Article 39

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The Architecture of Urban Stream Buffers

Headwater streams comprise as much as 75% of the total stream and river mileage in the contiguous United States (Leopold *et al.*, 1964). These critical headwater streams are often severely degraded by the urbanization process (Schueler, 1995). As a consequence, many communities have adopted stream buffer requirements as one element of an overall urban watershed protection strategy. Up to now, buffer requirements have been relatively simplistic—the "design" of a stream buffer often consists of no more than drawing a line of uniform width on a site plan. As Heraty (1993) notes, buffers designed in this manner often become invisible to contractors, property owners, and even local governments. As a result, many stream buffers fail to perform their intended function, and are subject to disturbance and encroachment.

A buffer network acts as the "right-of-way" for a stream and functions as an integral part of the stream ecosystem. Stream buffers add to the quality of the stream and the community in many diverse ways, as summarized in Table 1. In many regions, these benefits are multiplied when the streamside zone is in a forested condition. While the benefits of urban stream buffers are impressive, their capability to remove pollutants borne in urban stormwater should not be overstated. Although communities frequently cite pollutant removal as the key benefit when justifying the establishment of stream buffers in urbanizing areas (Heraty, 1993), their capability to remove pollutants in urban stormwater is fairly limited. This is a surprising conclusion given the moderate to excellent sediment and nutrients removal reported for forested buffers in rural areas (Desbonnet *et al.*, 1994) Much of the pollutant removal observed in rural and agricultural buffers appears to be due to relatively slow transport of pollutants across the buffer in sheetflow or under it in shallow groundwater. In both cases, this relatively slow movement promotes greater removal by soils, roots, and microbes.

Ideal buffer conditions are rarely encountered in urban watersheds. In urban watersheds rainfall is rapidly converted into concentrated flow. Once flow concentrates, it forms a channel that effectively short-circuits a buffer. Unfortunately, stormwater flows quickly concentrate within a short distance in urban areas. It is doubtful, for example, whether sheetflow condition can be maintained over a distance of 150 feet for pervious areas and 75 feet for impervious areas (Figure 1). Consequently, as much as 90% of the surface runoff generated in an urban watershed concentrates before it reaches the buffer, and ultimately crosses it in an open channel or an enclosed stormdrain pipe. As a result, some kind of structural stormwater practice is often needed to remove pollutants from runoff before they enter the stream.

Figure 1: Watershed Geometry and the Concentration of Flow: The Overland Flow Path to the Stream and the Distance Before Flow Concentrates

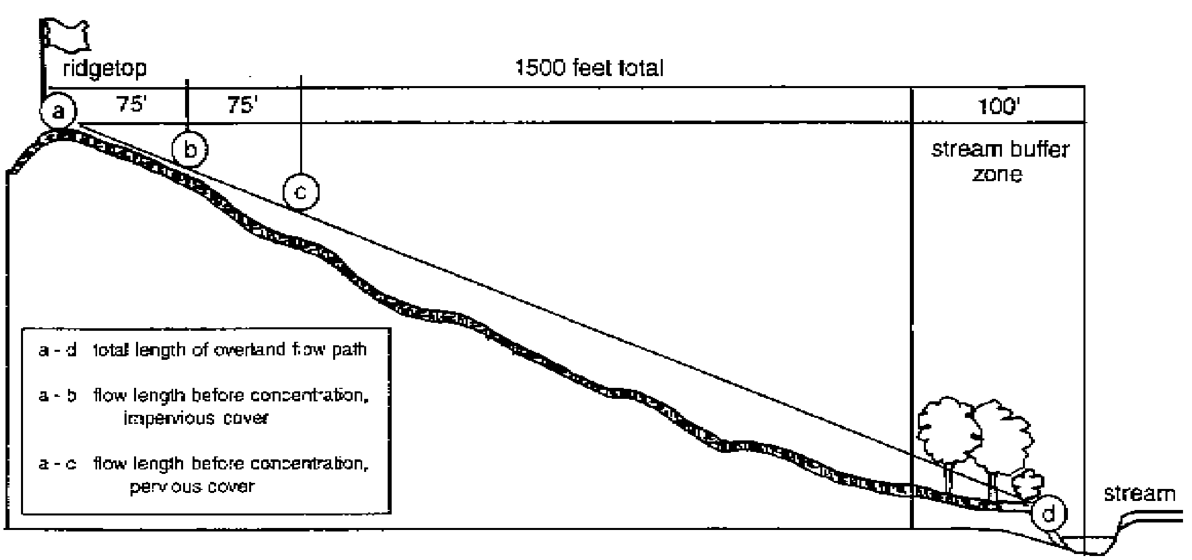


Table 1: Twenty Benefits of Urban Stream Buffers
(*f*) = Benefit Amplified by or Requires Forest Cover

