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### Geomorphological Approach to Toxic Trace Metal Distribution Across a Medial Bar Deposit in the Trout Brook of the Park River Watershed, Hartford, CT

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GEOMORPHOLOGICAL APPROACH TO TOXIC TRACE METAL DISTRIBUTION  
ACROSS A MEDIAL BAR DEPOSIT IN THE TROUT BROOK OF THE PARK RIVER  
WATERSHED, HARTFORD, CT

BY

KELSEY SEMROD

A THESIS SUBMITTED TO  
THE FACULTY OF THE ENVIRONMENTAL SCIENCE PROGRAM  
IN CANDIDACY FOR THE BACCALAUREATE DEGREE  
WITH HONORS IN ENVIRONMENTAL SCIENCE

ENVIRONMENTAL SCIENCE PROGRAM

HARTFORD, CONNECTICUT

MAY 2, 2012

GEOMORPHOLOGICAL APPROACH TO TOXIC TRACE METAL DISTRIBUTION  
ACROSS A MEDIAL BAR DEPOSIT IN THE TROUT BROOK OF THE PARK RIVER  
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Honors Thesis Committee

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## **Abstract**

The Trout Brook, a major tributary of the Park River watershed, was sampled for heavy metals in sediment with a focus on Pb, Cu, Cd, and Zn. These metals are known to be contaminating the river due to a history of discharge from metal finishing industries. In a watershed-wide survey conducted in September 2011, high concentrations of metals were found in the Trout Brook, with some sites exceeding the probable effect concentration (PEC). The Trout Brook contains a Sanitary Sewer Overflow (SSO) and a vegetated medial bar that may be trapping sediment. Based on the results of the earlier studies, this site was chosen for an in depth analysis. In 2010, a detailed sediment study was performed at the landfill site, located on the north bank of the Trout Brook further downstream from the SSO site, which contained a landfill point source and a sand bar. It was unclear what lead to the high heavy metals values: the SSO or the effects of sediment transport around the bar. The Trout Brook SSO site provides the opportunity for a more detailed analysis of the relationship between a potential point source and a vegetated bar and resulting sediment contamination. The purpose of the study was to determine the degree to which the SSO and the medial bar affect the distribution of heavy metals. Forty-nine samples were taken on the north and south banks of the Trout Brook SSO site and on either side of the vegetated bar. Five sediment cores were taken from the bar to determine if trace metals are accumulated within the river's older deposits. Trace metals in sediments were analyzed using a weak-acid digestion method and an Inductively Coupled Plasma-OES (ICP-OES). Highest concentrations of metals were found at the SSO and therefore it is concluded that the SSO acts as the main source of heavy metal contamination, and that the medial bar has no effect on the distribution of metals in sediment.

## **Introduction**

Trace metal contamination in watersheds is common in urban areas due to large areas of impervious surface, waste discharge, and overall urbanization. The Park River Watershed in central Connecticut is an urban watershed impacted by metal finishing facilities that historically have discharged metal waste directly into the stream. This study examines trace metal contamination in sediment of the Trout Brook, a tributary of the Park River, that is known for high heavy metal concentrations, and determines if sediment-bound metal distribution is more affected by the presence of a medial vegetated bar or a Sanitary Sewer Overflow (SSO) point source discharge. It is hypothesized that the main source of metal contamination in the Trout Brook comes from the SSO.

This paper will first discuss metal contamination and the process by which metals bind to sediment particles in freshwater under the “Metal Contamination in Aquatic Sediments” section. This section will also outline the sources of heavy metal pollution, how these metals affect aquatic life, and the importance of a vegetated bar in the distribution of metals in sediment. Secondly, sediment quality guidelines and past studies on heavy metal contamination in sediment are discussed to provide context to metal concentration values. In the sections titled “Park River Watershed” and “Past Studies on the Park River Watershed”, the history of the watershed is discussed as well as the results of metal contamination from previous studies. These past studies help to understand the severity of metal contamination in the area and put the Trout Brook site in greater overall context. Next the West Hartford Landfill study is discussed as it contains two variables present in the Trout Brook: a potential point source and a landmass that may trap sediments. The “West Hartford Clean Water Project” section provides insight on the steps the West Hartford city council is taking toward

the reconstruction and clean-up of its sewer systems.

### *Metal Contamination in Aquatic Sediments*

Sediments accumulate a variety of contaminants and are considered sources of pollution to the various ecosystems in which they are found. Contaminants, such as trace metals (i.e. lead (Pb), zinc (Zn), cadmium (Cd), and copper (Cu)), tend to bind to both inorganic and organic materials that are deposited into the environment (Miller and Miller 2007). These trace metals are harmful to organisms that inhabit the ecosystem (Lyman et al. 1987). For example, when organisms such as benthic macroinvertebrates or freshwater fish ingest toxic trace metals, they are susceptible to mutations, which have negative effects on reproduction, and therefore could lead to declines in the population (Burton 2000).

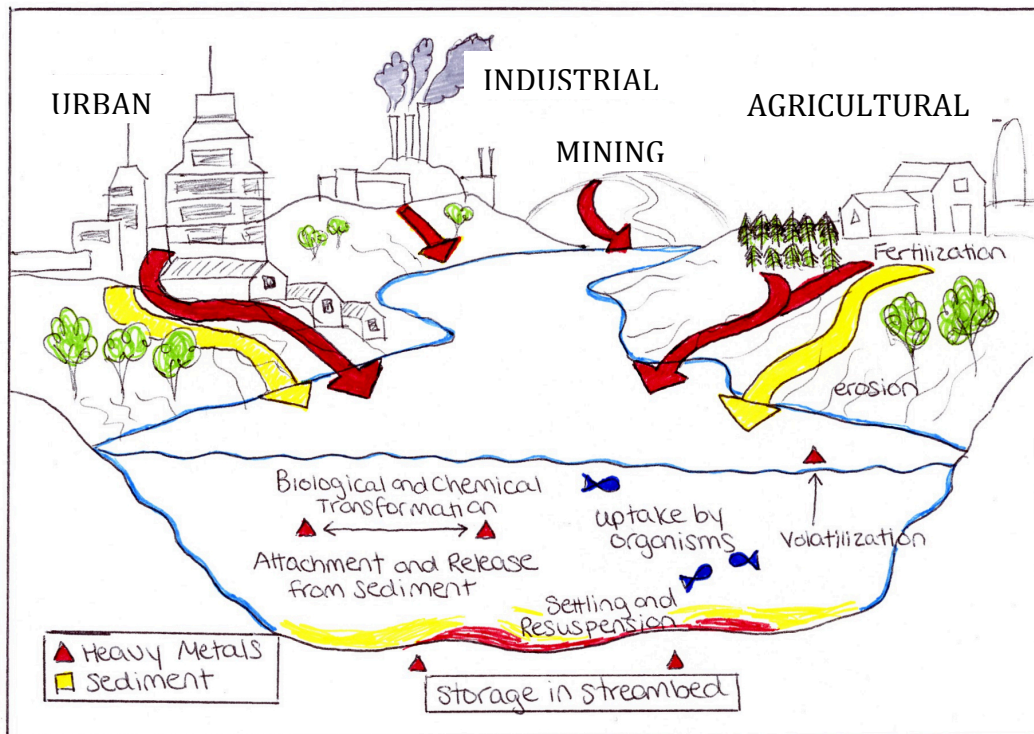
Trace metals can have harmful effects on living organisms when found naturally in water or sediment, and concentrations less than 1 ppm in both water and sediment can be detrimental to ecosystems in which they are found (USGS 2011). For example, organisms in these heavily polluted environments can either develop a resistance to the metals or possibly adapt genetically, or they are removed from the ecosystem altogether (Klerks 1986). These adaptations can affect the ecosystem's food chain or cause a species to become extinct.

Trace metals can enter terrestrial and aquatic ecosystems through atmospheric deposition and point and non-point sources discharging into surface water (Fig. 1). Point and non-point sources of these contaminants are more often found in or around urban areas. Examples of point source emissions include industrial and storm water sewer outfalls. Urban specific non-point sources include automobile emissions, runoff from roadways and gas leaks. Rural specific non-point sources include runoff from manure and artificial fertilizers



from farms that contain heavy metals. Trace metals can also come from natural sources such as volcanic emissions and the weathering of rocks (Rice 1999).

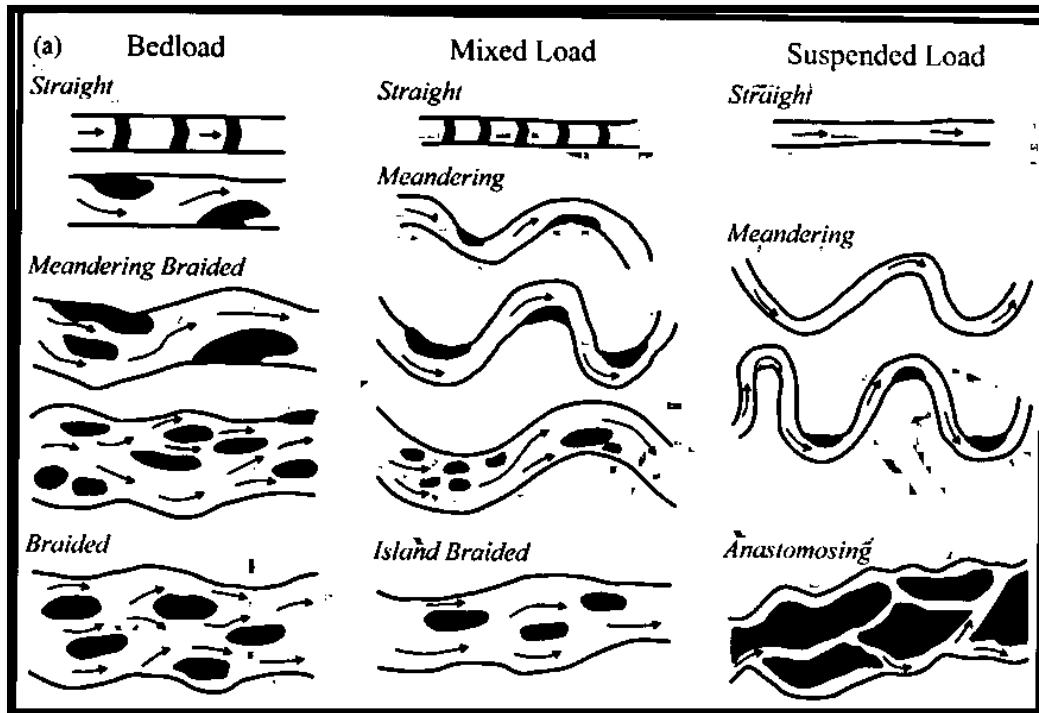
Trace metals have an affinity to adsorb to finer bedload sediment due to higher surface area to volume ratio of the particles. Also, finer grained sediment tends to have more reactive surfaces in which metal adsorption occurs at a high level; such is the case with clay minerals, organic materials and Fe/Mn oxides (Miller and Miller 2007). Once the contaminants bond with the sediment particles, they are less likely to be released, and desorption is slow. Unless there are significant chemical changes in the aquatic system, contaminants reside in the bedload sediments for long periods of time (Burton 2007). High concentrations of trace metals are not found in stream waters that have basic pH values because metals are more likely to bind to charged sediment particles in those high pH environments (Miller and Miller 2007).



