Case Study 8

Copper Mine Brook, Burlington, Connecticut



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Cover photo: Treated section of Copper Mine Brook, Burlington, Connecticut

Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.

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Copper Mine Brook, Burlington, Connecticut

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Introduction

The purpose of this case study is to illustrate some of the typical problems and goals of stream rehabilitation in a suburbanized area of Connecticut. To accomplish this, the Copper Mine Brook Emergency Watershed Protection project (EWP) is described. This project illustrates the work done to address various stakeholders' goals; analyze risks, consequences, and uncertainty; select appropriate design tools and features; and evaluate performance. It is assumed that the tools Connecticut needed will also be useful for other areas with high-population density, particularly areas of the country with both glacial till and alluvial soils where erosive forces are produced by both water and ice attack.

Stakeholders for stream rehabilitation projects in Connecticut desire to address increasing numbers of objectives for stream projects. The Copper Mine Brook EWP project is presented to illustrate what some of these objectives are, what the local landscape looks like, and what design constraints exist. Two main objectives are to protect flood plain infrastructure and simultaneously maintain or enhance aquatic habitat. What stakeholders wanted to do, what rehabilitation features were finally used, and how the project has performed are described.

Location, stream order, and drainage area

Copper Mine Brook is located in west-central Connecticut and begins at the confluence of Whigville Brook and Wildcat Brook in the town of Burlington. It is a third order stream. At the confluence, the drainage area of Whigville Brook is 4.8 square miles, and the drainage area of Wildcat Brook is 2.3 square miles, for a total of 7.1 square miles for Copper Mine Brook (fig. CS8–1).

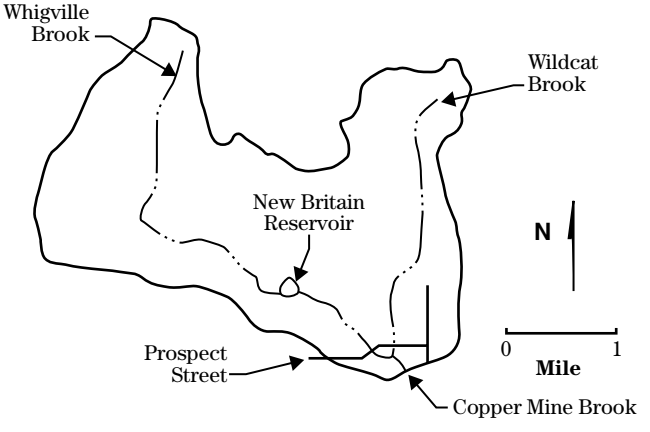
Site description

Damage assessment

Hurricane Floyd occurred on September 16, 1999. Two days later, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) engineering staff in Connecticut inspected damages on Copper Mine Brook and Whigville Brook. The damages were viewed in the context of what measures could be used under the EWP to restore the stream. The EWP program is meant to remove sudden watershed impairments caused by catastrophic events. For streams, the goal is to restore the stream to prestorm or precatastrophic events. Using additional funds to improve the stream beyond prestorm conditions is not within the scope or intent of the program.

What ultimately became the project site started at Prospect Street and extended down Whigville Brook for 900 feet and continued down Copper Mine Brook for another 500 feet (fig. CS8–1). The aerial photograph (fig. CS8–2) shows the land use in the vicinity of the project site. The view shows woodland and hay fields north of Prospect Street. Whigville Brook flows from the west through New Britain Reservoir. Wildcat

Figure CS8–1 Plan view of Copper Mine Brook Watershed, near Burlington, CT



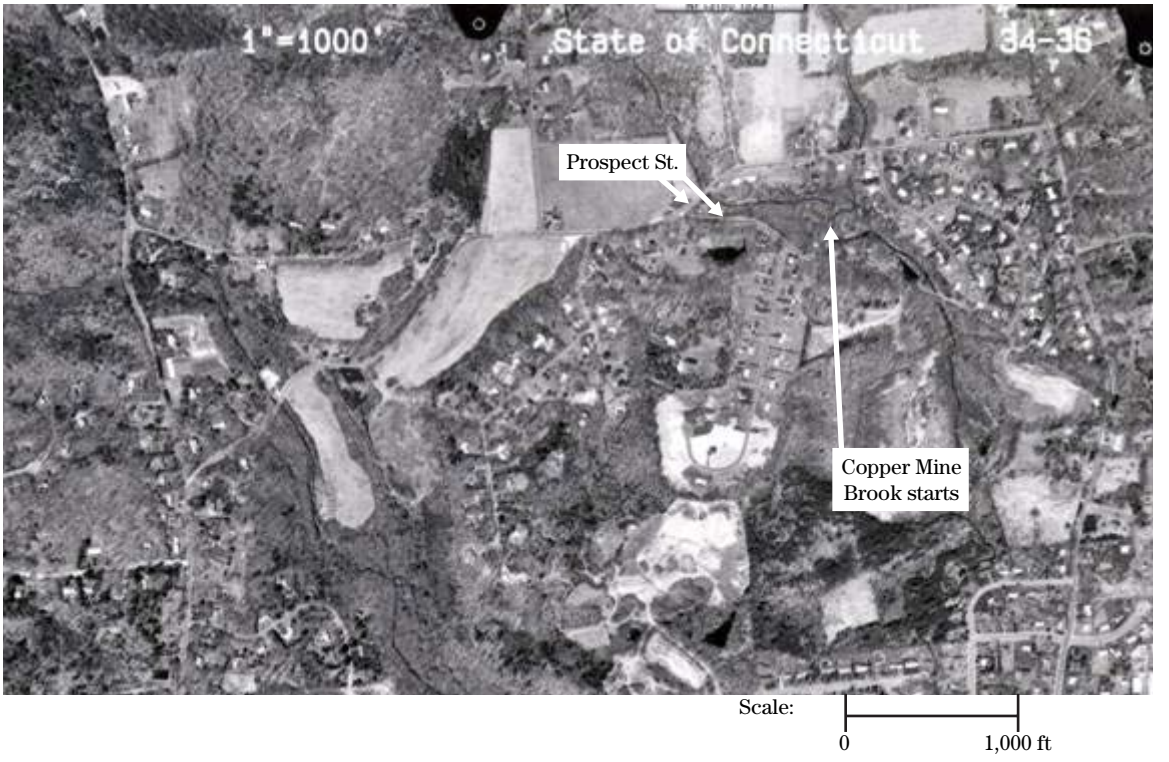
Brook flows from the east. Both pass under Prospect Street and form Copper Mine Brook. The locations of the damages found during the investigation are referenced to the stream centerline stationing used in figure CS8–3. The site features and damages found, starting at Prospect Street and working downstream, are shown in table CS8–1.

