# Continuity Along Stream Corridors
## *Making Natural Connections*

Problem Statement:
Balancing the needs of community development, economic growth, and transportation systems with equally important environmental and outdoor recreation needs can pose important challenges in stream corridors. Fragmentation, or disconnections in the stream environment and associated habitat, degrades quality of life for both people and watershed systems.

Southeastern Wisconsin Regional Planning Commission

**The purpose of this document is to highlight some concepts that address issues associated with stream crossings and their effects on water quality, water movement, fisheries passage, flooding, and riverside communities.**

Preparation of this publication by SEWRPC was funded in part by the U.S. Environmental Protection Agency, Great Lakes National Program Office, and Lake Michigan Watershed Academy.

## Contents



Front cover photo: Rehabilitated section of Underwood Creek in Milwaukee County after a concrete channel was removed and natural floodplain connectivity restored.

*Source: SEWRPC.*

# Introduction

This Southeastern Wisconsin Regional Planning Commission (SEWRPC) educational booklet is designed to promote watershed management through the protection and proper sustainable management of continuous natural connections along and within waterbodies. Significant components of such connections are well-vegetated **riparian buffers that are beneficial as:**

- **Natural filter strips for removing pollutants from runoff waters,** so that streams can flow clean and clear;
- **Vegetated groundwater infiltration and natural spring discharge zones,** where surface flow may slowly progress and infiltrate to the groundwater;
- **Reproductive nursery cycle transitional safe havens,** which allow gradual emergence of maturing amphibians and aquatic insects after metamorphosis, and also provide **hiding or early-life protection niches** for newly-spawned fish; and
- **Wildlife habitat and / or travel corridors.**

These buffer resources comprise miles of streambanks, lakeshores, and the full extent of natural wetlands and floodlands. The buffers may further include, integrate with, and/or have beneficial application for protecting remnant high-quality natural areas and critical species habitat. Protecting green connections and increasingly rare and valuable natural parcels is essential to a livable and well-balanced metropolitan region in southeastern Wisconsin.

## Booklet Goals

**Featured in this booklet** are concepts for understanding the importance of environmental corridors and basic riparian corridor management principles.

SEWRPC's **goals for the publication** are to:

1. Aid the implementation of improvements in the riparian environment and,
2. Help prevent or mitigate further environmental degradation in situations where problems have grown over time.

**Booklet users**...As with SEWRPC's earlier buffer guidance, readers should find this new booklet to be of reference value whether they represent Federal or State agencies, regional planning organizations, counties, municipalities, land trusts, stewardship-minded property owners, environmental groups, or are interested citizens or students of ecological and social studies.

Photo 1 Multi-benefit stream corridor.
*Photo source: U.S. Geological Survey.*

## Background

This booklet is a companion to the previously published *Managing the Water's Edge: Making Natural Connections*. Continuing the ***Making Natural Connections*** series, ***Continuity Along Stream Corridors*** describes how poor water quality and "hard" infrastructure in riparian corridors (e.g., bridges, concrete channels, culverts, step-like weirs, and dams) collectively impair the performance of aquatic and riparian resources.

Related conceptual and planning support for this booklet can be found in: the U.S. Environmental Protection Agency *Lake Michigan Lakewide Management Plan* (*LaMP*), the Nature Conservancy *Lake Michigan Biodiversity Conservation Strategy*, the Wisconsin Department of Natural Resources *Milwaukee Harbor Estuary Remedial Action Plan*, and the SEWRPC *Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*, among other plans.

Riparian buffers have been identified as important **to improving the health of downstream waters, notably Lake Michigan and the other Great Lakes,** through the prevention of water pollution and the **promotion of sustainable, diverse biological systems**. For example, SEWRPC's *Regional Water Quality Management Plan Update* identifies the **need for a comprehensive buffering effort** and associated riparian buffer guidance to integrate **multiple considerations regarding riparian buffers** in both urban and rural areas. SEWRPC's watershed plans recommend the **preservation of primary environmental corridors,** including **high-quality natural areas, and the establishment or expansion of riparian buffers** along hundreds of additional miles of streambank and inland lake shoreline.

## Components of Stream Continuity

Continuity along and among environmental corridors, including stream corridors, may be viewed in several basic ways, which complement and reinforce one another:

- **Continuously flowing and uninterrupted long distances of stream *within which*** aquatic organisms can travel or migrate. This must include a consistent supply of good quality water;

- **Continuous streamside buffers of natural vegetation *along which*** organisms can travel or migrate parallel to streams while utilizing the water or the generally moist riparian environment as needed;

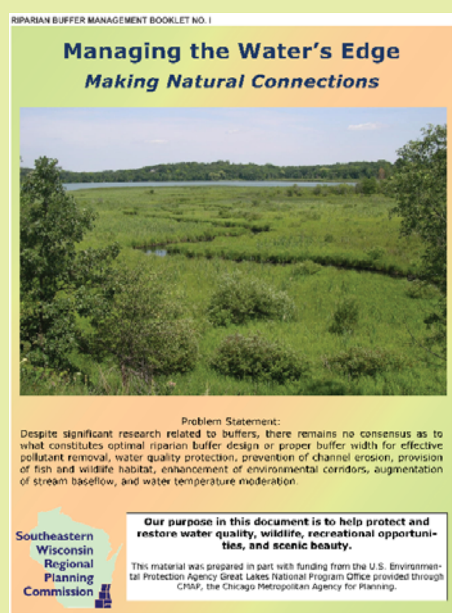
- **Continuous and sufficiently wide <u>environmental corridors</u> *throughout which*** terrestrial and aquatic riparian travel or migration are possible and **suitable size tracts of habitat exist** to maintain viable populations of important species and sustain healthy ecological systems;

- **Connection to, or among, vital tracts of natural areas and / or critical species habitat,** enabling the travel or migration of organisms.

**Environmental corridors may be regarded as highly valuable** "necklaces," while **significant natural areas and critical species habitat stand out as invaluable** "jewels" linked by the balance of the corridors.

Photo 2 Environmental corridor.
*Photo source: SEWRPC.*

The first booklet in the series, *Managing the Water's Edge* (Booklet I), addressed the need for an **adequately wide** stream buffer to provide important natural resource functions. *Continuity Along Stream Corridors* emphasizes **adequately long and uninterrupted** stream systems, including buffers, so that travel and habitat gaps do not become serious upstream or downstream impediments to ongoing or future riparian life. **The size of protected areas is also important** for many species to thrive or even for some to survive. At times, the area available as naturally significant riparian habitat is supplemented by small/ modest woodlots; naturalized fence rows; habitat preserved within cluster or conservation subdivisions; and various agricultural cover crops, notably hay/alfalfa, the latter to help accommodate ground-nesting birds and other species of grassland-dependent wildlife. **Each set of attributes enhances the others.**



RIPARIAN BUFFER MANAGEMENT BOOKLET NO. I

Managing the Water's Edge

*Making Natural Connections*

Problem Statement:
Despite significant research related to buffers, there remains no consensus as to what constitutes optimal riparian buffer design or proper buffer width for effective pollutant removal, water quality protection, prevention of channel erosion, provision of fish and wildlife habitat, enhancement of environmental corridors, augmentation of stream baseflow, and water temperature moderation.

Southeastern Wisconsin Regional Planning Commission

**Our purpose in this document is to help protect and restore water quality, wildlife, recreational opportunities, and scenic beauty.**

This material was prepared in part with funding from the U.S. Environmental Protection Agency Great Lakes National Program Office provided through CMAP, the Chicago Metropolitan Agency for Planning.

# Historical Context

## Pre-settlement Natural Landscape

**Preceding the arrival of European immigrants** in southeastern Wisconsin, when Native Americans created the only human influences on the landscape, this was a region of valuable, diverse, and free-flowing pristine streams. The natural vegetation included vast tracts of forest and other protective ground covers that virtually blanketed the soil surface against the potentially erosive effect of heavy rains.

The land surface was protected by a canopy of the tallest trees in what is termed "climax" (mature and stable) forest. This forest canopy was a first line of defense in **a very effective system for protecting soil and water resources**.

Closer to the ground in the pre-development forest stood an "understory" or sub-canopy of small to medium-sized trees reaching up to capture available sunlight. Any precipitation making its way past the tall tree canopy would have been intercepted by understory treetops. Beneath these trees stood tree saplings and shrubs, ground layer "forest floor" plants, dead and decaying leaves, a layer of organic matter known as humus, and under all these a thick network of roots and soil to hold water like an enormous, spongy, tightly-knit natural blanket. Soil largely remained in place and was ready to retain and gradually release moisture while binding plant nutrients that might otherwise make their way toward surface water and groundwater resources. Remaining trickles of clean, clear water from rain or melting snow would stay behind or slowly move on.

The prairie was also a "climax" vegetation community consisting of dense flowering forbs and grasses, along with a thick ground mulch and root mass. Unfortunately, when settlers tried to turn the natural landscape to profit via logging and farming enterprises, the stage was set for a scene change that had not been previously experienced by the native ecosystems.

## Settlement Period Alters Streams

During the mid-1800s and into the 1900s, **stream continuity abruptly changed, with waves of settlers coming to southeastern Wisconsin** primarily from Western Europe. Land use and protective ground covers that had held the native soil in place disappeared with forest clearing and prairie plowing.

If stabilizing vegetation is removed, less precipitation soaks into the ground and more water runs off the land into streams, carrying away valuable topsoil and muddying the water. When stream

Photo 3 Kettle Moraine prairie.
*Photo source: Ronald C. Kurowski.*

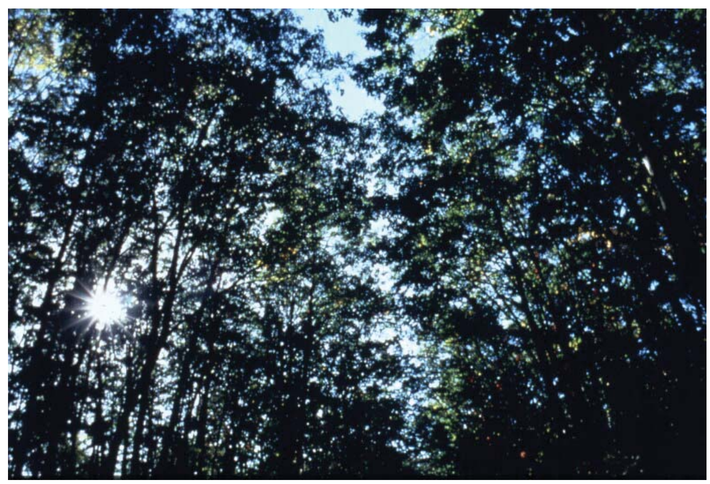


Photo 4 Mature forest tree canopy.
*Photo source: University of Wisconsin Extension.*

Photo 5 Good quality woodland stream.
*Photo source: SEWRPC.*

Photo 6 Agricultural gully erosion.
*Photo source: U.S. Natural Resource Conservation Service.*

Photo 9 Agricultural sheet erosion.
*Photo source: University of Wisconsin Extension.*

Photo 7 Muddy woodland stream.
*Photo source: SEWRPC.*

Photo 8 Incised channel in an agricultural setting.
*Photo source: SEWRPC.*

velocity slows, soil settles from the water to form silty stream bottoms and murky waters. Stream channels then may no longer have adequate natural capacity and scoured banks break down and collapse, adding to what becomes a clogged, broken system. The worst results of this type of scenario can be seen in Photo 7. Though cover crops like hay are fairly protective, farmland soaks up less precipitation than either forests or prairies. **More runoff volume results.**

When cropped soils are viewed as being too wet to farm productively, they may be ditched (Photo 8) or tiled to remove excess water more quickly. Many wetlands have been drained to accommodate more farmland or filled to form risky building sites.

