Institute of Water Resources

Annual Technical Report

FY 2000

Introduction

Dr. Hugo Thomas who had been director of the Institute since October 1994 retired on June 30, 2000. Dr Glenn Warner is the Institutes new Director, and Dr. Patricia Bresnahan is continuing as the Associate Director.

The relationship between IWR, the Connecticut Department of Environmental Protection (DEP), and the Environmental Research Institute at the University of Connecticut (ERI) remains strong. There is a regular meeting once a week with representatives of IWR, ERI and DEP to review and discuss existing research projects and future research opportunities. This relationship ensures continued collaboration among the dominant water-related research institutions in Connecticut and the State government agency most responsible for implementing water policy and programs. The DEP has recently awarded the IWR a $30,000, two-year grant to conduct information transfer activities related to golf course water management. Information provided to the DEP thought this grant will be used in developing Best Management Practices for golf course water supply, demand and quality.

The College of Agriculture and Natural Resources has several thematic research groups. The concept is to bring together faculty from throughout the College that have a common interest and provide a better means of collaboration among themselves and the external University community. The Water Resources Group is co-chaired by Dr. David Schroeder from the Department of Natural Resources Management and Engineering and Dr. Warner from the IWR.

The Institute continues to have a Technical Committee, composed of academic researchers and a State Advisory Board, composed of diverse water resource related organizations. Two joint regular meetings were held during the reporting period.

Research Program

The Connecticut Institute sponsored three research projects through its annual base grand award, and the continuation of a previously sponsored project. These projects, described below, are:

B-06: A study of vernal pool ecosystems in southern New England, Pyle and Jokinen. B-10: Internal Phosphorous Loading in Ponds. Rich and Torgersen. B-11: Monitoring small upland watersheds to determine ground water surface water interactions and runoff processes. Warner and Ogden.

During this reporting period, work was also completed on a previously awarded regional competitive grant:

G-03: An assessment of the transferability of habitat suitability criteria for brown trout in southern New England Streams. Jacobson and Neumann.

Basic Information

Title:	Internal Phosphorous Loading in Ponds
Project Number:	B-10
Start Date:	3/1/2000
End Date:	2/29/2001
Research Category:	Water Quality
Focus Category:	Nutrients, Non Point Pollution, Water Quality
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	Peter Rich, Thomas Torgersen

Publication

Critical Regional/State Water Problem

In the latter stages of pond succession and eutrophication, re-mobilization of P by anaerobic respiration enabled by micro-stratification, can produce very high fluxes of P to the water column (internal loading of P). These high fluxes can occur as event-like processes due to thermal instability driven by daily heating cycles. The magnitude of internal P-loading is likely closer in magnitude to decades of external input and is a function of sedimentation rate, sediment mixing depths, and the depth of sediment thermal stratification. The more significant the early success of ponds as a sink for externally loaded P, the more likely their eventual failure will be just as significant.

Ponds provide primary water quality improvement because dissolved phosphorus (PO_{4-}^{3}) combines with oxidized iron (Fe^{+3}) to create insoluble compounds that can be buried in pond sediments. But, Fe^{+3} is chemically reduced to soluble Fe^{+2} in anoxic bottom sediments, making P mobile once more. In deeper lakes, oxygenated water below the photosynthetic zone recycles P back to the sediments. But in shallow ponds P released by sediments is taken up by photosynthetic algae blooms faster than it is returned to the sediments. Because residence times for water in ponds are short, a significant fraction of P released by sediments can be discharged downstream, creating poor water quality elsewhere. By the time effects of the P-loading are apparent, little evidence may remain of the thermal gradients and anoxia that caused the internal P-loading, and the evidence of the controlling processes (micro-stratification and de-stabilization) no longer exist. Ponds have been promoted as a Best Management Practice because they were thought to mimic the dynamics of lakes in retaining P. Differences in both scales and response times of small ponds suggest that BMPs involving ponds be re-examined.

Results and Benefits

Mirror and Swan Lakes (ca. 1.5m maximum depth) on the Storrs Campus of the University of Connecticut are typically mis-used urban ponds. Easily accessible to research, they provide a rare opportunity to evaluate the use of ponds to remove nutrients and metals in runoff as well as the re-mobilization, internal loading, and export of excess nutrients and metals from aging ponds. Located on the campus of a major University the ponds are an ideal place to combine fundamental research with education and technology transfer.

Scheduled on time and space scales appropriate to ponds, the data to be collected and already collected from Mirror/Swan ponds (Figures 1,2,3) define and quantify pond processes and couplings among specific physical, chemical, and biological processes. The development of a mathematical model of pond processes (building on the first order model shown in Figure 4) constructed with those data can predict specific pond responses to external events, including responses of ponds over time (e.g. export of nutrients and metals). The model is to be generic for pond processes, and transferable to other ponds in other places, needing only measurements of a few pond-specific parameters (e.g. primary production, internal nutrient recycling, respiration redox reactions) . Mathematical models enable exploration of the error of predicted response, and of engineering safety factors within which the pond must operate. The sheer numbers of ponds currently in use as detention/retention basins suggest such a pond process model has extensive application, and will contribute to development of BMPs that specify maintenance for ponds rather than emergency retrofits.

