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**Title: Five-Year Field Study of the Water Quality  
Effects of Tire Shreds Placed Above the  
Water Table**

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## **FIVE-YEAR FIELD STUDY OF THE WATER QUALITY EFFECTS OF TIRE SHREDS PLACED ABOVE THE WATER TABLE**

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**Abstract.** A field trial was constructed beneath a secondary state highway in North Yarmouth, Maine to investigate the water quality effects of tire shred fills placed above the groundwater table. Samples were collected in three 3-m square geomembrane lined basins located beneath the shoulder of the road. Two of the basins are overlain by 0.61 m of tire shreds with a 75-mm maximum size topped by 0.72 to 1.37 m of granular soil. The third basin serves as a control and is overlain only by 0.72 m of granular soil. Quarterly samples for inorganic constituents were taken from January, 1994 through June, 1999. In addition, samples were taken for volatile and semivolatile organic compounds on three dates. Filtered and unfiltered samples were analyzed for the following substances that have a primary drinking water standard: barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), and selenium (Se). There was no evidence that the presence of tire shreds altered the concentrations of these substances from their naturally occurring background levels. In addition, there was no evidence that tire shreds increased the levels of aluminum (Al), zinc (Zn), chloride (Cl<sup>-</sup>) or sulfate (SO<sub>4</sub>), which have secondary (aesthetic) drinking water standards. In a few samples, iron (Fe) levels exceed their secondary standard. Manganese (Mn) levels consistently exceeded their

secondary standard, however, this is an esthetic based standard. Three sets of samples were tested for organics. Negligible levels of organics were found.

## **INTRODUCTION**

Tire shreds are waste tires that have been cut into pieces that are generally 50 to 300 mm in size (1). They offer the following advantages when used as a fill material: lightweight, low lateral pressure, low thermal conductivity, and free draining (1). Because of these advantages they have been used on more than 100 road construction projects across the United States. While the potential effect on groundwater quality is thought to be small when used for highway applications, there have been few extended studies of the effects for field conditions.

Previous laboratory leaching studies have shown that tire shreds are not a hazardous waste as defined by the Resource Conservation and Recovery Act (as amended). However, these same studies detected low levels of some metals and organic compounds in the leachate (2, 3, 4, 5, 6). This indicated that testing the effects of tire shreds on water quality under field conditions was warranted.

A limited field study was performed for the Minnesota Pollution Control Agency (3). Unfortunately, samples were taken on only one date from open boreholes. This sampling procedure casts doubt on the validity of the results. Edil and Bosscher (4) installed two pan lysimeters beneath tire shred layers in a test road embankment. The study had no control for sampling an area with no tire shreds, so it was not possible to separate the effects of the tire shreds from the compounds naturally present in the groundwater. The levels of inorganic compounds in groundwater adjacent to a tire shred

project in Richmond, Maine have been monitored (7). In this project, tire shreds were found to have no effect but the period of monitoring was limited and organics were not included in the study.

One purpose of the North Yarmouth Field Trial was to carry out long term monitoring of the water quality effects of tire shreds placed above the water table. The study includes a control section to measure the levels of substances naturally present in the water. Preliminary results were presented in Humphrey, et al. (8). This paper presents the results and conclusions from the entire 5.5-year monitoring period. Another purpose of the field trial was to measure the effect of a compressible tire shred layer on asphaltic concrete pavement performance. To date there has been no difference in pavement performance for sections underlain by tire shreds compared to the control section (9, 10). A separate study was performed on water quality effects of tire shreds placed below the groundwater table. In this latter study 1.4 metric tons of tire shreds were buried below the water table in glacial till, marine clay, and peat. Preliminary results are given in Downs et al. (6).

## **SITE AND MONITORING WELL DESCRIPTIONS**

The North Yarmouth Field Trial is located on Route 231, a secondary highway in North Yarmouth, Maine. It consists of four 33-m long sections each with a 0.61-m thick tire shred layer (9, 10). The tire shred layer was covered with a total thickness of between 0.76 m and 1.37 m of granular soil prior to paving. The granular soil was composed of 0.635 m of subbase gravel and with the balance of the thickness being granular common borrow. The pavement was 0.127 m thick. In addition, two sizes of tire

shreds were used (passing a 75-mm sieve and passing a 305-mm sieve) to investigate the effect of soil cover thickness and tire shred size on pavement deflection. The shreds were made from a combination of steel and glass belted tires. Steel belts were exposed at the cut edges of the shreds. Approximately 100,000 tires were used in this test project. In addition, there was a 33-m long control section designed according to Maine Department of Transportation standards with conventional soil fill. A longitudinal cross section is shown in Fig. 1.

Two seepage collection basins were installed beneath sections with tire shreds passing the 75-mm sieve to collect samples for water quality testing. The seepage collection basins were 3-m by 3-m in plan and were lined with a HDPE geomembrane. A drain in the center of the liner lead to a collection tube located along the side of the embankment as shown in Fig. 2. The design was similar to that used by Edil and Bosscher (4). New pavement is nearly impervious, so to obtain infiltration, the basin projected beyond the edge of the pavement. This allowed water that ran off the edge of the pavement to infiltrate into the embankment sideslope and enter the basin. With this design, there is no opportunity for substances leached from the tire shreds to be sorbed onto the soil prior to sampling. The basins were located directly below the tire shred layer. One basin (Section C) was overlain by 0.61 m of tire shreds followed by 1.37 m of granular soil and the other (Section D) was overlain by 0.61 m of tire shreds followed by 0.72 m of granular soil. A third seepage collection basin was installed in the control section. It was overlain by 0.72 m of granular soil.

## **SAMPLING AND TESTING PROCEDURES**

Quarterly samples for inorganic constituents and water quality index tests were taken from January, 1994 through June, 1999 giving a total of 22 sets of samples. In addition, on December 28, 1995, April 5, 1996, and June 22, 1999 samples were taken for volatile organic compounds (VOC's) and semivolatile organic compounds (SVOC's).

For the period January, 1994, through September, 1995, samples were taken from the water that accumulated in the collection tube since the previous sampling period. On each sampling date the tubes were full and it was apparent that water had been flowing out of each tube's overflow pipe. After sampling, the tube was bailed dry in preparation for the next sampling period. This procedure raised the concern that sediments could accumulate in the bottom of the tube. For this reason, the sampling procedure was changed starting with the December, 1995, sample. From this date onward, the tubes were bailed dry two to three weeks prior to the desired sampling date. Samples were subsequently taken from the water that had accumulated over this short period. Samples were obtained with disposable 1-liter capacity high density polyethylene (HDPE) bailers.

The following sample types were taken from each well: leachate filtered through a 0.3-micron filter and preserved with nitric acid (1.5 ml/L) as appropriate for determination of dissolved metals (11); unfiltered leachate preserved with nitric acid (1.5 ml/L) for determination of total metals; and unfiltered leachate with no acid for water quality index tests such as pH. Samples were stored in HDPE bottles and were refrigerated to minimize degradation of sample quality. In addition, on five dates samples were taken for biological oxygen demand (BOD<sub>5</sub>) determination.

The samples were tested for the substances listed in Table 1. Samples for metals analysis except for lead and selenium were prepared in accordance with EPA Method 200.7 (Inductively Coupled Plasma - Atomic Emission Spectrometric Method for Trace Element Analysis) (12). Samples for lead and selenium were prepared in accordance with EPA Method 200.9 (Determination of Trace Elements by Stabilized Temperature Graphite Furnace Atomic Absorption Spectrometry) (12). The tests were carried out in accordance with EPA Method 7421 Lead (Atomic Absorption, Furnace Technique) and EPA Method 7740 Selenium (Atomic Absorption, Furnace Technique) (13). Chloride and sulfate were measured in accordance with EPA Method 300.0 (Determination of Inorganic Anions by Ion Chromatography) (14). Water quality index tests such as pH, alkalinity, BOD<sub>5</sub>, chemical oxygen demand (COD), conductivity, total dissolved solids, and hardness were also performed.

For most substances, tests were performed on both acid preserved filtered and acid preserved unfiltered samples. The unfiltered samples generally contained some fine grained particles that imparted a slight turbidity to the water. Since wells for drinking water are designed to prevent any significant amount of particulate matter from entering the well, it would not be representative to compare the results from unfiltered samples to drinking water standards. Thus, results from unfiltered samples provide supplementary information only and were not compared to drinking water standards.