Photo 10 illustrates **well-installed soil and water conservation at work in an agricultural landscape that is both environmentally and economically viable.** Multiple surveys of town residents in southeastern Wisconsin reveal that such a landscape is both appreciated and preferred. These viewpoints pertain to both rural areas and communities experiencing some rural development.

## Uncontrolled Urban Development Amplifies Problems

Suburban and urban development removes green spaces and replaces them with rooftops, driveways, and roads, which shed water that travels to streams, and which do not provide wildlife habitat. Enclosing small, headwater streams in storm sewers eliminates those important streams and hastens the conveyance of runoff. Increased volumes of flow in streams result in down-cutting and widening of those streams. The wider, but partly

Photo 10  Farm fields and contour strips.
*Photo source:  Wisconsin Department of Natural Resources.*

Photo 11  Low-density pasturing of dairy cattle.
*Photo source:  SEWRPC.*

sediment-clogged, streams lose good habitat and water transport capacity. Plant roots that anchored the banks in place are also compromised as multi-benefit protections.

Less obvious to the eye, but just as dramatic in effect, is the way in which the supply of cool, clean baseflow to streams, lakes, and wetlands is “turned down,” almost as if by a giant faucet. Less precipitation soaks into the soil and the outcome is less groundwater available to provide consistent, cool, high quality water to streams.

Where stream corridors are grazed by livestock, the soil erosion is most severe, as the concentration of farm animals breaks down the banks. However, not all grazing is equally damaging. See Photo 11 for an example of low-density, low-impact grazing.

Agricultural lanes and small roads initiated some of the first culvert and bridge obstructions along streams. Bigger roads with larger crossings followed where there was a need to establish frequently used transportation connections. In concentrated areas of development (small city, village, and crossroad centers), dams were erected along some major rapids to hold back water and harness its gravitational fall to use as a power source. Oxygenation of water by free-flowing rapids over rocks nearly vanished in some locations where dams created impoundments (reservoirs).

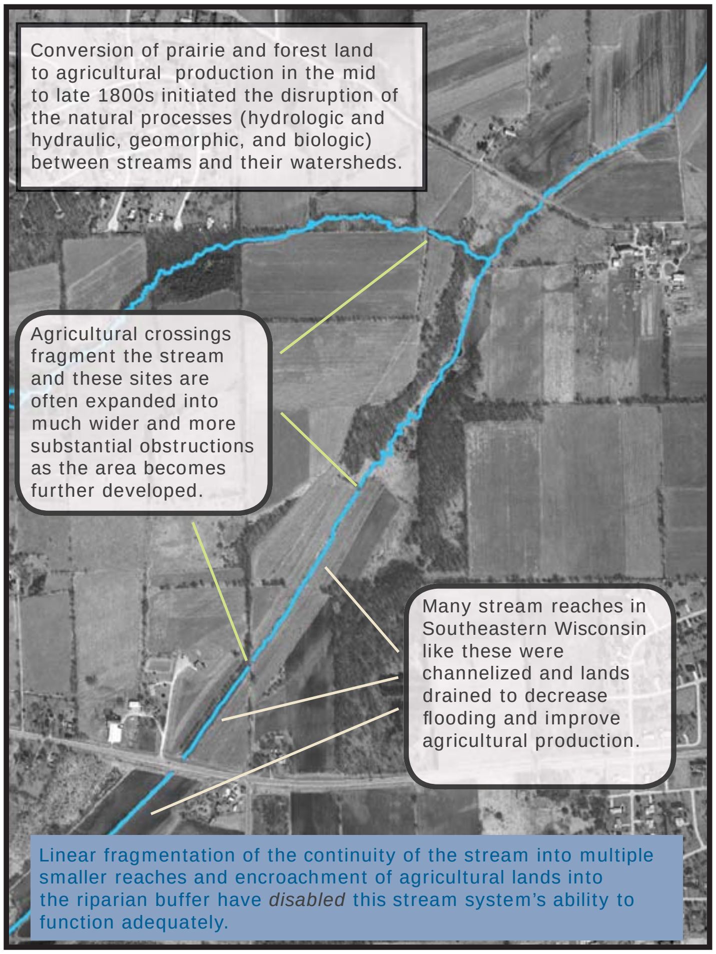
## Historical Stream Channel Alteration

Historically, streams and rivers have been channelized for a number of reasons. A major reason for the channelization of many streams in southeastern Wisconsin was to create more land area usable for

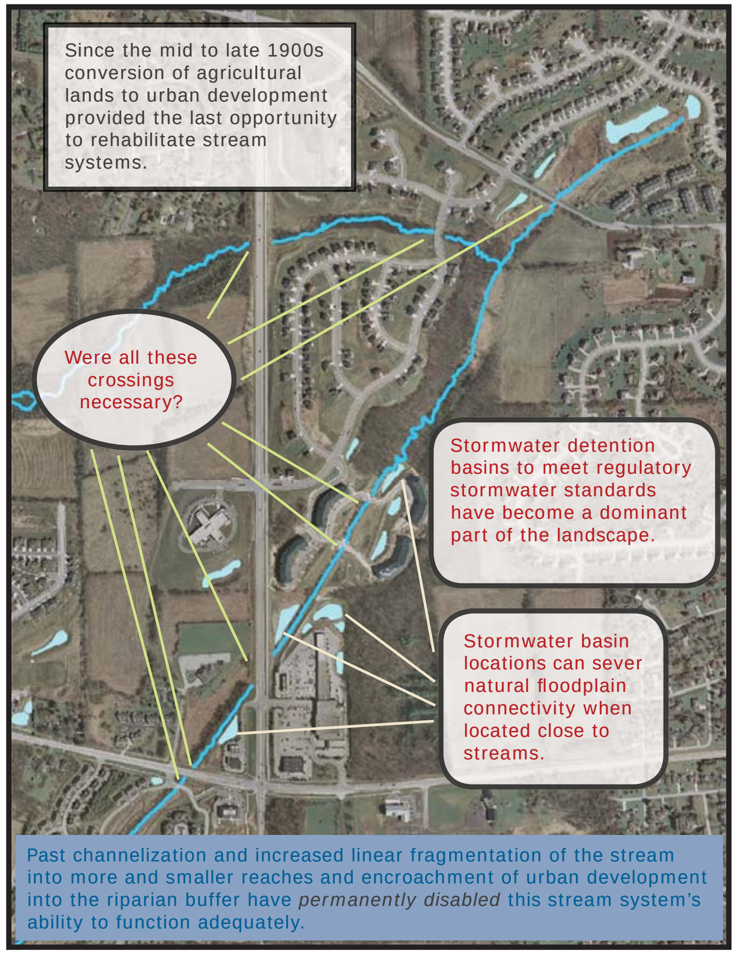
Photo 12  Suburban-area impervious surfaces.
*Photo source: University of Wisconsin Extension.*

Photo 13  Braided stream channels within rural environmental corridor.
*Photo source:  Wisconsin Department of Natural Resources.*

**Stream Systems Can Become Disabled: Year 1990**




**Stream Systems Can Become Disabled: Year 2010**




*Source: SEWRPC.*

agriculture, roads, or other purposes immediately adjacent to the stream. Other reasons for channelization of streams are related to stormwater and flood control. Many streams were channelized in an attempt to improve the drainage of precipitation off the land with a resulting improvement in stormwater control and reduction of flooding in the areas adjacent to the channelized sections. In addition, larger rivers were often channelized to make them more suitable for navigation. Finally, many streams were channelized and lined to reduce the potential for migration of the channel.

## Anatomy of a Stream

Just as the human anatomy has many component parts and systems that must work thogether to ensure health, so it is with a stream system.

The key components of stream anatomy are briefly described below and are shown in Figure 1.

### Channel

The most obvious feature of a stream is the channel, which conveys low flows.

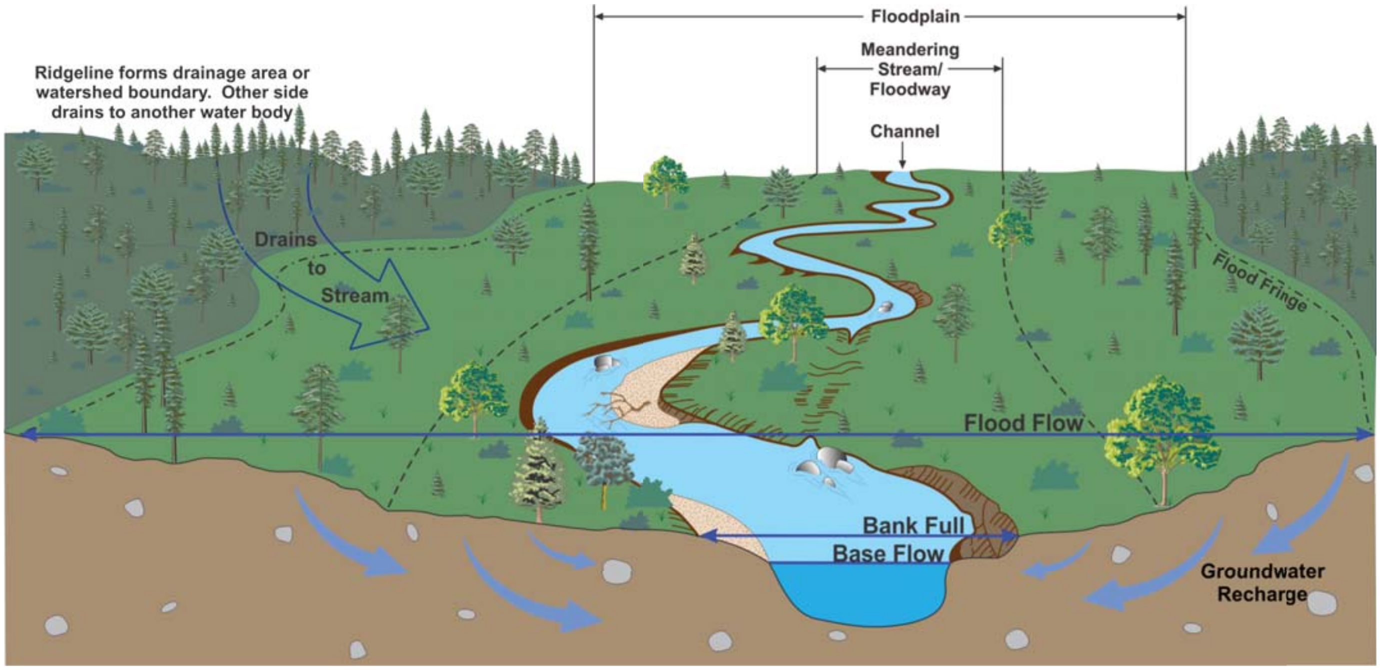
### Meandering

Stream meandering is a natural process in response to the erosive power of flowing water as it is deflected bank-to-bank across the channel and progresses downstream.