**Figure 1:** The distribution and transport of trace metals in sediment and their sources (Hill, 2010). Trace metals may be deposited by urban, industrial, or agricultural sources. They then may attach to sediment, be suspended at the bottom of a water body, or be taken up by organisms.

Stream discharge and velocity patterns also affect the ability of trace metals to accumulate in sediment. Contaminants will generally accumulate in areas of a river with low velocity, for example, or along river banks, deep pools, and sand bars, where a large quantity of fine sediment (grain size  $<63 \mu\text{m}$ ) can be found (Miller and Miller 2007).

Highly dynamic stream channels with excess sediment may develop into braided morphologies with abundant sand bars. These medial or longitudinal bars are oriented roughly parallel to the general flow direction (Fig. 2) and are generally migratory and transient (Miller and Miller 2007). Flow is sometimes diverted around the bars causing some erosion of the bank sediment. The combined effect of bed and bank erosion lowers the water level and a bar emerges that separates the channel. As sediment moves through the channel, some particles are deposited at the downstream end of the medial bar where depth increases and flow velocities decrease. Characteristics of these bars are important in determining the degree to which their shape can affect the distribution of heavy metals in sediment. The combination of certain characteristics, like low water velocity and a curved bank, may allow higher contamination in some areas over others.



**Figure 2:** Classification of channel bed patterns (Miller and Miller 2007).

## *Sediment Quality Criteria*

Trace metal contamination of freshwater sediment is a phenomenon that has been studied by many researchers from as early as the 1980's (Lyman et al. 1987, Ingersoll et al. 2000, MacDonald et al. 2000, Giddings 2001, Rice 2009). Their research showed that sediment quality guidelines could substantially increase the reliability, predictive ability, and level of confidence in determining overall health of freshwater systems.

Ingersoll et al. (2000) and MacDonald et al. (2000) calculated mean sediment quality guidelines (SQG) and probable effect concentrations (PEC) in order to evaluate the combined effects of multiple contaminants in sediments on organisms (Table 1). In MacDonald's study, concentrations of different metals were tested on a variety of organisms to determine dangerous metal contamination levels. SQG values represent a range of metal concentrations by which an ecosystem is likely to be negatively influenced by the metal. The PEC represents the metal concentration above which harmful effects on sediment dwelling organisms are expected to occur frequently (MacDonald 2000).

<b>Metal</b>	<b>Sediment Quality Guidelines (SQG)</b>	<b>Probable Effect Concentration (PEC)</b>
Cadmium	3 – 10 ppm	4.98 ppm
Copper	86 – 390 ppm	149 ppm
Lead	82 – 250 ppm	128 ppm
Zinc	270 – 820 ppm	459 ppm

**Table 1:** Sediment Quality Guidelines (SQG) and Probable Effect Concentrations (PEC) for heavy metal concentrations in sediment in determining stream quality (MacDonald et al. 2000).

### *Sediment Quality Studies*

Sediment quality studies across the United States performed by the USGS and EPA have indicated that industrial sources are the primary contributors to high concentrations of trace metals in the environment (Burton 2000). Rice (2009) analyzed very fine (<63 µm) streambed sediment collected from 20 study areas across the continental United States. Forty-nine percent of the samples collected from urban settings in Rice's study had concentrations of one or several trace metals that could cause adverse biological effects on aquatic biota. Giddings (2001) looked at contaminated sediment in Utah, in areas historically mined for silver and lead ores. Concentrations of streambed sediment exceeded background concentrations and scientists established aquatic life criteria at most sites. In the northeast region of the United States, due to its high levels of industrial activity, there are elevated concentrations of trace metals in sediment (Lyman 1987).

### *The Park River Watershed*

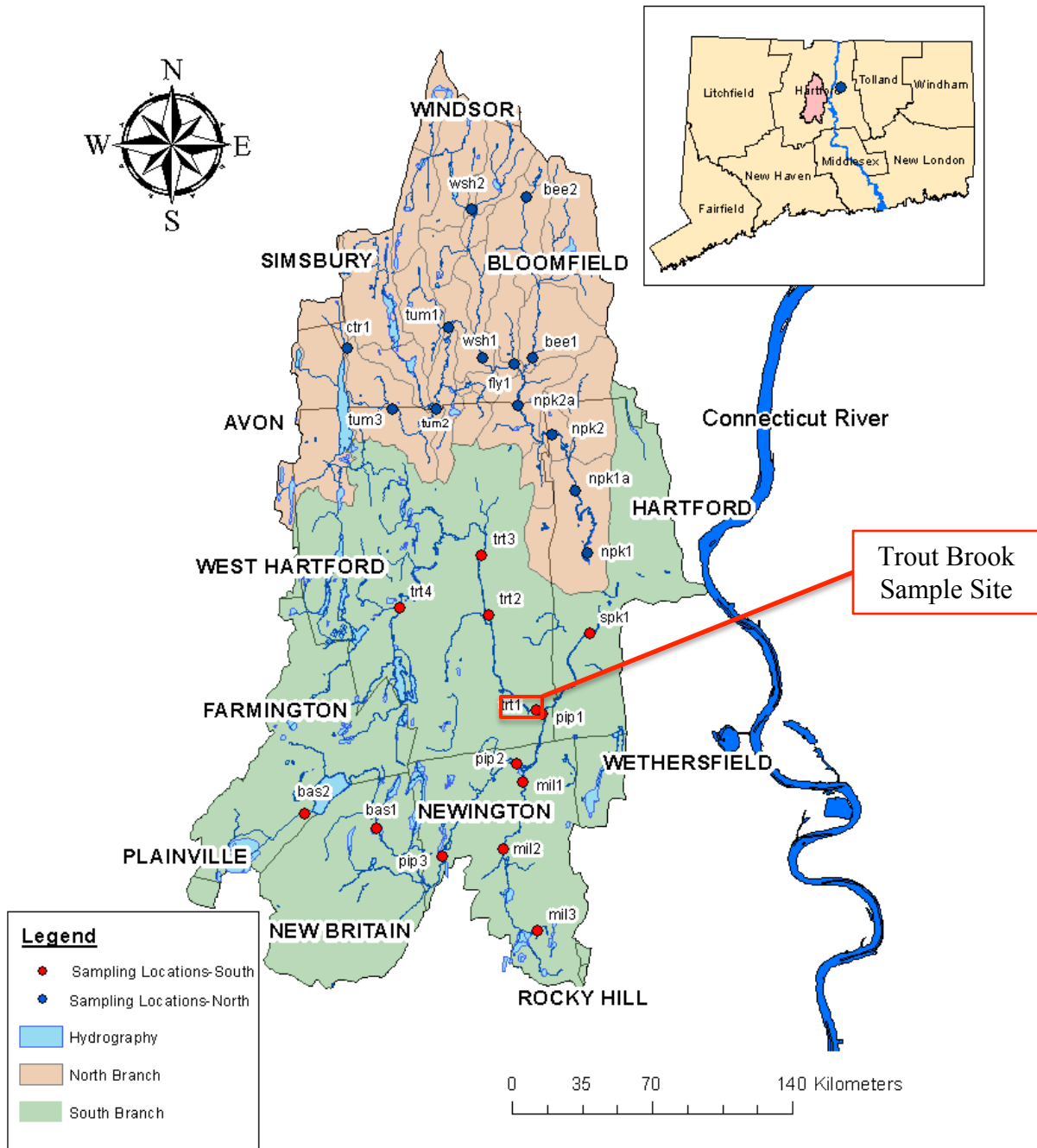
In order to better understand the sources of trace metal in the Trout Brook site (this study's focus area), it is necessary to understand the overall distribution of trace metals across the entire the Park River Watershed. The Park River Watershed, located in Hartford, Connecticut has known metal contamination from industrial sources. Past studies (Doñé et al. 2009) have focused on macroinvertebrates, water, and sediment throughout the watershed to determine the degree of contamination and overall stream quality. High metal concentrations are mostly seen in the south branch of the Park River Watershed due to high urbanization (Doñé et al. 2009) and a high concentration of industries that report trace metal discharges in their waste water effluent.

The Park River Watershed is a sub-watershed of the Lower Connecticut watershed (Fig. 3). Towns included in the watershed are West Hartford, Newington, Wethersfield, Bloomfield, Avon, New Britain, Farmington, Simsbury, and Hartford. The watershed covers 77.2 square miles and the river itself eventually empties into the Connecticut River, just south of downtown Hartford (Fig.3).

The north and south branches of the Park River converge into two parallel tunnels beneath downtown Hartford. From the entrance of the tunnel, the North branch extends 6.2 miles upstream to the north and northwest before it reaches the tributaries of Wash Brook and Tumble Brook. The South branch of the Park River extends south 4.1 miles upstream before it splits into the tributaries of Piper Brook and Trout Brook. The North branch of the Park River has a drainage area of about 27.7 square miles and the South branch has a drainage area of 47 square miles (Caruso 2005).

The Park River watershed has a long history of being used as a waste disposal site for much of the industry in the greater Hartford area. During the 1800's, as Hartford continued to grow, companies dumped their excess waste into the river (Caruso 2005). Current sources of waste disposal into the Park River include metal finishing, metal plating, aerospace industries, and firearms manufacturing (Right-To-Know-Network 2010). These industries have specifically discharged Pb, Chromium (Cr) and Cu into the river for at least 20 years (Right-To-Know-Network 2010).

