WETLAND MITIGATION

Executive Summary
February 1994

Michael Wm. Lefor, John S. Barclay,
John C. Cooke, Robert J. Craig,
Sigrun N. Gadwa, Eileen H. Jokinen,
Thomas E. Murray, Christopher Perkins,
and Peter H. Rich

JHR 94-225 Proj. 87-6

This research has been sponsored by the Joint Highway Research Advisory Council of The University of Connecticut and Connecticut Department of Transportation. The work is being carried out in the Civil Engineering Department at The University of Connecticut.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
JHR 94-225		

4. Title and Subtitle	5. Report Date
WETLAND MITIGATION. Executive Summary	February 1994
	6. Performing Organization Code
7. Author(s) Michael Wm. Lefor et al.	8. Performing Organization Report No. JHR 94-225
9. Performing Organization Name and Address University of Connecticut Department of Civil Engineering 191 Auditorium Road, Box U-37 TI Storrs, CT 06269	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Connecticut Department of Transportation 280 West Street Rocky Hill, CT 06067-0207	13. Type of Report and Period Covered Executive Summary Report 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This document briefly summarizes the theoretical basis and applied results of a five-year study on various aspects of wetland mitigation conducted at the University of Connecticut, Storrs. Sixteen "reference" and four "experimental" wetlands were examined for physical and biological parameters. Experimental areas were mapped and observed over three years to trace the development of wetland vegetation on the bare soil shorelines and slopes of mitigation basins. Among the important conclusions are that: 1) wetlands respond quickly to hydrologic changes; 2) flashy hydrology leads to bare soils and the development of weedy vegetation; 3) water quality in a created wetland is one of the most important parameters of the system. In many situations, created wetlands should be two-stage, terraced systems, with a biofilter wetland for influent waters above a lower wetland with more stable base flows, and cleaner water, largely free of excess nutrients; 4) in many cases, weedy species such as Purple Loosestrife, Willows, Poplars, and Reeds should be removed from nearby seed-source wetlands; and 5) wetland construction should take place last in the construction sequence, and should proceed from upstream to downstream, and systems should be made adjustable and adaptable to site conditions, by means of adjustable weirs. The Final Report will be issued in six volumes, and contains detailed recommendations for wildlife populations and management; soil microflora and soil management; water quality parameters; plant names of native and introduced species; plant propagation; and long-term monitoring.

17. Key Words	18. Distribution Statement
Wetland mitigation, Connecticut, Vegetation dynamics, Wildlife populations, Mycorrhizae, Water quality, Flora, Construction sequence.	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	11	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	mililitres	mL
gal	gallons	3.785	Litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greator than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

*SI is the symbol for the International System of Measurement

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F

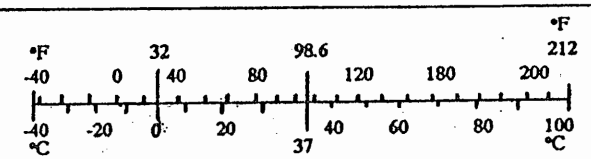

TABLE OF CONTENTS

THE UNIVERSITY OF CONNECTICUT

JOINT HIGHWAY RESEARCH ADVISORY COUNCIL

EXECUTIVE SUMMARY
PROJECT 87-06: WETLAND MITIGATION

INVESTIGATORS: MICHAEL WM. LEFOR, JOHN S. BARCLAY, JOHN C. COOKE, ROBERT J. CRAIG, SIGRUN N. GADWA, EILEEN H. JOKINEN, THOMAS E. MURRAY, CHRISTOPHER PERKINS, & PETER H. RICH

February 10, 1994

Purposes. This work was conducted by the above-named researchers at the University of Connecticut, Storrs, from mid-1987 to 1993. As this is written, all phases of the research are complete except for some of the data analysis in the sections dealing with zoology and botany, and the training guide. An *Annotated Bibliography for Wetland Mitigation* and a Colloquium Proceedings volume, along with a *Preliminary Report*, have already been issued from this project by the Transportation Institute in UConn's Civil Engineering Department. The *Final Report* will appear in six volumes in 1994. Draft versions of vol. 3, *Mycorrhizae*, vol. 4, *Water Quality*, vol. 5., a *Technical Summary Report*, and vol. 6., *Appendices: A. Lists of Names of Connecticut Plants with Selected Synonyms and Notes and B. Propagation Practices for Selected Connecticut Wetland Plants*, are complete, and in the publication stream. The purposes of this research are:

1. To evaluate the feasibility of building artificial wetlands as mitigation for unavoidable loss of wetlands in transportation projects;
2. To provide guidelines for the construction and restoration of wetlands; and,
3. To provide implementation and training aids.