Sometimes the overflow of water from one meander to another will produce a secondary or overflow channel that has permanence. When that occurs, the stream has a braided look with channels intertwining around elongated islands or peninsulas (see Photo 13). Places where the strands of the braids converge can be dangerous due to increased water volume, turbulence, stream velocity, and debris settling out following flooding. However, for landscape diversity, fish and wildlife habitat, fishing, canoeing, and kayaking, such areas create desirable recreational variety.

**Figure 1**

**STREAM ANATOMY – RIPARIAN LANDSCAPE CROSS-SECTION**




*Source: SEWRPC.*

## Flow

The primary physical function of a stream is to move water from an area of higher elevation to a location of lower elevation. This occurs primarily as a result of a stream channel's position and slope (see Figure 2).

**Key inputs to streamflow are** (see Figure 3):

- **Precipitation** landing on the stream's surface;
- **Runoff** of precipitation that has not soaked into the ground; and/or,
- **Groundwater seepage,** whereby water infiltrates from the land surface into the ground and then moves slowly underground toward the stream.

A stream's level or elevation may change substantially from its source to its mouth. The predominant influences on water depth are the change in elevation of the stream bottom as shown in Figure 2; the resistance to flow from vegetation and from the streambed and bank material; and structures such as bridges, culverts, and dams placed in, or across, the stream.

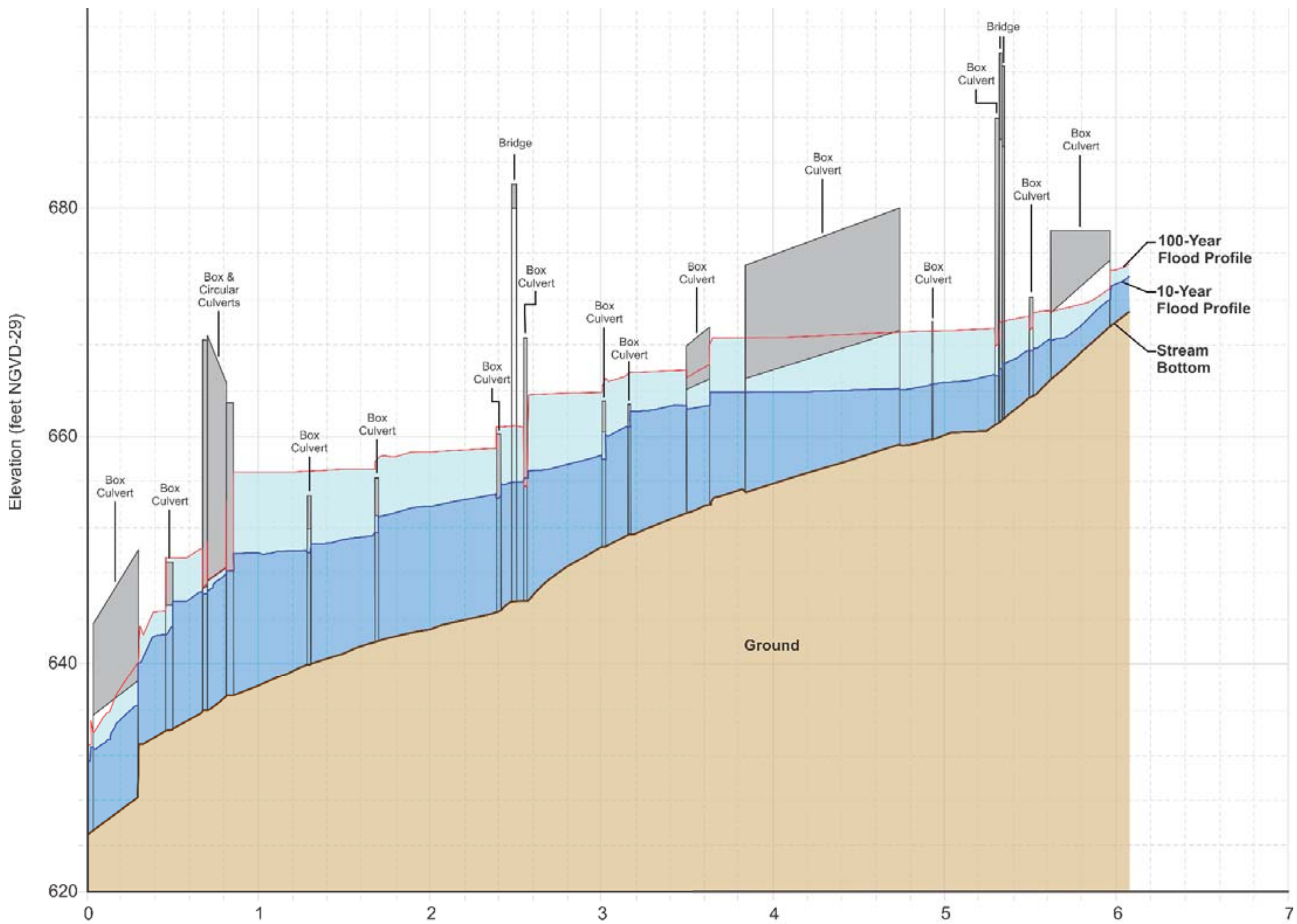
## Base Flow

*Base flow* is primarily the product of a slow but steady discharge of groundwater to the stream. Relatively variable surface water runoff may move into and out of a stream quickly, while the more steady inputs of groundwater provide the base flow. Discrete points at which such groundwater generally enters the stream are called springs or seeps. Due to the uniformity of groundwater temperature and discharge rates, such groundwater normally enters the stream steadily and year-round at a relatively cool

Photo 14 Meandering stream channel.
*Photo source: SEWRPC.*

**Figure 2**

**ANATOMY OF A STREAM PROFILE**




*Source: SEWRPC.*

temperature. **Because cool water holds more dissolved oxygen than warm water, many aquatic organisms benefit from this groundwater flow to a stream.**

## Bank Full

The *bank full* stage of a stream represents a condition when the banks are full up to their tops as shown in Figure 1. After a precipitation and/or snowmelt event, streams can progress from base flow to bank full stages and back within a short time (as the source water can quickly progress from groundwater inflow to storm water runoff with a sudden or heavy downpour and/or quickly melting ice and snow). When the overall volume of water becomes too great it will exceed stream capacity, stream banks will overflow, and flooding may occur.

## Floodplain

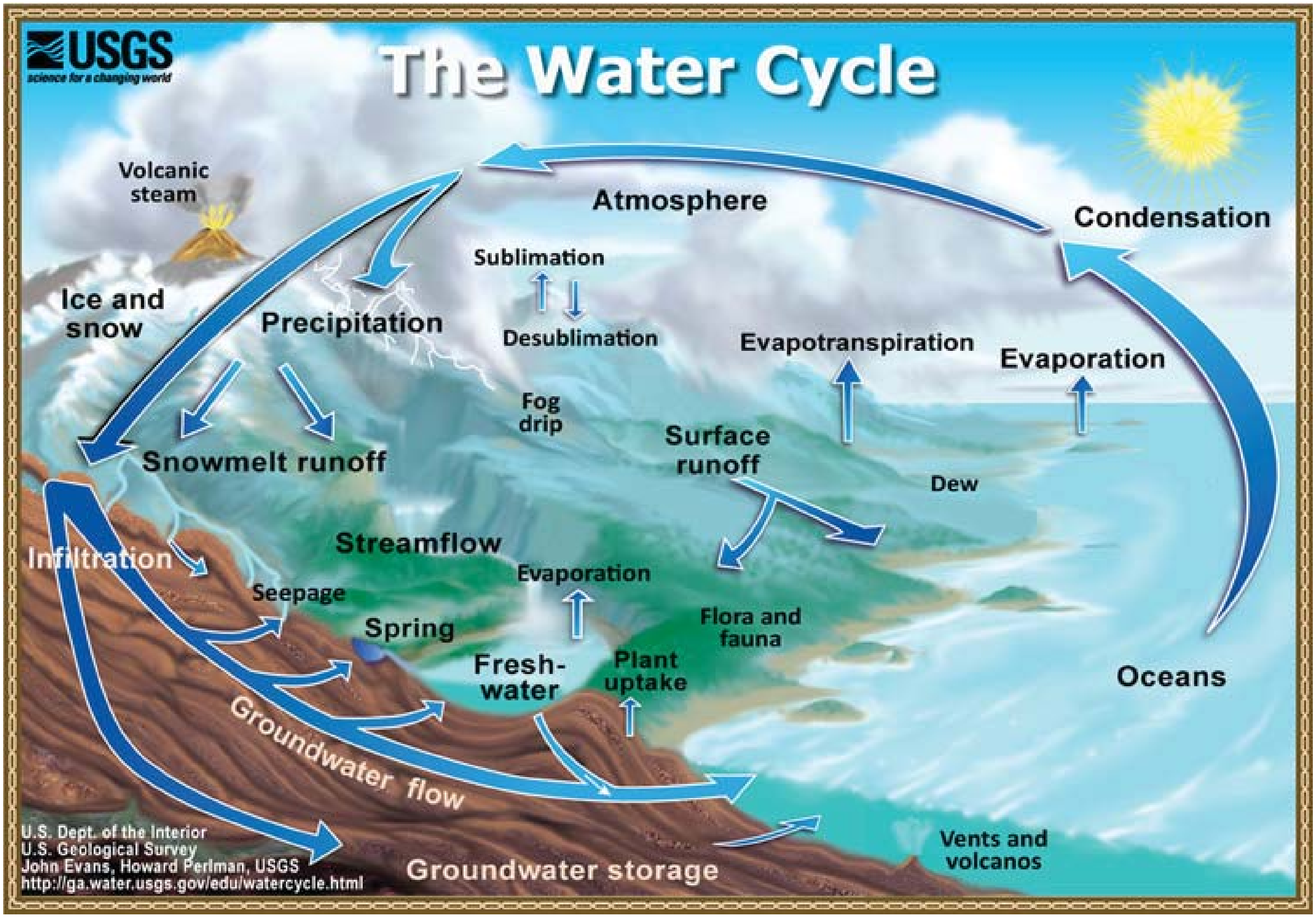
A **floodplain** is the generally flat land adjoining a stream or lake into which water overflows during periods of higher flows. An important part of healthy natural streams is the capacity of the floodplain to store, filter, and slowly release floodwaters to areas downstream.

**Streams can quickly overflow into the floodplain, where water is temporarily stored and held.** Photo 15 shows substantial agricultural field flooding and storage of floodwater along Cedar Creek in the Milwaukee River Watershed.

