CHANGES IN CONTAMINANT LEVELS IN THE BOW RIVER FOLLOWING THE INSTALLATION OF A CONTAINMENT SYSTEM AT THE CANADA CREOSOTE SITE

Prepared by:

Al Sosiak, M.Sc.
Limnologist

Water Sciences Branch
Water Management Division
Natural Resources Service

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Any comments, questions, or suggestions regarding the content of this document may be directed to:

Environmental Monitoring and Evaluation Branch
Alberta Environment
10th Floor, Oxbridge Place
9820 – 106th Street
Edmonton, Alberta T5K 2J6
Phone: (780) 427-6278
Fax: (780) 422-6712

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Information Centre
Alberta Environment
Main Floor, Oxbridge Place
9820 – 106th Street
Edmonton, Alberta T5K 2J6
Phone: (780) 427-2700
Fax: (780) 422-4086
Email: env.infocent@gov.ab.ca

EXECUTIVE SUMMARY

In November 1989, a liquid mixture of various contaminants including the wood preservatives creosote and pentachlorophenol (PCP) was found seeping into the Bow River adjacent to the abandoned Canada Creosote site in Calgary. A temporary berm was built in the river around the seepage area on November 6-9, 1989, and rebuilt on October 9-19, 1990. Contaminants were removed from the bermed area. A permanent barrier to contaminant flow was installed along the entire shoreline between April 29 and May 3, 1995, and a system designed to prevent the flow of contaminated groundwater to the river around the barrier was operational by February 8, 1996.

Alberta Environmental Protection has intensively monitored the Bow River ecosystem since 1989. This work was designed to determine the distribution of contaminants from the Canada Creosote site in the aquatic ecosystem, to protect domestic water supplies, and to ensure that human consumption of fish was safe. Scans for PCP and for 14 polycyclic aromatic hydrocarbons (PAH) typical of creosote at this site have been conducted. This report summarizes changes in water quality and fish tissue residues in the Bow River after the installation of the second temporary berm in 1990 and after the permanent barrier and ground water treatment system were installed in 1995-96.

Levels of four PAH compounds (naphthalene, methylnaphthalene, fluorene, phenanthrene/anthracene) and PCP decreased significantly in the Bow River immediately downstream from the Canada Creosote site after the second temporary berm was installed in October 1990. Naphthalene levels also declined at a site 7 km downstream from Calgary (Stier's Ranch). Levels of all other compounds were generally low at Stier's Ranch, and at an upstream control site, both before and after the barrier was installed in 1995. Levels of three compounds (naphthalene, carbazole and PCP) declined significantly downstream from the Canada Creosote site after the permanent barrier was installed in May 1995.

PCP occasionally exceeded the CCME water quality guideline and three carcinogens were detected at both sites downstream from the Canada Creosote site before the containment system was fully-operational (February 8, 1996). However, no compounds exceeded water quality guidelines downstream from this site, and no carcinogens were detected to December 17, 1996.

Brown trout and mountain whitefish muscle collected from the Bow River between the Canada Creosote site and the W.I.D. weir contained low levels of some PAH compounds and PCP in December 1989 (median [PAH] $\leq$ 0.32 ppm), but were considered safe for human consumption. None of these compounds were detected in fish samples from the same reach of the Bow River in November 1995, after the installation of the permanent barrier.

The installation of both the second temporary berm (October 1990) and the permanent barrier (May 1995) significantly reduced the movement of contaminants to the Bow River from the Canada Creosote site. However, only after the permanent barrier was installed were all compounds consistently below water quality guidelines.

ACKNOWLEDGEMENTS

I thank all technical and professional staff of Alberta Environmental Protection who have assisted in the sampling of the Bow River during this program. Bridgette Halbig, Water Sciences Branch, AEP assisted in data compilation and report preparation. Karen Saffran, Water Sciences Branch, tested the data statistically. Review comments on the draft report were provided by Dave Trew and Karen Saffran, Water Sciences Branch.

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1.0 INTRODUCTION

The former Canada Creosote plant was located beside the Bow River in downtown Calgary, Alberta. The plant used tars, creosote and petroleum oils to preserve wood over about 38 years from 1924 to 1962. Pentachlorophenol (PCP) was used during the 1950's. Drilling at the site in 1988 by O'Connor Environmental Associates Inc., during the H.E.L.P. (Help Eliminate Landfill Pollution) program, determined that a liquid mixture of creosote, PCP, dioxins and dibenzofurans and other contaminants occurred beneath the former treatment plant.

In 1989, the Water Quality Section of Alberta Environmental Protection (AEP) was asked to determine whether contaminants were entering the Bow River from the Canada Creosote site. Sampling of water, sediment and aquatic invertebrates immediately upstream and downstream from the site on August 8-10, 1989 determined that organic compounds typical of the contaminants at the Canada Creosote site had entered the Bow River. To determine background levels and the spatial distribution of these contaminants, water, sediments, aquatic invertebrates and fish were sampled at eight mainstem Bow River sites from above Lake Louise to McKinnon Flats during October 4-13, 1989. Water and sediment from lower Bighill Creek, near a second wood treatment plant in Cochrane, were also sampled on October 13, 1989.

During this second survey, AEP staff observed hydrocarbon sheen and brown liquid in the river substratum adjacent to the Canada Creosote site. A sample of dense non-aqueous phase liquid (DNAPL) was collected from the river bed adjacent to the Canada Creosote site using a vacuum pump on November 2, 1989. On November 3, 1989, DNAPL was found seeping into the Bow River by a H.E.L.P. project consultant. A temporary berm was built in the river to contain contaminants from the seepage area and to assist operations on November 6-9, 1989, and rebuilt on October 9-19, 1990. DNAPL was also removed from the bermed area in 1989-90. A permanent barrier to contaminant flow was installed along the entire shoreline between April 29 and May 3, 1995 and a system designed to prevent the flow of contaminated groundwater to the river around the barrier was fully operational by February 8, 1996.

AEP has intensively monitored the Bow River ecosystem since 1989. This work was designed to determine the distribution of contaminants from the Canada Creosote site in the aquatic ecosystem, to protect domestic water supplies, and to ensure that human consumption of fish was

safe. Scans for PCP and for 14 polycyclic aromatic hydrocarbons (PAH) typical of creosote at this site have been conducted. The following report summarizes changes in water quality at sites upstream and downstream from the Canada Creosote site, and fish muscle residues at various locations in the Bow River, after the installation of the second temporary berm in 1990 and the permanent containment system in 1995-96.

2.0 MATERIALS AND METHODS

2.1 SAMPLING

Subsurface grab samples of river water were collected in pre-cleaned glass bottles supplied by the analytical laboratory at the locations in Figure 1 during 1989-1997. Sites immediately upstream and two locations downstream from the Canada Creosote site were sampled daily from November 6, 1989, after the DNAPL deposit in the Bow River was first discovered until December 20, 1989. The sampling frequency was then gradually reduced until monthly sampling began on December 12, 1991. Monthly sampling will continue at least until April 1998 (sampling frequencies are summarized in Table 1). More frequent sampling occurred in April-July 1995 during and after the installation of the permanent barrier. On each sampling occasion, a sample of Type 1 Laboratory water (treated with reverse osmosis and double distilled) was spiked with one or two vials containing a mixture of PAH and PCP in concentrations known only to AEP staff, and submitted "blind" for analysis, as a form of quality assurance.

Samples of rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*) or mountain whitefish (*Prosopium williamsoni*) were collected by Fisheries Management Division, AEP on five sampling trips from October 1989 to November 1995. Composite samples of lateral fillet from five fish were prepared at Enviro-Test Laboratories, except in November and December 1989, when fish were individually analyzed. Fish were of a size range that is commonly harvested from the Bow River. Fat and bile samples were also analyzed on some dates in 1989.

2.2 CHEMICAL AND DATA ANALYSES

All chemical analyses on water and fish were conducted by Enviro-Test Laboratories. A list of target PAH compounds and PCP (Table 2) was developed based on the most abundant and

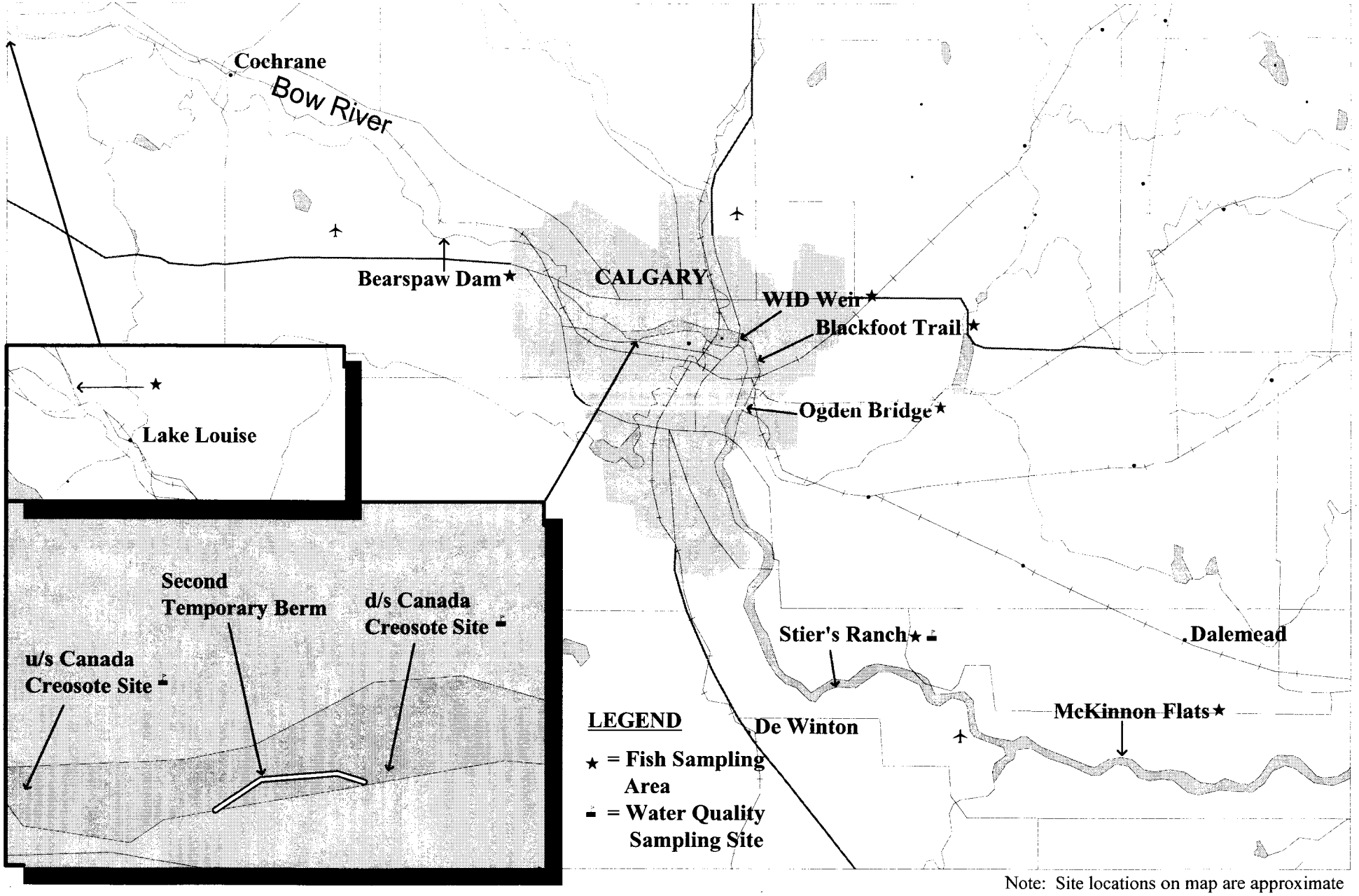

Figure 1. Location of Canada Creosote sampling sites on the Bow River.

