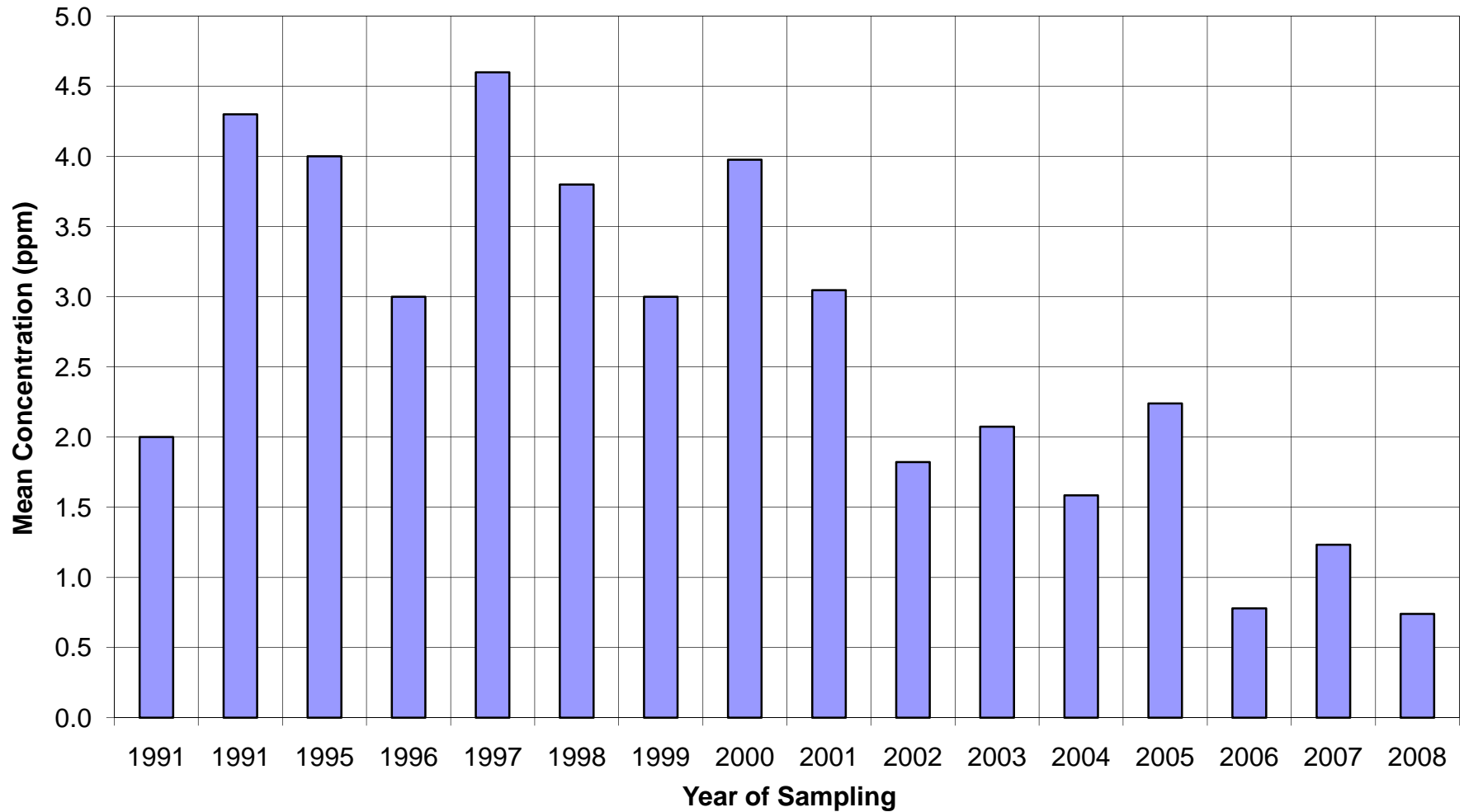


■ Cu

**Stream Sediment Site W05 - Mercury (Hg)
BC-1: Laura Creek 50m above the Ditch Road**