Maintaining the connection between the stream channel and the floodplain promotes streambank stability by allowing the flow to spread out into the floodplain, reducing overall flow velocities and corresponding erosive forces.

**Figure 3**

**HYDROLOGIC CYCLE**




*Source: USGS.*

*Floodplains* are also important for wildlife habitat, and as natural areas for plant and animal communities.

## Continuity Over Time

It is important for streams and other portions of environmental corridors to remain continuous over time. This means that it is vital to have connected natural features that enable organisms within such corridors to access the habitats in which they can thrive and reproduce.

Such aquatic and riparian habitat continuity relates to more than just removal or mitigation of physical impediments to movement. For example, in an agricultural area, the discharge of liquid manure from a spill, or from poorly managed field-spreading, if

Photo 15 Flooded farmland.
*Photo source: Wisconsin Department of Natural Resources.*

washed off by heavy rains or meltwaters, would not physically block streamflow and halt the passage of fish or other aquatic organisms. However, the presence of ammonia from concentrated animal waste can be toxic. Additionally, bacterial decomposers can rob the water of oxygen as they break down the waste and other organic matter, possibly creating a stream or lake “dead zone” that makes the downstream stretch uninhabitable and, therefore, an impediment to movement along a stream for some types of aquatic life during certain periods.

Given the complex relationships that exist in ecological communities, adverse impacts among interdependent species can mount a series of threats. These threats can then become larger dangers for survival; a series of dangers can be harmful to certain plants and animals over time. If a species were eliminated or eradicated from a stretch of stream, one would reasonably conclude that such a stream segment had poor continuity or was, perhaps, “disabled” at that place and time.

In a watershed system, the concept of stream continuity is principally meant to convey the importance of physical connectedness—from the farthest upstream reaches to the farthest downstream channels and everything in between. Simply put, stream continuity is needed over the entire stream length. Unfortunately, many substantial interruptions in stream continuity already exist.

Major dams block the migration of certain aquatic organisms, including fish, and impound water while holding back sediment and plant nutrients from passage downstream. As a result, stream reaches may become shallower, muddier, and eutrophic (weed-or algae-clogged) immediately upstream from dams.

Other barriers to stream continuity may be seemingly harmless, such as inappropriately aligned culverts under roads, which inadvertently function as mini-dams, holding back water and key components of aquatic life, while partially blocking migration of organisms from downstream to upstream (see Photo 17). In sequence, as shown in Figure 2, series of culverts can have compounding effects on water levels and migration of aquatic and terrrestrial species along the stream corridor. Stream crossings in close sequence may thus be more like dams and less like the piecemeal limited-purpose crossings for which they may have first been constructed, often without much forethought or environmental analysis.

Photo 16 Bridge crossing with naturalized bed enabling passage of aquatic organisms.
*Photo source: SEWRPC.*

Photo 17 Perched culvert outlet blocking passage of aquatic organisms from downstream to upstream.
*Photo source: SEWRPC.*

Depending upon their location, these seemingly minor interruptions to stream continuity may remove entire upstream tributary areas from connection with the rest of a watershed.

## Channelization and Concrete-Lined Channels

Natural, unmodified streams typically exhibit a high degree of variety, or heterogeneity, in channel morphology and alignment within their channels, including variations of depths, widths, and flow patterns. Patterns of flow in these streams can be quite complex, encompassing areas of both slow- and fast-moving water, areas of smooth, laminar flow, and areas of turbulent flow. Water depth can also vary, with deeper water usually found in areas of scour, such as along the outside of bends in the channel, and immediately downstream of areas with high water velocity, such as riffles. This heterogeneity also has a temporal component. Over time, long-term changes in the watershed produce gradual alterations in channel geometry. These long-term changes result from cyclical patterns of small scale streambank and streambed degradation, caused by scouring and erosion, and streambank and streambed aggradation caused by sedimentation. Over long periods of time, the position and geometry of an undisturbed stream's channel can vary considerably.

**Channelization usually includes** one or more of the following changes to the natural stream channel: channel straightening; channel deepening; channel widening; placement of a concrete bottom and sidewalls (see Photo 18), and sills, or other obstructions to flow; and reconstruction of selected bridges and culverts. At times the natural channel may be relocated or completely enclosed in a conduit. These modifications to the natural channel generally yield a steeper, hydraulically more efficient waterway, which results in lower flood stages within the channelized reach.

Channelization can produce a number of effects on the hydrology of a stream or river. Because straightening the channel reduces its total length without decreasing the elevation through which the stream must drop, channelization often results in an increase of the stream's gradient and an accompanying increase in the speed at which water moves downstream through the channel. This increase in stream velocity can have major effects on the stability of the channel. Unless the streambank is well-protected, the higher water velocity may result in erosion and degradation of the bank and an increase in the sediment load carried by the stream. The sediment mobilized by this degradation will be deposited downstream, covering coarse substrates and filling pools and holes in the bed. As a result, the width of the channel will increase while the depth of the channel decreases. When the streambank is well-protected, scouring of the existing streambed can occur. This erosion, referred to as head cutting, tends to move from downstream to upstream. This will also lead to increased sediment loads and deposition of sediment downstream and can result in an

Photo 18 Concrete-lined channel.
*Photo source: SEWRPC.*

Photo 19 Stream rehabilitation in progress along a formerly concrete-lined channel.
*Photo source: SEWRPC.*

increase in channel width and a decrease in channel depth in the downstream reach. These changes in channel geometry tend to disrupt the pool-riffle structure of the stream, resulting in a decrease in heterogeneity in channel width and depth and flow patterns. In addition, the higher stream velocities that result from channelization hasten the conveyance of water through the stream. This can result in lower base flows during dry periods and flashier flows during high-water events, both of which are potentially problematic. These changes resulting from channelization reflect the stream's tendency to return to a more gradual slope and may be accompanied by effects in areas of the stream well

## CRITERIA AND GUIDELINES FOR DESIGNING STREAM CROSSINGS TO ALLOW FISH PASSAGE AND MAINTAIN STREAM STABILITY

### Types of Crossing

- The number of stream crossings should be minimized.
- If a crossing is necessary, structures that maintain to the extent possible the existing streambed and bank conditions are preferable; therefore, bridges spanning streams are preferable to other structures.
- If a culvert is necessary, open bottom structures are preferable to closed bottom structures.
- If a closed bottom culvert is necessary, box culverts, elliptical, or pipe arch culverts are preferable to round pipe culverts, because round pipes generally reduce stream width to a much larger degree than the other culverts mentioned, causing long-term upstream and downstream passage limitations (see physical considerations below).

### Biological Considerations

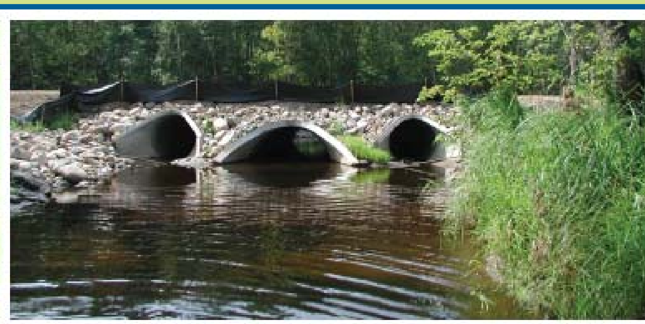
- Contact the area WDNR fisheries manager prior to design.
- Species of fish present (coldwater, warmwater, threatened, endangered, species of special concern).
- Life stages to be potentially impacted (e.g., egg development within substrates should be avoided).
- Migration timing of affected species/life stages (e.g., adult spawning times should be avoided).

### Physical Considerations

To achieve the minimum physical criteria outlined below, the culvert(s) will need to be oversized as part of the design to ensure adequate long-term fish passage as well as the ability to pass the design rainfall event.

**COMPARISON OF UNDERSIZED AND ADEQUATELY SIZED AND PLACED CULVERTS**

Undersized culvert.



Properly sized and placed culverts.

*Source: Minnesota Department of Natural Resources.*

It may not be possible to achieve some of the minimum passage criteria below based upon specific on-site conditions or constraints. However, the closer the designed and completed culvert meets these criteria, the better the long-term passage and overall sustainability of the fishery will be in this region.

### *Provide Adequate Depth*

- Slope—Culvert should be installed with a slope that matches the riffle slope as measured along the thalweg (lowest part) of the stream.
- Water Depth—Depths should maintain the determined thalweg depth at any point within the culvert during low flow periods.
- Installation Below Grade—The culvert should be installed so that the bottom of the structure is buried to a depth equal to 1/6th the bankfull width of the stream (up to two feet) below the natural grade line elevation of the stream bottom. The culvert should then be filled to stream grade with natural substrates. The substrates should consist of a variety of gravel ranging from one to four inches in diameter and either mixed with nonuniformly laid riprap or uniformly placed alternate riprap baffles, large enough to be stable during the culvert design discharge, which will ensure stability of substrates during high-flow events.

### *Provide Adequate Width*

- Width—Culvert width should match the bankfull width (minimum) of the existing channel.
- Offsetting Multiple Culverts—The number of culverts should be minimized. However, if multiple culverts are necessary, it is recommended that the culvert inverts be offset vertically and only one culvert be designed to provide passage during low-flow conditions with the additional culverts used to pass the higher flow events (see photos on page at left). Therefore, the low-flow culvert will be the only culvert, in a series of two or more culverts, designed to provide fish passage during low flows and should meet the physical requirements of passage described above.

### *Provide Adequate Resting Areas*

- Length—Additional resting areas should be provided (e.g., through installation of baffles or weirs) to facilitate passage within culverts that exceed 75 feet in length.

Inlet and Outlet Protection

- Align the culvert with the existing stream alignment (90-degree bends at the inlet or outlet should be avoided, even though this will increase culvert length).
- The low-flow culvert should be centered on the thalweg of the channel to ensure adequate depths inside the culvert.
- Provide grade control where there is potential for head cuts that could degrade the channel.
- It may be necessary to install riprap protection on the outside bank below the outlet to reduce bank erosion during high-flow events.

upstream and downstream of the channelized section. Finally, lining a channel with concrete significantly impairs the ability for the channel to interact with the groundwater. The ability of the stream to buffer itself through infiltration to the channel from the groundwater is almost completely eliminated and the maintenance of a longitudinally distributed base flow is disrupted because the concrete lining presents a barrier to groundwater inflow along the channel length, with baseflow from groundwater only allowed to enter the channel through drains in the concrete sides or bed.

While channelization can be an effective means of reducing flood damages, it may entail high aesthetic and ecological costs. Furthermore, because of decreased floodplain storage and increased streamflow velocities resulting from channelization, channel modifications tend to increase downstream flood discharges and stages, and, therefore, may cause new flood problems or exacerbate existing ones. It is possible, however, depending on the relative position of the channelized reach or reaches in the watershed stream system, for channelization to result in reduced downstream discharges. Channelization in the lower reaches of a watershed or subwatershed may provide for the rapid removal of runoff from the lower reaches prior to the arrival of runoff from the middle and upper portions of the watershed or subwatershed, thereby reducing peak discharges and stages in those lower reaches.