After the damage assessment, the Connecticut NRCS resource conservationist performed a geomorphic classification and assessment and an aquatic habitat assessment. Following are highlights from those assessment reports.

Geomorphic classification and assessment

The proposed project is located in a stream reach that displays characteristics of a Type C4 stream (Rosgen 1994) based on the approximation of entrenchment ratio, slope, width/depth ratio, sinuosity, and dominant channel materials. The reach is slightly incised with uninhibited access to the flood plain. It is a third order stream with average bankfull width of 20 feet (size S–4), dominant depositional features are point bars (B–1), and the meander pattern can be classified as irregular (M–3).

Figure CS8–2 Aerial photo of project area



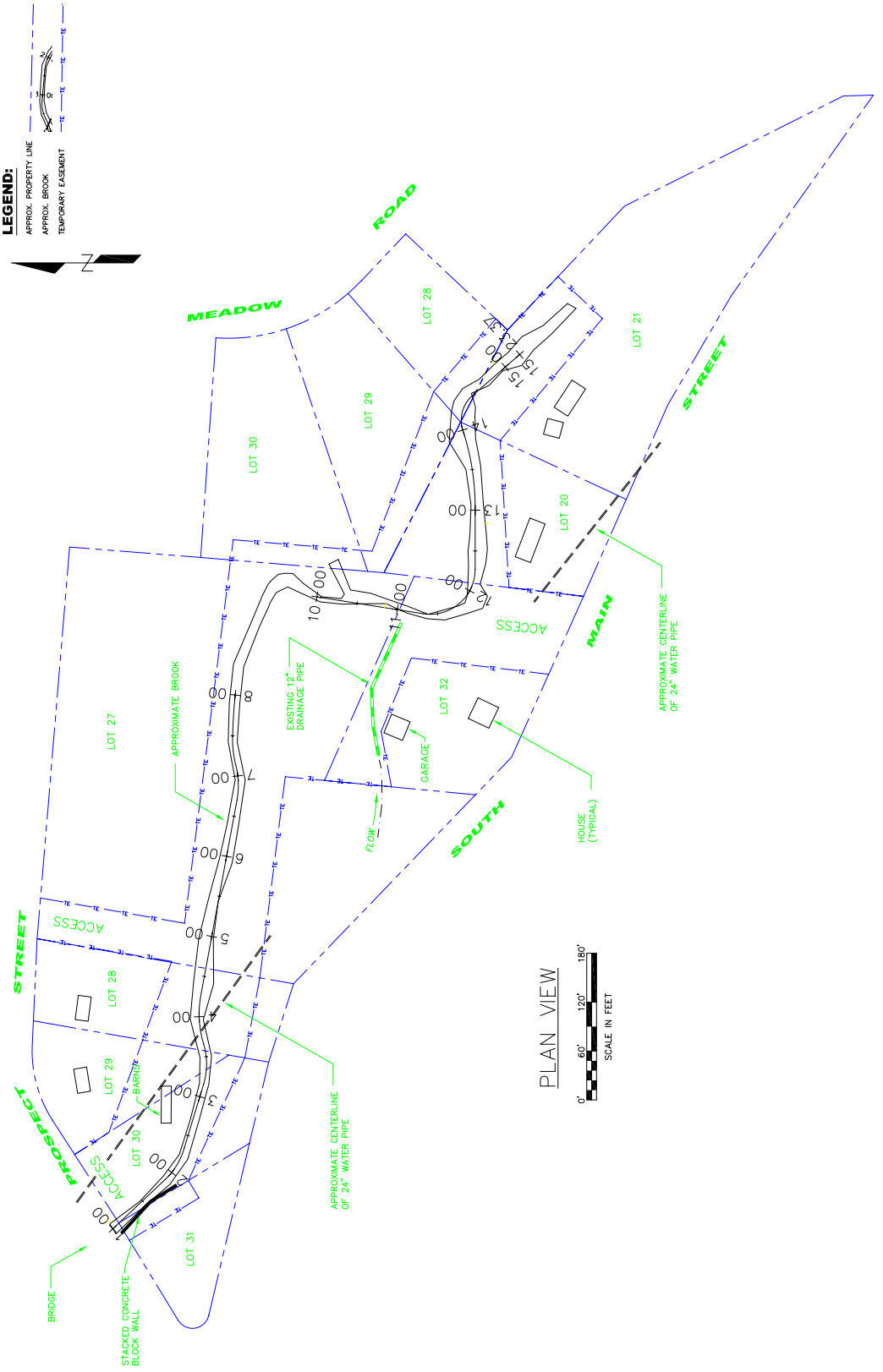


Figure CS8–3 Stream centerline stations, Copper Mine Brook EWP project

Table CS8–1 Site features on Copper Mine Brook EWP project

Station	Description
1+00 to 4+00	The brook flowed through three properties with houses, small barns, and onsite septic systems
1+00 to 2+00	Immediately downstream of the Prospect Bridge, the channel had started to incise along a 7-ft-high stacked concrete block wall near a house. This was a concern because the wall had fallen down two times previously
2+75	The brook had flooded two small cojoined barns and placed some debris on the flood plain
4+00 area	A 24-in-diameter water main, supplying the city of Bristol and owned by the New Britain Water Company, passed underneath the brook. This area had gravel and woody deposition that increased the flooding hazards to the houses and barns upstream. The debris had raised flood levels and caused much of the Hurricane Floyd flood to pass down the right (west) flood plain, increasing flood hazards on two houses further downstream
4+50 to 10+00	The brook flowed through 600 ft of woods. This part of the brook was in a fairly natural condition with one 2-ft-high waterfall created by LWM. It is not known whether this was here prior to Hurricane Floyd. Streambank erosion here was minimal, but there were some gravel deposits
10+25 to 15+25	The last 500 ft downstream flowed through five residential properties with onsite septic systems. Two of the properties had experienced some bank erosion. Some trees were being undermined, as were two stormwater outlet headwalls. Gravel deposits in this area had created higher flood elevations with an adverse impact on the foundation drain of one of the houses at lot 32. This house and its garage were also affected by overland flows on the west flood plain. These flows had entered the flood plain farther upstream because of debris partially blocking the channel at station 3+75 near the 24-in water main. These flows had to pass through a 12-in culvert previously used for local drainage

In general, the stream system within this reach can be classified as stable with isolated areas of accelerated streambank erosion. The areas of streambank instability are associated with previous alterations to the riparian area by the streamside landowners. As a result of Hurricane Floyd, the channel has experienced some morphological alterations including streambank erosion and redistribution of bed materials.

Aquatic habitat assessment

A physical stream assessment was conducted using the Stream Visual Assessment Protocol from the NRCS National Water Quality Handbook. The assessment revealed a Habitat Suitability Index (HSI) rating of ten (10). An HSI score greater than nine (9) is classified as excellent. The instream fisheries habitat identified included large woody material (LWM), deep pools, overhanging vegetation, cobbles/boulders, riffles, undercut banks, and thick root mats.

