THE SCIENTIFIC BASIS FOR WETLAND & WATERCOURSE BUFFER ZONES

Prepared by Sigrun N. Gadwa, MS, PWS and George T. Logan, MS, PWS, CE

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1.0 INTRODUCTION

Buffer zones are natural or enhanced vegetated areas, upslope of a wetland or surface water (i.e. ponds, lakes, streams, rivers). They are a ***land use management tool*** that can effectively protect regulated resources from multiple *"indirect" physical impacts* associated with development proposals,[1] including hydrologic alterations, sedimentation, degradation by excess nutrients and toxicants, and increases in light, temperature, and/or or ambient sound levels.

Many scientific studies have been conducted on buffer performance, most focusing on a particular narrow buffer function, such as removal of nitrogen or a particular pesticide. This report cites such narrow studies, and also paints a broad picture. It explains how buffer zones preserve and enhance the integrity of a wetland's or watercourse's water supply and quality. Adjacent buffers also help maintain wetland vegetation structure and soil characteristics, which are recognized physical wetland properties. Forested buffers, in particular, are an important source of leaf litter, woody debris, and groundwater enriched with minerals (e.g. calcium and magnesium) and dissolved organic matter (DOM). These buffer exports are all key components of wetlands and stream ecosystems.

Buffers provide essential, complementary terrestrial habitat for many wildlife species that forage and/or breed in wetlands and watercourses, that is, wetland-dependent and wetland-associated species. Most widely known are the vernal pool species. Wood frogs and spotted salamanders, two of the keystone species, are crucial players in the vernal pool and forest food web, which is based on leaf litter, algae, and the assorted invertebrates that feed in forest soil and vernal pools. Through the food chain, and the "production export"[2] wetland function, wildlife is part of the physical cycling of carbon, nitrogen, phosphorus, etc., that takes place in wetlands. However, if a buffer is severely degraded by invasive species and/or other disturbance, certain buffer functions and/or values, such as wildlife support and aesthetics, may be much diminished, while others remain intact (e.g. hydrologic and filtration functions). Less-than-optimal buffer widths are often mitigated by buffer restoration and/or enhancement, with the goal of a net gain in wetland functions and values.

2.0 BUFFER FUNCTIONS

The functions of riparian and wetland buffer zones are succinctly described in the 1991 *Policy Statement: Riparian Corridor Protection,* issued by the Inland Fisheries Division of

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[1] Wetlands agencies in Connecticut must not make permitting decisions based on impacts to wildlife or plants, unless accompanied by *physical* impacts to wetlands (2004 Amendment to the Wetlands Statute). The definition of wetlands now inlcudes wildlife, vegetation, and habitat.

[2] "Production Export" is one of the thirteen functions and values of wetlands in the New England Army Corps (USACOE) functional assessment methodology (1995). It includes the export of decaying vegetation from the outlet stream of a marsh, and the export of biomass (includng carbon and nitrogen) from a wetland via the food chain, in nectar, fruit, or decaying vegetation, or animal prey.

the Connecticut Department of Environmental Protection (CT DEP 1991). This document recommends a 100-foot buffer to perennial streams, and a 50-foot buffer to intermittent watercourses. These functions are also elucidated in the *Guidelines: Upland Review Area Regulations; Connecticut's Inland Wetlands & Watercourses Act*, by the CT DEP's Wetlands Management Section (CT DEP 1997). A 100-foot upland review area (URA) is recommended in this document. Avoiding degradation of water resources is also spelled out as a guiding principal for environmental planning in Connecticut's official Water Resources Policy in Section 22a-380 of the Connecticut General Statutes.[3] The CT DEP OLISP (Office of Long Island Sound Programs) Tidal Wetlands Buffer Guidance document (2003) also describes buffer functions and calls for a 100-foot setback. It references am early version of this present REMA document (i.e. 2003).

Buffer zones offer a variety of ecological and social functions.[4] The most widely recognized functions are:

1. Hydrologic Effects. Surface runoff and groundwater discharge from buffer areas provide water to wetland vegetation and aquatic life, as well as to overhanging trees and shrubs.[5] Buffers maximize groundwater recharge and store groundwater. In a developed setting, they infiltrate runoff from impervious surfaces and lawns. Forested buffers also reduce evaporation by reducing sunlight penetration. Buffer zones moderate stressful, seasonal "low flows" in streams and rivers; they also moderate flooding by intercepting rain and snow melt, and storing flood waters that overflow stream banks, lakes and wetlands.

2. Support for the Wetland Ecological Community. Buffer zones provide foraging and nesting habitat and cover for a variety of upland, aquatic and wetland species, including vernal pool amphibians, and most of the larger predators, such as barred owls and red-shouldered hawks. Well-vegetated buffer zones support wetland plant diversity. Minerotrophic plant species[6] are supported by groundwater that is enriched with minerals as it flows through a

[3] Sec. 22a-380. Water resources policy: The following are declared to be the goals and policies of the state: (1) To preserve and protect water supply watershed lands and prevent degradation of surface water and groundwaters;…

[4] The following section, and portions of other sections draws heavily on prior riparian and wetland buffer zone publications and research by George Logan of *Rema Ecological Services, LLC*, Manchester, CT. Roy Schiff, working for the Quinnipiac River Watershed Partnership and Quinnipiac River Watershed Association also assembled many of the references.