Samples were taken for volatile organic compounds (VOC's) and semivolatile organic compounds (SVOC's) on three dates. The containers used for the VOC samples were clear 40 mL borosilicate glass vials with polypropylene closures and Teflon faced silicone septa. The samples were preserved by adding 4 drops of ultrapure hydrochloric

(HCl) to each vial before collecting the samples. Leachate from the bailer was placed directly in the vial with no sample preparation. The VOC samples were tested in accordance with EPA Method 8260 (Determination of Volatile Organics by Purge-and-Trap Capillary Column GC/MS). A total of 82 VOC's were targeted for analysis. The compounds were chosen based on the chemical composition of tires and likely breakdown products. SVOC samples were collected in 1 L amber borosilicate glass bottles with polypropylene closures with Teflon liners. Leachate from the bailer was placed directly in the bottles with no sample preparation. The SVOC samples were tested in accordance with EPA Method 8270 (Determination of Semivolatile Organics by Capillary Column GC/MS). A total of 69 base neutral extractable, acid extractable, and polyaromatic hydrocarbon SVOC's were targeted for analysis. The compounds were chosen based on the chemical composition of tires and likely breakdown products.

### **WATER QUALITY INDEX TESTS**

The pH of the samples varied from slightly greater than 8 to about 6 as shown in Fig. 3. There was no apparent pattern with date or with sample location. Overall, the pH was near neutral. Thus, the results of this study are applicable to similar pH conditions. The dissolved and total solids varied from about 100 to 4000 mg/L. On a given date the concentration was about the same in the two tire shred sections as the control section. The concentration was generally the highest in the sets of samples taken in April and lowest in the sets of samples taken in December or January. The BOD<sub>5</sub> was very low and varied between about 0.5 and 3.0 mg/L. On a given date the COD was about the same in

the two tire shred sections as in the control section. It varied from a low of about zero to a high of about 600 mg/L with no apparent pattern versus date.

## **INORGANIC RESULTS**

### Substances with Primary Drinking Water Standards

Substances with a primary drinking water standard are a known or suspected health risk. The following metals with this classification were included in the analysis: barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and selenium (Se). Results for filtered and unfiltered samples of barium (Ba) and chromium (Cr) are shown in Figs. 4 and 5. These two substances are present in the control section, indicating that they are naturally occurring in the soil. However, the levels found in the two tire shred sections are essentially the same as in the control section. This indicates that the presence of the tire shred layer does not cause a measurable alteration of the naturally occurring background concentrations of barium (Ba) and chromium (Cr).

The concentrations of cadmium (Cd), copper (Cu), lead (Pb), and selenium (Se) were generally below the test method detection limits (MDL). Although, the MDL's varied slightly over the course of the study, the following are applicable to most test dates: 0.0005 mg/L for cadmium (Cd), 0.009 mg/L for copper (Cu), 0.002 mg/L for lead (Pb), and 0.00017 mg/L for selenium (Se). The limited number of samples that exceeded the MDL's are discussed in the following. Cadmium was below the MDL for all but three samples. The filtered Cd sample from the control section taken in April 1995 and the filtered and unfiltered samples in Section D taken in June 1995 slightly exceeded the regulatory allowable limit (RAL) of 0.005 mg/L. It is believed that the three samples that

exceeded the RAL are not representative of the overall cadmium concentration as the concentration was less than the MDL of 0.0005 mg/L on the other sampling dates. For all other substances with primary drinking water standards, the levels were well below the applicable RAL. Copper was present above the MDL in filtered samples on two dates in the control section, two dates in Section C, and one date in Section D, but the highest concentration was 0.010 mg/L compared to a RAL of 1.3 mg/L. Lead was present in filtered samples at levels above the MDL on two samples in the control section (highest concentration 0.009 mg/L) and in three samples in tire shred sections (highest concentration 0.0024 mg/L). The concentrations were less than the RAL for lead, which is 0.015 mg/L. Lead was present above the MDL in 33% of the unfiltered samples from the control section with the highest concentration being 0.054 mg/L and in 17% of the unfiltered samples from the tire shred sections with the highest concentration being 0.016 mg/L. Overall, filtered and unfiltered lead concentrations appeared to be higher in the control section compared to the tire shred sections.

#### Substances with Secondary Drinking Water Standards.

Substances with a secondary drinking water standard are of aesthetic concern meaning that they may impart some taste, odor, or color to water but are not a health concern. Filtered and unfiltered results for aluminum (Al), iron (Fe), manganese (Mn), and zinc (Zn) are plotted versus date in Figs. 6 through 9. The filtered and unfiltered concentrations of manganese (Mn) and zinc (Zn) are about the same. However, the unfiltered concentrations of aluminum (Al) and iron (Fe) are often higher than the filtered concentrations. For aluminum this is most likely due to soil sediment that was present in the samples, especially those taken from the control section in 1998. For iron this is most

likely due to particulate iron oxide that passed directly from the tire shreds into the collection tube. As discussed previously, drinking water standards should be compared only with results for filtered samples.

Aluminum (Al), iron (Fe), manganese (Mn), and zinc (Zn) are naturally present in the soil as evidenced by the occurrence of these metals in samples from the control section, however, there is no evidence that tire shreds increased the levels of aluminum (Al) or zinc (Zn). In fact, the zinc levels are generally higher in the control section than the two tire shred sections (Fig. 9). This is an interesting finding since the steel belts in tires are often zinc coated and zinc oxide is present in the rubber. The filtered iron (Fe) levels in the tire shred and control sections are about the same on most sampling dates. However, on a few dates the iron levels in the tire shred sections are higher than in the control section and the level exceeds the secondary RAL. In contrast, the unfiltered iron levels were consistently higher in the tire shred sections compared to the control section. On almost all sampling dates the levels of manganese (Mn) are higher in the tire shred sections than in the control section. Manganese is present as an alloy in the steel belts at the rate of 2 to 3% by weight of steel. The manganese levels in filtered samples from the tire shred sections generally exceed the RAL by a factor of 10 to 400.

The levels of chloride ( $\text{Cl}^-$ ) are plotted in Fig. 10. Concentrations higher than the applicable secondary RAL are generally present for samples taken in April. This is most likely due to infiltration from road salt. There was no evidence that tire shreds increase the concentration of sulfate ( $\text{SO}_4$ ), calcium (Ca), magnesium (Mg), or sodium (Na) as shown in Figs. 11 through 14.

## ORGANIC RESULTS

Samples taken on December 28, 1995, April 5, 1996, and June 22, 1999 were tested for volatile and semi-volatile organics. On the first two sampling dates the levels for all compounds were below the test method detection limits. In the control section on the third sampling date one volatile organic compound was found (toluene at a concentration of 0.070 mg/L) and three semi-volatile organic compounds were found (3&4-methylphenol – 0.100 mg/L, benzoic acid – 0.025 mg/L, and phenol – 0.074 mg/L). The source of these compounds is unknown. They were not present in the two tire shred sections.

On the June 22, 1999 sample date, the volatile compounds 1,1-dichloroethane and 4-methyl-2-pentanone were present at trace levels (<0.005 mg/L) in Section D. The semi-volatile compound 2-(4-morpholinyl)-benzothiazole was tentatively identified in the two tire shred sections on this date.

These results are consistent with the results of another field study where tire shreds were used as backfill for a roadway edge drain on the University of Maine campus (15). For this project, water emerging from the edge drain was sampled for VOC's and SVOC's on June 27, 1997. All compounds were below the detection limit.

The negligible levels of VOC's are supported by results of a laboratory leaching study (6). In this study, tire shreds and tire shred/soil mixtures were placed in a glass reactor, the reactor was filled with water, and then sealed for 10 months. Six VOC's were above the detection limit but the concentrations were less than 5 mg/L. This is an important check on the results of the field study since the design of the seepage collection

basins and sampling tubes leaves open the possibility that VOC's volatilized from the leachate prior to sampling.

## CONCLUSIONS

1. Most of the inorganic substances that can potentially leach from tires are naturally present at low levels in groundwater. This includes aluminum (Al), barium (Ba), chromium (Cr), iron (Fe), lead (Pb), manganese (Mn), and zinc (Zn). Thus, it is critical that a control section be used to measure the natural background levels of these substances. This allows changes in level caused by the tire shreds to be separated from background levels.

2. No evidence was found that tire shreds increased the concentration of substances that have a primary drinking water standard including: barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and selenium (Se).