The current stream morphology provides the habitat complexity necessary for the maintenance of a sustainable cold-water fishery. The stream system currently supports a population of wild brook trout and wild brown trout. During the assessment, adult and juvenile brook trout and blacknosed dace were observed.

A cursory review of the benthic invertebrate community revealed dominance by pollution-sensitive invertebrates including mayfly, caddisfly, and water penny of the orders Ephemeroptera, Trichoptera, and Coleoptera, respectively. This is expected due to the health of the watershed.

Some of the stream features of noted value and their locations are shown in table CS8–2.

Watershed description and history

This watershed has a system of cold-water streams that support a sustainable wild brook trout and brown trout fishery and provide water for the City of Bristol. The tributaries are in steep watersheds with the headwaters of Whigville Brook at elevation 1,000 feet above mean sea level and with Wildcat Brook at elevation 900 feet. The confluence of the two is at elevation 380 feet where a flat flood plain area has formed. The New Britain Water Company has a water supply reservoir located about 1 mile up Whigville Brook with a drainage area of 4.1 square miles and a surface area of 10 acres (fig. CS8–1). The New Britain Water Company sells water to the City of Bristol and frequently draws water levels down in the reservoir. This drawdown provides some flood storage that can significantly reduce flood flows from storms smaller than the 10-year event. Although 80 percent of the watershed is forested, significant housing subdivisions have been built on the east side of Wildcat Brook, and less intense development has occurred throughout the watershed.

In the mid 1950s, the project site and surrounding land was predominantly used for vegetable crops. Since that time, much of the land has grown back to forest with trees about 30 to 40 feet high. Many of the houses within the watershed were built in the 1980s and 1990s. In 1955, a major hurricane produced flooding in the project site as shown in figure CS8–4. This view is looking upstream at Prospect Street. The 1955 flood deposited a significant amount of sediment in this channel and flood plain. The U.S. Army Corps of Engineers (USACE) removed much of this material from the channel. This is a flat flood plain with no buildings and few trees. Note the open fields on the left flood plain and upstream of Prospect Street and the amount of water flowing over Prospect Street and the bridge guide rails still visible.

Figure CS8–5 is a photo taken in 2000 from approximately the same area looking upstream at the Prospect Street Bridge. Note the red barn, house, and numerous trees in the flood plain that were not there in 1955. The left flood plain has another barn and two more houses on the left flood plain not shown. Compared to figure CS8–4, this shows how watershed land use can change. In the late 1950s, a local farm family also built a 4-foot-high dam on the river within the project site to create a swimming area. This small dam had been removed prior to 1999. During Hurricane Floyd, it is surmised damages were high in the project area because the New Britain Water Company had opened the dam gates during the storm to lower levels in the reservoir. If this happened near the peak of the