1. **Reduces watershed imperviousness by 5%.** An average buffer width of 100 feet protects up to 5% of watershed area from future development.
2. **Distances areas of impervious cover from the stream.** More room is made available for placement of stormwater practices, and septic system performance is improved. (*f*)
3. **Reduces small drainage problems and complaints.** When properties are located too close to a stream, residents are likely to experience and complain about backyard flooding, standing water, and bank erosion. A buffer greatly reduces complaints.
4. **Stream "right of way" allows for lateral movement.** Most stream channels shift or widen over time; a buffer protects both the stream and nearby properties.
5. **Effective flood control.** Other, expensive flood controls not necessary if buffer includes the 100-yr floodplain.
6. **Protection from streambank erosion.** Tree roots consolidate the soils of floodplain and stream banks, reducing the potential for severe bank erosion. (*f*)
7. **Increases property values.** Homebuyers perceive buffers as attractive amenities to the community. 90% of buffer administrators feel buffers have a neutral or positive impact on property values. (*f*)
8. **Increased pollutant removal.** Buffers can provide effective pollutant removal for development located within 150 feet of the buffer boundary, when designed properly.
9. **Foundation for present or future greenways.** Linear nature of the buffer provides for connected open space, allowing pedestrians and bikes to move more efficiently through a community. (*f*)
10. **Provides food and habitat for wildlife.** Leaf litter is the base food source for many stream ecosystems; forests also provides woody debris that creates cover and habitat structure for aquatic insects and fish. (*f*)
11. **Mitigates stream warming.** Shading by the forest canopy prevents further stream warming in urban watersheds. (*f*)
12. **Protection of associated wetlands.** A wide stream buffer can include riverine and palustrine wetlands that are frequently found along the stream corridor.
13. **Prevent disturbance to steep slopes.** Removing construction activity from these sensitive areas is the best way to prevent severe rates of soil erosion. (*f*)
14. **Preserves important terrestrial habitat.** Riparian corridors are important transition zones, rich in species. A mile of stream buffer can provide 25-40 acres of habitat area. (*f*)
15. **Corridors for conservation.** Unbroken stream buffers provide "highways" for migration of plant and animal populations. (*f*)
16. **Essential habitat for amphibians.** Amphibians require both aquatic and terrestrial habitats and are dependent on riparian environments to complete their life cycle. (*f*)
17. **Fewer barriers to fish migration.** Chances for migrating fish are improved when stream crossings are prevented or carefully planned.
18. **Discourages excessive storm drain enclosures/channel hardening.** Can protect headwater streams from extensive modification.
19. **Provides space for stormwater ponds.** When properly placed, structural stormwater practices within the buffer can be an ideal location for stormwater practices that remove pollutants and control flows from urban areas.
20. **Allowance for future restoration.** Even a modest buffer provides space and access for future stream restoration, bank stabilization, or reforestation.

The ability of a particular buffer to actually realize its many benefits depends on how well the buffer is planned or designed. In this article, we present a more detailed scheme for stream buffer design, drawn from field research and local experience across the country. The suggested urban stream buffer criteria are based on 10 practical performance criteria that govern how a buffer will be sized, delineated, managed, and crossed (Table 2). In addition, the buffer design contains several provisions to respect the property rights of adjacent landowners.