The changes in hydrology resulting from channelization can have profound effects on the suitability of a stream as habitat for fish and other aquatic organisms, and such changes can serve to hinder, or prohibit, fish passage, or to create unfavorable habitat conditions for fish and aquatic life, thereby reducing continuity along a stream. Increased stream velocity resulting from a higher gradient may make the stream unsuitable as habitat for fish and invertebrate species that cannot tolerate fast-moving water. Deposition of fine sediments over coarser substrates can adversely impact fish habitat and fish populations in warmwater streams, reduce these substrates' food-producing capabilities, and make the substrates unsuitable as spawning habitat for fish. In addition, many gamefish species require the deeper water found in pools as habitat. Sediment deposition in pools can reduce the size and number of essential deeper habitats. The removal of large woody debris and boulders from the channel during channelization also reduces the amount of cover and food-producing areas available to gamefish. Finally, the removal of vegetation from along the streambank that often accompanies channelization can result in a reduction in cover and food for wildlife.

Photo 20 Dams can be a barrier to movement of aquatic organisms from upstream to downstream.
*Photo source: SEWRPC.*

## Dams, Culverts, and Bridges

Species are also hampered in instream movement by dams and improperly aligned culverts and, in some instances, bridges (see Photos 17 and 20).

### *Dams*

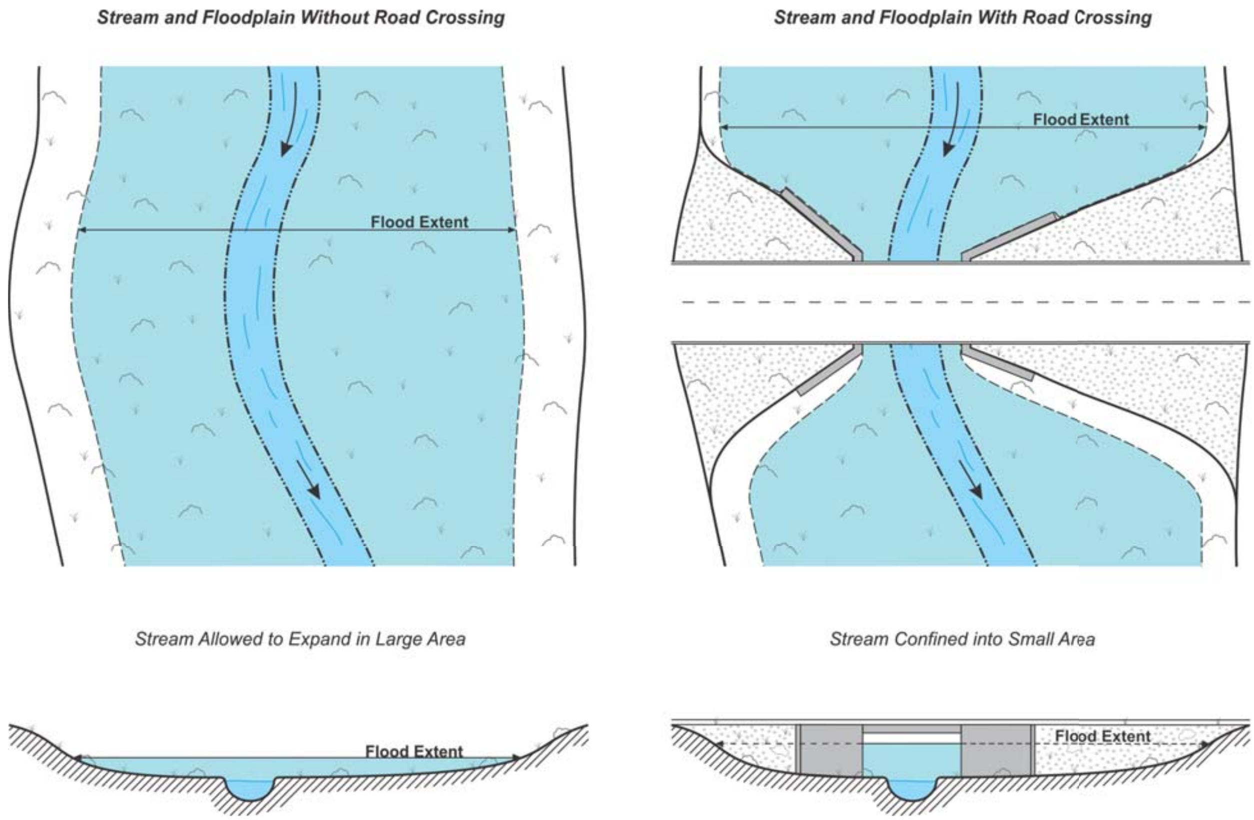
Historically, dams have been built for a number of reasons, including: flood control; creation of reservoirs for water supply, recreation, fire control, and agricultural uses; capture of energy to run mills or electrical turbines; and increasing stream depth for navigation.

The effects that a dam has on a watercourse depend upon the type, size, and operation of the dam. The presence of a dam on a stream can produce several effects, including:

- By posing a barrier to movement, **dams can act to fragment populations of organisms** and cut organisms off from habitat needed for feeding, cover, or reproduction.

**Figure 4**

**CORRIDOR FRAGMENTATION BY A ROAD CROSSING**




*Source: SEWRPC.*

- **Dams can change the pattern of sediment transport** and distribution in a stream. Typically, suspended sediment is deposited in the reservoir upstream of a dam. This results in less sediment being transported to downstream reaches, and can ultimately lead to increases in erosion and armoring of the channel in downstream reaches.
- **Water-quality characteristics in reservoirs created by dams often resemble those of pond or lake systems more than those of flowing water systems.** For example, water temperature in a reservoir may be altered through solar insolation. This change may include vertical temperature stratification of the reservoir. The location in the water column where water is removed from the reservoir can lead to either higher or lower water temperatures in downstream reaches of the stream. In addition, oxygen and nutrients may be removed from water in the reservoirs through biological processes similar to those found in lakes.
- **The presence of a dam can also adversely impact aquatic organisms** (e.g., fish can be killed as they pass through or over dams).

The operation of a dam can also affect the hydrology and ecology of a stream. The patterns of water release determined by the operator can alter fundamental characteristics of flow in the stream, including the magnitudes and frequencies of peak flows, mean flows, and base flows; the timing or seasonality of peak and low flows; and the rate of change between high and low flows. These disruptions of normal changes in flow patterns can cause changes in stream morphology and water quality downstream of the dam. Some of these downstream effects can be mitigated by changes in operations designed to more accurately mimic seasonal flow rates under natural conditons.

### *Bridges and Culverts*

Bridges and culverts can affect stream widths, water and sediment depths, velocities, and substrates. **These structures also have the potential to pose physical and/or hydrologic barriers to fisheries and other aquatic organisms.**

Figure 4 illustrates how a roadway crossing a stream can contribute to fragmentation of a natural, linear riparian corridor. Constriction of the floodplain at the bridge and the roadway can serve to block, or inhibit, migration of aquatic and terrestrial organisms.

Culverts can fragment populations of organisms by acting as obstructions to passage. High water velocities, low water depths, elevated outlets, and blocked outlet pools resulting from inappropriately designed or installed culverts can act as barriers to fish passage, effectively cutting fish off from habitat needed for feeding, cover, or reproduction. Over time, this can act to exclude fish from portions of the stream system, including essential wetlands. The combined impact of multiple culverts along a stream can have a significant impact on fish communities. Culverts tend to have a destabilizing influence on stream morphology that can create selective barriers to fish migration because swimming capabilities vary substantially among species and size-classes of fish, affecting their ability to traverse the altered hydrologic regime within the culverts.

Fish of all ages require freedom of movement to fulfill needs for feeding, growth, and spawning. Such needs generally cannot be found in only one particular area of a stream system. These movements may be upstream or downstream and occur over an extended period of time, especially in regard to feeding. In addition, before winter freeze-up, fish tend to move downstream to deeper pools for overwintering. Fry and juvenile fish also require access up and down the stream system while seeking rearing habitat for feeding and protection from predators. The recognition that fish populations are often adversely affected by culverts has resulted in numerous designs and guidelines that have been developed to allow for better fish passage and to help ensure a healthy sustainable fisheries community. (See pages 14 and 15 for guidelines.)

### *Beaver Activity*

Beavers can cut trees and alter environments to a greater extent than any other mammal besides humans. Their ability to increase landscape heterogeneity, or variability, by felling trees and constructing impoundments and canals goes beyond their immediate needs for food and shelter. They can dramatically alter nutrient cycles and food webs in aquatic and terrestrial ecosystems by modifying hydrology and selectively removing riparian trees. The activities of beavers in streams provides an example of a natural alteration to ecosystem structure and dynamics. Beaver activity may result in differing degrees of alterations that: 1) modify channels; 2) increase retention of sediment and organic matter; 3) create and maintain wetlands; 4) modify nutrient cycling and decomposition by wetting soils, altering the hydrologic regime, and creating anaerobic, or oxygen-deprived, zones in soils and sediments; 5) modify the riparian zone, including the species composition and growth form of plants; 6) influence