Table CS8—2 Stream features, Copper Mine Brook EWP project, CT

Station	Stream features
1+00 to 4+50	This section contains a deep pool (2–3 ft) with an adjacent undercut bank (3.5 ft undercut) on the southwest bank. This undercut was formed by Hurricane Floyd. Currently, this undercut and associated pool area provides exceptional fisheries habitat. Two spawning pairs of blacknosed dace were observed at the downstream end of this pool area. The root mats of the vegetation forming the undercut also provide excellent substrate for insect production
4+50 to 10+00	Throughout this reach there are numerous locations of undercut banks on both the east and west sides of the channel. The lateral stability of C4 streams is related to the presence and condition of riparian vegetation. The riparian vegetation, a mix of deciduous trees including, but not limited to maple, black locus, and red twig dogwood, are essential for providing coarse particulate organic material, fine woody material and LWM to the stream system. The current LWM facilitates the maintenance of a deep hole immediately downstream of the LWM. The hole is approximately 2.5 ft deep. The bottom of the pool is obscured by bubble-cover. This is a significant habitat element of this stream reach
10+30 to 12+50	There is a deep pool directly adjacent to a deep undercut bank on the extreme south bank of Copper Mine Brook. The variable topography of the stream bottom, in addition to the pool area and undercut bank, provide the habitat complexity needed for sustainable fisheries
14+00 to 14+75	There is evidence of extensive streambank erosion in this location. The north/northeast bank is vertical and unstable. Currently there is a significant undercut bank at the downstream end of this pool, which provides excellent habitat complexity

Figure CS8–4 1955 flood looking upstream at Prospect St.

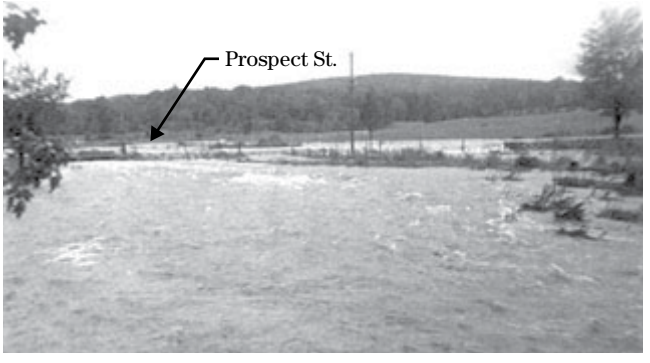
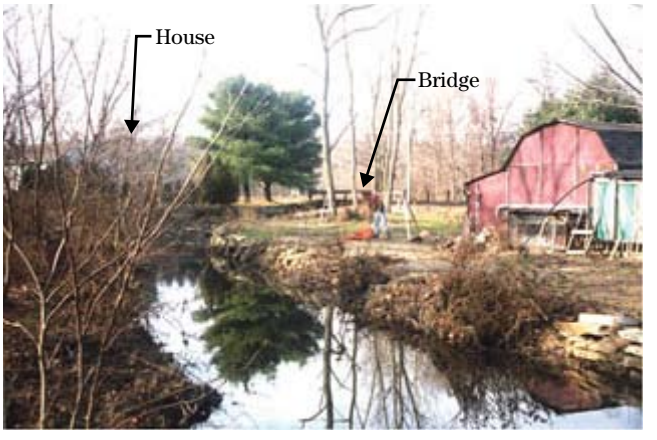


Figure CS8–5 Year 2000 looking upstream at Prospect St.



hydrograph, flows and damages would have likely increased downstream.

In summary, the project site has been affected by the following activities:

- The watershed hydrology was affected by land use changes and flood storage.
- The channel hydraulics were modified by direct excavation and by a small dam within the area of the project site.
- Vegetation along the riverbanks over the years has changed, ranging from farmland to trees to suburban lawn.

Some geomorphic design approaches to natural stream restoration try to allow the channel to reach a dynamically stable equilibrium with the hydrology of the watershed. This is difficult to achieve at Copper Mine Brook because the hydrology is constantly being modified by reservoir releases and land use changes. These changes will probably continue into the future.

Stakeholders and goals

Stakeholders in a stream project are the individuals and groups who either fund the project or are affected by the stream. Ideally, all the stakeholders work together to set goals for the stream design. The stakeholders for this project were the:

- owners of 10 residential riparian properties
- town of Burlington
- city of Bristol
- New Britain Water Company
- Connecticut Department of Environmental Protection, Inland Waters Division
- Connecticut Department of Environmental Protection, Fisheries Division
- NRCS

The goals of this project were set to:

- prevent streambank erosion on 10 residential properties to protect infrastructure
- prevent flooding of 10 residential properties caused by debris in the channel
- protect the town of Burlington's bridge on Prospect Street
- protect the New Britain Water Company's water main
- maintain fish habitat
- maintain water quality

The residential homeowners were predominantly interested in repairing eroded banks and removing debris blocking the channel to protect their yards, drainage pipes, septic systems, retaining walls, barns, and houses. The New Britain Water Company and the city of Bristol wanted the 24-inch water main secured. The town of Burlington did not want a headcut to erode the bridge abutments at Prospect Street. The Connecticut Department of Environmental Protection Inland Waters Division was predominantly concerned with protecting human infrastructure. The Connecticut Department of Environmental Protection Fisheries Division was predominantly interested in maintaining or improving aquatic habitat. The NRCS was focused on achieving the goals of all the stakeholders, maintaining water quality, and doing the job quickly.

In general, the stakeholders' interests produced goals that can be grouped into two main categories. These categories with their corresponding goals are:

- maintain or rehabilitate environmental quality by designing and constructing stream rehabilitation projects that:
  - look natural
  - function naturally with channels connected to flood plains
  - provide desirable stream and riparian habitat including overhanging root cover and LWM
  - maintain water quality
  - are economical to design and build
- protect infrastructure in channels and flood plains by designing and constructing stream rehabilitation projects that:
  - do not increase flooding

- do not migrate across flood plains
- remove trees in jeopardy of falling over
- do not send debris downstream to plug bridges and culverts
- maintain water quality
- are economical to design and build

Sometimes these goals are incompatible, and sometimes they are mutually supportive. Some instances of incompatibilities are:

- Natural streams can migrate across flood plains and can cause trees to fall over. The trees can fall on houses or travel downstream, plugging bridges.
- Woody material can increase flooding, even without plugging bridges.