[5] Vegetation rooted in upland soil on the wetland perimeter, often overhangs the wetland and contributes to wetland function.

[6] Herbaceous species of mineral-rich, slope-base landscape position include many of the spring ephemeral wildflowers, such as red trillium, blue cohosh, dolls' eyes (*Actaea* spp.) and the laxiflorae sedges. They are especially prevalent in traprock and shale areas and include uncommon species such as leatherwood (*Dirca palustris*). Distributions of this group of species typically include the outer portion of the wetland and the lower portion of the adjacent upland buffer. As a group, minerotrophic herbaceous plant species are important to wetland vegetation structure and nutrient cycling because of their their phenology (active growth in spring) and the

buffer toward a wetland.[7] Buffer vegetation moderates light, wind and humidity levels in wetlands. Leaf litter blown in from nearby forested buffers is also a parent material for wetland organic soils. Buffers can also serve as travel routes for migratory and nomadic, as well as for resident wildlife species. In Connecticut, river corridors are essential for the spring bird migration. Large diameter trees and tall trees for platform nests are important buffer habitat features for raptors, larger mammals, and bats.

3. Shade. In a developed setting, forested buffers help maintain cool stream temperatures and wooded swamp vegetation by casting *shade*. Shade also prevents colonization of wetlands by invasive plant species and leaf litter protects the soil.

4. Protection from harmful runoff and leachate constituents. Sediment, phosphorus, nitrogen, herbicides, and insecticides can all be at least partly removed from runoff and leachate passing through naturally vegetated setback zones. Through biological, chemical and physical processes, setbacks can filter, transform and store significant quantities of pollutants carried by surface runoff. These processes are more effective when runoff is spread out as sheet flow, than when it is channelized. Forested buffers also contribute to neutralization of acid precipitation, due to ion exchange that occurs as precipitation filters through the forest canopy. The percentage of pollutant reduction depends on the pollutant load, nature of the material, amount of runoff, extent of dilution by groundwater, and the character of the buffer area. Klapproth and Johnson (2000) have compiled an excellent review of the science behind the water quality renovation function of buffers.

5. Ecological Integrity. A well-buffered wetland with a range of different predators (e.g. insectivorous songbirds, amphibians, bats, hawks, owls, otters, mink) has a more complex and stable foodweb, and a more complex nitrogen and carbon cycle than a wetland with minimal adjacent upland habitat.[8, 9] Predators control population levels of mosquitoes, and also control herbivores such as voles, rabbits, and foliage insects.[10] Buffers protect wildlife and aquatic organisms from adverse physical changes to their environment (altered noise and light levels) by screening excess illumination and noise. Dense plantings can enhance the screening

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fact that most are perennials with underground storage organs, a winter food source for herbivores. They also have high aesthetic value.

[7] The extent to which soil minerals are released into groundwater and infiltrating precipitation depends on the type of parent soil material (Gradey and Mullaney, USGS,1998) and the duration of contact time. Higher mineral content (reflected in specific conductivity) was found to be associated with higher plant diversity in a study of wetlands in St. Lawrence County, New York (1994). This is consistent with the widely accepted pattern of diverse, slope-base plant communities in mineral-rich soils on wetland margins. A substantial buffer with intact soils is needed to enrich seepage groundwater.

[8] It is a widely accepted ecological principal that with more and different predators, more prey species can coexist, applicable in ecosystems as different as coral reefs and vernal pools.

[9] A shortage of predators may have undesirable public health ramifications, e.g., excessive densities of mosquitoes, tick-carrying white-footed mice, or an outbreak of a foliage insect.

[10] Because herbivory significantly impacts vegetation structure and composition (Howe and Lane 2004), wetland function improves, if the wetland supports predator populations.

function of buffers, a form of mitigation, compensating for sub-optimal buffer width. Scientific research has shown that buffer zones are an *integral component of the landscape* and can protect significant wetland and watercourse functions (Chase et al. 1995, Castelle et al. 1992, Welch 1991, Brown et al. 1987).

3.0 DETERMINATION OF BUFFER WIDTH:

POLLUTANT REMOVAL MECHANISMS AND STUDY RESULTS

The width of wetland/watercourse buffer zone needed to prevent significant adverse impacts to the wetland and/or watercourse is related to three factors: (1) the intrinsic ***properties*** of the buffer zone and setbacks (e.g. habitat quality, steepness, soil permeability, depth to water table, and vegetation density (Brinson 1993); (2) the ***intensity*** of the development, and (3) the ***sensitivity*** of the receiving wetland or watercourses.