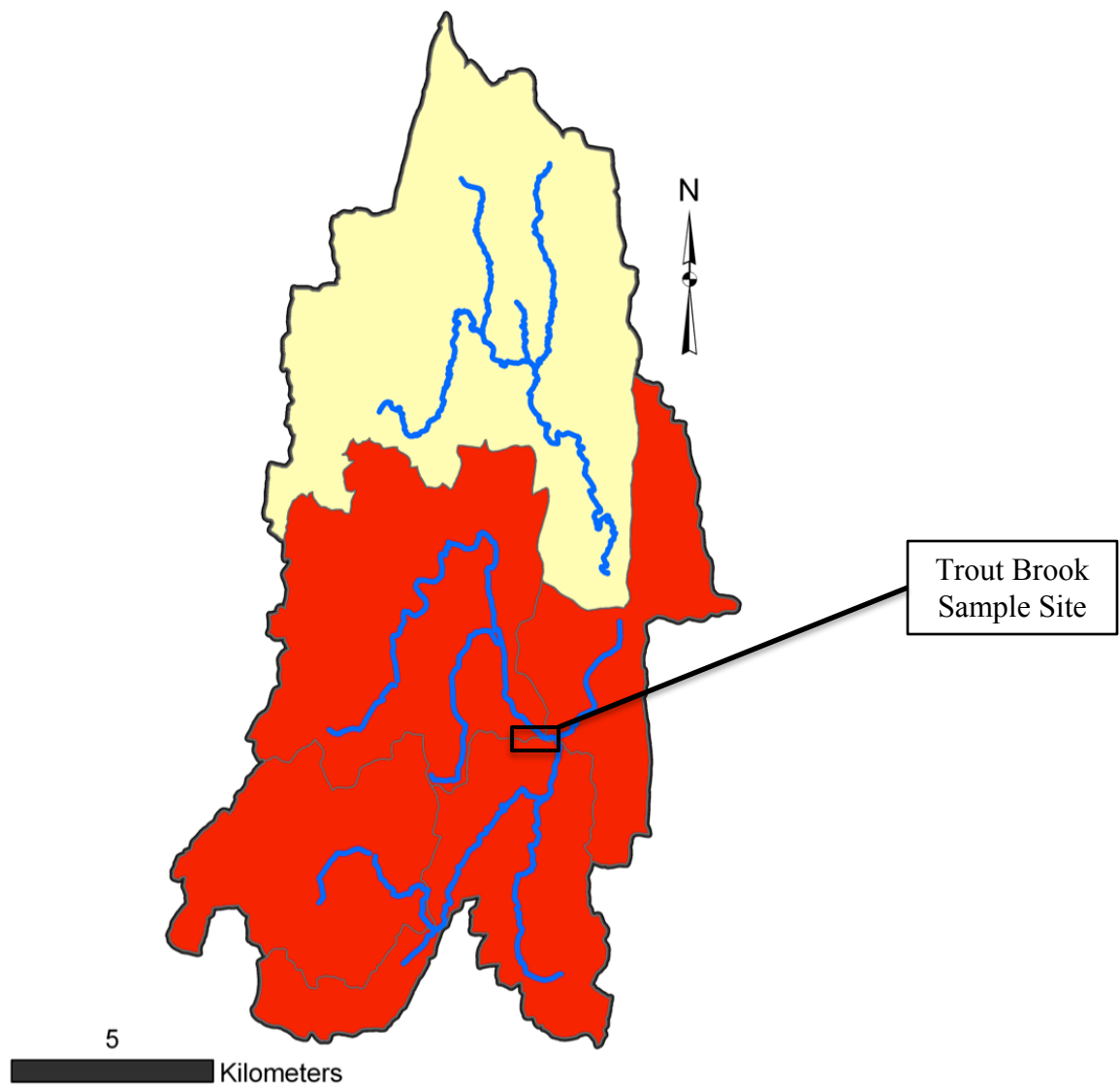




**Figure 3:** Location of Park River watershed in CT. Sediment sample locations in the North and South Branch of the Park River watershed from 2011 providing a ‘watershed-wide’ view of metal distribution in sediment. The Trout Brook sample site (this study) is denoted by the red box.

Many of these metal-finishing sites discharge their waste into nearby streams through storm water. In the Hartford region, storm water is often combined with sanitary sewage when it rains. This combined waste stream is discharged directly to the Park River system in an Sanitary Sewer Overflow (SSO). An SSO may contain high levels of trace metals, suspended solids, pathogenic organisms, toxic pollutants, nutrients, and oil. During precipitation events, especially during ‘peak flow’, discharge is heightened and the sewer system reaches capacity and overflows (MDC 2012).

The south branch of the Park River watershed also contains a greater area of impervious surfaces than the North Branch (Fig. 4). During instances of rain, contaminants are more likely to run off across these impervious surfaces into the tributaries of the Park River, thus increasing non-point sources of pollution into the south branch. Therefore, higher amounts of impervious surfaces can lead to increased adverse effects of trace metals on ecosystems in this stream and its tributaries (Doñé and Gourley 2009; Pool 2012).

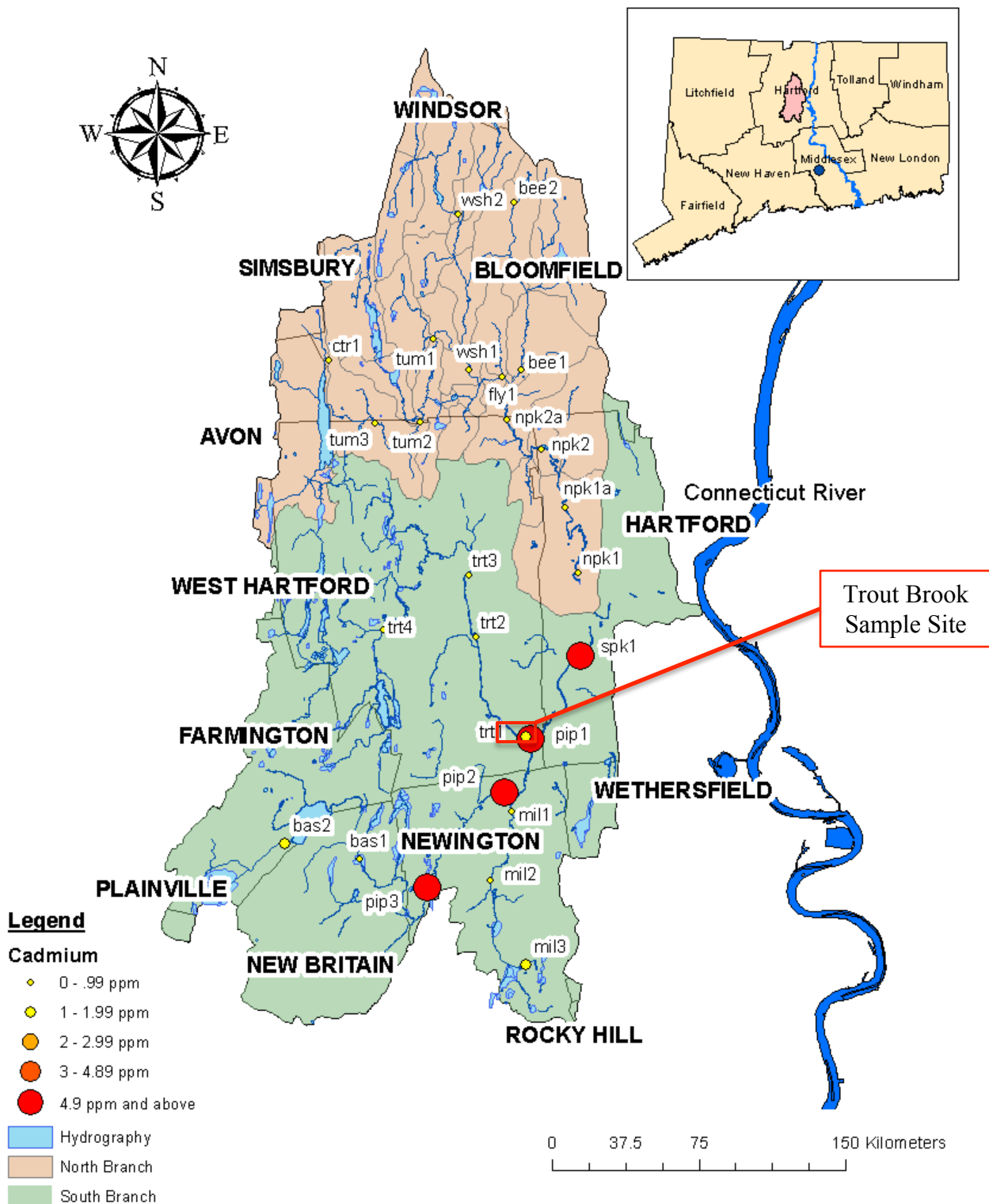


**Figure 4:** Percent impervious surface coverage in the park river watershed. The red denotes impervious surface coverage over 25 % (Doñé et. al. 2009). The south branch contains the highest amounts of impervious cover and therefore contributes more to metal contamination.

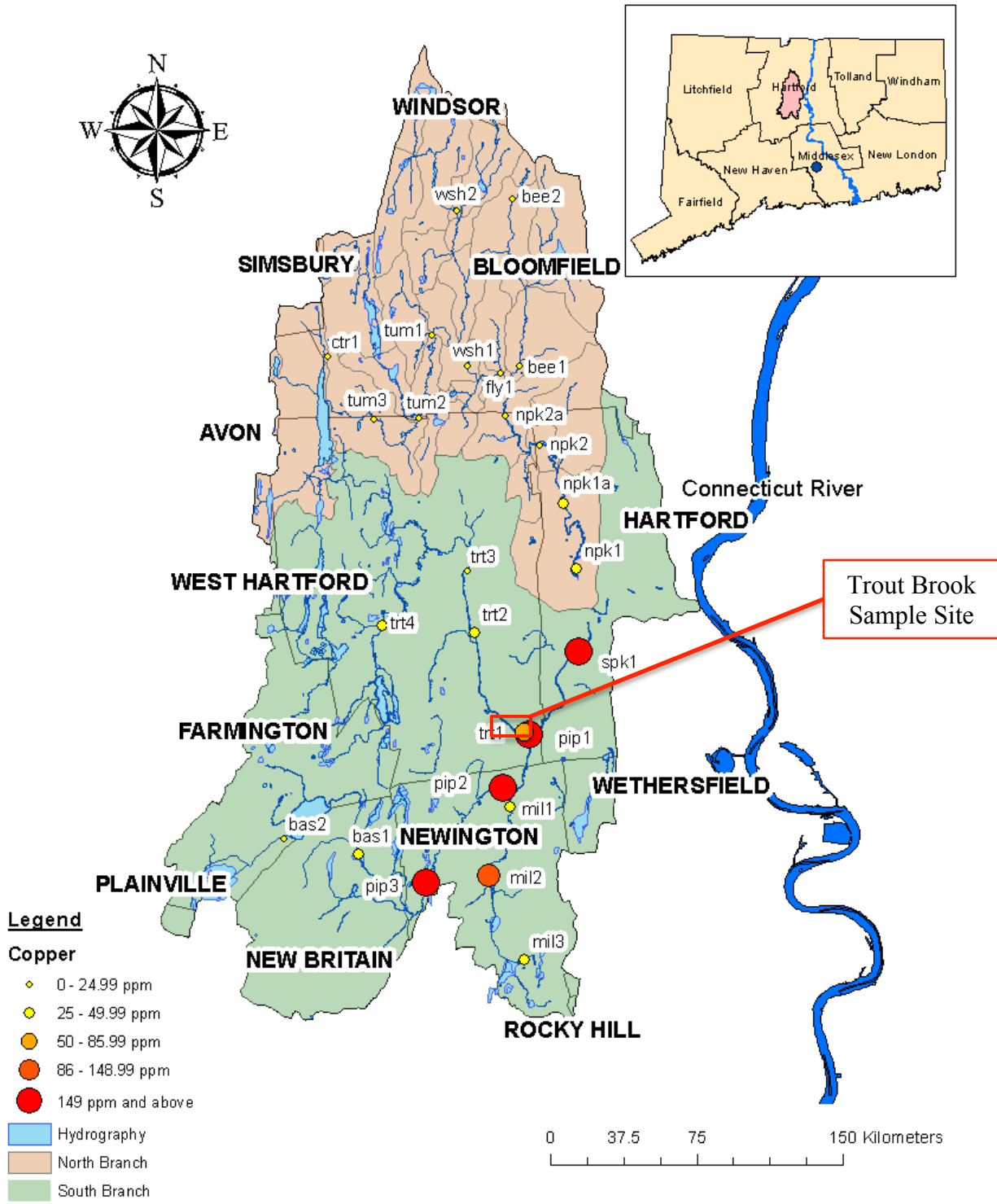
### *Past Studies on the Park River Watershed*

There has been some recent investigation into trace metal contamination in the Park River. Doñé et al. (2009) and Gourley (2009) have shown the severity of contamination by trace metals Pb, Cd, Zn and Cu in the river sediment. These studies help to understand the severity of metal contamination in the area as well as the most contaminated areas that need further study. Many sites in the south branch region of the watershed, for example, contain metal concentrations above the PEC (Gourley 2009).