Table 2: Nuts and Bolts of an Urban Stream Buffer

- ■ Minimum total width of 100 feet, including floodplain
- ■ Zone-specific goals and restrictions for the outer, middle, and streamside zones
- ■ Adopt a vegetative target based on predevelopment plant community
- ■ Expand the width of the middle zone to pick up wetlands,slopes and larger streams
- ■ Use clear and measurable criteria to delineate the origin and boundaries of the buffer
- ■ The number and conditions for stream and buffer crossings should be limited
- ■ The use of buffer for stormwater runoff treatment should be carefully prescribed
- ■ Buffer boundaries should be visible before, during, and after construction
- ■ Buffer education and enforcement are needed to protect buffer integrity
- ■ Buffer administration should be flexible and fair to landowners

Criteria 1: Minimum Total Buffer Width

Most local buffer criteria are composed of a single requirement that the buffer be a fixed and uniform width from the stream channel. Urban stream buffers range from 20 to 200 feet in width on each side of the stream according to a national survey of 36 local buffer programs, with a median of 100 feet (Heraty, 1993). Most jurisdictions arrived at their buffer width requirement by borrowing other state and local criteria, local experience, and, finally, through political compromise during the buffer adoption process. Most communities require that the buffer fully incorporate all lands within the 100-year floodplain, and others may extend the buffer to pick up adjacent wetlands, steep slopes or critical habitat areas.

In general, a minimum base width of at least 100 feet is recommended to provide adequate stream protection. In most regions of the country, this requirement translates to a buffer that is perhaps three to five mature trees wide on each side of the channel.

Criteria 2: Three-Zone Buffer System

Effective urban stream buffers are divided into three lateral zones: streamside, middle core, and outer zone. Each zone performs a different function, and has a different width, vegetative target and management scheme, as follows:

- The *streamside zone* protects the physical and ecological integrity of the stream ecosystem. The vegetative target is mature riparian forest that can provide shade, leaf litter, woody debris and erosion protection to the stream. The minimum width is 25 feet from each stream bank—about the distance of one or two mature trees from the streambank. Land use is highly restricted and is limited to stormwater channels, footpaths, and a few utility or roadway crossings.

- The *middle zone* extends from the outward boundary of the streamside zone, and varies in width, depending on stream order, the extent of the 100-year floodplain, adjacent steep slopes and protected wetland areas. Its functions are to protect key components of the stream and provide further distance between upland development and the stream. The vegetative target for this zone is also mature forest, but some clearing may be allowed for stormwater management, access, and recreational uses. A wider range of activities and uses are allowed within this zone, e.g., recreation, bike paths, and stormwater practices. The minimum width of the middle core is about 50 feet, but it is often expanded based on stream order, slope or the presence of critical habitats.

- The *outer zone* is the buffer's buffer, an additional 25-foot setback from the outward edge of the middle zone to the nearest permanent structure. In most instances, it is a residential backyard. The vegetative target for the outer zone is usually turf or lawn, although the property owner is encouraged to plant trees and shrubs, and thus increase the total width of the buffer. Very few uses are restricted in this zone. Indeed, gardening, compost piles, yard wastes, and other common residential activities are promoted within the zone. The only major restrictions are no septic systems and no new permanent structures.

Criteria 3: Predevelopment Vegetative Target

The ultimate vegetative target for the streamside and middle zone of most urban stream buffers should be specified as the predevelopment riparian plant community—usually mature forest. Notable exceptions include prairie streams of the Midwest, or arroyos of the arid West, that may have a grass or shrub cover in the riparian zone. In general, the target should be based on the natural vegetative community present in the floodplain, as determined from reference riparian zones.

A vegetative target has several management implications. First, if the streamside zone does not currently meet its vegetative target, it should be managed to ultimately achieve it. For example, a grassy area should be allowed to grow into a forest over time. In some cases, active reforestation may be necessary to speed up the successional process. Second, a vegetative target implies that the buffer will contain mostly native species adapted to the floodplain. Thus, non-native or invasive tree, shrub and vine species should be avoided when revegetating the buffer. Removal of exotic shrubs and vines (e.g. multiflora rose or honeysuckle) that are often prevalent along the buffer edge should be encouraged.