3. No evidence was found that tire shreds increased the concentration of the following substances that have a secondary drinking water standard: aluminum (Al), chloride (Cl<sup>-</sup>), sulfate (SO<sub>4</sub>), and zinc (Zn). There was some evidence that tire shreds could increase the levels of iron (Fe) and exceed the secondary drinking water standard under some conditions.

4. Tire shreds increase the levels of manganese (Mn), which has a secondary drinking water standard. It is likely that the levels will exceed this standard. However, manganese is of aesthetic concern only.

5. Negligible levels of organics were measured in three sets of samples taken from the North Yarmouth Field Trial.

6. Tire shreds placed above the water table had a negligible impact on water quality for the near neutral pH conditions found at the North Yarmouth Field Trial. This opens the way for tire shreds to be used as lightweight embankment fill, retaining wall backfill, insulation to limit frost penetration, and backfill for edge drains on a wide range of highway projects.

### **ACKNOWLEDGMENTS**

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TABLE 1—List of inorganic substances tested for in study.

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Aluminum (Al)**	Magnesium (Mg)
Barium (Ba)*	Manganese (Mn)**
Cadmium (Cd)*	Selenium (Se)*
Calcium (Ca)	Sodium (Na)
Copper (Cu)*	Zinc (Zn)**
Chromium (Cr)*	Chloride (Cl <sup>-</sup> )**
Iron (Fe)**	Sulfate (SO <sub>4</sub> )**
Lead (Pb)	

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\*Has primary drinking water standard

\*\* Has secondary drinking water standard

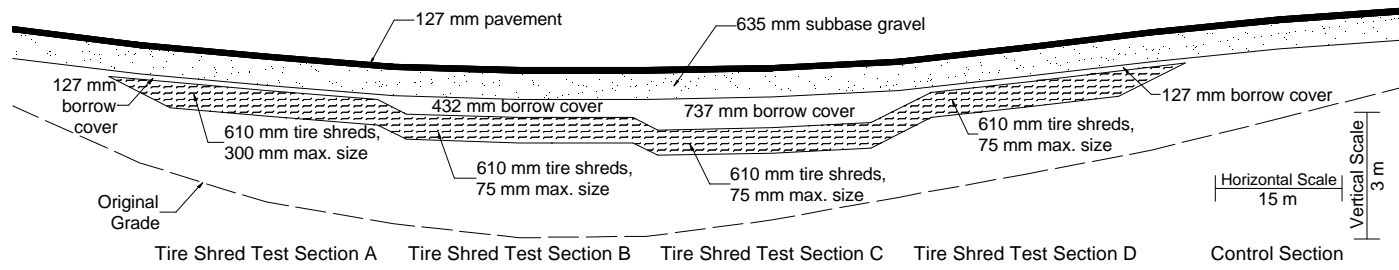


Fig. 1 Longitudinal section.

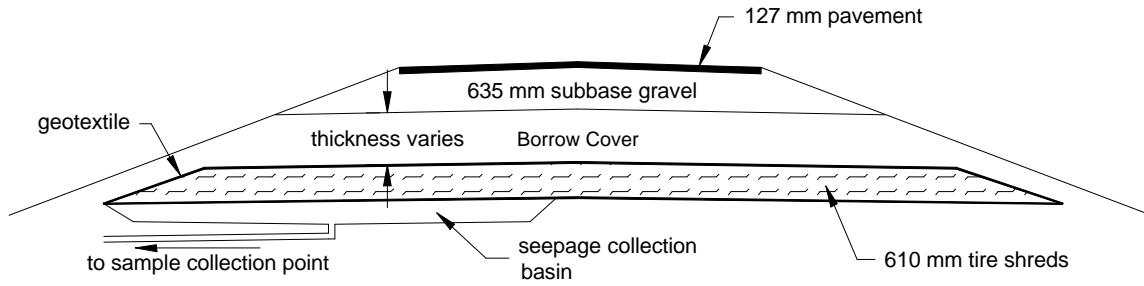


Fig. 2 Typical cross section showing location of seepage collection basin.

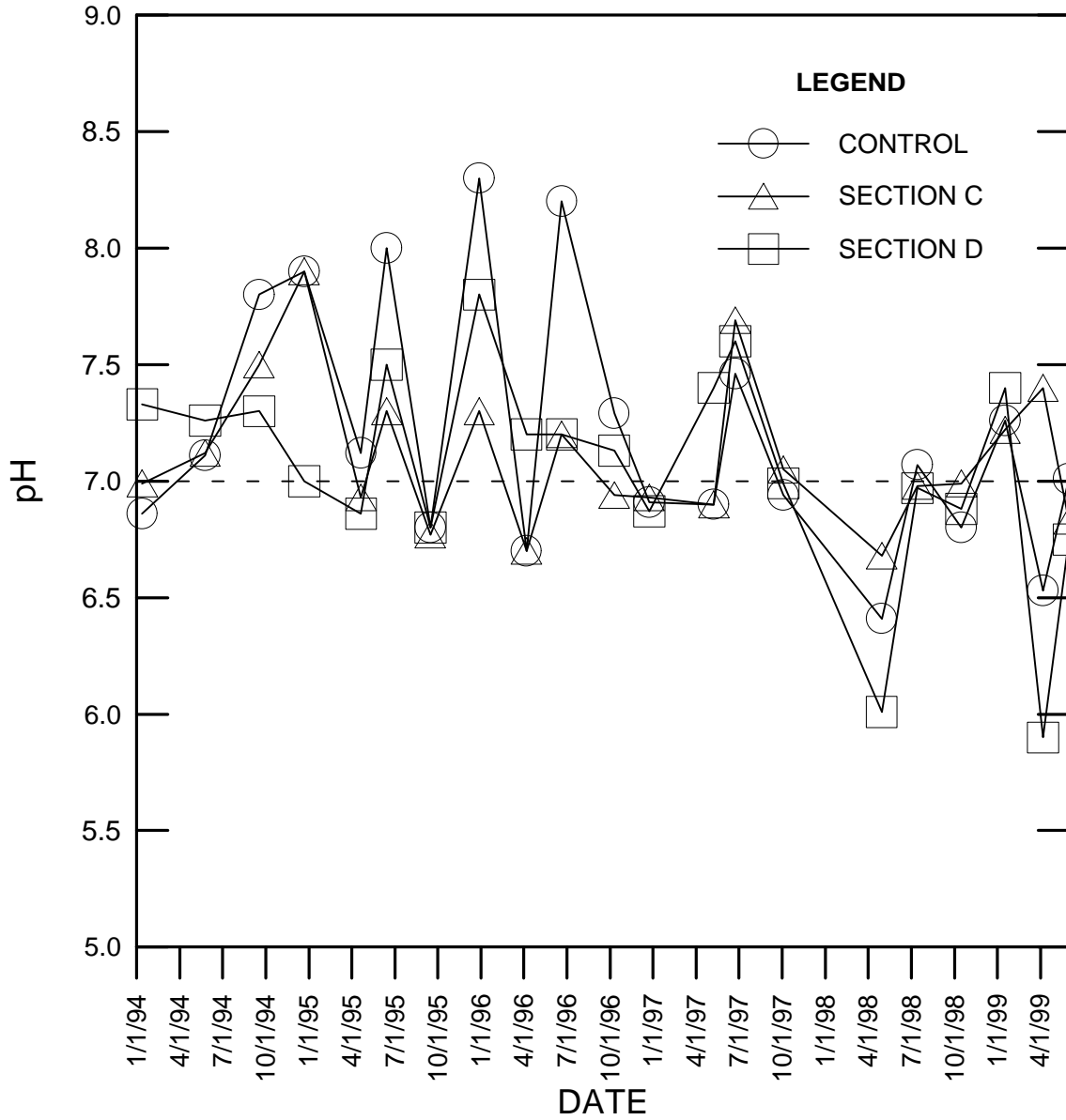


Fig. 3 pH values of field samples.