Until in-pond P loading is understood, defined in terms of its processes, and dynamically constrained by the time constants of the processes, a useful Best Management Practice (the use of ponds in urban/suburban landscapes) is questionable. Understanding the specific controls and driving forces for intermittent thermal stratification and internal P loading from pond bottoms will lead to better management of ponds for the same reasons that understanding *external* P-loading from drainage basins led to effective management of lakes in the 1970s. Upon completion of this research, we will have demonstrated (or scientifically refuted) the role of micro-stratification and de-stabilization as a control process for internal P-loading in small ponds.

Based on data obtained with last year's funding, we are seeking additional funding through this and other appropriate avenues, including collaboration with the Connecticut Dept. of Environmental Protection (CTDEP) and Dept. of Transportation (CTDOT) in implementation and evaluation of BMPs in other ponds. Regardless of the outcome, our analytical techniques and the close-interval sampling equipment installed in Mirror Lake will be available to colleagues in three Colleges (Liberal Arts & Science, Engineering, and Agriculture) within the University of Connecticut for demonstrations, environmental science laboratories and graduate student projects.

Nature, Scope, and Objectives of Research

In early spring pond sediments remain significantly cooler than overlying water, tending to stabilize the water column (essentially acting as a cold boundary condition) by creating a stable density structure from the deep sediment to the pond surface. Stable density stratification means organic decomposition produces anaerobic conditions in the sediments of small, eutrophic ponds. The sediments act physically and chemically much like hypolimnetic bottom water in a lake. However, as spring progresses, the sediments of ponds receive radiant solar energy directly, and warm to temperatures occasionally higher than night time temperatures of surface water re-radiating heat into the atmosphere. The higher temperatures in the sediments drive chemical decomposition reactions in the sediment faster and deeper. The decomposition of organic matter results in the release of P.

Bacteria continue to oxidize organic matter by using Alternate (to oxygen) Terminal Electron Acceptors (ATEAs) long after oxygen is exhausted. A typical oxygen source and ATEA sequence is O_2, NO_3^-, MnO_2, $Fe(OH)_3$, SO_4^{-2} and CO_2 . Very quickly following anoxia (loss of oxygen), the ATEA is ferric iron (Fe^{+3}) oxide including $FePO_4$ long known to be the ultimate P sink in lakes. When ferric phosphate is used as an ATEA, ferric iron is chemically reduced to soluble ferrous (Fe^{+2}) iron, and PO_4 is released in the dissolved state. available for transport to the water column. The result is much higher concentrations of P in anoxic pond sediments. Thus, prokaryotic biochemistry (anaerobic respiration) initiates chemical processes (oxidation-reduction reactions) that cause aquatic soils (sediments) to release otherwise insoluble P, a process almost unknown in oxidized terrestrial soils. So when the sediments finally destabilize (and they must), the amount of re-mobilized nutrients represents a significant internal loading to the pond. The rapid uptake of liberated P by photosynthetic organisms creates conditions for blooms and degradation of pond water quality. If the residence time of water in the pond is comparable to the uptake time for photosynthesis, the anaerobic re-mobilization of PO_4 can cause export of P downstream and significant reduction of downstream water quality.

The temperature rise that occurs within the sediments during late spring does not immediately mix (overturn) sediment porewaters. In the water column of a lake, a density instability must overcome the viscosity or frictional resistance of the water. For the sediment porewaters to overturn, the thermal density instability must overcome not only the higher viscosity and frictional forces of the fluidized sediment but also the stable non-thermal density profile of water to sediment --- sediment being more dense than water. The process of pond porewater de-stratification is deepened by the non-linear variation of water density with temperature. Water becomes increasingly less dense per degree as water gets warmer. Thus, the density change between 24 & 25^{o}C is more than 31 times the density change between 4 & 5^{o}C (Cole 1994:197), and the critical temperatures for porewater instability are approached more rapidly at high temperature. Thus the physics of cryptic pond stratification delays overturn, enhances chemical reactivity, re-mobilizes total P, and produces ideal conditions for internal P-loading events in shallow ponds.

Our goal is to measure physical, chemical, and biological processes with sufficient accuracy and precision to produce a generic mathematical model of ponds. Our initial selection of processes includes: (a) thermal gradients, (b) heat flux, (c) oxygen metabolism, (d) gradients of redox states of Fe and Mn, (e) transport of dissolved P in the sediments, porewater, and overlying water, (f) underwater irradiance, (g) DIC metabolism (IR-CO_2), (h) HS- flux, (i) DIN flux. Ra-224 measurements proved highly effective during the last funding year in defining the mechanisms and space scale for sediment processes. Ra-224 and other surrogates for P processes will be included in this project as needed on a no cost basis.

Research conducted to date (see figures) indicates that the understanding of pond processes requires samples closely spaced in time as well as space. The best means by which to obtain this resolution effectively is with *in situ* probes backed up with water samples collected at critical times and depths as determined from the *in situ* probes. To accomplish this, we request budgetary support for a YSI 6600 sonde package. The system will enable us to resolve temperature, conductivity, pH (CO_2 via the dissolved carbon equilibrium), depth (pressure), dissolved oxygen, redox potential (metal reduction, ORP), chlorophyl, and turbidity. We will communicate with the package by a CDPD (cellular digital packetized data) modem (fiscal match) to enable the data stream to be read in real time via a web-accessible address. The real time data will enable us to fix schedules for specific wet sampling times by activating a borrowed ISCO water sampler remotely.

Support for chemical nutrient analyses is requested to identify key nutrient and metal species releases and internal recycling processes. We are working with YSI to obtain (on-loan) ammonia/nitrate probes for which Mirror Lake may have enough [DIN] to be above the detection limit.