Criteria 4. Buffer Expansion and Contraction

Many communities require that the minimum width of the buffer be expanded under certain conditions. Thus, while the streamside and outer zones of the buffer are fixed, the width of the middle zone may vary. Specifically, the average width of the middle zone can be expanded to include:

- The full extent of the 100-year floodplain
- All undevelopable steep slopes (> 25%)
- Steep slopes (five to 25% slope, at four additional feet of slope per 1% increment of slope above 5%)
- Adjacent delineated wetlands or critical habitats

The middle zone also expands to protect streams of higher order or quality in a downstream direction. For example, the width of the middle zone may increase from 75 feet (for first- and second-order streams) to 100 feet (for third- and fourth-order streams) and as much as 125 feet for fifth- or higher order streams/rivers. The width of the buffer can also be contracted in some circumstances to accommodate unusual or historical development patterns, shallow lots, stream crossings, or stormwater ponds (see Criteria 10).

Criteria 5: Buffer Delineation

Three key decisions must be made when delineating the boundaries of a buffer. At what mapping scale will streams be defined? Where does the stream begin and the buffer end? And from what point should the inner edge of the buffer be measured?

The *mapping unit*. The traditional mapping scale used to define the stream network are the bluelines present on USGS 7.5 minute quadrangle maps (1 inch = 2,000 feet). It should be kept in mind that bluelines are only a first approximation for delineating streams, as this scale does not always reveal all first order perennial streams or intermittent channels in the landscape or precisely mark the transition between the two. Consequently, the actual location of the stream channel can only be confirmed in the field

The *origin of a first order stream* is always a matter of contention. As a practical rule, the origin of the stream can be defined as the point where intermittent stream forms a distinct channel, as indicated by the presence of an unvegetated streambed and high water marks. Other regions define the origin of a stream as the upper limit of running water during the wettest season of the year. Problems are frequently encountered when the stream network has been extensively modified by prior agricultural drainage practices.

The *inner edge* of the buffer can be defined from the centerline of small first- or second-order streams. The accuracy of this method is questionable in higher order streams with wider channels. Thus, the inner edge of the buffer is measured from the top of each streambank for third and higher order streams.