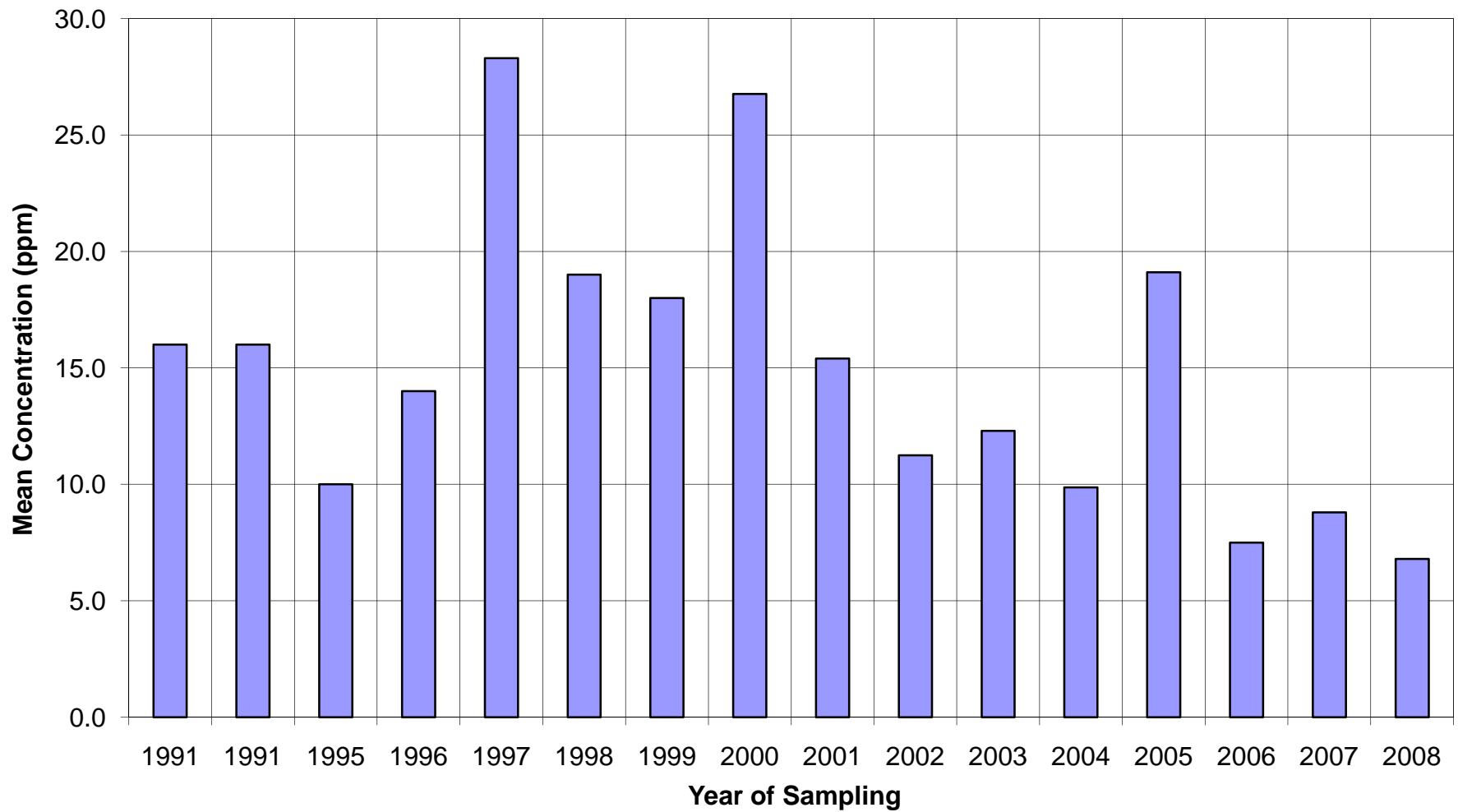


Stream Sediment Site W05 - Molybdenum (Mo)
BC-1: Laura Creek 50m above the Ditch Road