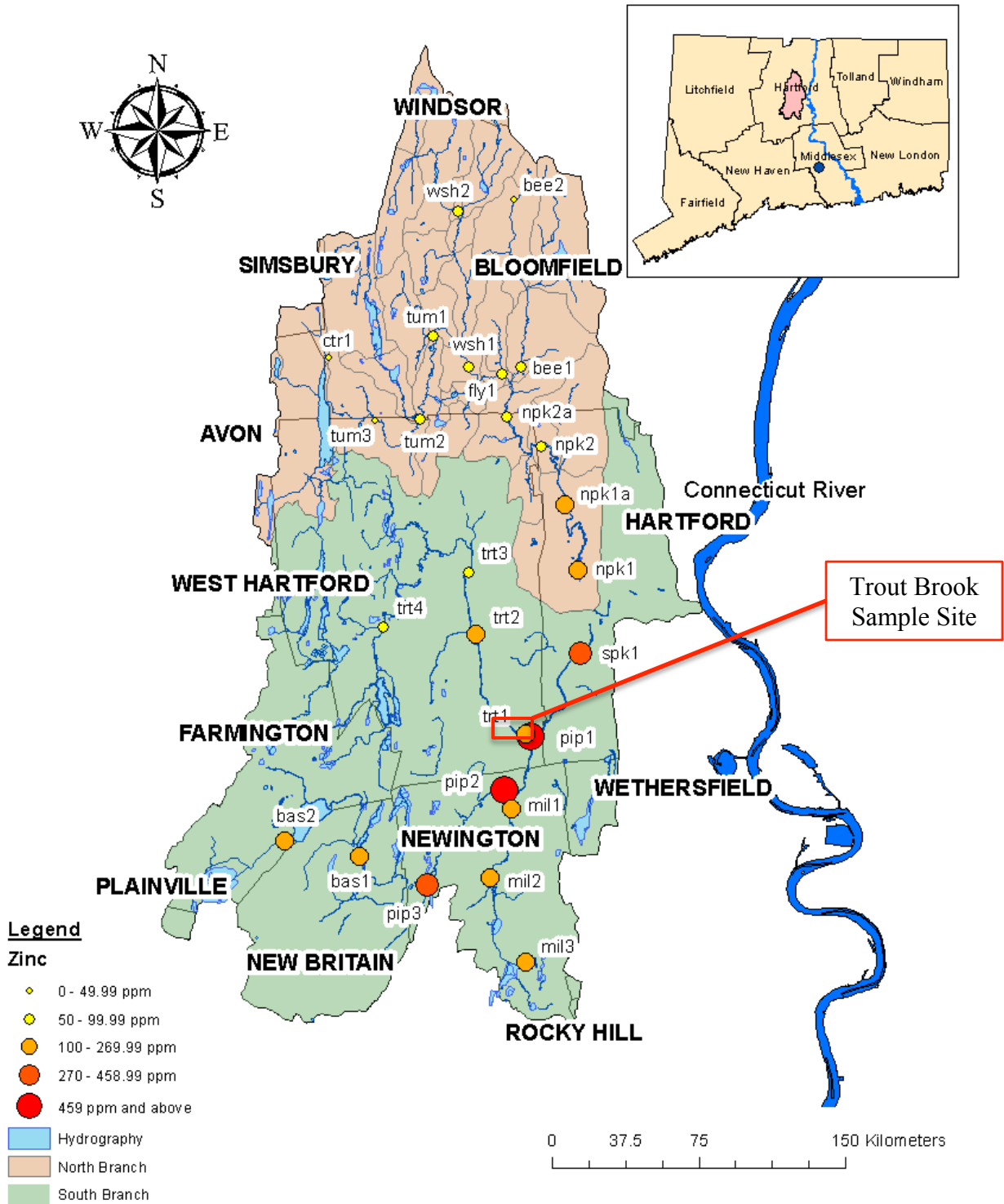
In fall of 2011, 26 sediment samples were taken on two consecutive days at all sampling locations to get a ‘watershed-wide’ snapshot of heavy metal distribution in sediment throughout the watershed. Cd was found to be highest in the Piper Brook and the South Park locations and was present in levels above the PEC (Fig. 5). Cu values above the PEC were also recorded in the same four locations as Cd, with two other sample sites showing Cu values in the SQG range (Fig. 6). Zn values above the PEC were located in two Mill Brook and Piper Brook sites and a few other sample sites in the south branch showed Zn values were in the SQG range (Fig. 7). Pb is unique in that high values were seen across the entire southeastern portion of the watershed (Fig. 8). In each case, Pb, Cu, Cd, and Zn concentrations were highest in the south branch, where the watershed is more urbanized. The elevated heavy metal contamination in the south branch inspired further study of this sub-basin.



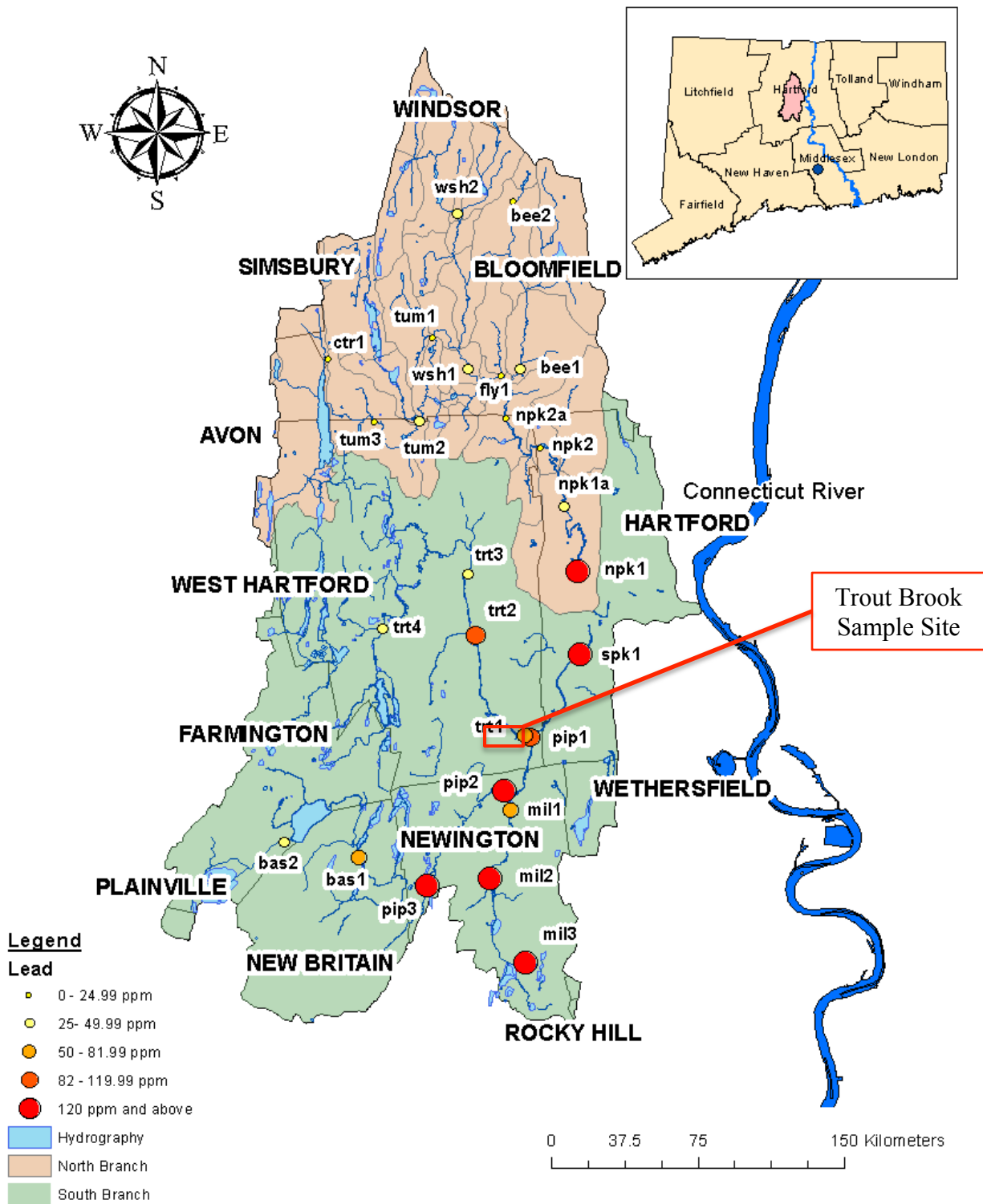
**Figure 5:** Cadmium concentrations throughout the entire watershed. The map shows that the South Branch contains higher concentrations of the cadmium in the watershed. Red circles indicate values above the PEC.



**Figure 6:** Copper concentrations throughout the entire watershed. The map shows that the South Branch contains higher concentrations of the copper in the watershed. Red circles indicate values above the PEC.



**Figure 7:** Zinc concentrations throughout the entire watershed. The map shows that the South Branch contains higher concentrations of the zinc in the watershed. Red circles indicate values above the PEC.