As runoff moves across a naturally vegetated buffer as sheet flow or as shallow groundwater, it gradually *infiltrates* into the soil, ***sediment is filtered***[11]***,*** and ***nutrients are utilized by vegetation*** or converted into nitrogen gas by ***denitrification***. Processes such as ***volatilization, photo-degradation, biodegradation, bio-uptake, and adsorption*** work to break down or reduce toxicity of potential pollutants found in runoff (Hemmond and Fechner, 1994; Klapproth et al, 2000), operating more effectively in natural soils with high organic matter content and microbial activity.
Dilution by groundwater is also important. Hemmond and Fechner emphasize the importance of the ***duration of travel time***, in determining how much toxin actually reaches a sensitive wetland community or a sensitive receiving water body. A longer travel time provides more opportunity for these various processes to eliminate pollutants or make them less harmful. Research has shown the ***importance of deep roots of woody plants***, in extraction of nitrates and other constituents from shallow groundwater in subsoil (Hefting and Klein, 1998 and Correl 1997). These constituents are incorporated into wood and also leaf litter, which is eventually incorporated into surface soil horizons where denitrification and other breakdown processes are much more active than in the subsoil.

Travel time is a function of ***setback distance***, moderated by factors such as ***slope, soil infiltration capability and permeability, water storage capacity,*** and ***vegetative cover***. A

[11] Stormwater runoff that has passed through and treated by a treatment train of a stormwater management system still contains suspended fine sediment that is effectively polished by sheet flow over permeable buffer soils.

number of independent investigators have reviewed the technical literature [e.g., Diamond & Nilson (RGH, Inc), 1988; Schueler, 1995, Welch, 1991] and have concluded that a ***minimum* of 75 feet to 100 feet** to the sensitive receiving wetland and/or watercourse is needed for water quality renovation; ***larger distances are needed if soils are very pervious (sandy) or shallow, or if slopes are steep.*** A guidance document produced by the NRCS-USDA (March 2000) also recommends buffer widths of at least **100 feet** for removal of soluble pollutants such as soluble triazine herbicides. This document points out that *"It takes more surface area and longer flow paths to adsorb and infiltrate soluble material than to entrap solid material. Climate conditions and storm events… influence the effectiveness of the buffer to retard flow and remove pollutants."*

A guidance document produced by the USDA Forest Service, *Riparian Forest Buffers, Function and Design for Protection and Enhancement of Water Resources (NA PR 0791)* recommends streamside buffers ranging from **75 feet to 150 feet** in width depending on ***soil capability classes.*** This document emphasizes that certain uses such as trails and selective logging may be compatible with buffer effectiveness, with stricter restriction needed in the zone closest to a stream.

Diamond (1988) and Tom Schueler (1995) (among others) recommend adjusting wetland buffer width based on slope steepness. Various formulas have been devised. One frequent element is to subtract the sections with slopes steeper than a certain threshold (e.g. 15%), when calculating buffer widths for regulatory purposes. Steep slopes exacerbate the natural tendency of flows to concentrate, converging into larger and larger channels, which erode rills and gullies, becoming a sediment source rather than a sediment filter.

A buffer review paper by Barling and Moore (1994) also emphasizes that the pollutant removal capacity of a given buffer width varies with site conditions. Barling and Moore cite a study by Philips (1989) of the distances needed to remove nitrate in agricultural runoff, finding that fifty meters (150 feet) was not wide enough in some cases, but 15 meters (45 feet) was sufficient under other site conditions. Hefting and Klein (1998) found greater nitrate removal by forested than non-forested buffer zones. In the absence of detailed investigations of buffer characteristics, a conservative buffer width – at least 100 feet - is desirable. Of course, the types and concentrations of nutrients and toxicants to be treated or diluted also influenced the setback width needed. Note that nitrogen and phosphorus levels in groundwater discharging from forested buffers – and in streams and wetlands with undeveloped watersheds – are very low, typically under 0.2 micrograms/liter for total phosphorus and under 1.5 milligrams/liter for nitrate-nitrogen, based on an extensive data set developed by USEPA.

4.0 RESOURCE SENSITIVITY AND BUFFER NEEDS

Several characteristics of waterbodies and wetlands make them more sensitive to human disturbance, and increase the need for generous setbacks. This is especially so, if these are high-functioning wetlands or support valuable and/or unique ecological communities.

4.1 Sensitivity of Aquatic Fauna and Flora to Toxins

Numerous studies have shown close correlation between stream health as measured by biotic indices (measuring the diversity and composition of aquatic invertebrate communities) and the percent of developed land in its watershed. A recent major study by Morley et al (2002) is set in the Portland area. Healthy, diverse, aquatic communities with ***pollution-intolerant macroinvertebrate organisms*** such as stoneflies, mayflies, and case-bearing caddisflies are an important food source for trout and are very sensitive even to relatively low concentrations of stormwater pollutants, especially PAHs (Polyaromatic hydrocarbons and heavy metals). The classic study by Plafkin (1989) classified stream organisms based on sensitivity to stream pollution, and is still the basis for the USEPA Stream Bioassessment methodology. In Connecticut the CT DEP Pesticide Division has been studying the effects of toxic organophosphate insecticides on stream insects. ***Vernal pool breeding amphibians***, such as the mole salamanders and wood frogs are also known to be intolerant of water pollution, more so than amphibians of permanent ponds, such as green frogs and bullfrogs.