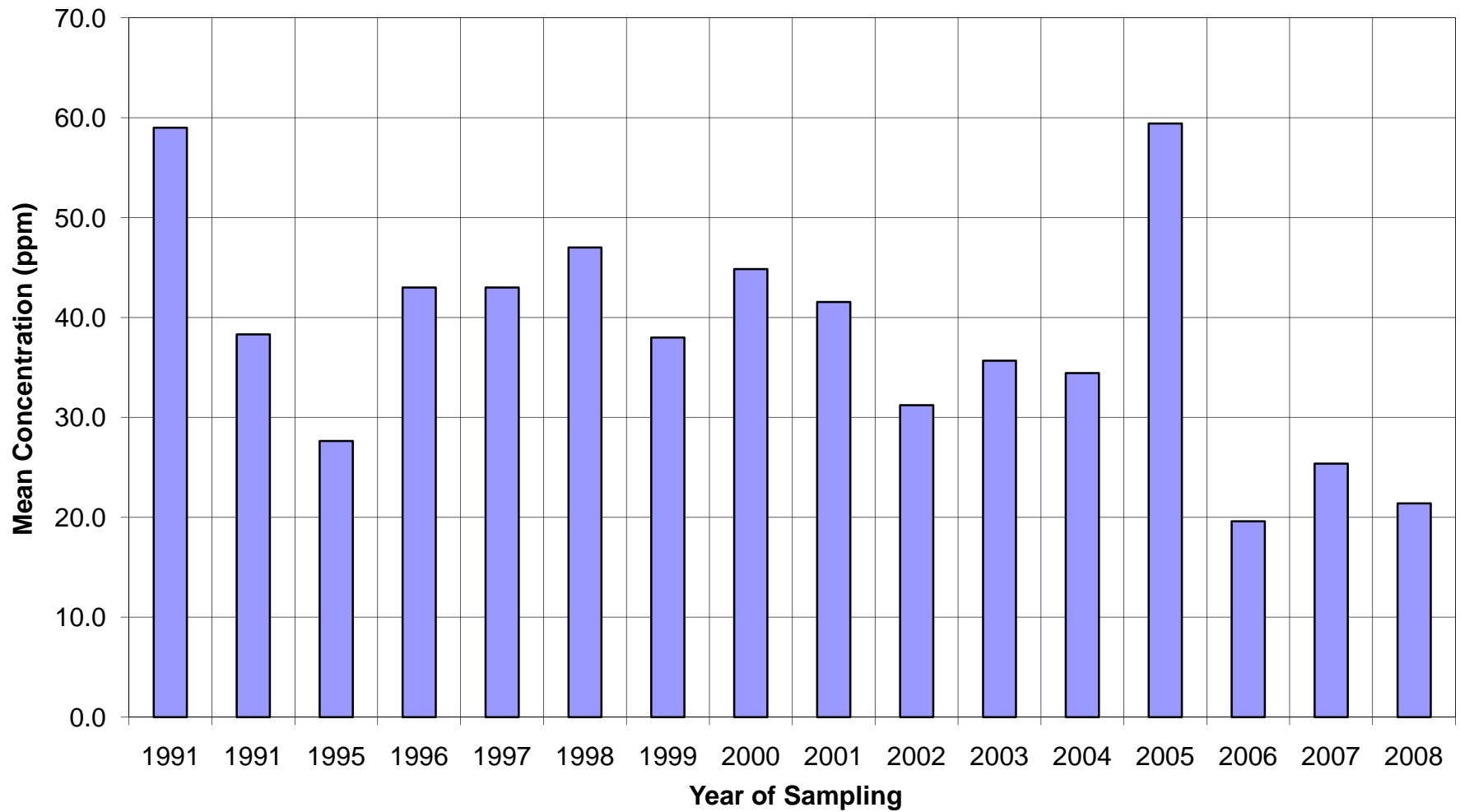
Mo

**Stream Sediment Site W05 - Lead (Pb)
BC-1: Laura Creek 50m above the Ditch Road**



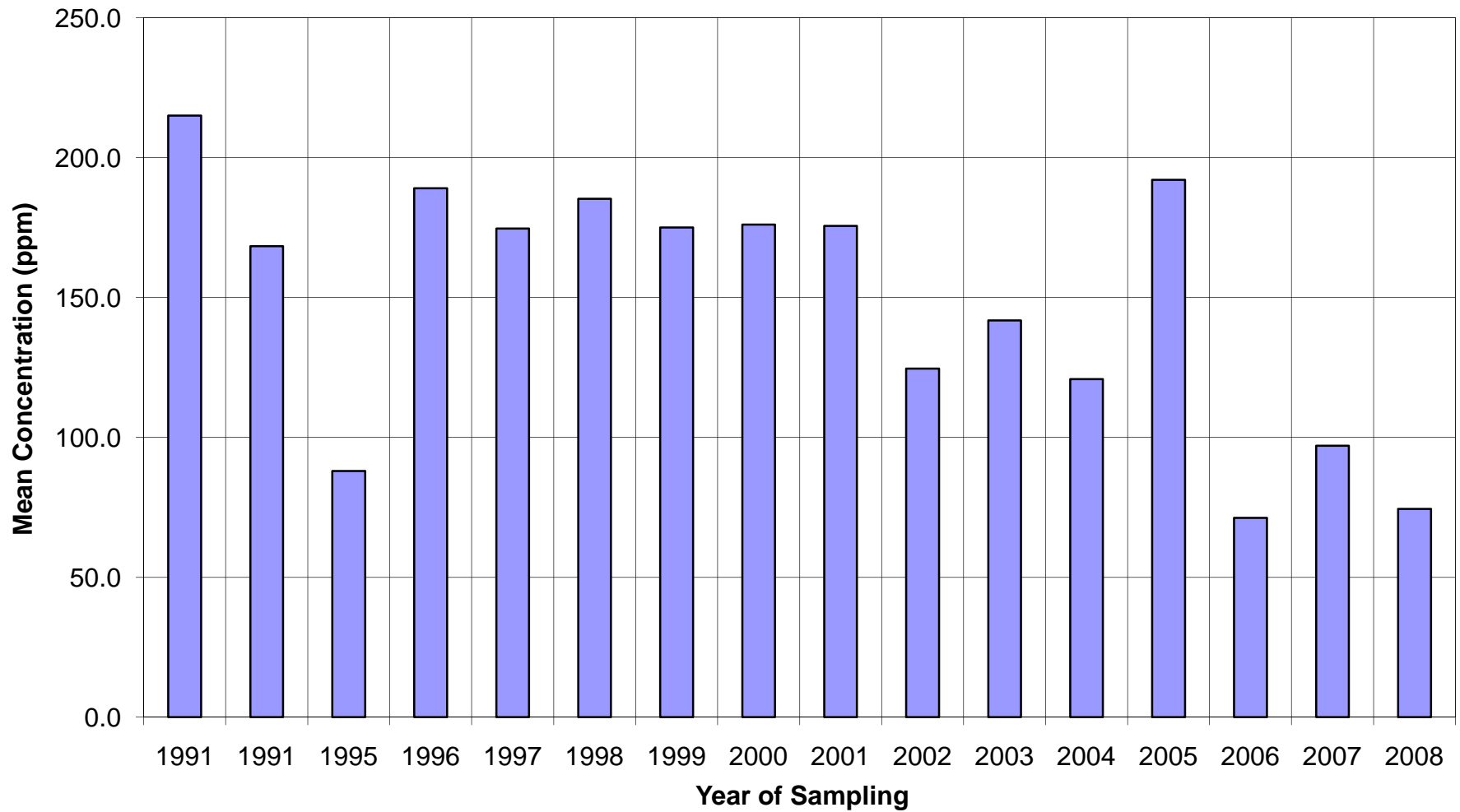
■ Pb

**Stream Sediment Site W05 - Nickel (Ni)
BC-1: Laura Creek 50m above the Ditch Road**



■ Ni

Stream Sediment Site W05 - Zinc (Zn)
BC-1: Laura Creek 50m above the Ditch Road



■ Zn

**Brewery Creek - From Assessment and Permitting through
Production to Post Closure:
A Post Closure Analysis of a Northern Heap Leach Mine**

Appendix D

Reclamation and Revegetation Photos



2006 Site Visit Photos



Looking east from the above the access road over the heap leach towards the open pits (2006)



Looking northeast from above the heap leach towards the open pits (2006)



Looking west over the heap leach towards the access road (2006)

2008 Site Visit Photos



Looking north towards the Blue pit (2008)



Looking north towards the Canadian pit (2008)



Extensive revegetation on level slopes looking north towards the Kokanee pit (2008)



Steep slopes with minimal revegetation (2008)

2008 Reclamation Photos



Removal of liner in water treatment ponds



Final reclamation of water treatment pond



Removal of sludge and liner from preg pond



All sludge and liner removed from the preg pond



Final recontouring of preg pond



Liner removed from overflow pond



Final recontouring of overflow pond