We request partial support for undergraduate and graduate assistants. The use of *in situ* probes may lighten the manpower requirements in the long term, but this salary support is the minimum necessary to accomplish the project goals. We are actively pursuing other internal means of obtaining the equipment described above. Should we be successful, we will convert equipment support to graduate student support to enhance the science and productivity of the project.

Related Research

Research on "lake/pond" heat flux is scanty, e.g. research on CT lakes by Rich & students (Rich 1975, 1979, 1984; Kortmann 1980; Murray & Rich 1995), and Benoit and Hemond's research on Bickford Reservoir, MA (Benoit & Hemond 1987, 1990, 1991, 1996). Authors attempt to connect physical limnology (hydrology, light, heat, and stratification) to biochemical limnology (aerobic/anaerobic metabolism and oxic/anoxic water chemistry) and to lake/pond trophic status and management. This research builds on previous work, and examines sufficient variables to detect courses of pond management.

Research on the use of naturally occurring isotopes to corroborate and improve estimates of solute diffusion and transport is growing rapidly. Authors typically experiment in both fresh and salt water, e.g. research in Long Island Sound by Torgersen & students (Benoit 1990, Benoit *et al.* 1991; DeAngelo 1993; Sun & Torgersen 1998a&b; Torgersen *et al.* 1996).

Methods, Procedures, and Facilities

Study Site: Almost half the 2500 developed acres of the University of Connecticut Storrs campus drain into Mirror Lake, a man-made (excavated to 4m) detention/retention and ornamental pond (1.83ha). A central landscape element of the campus, the pond is in the later stages of eutrophication and succession. Evidence exists of both external nutrient loading from its drainage basin and internal phosphorus loading from its sediments. Episodes of anoxia are implicated in the proliferation of *Clostridium* (botulism) bacilli, which periodically kill wildfowl on the pond. Outflow from Mirror Lake enters Willow Brook and eventually the Fenton River, a State stocked trout stream. Periodically, attached algae grow on the bottom of Willow Brook to its confluence with the Fenton River and for some distance downstream in the Fenton. The attached algae are associated with high levels of phosphorus in water leaving and immediately downstream of Mirror Lake (J. Clausen pers. comm.). Thus the evidence for high internal P-loading suggests that Mirror represents a type locality to study the issue of cryptic thermal stratification, enhanced anaerobic degradation, and thermally driven internal P loading events.

Thermal Stratification: Thermal stratification is measured every 15 minutes with an *in situ* vertical array of Onset StowAway Tidbit transducers/data loggers. The small (0.5oz) self-contained units (accuracy 0.1^{o}C; resolution 0.2^{o}C; waterproof to 100+m) have selectable sampling intervals, 7,944 sample capacity, and are programmed and downloaded by computer. Wind velocity 10m above the water will be measured nearby.

The thermal sensors are arrayed on a structure of 1.5" ABS pipe used for near-bottom water sampling. Sixteen sensors (20cm in the sediment to 1m above the bottom) are deployed at the deepest point. Data from the arrays will be reduced to Relative Thermal Resistance to mixing (RTR) values, and later used to calculate heat flux and coefficients of eddy diffusion (Benoit & Hemond 1996). The heat balance may have sufficient sensitivity to identify the influx of heat to the water column from the overturn of sediment and release of sediment porewater.

Independent estimates of pore water diffusivity were obtained using natural

Radium-224 (Benoit *et al.* 1991;Torgersen *et al.* 1996; Sun & Torgersen 1997b)(see below). Ra-224 dynamics in the water column is controlled by the flux of Ra-224 from the sediments. Since Ra follows the (MnO_2) and $Fe(OH)_3$ cycles of the sediments, high concentrations of Ra-224 in the water column are directly attributable to enhanced fluxes from the sediment. Thus, Ra-224 tracks de-stabilization release events (internal P loading events) where temperature and heat budget calculations may not have adequate sensitivity, and track the internal P loading event to a better degree than a time series of P measurements because Ra-224 is not readily involved in the biotic cycles like P.

A Ra-224 mass balance was constructed for Mirror Lake. One interpretation of the data indicates the standing crop of Ra-224 in the water column can be supplied by <2cm of sediment, and that the flux of Ra-224 from the sediments is supplied with a diffusion coefficient that approximates molecular processes. This <2cm layer is also subject to diel heating and temperature instabilities hypothesized to cause spike-like internal nutrient loading events. Use of *in situ* temperature, dissolved oxygen, redox (ORP), etc. probes with <10 minute resolution will allow the hypothesis to be tested. A second interpretation allows the Ra-224 mass balance in Mirror Lake to be accomplished by a 20cm benthic boundary layer characterized as sediment "soup" rather than sediment "pudding." This benthic layer is isolated in daytime by thermal stratification and mixed nightly by thermal de-stratification (see Fig. 2). Monitoring the benthic "soup" layer with *in situ* temperature, oxygen and redox probes will establish if this is the primary layer for internal nutrient recycling.

Underwater light (heat source for the temperature and heat budget) are measured weekly (<5 centimeter intervals near bottom) with a LiCor underwater light meter and deck cell, and surface irradiance data is collected at the Plant Science Farm.