Table 1. Sampling frequency during monitoring of the Canada Creosote site.

SITE	PERIOD OF DATA (M/D/Y)	SAMPLING FREQUENCY
Bow River u/s Canada Creosote	11/02/89 - 03/30/90	Every other day
	10/03/91 - 11/01/91	Weekly
	08/08/95 - 12/17/96	Monthly
Bow River d/s Canada Creosote	11/02/89 - 12/29/89	Daily
	01/03/90 - 03/30/90	Every other day
	05/23/90 - 07/26/90	Every other day
	08/02/90 - 12/12/91	Every other day/Weekly
	01/09/92 - 12/07/94	Monthly
	04/07/95 - 07/10/95	Weekly
	08/08/95 - 12/17/96	Monthly
Bow River at Stier's Ranch	11/04/89 - 12/21/89	Daily
	01/03/90 - 10/24/90	Every other day
	11/01/90 - 12/12/91	Weekly
	01/09/92 - 12/07/94	Monthly
	04/07/95 - 07/10/95	Weekly
	08/08/95 - 12/17/96	Monthly

Table 2. Detection limits used in the analyses of water samples.

VARIABLE	CCME GUIDELINE	DETECTION LIMIT (µg/L)	D.L. DATES
Naphthalene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Methylnaphthalene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Dimethylnaphthalene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Acenaphthylene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Acenaphthene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Fluorene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Phenanthrene/Anthracene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Dibenzofuran		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Pentachlorophenol	0.5 µg/L (Freshwater Aquatic Life)	L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Carbazole		L0.2	11/89 - 08/90
		L0.01	09/90 - 12/96
Methyl Phenanthrene/Anthracene		L0.1	11/89 - 08/90
		L0.01	09/90 - 12/96
Benzo(a)Pyrene	0.01 µg/L (Protection of Community Water Supplies)	L0.01	11/04/89 - 09/20/90
		L0.005	09/27/90 - 08/02/94
		L0.01	09/19/94 - 12/17/96
Methyl Phenanthrene		L0.01	11/89 - 12/96
Benzo(a)Anthracene		L1.0	1984-1987 (1 sample/yr)
		L0.01	11/04/89 - 09/20/90
		L0.005	09/27/90 - 08/02/94
		L0.01	09/19/94 - 12/17/96
Benzo(b)Fluoranthene		L3.0	10/07/1987 (1 sample)
		L0.01	11/04/89 - 09/20/90
		L0.005	09/27/90 - 08/02/94
		L0.01	09/19/94 - 12/17/96

important compounds in several detailed gas chromatography/mass spectrometry (GC/MS) scans of DNAPL recovered from the river bed. The carcinogens benzo(a)anthracene and benzo(b)fluoranthene were added to the routine scans after September 20, 1990. Specific congenors of dioxins and furans were also analyzed on a few samples of each type in 1989, and water samples from the temporary berm were analyzed for volatile priority pollutants by the Alberta Environmental Centre in 1989-90.

Water samples from 1989-1994 were prepared using a modified version of USEPA extraction method 3510, and method 3520 after January 6, 1995. USEPA detection method 8270 was modified for selected ion monitoring by GC/MS, to provide lower detection limits. Detection limits improved over time with changes in sampling and analytical methods (summary of changes in Table 2). Methylphenanthrene, phenanthrene and anthracene were reported as combined measurements, as in Table 2. Fish muscle samples were prepared using EPA extraction method 3540, and compounds were detected using EPA detection method 8270, modified for selected ion monitoring by GC/MS. To monitor method efficiency, water samples were spiked with surrogate compounds, and duplicate fish muscle extracts were spiked with target compounds.

The statistical significance ($\alpha = 0.10$) of incremental changes (step trends) in the concentration of PAH compounds and PCP when the second temporary berm and the permanent barrier were installed was tested with the Seasonal Wilcoxon Mann-Whitney test using the statistical package WQHYDRO (Aroner 1994). The decline in median concentration was also estimated using the Seasonal Hodges-Lehmann estimate. There were too few data available to statistically test the influence of the first temporary berm and the ground water treatment system. The influence of the second temporary berm was tested by comparing weekly data for the period November 4, 1989 to October 19, 1990 with the period October 20, 1990 to December 31, 1991. If more than four results per month were available, a subsample of four was chosen at random using a procedure in WQHYDRO. The impact of the permanent barrier was tested by comparing September 1, 1993 to May 3, 1995 data with the period June 1, 1995 to December 17, 1996. To compensate for changes in detection limits and allow statistical testing, data less than the method detection limit were converted to one-half the highest detection limit for the period of analysis.

3.0 RESULTS AND DISCUSSION

3.1 IMPACT OF THE SECOND BERM ON RIVER CHEMISTRY

All available data for each compound for the period November 4, 1989 to December 17, 1996 are plotted in Figures 2 to 16. Benzo(a)anthracene and benzo(b)fluoranthene data from samples collected at Stier's Ranch during 1984-87 were also included in the plots. Statistically-significant changes in median concentration are presented in Sections 3.1 and 3.2. There was no significant change in the concentration of other compounds.

Levels of five compounds decreased significantly in the Bow River immediately downstream from the Canada Creosote site after site cleanup and the installation of the second berm in October 9-19, 1990 (median decrease - naphthalene: 0.570 µg/L; methylnaphthalene: 0.023 µg/L; fluorene: 0.017 µg/L; phenanthrene/anthracene: 0.036 µg/L; PCP: 0.027 µg/L). Levels of some other compounds (e.g., dimethylnaphthalene, acenaphthylene, carbazole) were also somewhat lower after the installation of the second berm, but none of these changes were statistically significant. These compounds were often below the relatively high detection limits used before the second temporary berm was installed. Therefore, improvements in detection limits over time (Table 2) may account for the failure to detect a significant decrease in some of these compounds.

Levels of naphthalene decreased significantly (median decrease: 0.026 µg/L) at a site about 7 km downstream from Calgary (Stier's Ranch) after the initial cleanup and second berm was installed in October 1990, but there was no significant change in levels of other compounds at this site. Levels of all compounds except naphthalene were very low at this site after 1993.

3.2 IMPACT OF THE PERMANENT BARRIER ON RIVER CHEMISTRY

Statistically significant declines were only observed for three compounds (median decrease - naphthalene: 0.410 µg/L, PCP: 0.025 µg/L, carbazole: not available) downstream from the Canada Creosote site after the permanent barrier was installed in May 1995. Since that time, most compounds have been below detection limits most of the time. Low levels of PCP and certain PAH's (e.g., naphthalene, methylnaphthalene, acenaphthene) have been detected downstream from the Canada Creosote site since the installation of the permanent barrier. These results probably

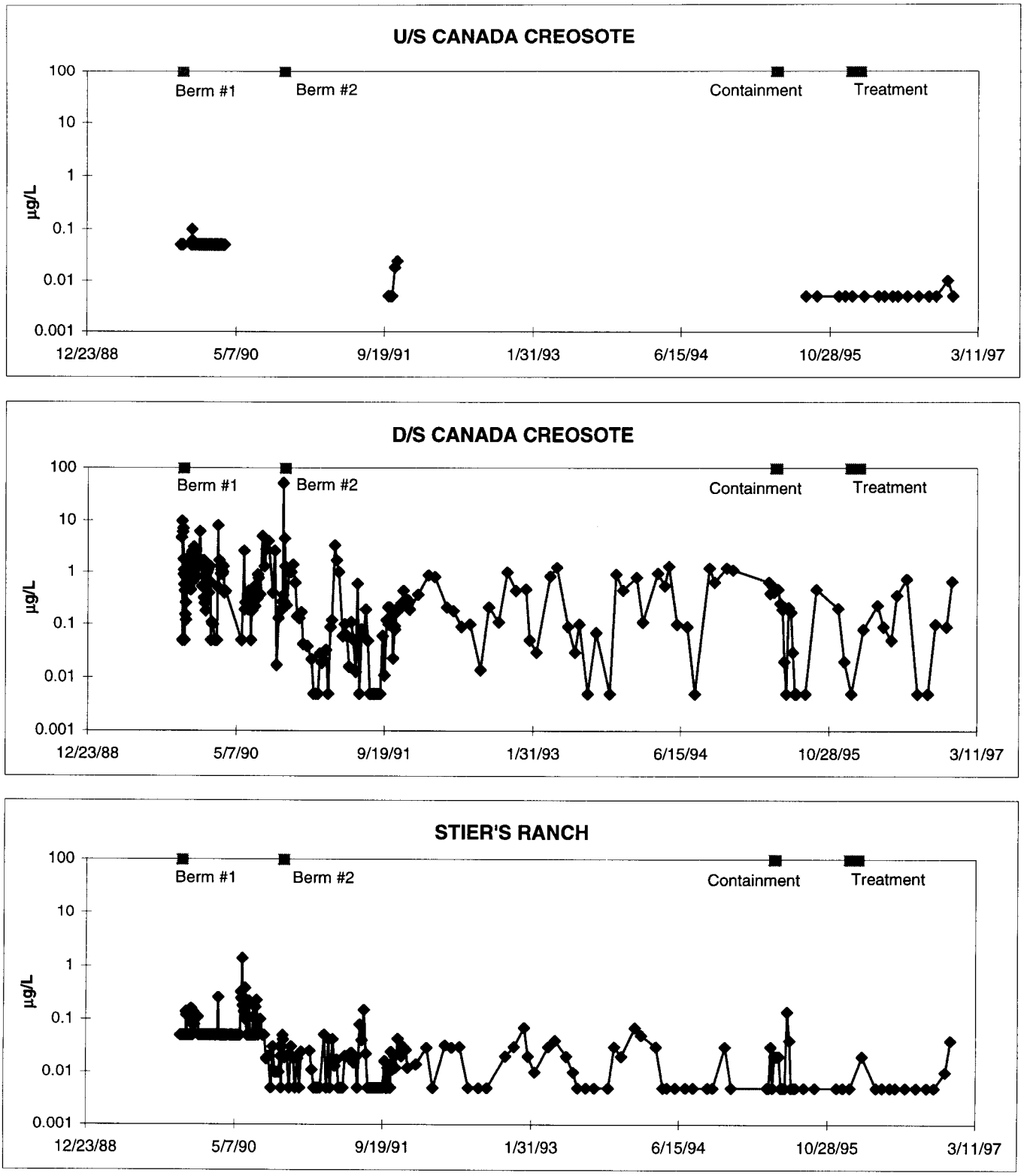

Figure 2. Concentrations of napthalene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