Toxicity screening has shown that widely used landscaping and agricultural pesticides and partially degraded toxic compounds will adversely impact ***wetland plants[12], fungi, pollinators[13], soil invertebrates, and frogs[14],*** *both individually and via foodweb alterations.* One hundred (100) foot setbacks between wetlands and areas of pesticide application are recommended in several federal guidance documents, and on the labels of

[12] Seed germination and seedling development in many plant species is inhibited by hydrocarbon breakdown products. Runoff containing glyphosate, the widely used and highly souble herbicide in RoundUp, may cause marsh vegetation kills. The authors have observed this personally in a wetland downgradient of an Ellington utility corridor.
[13] Neonicotinoid insecticides (widespread lawn and farm pesticides) are neurotoxins that disorient honeybees and other insects, at low concentrations (less than 30 ppb) - sublethal adverse impacts.
[14] Atrazine, a widely used farm herbicide, is an endocrine disrupter of frogs, at very low concentrations (less than 20 ppb based on studies with leopard frog and other frog species.

many individual pesticide products, used for landscaping as well as farming.[15] Note that pesticide labels calling for wide setbacks to wetlands are often ignored, especially if thickets visually obscure the nearby wetland; this is less of a problem if an ecologically conservative Integrated Pest Management (IPM) program is in place.

Toxins may reach wetlands and streams via shallow groundwater flows, via drift, or via surface runoff. Indirect adverse impacts occur through consumption of contaminated worms and other soil invertebrates, or a diminished prey supply. Headwaters streams and wetlands with little throughflow are most vulnerable to toxins. Flushing and dilution of pollutants is minimal in still pools and slow-moving channels, and low water volumes. Roadway pollutants such as polycyclic aromatic hydrocarbons (PAHs) tend to build up in these areas. Periods of low dissolved oxygen (DO) may heighten the biological impact of toxic pollutants such as heavy metals by bringing them into solution.

Generous setbacks between wetlands and stormwater outfalls, lawns or farm fields protect sensitive wetland organisms. They also prevent incidental harm because pollinators, birds, and other larger wetland creatures often wander into treated upland areas near wetlands.

A wetland buffer of **at least 100 feet** is especially important where the resource has been designated a critical habitat or is known to have exceptional functional value.

4.2 Variable Vulnerability to Sediment &Nutrients, for Different Wetland Types

Wetland and stream sensitivities to sediment and nutrients vary widely. Nutrient and sediment sources include partly treated stormwater runoff, excess fertilizers from farm fields and lawns, .and partly treated septic leachate[16] in shallow groundwater flow.

Less vulnerable wetland types include *emergent marshes* and *wet meadows*, and also *floodplains of larger streams and rivers*, which already have a relatively high nutrient status, and are subject to natural sediment deposition. The majority of wetland types are somewhat vulnerable to nutrient and sediment inputs.

[15] 100-foot buffers are recommended in Conservation Buffers to Reduce Pesticide Losses and the USDA March 2000 and the US District Court (Coughgenour) pesticide buffer ruling 1/27/2004.

[16] See further discussion in Sections 4.3 and 5.2 of this report, explaining how a fully compliant, per CT Heath Code, septic system can still pose a singificant threat to the water quality of certain streams and wetlands.

Some types of wetlands are highly sensitive. The unusual plant communities and wetland soils in oligotrophic (low nutrient) wetlands such as *bogs, fens, and headwaters seeps* will be irreversibly degraded by nutrients in sediment and partially treated stormwater runoff, especially phosphorus. These wetland types are often ***valuable***, due to high functions and/or values. Some headwaters ecological communities, like bogs, are uncommon in the Connecticut landscape.

In mesotrophic (moderate nutrient status) *ponds and lakes,* excessive nutrient inputs typically cause algal growth and eutrophication. If buffers are inadequate, they also cause adverse changes to *mesotrophic wooded swamps*; the cinnamon fern - high bush blueberry-red maple community; organic and mossy substrates in wetlands; and populations of perennial wildflowers or ferns are all significantly altered by deposition of sediment, and changing hydrology and nutrient status. Sediment deposits in wetlands form a seedbed for weedy, annual, nutrient-demanding colonizers like jewelweed and invasive plants such as *Phragmites* (i.e. common reed) and purple loosestrife, and may eliminate rare and uncommon species. A wetland's *physical structure* is altered when non-persistent, nutrient-loving annuals like false nettle and jewelweed become dominant rather than ferns and sedge tussocks, which provide year-round cover.