Design Rationale and Theory. The initial research design rationale was as follows: 1. At the beginning of the project in 1987, the Federal charge to ConnDOT, and FedDOT (via Federal EPA authority), was that if Federal transportation construction funds are used to destroy or alter wetlands as part of a transportation project, then those wetlands must be replaced, taking into account the functional values of the wetlands that are unavoidably being impacted. All reasonable attempts are to be made to replace wetland acreage on a one-for-one basis, based on functional assessment. Off-site *vs.* on-site mitigation was not an issue at the time, so the focus was on on-site mitigation. The EPA charge was later modified to one of replacing not just wetland *appearance*, but wetland *function*. 2. It was known from past observations that wetlands are dynamic metastable systems subject to wide swings in environmental influences of hydrology and disturbance, both human-induced and "natural." 3. It was also known that existing wetlands have arisen spontaneously as both natural phenomena and as human-induced phenomena; 4. therefore, a series of man-induced and(or) man-influenced wetlands of different cover-types was selected as reference ("control") systems and several "experimental" systems which were arising on wet-bare soil in highway construction projects to follow through the research period, on the assumption that if wetlands arose on wet bare soils in nature with the recession of the last glaciation, some of the same or similar processes might be at work in construction projects. The overriding theoretical assumptions regarding wetlands (as all natural systems) are that they are multi-variate; subject to chance events of different magnitudes at different periodicities; and that different environmental influences are of differing importance in the development of these systems at any one time. In other words, natural systems — and especially wetlands, which are not lakes, not forests, but highly energetic systems dominated by surface and(or) ground-water lying between the two — are *non-linear systems.* If nature, and wetlands in particular, have a mathematics that describes them, it is fractal, not Euclidean. At the simplest, the description of any part of a wetland at any point in time is four-dimensional, and the challenge for those interested in manipulating the development of wetlands is to choose the correct scale of parameter to manipulate at the right time, while allowing for the occurrence of chance events at greater and lesser scales. In practical terms, this can be as simple as understanding the variations in ecological parameters that will be managed by engineered structures. For example, in designing a wetland, an engineered control structure usually has a safety factor built in for the water level, so that it is standard practice to show a water level on the upstream side of a dam of *x*. In reality, the water level will fall anywhere between (and (or) fluctuate between) *x plus or minus one foot*. That sort of variation is unsuited for the growth and development of most wetland plant species, which need a fluctuating water level of *plus or minus one inch*. The practical solution in many cases is simple (depending on the hydrograph and the water quality, etc.): provide an adjustable control structure so that the water-level can be made adjustable, or "fine-tuned," at the next lower level of organization.

Botany. Sixteen "reference" wetlands and four "experimental" wetlands were examined for a variety of environmental parameters. The reference wetlands were examined for vegetation type and history of disturbance, bearing in mind the wide ranges of response to changes in hydrology and human influence pointed out in related JHRAC projects by R. M. Thorson. The experimental areas were mapped and observed over three years for the development of wetland vegetation on wet bare soil. All plants were tracked through the research period and correlated with ground- and surface-water levels, slope, aspect, soil types and nutrients, and for seed inputs, as already detailed in our vol. 5. of the Final Report, *Technical Summary Report: Wetland Mitigation*, now in final revision. Vegetation was observed and quantified in over 80 belt transects, resulting in over 21,000 data entries, each of 28 parameters (not all parameters were measured, depending on the species), for a total data matrix of approximately 568,000 points (not counting correlative data). The results of this work will permit the development of slope and planting guidelines for wetland construction, when taken together with the recommendations from the other areas of the study. We concentrated our efforts on analysis of the data from the research area at I-84 and Conn. Rte. 322 at Cheshire, since that area was most stable the longest. The remaining areas (East Berlin, Cromwell, Newington-New Britain 1985 sites) along the route of the Central Connecticut Expressway, have been dropped from the detailed analyses because of pollution, dam and slope failure, and human disturbance and inappropriate design and execution, respectively, but will be considered for the lessons they offer in the Final Report. Some general conclusions have been formulated, and are presented here at the end of this report.