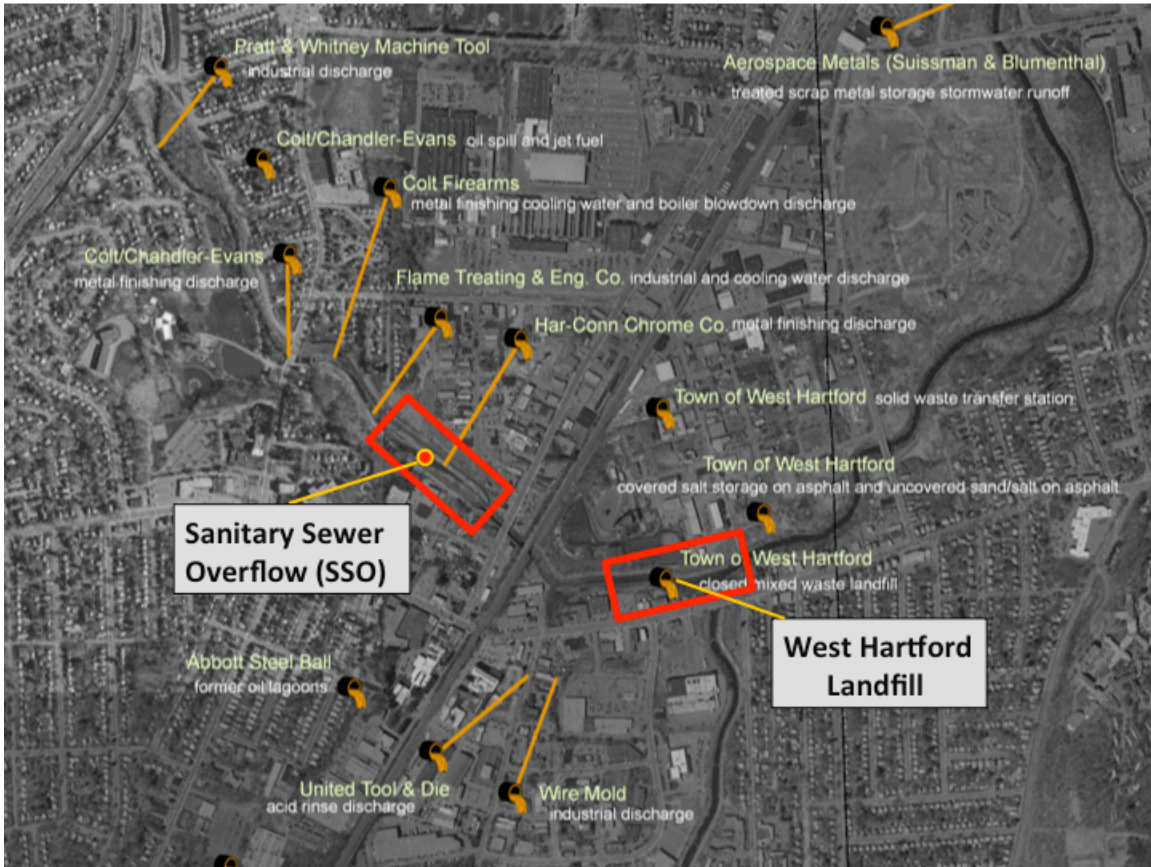
**Figure 8:** Sample sites in the South Branch contain higher concentrations of lead than other sample sites in the Park River watershed. The red circles indicate values above the PEC.



### *West Hartford Landfill*

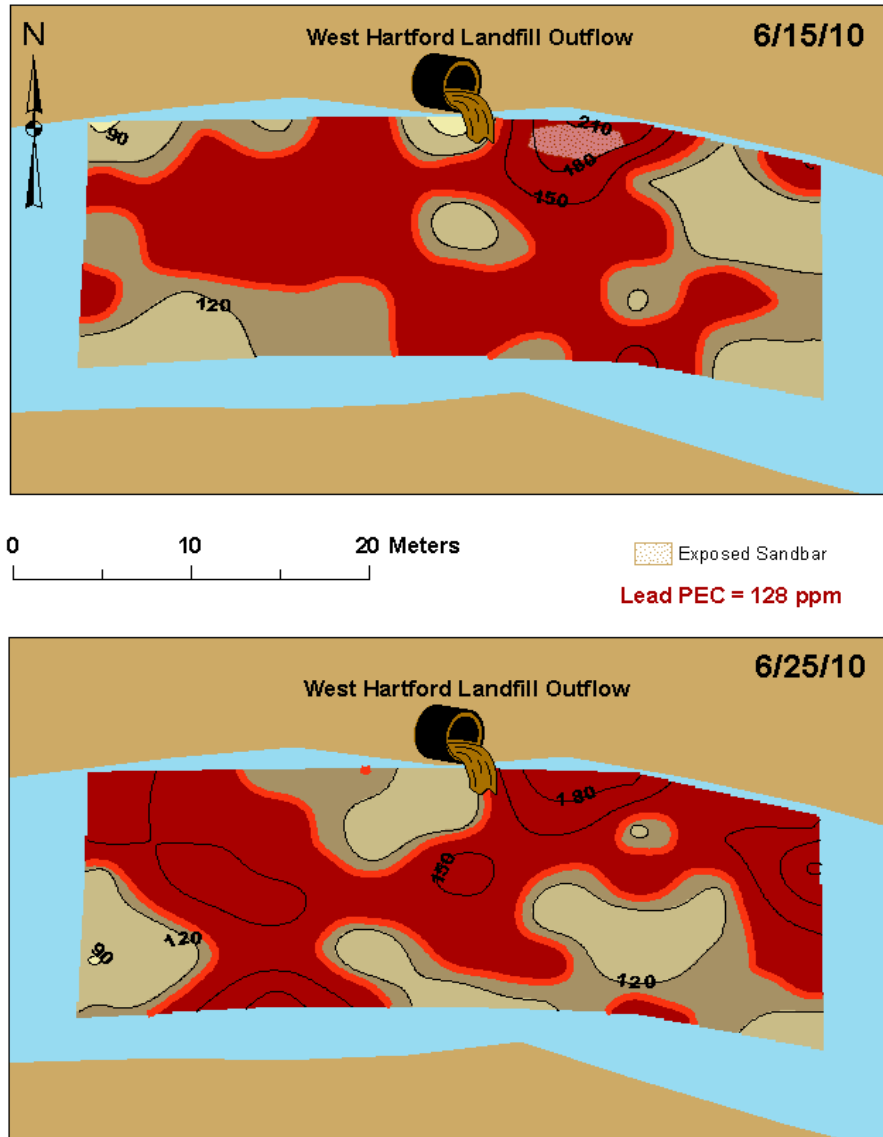
In 2010, a detailed sediment study was performed at the West Hartford landfill, located on the north bank of the Trout Brook further downstream from the SSO site (Fig. 9) (Doñé et al. 2010). This study provides a relevant comparison to the Trout Brook SSO sample site because it contains the same two variables of a potential point source and a land mass downstream of the source that could be trapping sediment (a sand bar in this case). High concentrations of Pb, Cu, Cd, and Zn were recorded downstream of the landfill before and after rain events (Figs. 10 and 11). Pb in particular was found to be in high concentrations throughout the sediment of the study site and not just at the landfill outfall. While it was suspected that the landfill point source was a source of heavy metals, it was not clear if the sediment below the landfill was contaminated because of the sand bar acting as a sediment trap, or because of the proximity to the outfall.

To test the problem at another location, this current study investigated another major storm water outfall in proximity to channel bar deposits. The Trout Brook SSO site was chosen to compare to the West Hartford landfill study (Doñé et al. 2010) and to provide more detailed analysis of the relationship between a potential point source and a sand bar in an attempt to see how each affects the distribution of heavy metals in sediment.



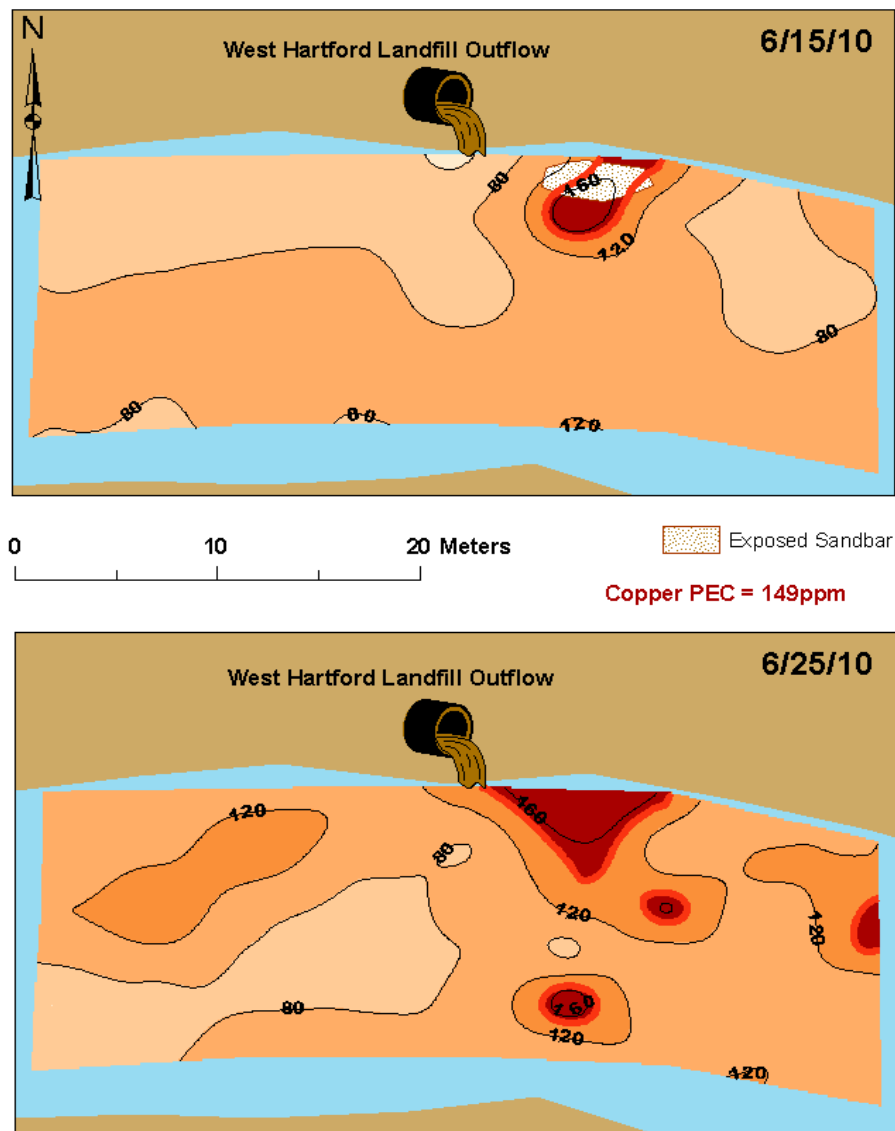
**Figure 9:** The Trout Brook SSO site lies further upstream from the West Hartford Landfill site before the convergence of the Trout Brook and Piper Brook.

### Contoured Lead Concentrations (ppm) at the West Hartford Landfill Outflow



**Figure 10:** High concentrations of lead throughout the sampling area are shown, before and after the rain events that occurred between 6/15/10 and 6/25/10. The highest concentrations of lead were found directly downstream from the West Hartford Landfill outflow on the north bank (Doñé et al. 2010).