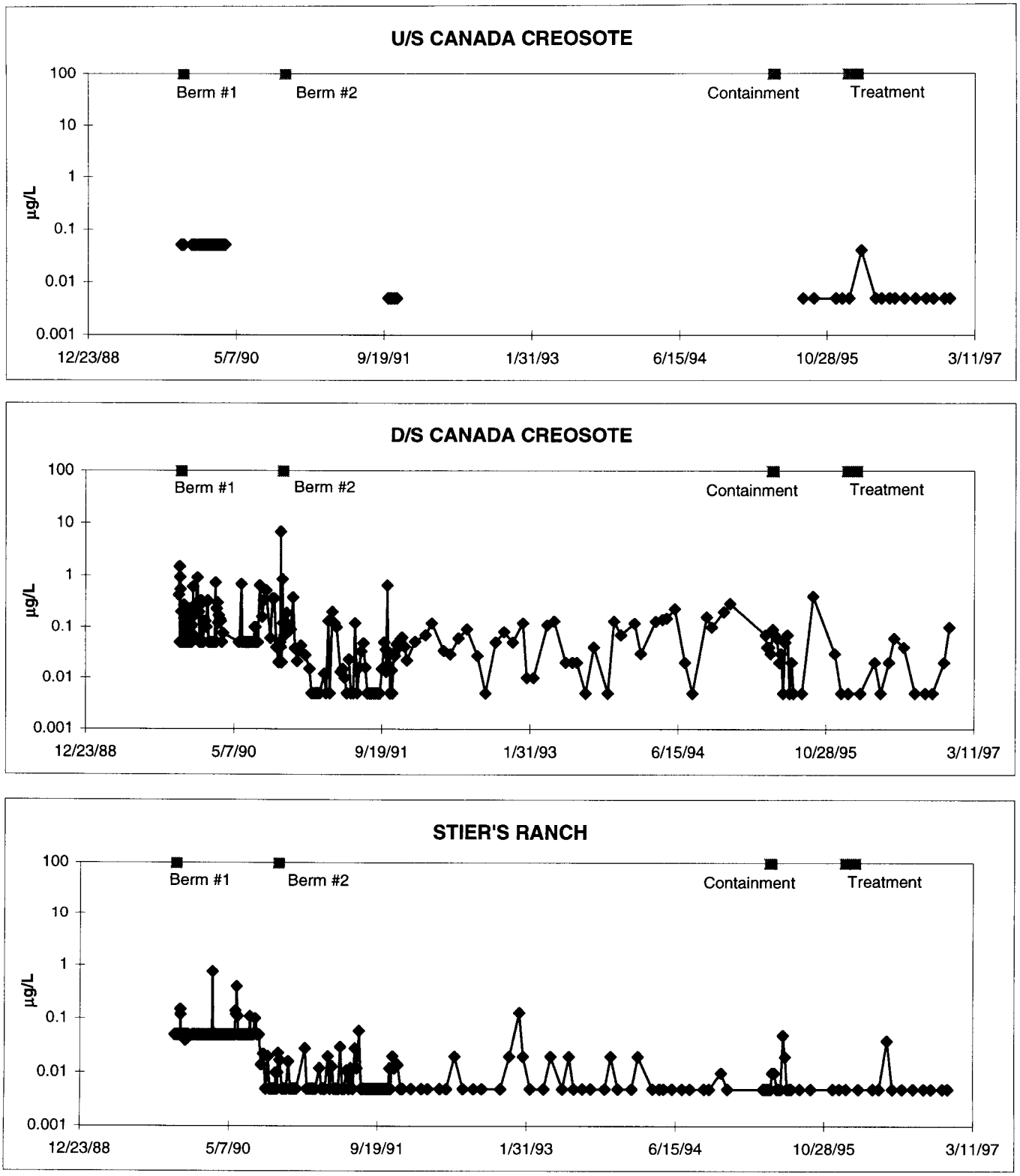

Figure 3. Concentrations of methylnaphthalene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

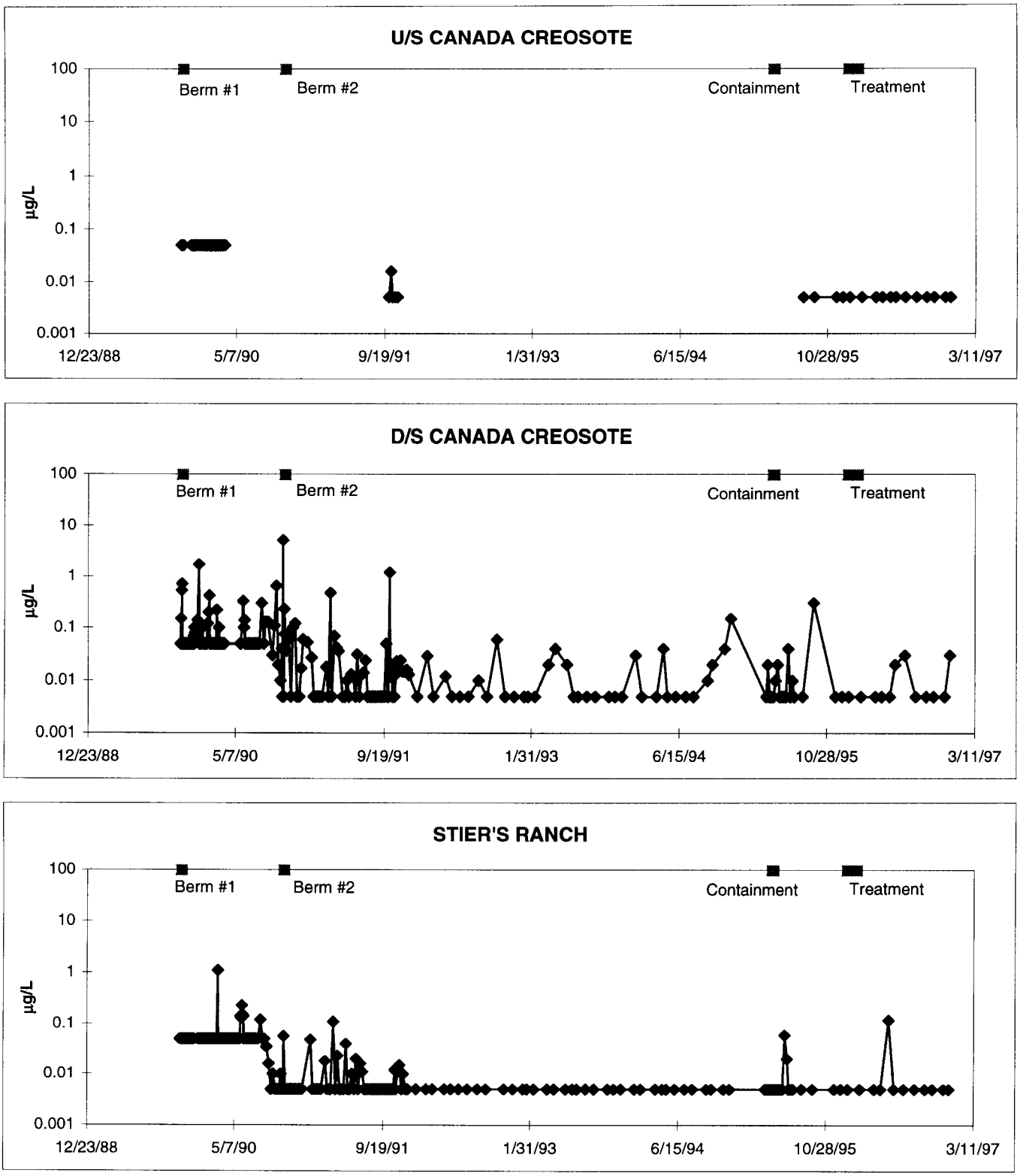

Figure 4. Concentrations of dimethylnaphthalene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

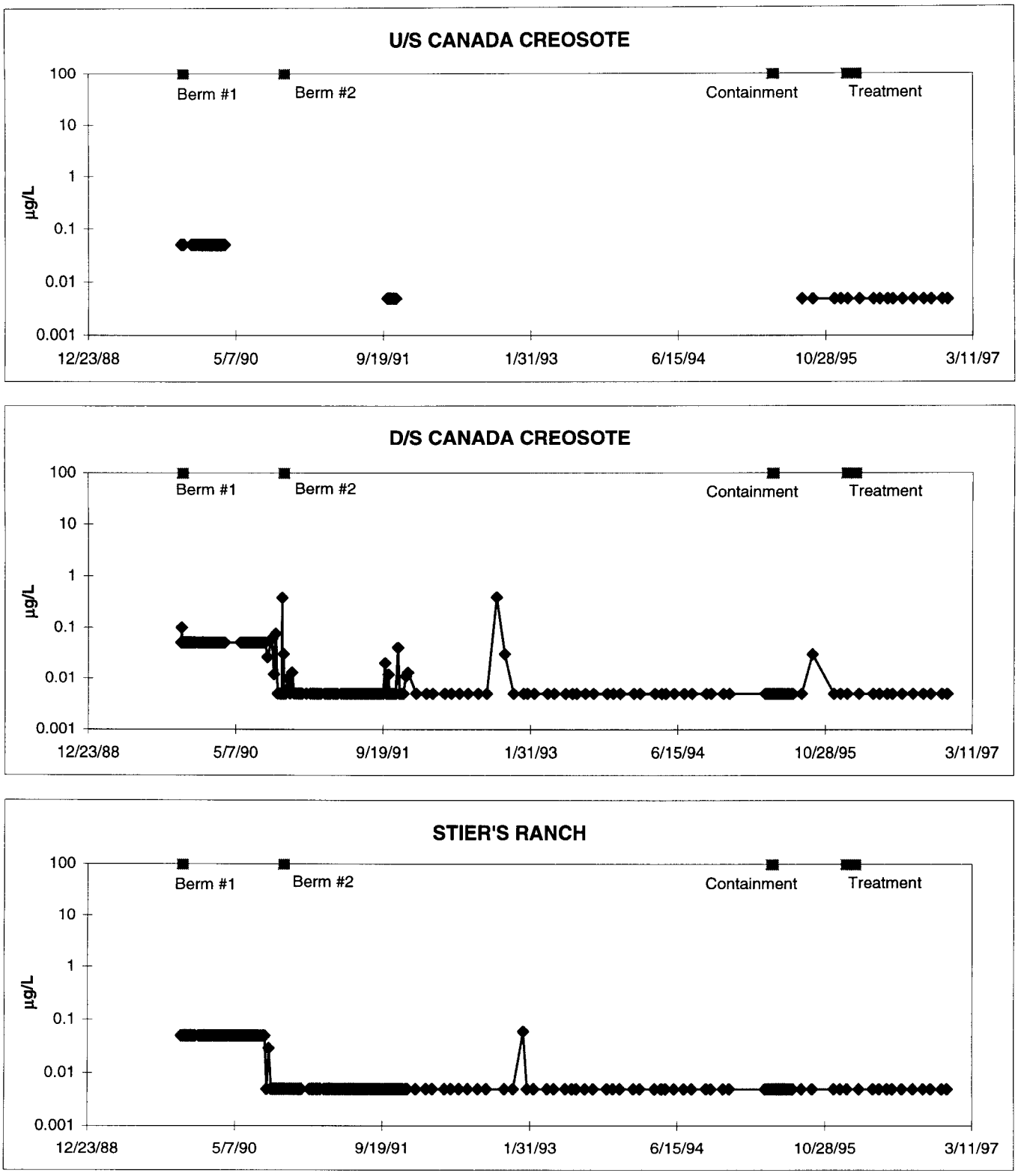

Figure 5. Concentrations of acenaphthylene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