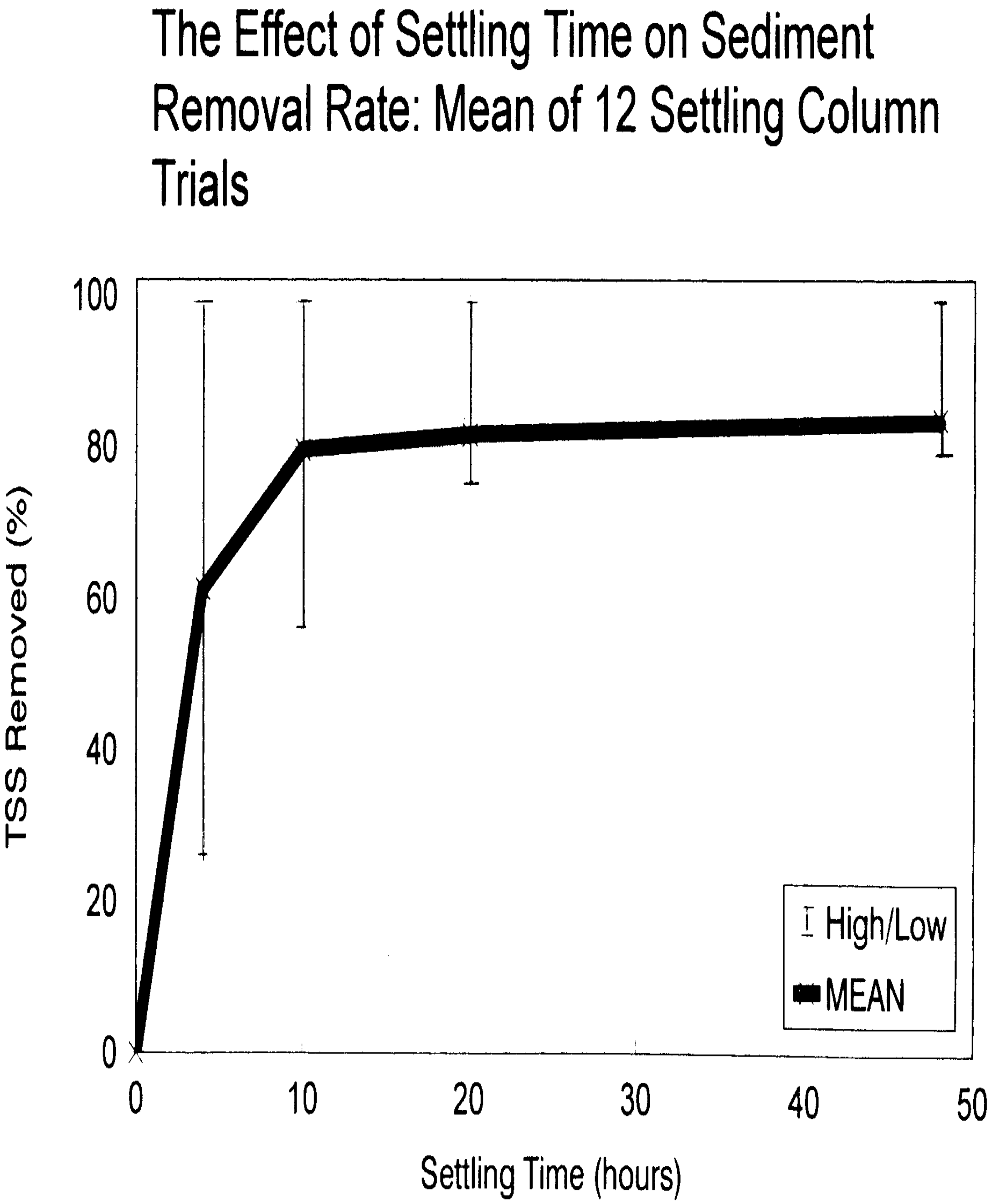
Criteria 6. Buffer Crossings

Two major goals of a stream buffer network are to maintain an unbroken corridor of riparian forest and maintain the upstream and downstream passage of fish in the stream channel. From a practical standpoint, it is not always possible to meet both goals everywhere along the stream buffer network. Some provision must be made for linear forms of development that must cross the stream or the buffer (Figure 2), such as roads, bridges, fairways, underground utilities, enclosed storm drains or outfall channels.

It is still possible to minimize the impact to the continuity of the buffer network and fish passage. Performance criteria should specifically describe the conditions under which the stream or its buffers can be crossed. Some performance criteria could include:

- *Crossing width.* Minimum width to allow for maintenance access.
- *Crossing angle.* Direct right angles are preferred over oblique crossing angles, since they require less clearing in the buffer.
- *Crossing frequency*. Only one road crossing is allowed within each subdivision, and no more than one fairway crossing is allowed for every 1,000 feet of buffer.
- *Crossing elevation.* All direct outfall channels should discharge at the invert elevation of the stream. Underground utility and pipe crossings should be located at least three feet below the stream invert, so that future channel erosion does not expose them, creating unintentional fish barriers. All roadway crossings and culverts should be capable of passing the ultimate 100-year flood

Figure 2: Crossing the Stream Buffer: Guidance on Minimizing Disruption to the Stream Network



event. Bridges should be used in lieu of culverts when crossings require a 72 inch or greater diameter pipe. The use of corrugated metal pipe for small stream crossings should be avoided, as they tend to create fish barriers. The use of slab, arch or box culverts are much better alternatives. Where possible, the culvert should be "bottomless" to ensure passage of water during dry weather periods (i.e., the natural channel bottom should not be hardened or otherwise encased).

Criteria 7: Stormwater Runoff

Buffers can be an important component of the stormwater treatment system at a development site. They cannot, however, treat all the stormwater runoff generated within a watershed (generally, a buffer system can only treat runoff from less than 10% of the contributing watershed to the stream). Therefore, some kind of structural stormwater practice must be installed to treat the quantity and quality and stormwater runoff from the remaining 90% of the watershed. More often than not, the most desirable location for the practices is within or adjacent to the stream buffer. The following guidance is recommended for integrating stormwater practices into the buffer.

A. The Use of Buffers for Stormwater Treatment

The outer and middle zone of the stream buffer may be used as a combination grass/forest filter strip under very limited circumstances (Figure 3). For example, if the buffer cannot treat more than 75 feet of overland flow from impervious areas and 150 feet of pervious areas (backyards or rooftop runoff discharged to the backyard), the designer should compute the maximum runoff velocity for both the six-month and two-year storm designs from each contributing overland flow path, based on the slope, soil, and vegetative cover present. If the computation indicates that velocities will be erosive under either condition (greater than 3 fps for six-month storm, 5 fps for two-year storm), the allowable length of contributing flow should be reduced.