Photo 21 Beaver dam.
*Photo source: SEWRPC.*

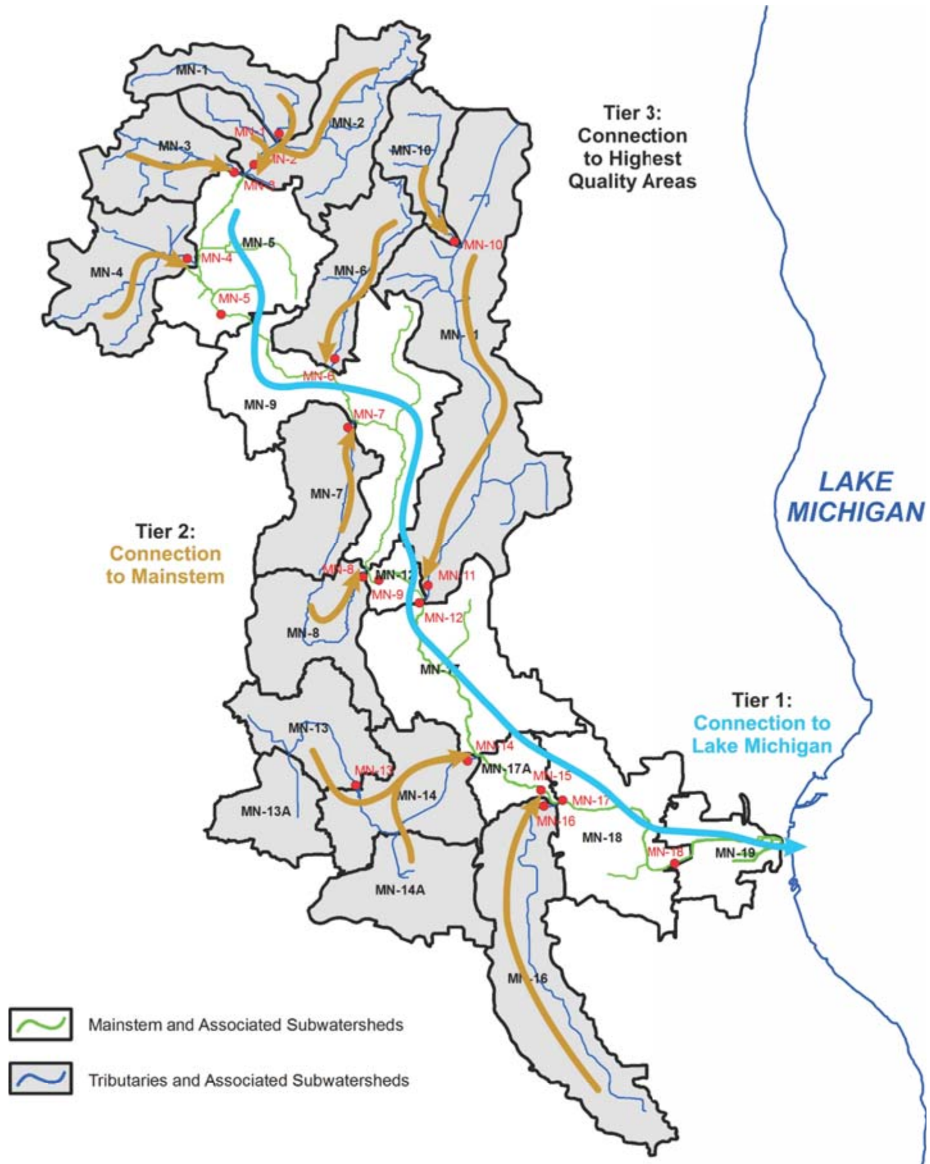
the character of water and materials transported downstream; and 7) modify instream aquatic habitat, which ultimately influences community composition (e.g., fish and macroinvertebrates, or aquatic insects) and diversity. Fundamentally, beaver dams convert stretches of former channel from free flowing water to a ponded condition.

Beaver dams are not permanent structures; without constant maintenance the dams will be breached and blowouts will occur. In addition, dams are frequently abandoned when beavers move on to new areas, depending on food and habitat availability. There is no set time frame within which beavers inhabit areas and maintain dams. It has been documented that dams can be maintained over long periods of time, or used only seasonally. It is likely that, under normal conditions, beaver dams are obstructions for most fish species in terms of upstream passage. Most fish species can go downstream without problems; however, it is unknown how passable beaver dams are under high flow conditions.

Beaver dams have been shown to enhance fisheries over watershedwide scales. When beaver impound streams by building dams, they substantially alter stream hydraulics in ways that benefit many fish species. Early research suggested that beaver dams might be detrimental to fish, primarily by hindering fish passage, and it has been demonstrated that beaver dams seasonally restrict movement of fishes. Until recently, it was common for fish managers to remove beaver dams. However, more than 80 North American fishes have been documented in beaver ponds, including 48 species that commonly use these habitats, and the beaver ponds' overall benefit to numerous fishes has been well-documented, causing managers to rethink the practice of removing beaver dams. In agricultural areas, beaver dams may impound water and submerge drain tile outlets, reducing the effectiveness of the tile systems and adversely affecting crops. Therefore, management of beaver activity is a complicated and controversial issue, so decisions to remove beaver dams should be addressed on a case-by-case basis.

**Figure 5**

**INSTREAM THREE-TIER PRIORITIZATION STRATEGY WITHIN THE MENOMONEE RIVER WATERSHED**




*Source: SEWRPC.*

## Preserving or Restoring Connectivity

Figure 5 illustrates an approach to preserving, or restoring, connectivity in a stream and lake system. The example depicted schematically relates to enhancing the connection of the streams and wetlands in Southeastern Wisconsin's Menomonee River watershed tributary to Lake Michigan. A similar approach could be applied for any watershed that is, or could be, better-connected to a high-quality water resource. **The goal of this approach is to restore a sustainable fishery** throughout the watershed.

This framework is based upon a three-tiered approach, focused on the reconnection of waterways that have been historically isolated from the stream system tributary to Lake Michigan through construction of dams, roadways, and flow control structures, or modified through construction of single-purpose systems, such as stormwater conveyances. The three components of this strategy are:

- **Tier 1**—Restoring connectivity and habitat quality between the mainstem waterways and the Lake Michigan endpoint,
- **Tier 2**—Restoring connectivity and habitat quality between the tributary streams and the mainstem of the Menomonee River, and
- **Tier 3**—Expanding connection of highest-quality fish, invertebrate, and habitat sites within the watershed.

The third tier is a "catch-all" that enables stakeholders to link the goals of habitat restoration and improvement of recreational options with ongoing activities throughout each watershed. This strategic element provides the flexibility for communities and stakeholders to take advantage of opportunities throughout each watershed that may arise independently of the primary strategy of restoring linkages with Lake Michigan and tributary streams. An example of this latter strategic approach would be using the opportunity provided by scheduled reconstruction of area roadways to remove obstructions or modify channelized stream segments that might not fully conform to the first two strategic priorities. To this end, it is further noted that provision of fish passage will provide passage for other aquatic organisms such as invertebrates. Providing restored connectivity, and associated habitat, can further the purpose of establishing a sustainable fishery and enhance human economic opportunities and recreational and aesthetic values.

## Environmental Corridors and Their Role in Continuity

Environmental corridors are areas in the landscape containing especially high-value natural, scenic, historic, scientific, and recreational features. In Southeastern Wisconsin they generally lie along major stream valleys, within county parkway systems, around major lakes, and in the Kettle Moraine area.

From the air, environmental corridors appear as long intertwining ribbons of natural vegetation and surface waters. They contain the best remaining woodlands and wetlands, wildlife habitats, undeveloped shorelands and floodlands, groundwater recharge and discharge areas, and steeply sloped lands in the Region.

### Types of Environmental Corridors Favoring Stream Continuity

- **Primary environmental/riparian corridors,** containing large concentrations of our most significant natural resources. They are at least 400 acres in size, at least two miles long, and at least 200 feet wide;

- **Secondary environmental/riparian corridors,** containing significant but slightly smaller concentrations of natural resources. They are at least 100 acres in size, 100 feet wide, and are at least one mile long, unless serving to link primary corridors justifies lesser dimensions; and

- **Isolated natural resource areas,** containing significant resources, apart from formally delineated environmental corridors. These areas are at least five acres in size and at least 200 feet wide. They are different from, and of lesser preservation importance than, the natural areas of State, regional, or county significance as identified in *A Regional Natural Area and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin (*completed by SEWRPC in 2000 and amended in 2010, see Map 2).

### Environmental Corridor Connection Functions

High-value lakes, wetlands, prairies, and woodlands become all the more valuable when linked by corridors of concentrated natural resource value. Like beads on a necklace, the best resource features are strung together to become part of a larger functioning system. Fish and wildlife, songbirds, native plant distribution, and even clean water are all dependent upon movement through environmental corridors—and upon the vital connecting functions these resources perform.

Protection of environmental corridors has been a longstanding principal recommendation of the Southeastern Wisconsin Regional Planning Commission. It is fundamental to the regional land use plan for the Region. Primary environmental corridors should not be altered in any way that measurably diminishes their natural attributes and societal benefits.

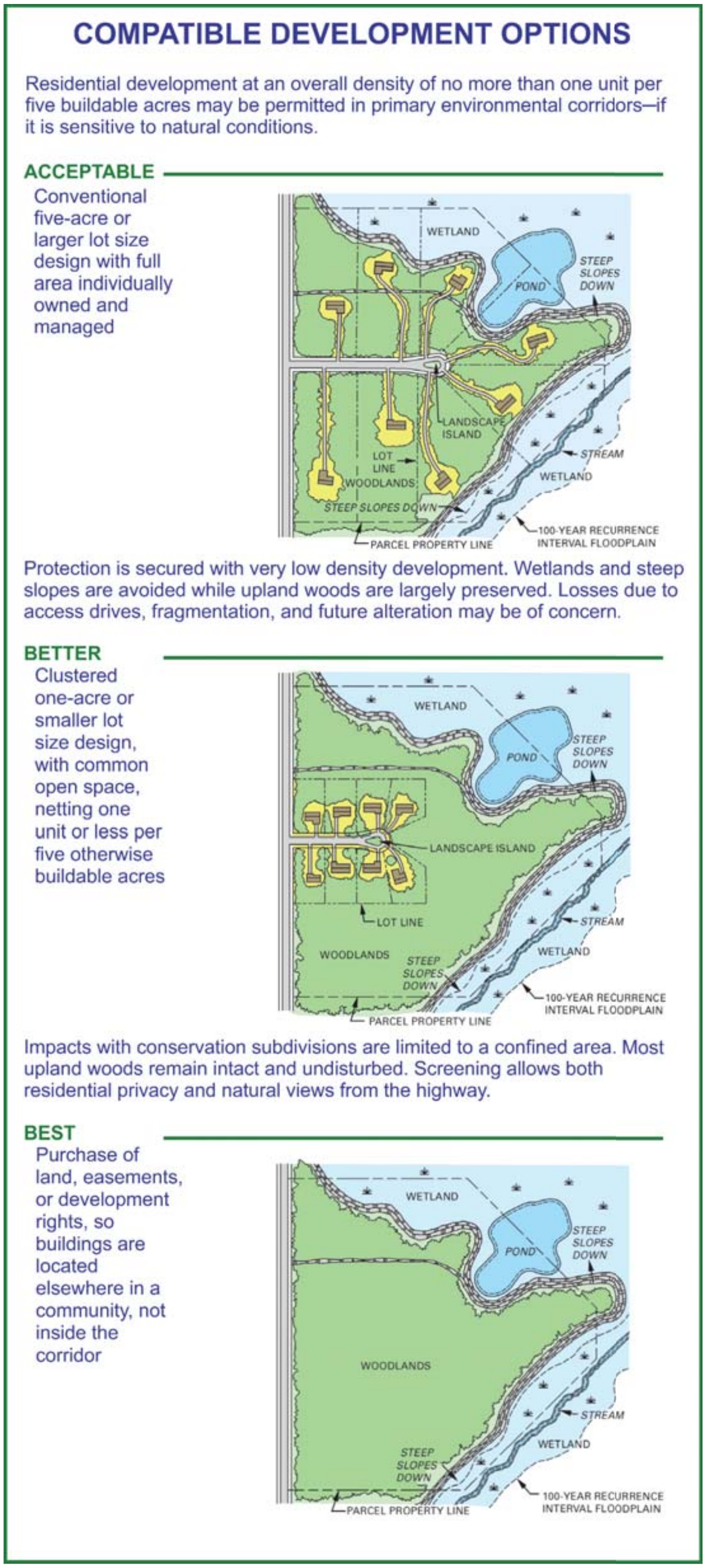
### Preservation of Environmental Corridors

Through the efforts of State and local governments, land trusts, private property owners, and SEWRPC, about 87 percent of the primary environmental corridors in Southeastern Wisconsin have received some level of protection (see Map 1). Yet, the remaining corridors—including upland woods and some key outdoor recreation sites—prove among the most difficult to preserve. Other areas enjoy only weak or interim protection that needs strengthening.