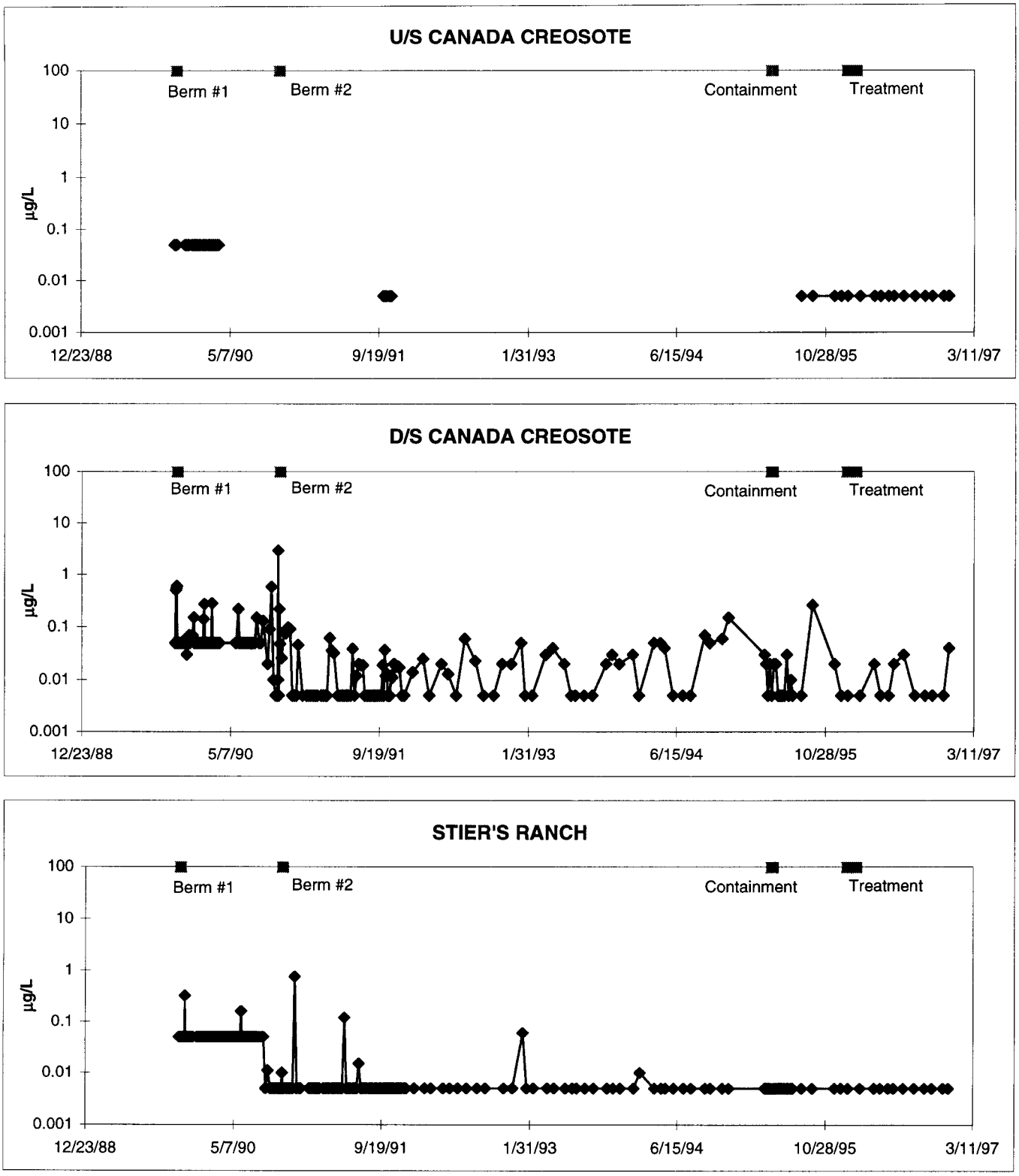

Figure 6. Concentrations of acenaphthene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

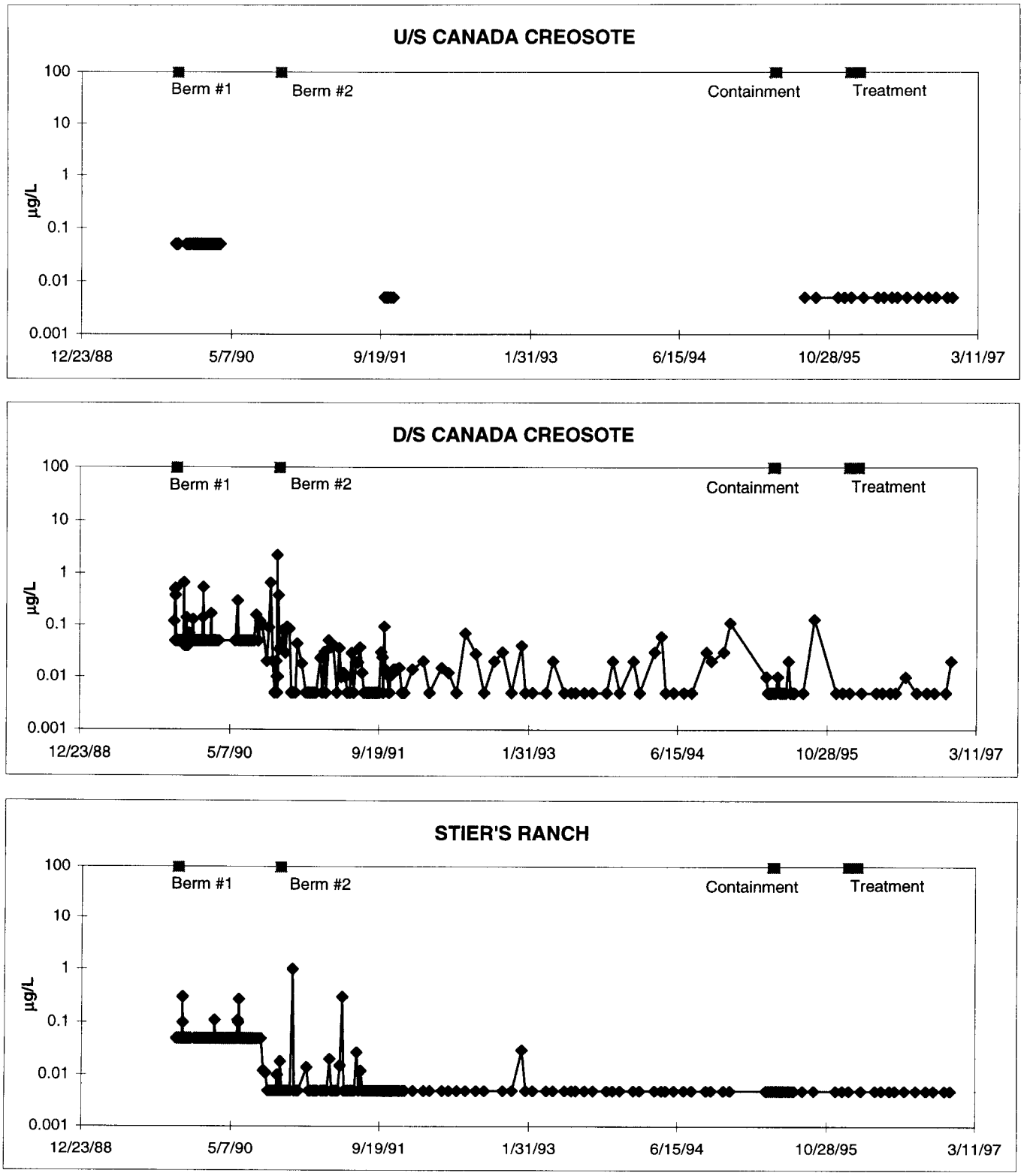

Figure 7. Concentrations of fluorene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

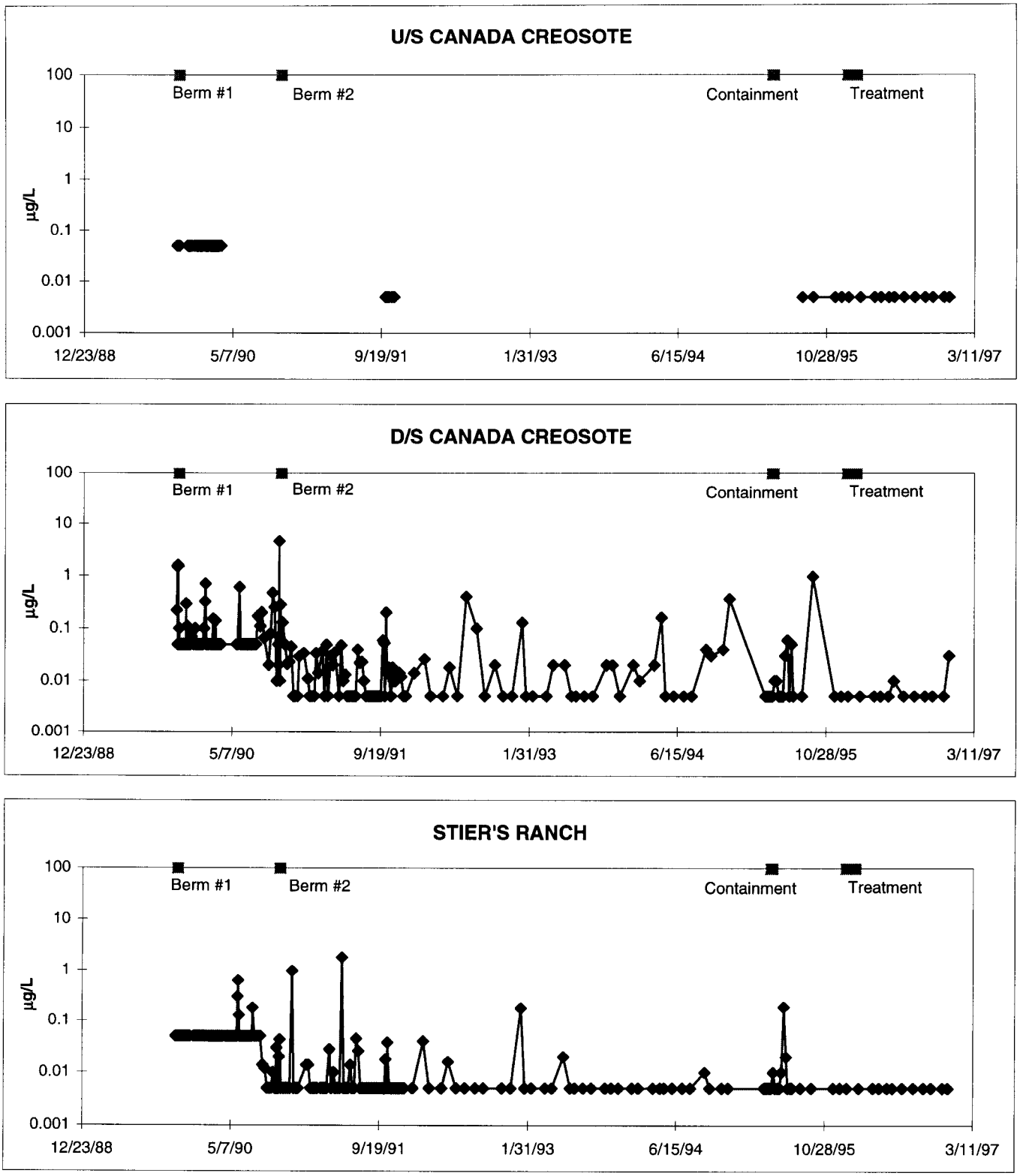

Figure 8. Concentrations of phenanthrene/anthracene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