<u>Anoxic Bottom Water</u>: The requested YSI sonde will sample temperature, conductivity, pH, dissolved oxygen, ORP, water depth, etc., and can be taken at <10 minute intervals. Discrete water samples can be taken automatically, but at much lower frequency with a borrowed ISCO automatic water sampler. Conventional samples of near-bottom water are taken (at 10cm intervals) by pumping water from vertical manifolds installed on a vertical ABS structure resting on the pond bottom at the deepest point and at mean depth. Dissolved oxygen is measured with both polarography (YSI 59) and Winkler (azide) methods. Anoxia will be verified by analyses of bottom [DO], [$Fe^{+2/+3}$], [$Mn^{+2/+4}$], [HS-], [NH_4^+], [NO_{3-}], respiratory quotients (DCO_2/DO_2) (IR-CO_2 analysis), alkalinity, pH, and Eh during both summer and winter stratification. All analyses will be by standard methods unless noted (APHA 1992), and conventional samples will be used to calibrate the automatic sonde.

<u>P Release from Sediments</u>: The requested YSI equipment will take discrete water samples at regular intervals for determination of both Total P, Dissolved P, and

surrogates such as reduced metals, and sulfide. P also is likely to correlate with changes in ORP, conductivity, and pH. Total internal P loading will be determined weekly from a pond P mass balance, achieved through measurement of vertical water samples (0.5m intervals), water going over the spillway, and from water entering Mirror from several large culverts. Origins of incoming water will be monitored by AA determinations of [Na], [K], [Ca], & [Mg] (Rich & Murray 1990). Internal P loading and anoxia will be verified by analyses of bottom water [P_{tot}], [DO], [$Fe^{+2/+3}$], [HS-], respiratory quotients (CO_2/O_2) (Murray & Rich 1995), and Ra-224 transport as noted above and below.

The *in situ* YSI probe data will define times and conditions for cryptic destratification by thermal instabilities in the sediments and concomitant release of sediment nutrients. The result will be an event of increased biological productivity that can be quantified by the *in situ* oxygen probes. Monitoring of the processes in the water column and the benthic “soup” will identify whether primary internal recycling of nutrients occurs within the “soup” or within the sediments.

<u>Expected Results</u>: In conjunction with P measures, the above will establish adsorption/reaction/diffusion rates for P fluxes by quantification of the Fe^{+2}, the dynamics of the redox-active Fe/Mn layer, and the application of sediment transport parameters directly to the P profiles. Sediment porewater transport parameters will indicate episodes of thermally induced instability in the sediments that enhance P transport to the water column. Eruptions of P should be accompanied by Ra-224 releases in excess of transport calculated before and after an eruption event. Also, the water column Ra-224/$P_{tot.}$ ratio will be used as a first order estimation of the residence time (between release and uptake by biota) of dissolved P in the water column. The quantification of molecular diffusion (see Ra-224 mass balance discussion above) as the primary sediment transport rate indicates that observation of these processes in the sediments will require a benthic lander probe which is not included in this proposal.(We are, however, conducting discussions with others on this possibility on a short term loaner basis.) The collection of *in situ* probe measures on the space and time scale appropriate to pond processes (as defined in the previous years results, see figures) will enable the development of a mathematical pond model. This model will include the critical pond process parameters in the critical pond time/space scale that define pond operations. Such a pond model is directly transferable to other ponds with the inclusion of pond specific parameters which can be obtained by the means and methods being developed in this project.

The mean residence time of P in the water column is a critical parameter. When the residence time of P becomes greater than the residence time of water in the basin (volume/outflow rate), export of P over the spillway (typically asTotal P) and downstream is imminent or in progress. The ability to predict, detect, and estimate P outputs from a pond-lake provides significant management criteria. Something as simple as knowing when to close the spillway briefly might solve otherwise intractable problems downstream, and is immediately applicable to (e.g.) Mirror Lake.

Continuance of this development project will test the fundamental hypothesis of cryptic stratification as a control of internal P loading in shallow ponds. It will also provide testable initial strategies and tactics to develop an overall program for defining and testing a model and the critical parameters for BMP use of small ponds. Any pond may serve as a filter within a pond/stream system, but as the pond reaches age induced eutrophication, the pond may become as much of a problem as it was designed to address. An evaluation of the dynamics of internal P loading in small ponds will lengthen their usable lifetime and suggest methodologies to limit their detrimental impact within the pond and downstream of the pond.

Principal Findings

Decades of good water quality and nutrient retention in drainage ponds result in accumulations of organic and inorganic sediments, nutrients, and metals on pond bottoms. As ponds age and fill, those accumulations periodically re-mobilize as a result of anoxia, advection, and other mechanisms. Two factors have caused previous measurements of re-mobilization in ponds to under-estimate nutrient and sediment releases.

1. Solar energy drives 24 hour cycles of heat and thermal density in the water and sediments of ponds. When cloud cover reflects infra-red radiation back into ponds at night, the thermal cycles run together, accumulating heat in the surface water that causes water at the pond bottom to become stagnant and anoxic. As a result, ponds can generate and discharge phosphorus, ammonia, and metals without external events.

2. Small ponds flush rapidly in storm events. Samples of discharge are obtained mechanically using pre-set programs modulated by changes in water level. Without measurements of pre-existing conditions in ponds (gradients of thermal density and diffusion, anoxia, accumulations of suspended particles, etc.), however, pre-set programs and collected samples are likely to underestimate pollutant discharge.

In short, measurements of re-mobilization of pollutants in ponds require sampling frequencies on the order of minutes, not days or weeks.