Some instances of mutually supportive goals are:

- LWM is valuable for aquatic habitat and on some streams can help achieve some channel stability.
- Natural streams with channels connected to flood plains can reduce tractive forces in the channel, thereby increasing channel stability.

In some cases, a compromise needs to be reached between goals for infrastructure protection and aquatic habitat improvement. The following example at Copper Mine Brook illustrates one such compromise. During construction, an overhanging tree root was found to have a cavity extending 8 feet horizontally beneath it into the bank. The adjacent homeowner, fearing the tree could fall on his house or well casing, wanted the cavity filled with boulders. NRCS and the Connecticut Department of Environmental Protection wanted it left open for fish habitat. An optimal solution for infrastructure protection would have been to cut the tree down or fill the cavity with boulders, but this might have been very detrimental to aquatic habitat. After weighing the relative benefits, risks, and consequences, NRCS directed the contractor to partially fill the cavity with boulders and deflect the current somewhat by placing boulders upstream and downstream of the cavity. The downstream boulders were used to protect against back eddies formed by the protruding tree roots. NRCS felt this was a risk worth taking to maintain aquatic habitat. Since the boulders placed in the cavity had gaps between them, numerous small refuge areas were created. It is possible this created better habitat than one single large cavity. When some fish locate themselves by large instream boulders, they will exclude other fish they can see from their side of the boulder. So it is possible that more fish will inhabit a multisegmented cavity where they cannot see each other.

Risks, consequences, and uncertainty

Evaluating risks, consequences, and uncertainty helps designers and stakeholders make decisions on design choices. Risk is the probability of some event happening. Consequence is what happens if the event occurs. Uncertainty describes the level of error in estimates of risk and consequences. Examples of these are:

Risk—There is a 50 percent chance that a 2-year storm will be equaled or exceeded in a year. However, this storm could occur at any time and several times during a 1-year period.

Consequences—If the 2-year storm occurs, the following series of consequences could happen:

- The streambank could erode 5 feet.
- Part of a state highway could slide into the river.
- Motorists could be killed, and highway repairs would be expensive.
- Uncertainty—tools to predict the discharge and velocities from various frequency storms are somewhat accurate and precise. Given a certain frequency storm, present tools to evaluate the certainty of the bank eroding with resultant damages are not that accurate or precise.

The risks and consequences at Copper Mine Brook can be divided into two categories. The first involves infrastructure concerns, and the second involves biological and physical stream processes. The following list describes these categories.

Infrastructure concerns—The uncertainty of the following risks and consequences was moderately high. Regarding risk, it is known that at some time a large event like the 100-year storm will occur, although it is not known exactly when it will occur. Furthermore, existing techniques cannot accurately predict how much damage would be done when it does occur. However, if the brook were left as it was, subjective judgments estimate that future flooding could:

- undermine the Prospect Street Bridge abutments
- undermine a stacked concrete wall (that had fallen twice before)
- flood houses and barns with overland flow and from backwater in foundation drains
- breach a 24-inch-diameter municipal water line
- encroach on septic leach fields and send polluted water downstream
- undermine and topple trees, one of which could fall on a house
- encroach on a well casing
- undermine stormwater outlet headwalls
- create a new channel in other parts of the flood plain

Biological and physical stream processes—If the infrastructure were protected by removing large amounts of debris, removing vegetation, widening channels, and installing large amounts of grouted and ungrouted riprap, the consequence with a high degree of certainty would be that aquatic habitat would be diminished. If the brook were left as it was after Hurricane Floyd, aquatic habitat would be reasonably good. There would be some chance that the brook could create a new channel in the west flood plain.

As-built design

By analyzing risk, consequences, and uncertainty, NRCS produced a design that attempted to fulfill the stakeholders' goals to the greatest extent. Construction was completed in May 2001 (see the as-built design plan views shown in figs. CS8–6 and CS8–7). Each stream rehabilitation measure used throughout the project was evaluated for risk, consequences, and uncertainty. In locations where future erosion or flooding could be tolerated, less armoring or excavation was included in the design. This project placed a greater emphasis on maintaining fish habitat than previous EWP projects. In addition, debris removal, grade control structures, grouted and ungrouted riprap, and bedding stone were used less vigorously than in past EWP jobs. In many cases, bank-placed boulders were used in place of riprap. The rock riprap was sized by tractive force methods. To achieve habitat refuge, the bank-placed boulders needed to be larger than the maximum riprap size so flood currents would not move them. However, there was some concern that fines might pipe out from behind and underneath the bank-placed boulders.

Pre- and postproject photographs, design objectives, and project performance

Figures CS8–8 through CS8–21 show what various parts of the project looked like before and after construction. Figure CS8–8 shows the locations of where photographs were taken. The associated commentary on the captions explains why various techniques were used and how they have performed. Note that the figures use standard streambank nomenclature defining right and left banks and flood plains as looking downstream. For those figures showing a view looking upstream, the right bank appears on the left side of the figure.

At time of this case study documentation (2 years after construction), this project has functioned as follows:

- Some erosion started to occur upstream of the bank-placed boulders near station 2+40, downstream of the stacked concrete wall. The roots above and around the first boulder were not well developed, and there were no tie-back rocks.
- The bank-placed boulders located downstream at station 14+50 to 15+10 are functioning very well. They have very well-developed roots around them and stable riprap upstream.
- So far, no piping of fines has occurred around the bank-placed boulders. The site has not been

subjected to any large floods since construction.