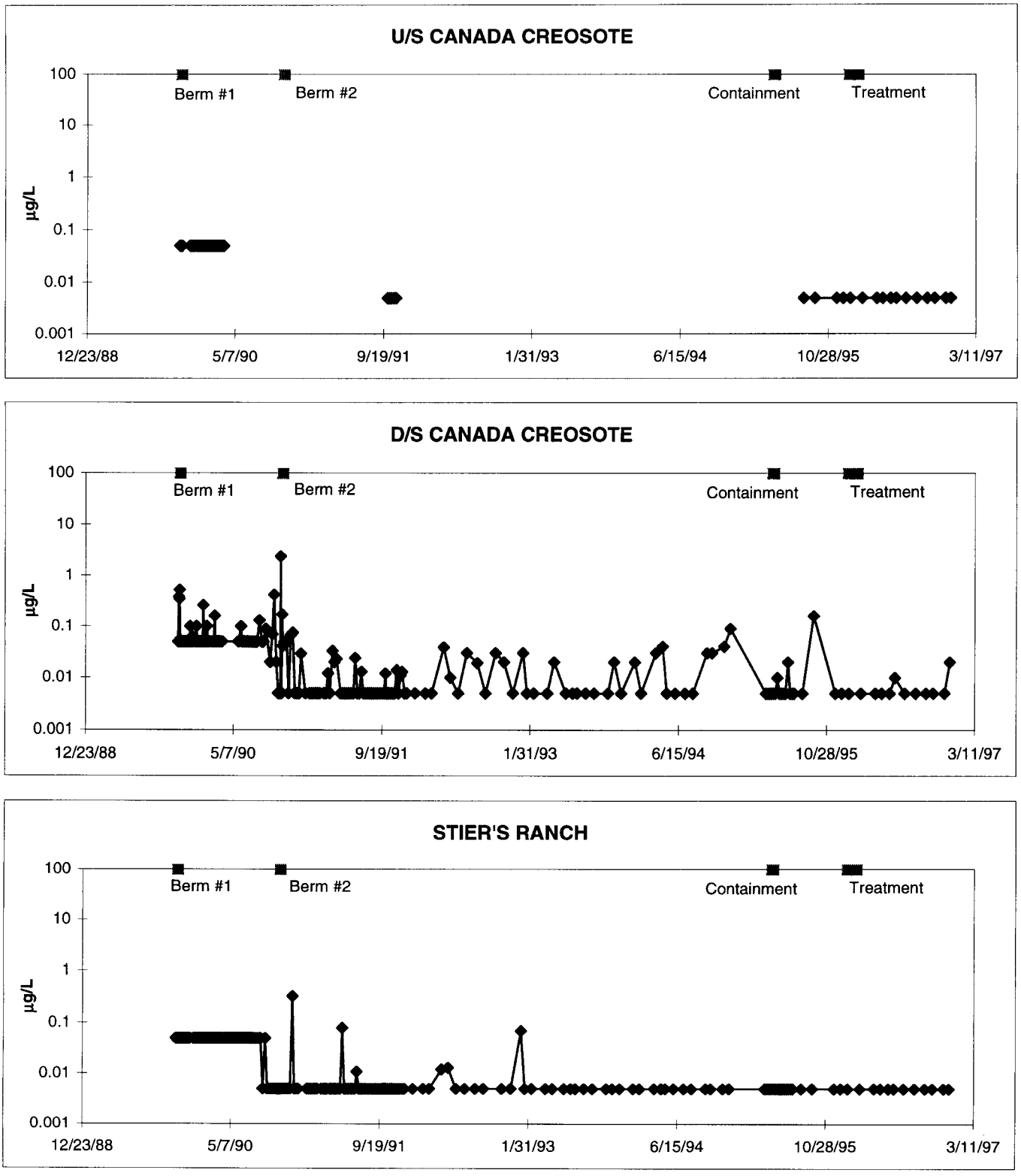

Figure 9. Concentrations of dibenzofuran at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

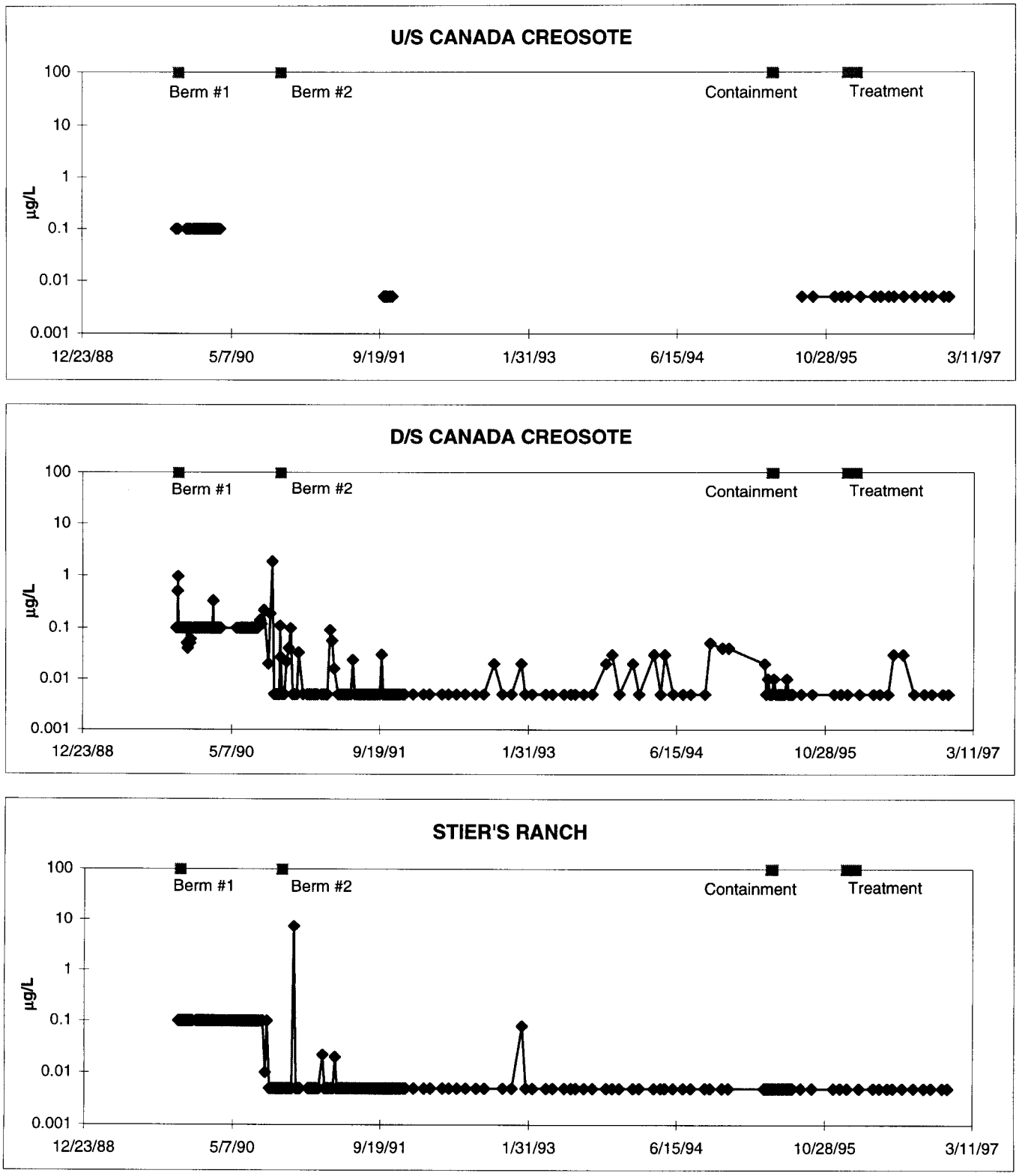

Figure 10. Concentrations of carbazole at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