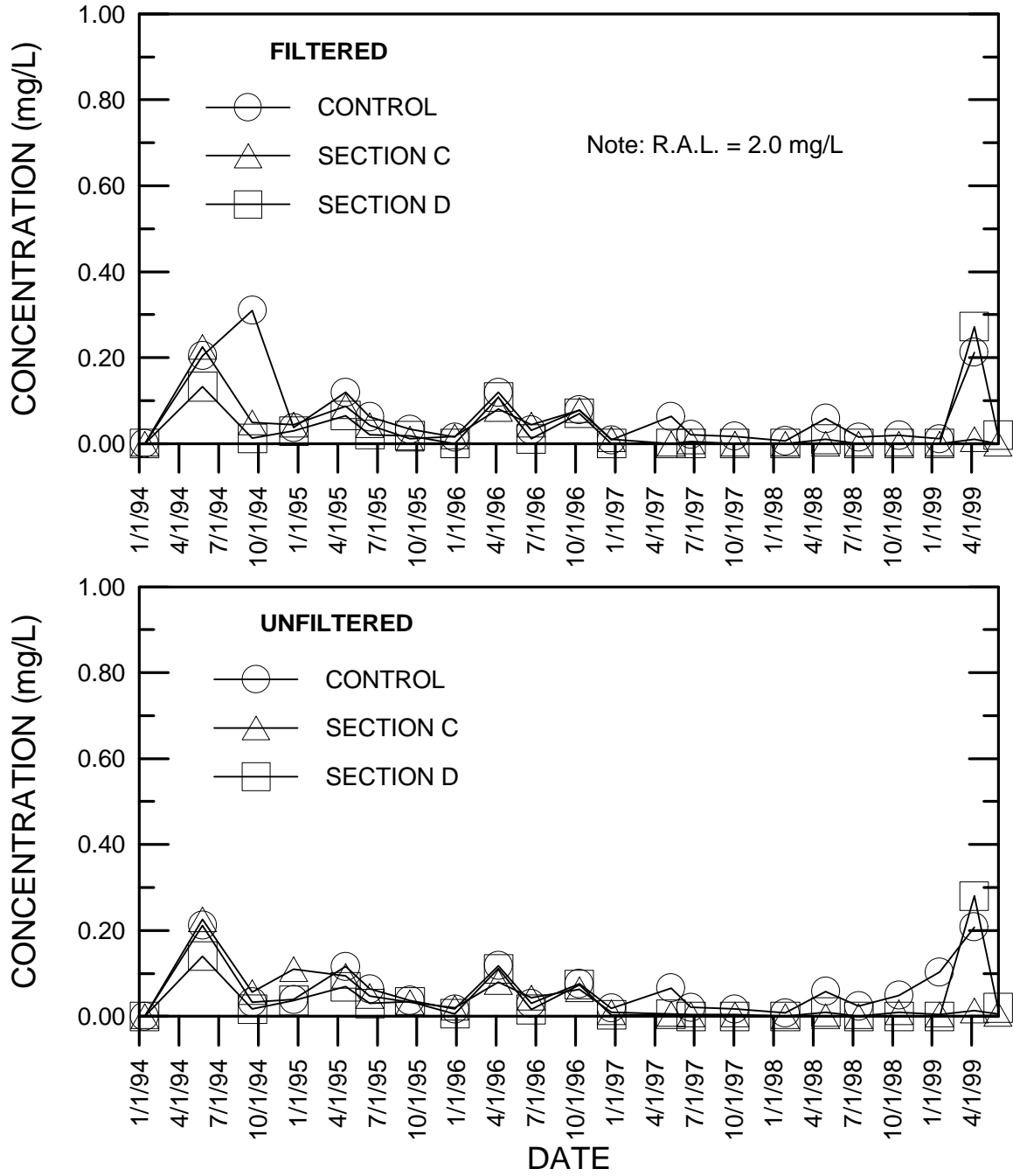


Fig. 4 Filtered and unfiltered barium (Ba) concentrations.

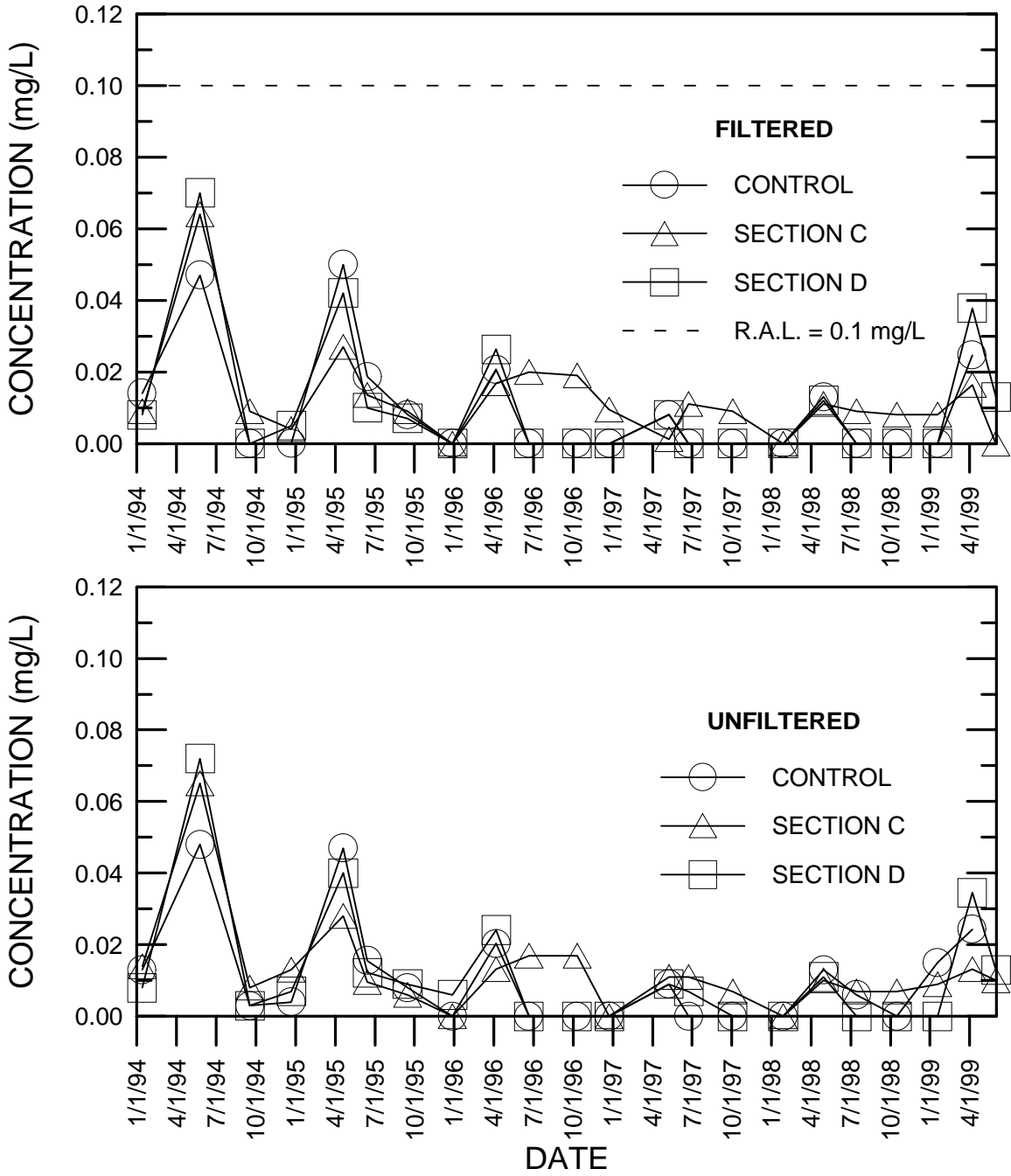


Fig. 5 Filtered and unfiltered chromium (Cr) concentrations.