Zoology. The objectives of this section of the research were:

1. To determine the degree and ways in which created wetlands serve as wildlife habitat;
2. To assess wildlife use of created wetlands as a measure of their function; and,
3. To evaluate what biological and engineering factors should be considered in creating and managing highway wetlands and wildlife habitat.

Portions of this part of the work were scheduled for up to five years of observation, depending on the site. In particular, the split basin at Cromwell was selected for continued observation, but this was interrupted on two occasions by unscheduled repair work and construction delays. Baseline data was gathered in Cromwell, on five "reference" sites mentioned above, and in the I-84-322 basin at Cheshire. The results for small mammals and birds have been tabulated and are being written up as vol. 2, *Zoology*. The degree to which wildlife is present in a wetland is a manifestation of the degree to which each site is functioning as a physical, chemical, and biological entity within a given watershed. Species, their abundances, their interactions, and their general well-being are in constant flux. Wetland wildlife communities are closely linked to, and interact with, the condition and dynamics of the plant community and hydrology of a given wetland.

Species were evaluated by standard wildlife population measurement techniques for determining seasonal abundance, relative abundance, species richness, habitat use, and species interactions, along with assessing the influence of the animal populations on the vegetation. Sites were cover-mapped from aerial photography at 1:12,000, and detailed trapping and observations for birds, mammals, reptiles, and amphibia were made beginning in 1987, in a variety of habitat types representative of Connecticut wetlands generally. Preliminary invertebrate censuses were carried out and are to be presented in the final volume on this part of the work, but a full analysis was beyond the scope of the project. Animals responded quickly to the development of wetland vegetation and habitat in the experimental areas, with Muskrats, Canada Geese, and Voles ("field mice") demonstrating considerable impact on the developing vegetation in some areas.

Mycorrhizae. Mycorrhizae, or symbiotic obligate fungal root-parasites, have recently assumed importance in the soil ecosystem and as valuable members of the developing root-soil interface in areas of plant colonization. With that in mind, a systematic survey was conducted among 290 root collections from 90 species of higher plants distributed among 76 genera from a variety of sites and in various stages of vegetation development. A large number of samples was found to possess vesicular-arbuscular mycorrhizal (VAM) fungi as symbionts in at least some part of the life cycle of each species, especially those plants with roots in the upper strata of wet bare soils. VA mycorrhizae were reported as new to science in a number of genera and families. Later, the fungi drop out after the plants have stabilized. The results of this work are presented in vol. 3 of the Final Report, *Mycorrhizal Associations of Some Connecticut Wetland Plants*, and indicate that attention to the mycorrhizal condition will be important in encouraging and maintaining wetland plant associations.

Water Quality. The work on water quality consisted of detailed investigation of all watersheds and surface-water sources in the Bass and Piper Brook systems and at Cromwell. Also included were seasonal investigations at Cheshire, Berlin, and East Berlin, and baseline investigations at certain of the "reference" areas. Water samples were collected on a regular basis and analyzed per season for nutrients and other major ion species according to standard methods. Special attention was given to recording and sampling peak flows at rainstorm events, since most excess nutrients entering streams and wetlands enter in the first 15 minutes to half-hour of runoff, especially in flashy urbanizing watersheds. Unit hydrographs were calculated, as were inputs upstream of wetlands and outputs down stream of wetlands. Throughputs at Cromwell could not be measured because of dam and slope failure and the draining of the basins mid-way through the project.

From a water quality perspective, the success of a wetland mitigation requires that a created or restored wetland improves water quality. Wetland plants and the microorganisms remove nutrients from the water which flows around them, and the decrease in water velocity associated with wetlands promotes the sedimentation of particulates. Both uptake and sedimentation improve the quality of the water. However, for a functioning wetland system to become established, the water entering from the surrounding drainage basin must be of sufficient quantity and quality to promote and support a complex system of plants and animals. Engineers have developed extensive technology for moving and storing *quantities* of water, and that technology can be applied to wetlands; but in wetland work, water *quality* must also be considered. The results from this part of the investigation have lead to the recommendation of tiered systems: an upstream wetland which slows influent water and removes nutrients and particulates, feeding a downstream wetland that finishes the job of water quality renovation and habitat reconstruction.