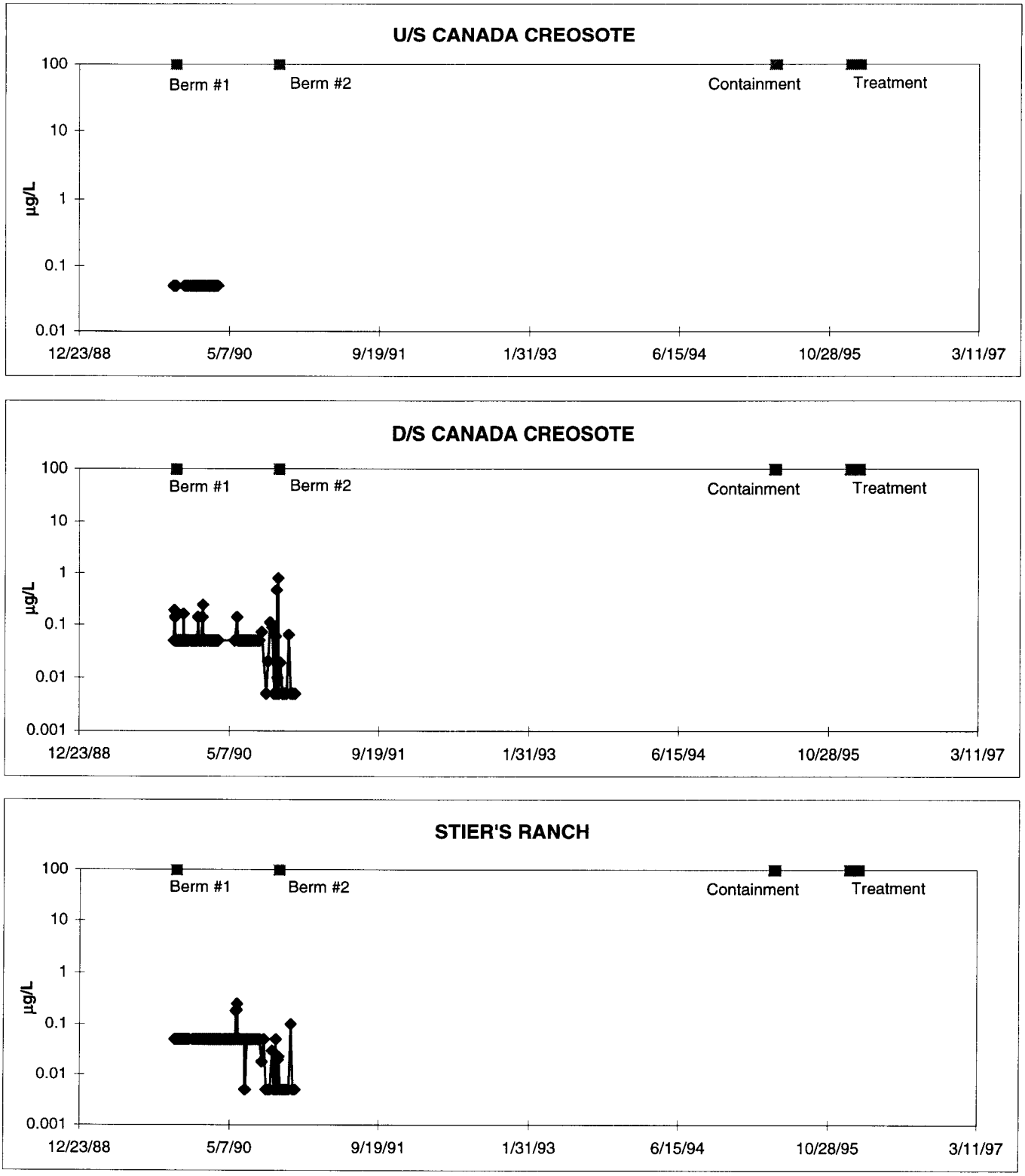

Figure 11. Concentrations of methylphenanthrene/anthracene at three sites on the Bow River, November, 1989 to December, 1990. Note: logarithmic scale used.

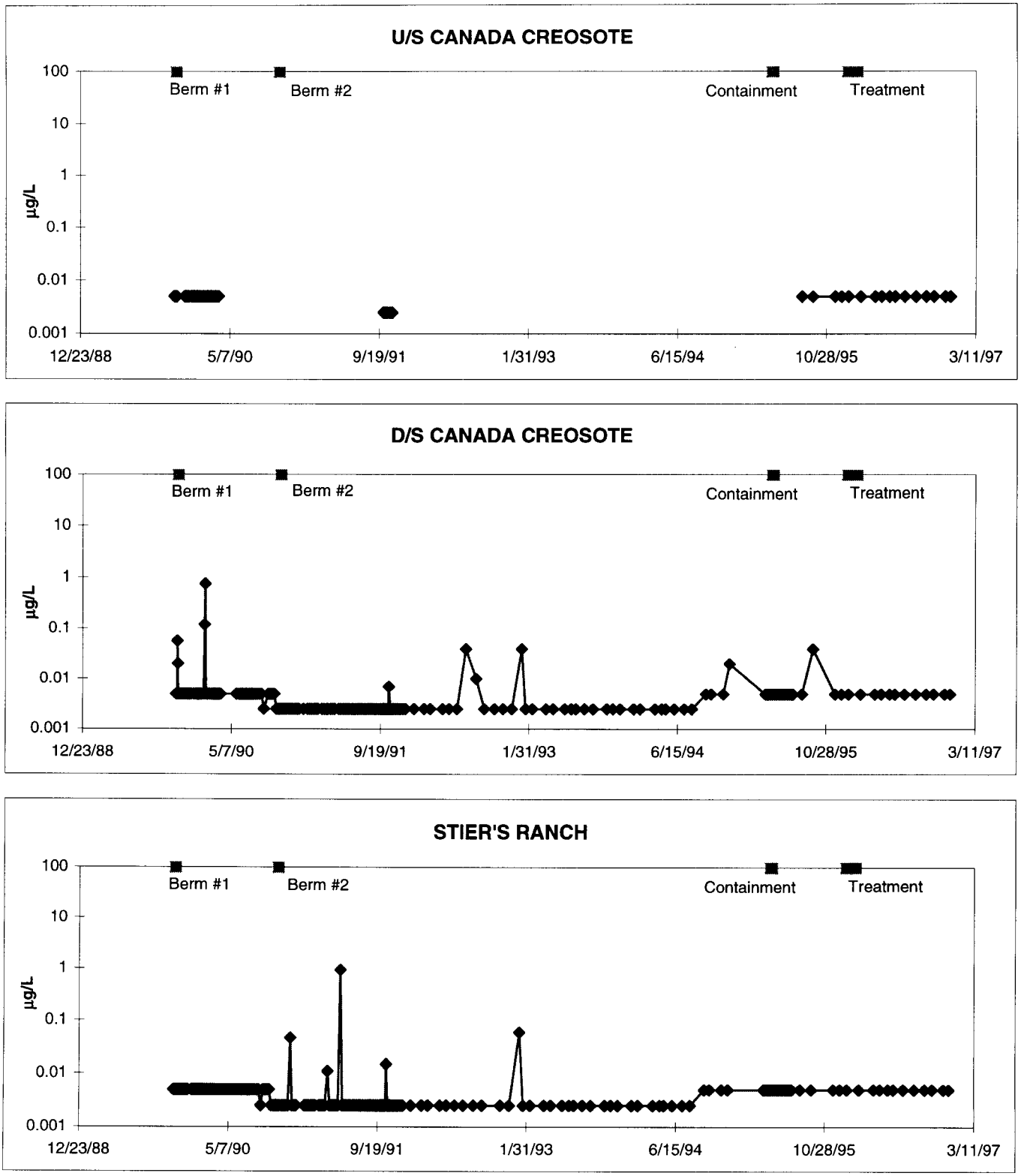

Figure 12. Concentrations of benzo(a)pyrene at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

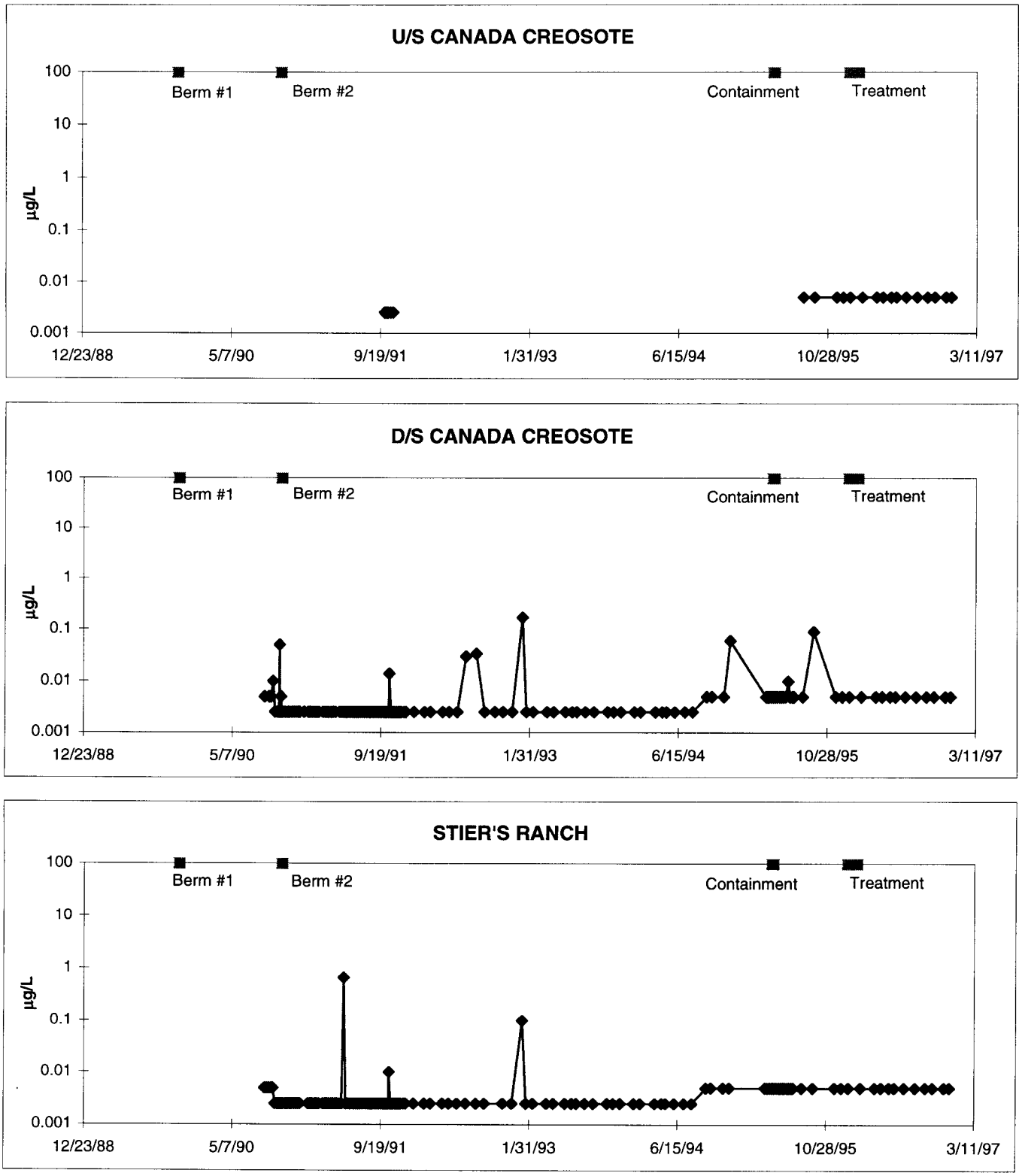

Figure 13. Concentrations of benzo(b)fluoranthene at three sites on the Bow River, August, 1990 to December, 1996. Note: logarithmic scale used.