- The LWM at 10+00 that formed a waterfall is gone.
- Throughout the project, fairly good riffles and pools have been maintained within a gravel-armored channel. So far, there is no excessive deposition of stream gravel.
- The riprap is stable.

Conclusion

By describing the work on Copper Mine Brook, the reader should have a better understanding of the Connecticut stream landscape, goals, and design problems. The major design challenges at Copper Mine Brook were to prevent damage to infrastructure in the flood plain and channel and maintain fish habitat. Although the stream and valley types could change, this will be a very common design scenario in Connecticut.

Figure CS8–6 As-built plan view starting at Prospect St.

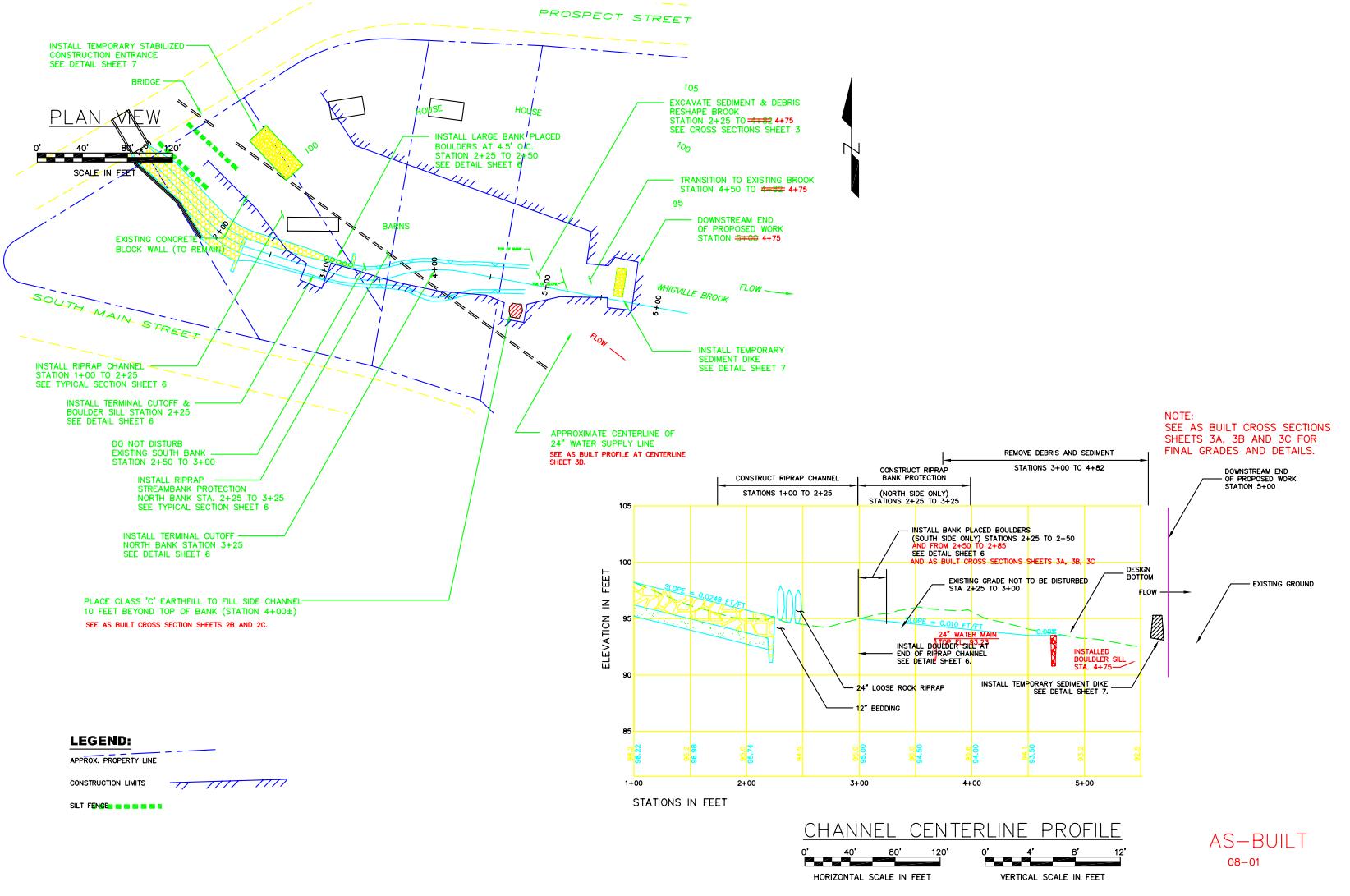


Figure CS8–7 As-built plan view starting 940 feet downstream of Prospect St.