Benthic (stream-bottom) macroinvertebrate communities are highly sensitive. Sediment deposits on gravelly or cobbly substrate or woody debris smothers gravelly fish-spawning habitat and habitat used by stream-bottom invertebrates: crevices, stones, twigs, and leaf litter. It may degrade habitat needed by rare state-listed species such as wood turtles and certain freshwater mussels (e.g., eastern pearly shell). *Suspended* sediment abrades the gills of fish, being most harmful to juveniles, and clogs the gills of certain sensitive macroinvertebrates (e.g. case bearing caddisflies, stoneflies, and mayflies). Sediment and algal proliferation (triggered by excess nutrients) also smothers key aquatic food sources: decomposing leaves and microscopic plants (diatoms). Nutrient-stimulated green algae proliferate at the expense of diatoms.[17] Large, slow-flowing streams or rivers with naturally sandy bottoms are less vulnerable than smaller, rocky streams. Larger watercourses are better able dilute turbid water (or other pollutants) that may reach them.

4.3 Comparing Nutrient Removal Efficiencies

[17] The multiple adverse impacts of sediment on aquatic habitat are thoroughly covered in *Impacts of Suspended and Deposited Sediment* by Wood amd Armitage (1997) and Crowe (2004). Periphyton is the scientific term for the thin film of microscopic plants that coats the substrate of a healthy stream, and is a major food supply.

A supplemental buffer is usually needed to protect wetlands from nutrients and sediment because other best management practices BMP's) are not sufficient. This generalization applies to septic systems, stormwater basins/treatment trains, perimeter silt fence, and perimeter silt socks.

Properly functioning septic systems remove only 40-50% of the nitrogen that enters the system, though they do filter most of the phosphorus. With a 100-foot buffer, the roots of trees and shrubs, and dilution by groundwater will substantially reduce nitrate concentrations reaching the wetland.[18] Similarly, correctly designed stormwater management system will still discharge a substantial percentage of the nutrients that enter the system. Large data sets on performance of water quality basins (e.g. EPA NURP data, UNH-SC 2010[19]) show that average phosphorus and nitrogen removal rates in excess of 80% are rare, and expensive to achieve, and 40-60% removal is common.

None of the alternative, sophisticated erosion and sediment or stormwater management control practices match natural wetland buffers as a sediment filtering tool. Tom Schueler principal scientist at the Center for Watershed Protection (1995) focused on sediment removal, in formulating his recommendation of an **80-foot minimum buffer.**

Regardless of how well sediment barriers are installed, fine sediment (fine sand or finer) passes through the mesh of silt fence or between hay strands in hay bales; these perimeter controls are *not complete sediment barriers*. In fact they depend on through-flow to function.[20] The 2002 CT DEP Erosion and Sedimentation Guidelines specify only 75% removal efficiency for geotextile silt fencing. This is less of an issue for a large construction site that depends primarily on earthen berms, rather than barrier fencing.

Compost berms (silt socks) can remove a high percentage of sediment. However, they release dissolved phosphorus unless specialized additives are inserted into the medium, at additional cost (rarely done). Long-term, a narrow setback behind a compost tube will also be unable to perform multiple other buffer functions post-construction (see Section 3.0).

[18] To accurately model the setback needed from the septic leachfield to the wetland, use the latest CTDEP Dilution model (2003), which takes soil type and watershed area into consideration. It is usually used for community septic systems but is applicable to any setting, per CTDEP staff. Also consider resource senstivity.
[19] UNH-SC, 2010. University of New Hampshire Stormwater Center. 2009 Biannual Report.
[20] The mesh size in AMOCO silt fence (when stretched by water under pressure) according to specifications provided by the vendor is between 850 and 710 microns, the size of a medium to coarse sand grain particle.

By contrast, overland sheet flow through a forested wetland buffer, over forest leaf litter or through meadow vegetation, will achieve nearly complete sediment filtration *and* nutrient uptake, if the buffer is over 80 feet wide with a gentle to moderate slope, and flow volumes are low and dispersed. Groundwater discharge into the wetland will contain minerals and dissolved organic matter. Especially where proposed grading is extensive, with steep cut slopes, buffers are an important supplementary best management practice (BMP). If the project includes on-site sewage disposal, excess nitrogen in septic effluent will also be removed. Dissolved phosphorus in lawn runoff will be removed by a buffer with a minimum width of roughly 50 feet[21] (Woodard and Rock, 1995[22]), provided the wetland or watercourse is not oligotrophic already (i.e. low nutrient) and, therefore, more sensitive than most other resources.

4.4 Ecological Integrity and Productivity

Leaving a vegetated buffer increases the likelihood that disturbance- or area-sensitive wildlife will remain in a wetland, as a part of the food web, adding to the wetland's overall function. Many wildlife species of wetlands and stream corridors, such as wood duck, green heron, barred owl, and veery, are sensitive to human disturbance and/or have specific habitat area requirements. Buffer vegetation also absorbs sound, enhancing avian habitat quality and wetland value for human users. A study by Reijnen and Foppen (1997) showed significantly decreased bird density and diversity closer to major highway noise sources, with measurable impacts extending out as far as 300 feet. Longcore and Rich (2004) recently reviewed the available research, and found multiple studies showing disruption of predator-prey relationships and foraging behavior by elevated light levels.[23] An approximately **100 foot wide buffer** has been found to be sufficient for general avian use, although wider setback needs (over 300 feet) were demonstrated for forest interior birds (Milligan, D.A, 1985), such as veery, a wetland-dependent species. Wetland/watercourse buffers widths of 96 to 117 feet encompass home ranges of 12 New England mammals (DeGraaf, et al. 1987).