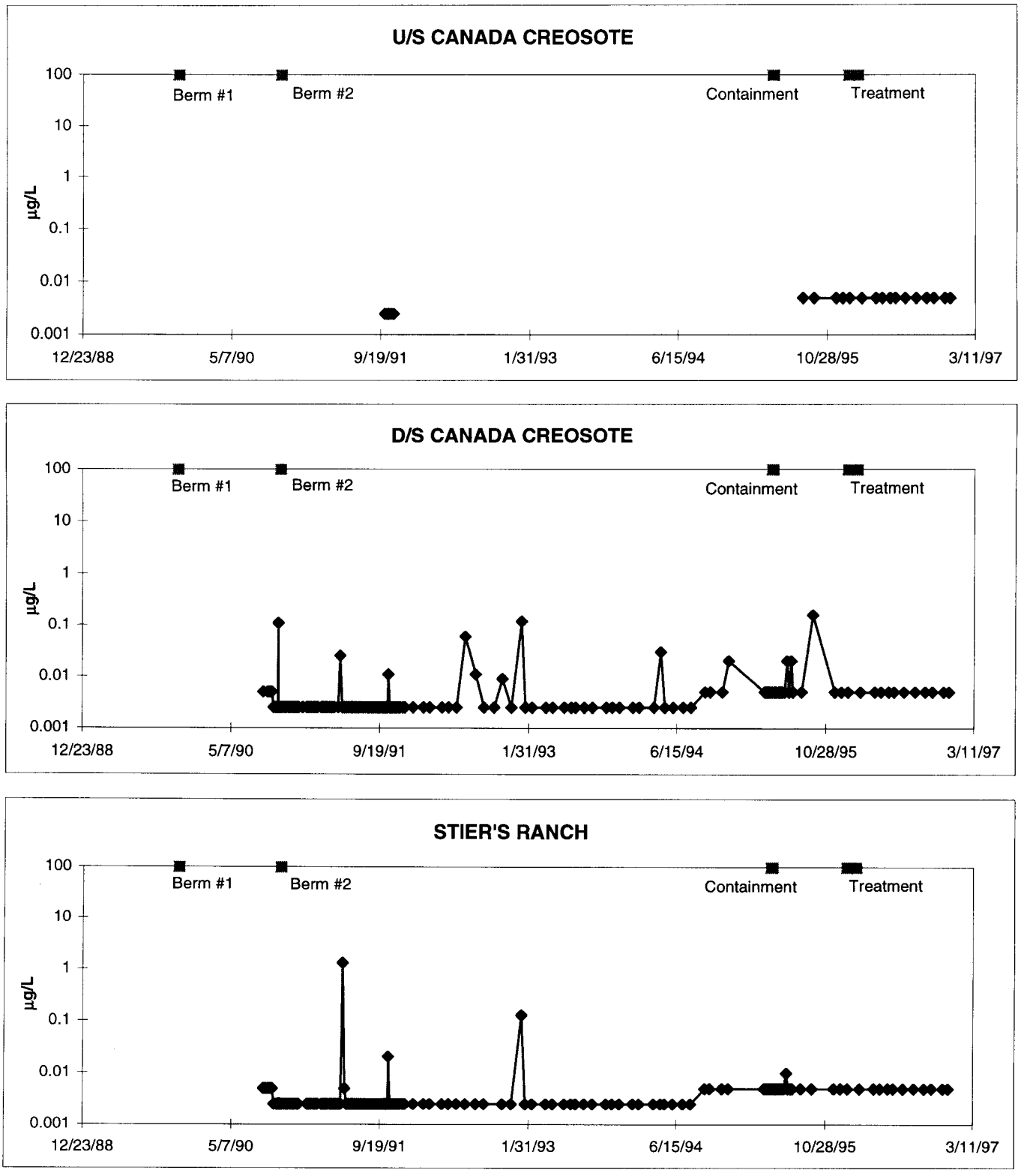

Figure 14. Concentrations of benzo(a)anthracene at three sites on the Bow River, August, 1990 to December, 1996. Note: logarithmic scale used.

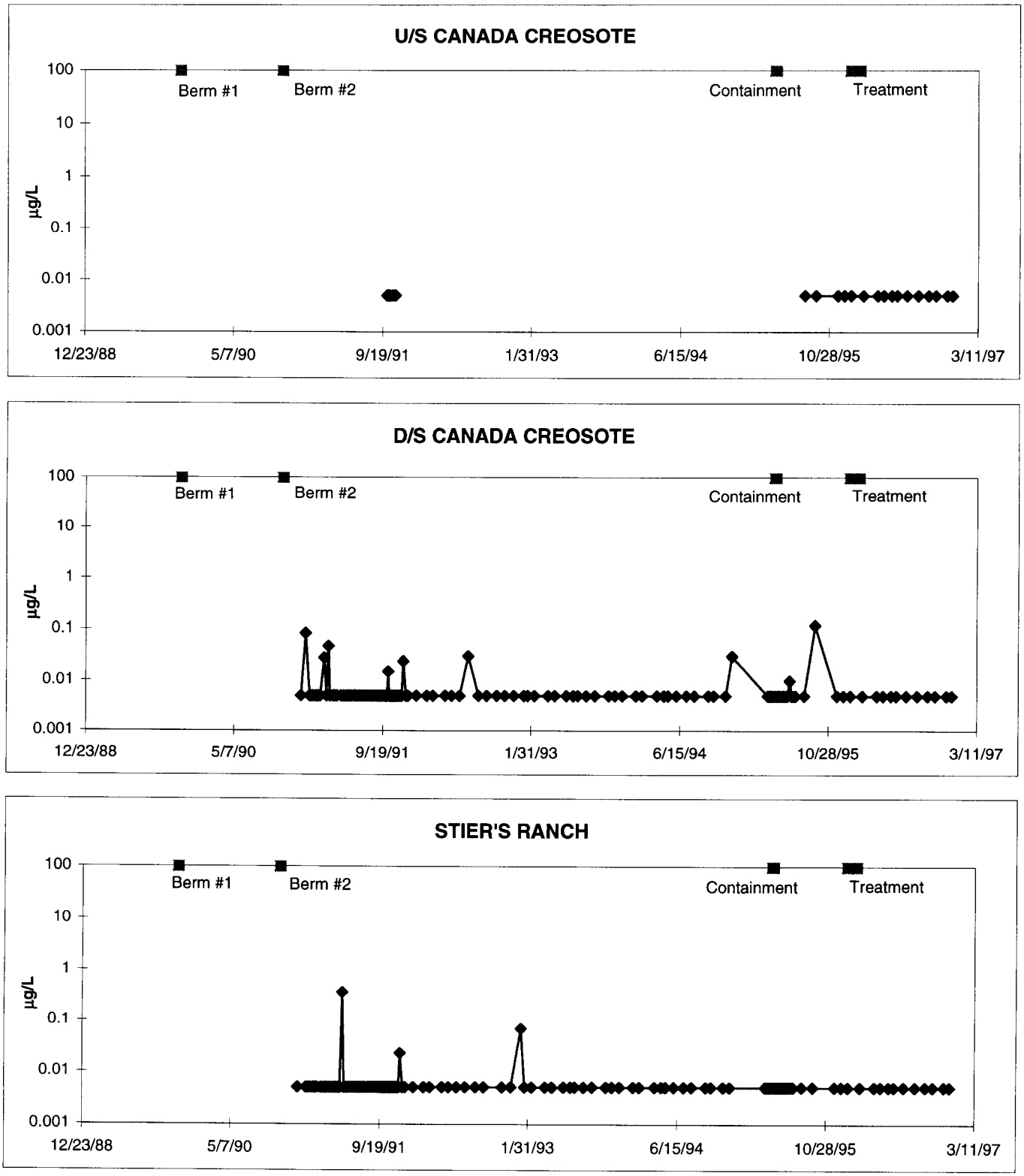

Figure 15. Concentrations of methylphenanthrene at three sites on the Bow River, December, 1990 to December, 1996. Note: logarithmic scale used.

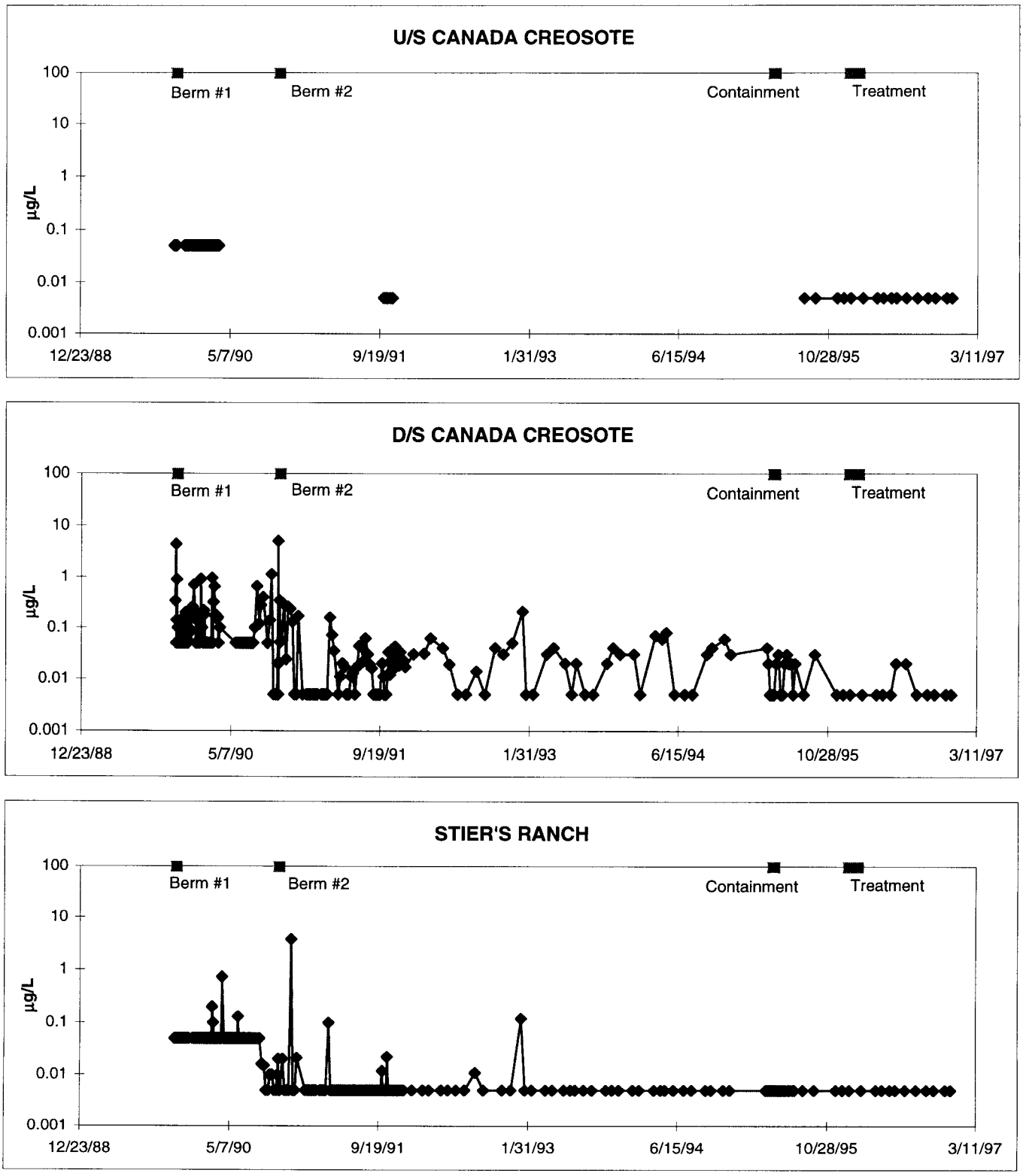

Figure 16. Concentrations of pentachlorophenol at three sites on the Bow River, November, 1989 to December, 1996. Note: logarithmic scale used.

reflect the scouring of contaminants from the river bed, or movement of more soluble PAH from the deposit that remains in the bed. Most compounds were at very low concentrations at the Stier's Ranch site in 1995, and there were no significant changes in the concentration of any compound after the permanent barrier was installed.

Trace levels of naphthalene, methyl and dimethylnaphthalene (but no other compounds) were sometimes detected at the site upstream from Canada Creosote, both before and after the installation of the berms and containment system. Low levels of PAH compounds can occur in urban runoff (CCME 1995), and probably account for the trace levels found at this upstream site. There were insufficient data from this site to test the statistical significance of changes in concentration.