2008 Revegetation Assessment Photos



Photo #1: Small erosion gully in Plot 2 of the Blue Zone WRSA gradually filling in with leaf litter and soil.



Photo #2: Gully in Plot 3 of the Blue Zone WRSA supporting thick growth of grasses.



Photo #3: Plot #1 on the top of the Leach Pad.



Photo #4: Plot #3 on the southeast slope of the Leach Pad.



Photo #5: Moosehead – willows and poplars are colonizing and becoming established in parts of this zone.



Photo #6: Willows, aspen and birch are colonizing the top of Canadian WRSA, looking toward Blue Zone.



Photo #7: White Clover dominates the vegetation of the Canadian Stockpile area.



Photo #8: Several species of willow are colonizing the flat section of Upper Fosters.



Photo #9: The Kokanee Inpit backfill area with the Haul Road in the foreground.



Photo #10: The slopes of North Golden support good growth of the recently seeded species.



Photo #11: The side walls of South Golden are gradually revegetating naturally.



Photo #12: A dense growth of aspen and willows have become established at the base of the wall of South Golden.



Photo #13: Willows are growing on the wall of Lucky Pit.



Photo #14: Caterpillars of *Nymphalis antiopa* eating willow and poplar leaves in the undisturbed forest by Lucky.



Photo #15: Treatment Pond Area.



Photo #16: Fireweed and shrubs are starting to colonize Shale Hill.