[21] In this study a 15 meter buffer strip was adequate to return total phosphorus levels to background levels (i.e., <1.5 mg/l).
[22] Woodward, S.E., and C.A. Rock. 1995. Control of Residential Stormwater by Natural Buffer Strips. Lake and Reservoir Management. 11(1):37-35.
[23] Light inhibited foraging by smaller nocturnal wildlife species (e.g. small mammals, amphibians, and slow-flying bats). Similarly, one study showed that fewer zooplankton migrated to the water surface at night to feed on algae under well-lit conditions, a behavior presumably related to avoidance of fish predation. Night lighting inhibited reproductive behavior in frogs.

The wildlife habitat value of a buffer, in terms of ecosystem productivity[24], is affected by the width of the zone adjacent to the wetland with high humidy and dense vegetation. The high insect densities and thick vegetation in wetlands and in moist upland buffers make them less desirable for human residential use, but very valuable for wildife, more so than typical well-drained upland oak forest. A large scale study in Massachusetts of bird distribution in relation to habitat components (Swift et al. 1983) demonstrated signficantly higher bird densities within and adjacent to forested wetlands, than in well-drained upland forest, even for faculative birds that use both uplands and wetlands. Densities of treefrog, woodfrog, bats, shrews, and predaceous invertebrates are also assumed to be higher, than in well-drained upland habitat. The larger combined area of a wetland and its adjacent moist upland buffer can support more wetland-associated wildlife, than a wetland closely flanked by development.

Because mosquitoes are intolerant of dry air, they are active in humid, low-lying upland buffer habitat, in the vicinity of wetlands with standing water, but *not* in drier upland buffer areas. Because high mosquito densities may be associated with health concerns, pesticide application is more likely, with potential adverse impacts on aquatic habitat, when homes are built in moist, low-elevation, upland areas, near wetlands. In a nutshell, generous wetland and watercourse buffers provide a margin of safety for public health – and protect the wetlands from pesticides. Note that if the wetland or stream is bordered by well-drained uplands, these particular concerns regarding health and quality-of-life are reduced, for a setback less than 100 feet wide.

4.5 Headwaters Wetlands

Generous protective buffers are especially important for low order streams and headwater wetlands. Mark Brinson emphasized the vulnerability of headwater wetlands in his 1993 landmark paper. He pointed out that a given area of adjacent soil disturbance would affect lower order, headwaters streams *proportionately more* than large, higher order streams. Biodiversity, including rare species, is especially high in headwaters seeps and streams (Meyer et al 2003). Because significant *denitrification* takes place in the microbe-rich substrate of healthy streams and stream banks, maintaining the integrity of lower order

[24] The carrying capacity of the habitat unit (wetland and adjacent moist buffer) is the total number of songbirds, insectivorous amphibians and bats and other small mammals that it supports. A wide body of research has shown that larger populations of plants and animals are genetically healthier (more genetic diversity and less prone to inbreeding depression, infertility, and loss of alleles from genetic drift). If buffer habitat is moist enough to support wetland-associated species, the wetland ecosystem benefits from the larger population sizes, and greater production export.

streams has a significant role in protecting downgradient waterbodies, including Long Island Sound from excess nitrogen inputs (Meyer et al. 1997).

Buffer areas and level spreaders between stormwater outfalls and streams help reduce concentrations of roadway pollutants, but headwaters open space preserves and "soft" drainage systems (without catchbasins and stormdrains) provide the best protection for headwater streams. Note that headwaters streams in urbanized watershed may already be so degraded that their value and functional level is low, reducing the impact of activities within buffers, although downstream impacts remain an issue.

5.0 TOXIN MOVEMENT AND DEGRADATION IN WETLAND BUFFERS

5.1 Pesticides

The NRCS-USDA document, *Conservation Buffers to Reduce Pesticide Losses* (March 2000), recommends a 100-foot setback from farm fields to streams, as noted in Section 3.1 (Footnote 15)[25]. The stated rationale is to allow sufficient dilution and degradation, on average, to protect aquatic resources. This paper also emphasizes the need to protect intermittent streams, pointing out that smaller streams combine to provide the water source for perennial streams with fish populations – the watershed perspective. The impacts to wetland biota of toxins such as pesticides and PAHs have already been discussed in Section 4.1. This section provides more detail in support of the buffer needs to protect wetland resources.

Because ***soluble pollutants move readily through saturated soil***, it is important that setback distances be measured from the wetland boundary, not the bank of the watercourse. In evaluating a proposed setback to regulated activities, the perennial question is as follows: Will fertilizers and pesticides from the lawn or farm field reach the downgradient aquatic resources in sufficient concentrations to harm aquatic organisms or plants? Will they harm invertebrates in wetland soils? Sub-lethal effects of neurotoxins should also be considered.