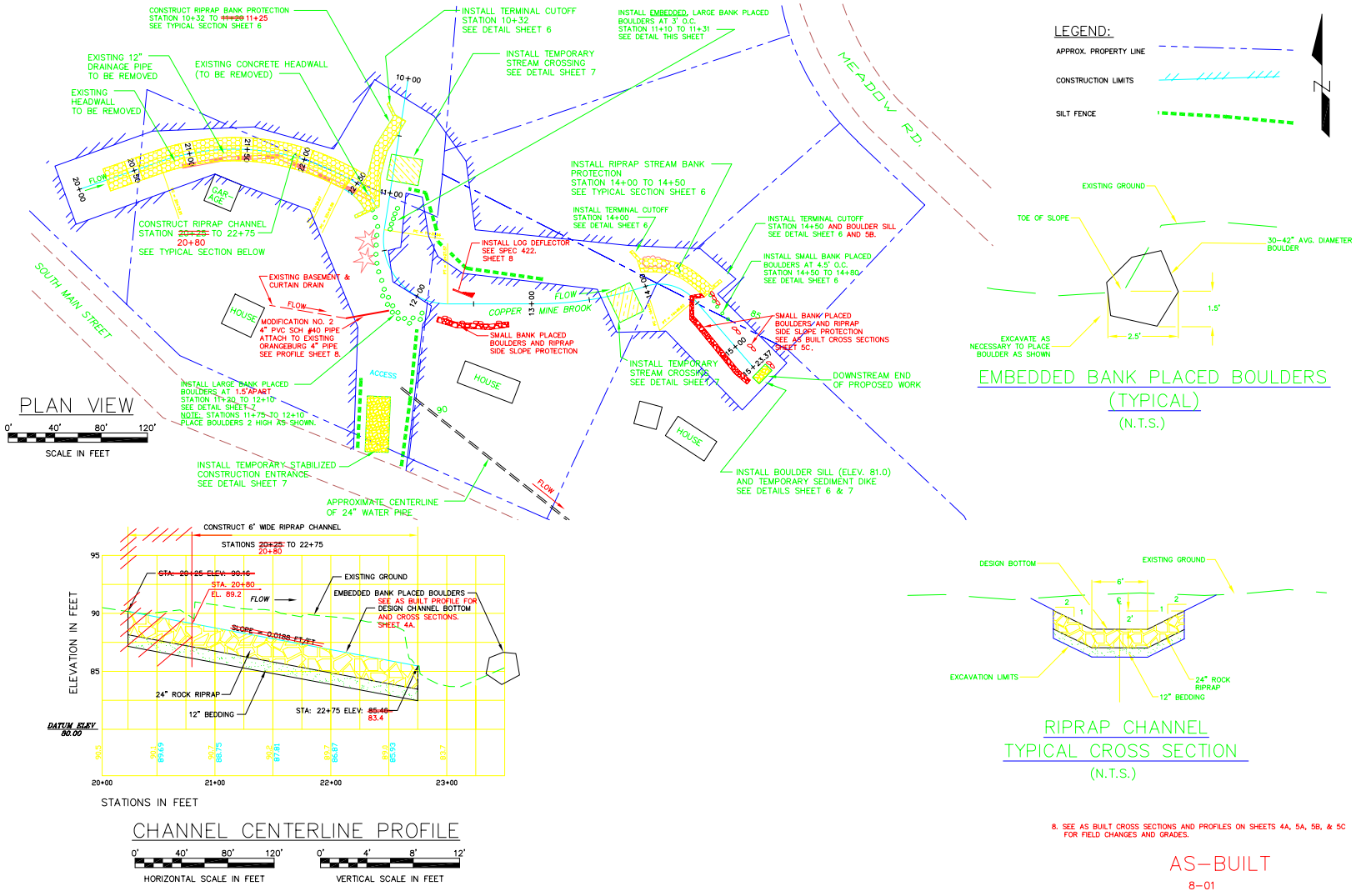


Figure CS8–8 Photo sites orientation aerial map

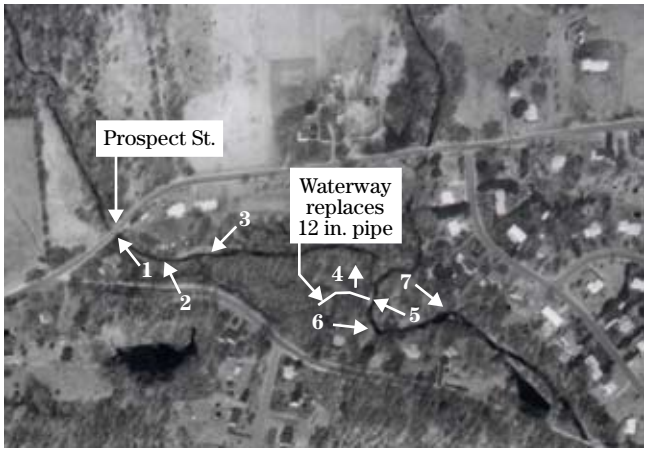


Figure CS8–10 Site 1 before project—looking upstream at Prospect Street Bridge



The stream is incising. Stacked concrete block wall on right bank had fallen down twice before. Some rock on left bank has moved onto the flood plain.

Figure CS8–9 Site 4—looking upstream at LWM waterfall



Site 4 is approximately at station 10+00 and was left unchanged during construction. The woody material created a 2-foot-high waterfall with a 2.5-foot-deep pool downstream. The woody material also helped prevent a headcut from migrating upstream. It decomposed or eroded away within 2 years of Hurricane Floyd. The brook has incised a small amount for the first 50 feet upstream. No major floods have occurred since construction.

Figure CS8–11 Site 1 after project—looking upstream at Prospect Street Bridge



This photo shows the brook 2 years after construction was completed. Consequences of failure here would jeopardize the bridge and the house on the right bank, along with its septic system. The original vertical rock wall on the left bank was removed, and the bank reduced to a 2H:1V slope. The channel and bank were armored with bedding stone and riprap. Bank riprap was topsoiled and seeded to grass. The toes of both side slopes were covered with round native stone, some of which has eroded away.

Figure CS8–12 Site 1 after project—looking downstream from Prospect Street Bridge



This photo shows the site 3 months after construction. The downstream end of the riprap terminates with a buried boulder sill. Rounded native stone was placed on both toes to help define a narrower low-flow channel and make the brook look more natural.