Only naphthalene and PCP declined significantly in concentration downstream from the Canada Creosote site after the installation of the second berm, and again after the permanent barrier was installed. Naphthalene is the most water-soluble compound analyzed in this program. As a result, naphthalene levels were usually higher than other compounds downstream from the Canada Creosote site. Naphthalene levels declined more than any other compound.

PCP is unique to the Canada Creosote site; there are no other known sources of this compound along this reach of the Bow River. PCP was the only other compound which declined significantly after both the second berm and permanent barrier were installed. Although PCP occasionally exceeded the CCME guideline (0.5 µg/L) before the permanent barrier was installed, both downstream from Canada Creosote and at Stier's Ranch, PCP and all other compounds have since remained below all water quality guidelines at these locations.

Three carcinogens (benzo(a)pyrene, benzo(b/k)fluoranthene, benzo(a)anthracene) (NRCC 1983) were sometimes detected downstream from the Canada Creosote site and at Stier's Ranch, before the groundwater treatment system became operational in February 1996. Benzo(a)pyrene in the river occasionally exceeded the CCME guideline for "finished" drinking water (0.01 µg/L). However, since the installation of the groundwater treatment system there have been no detections of these carcinogens at these locations.

3.3 RESIDUES IN FISH MUSCLE

Fish muscle residues from the five sampling trips are summarized in Table 3. Results are arranged by the location of each sampling site (km from headwaters), then by sampling period and species. Brown trout and whitefish muscle collected from the Bow River downstream from the Canada Creosote site had the highest levels of each PAH compound and PCP in December 1989 (median naphthalene ≤ 0.32 ppm). Except for one sampling date at McKinnon Flats, mountain whitefish had higher residue levels than either brown or rainbow trout collected at the same site and date.

There are no accepted national guidelines for human consumption of fish containing the measured compounds. However, the residue levels measured in fish muscle in 1989 were considered safe for human consumption in an evaluation by Alberta Environmental Protection (Ramamoorthy 1990), and in a second evaluation by Health and Welfare Canada. Furthermore, Golder Associates Ltd. (1990) concluded that the six contaminants they evaluated were not at levels sufficiently elevated to pose a risk to fish populations, or wildlife species that consumed those fish.

It should be noted that all the fish species sampled in this study are migratory, and the history of exposure to contaminants from the Canada Creosote site was not controlled. Fish muscle samples collected upstream from the Canada Creosote site, near Bearspaw, contained detectable residues (Table 3) in 1989 and 1991. These fish probably migrated upstream through the zone of impact of the Canada Creosote site.

Median contaminant levels were higher in fish samples collected in December 1989 than in composite analyses from October and individual analyses from November 1989, when the liquid contaminants were found seeping into the Bow River. The fact that contaminant levels were higher in fish collected one month after the discovery of the deposit in the river supports the theory that fish acquired the contaminants through the aquatic food chain over time (Golder Associates Ltd., 1990), rather than direct uptake from the water. Composite samples of fish muscle collected just downstream from the Canada Creosote site in November 1991 generally had lower contaminant levels than were found in 1989, and none of these compounds were detected in composite samples from the same sites in November 1995, after the permanent barrier was installed. These later results

Table 3. Concentration of PAH and PCP in fish muscle samples from the Bow River, 1989-1995. Results are expressed as µg/g (ppm) wet weight. (na = not available)

km from Headwaters	50	250	250	250	268	268	268	268	276	276	276	276	305	327
Species	**cutthroat trout**	**brown trout**	**brown trout**	**brown trout**	**rainbow trout**	**brown trout**	**brown trout**	**brown trout**	**rainbow trout**	**brown trout**	**brown trout**	**brown trout**	**rainbow trout**	**rainbow trout**
Site	upstream L. Louise at HW 93	near Bearspaw	near Bearspaw	near Bearspaw	Canada Creosote-WID weir	Canada Creosote-WID weir	Canada Creosote-WID weir	Canada Creosote-WID weir	Blackfoot Tr.-Ogden Br.	Blackfoot Tr.-Ogden Br.	Blackfoot Tr.-Ogden Br.	Blackfoot Tr.-Ogden Br.	Stier's Ranch	McKinnon Flats
Sample Type	composite	median of individual samples	composite	composite	individual sample	median of individual samples	composite	composite	composite	median of individual samples	median of individual samples	composite	composite	median of individual samples
Sampling Date	13-10-89	8-11-89	17-11-95	6-11-91	7-12-89	7-12-89	6-11-91	17-11-95	12-10-89	8-11-89	6-12-89	5-11-91	11-10-89	6-12-89
Compound														
Naphthalene	<0.005	0.009	<0.01	0.017	0.220	0.130	0.025	<0.01	<0.005	<0.005	0.040	0.023	<0.005	0.095
Methylnaphthalene	<0.005	<0.005	<0.01	0.010	0.040	0.040	0.025	<0.01	<0.005	<0.005	<0.005	0.014	<0.005	0.055
Dimethylnaphthalene	<0.005	<0.005	<0.01	<0.002	0.030	0.020	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	0.010
Acenaphthylene	<0.005	<0.005	<0.01	<0.002	<0.005	<0.005	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005
Acenaphthene	<0.005	<0.005	<0.01	<0.002	0.010	<0.005	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005
Fluorene	<0.005	<0.005	<0.01	<0.002	0.010	0.020	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	0.023
Phenanthrene/Anthracene	<0.005	<0.005	<0.01	0.005	0.020	<0.005	0.007	<0.01	<0.005	<0.005	<0.005	0.058	<0.005	<0.005
Dibenzofuran	<0.005	<0.005	<0.01	<0.002	<0.005	0.012	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005
Carbazole	<0.005	<0.005	<0.01	<0.002	<0.005	<0.005	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005
Methyl Phenanthrene/Anthracene	<0.005	<0.005	<0.01	<0.002	<0.005	<0.005	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005
Benzo(a)Pyrene	<0.005	<0.005	<0.01	<0.002	<0.005	<0.005	<0.002	<0.01	<0.005	<0.005	<0.005	<0.002	<0.005	<0.005
Pentachlorophenol	<0.005	<0.005	<0.01	trace	0.007	0.008	trace	<0.01	<0.005	<0.005	0.005	trace	<0.005	0.009
sample size	na	7	5	5	1	5	5	5	5	10	5	5	5	10
fork length range, mm	na	316-625	318-490	465-575	190	250-370	290-540	199-345	206-430	310-510	410-500	240-510	376-498	220-460
Species		**mountain whitefish**	**mountain whitefish**	**mountain whitefish**	**mountain whitefish**	**mountain whitefish**	**mountain whitefish**		**mountain whitefish**	**mountain whitefish**	**mountain whitefish**		**mountain whitefish**	**mountain whitefish**
Site		near Bearspaw	near Bearspaw	near Bearspaw	Canada Creosote-WID weir	Canada Creosote-WID weir	Canada Creosote-WID weir		Blackfoot Tr.-Ogden Br.	Blackfoot Tr.-Ogden Br.	Blackfoot Tr.-Ogden Br.		Stier's Ranch	McKinnon Flats
Sample Type		duplicate composite	duplicate composite	composite	median of individual samples	composite	composite		composite	median of individual samples	composite		composite	median of individual samples
Sampling Date		5-11-91	5-11-91	17-11-95	7-12-89	6-11-91	17-11-95		13-10-89	6-12-89	5-11-91		12-10-89	6-12-89
Compound														
Naphthalene		0.036	0.037	<0.01	0.320	0.054	<0.01		0.016	0.070	0.064		0.006	0.040
Methylnaphthalene		0.023	0.031	<0.01	0.130	0.038	<0.01		<0.005	0.060	0.065		<0.005	0.009
Dimethylnaphthalene		<0.002	<0.002	<0.01	<0.005	<0.002	<0.01		<0.005	0.040	<0.002		<0.005	<0.005
Acenaphthylene		<0.002	<0.002	<0.01	0.010	<0.002	<0.01		<0.005	0.010	<0.002		<0.005	<0.005
Acenaphthene		<0.002	<0.002	<0.01	0.020	<0.002	<0.01		<0.005	0.010	<0.002		<0.005	<0.005
Fluorene		<0.002	<0.002	<0.01	0.100	<0.002	<0.01		<0.005	0.012	<0.002		<0.005	<0.005
Phenanthrene/Anthracene		0.012	0.013	<0.01	0.080	0.013	<0.01		<0.005	0.015	0.011		<0.005	<0.005
Dibenzofuran		<0.002	<0.002	<0.01	<0.005	<0.002	<0.01		<0.005	<0.005	<0.002		<0.005	<0.005
Carbazole		<0.002	<0.002	<0.01	<0.005	<0.002	<0.01		<0.005	<0.005	<0.002		<0.005	<0.005
Methyl Phenanthrene/Anthracene		<0.002	<0.002	<0.01	<0.005	<0.002	<0.01		<0.005	<0.005	<0.002		<0.005	<0.005
Benzo(a)Pyrene		<0.002	<0.002	<0.01	<0.005	<0.002	<0.01		<0.005	<0.005	<0.002		<0.005	<0.005
Pentachlorophenol		<0.002	<0.002	<0.01	<0.005	trace	<0.01		0.005	0.005	trace		0.005	<0.005
sample size		5	5	5	5	5	5		5	5	5		5	5
fork length range, mm		250-380	250-380	240-390	230-380	290-375	195-285		281-366	330-360	295-375		286-367	380-420

indicate that the permanent barrier prevented significant movement of contaminants from this site to aquatic organisms in the Bow River.

4.0 CONCLUSIONS

1. Levels of four PAH compounds (naphthalene, methylnaphthalene, fluorene, phenanthrene/anthracene) and PCP decreased significantly in the Bow River immediately downstream from the Canada Creosote site after the second temporary berm was installed in October 1990. Naphthalene levels alone declined significantly at a site 7 km downstream from Calgary (Stier's Ranch) in 1990. The installation of the second temporary berm in October 1990 significantly reduced the movement of contaminants to the Bow River from the Canada Creosote site.
2. Levels of three compounds (naphthalene, carbazole and PCP) declined significantly downstream from the Canada Creosote site after the permanent barrier was installed in May 1995. These results suggest that the installation of the permanent barrier (May 1995) further reduced the movement of contaminants to the Bow River from the Canada Creosote site. Levels of many other compounds were generally low at Stier's Ranch, and at an upstream control site, both before and after the barrier was installed in 1995.
3. Only after the groundwater containment system was fully operational (February 8, 1996) were all compounds consistently below water quality guidelines. PCP occasionally exceeded the CCME water quality guideline and three carcinogens were detected at both sites downstream from the Canada Creosote site before the containment system was fully operational. However, no compounds exceeded water quality guidelines downstream from this site after February 8, 1996, and no carcinogens were detected to December 17, 1996.
4. Brown trout and mountain whitefish muscle collected from the Bow River between the Canada Creosote site and the W.I.D. weir contained low levels of some PAH compounds and PCP in December 1989 (median [PAH] $\leq$ 0.32 ppm), but were considered safe for human consumption. None of these compounds were detected in fish samples from the same reach of the Bow River in November 1995, after the installation of the permanent barrier.

5.0 LITERATURE CITED

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