### Contoured Copper Concentrations (ppm) at the West Hartford Landfill Outflow

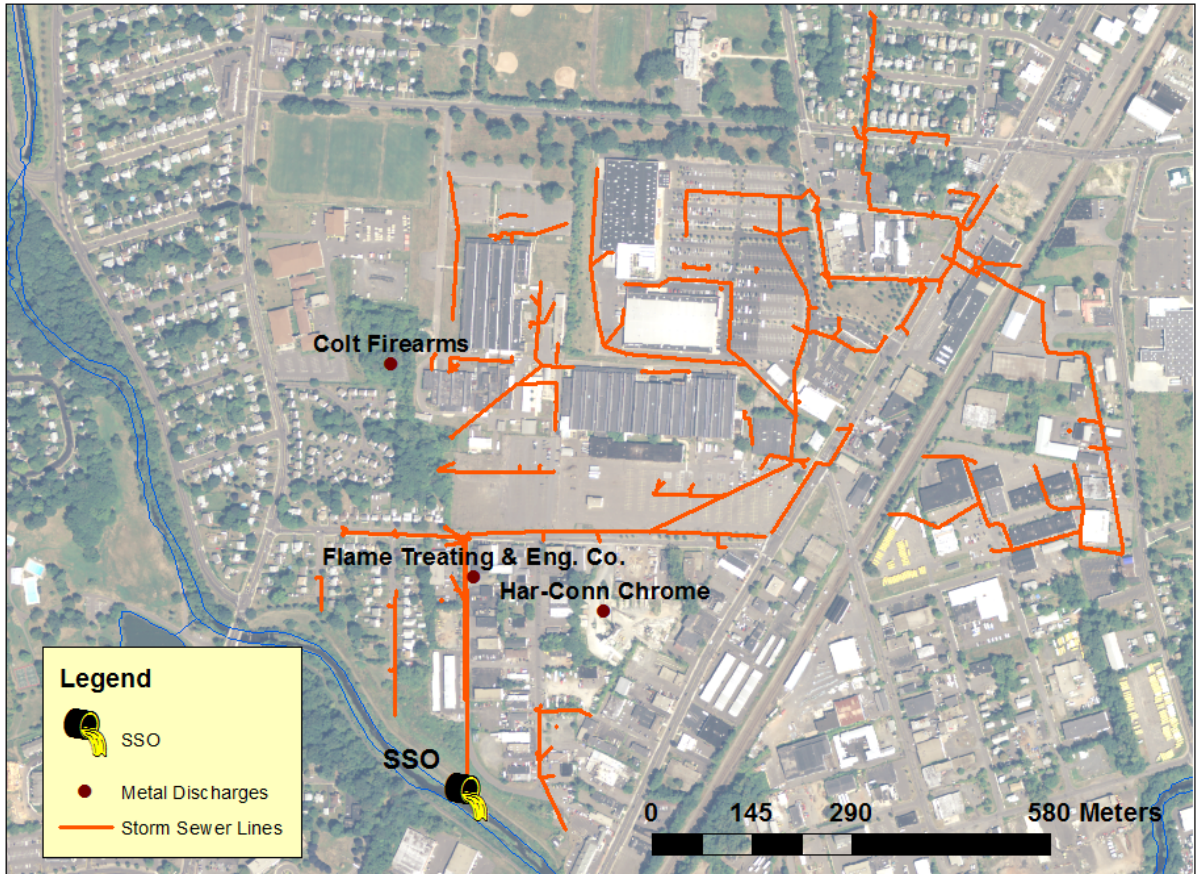


**Figure 11:** Concentrations of copper found both upstream and downstream of the landfill outflow. The highest concentrations of copper before the June rain events were found to be directly downstream of the outflow, around the exposed sandbar. After the rain event, high concentrations of copper were found throughout the sample area downstream of the outflow, with the largest plume located directly downstream of the outflow along the north bank (Doñé et al. 2010).

## *West Hartford Clean Water Project*

Many of the sewer systems in Hartford and West Hartford are over 100 years old and the cities are facing serious waste backups and major water pollution. The original sewer systems in the area were divided into separate pipes designed to keep sewage separate from drainage (MDC 2012). With time, cracks have developed in sewer pipes and have let groundwater seepage occur. In addition, many residents and industries use unauthorized sump pumps, roof leaders, and illegal drainage connections that send storm water to sewage pipes. Instead of being divided, these pipes are now connected. During rain events this excess water fills sewage pipes beyond their capacity causing them to overflow.

The result of combining pipes is seen in areas like the Trout Brook where sanitary sewer overflows (SSO's) leak raw sewage containing trace metals into freshwater ecosystems. Over 1 billion gallons of untreated sewage overflows every year in the greater Hartford area (MDC 2012). The Metropolitan District of Hartford, Connecticut (MDC) has developed the Clean Water Project to address these issues. In 2006, the MDC and EPA reached consent to eliminate illegal discharges from the sewers of Hartford. Sewer lines from three main sources, Colt Firearms, Flame Treating and Engineering Company and Har-Conn Chrome Company overflow into the Trout Brook (Fig. 12). These sources are most likely contributing to higher heavy metal contamination in sediment. The MDC plans to improve the sewer systems in West Hartford and other MDC towns to reduce sanitary sewer overflows into the Trout Brook. Storm water discharges will continue and could actually increase if storm water and sanitary sewers are completely separated. However, it seems that the MDC is mostly focusing on the city of Hartford, and it is unclear if the Trout Brook SSO site falls within its boundaries of regulation.



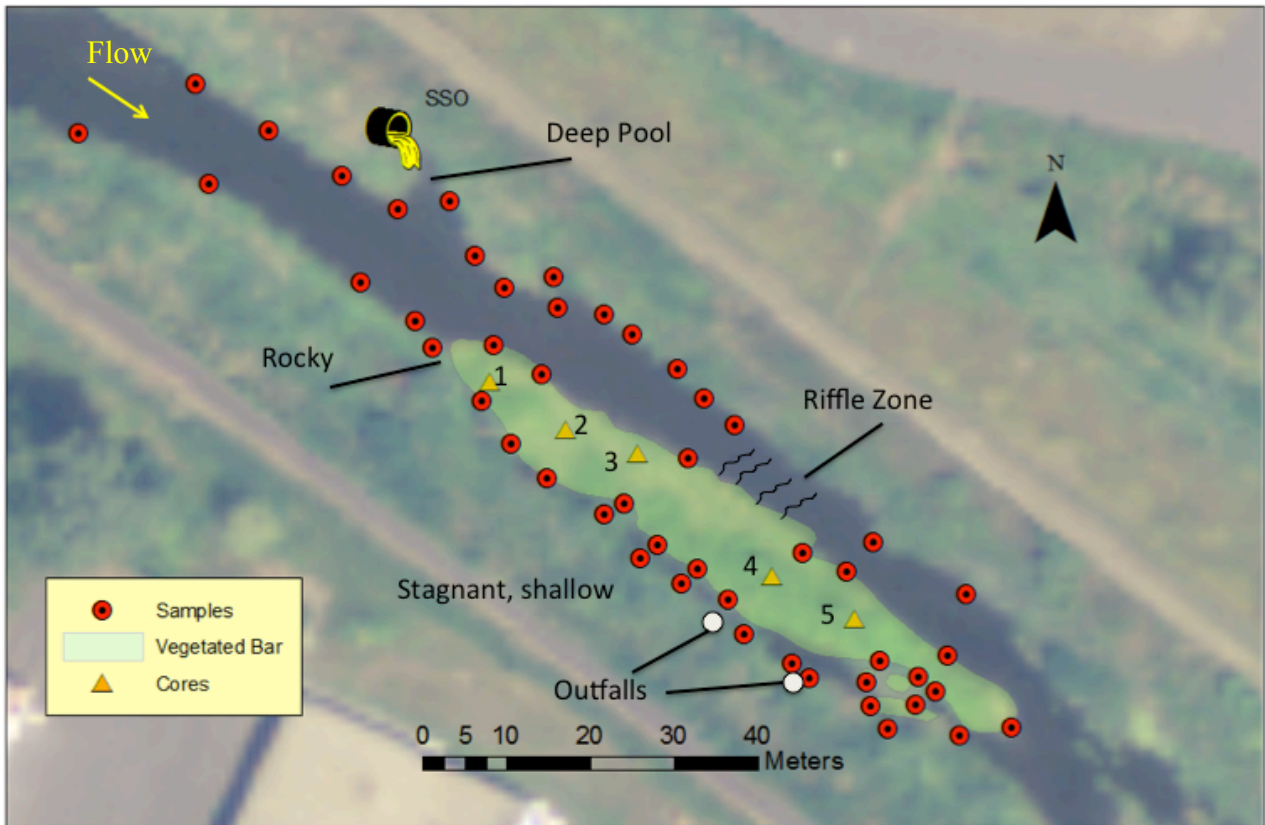
**Figure 12:** Storm water sewer lines from Colt Firearms, Flame Treating and Engineering Company, and Har-Conn Chrome Company connected to the SSO. This map indicates several know sources of metal contamination and how the sewer lines connect them to the SSO in the Trout Brook.

### *The SSO Trout Brook Sample Site*

In order to test whether sand bars play a significant role in concentrating heavy metals in sediments within the Park River, a location was identified where a known SSO point source is in proximity to a vegetated sand bar that is located in the middle of the stream channel (Fig. 13). The objective of the study was to determine whether the SSO point source or the vegetated medial bar contributed to the distribution of heavy metals in sediment.

After the West Hartford landfill study was performed (Doñé et al. 2010), the Trout Brook SSO site was chosen to provide a more detailed analysis of the relationship between a point source and a vegetated bar and their potential to distribute and trap heavy metals. The sample site is located upstream from the intersection of the Piper Brook and the Trout Brook in the southeastern section of West Hartford (Fig. 13).

The longitudinal medial bar in the Trout Brook hugs the southern bank of the sample site. Directly downstream of the SSO is a deep, relatively stagnant pool that is approximately 1.5 – 2 meters across and 4 meters from the entrance of the SSO to the main stream section (Fig.13). On the far bank from the SSO, at the upstream end of the medial bar, is an area of large cobbles which continues downstream a few meter along the southern side of bar. This area contains very little fine sediment. In between the south bank of the stream and the medial bar, the water is shallow and slow moving and the area contains high amounts of organic matter and algae. The south bank contains two more small outfalls (Fig. 13). These outfalls do not appear to flow with as much volume as the SSO and appear to drain nearby parking lots. In the middle of the sample area between the medial bar and the northern bank of the stream is a riffle zone where the water velocity is high and little fine sediment is found.



**Figure 13:** The SSO Trout Brook Sample Site



Forty-nine sediment samples were taken along the north and south banks of the stream and along the medial bar where finer sediment was in abundance. Sediment cores (5) were also taken along the long axis of the medial bar.

It is hypothesized that the SSO is the main cause of heavy metal distribution in the Trout Brook, and therefore may be causing long term and lasting effects to the overall ecosystem. The medial bar is hypothesized to have little effect on metal distribution.