Learning to capture re-mobilization events adequately has been our major investment of time, effort, and resources. Permission to transfer money in our IWR budget from the personnel to the equipment category allowed us to initiate automatic sampling with a YSI 6200 data acquisition system and a YSI 6600 multi-parameter water quality monitor. Tom Torgersen was also awarded two NSF grants

($264K & $89K) to purchase an additional YSI 6600 sonde and to modify it to sample at multiple depths. The YSI 6600 supports up to10 data channels for a wide variety of sophisticated transducers. Currently, two ponds on the University of Connecticut campus are being sampled with digital electronics:

Mirror Lake: max. depth ~1.1m, hyper-eutrophic, transparency ~0.5m due to constant algal blooms, 0.5-0.8m organic sediment.

Swan Lake: max. depth ~1.8m, mesotrophic, transparency to bottom, higher aquatic plants cover bottom, ~0.1m organic sediment.

All devices sample in fractions of an hour. Data produced are scheduled to go online to a website this summer to make them available to co-PIs in the University of Connecticut system and to all interested researchers and instructors on the Internet.

Other research and equipment supported by IWR include studies at and below the sediment surfaces of both ponds using data-logging thermistors (Onset TidBits) and two LiCor Li1400s (5-channel A/D converter/data-logger). The devices are small and portable, and their purposes are to examine events at the bottoms, edges, and inflows of ponds.

References

Benoit, J. 1990. Infaunal fluid/particle transport in marine sediments: models and applications. MS thesis, Univ. Connecticut. 178pp.

Benoit, G. & H.F. Hemond. 1987. Biogeochemical mass balance of Po-210 and Pb-210 in a New England lake. *Geochim. Cosmochim. Acta* 51:1445-6.

______. 1990. Po-210 and Pb-210 remobilization from lake sediments in relation to iron and manganese cycling. *Environ. Sci. Technol.* 24:1224-34.

______. 1991. Evidence for diffusive redistribution of Pb-210 in lake sediments. *Geochim. Cosmochim. Acta* 55:1963-75.

______. 1996. Vertical eddy diffusion calculated by the flux gradient method: significance of sediment-water heat exchange. *Limnol. Oceanogr.* 41:157-68.

Benoit, J., T. Torgersen, & J. O'Donnell. 1991. An advection/diffusion model for Rn-222 transport in near shore sediments inhabited by sedentary polychaetes. *Earth Planet Sci. Lett.* 105:463-473.

Bollinger, M.S. & W.S. Moore. 1993. Evaluation of salt marsh hydrology using Ra as a tracer. *Geochim. Cosmochim. Acta* 57:2203-2212.

______. 1984. Radium fluxes from a salt marsh. *Nature* 309:444-446.

Cochran, J.K., D. Hirschberg, J. Wang & C. Dere. Atmospheric deposition of metals to Long Island Sound: evidence from salt marsh deposits. Submitted to *Estuarine, Coastal, & Shelf Research*.

Cole, G.A. 1994. Textbook of Limnology 4th ed. Waveland Press, Inc. Prospect Heights, IL.

DeAngelo, E.C. 1993. Quantification of biologically enhanced porewater transport during hypoxia in western Long Island Sound sediments. MS Thesis, Univ. Connecticut. 117pp.

Hancock, J.G. & A.S. Murray, 1996. Source and distribution of dissolved radium in the Bega River Estuary, Southeastern Australia. *Earth Planet Sci. Lett.* 138:145-155.

Kortmann, R.W. 1980. Benthic and atmospheric contributions to the nutrient budgets of a soft-water lake. *Limnol. Oceanogr*. 25:229-39.

Li, Y.-H. & L.-H. Chan. 1979. Desorption of Ba and Ra from river borne sediments in the Hudson Estuary. *Earth Planet Sci. Lett.* 43:343-350.

Martin, W.R. & F.L. Sayles. 1987. Seasonal cycles of particle and solute transport processes in nearshore sediments: Rn-222/Ra-226 and Th-234/U-238 disequilibrium at a site in Buzzards Bay, MA. *Geochim. Cosmochim. Acta* 51:927-943.

Moore, W.S.. 1976. Sampling Ra-228 in the deep ocean. *Deep Sea Res.* 23:647-651.

Murray, T.E. & P.H. Rich. 1995. Respiratory quotients predict increases in reducing products in the hypolimnion of a stratified lake. *Can. J. Fish. Aquat. Sci.* 52:1183-89.

Rama, Todd, Butts, & Moore. 1987. A new method for the rapid measurements of Ra-224 in natural waters. *Mar. Chem.* 22:43-54.

Rich, P.H. 1975. Benthic metabolism of a soft-water lake. *Verh. Internat. Verein. Limnol.* 19:1023-8.

______. 1979. Differential CO_2 and O_2 benthic community metabolism in a soft-water lake. *Can. J. Fish. Aquat. Sci.* 36:1377-89.

______. 1984. Further analysis of respiration in a North American lake ecosystem. *Verh. Internat. Verein. Limnol.* 22:542-8.

______. & A.H. Devol. 1978. Analysis of five North American lake ecosystems. VII. Sediment processing. *Verh. Internat. Verein. Limnol.* 20:589-604.

______. & T.E. Murray. 1990. De-icing salts in an urban drainage basin. *Verh. Internat. Verein. Limnol.* 24:162-5.

Santschi, 1984. Particle flux and trace metal residence times in natural waters. *Limnol Oceanog.* 29:110-1108.

Sun, Yin. 1998. PhD thesis. University of Connecticut (draft copy).