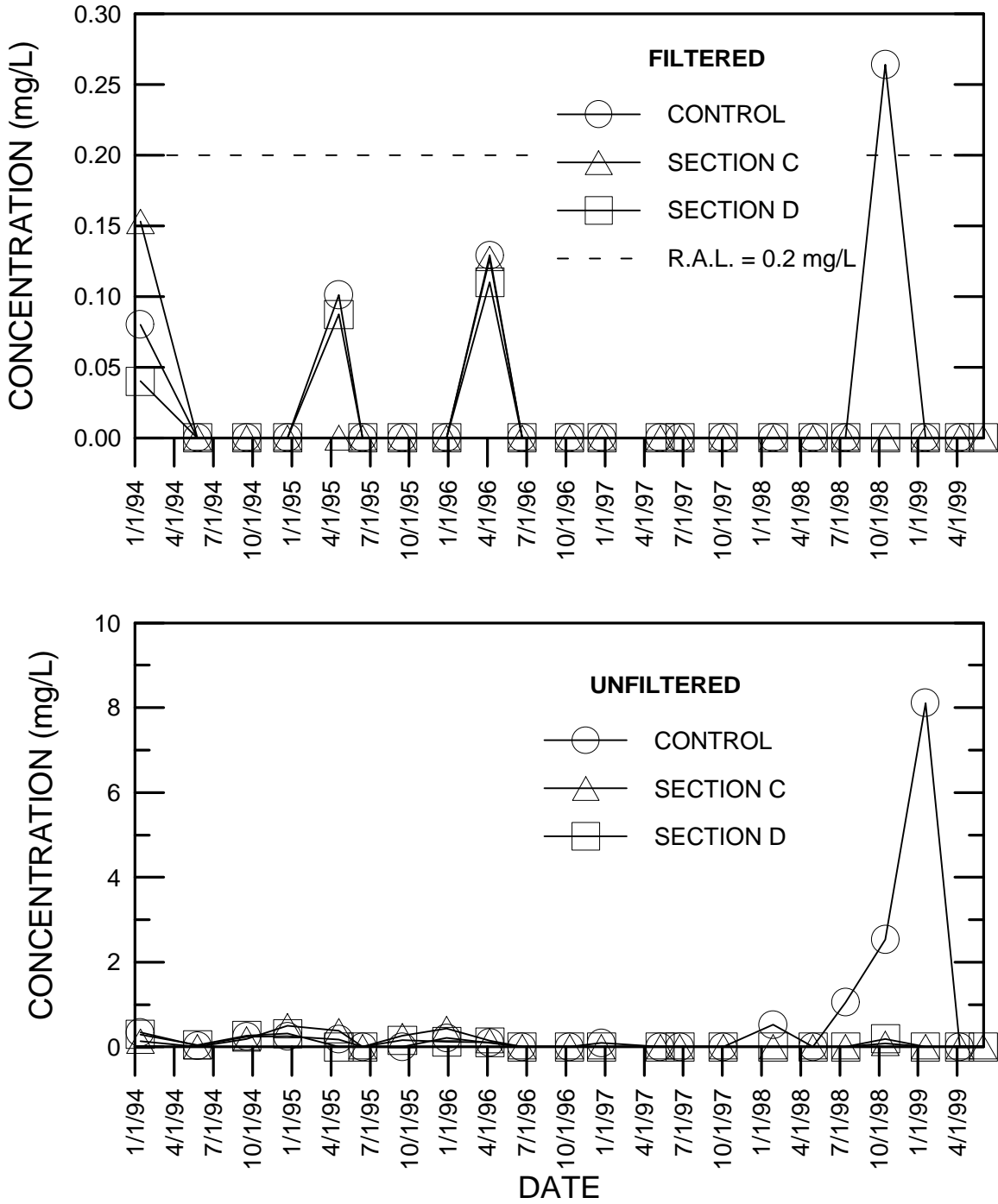


Fig. 6 Filtered and unfiltered aluminum (Al) concentrations.

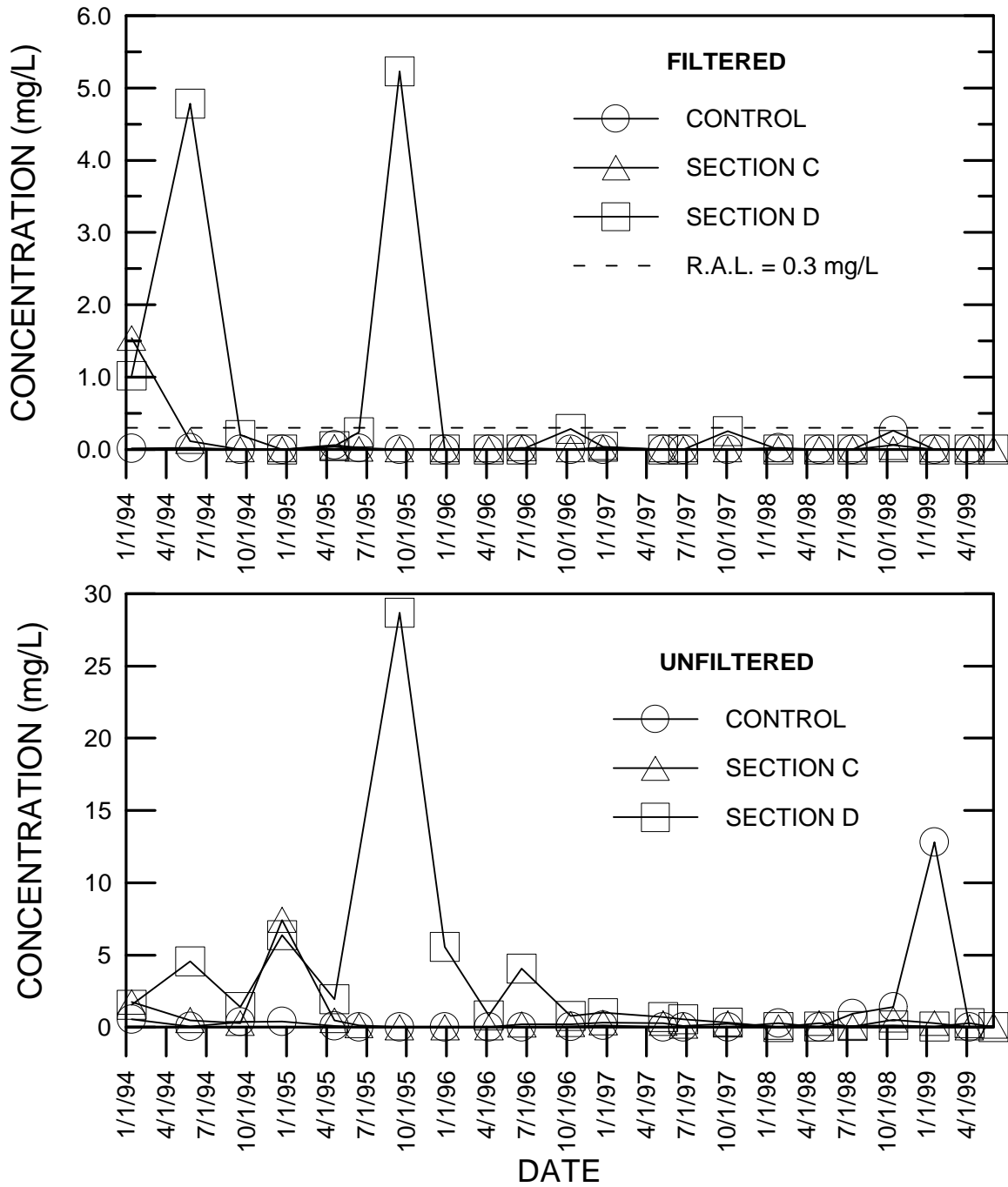


Fig. 7 Filtered and unfiltered iron (Fe) concentrations.