Although highly persistent organochlorine pesticides (e.g. DDT) are no longer available in the USA, numerous products are still in use with high aquatic toxicity, rapid mobility in soil, high solubility in runoff, and/or long persistence (half lives over 60 days). Even pesticides with a "rapid" breakdown rating have half-lives of several days to a week. Based on their physical properties, several commonly used turf chemicals can be expected to pass too rapidly through narrow setbacks, for breakdown to occur. For example, the

[25] available on the internet from the USDA web site

time needed for 75% to 100% breakdown of the herbicide 2,4-D is four weeks. The popular, soluble grub pesticide Imidacloprid (Merit), linked to honeybee decline, takes 48 to 190 days to break down. A study evaluating herbicide removal by a 20-meter (i.e. 66-foot) wide grassed buffer strip under natural rainfall, showed reduction of Atrazine by only 9% to 12%, of Metolachlor by 15% to 27%, and of Cyanazine by 7% to 21% (Arora et al. 1993). Moreover, initial breakdown products of pesticides and herbicides may still be toxic if the biologically active functional groups are still intact[26].

In assessing the need for buffers to attenuate pesticides, consider the intensity of the threat: total upgradient areas of lawn, fairway, or farm field; anticipated rates of application; whether an Integrated Pest Management Plan will be in place; soil permeability, and the details of that plan. A highly conservative IPM plans might make substantial use of cultural practices and choose pest control products with minimal impacts to non-target organisms (Carlisle 2006).

With a small project, land use commissions simply ***cannot enforce permit stipulations that restrict fertilizer or pesticide use***, e.g. allowing only products with low aquatic toxicity or low mobility in soil. Product-based regulation is not practical, due to the number of available products. Pesticide monitoring (enforcement of IPM plans) by a golf course or a planned community is hampered by the large number of chemicals & breakdown products requiring different assay techniques. The solution, however, is fairly straightforward: the provision of generous buffer zones to wetlands and watercourses, based on the scientific literature and the best site-specific information available.

5.2 Septic Effluent

As noted in Section 4.3, properly functioning septic systems unavoidably release effluent with high concentrations of soluble nitrate. When permitting any site plan with a septic system upgradient of a wetland, a question to be asked is whether distance will be sufficient to adequately dilute nutrients in septic leachate? Many officials are unaware that the existing standards determining septic system placement (50 foot setback to waterbodies and 10 mg/L nitrate per liter in groundwater leaving the site) are based <u>solely on human health criteria</u>.

The CTDEP is in the process of developing a new set of criteria based on ecological considerations, under a directive from USEPA (2000). Draft EPA nutrient standards for

[26] Judy Singer, CTDEP Pesticide Division, personal communication, December 2000.

Ecoregion 1V, which includes Connecticut, are based on levels in non-impaired streams: total phosphorus – 31.25 µg/l, and total nitrogen – 0.71 mg/l. Although nitrate-nitrogen is soluble in groundwater, substantial plant uptake, denitrification, and dilution can be expected to occur in a watercourse buffer, particularly if it has a high proportion of moderately well drained soils and an intact topsoil layer with at least a moderate amount of organic carbon (e.g. 4-5% or more).

As discussed above in Section 4.2, the ***ecological communities in bogs, fens, and headwater seeps and streams*** are all vulnerable to ***nutrient*** pollution, far more so than cattail emergent marshes and hayfield wet meadows, although there is a lack of available data on the exact thresholds of nutrient inputs that cause degradation of different types of wetlands. Dilution and diffusion – within wetland setbacks - are relied upon to bring nitrogen concentrations in septic system leachate down to levels that do not present a *human* health risk. Wider setbacks to septic systems than mandated by the Connecticut health code (e.g. at least 100 feet to wetland boundaries) are typically needed to maintain concentrations in receiving water bodies that are close to the USEPA draft standards. Large nutrient inputs into lakes and ponds, as well as the Long Island Sound, usually triggers adverse impacts via eutrophication/hypoxia.

5.3 Chlorine

If an above ground pool were emptied prematurely in the fall, would *chlorine* reach the resource? Chlorine is highly toxic to aquatic life at extremely low concentrations; the acute toxicity standard is 19 ppb (i.e. parts per billion) and the chronic toxicity standard is 11 ppb. Generous buffers in residential areas prevent the accidental release from swimming pools into wetlands and watercourses.

5.4 Fertilizers

Severe eutrophication often occurs in watercourses receiving lawn runoff, especially from up-scale residential neighborhoods. Excessive nutrient inputs can also dramatically change the composition of a natural wetland plant community, as discussed above. Releases of lawn chemicals vary widely, depending on the practices of the individual homeowner or lawn care service. Several no-phosphorus and low-phosphorus fertilizers are produced, but are not readily available in the retail market, or often selected. Unfortunately, lawn care services may profit from applying fertilizers, pesticides, and herbicides more often and more heavily than necessary. However, naturally vegetated buffers are very effective at preventing excess nutrients from reaching watercourses, ponds, and lakes.