Sun, Yin & T. Torgersen. 1998a. Improved methodology for Ra-224 measurements by Rn-220 emanation: the effects of water content and Mn-fiber surface conditions. *Marine Chemistry.*

Sun, Yin & T. Torgersen. 1998b. Rapid and precise measurement method for adsorbed Ra-224 on sediments. *Marine Chemistry*.

Torgersen, T., K.K. Turekian, V.C. Turekian, N. Tanaka, E.DeAngelo, & J. O'Donnell. 1996. Ra-224 distribution in surface and deep water of Long Island

Sound: sources and horizontal mixing rates. *Cont. Shelf Res.* 16:1545-1559.

Webster, I., G.J. Hancock, & A.S. Murray. 1994. Use of radium isotopes to examine porewater exchange in an estuary. *Limnol. Oceanogr.* 39:1917-1927.

Basic Information

Title:	Monitoring Small Upland Watersheds to Determine Ground Water - Surface Water Interactions and Runoff Processes
Project Number:	B-11
Start Date:	3/1/2000
End Date:	2/29/2001
Research Category:	Ground-water Flow and Transport
Focus Category:	Surface Water, Groundwater, Hydrology
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	Glenn Warner, Fred Ogden

Publication

Statement of critical regional or State water problems

Most hydrology textbooks and reference manuals show runoff coefficients, such as the ‘C’ value for the Rational Equation or the Curve Number (CN), increasing as watershed slopes increase. Recent observations and preliminary data from small watersheds being monitored by the PI’s exhibit the opposite relationship. We recently observed that a flat, 8 acre watershed produced quicker and more runoff than a steep, 41 acre watershed (See Figure 2 below). An 18 acre watershed with a flat, frequently saturated area near the outlet produced an intermediate amount of runoff. The observed phenomena are thought to be due to position of the watershed in the landscape, land-use/land-cover, and different sensitivities to antecedent moisture conditions. We also hypothesize that there are a variety of runoff mechanisms at work. In the flat watersheds near hilltops, rising water tables result in saturated source runoff, while mostly shallow subsurface flow occurs in the steeper watersheds.

A number of medium-to-large sized watersheds (4 square miles and larger) have been monitored for years by the U.S. Geological Survey in Connecticut. However, there is a lack of rainfall–runoff data for very small watersheds for determination of runoff coefficients for the prediction of hydrologic impacts associated with land use changes. Values of coefficients currently used in the state were developed on mostly urbanized or agricultural fields in other parts of the country where the Hortonian runoff mechanism dominates. However, there are limited data available to assess the importance of the position of the water table and the ground water–surface water interactions which are critical in Connecticut upland hydrology. Better rainfall–runoff data, including the roles of landscape position and land use, are needed by state (e.g. CT DEP and DOT) and federal agencies (USGS, NRCS), consultants and researchers for assessing runoff potential of projects, for the validation and calibration of models, and for testing different runoff theories. Furthermore, the USGS statewide regression equations are not applicable for headland watersheds smaller than 1 square mile.

Statement of results or benefits

The results of the proposed research will enhance the understanding of the ground water–surface water interactions as related to runoff in upland areas typical of Southern New England. The importance of landscape position, land use and watershed characteristics can be better assessed. In particular, the relationship of the water table level and resultant extent of saturated source areas

(SSA's) will be compared with runoff rates to develop new predictive methods based on topography, geology, and hydrometeorology.

The results should directly benefit engineers in better design of hydraulic structures. The results will also assist local, state and federal agencies in the analysis and review of hydrologic impacts of development projects. The ability to predict the spatio-temporal variability of SSA's in the landscape will provide opportunities to evaluate existing models and aid in the calibration of new models. Predictions of the extent of SSA’s are also useful to assess water quality impacts for different landuses and management schemes such as fertilizer applications, buffer zones, and land development.

Nature, scope, and objectives of the research

The proposed research would expand monitoring of surface runoff from very small watersheds on or near the Storrs campus of The University of Connecticut. Additional watersheds will be added to the existing cluster of five watersheds that are currently being monitored. As indicated above, the amount and rate of runoff on the three smallest (and non-urban) sites do not agree with conventional runoff theory. Monitoring of additional sites is needed to develop better rainfall–runoff relationships that address the role of ground and surface water interactions. Seven preliminary sites have been identified (three agriculture, two forested, and two urban/suburban). Final selection of at least five of these or other sites will depend on the suitability of preliminary sites and in some cases, permission of landowners. Figure 1 shows the location and watershed boundaries of the existing sites. The approximate location of the preliminary sites are indicated by ‘X’s. Table 1 lists some characteristics of the existing sites.

Table 1. Characteristics of existing monitoring sites

Name	**Approximate Size**	**Land use**
Weaver Road	8 acres	pasture
Pink Ravine	2967 acres	mixed
Dairy Mart	240 acres	urban
UConn Forest	41 acres	forest

Route 44 Flume	18 acres	Forest and road

The following existing items are available to support the proposed sites:

Two meteorological stations: a turf research station at the Spring Manor Farm (near the Depot campus) and the U.S. Weather Bureau station at the Agronomy Farm (3 kilometers south of Storrs campus),

Four automated rain gages and event data loggers established as part of project for existing five sites,

Five weirs with pressure transducers and data loggers at the five existing sites, and

Software for data loggers used at the existing sites.