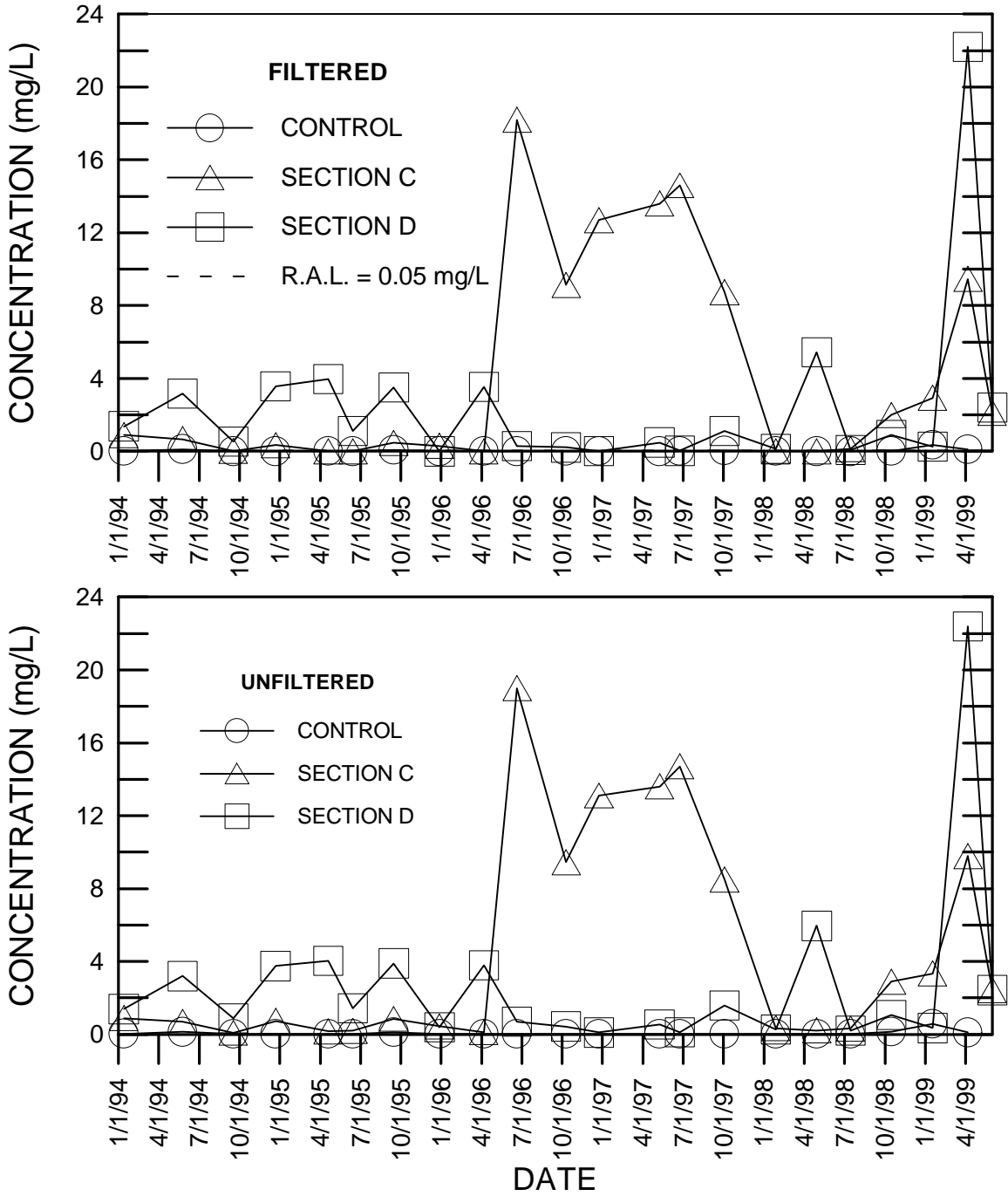


Fig. 8 Filtered and unfiltered manganese (Mn) concentrations.

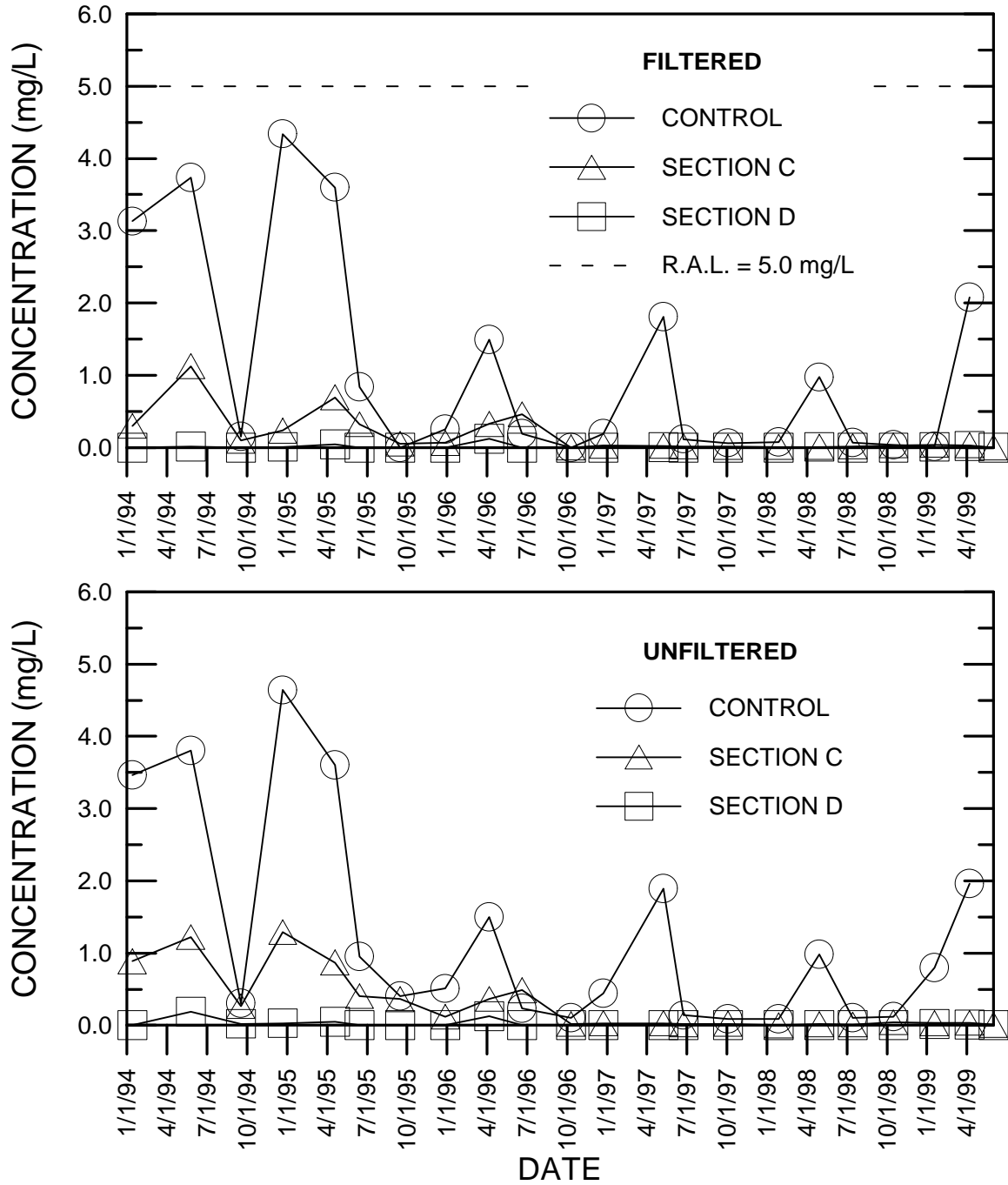


Fig. 9 Filtered and unfiltered zinc (Zn) concentrations.