Lowland portions of delineated environmental corridors, largely consisting of floodplains and wetlands, are substantially protected by State and Federal regulations. The upland portions of primary environmental corridors also should generally be preserved. State regulations do not allow the extension of sanitary sewer service into primary environmental corridors. Thus, these uplands should not be developed except for residential use at a density no greater than one household per five acres. Even then, significant natural areas and critical species habitat should not be destroyed or substantially disturbed. Also, unique resource features should be protected, and other limited disturbances within delineated

**Figure 6**

**COMPATIBLE DEVELOPMENT OPTIONS PROTECTION AND RESIDENTIAL USE**




*Source: SEWRPC.*

corridors should be accomplished in a manner that minimizes ecological harm. Figure 6 provides examples of alternative development approaches that employ sensitivity to an environmental corridor.

### Considerations and Benefits Related to Possible Expansion of Environmental Corridors

The following actions may be undertaken to facilitate appropriate expansion of environmental corridors:

- **Filling gaps in the environmental corridor system** so that continuous or longer corridors are prevalent rather than corridor fragments;

- **Widening stream corridors or other elongated natural areas** so that the area in question meets environmental corridor size criteria and can benefit from that protective designation;

- **Widening secondary environmental corridors for key stretches** so that they can be classified as primary environmental corridors;

- **Establishing streamside buffer strips** so that adjoining areas can be classified as secondary environmental corridors;

- **Bringing key natural areas into the environmental corridor system** (see Map 2), thereby resulting in an interconnected system of still greater size and resource value;

- **Adding selected areas of high or very high groundwater recharge potential** to environmental corridors;

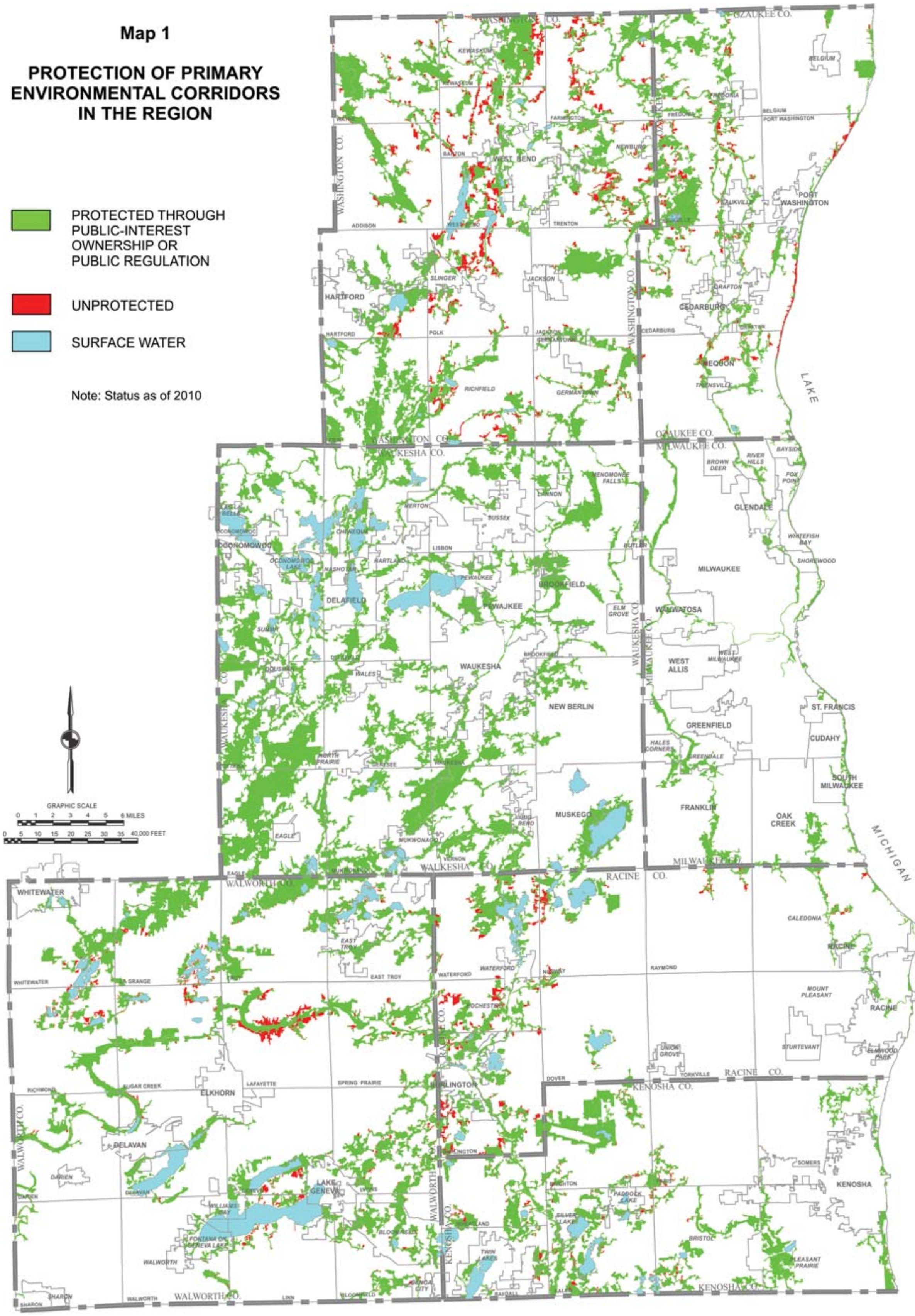
- **Increasing the significance of key natural areas via protected additions** (for example, classifications ranging from local to regional significance, or from regional to statewide significance due to a key increase in acreage);

- **Adding isolated natural resource areas to the contiguous environmental corridor system where appropriate;**

- **Further buffering environmental corridors and isolated natural resource areas** so that they are less fragile and less subject to disturbances;

**Map 1**

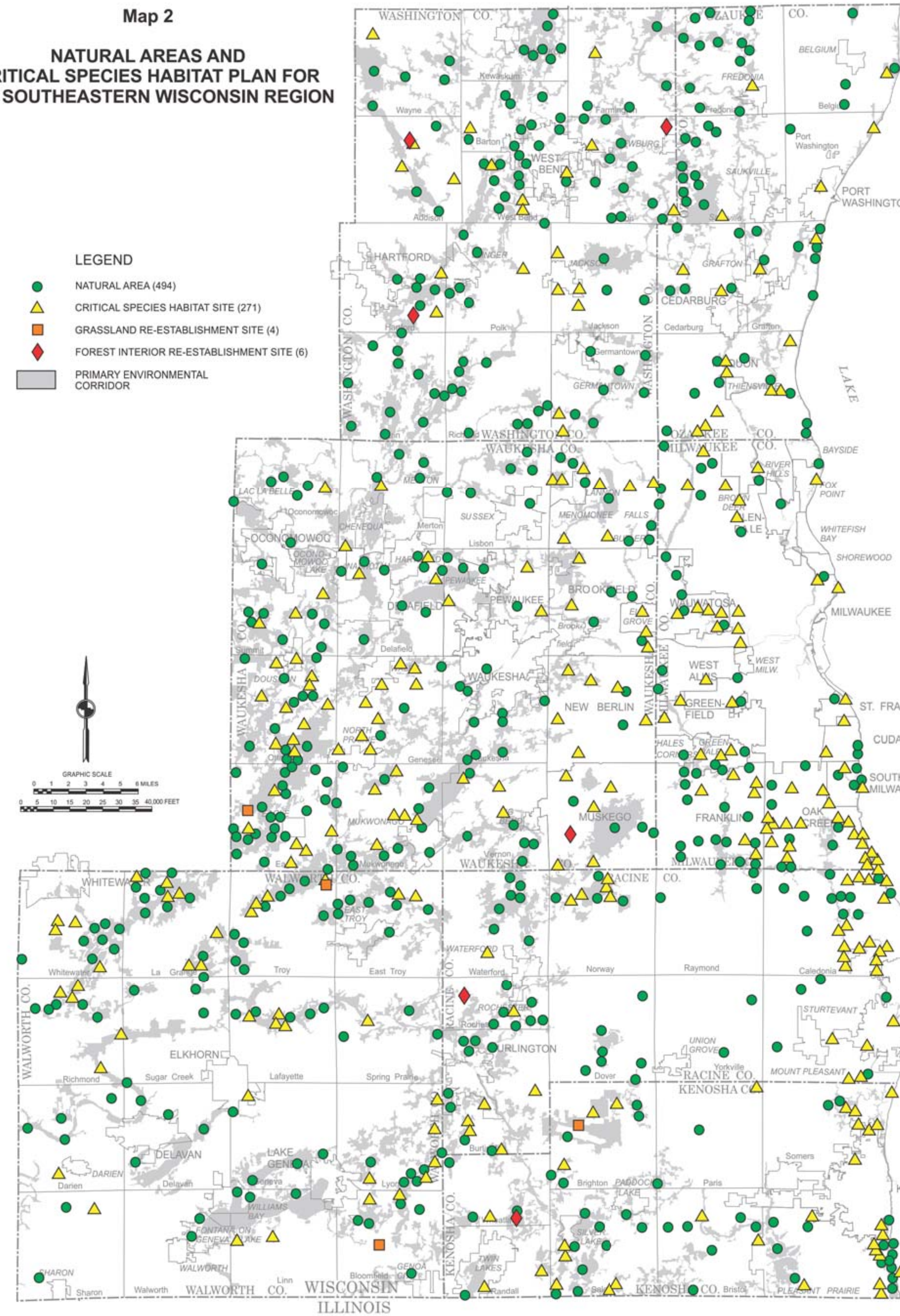
**PROTECTION OF PRIMARY ENVIRONMENTAL CORRIDORS IN THE REGION**




*Source: SEWRPC.*

**Map 2**

**NATURAL AREAS AND CRITICAL SPECIES HABITAT PLAN FOR THE SOUTHEASTERN WISCONSIN REGION**




Source: SEWRPC.

- **Increasing the habitat available for critical species of plants and animals,** particularly those which require large, unbroken tracts of land in order to thrive;
- **Preserving natural aesthetics** as a local attribute and a rural/natural atmosphere for communities, counties, and the Region;
- **Respecting the longstanding natural heritage of sparsely developed areas;** and
- **Protecting irreplaceable natural resources from degradation or loss.**

Photo 22 Protected urban environmental corridor.
*Photo source: SEWRPC.*

Photo 23 Mayapple.
*Photo source: Don Reed.*

## Strengthening Environmental Corridors

Though environmental and/or riparian corridors can be jeopardized by weak or missing links, they differ regarding the potential to be strengthened. The establishment of adjoining buffer or protective zones can widen delineated environmental corridors over time. This happens through the processes of soil stabilization and plant succession or naturalization. Likewise, conservation practices such as buffer strip establishment, reforestation, wetland restoration, and conservation reserve programs for highly erodible or flood-prone croplands benefit environmental corridors and enhance the valuable functions they perform (see Figure 7).