When the buffer receives flow directly from an impervious area, the designer should include curb cuts or spacers so that runoff can be spread evenly over the filter strip. The filter strip should be located three to six inches below the pavement surface to prevent sediment deposits from blocking inflow to the filter strip. A narrow stone layer at the pavements edge often works well.

The stream buffer can only be accepted as a stormwater filtering system if basic maintenance can be assured, such as routine mowing of the grass filter and annual removal of accumulated sediments at the edge of the impervious areas and the grass filter. An enforceable maintenance agreement that allows for public maintenance inspection is also helpful.

B. Location of Stormwater Ponds and Wetlands Within the Buffer

A particularly difficult management issue involves the location of stormwater ponds and wetlands in relation to the buffer. Should they be located inside or outside of the buffer? If they are allowed within the buffer, where exactly should they be put? Some of the possible options are outlined in Figure 3.

A number of good arguments can be made for locating ponds and wetlands within the buffer or on the stream itself. Constructing ponds on or near the stream, for example, affords treatment of the greatest possible drainage area, making construction easier and cheaper. Second, ponds and wetlands require the dry weather flow of a stream to maintain water levels and prevent nuisance conditions. Lastly, ponds and wetlands add a greater diversity of habitat types and structure, and can add to the total buffer width in some cases. On the other hand, placing a pond or wetland in the buffer can create environmental problems, including the localized clearing of trees, the sacrifice of stream channels above the stormwater practice, the creation of a barrier to fish migration, modification of existing wetlands, and stream warming.

Locating ponds and wetlands in buffers will always be a balancing act. Given the effectiveness of stormwater ponds and wetlands in removing pollutants, it is generally not advisable to completely prohibit their use within the buffer. It does make sense, however, to choose pond and wetland sites carefully. In this respect, it is useful to consider possible performance criteria that restrict the use of ponds or wetlands:

- A maximum contributing area (e.g. 100 acres)
- The first 500 feet of stream channel
- Clearing of the streamside buffer zone only for the outflow channel (if the pond is discharging from the middle zone into the stream)
- Off-line locations within the middle or outer zone of the buffer
- Use ponds only to manage stormwater quantity within the buffer

Criteria 8: Buffers During Plan Review and Construction

The limits and uses of the stream buffer system should be well defined during each stage of the development process—from initial plan review through construction. The following steps are helpful during the planning stage:

- Require that the buffer be delineated on preliminary and final concept plans
- Verify the stream delineation in the field