## **Methods**

### *Trout Brook SSO Sample Collection and Analysis*

Sediment samples were taken on three different days: 09/2/11, 10/21/11, and 10/24/11. Following methods outlined in Giddings et al. (2001) fine sediments (<63  $\mu\text{m}$ ), were collected using polyethylene acid-washed plastic scoopers. The sediments were wet-sieved using a 63 $\mu\text{m}$  nylon sieve into a new 1L #2 High Density Polyethylene (HDPE) Nalgene bottle.

For each sample, the fine suspended sediment was allowed to settle and the remaining water was decanted. The sediment was then transferred into a 50 ml digestion tube (digitube). The digitubes were freeze-dried overnight. A small amount (0.5 g) of each dried sample was digested in 10 mL of 0.6 N HCl using a weak acid digestion method (Giddings et al. 2001) and shaken for one hour on a wrist action shaker to desorb trace metals from the sediment particles. After shaking, samples were allowed to settle overnight and then filtered with a 0.45 $\mu\text{m}$  Teflon membrane filter. The remaining supernatant was analyzed using an Inductively Coupled Plasma – optical emission spectrometer (ICP-OES), which provides the concentrations of toxic heavy metals found in our samples.

In addition, 5 sediment cores were taken within the medial bar to determine if metals have accumulated in the bar. The samples were capped and stored at 4 °C. Each 12 – 16 cm core was cut at 2 – 3 cm intervals and sediment samples were stored in digitubes and analyzed for heavy metal concentrations as described above.

The results were evaluated following sediment quality guidelines (SQG) presented in MacDonald (2000). In the interpolation graphs of the Trout Brook site, the pink color denotes concentrations with the SQG range, and the red color indicates concentrations that are above the PEC as outlined in Table 1.

## **Results:**

For each metal the highest concentrations in sediment were found directly below the Sanitary Sewer Overflow (Figs. 14-17). While Pb was the only metal to exceed the probably effect concentration, Cu and Zn both were at high levels and ranged within the SQG. Cd was below either SQG or PEC throughout the site but was found in elevated levels at the SSO. The distribution of metal contamination did not appear to be influenced by the medial vegetated sand bar. Concentrations in general tended to decrease downstream from the SSO, and the bar apparently did not act as a sediment trap. In addition, water velocity was highest around the middle of the medial bar where fine sediment was not as prevalent.

Cd concentrations in sediment are low overall for the Trout Brook SSO site and fall below the SQG and PEC values given by McDonald et al (2010) (Fig. 14). Despite the low concentrations of Cd, the high concentrations at the SSO suggest that the SSO is a source of Cd in the area. Cd concentrations are lower upstream of the SSO and further downstream along the medial bar (Fig.14).

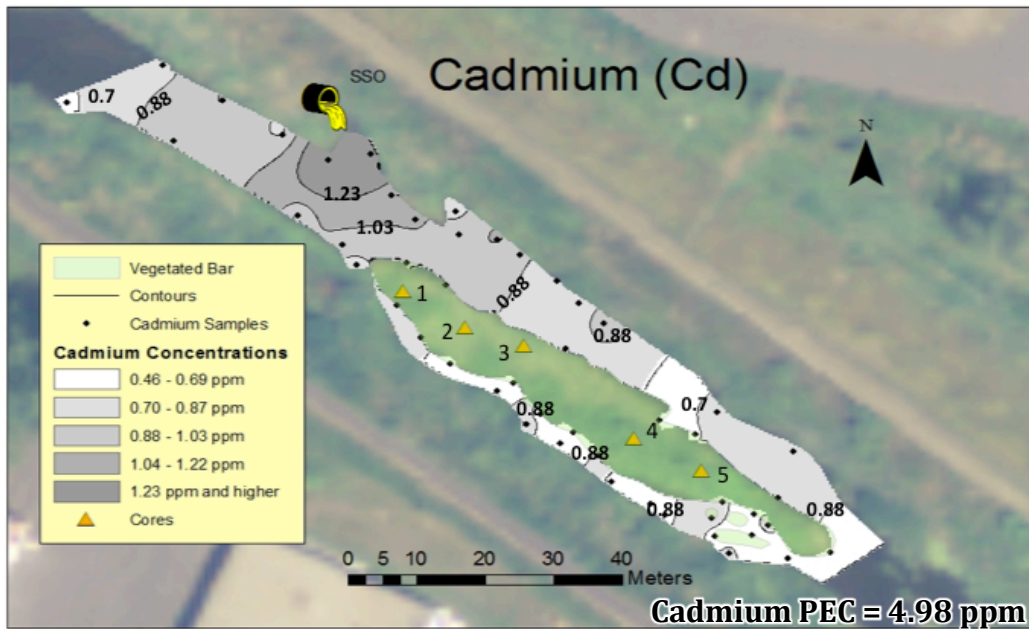
Cu concentrations only exceed the sediment quality guidelines in the deep pool directly downstream of the SSO indicating that it is a point source (Fig. 15). Cu occurs in low concentrations throughout and is dispersed further downstream, but shows a slight increase below the SSO.

The SSO acts as a point source for zinc as well. Zn concentrations follow the same pattern as copper, and exceed the SQG values directly downstream of the SSO (Fig. 16). Concentrations are also lower upstream of the SSO, indicating that the SSO is a point source for metal pollution. Zn concentrations are also lower further downstream, as is seen with copper.

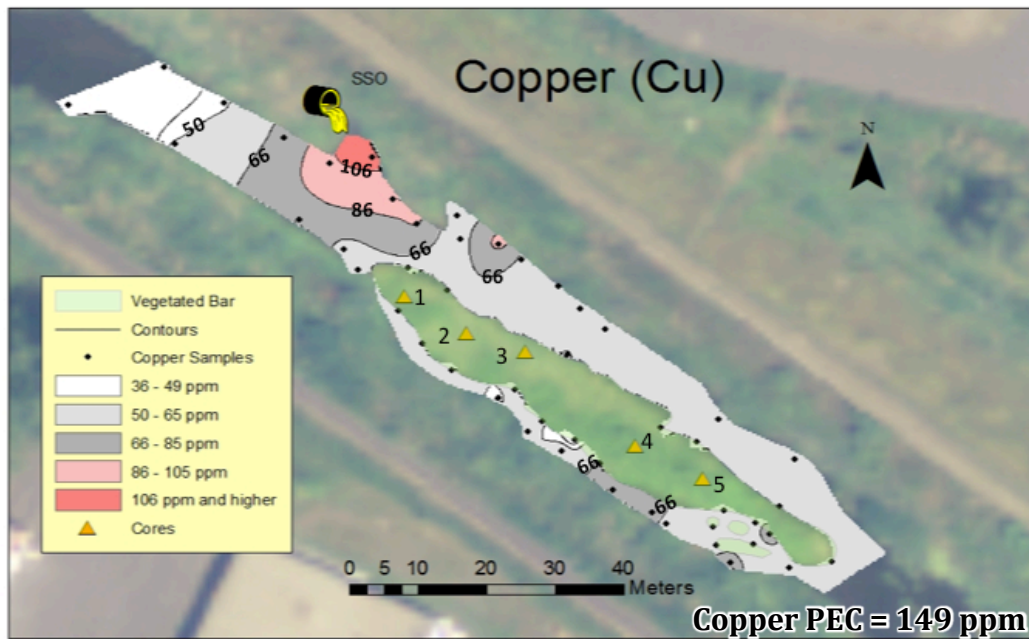
Pb concentrations in sediment follow the same pattern as Zn and Cu, but are recorded at much higher levels (Fig. 17). Pb is found in high concentrations throughout the Trout Brook both upstream and downstream of the SSO. However, the Pb in sediment only exceeds the PEC value directly below the SSO. The SSO is clearly a major point source of lead pollution, but Pb is most likely entering from sources further upstream as well and potentially from one of the minor outfalls on the south bank of the river, in the small back channel on the south side of the medial bar.

Metal concentrations in each sediment core were significantly lower for each metal than those calculated in river sediment (Figs. 18– 21). The cores, however, were not sieved and therefore contained more coarse sediment, which does not have a great affinity to adsorbing metals. Core 4 is an exception in that it contained higher amounts of fine sediment and therefore contained higher metal concentrations overall. In the second section of core 4, (4-6 cm), lead concentrations spiked to 160 ppm which is well above the SQG values. In future studies, sediment cores should be sieved so that fine grains (<63 µm) are separated.

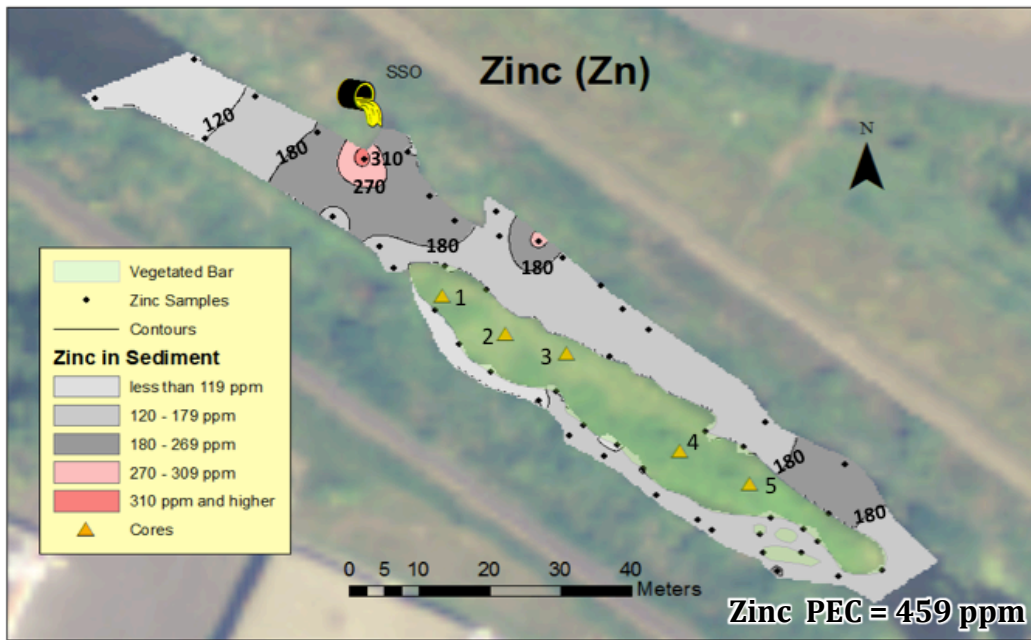
This will allow a more accurate comparison between river sediment and medial bar sediment in order to determine where most heavy metals are found.



