cyanazine concentration in about 25 percent of the post-application samples exceeded four times the HA (fig. 1). The maximum concentration of several herbicides exceeded 50 µg/L (fig. 1). Herbicide concentrations were much lower (generally less than 1 µg/L) during the pre-application and fall low-flow sampling periods; however, more than one-half the streams had detectable concentrations in all three sampling periods.

The 1989 reconnaissance documented for the first time the seasonal and geographic distribution of herbicides in streams at a regional scale. Because of the high post-application concentrations measured, and because of an increased level of concern caused by the results, a follow-up study was conducted in 1990 to verify the 1989 results. In the verification study 50 sites were selected for resampling. Selection of the sites was accomplished by ranking all samples from the 1989 post-application sampling round from highest to lowest according to the total herbicide concentration. This concentration is defined as the sum of the concentrations of all herbicides measured in each sample. These sites were then divided into three equal groups. From the group containing the highest concentrations, 25 sites were randomly selected. Similarly, 13 sites were randomly selected from the middle group, and 12 sites were randomly selected from the low concentration group. These sites were resampled before application and during the first runoff event after application in 1990 using the same protocols developed for the 1989 study. Results from the 1990 study confirmed the 1989 results. The statistical distributions of the concentrations of the major herbicides detected in these 50 streams were essentially the same during the pre- and post-application periods of both years (Goolsby and others 1991; also see figure 2). These results and those of other studies (Baker and Richards, 1989; Frank and others 1982; Leonard, 1988; Snow and Spalding, 1988; and Wauchope, 1978) further indicated that the "flush" of herbicides following application is an annual occurrence. Additional studies by the USGS in 1990 and 1991 using automatic samplers (Thurman and others 1992; Goolsby and Battaglin, 1993) show that the herbicide "flush" lasts for several weeks to several months following application. By late summer, herbicide concentrations generally decrease to low concentrations (less than 0.5 µg/L) and remain low until the process is repeated the following year.

Changes in Herbicide Use

Since the 1989-90 regional-scale studies were conducted, two reductions have occurred in the maximum application rate of atrazine recommended by the manufacturers' label. In 1990, because of concern about ground-water contamination, the manufacturers of atrazine voluntarily reduced the maximum recommended application rate for atrazine to 3 pounds a.i. (active ingredient) per acre per year for corn and sorghum (U.S. Environmental Protection Agency (EPA), written commun., Jan. 23, 1990). Prior to this, the recommended maximum application rate was 4 pounds a.i. per acre per year. The 1990 label change also restricted noncropland uses of atrazine to 10 pounds a.i. per year. This label change applied to all products released for shipment after September 1, 1990.

In 1992, due in part to concern about surface-water contamination, the manufacturers of atrazine further voluntarily reduced the maximum recommended application rate of atrazine to a range of 1.6 to 2.5 pounds a.i. per acre per year depending on soil organic residue and erosion potential. The maximum amount recommended per application is 2 pounds a.i. per acre. Up to 0.5 pound a.i. per acre per year can be applied in subsequent applications (EPA, written commun., March 8, 1993). The total of all applications cannot exceed 2.5 pounds a.i. per acre per year.