Figure 3: Options for Locating Stormwater Ponds Within the Stream Buffer Network

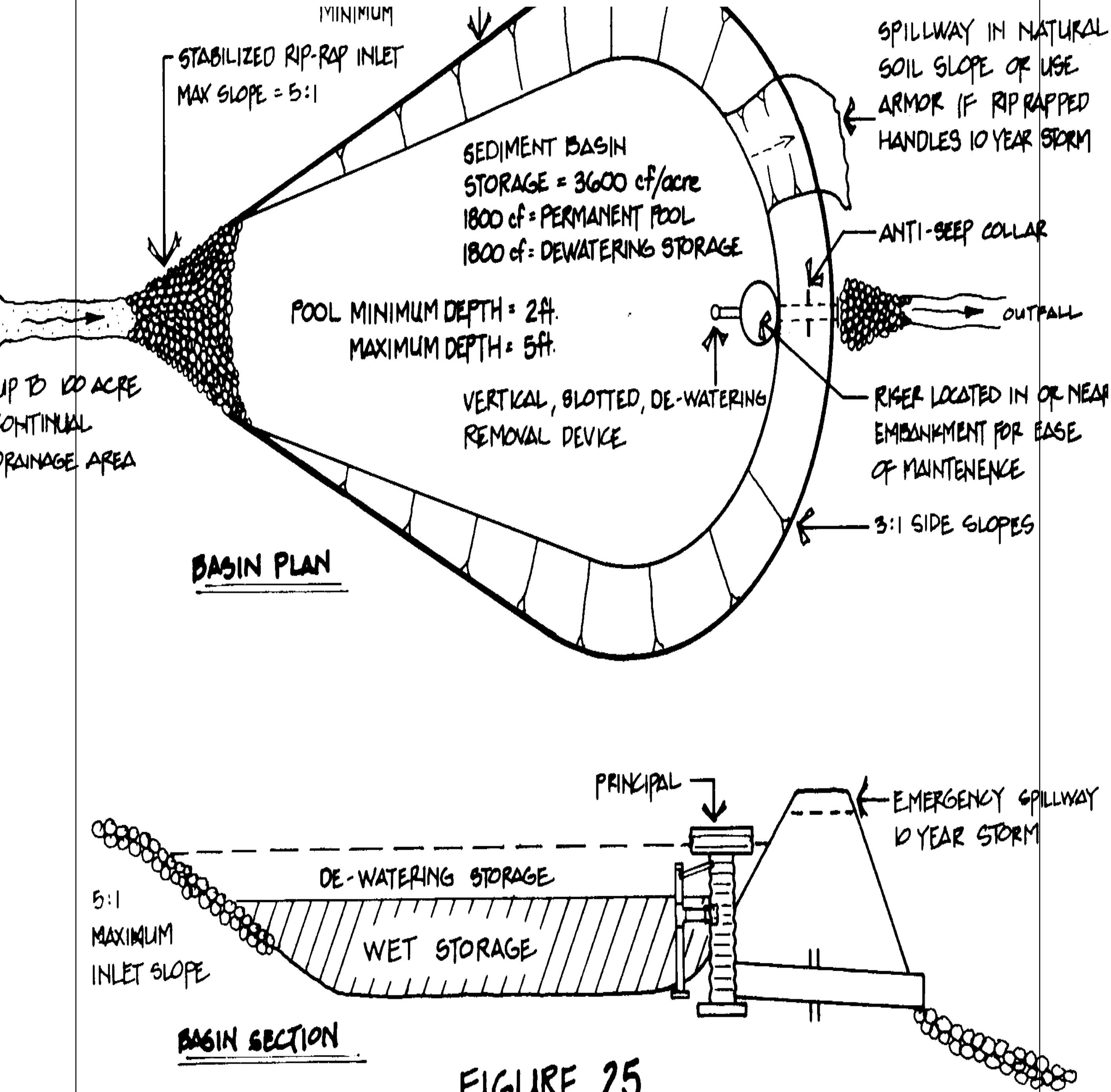


FIGURE 25

IDEALIZED SCHEMATIC OF
PROPOSED SEDIMENT BASIN DESIGN

NOT TO SCALE

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- Check that buffer expansions are computed and mapped properly
- Check suitability of use of buffer for stormwater treatment
- Ensure that the other stormwater practices are properly integrated in the buffer
- Examine any buffer crossings for problems

Stream buffers are vulnerable to disturbance during construction. Steps to prevent encroachment during this stage include:

- Mark buffer limits on all plans used during construction (i.e., clearing and grading plans, and erosion and sediment control plans)
- Conduct a preconstruction stakeout of buffers to define limit of disturbance
- Mark the limit of disturbance with silt or snow fence barriers, and signs to prevent the entry of construction equipment and stockpiling
- Familiarize contractors with the limit of disturbance during a preconstruction walk-through

Criteria 9: Buffer Education and Enforcement

Future integrity of the buffer system requires a strong education and enforcement program. Two primary goals are to make the buffer "visible" to the community, and to encourage greater buffer awareness and stewardship among adjacent residents. There are several simple steps that can accomplish these goals:

- Mark the buffer boundaries with permanent signs that describe allowable uses
- Educate buffer owners about the benefits and uses of the buffer with pamphlets, streamwalks and meetings with homeowners associations
- Ensure that new owners are fully informed about buffer limits/uses when property is sold or transferred
- Engage residents in a buffer stewardship program that includes reforestation and backyard "bufferscaping" programs
- Conduct annual bufferwalks to check on encroachment

The underlying theme of education is that most encroachment problems reflect ignorance rather than contempt for the buffer system. The awareness and education measures are intended to increase the recognition of the buffer within the community. Not all residents, however, will respond to this effort, and some kind of limited enforcement program may be necessary (Schueler, 1994). This usually involves a series of correction notices and site visits, with civil fines used as a last resort if compliance is not forthcoming. Some buffer ordinances have a further enforcement option, whereby the full cost of buffer restoration is charged as a property lien (Schueler, 1994). A fair and full appeals process should accompany any such enforcement action.