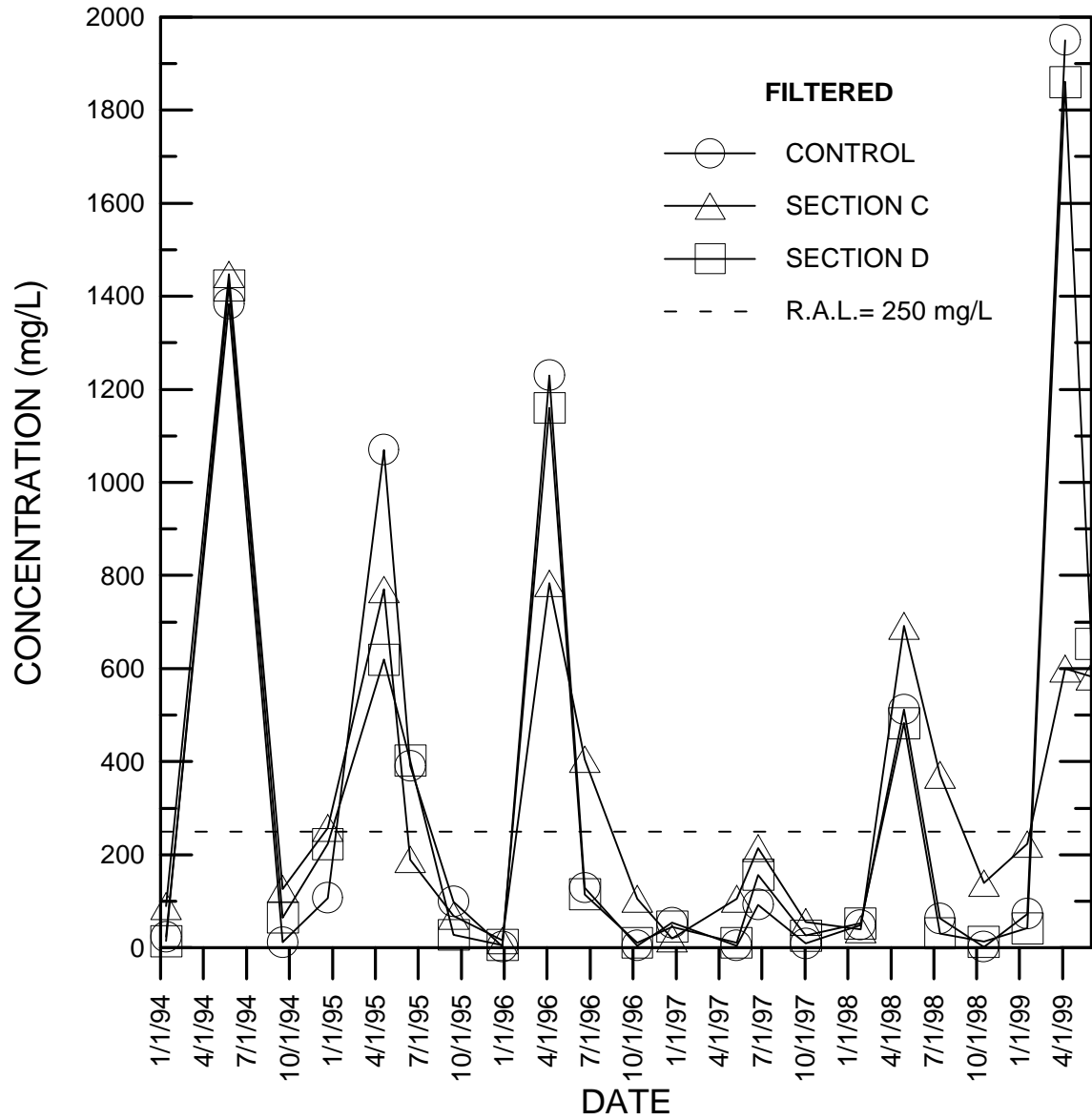


Fig. 10 Filtered chloride (Cl) concentrations.

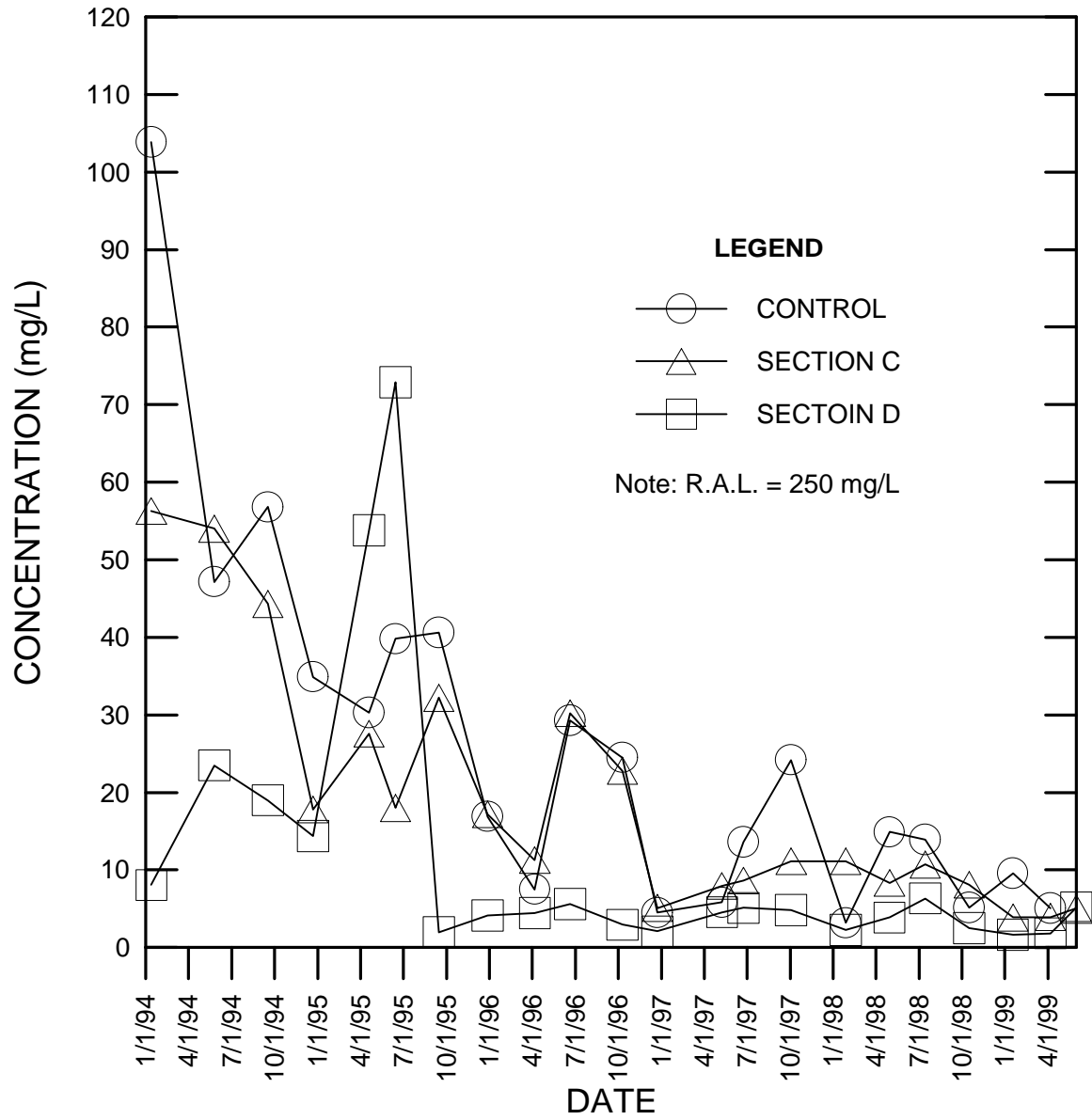


Fig. 11 Filtered sulfate (SO<sub>4</sub>) concentrations.

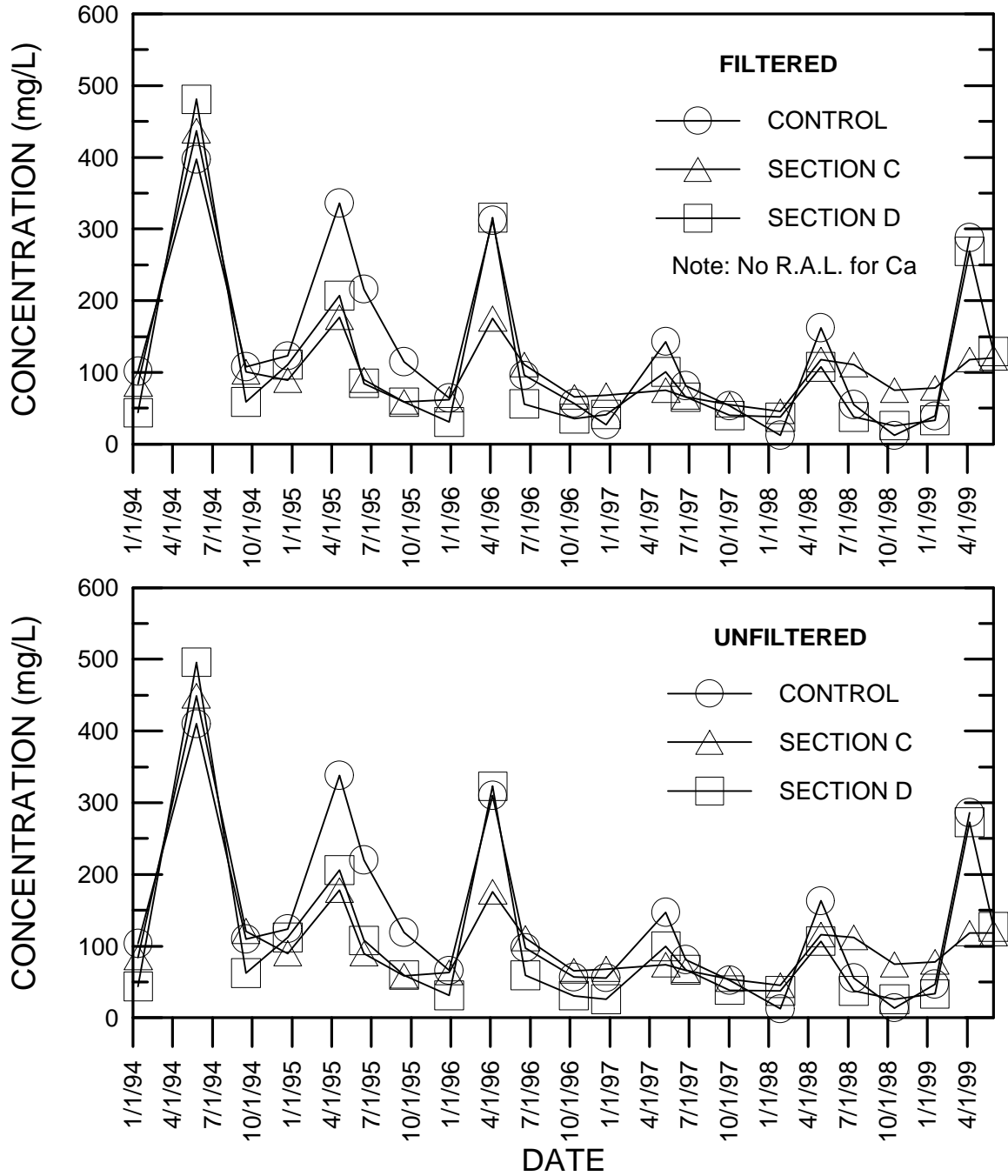


Fig. 12 Filtered and unfiltered calcium (Ca) concentrations.