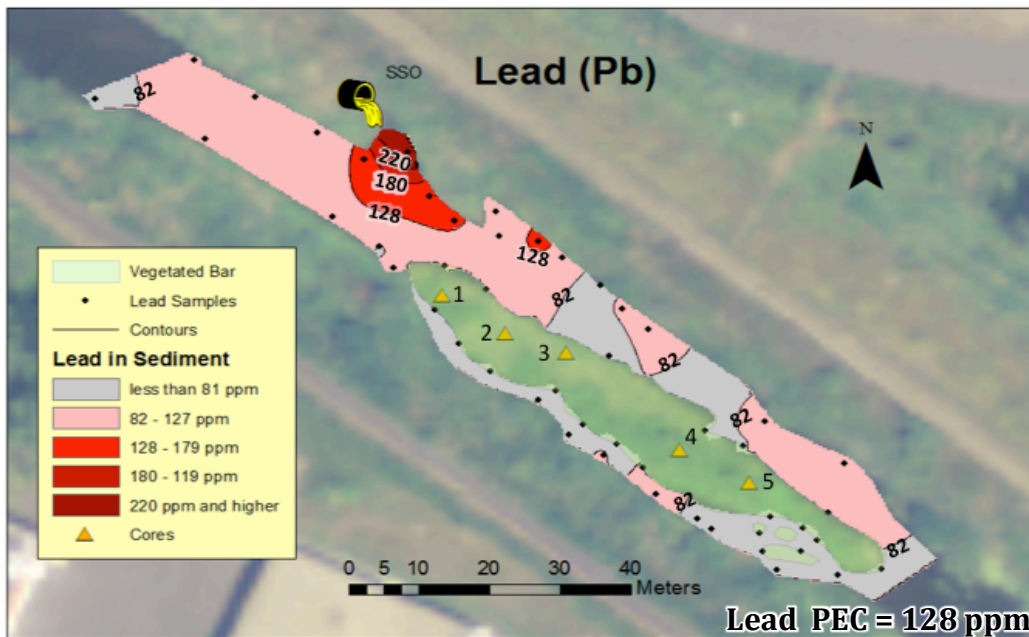
**Figure 14:** Distribution of cadmium in sediment in the Trout Brook SSO site. Values do not exceed the PEC but are highest directly below the SSO.



**Figure 15:** Distribution of copper in sediment in the Trout Brook SSO site. Values do not exceed the PEC but exceed SQG values directly below the SSO.

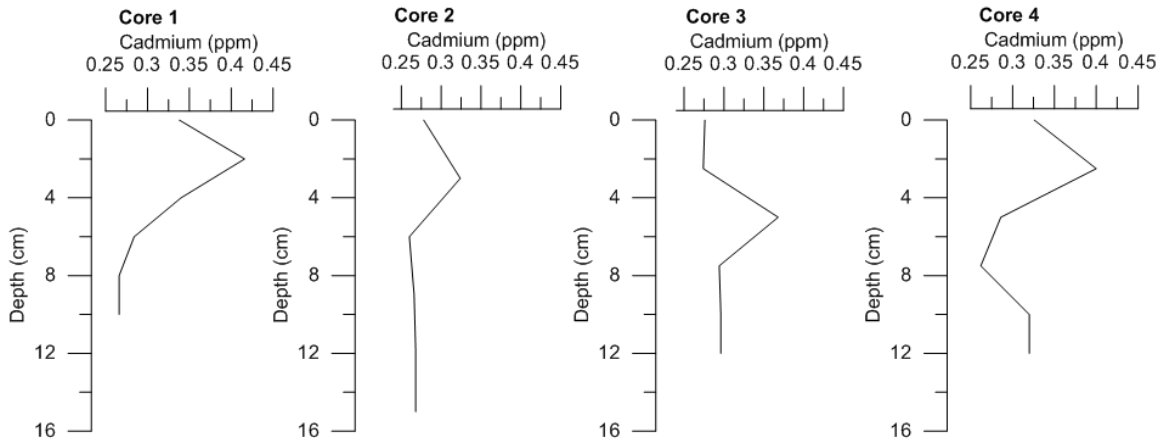


**Figure 16:** Distribution of zinc in sediment in the Trout Brook SSO site. Values do not exceed the PEC but exceed SQG values directly below the SSO.



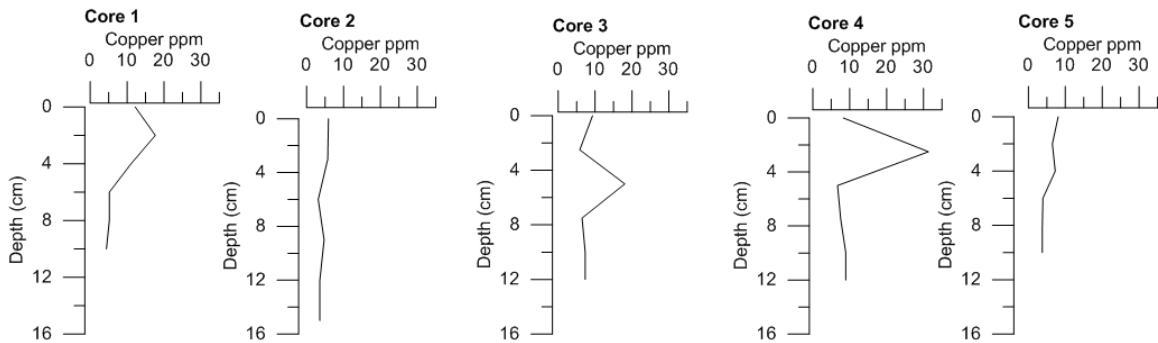
**Figure 17:** Distribution of lead in sediment in the Trout Brook SSO site. Values exceed the SQG and PEC. PEC values are indicated in red.

Cadmium Concentration in Sediment Cores



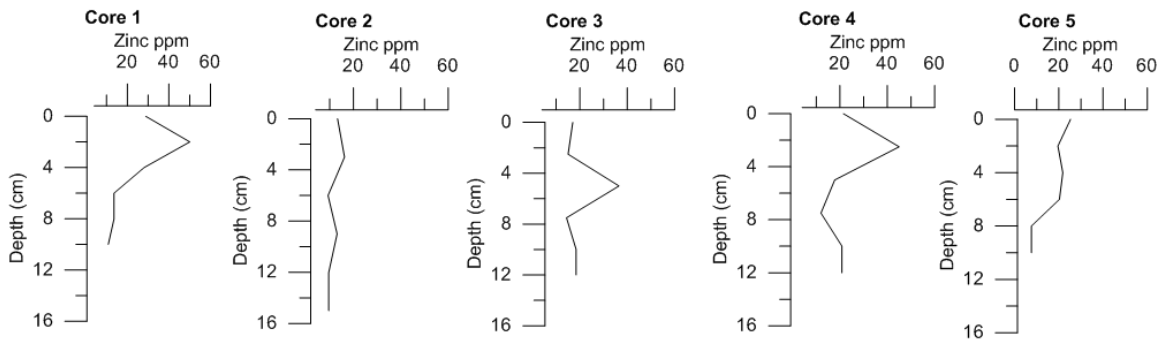
**Figure 18:** Concentrations of cadmium in cores 1-4. Core 5 was not recorded because all values were at 0. Values are highest in the second section.

Copper Concentrations in Sediment Cores



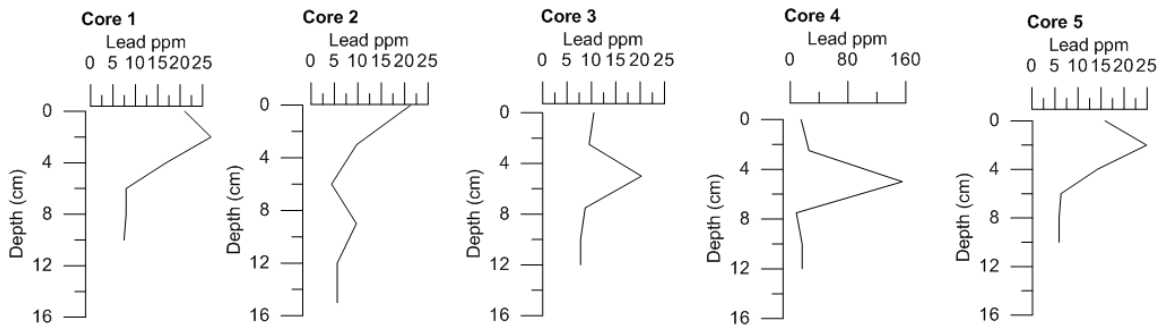
**Figure 19:** Concentrations of copper in cores 1-5. Values are highest in the second section of cores 1, 3, 4, and 5.

Zinc Concentrations in Sediment Cores



**Figure 20:** Concentrations of zinc in cores 1-5. Values are highest in the second section except in the fifth core.

Lead Concentrations in Sediment Cores



**Figure 21:** Concentrations of lead in cores 1-5. Values are highest in the second section. The scale of core 4 is much different because its values exceed the SQG.



## **Discussion:**

The highest metal concentrations are seen directly at the SSO outfall. The deep pool with low water velocity at the SSO allows greater amounts of fine sediment to accumulate. The metals in water that are discharged from the SSO therefore bind to the fine sediment particles resulting in higher metal concentrations at the outfall. Findings of this study suggest that the SSO is a significant point source for trace metal contamination in the Trout Brook. By extension it could be inferred that SSO's throughout the Park River watershed are depositing elevated levels of trace metals, especially at outfalls that drain industrialized urban areas with large areas of impervious surfaces. However, this particular SSO is connected to various metal finishing facilities that may be contributing to the particularly high heavy metal pollution in the Trout Brook.

Pb is found in high concentrations throughout the river above and below the overflow but is seen in significantly higher values below the SSO. The Pb values at the SSO far exceed the PEC value. Further downstream from the SSO, lower concentrations in metals are found, especially in the riffle zone in the middle of the site. This indicates that sediments are dispersed further downstream due to higher water velocity and distance from the SSO.

The medial bar appears to have little impact on heavy metal distribution downstream of this particular SSO outfall. It merely separates the section of the river, allowing slow moving water to accumulate along the south bank. It was initially hypothesized that by creating slow moving water, the bar would trap fine sediment. Fine sediments, however, are either trapped initially in the deep pool at the SSO or are washed further downstream, allowing less accumulation along the bar. The metal concentrations in the sediment cores were very low. High values were seen in Core 4, however, which is due to the greater amount

of fine sediment (<63  $\mu\text{m}$ ) that may have washed on top of the bar during storm events.

## **Conclusion**

High concentrations of Cu, Zn, Cd, and Pb in sediments in the Park River Watershed are due to overall industrialization and the dumping of waste that run off into tributaries like the Trout Brook. The high concentrations of heavy metals in the Trout Brook are believed to be primarily from the SSO point source discharge. The SSO discharge is magnified by the old sewage piping of the greater Hartford and West Hartford areas causing rainwater and sewage to be combined. Pb in particular appears to be in high concentrations throughout the river sediments, and while the SSO appears to be a significant source, Pb is prevalent throughout the southern part of the watershed. The medial bar does not appear to be accumulating fine sediments and is not heavily contaminated with trace metals.

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