Preliminary findings from the network of gages on or near the Storrs campus of The University of Connecticut show that the three small sites with either forest or grass cover (Weaver Road, Route 44 and UConn forest) do not exhibit expected patterns of runoff. Weaver Road is the smallest and flattest, yet it produces quicker and more runoff (at least on a per area basis, and sometimes irrespective of area). The Route 44 and UConn forest sites are mostly forested, but steep. Route 44 does have some impervious area runoff which can usually be separated on a hydrograph. The Dairy Mart watershed drains over half of the UConn campus, and is highly urbanized. The largest watershed, Pink Ravine, has considerable heterogeneity because of its’ large size.

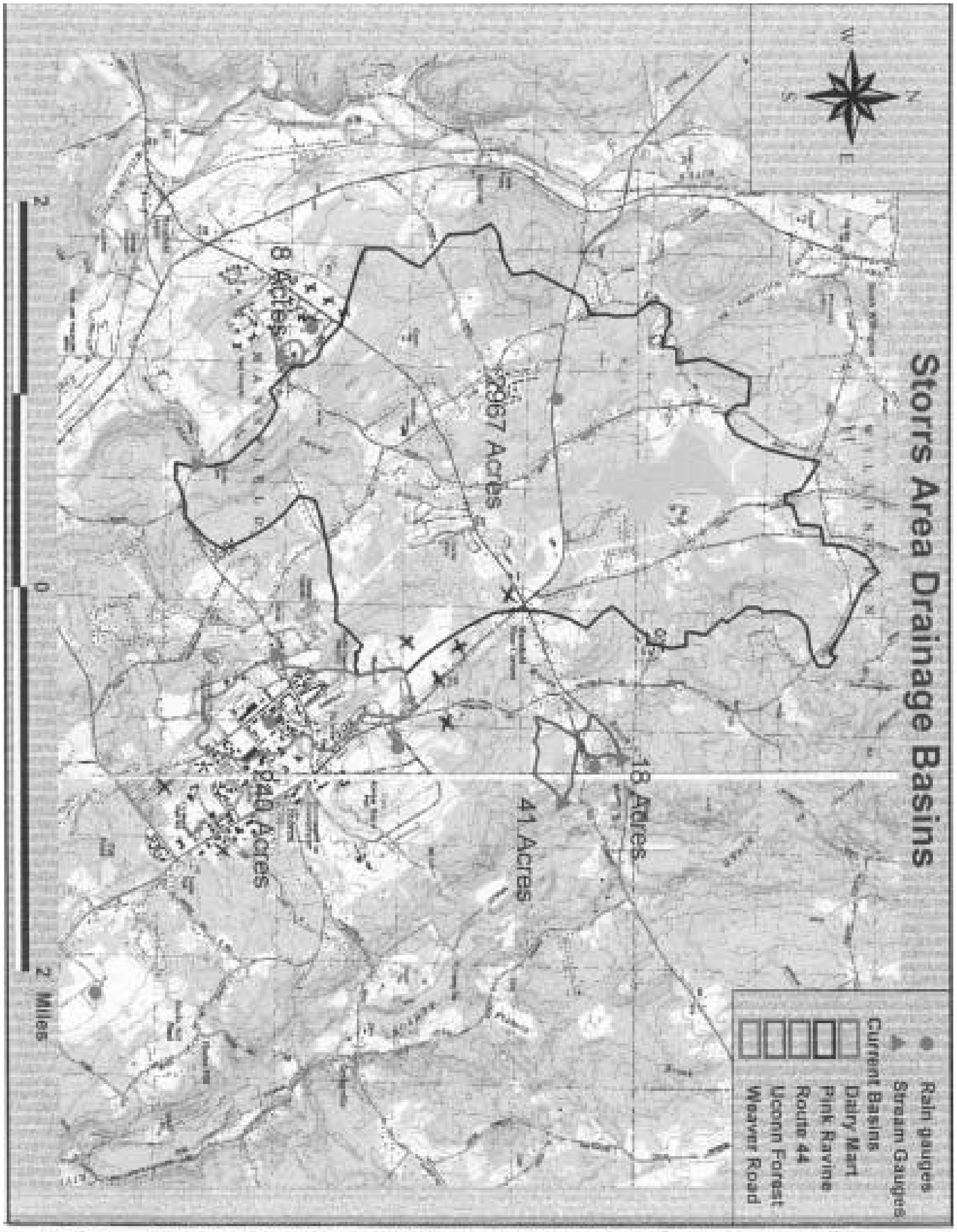

Figure 1. Currently monitored basins and potential future basins (X's).

Runoff hydrographs from the Weaver Road, UConn Forest, and Route 44 basins are shown in Figure 2. The vertical axis is given as an intensity of runoff in order to better compare the runoff from each site. The hydrographs were produced by rainfall from Tropical Storm Floyd on September 17, 1999. The steepest and largest basin, UConn Forest, has the slowest response time for initiation of runoff, the lowest peak discharge (both per area and absolute) and the smallest amount of runoff. The smallest and flattest basin, Weaver Road, has the quickest response time, highest peak discharge per area and largest runoff per area. The results could also be affected by the land use – pasture for Weaver Road versus forest for the other two. The study of additional watersheds will help address the land use effect.