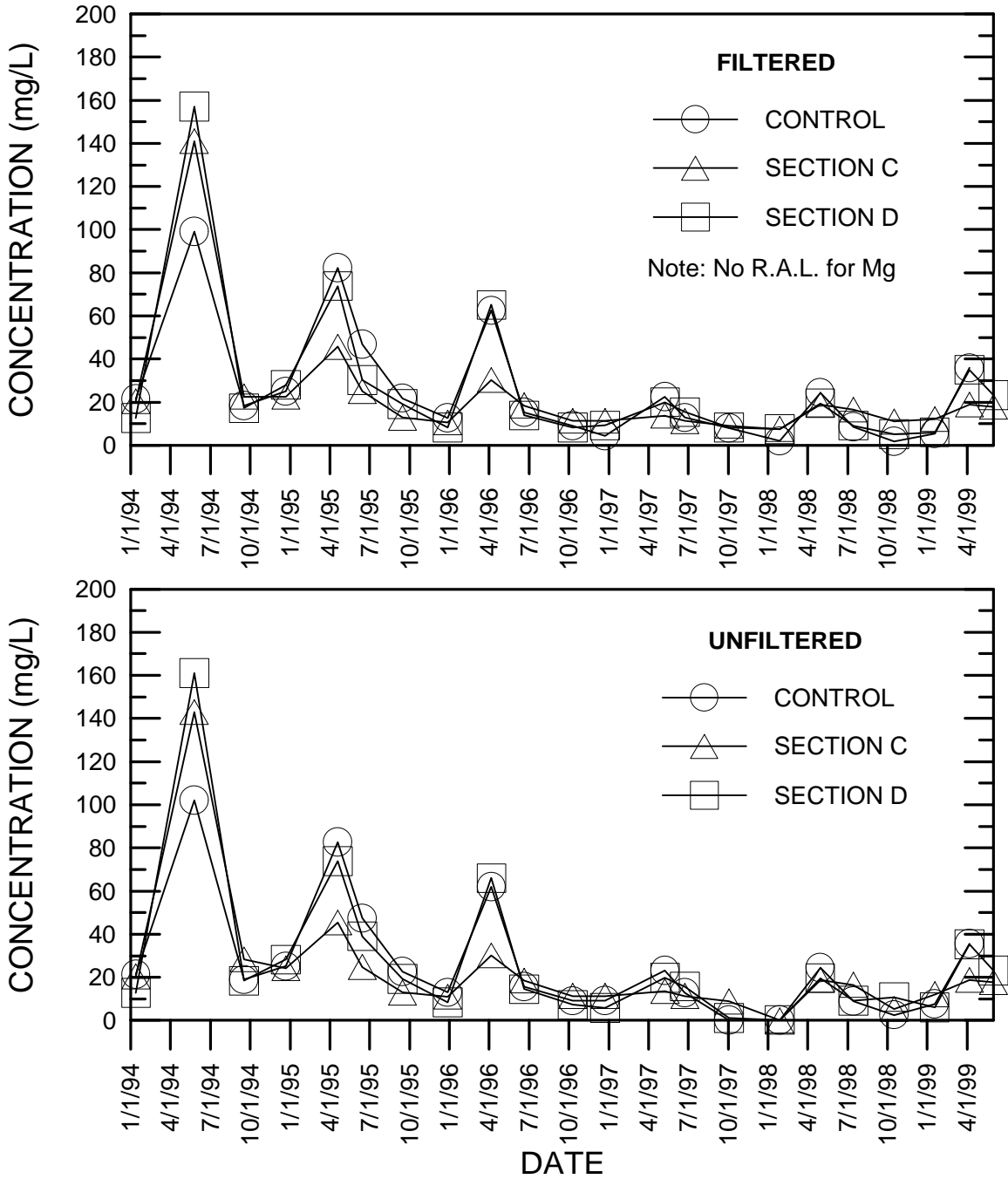


Fig. 13 Filtered and unfiltered magnesium (Mg) concentrations.

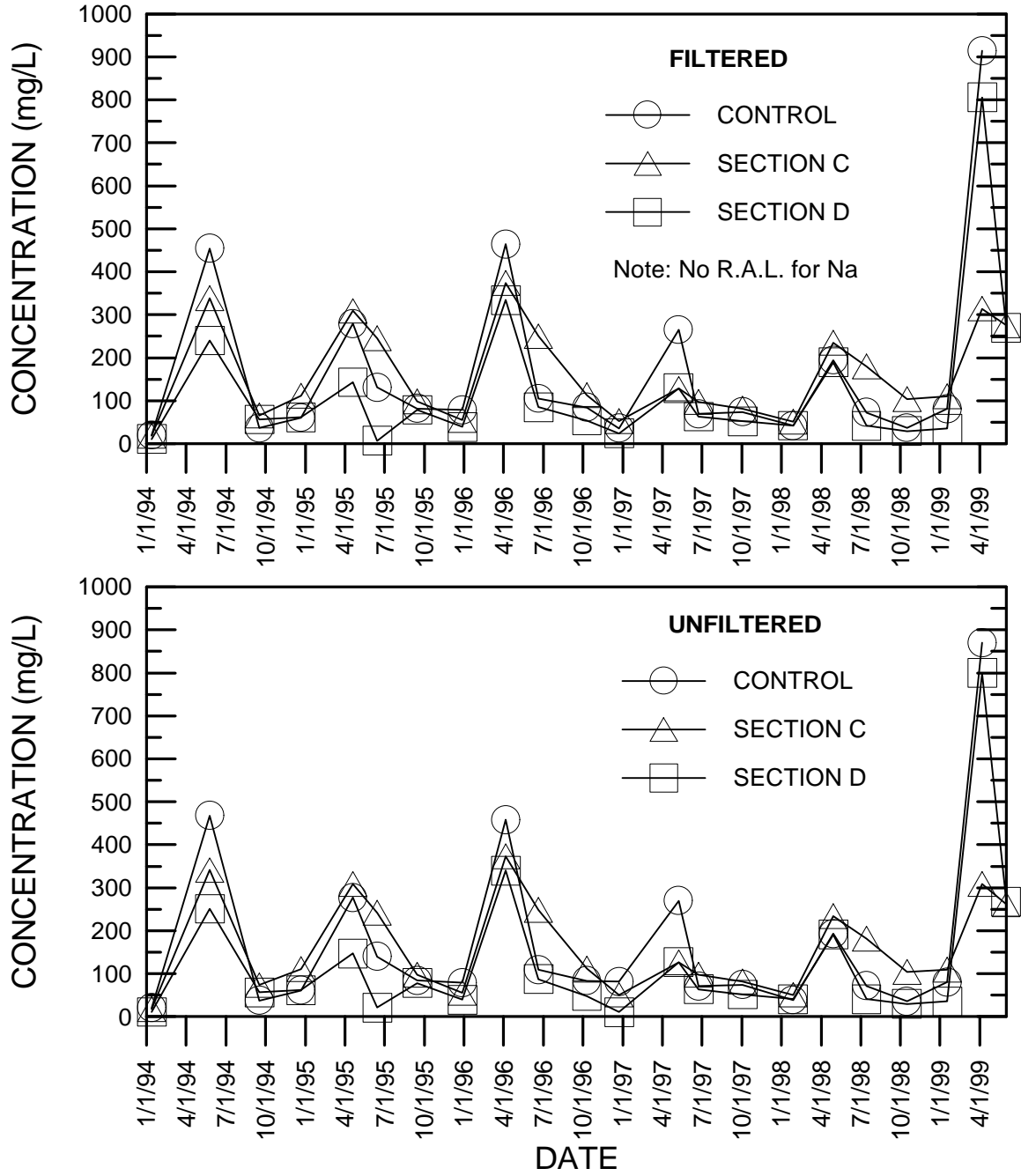


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