Rates of *nitrate* removal are a primary consideration for the approximately 100 foot wetland and watercourse setback recommendations by USDA and other researches discussed above. Since nitrate is highly soluble and does not adsorb to soil particles, generous setbacks are necessary, especially in areas with sandy outwash soils, to allow for sufficient dilution, such that groundwater–fed streams and ponds will not be impaired. Septic system spacing, per the Public Health Code, is intended to allow sufficient dilution to keep nitrate levels in the water table (and wells) at safe levels. Reduction of nitrate inputs into watercourses is a high priority for CT DEP because nitrogen has been identified as the primary cause of Long Island Sound's serious water quality problems.

Dissolved phosphorus is effectively removed by adsorption to soil particles in naturally vegetated buffer areas, with low available phosphorus levels, provided soils are suited to infiltration, and loading rates are not excessive (e.g. from a farm field), such that the soils in the buffer become saturated with phosphorus. This is a key buffer function because phosphorus is a major cause of algal blooms in ponds and impoundments of streams and rivers. Phosphorus also degrades wetlands with low to moderate natural nutrient levels. Because surface soils of most lawns are saturated with phosphorus, sheet runoff across lawns picks up significant concentrations of dissolved phosphorus, often sufficient to impair water quality if discharged directly into a watercourse or drainage ditch. Decomposing wood chip mulch and compost-filled silt sock sedimentation barriers also release phosphorus.

6.0 CONCLUSION

In summary, based on the scientific literature, ***a minimum* 100 - foot wide upland review area** (URA) is prudent, from a regulatory perspective. However, the width of buffer needed to protect and maintain the functions of a *particular* wetland and/or watercourse depends on three principal, *site-specific* factors: (1) the *sensitivity and functional value* of the resource; (2) the *intensity* of the proposed activity; and (3) the *characteristics of the proposed buffer or setback*, including its *effectiveness* at attenuating or buffering anticipated impacts, and its *habitat value* to the adjacent wetland ecosystem.

Examples of *highly sensitive* resources needing wider setbacks are a nutrient-sensitive bog or fen, a perennial headwaters seep, a productive vernal pool wetland, and a wildlife sanctuary;

the New Jersey buffer determination method (Diamond and Nilson 1988) recommends 300-foot setbacks adjacent to valuable nature sanctuaries. An example of a *low-sensitivity* resource would be an urban stream that briefly daylights in a vacant lot, or a small, isolated, fertile wetland surrounded by active agriculture.

Although the scientific literature supports a setback of 80 to 100 feet to protect wetland resources, there are exceptions. The *effectiveness* of a particular setback area generally depends on soils, slope, and vegetation properties; buffer areas with very steep slopes, shallow ledge or hardpan, highly erodible soils, and/or a sparse groundcover and litter have impaired effectiveness, so that wider setbacks are needed to protect the downgradient resources. The significance of loss of a given buffer area also depends on its *intrinsic habitat and wildlife value* to adjacent wildlife and vegetation. Adverse impacts from development somewhat closer than 100 feet from a regulated resource are less significant, if buffer habitat in the buffer area to be lost is degraded.

Each application before a municipal Inland Wetlands and Watercourses Agency (IWWA) must be considered on a site-specific basis, considering the three aforementioned factors: buffer quality, activity intensity (both short-term and long-term), and resource sensitivity and value. For example, impact to the resource from the proposed parking lot of a self-storage facility with a 40-foot buffer to a seasonal drainage swale, may be lower than impacts from the proposed parking lot of a busy supermarket with a 100-foot buffer to a natural stream corridor. This is because of the *low sensitivity and value of the first receiving resource*, and because the supermarket is a much *higher intensity* land use, generating higher concentrations of roadway pollutants and with a greater proportion of impervious surface in the wetland watershed, as well as higher noise and illumination levels. Additional protective measures will be needed for the supermarket application. The adverse impacts from a long, narrow private driveway (20 foot cleared swath and a 25-foot buffer to the wetland), passing through invasives-infested habitat at the edge of a large wetland system, would be low: 1) due to *low buffer quality*, 2) because the wetland is *not being fragmented*, and 3) due to the *low intensity* of the proposed activity. The formal New Jersey (Diamond and Nilson) buffer determination methodology (1988) explicitly requires wider buffers, for more intense landuses.

Buffer width determination methodologies, such as those of Diamond and Nilson (1988) and Pawlak and Logan (1995) (a.k.a., The Town of Cromwell Wetland Buffer Zone Designation Methodology) depend on data that document wetland sensitivity, buffer habitat quality, and the filtering/screening capacity of a given wetland setback. In the absence of detailed baseline information on wetland and buffer resources that would justify a narrower buffer in a particular area, the scientific literature supports site plans with buffers of at least 80 to 100 feet.

Authors' Note: We consider this to be a "living document," that is, a document that will periodically be revised and updated as the relevant science base and understanding increases.

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