The issue of natural connectedness should be carefully explored as regionally or locally appropriate to determine where, and to what extent, gaps in major natural corridors are a threat to future biodiversity. Narrow segments and interruptions in the environmental corridor system are an unfortunate byproduct of urbanization in our Region.

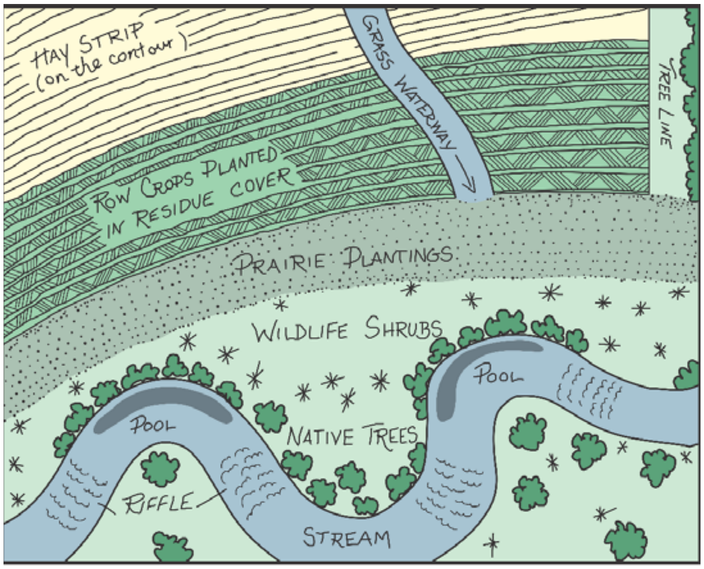
**The importance of preserving, enhancing, and restoring a natural riparian zone, ranging from formally delineated environmental corridors to functional riparian buffers, is important for future biodiversity.**

## Riparian Corridors

Perhaps no part of the landscape offers more variety and valuable functions than the natural areas

**Figure 7**

**FARM STREAM CORRIDOR CONSERVATION PLAN**




Farmers, if possible, should develop and follow a conservation plan for adjacent farmland. This will not only reduce sediment and other pollutants in runoff, it will also preserve soil for the long-term productivity of land.

*Source: Washington County Land Conservertion Department, University of Wisconsin Extension, and SEWRPC.*

bordering streams and other waters, some extending beyond traditional environmental corridors. These unique *riparian corridor* lands help filter pollutants from runoff, lessen downstream flooding, and maintain stream base flows, among other benefits. They also provide many recreational opportunities and habitat for fish and wildlife with their rich ecological diversity.

However, some riparian corridors no longer fulfill their potential due to the encroachment of agriculture, urban development, and improper management. Both *Managing the Water's Edge* and *Continuity Along Stream Corridors* in the *Making Natural Connections* booklet series contain guidance about riparian corridors that can help communities reap multiple benefits and buffer the adverse effects of a changing climate. Figure 7 illustrates a stream corridor conservation plan for a farm that combines agricultural best management practices to reduce polluted runoff with riparian buffer establishment and stream preservation.

## Partially Missing Stream Connections

Ideally, connections should exist between all streams within a watershed, upstream to downstream, linking ephemeral streams such as those present only following snowmelt, to intermittent streams, which are connected to perennial streams.

## Agricultural Drainage

This scenario can become complicated, especially in agricultural subwatershed areas, many of which may have been ditched, drained, diked, and/or tiled over time. At ground level, it may no longer look like a stream system even exists where part of the upstream network is buried underground.

Instead of tiny streams flowing within rocky banks and along bottoms, a four-inch concrete tile line or black plastic pipe may be all that remains of some stream segments. The migration of adult fish upstream to an open tile end instead of continuing into the former headwater streams is as problematic as if a concrete dam had been erected. Streambank trees and shrubs may have been torn out and burned. Some former confluences of intermittent streams may have been replaced by relatively sterile tile ends still discharging excess soil water or perhaps groundwater to the remnant upstream network within a watershed. What were once the small "twigs" of the dendritic ("tree-like") flow pattern, progressively converging down to the river's trunk or stream mainstem, may be missing. Areas of aquatic habitat and the upstream interface of streambank vegetation and marginal wetlands, or even primarily "dry" riparian lands, may be completely gone from some landscapes. Repeated throughout watersheds, the above scenario may represent large-scale discontinuities.

Photo 24 A well-developed riparian buffer in an agricultural setting.
*Photo source: Iowa State University.*

Even if connections are mostly complete, poor remnants or gaps along riparian habitat within an ecosystem can comprise profound collective losses. The effect on organisms moving upstream to reproduce can be devastating. For this reason, remaining stream channels even in ditch-linked environments are important to preserve in particular subwatersheds. Such remnant water features may be heavily used by aquatic organisms up to even the largest predator within a watershed system – such as Northern pike, which migrate into wetlands to spawn.

Photo 25 Well-vegetated stream corridor.
*Photo source: SEWRPC.*

### Gaining and Maintaining an Edge

An **edge,** when referring to the landscape, is the important boundary between two or more different areas of habitat. The habitat boundary often ends up being more diverse and more productive than each of the areas sharing the common boundary. Hunters, hikers, birdwatchers, and other outdoor enthusiasts know that the presence of natural or vegetatively buffered stream corridors, along with naturalized fencerows within farmland, are virtual magnets for attracting and viewing wildlife. The richness of species found within such areas can far exceed the proportional acreage of these connecting features in the landscape.

Examples of *edges* can be seen between a field and a woodland, between a prairie and an oak savannah, or along the dividing line between two different types of forests, grasslands, wetlands, or any combination of the above. Shorelands or shorelines also represent important natural areas of *edge*. In these cases, the division lies between water and land—between aquatic and terrestrial habitat—and it is, thus, doubly important. The water's edge is capable of attracting and supporting plants and animals that rely upon either the wetter or drier conditions, as well as species seeking both, such as amphibians, aquatic insects, or the organisms reliant upon these as prey.

Additionally, many animals come to, or through, the shoreland vegetation to access water. (For more information, see *"Managing the Water's Edge,"* Booklet I in SEWRPC's *Making Natural Connections* series).

Within a naturally vegetated stream corridor or along the edges between woodlots and hayfields (see Photo 25) lie the transition between animals of the forest and creatures of the prairie or open lands. Thus, woodland nesting birds and grassland nesting birds may both find homes nearby.

Unfortunately, some newer agricultural practices including bigger fields and bigger equipment using longer, straighter cultivating and cropping lines, has led to the removal of some fencerows and eliminated buffered small streams or drainageways. This results in the habitat loss and reduced natural stream connectivity described earlier.

## CONNECTIONS VIA PONDS

### Value and Importance of Riparian Ponds

The more we have come to know about riparian habitat, the more we have learned about the importance of ponds for the health and success of amphibians, which spend part of the time in the water and part on land. Amphibians have generally moist skin, even as adults. Thus, adequate moisture remains important throughout the life cycle of amphibians, which grow from eggs laid in the water to tadpoles and adults that swim and also roam across moist land surfaces. For this process to successfully unfold, riparian ponds are required.

Whereas people may follow stepping stones to cross a stream while keeping their feet dry, amphibians within riparian corridors can use “pond-jumping” as a means to:

- Remain moist;
- Complete the cycle of metamorphosis from egg to tadpole to adult;
- Escape temporarily from predators such as herons, which might otherwise pick an area clean of amphibial prey;
- Find an alternative breeding site with adequate water before their current water source begins to dry up; and
- Tap into the food sources within ponds.

### Additional Benefits of Ponds

Additional benefits of ponds include:

- **Ponds are often incredibly rich, diverse sources of life within a stream corridor system.**
- **Old stream channels or secondary floodways within a stream’s floodplain can be the location of many present-day ponds.** Even small depressions in a riparian corridor may give rise to pools that primarily store and hold precipitation and floodwaters to form valuable series of periodic or sometimes enduring ponds.
- Given that ponds serve as refuges for amphibians and other aquatic life during times of stress, the episodes of such **stress can be lessened in severity and long-term consequences can be somewhat diminished.**
- **Multiple ponds offer multiple sanctuaries, increasing the likelihood of survival** for individual amphibians including frogs, toads, and salamanders, and the likelihood of species survival in local areas.
- While ponds help serve the survival of various water-dependent species including amphibians, **these same ponds help assure that such surviving creatures remain available as a dispersed prey source** for other animals dependent on such a food supply.
- **Multiple ponds of multiple types help ensure** important elements of stream continuity over time.
- **Some ponds are very specialized** as to their location and function. Vernal (or early spring) ponds may exist in simple forest depressions beneath which the bottoms are plugged by small soil particles. Some vernal ponds are home to very specialized and interesting organisms, including fairy shrimp.
- **Pond-to-pond movement** of amphibians and other animals **helps ensure gene exchange** through the reproduction cycle which promotes diversity and strengthens local populations.

### Stream Channel Pools Becoming Ponds

Natural and healthy stream channels are comprised of alternating areas of deeper, quieter pools of water associated particularly with the outside bank of stream meanders, and riffles—the areas in between “rapids,” which are faster flowing and generally rock- or gravel-bottomed stretches. Upstream to downstream, the pools continue to serve as somewhat regularly spaced “ponds” of water persisting throughout much of any given year.

Wider sections of stream channels may contain slowly moving or “backwater” areas of mild current, allowing the widenings to function as elongated ponds (see Photo 13). Some of these pools/ponds may have been secondary or flood channels parallel to the main stream channel. During dry periods, the remaining areas of open water may be reduced to the former pools, while the riffles become moist, gravelly or muddy connections. By this time, silt has normally been washed away from the riffles and deposited in the pools, particularly those lying just downstream.

## CONCLUSION

When larger resource features such as woodlots, grasslands, lakes, and wetlands are linked to streams, habitat is improved and aquatic and terrestrial wildlife thrives. **Protecting and enhancing stream continuity and making natural connections thus protects and improves the natural environment and** increases the attractiveness and livability of the Region.

## MORE TO COME

Future editions in a riparian buffer planning series are being explored with the intent of focusing on key elements of this critical land and water interface. Topics may include:

- Information sharing and development of ordinances to integrate riparian buffers into existing land management plans and programs;
- Integration of stormwater management practices and riparian buffer best management practices;
- Application of buffers within highly constrained urban corridors with and without brownfield development;
- Installation of buffers within rural or agricultural lands being converted to urban uses;
- Utilization of buffers in agricultural areas and associated drainage systems;
- Integration of riparian buffers into environmental corridors to support resource preservation and recreation and aesthetic uses;
- Protection of groundwater recharge and discharge areas; and
- Protection of high-quality, sensitive coastal areas, including the preservation of recreational potential.

## MORE INFORMATION

This booklet can be found at www.sewrpc.org/Publications/ppr/rbmg-002-riparian-buffer-management-guide.pdf. Please visit www.sewrpc.org/SEWRPC/Environment.htm for more information, periodic updates, and a list of complementary publications.

* * *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