Criteria 10: Buffer Flexibility

In most regions of the country, a 100-foot buffer will take about 5% of the total land area in any given watershed out of production (Schueler, 1995). While this constitutes a relatively modest land reserve at the watershed scale, it can be a significant hardship for a landowner whose property is adjacent to a stream. Many communities are legitimately concerned that stream buffer requirements could represent an uncompensated taking of private property. These concerns can be eliminated if a community incorporates several simple measures to ensure fairness and flexibility when administering its buffer program. As a general rule, the intent of the buffer program is to modify the location of development in relation to the stream but not its overall intensity. Some flexible measures in the buffer ordinance include the following.

Maintaining Buffers in Private Ownership

Buffer ordinances that retain property in private ownership generally are considered by the courts to avoid the takings issue, as buffers provide compelling public safety, welfare and the environmental benefits to the community (Table 1) that justify partial restrictions on land use. Most buffer programs meet the "rough proportionality" test recently advanced by the Supreme Court for local land use regulation (Hornbach, 1993). Indeed stream buffers are generally perceived to have a neutral or positive impact on adjacent property value. The key point is that the reservation of the buffer cannot take away all economically beneficial use for the property. Four techniques—buffer averaging, density compensation, conservation easements, and variances—can ensure that the interests of the property owners are protected.

Buffer Averaging

In this scheme, a community provides some flexibility in the width of the buffer. The basic concept is to permit the buffer to become narrower at some points along the stream (e.g., to allow for an existing structure or to recover a lost lot), as long as the average width of the buffer meets the minimum requirement. In general, buffer narrowing is limited, such that the streamside zone is not disturbed, and no new structures are allowed within the 100-year floodplain (if this is a greater distance).

Density Compensation

This scheme grants a developer a credit for additional density elsewhere on the site, in compensation for developable land that has been lost due to the buffer requirement. Developable land is defined as the portion of buffer area remaining after the 100-year floodplain, wetland, and steep slope areas have been subtracted. Credits are granted when more than 5% of developable land is consumed, using the scale shown in Table 2. The density credit is accommodated at the development site by allowing greater flexibility in setbacks, frontage distances or minimum lot sizes to squeeze in "lost lots." Cluster development also allows the developer to recover lots that are taken out of production due to buffers and other requirements. The intent of stream buffers is to modify the location but not the intensity of development. Buffer averaging, density compensation, and variances can all minimize the impact on property owners.

Table 2: Example of the Use of Density Credits to Compensate Developers for Excessive Land Consumption by Buffers (Burns, 1992)

Percent of site lost to buffers	Density * credit
1 to 10 %	1.0
11 to 20%	1.1
21 to 30%	1.2
31 to 40%	1.3
41 to 50%	1.4
51 to 60% **	1.5
61 to 70% **	1.6
71 to 80% **	1.7
81 to 90% **	1.8
91 to 99% **	1.9

* Additional dwelling units allowed over base density (1.0)

** Credit may be transferred to a different parcel

Conservation Easements

Landowners should be afforded the option of protecting lands within the buffer by means of a perpetual conservation easement. The easement conditions the use of the buffer, and can be donated to a land trust as a charitable contribution that can reduce an owner's income tax burden. Alternatively, the conservation easement can be donated to a local government, in exchange for a reduction or elimination of property tax on the parcel.

Variances

The buffer ordinance should have provisions that enable a existing property owner to be granted a variance or waiver, if the owner can demonstrate severe economic hardship or unique circumstances make it impossible to meet some or all of the buffer requirements. The owner should also have access to a defined appeals process should the request for a variance be denied.

Summary

Urban stream buffers are an integral element of any local stream protection program. By adopting some of these rather simple performance criteria, communities can make their stream buffers more than just a line on a map. Better design and planning also ensure that communities realize the full environmental and social benefits of stream buffers.

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