Figure CS8–13 Site 3 before project—looking upstream from station 4+50



Station 3+75 in the foreground has channel gravel and woody material over a 24-inch-diameter water main. The brook had started to carve a new channel on the right flood plain upstream at station 4+00. Existing debris or further aggradation at this site could increase flooding potential and encourage the brook to erode a new channel on the right flood plain. A head cut migrating upstream could expose the water main. The constructed project put a buried boulder sill 105 feet downstream of the pipe and removed a 0 to 2-foot depth of gravel for 175 feet of channel. Gravel removal in a wooded area downstream of this site was reduced to protect aquatic habitat.

Figure CS8–14 Site 5 before project—looking at headwall at station 11+10



During Hurricane Floyd, when floodwaters started to cut a new channel upstream at station 4+00 on the right flood plain, this downstream garage area experienced increased flooding. This 12-inch-diameter culvert was plugged with sediment when floodwater and sediment entered its inlet located behind the garage at the right of the photo.

Figure CS8–15 Site 5 after project—looking at lined waterway, station 11+10



The pipe and headwall were replaced with this lined waterway entering from the right side of the photo. This was more economical than replacing the pipe and would provide much greater flood protection than a pipe. The upstream debris removal shown in figure CS8–13 had not been significant enough to remove all flooding potential here. Also, the area to the right of the lined waterway would revert to wetland plants, since the owner's access to it would be restricted with less chance of it being mowed.

Figure CS8–16 Site 6 during construction—looking downstream at station 12+00



Hurricane Floyd eroded the bank and cut below the tree on the right. Concerns here were that the tree could fall on the house to the right. Further erosion would encroach on the lawn area and a well casing 15 feet from top of bank. This deep pool, overhanging tree roots, and riffle underneath the excavator were valued for their excellent fishing habitat.

Figure CS8–17 Site 6 after construction—looking downstream at station 12+00



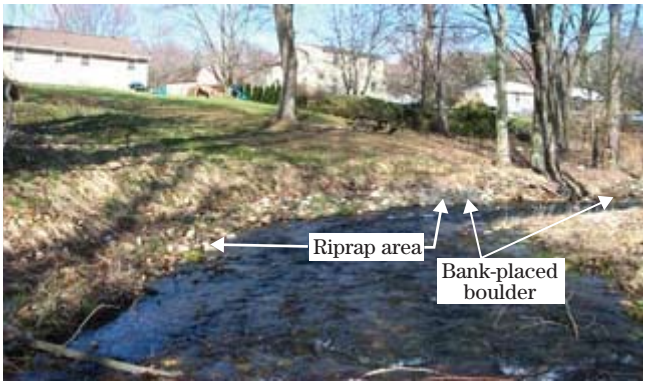
This is the site 2 years after construction. The angular bank-placed boulders are two boulders high into well-graded stream gravel. Lower row of boulders (mostly underwater) has 15-inch gaps for fish refugia. Cavity underneath the tree is only partially filled with boulders, providing more refugia and stability. Riffle downstream of meander was maintained. Fines have not piped out from gaps in bank-placed boulders. The site has not experienced any large floods since construction.

Figure CS8–18 Site 7 during construction—looking downstream at station 14+25



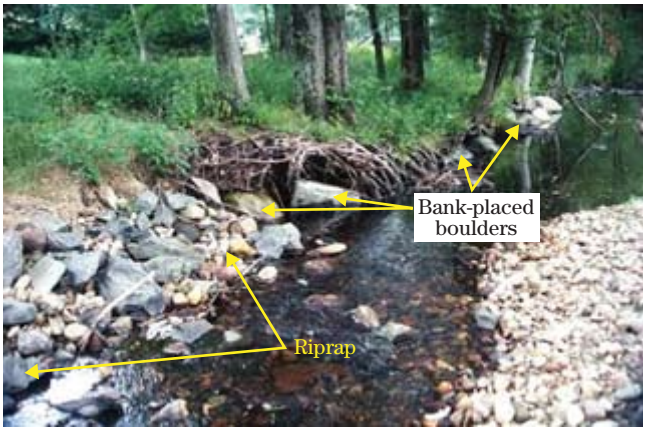
Survey tripod stands on the dewatering berm used during construction. Concerns here were that the brook was encroaching on the left flood plain, eroding into the lawn area and septic system and toppling trees. Area by the tree roots had deep pools and cover for fish, so saving the trees was desirable.

Figure CS8–19 Site 7 after construction—looking downstream at station 14+25



This photo shows site 2 years after construction. The sharp left meander is armored with bedding and riprap and covered with round native stone on the lower bank and topsoil and grass on the upper bank. The trees were protected with bank-placed boulders set into their root cavities, instead of cutting them down and placing riprap on the bank.

Figure CS8–20 Site 7—looking downstream at bank-placed boulders, station 14+50



This photo shows a close-up of bank-placed boulders 3 months after construction. Rounded and angular boulders were placed into the cavities of well-developed overhanging tree roots. Boulders were placed with gaps 1.5 feet apart for fish refugia. The upstream-most boulder is well protected by riprap to prevent erosion behind it.

Figure CS8–21 Site 2—looking downstream at bank-placed boulders, station 2+40



This photo taken 2 years after construction shows three boulders placed on the south (right bank) underneath overhanging roots. Concerns here were that the brook could carve a new channel into the right flood plain. The 5-foot gap between the boulders provides fish refugia. After a few months, bank erosion began to develop behind the boulder on the upstream side. This site is less stable than site 6 because there are no tieback rocks extending from the upstream bank-placed boulder back into the bank, and the root structure of the trees is smaller.