Conclusions and Recommendations. The more important conclusions and recommendations of the work are presented here; all are elaborated fully in the various volumes of the *Final Report:*

A. *Vegetation.*

1. Wetlands are dynamic, metastable systems that respond fairly quickly to changes in hydrology. Beavers, now reappearing as a force in the landscape, will be important members of the picture in the long term, in wetlands connected to streams. Hydrology now is flashier than before European settlement, and base flows are lower. This must be taken into account in engineering designs, and structures provided to slowly release the peak flows.

2. Unstable flashy flows lead to disturbed soil areas that permit the colonization of weedy species.

3. The two-stage system described above under *Water Quality* should be adopted for wetland design. The upper basin should begin with an energy dissipator and plunge-pool, and proceed to a shallow area that will support plants such as Cattails. This should flow to a lower basin with shallow (no steeper than 1 rise on 12 run) side slopes to permit colonization by, or successful planting of, wetland plants. Shelves are absolutely discouraged. Both basins should be controlled by adjustable structures to allow fine-tuning of the water-levels.

4. Abundant water must be available throughout the year. It is of no use to provide a basin which is wet only in the spring, and becomes a desert in August. Therefore surface and ground-water availability should be thoroughly investigated before design and construction start.

5. Weedy species such as Purple Loosestrife, Willows, Poplars, and Phragmites (Reed) should be removed from any nearby seed-source wetlands before ground is broken (their seeds persist in the soil and(or) seed in quickly in open wet areas).

6. Excavation for wetland basins takes place *last* in the construction sequence, after all slopes are stabilized and the site hydrology has stabilized. Wetlands should be designed *small* to be manageable, and be placed near the tops of the watersheds feeding them, to minimize detrimental impacts. Work from the top of the watershed to the bottom to maintain and improve water quality before discharging to receiving waters. It is easier to fix and manage a one-acre wetland than an 80-acre wetland well down slope.

7. Place wetlands to the south and east of seed source wetlands with their long axes places NE—SW. This maximizes wind-blown seed input (but see above), and minimizes wind-generated turbidity. Periodic drawdowns and floodings, and spot-application of environmentally-friendly herbicides such as Roundup may be necessary to manage the composition of the vegetation, and monitoring and periodic weeding or other minor maintenance will have to take place over a five-to-ten year period (with decreasing frequency).

8. Wetlands that are planted (rather than being permitted to colonize naturally) should be planted with pre-adapted (grown partly anaerobically, in wetland soils) local plants of plants of native wetland species of a large enough size to immediately begin colonizing vegetatively. One-gallon containers or better are acceptable. ConnDOT should set standards of such plants and encourage their commercial production. Wetland edge or buffer plants should be of native species, locally grown from local stocks (material grown or propagated out-of-state and(or) in another region are unacceptable for reasons of cold-hardiness or genetic diversity).

B. *Animals.*

1. Colonizing herbivores such as Beaver, Muskrats, Woodchucks, Rabbits, etc., can do considerable damage to new plantings, and must be trapped and removed if they are having serious effects on the developing vegetation. Exclusion fences may have to be used (stout wire, the bottom courses buried) to exclude these animals.

C. *Mycorrhizae and Soils.*

1. Any on-site wetland soil should be removed, stockpiled, and reused. If the soil is to be stored for a period longer than a week or so, it should be plated with a legume cover crop such as clover or alfalfa to increase the survival of nitrogen-fixing bacteria and mycorrhizae.

2. Topsoil removed during construction should not be mixed with subsoil before being replaced, but the addition of mulch and(or) lime is acceptable.

3. Any plants installed should be already be mycorrhizally infected.

D. *Water Quality.*

1. Constructing wetland basins designed to capture storm water as their primary water source is not recommended, nor is constructing wetlands at the bottom of a drainage basin. Wetlands should be linked in series, upstream to downstream.

2. Total inflow to a wetland basin from baseflow, stormflow, and groundwater discharge must be greater than outflow via stream discharge and groundwater recharge. The infiltration rate must be sufficiently slow to allow a permanent pool of water to exist for extended periods, and to account for evapotranspiration by plants.

3. Pretreatment basins may have to be re-excavated every 5-10 years. Allow for access, but avoid permanent pavement, and use grass-covered fill instead. Detailed design parameters are given in vols. 4 and 5 of the *Final Report.*

* * *