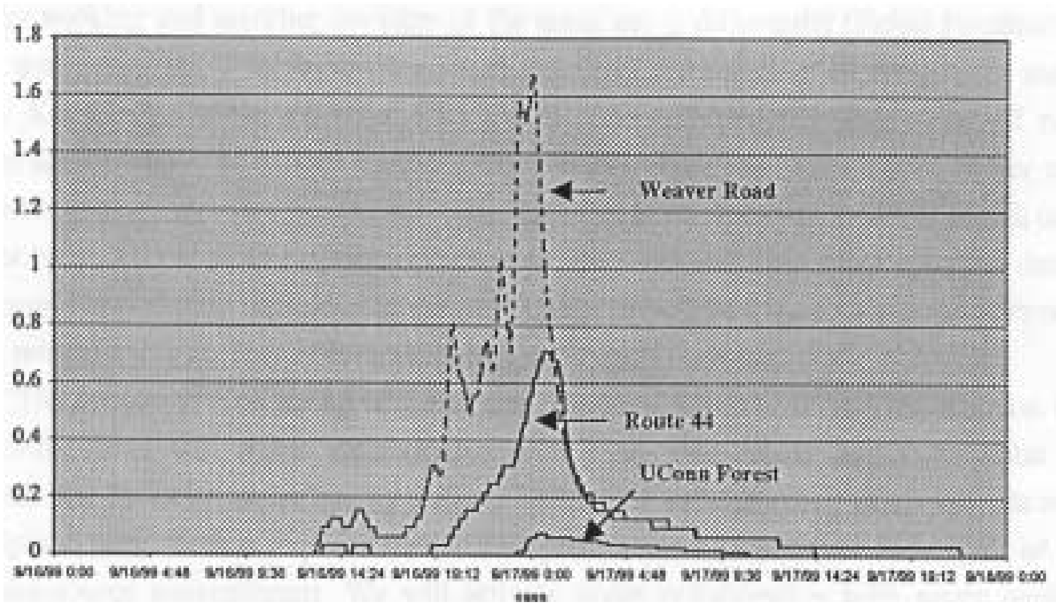

Figure 2. Hydrographs for three existing basins from Tropical Storm Floyd, 1999.

Soil moisture is also likely to play a significant role in the differences observed. The 24 hour rainfall totals for Floyd were about 4.5 inches in the area, so the limited response of the basins is remarkable. This is likely due to the drought conditions that existed in Connecticut during the summer of 1999. However, there was substantial rain, on the order of 5 inches, between September 1, 1999 and Floyd. In an ordinary year without drought conditions, over 9 inches of rainfall in September would produce significant runoff.

Observation of other watersheds during Floyd by the PI's, including some proposed for monitoring, confirmed the runoff data. Many small steep watershed had very little runoff from the storm. Other areas with noticeable areas that saturate quickly had quicker and more runoff; sites with substantial amounts of impervious surfaces of course responded very rapidly and produced substantial amounts of runoff. In September 1999, very little runoff was observed from steep, forested catchments. These observations indicate the complexity involved in runoff prediction and indicate the importance of soil moisture and other factors on runoff.

All new sites will be instrumented with weirs or flumes similar to the five existing sites, and both existing and proposed sites would have piezometers installed to monitor water table levels as appropriate. The added sites would not only add to the types of land uses under study, but would also add to the diversity of landscapes under observation. The existing network of recording rain gages that were established for rainfall input to the existing watersheds is sufficient since the proposed new watersheds are located among the existing rain gage network. About four non-recording gages may be added within some of the proposed watersheds to supplement and check the values from the recording rain gages.

The extent of saturated areas within the small watersheds will be monitored at selected times by walking and marking the edge of the areas using differential Global Positioning System (GPS) measurements. This approach permits the direct measurement of the growth and decay of SSA's. Knowledge of the extent of SSA's will allow comparisons with observed runoff, and accurate determination of runoff source (direct runoff, interflow, base-flow). Water table levels along with periodic measurement of soil water contents in some watersheds will permit calculation

of water balances. Potential evapotranspiration will be estimated from meteorological data from the Agronomy Farm station. Included in the water balance will be a relative storage parameter which will be related to the amount of saturated areas and runoff response.

The continued monitoring of the existing 5 study watersheds and the addition of 5 more study watersheds will allow collaboration with other researchers and submission of future proposals that focus on water quality aspects. Improved understanding of hydrologic response in small upland watersheds is required for accurate predictions of the fate and transport of point- and non-point-source contaminants. We will actively invite collaboration with water quality related projects that can take advantage of data collected in our monitoring program. Such collaborations have already borne fruit, such as our collaboration with Prof. Nikos Nikolaidis in his DEP-funded research on the origins, transport, and fate of architectural copper.

The specific objectives of the research are:

1. Monitor at least 5 new watersheds in addition to the 5 we are currently monitoring to increase data base of small watersheds with different land uses and topographic attributes

2. Quantitatively determine the role of ground water-surface water interactions in runoff from small watersheds as a function of watershed characteristics and antecedent moisture conditions

1. Apply the latest in positioning technology to map the space-time evolution of SSA's in upland watersheds, and use this knowledge to quantitatively identify runoff by source

1. Collect data to calculate a daily water balance on each watershed under study. This water balance will be used to develop runoff-wetness relationships, estimate the amount of ground water recharge, and improve understanding on the role of antecedent moisture conditions on runoff in Connecticut

1. Invite interested researchers to perform water quality monitoring of the watersheds.

The small watersheds proposed have uniform land use within each basin which will help separate land use effects on runoff. Soils and geology are also similar. Besides land uses, differences include variations in slopes, shape of watershed and percentage of saturated source area.

There are several advantages in monitoring a concentrated network of small watersheds:

1. It is cost effective due to travel time for installation of equipment and monitoring

2. The concentration of rain gages provides greater spatial and temporal accuracy on rainfall inputs

1. The watersheds are subject to the same storms which permits direct comparisons

2. Similar antecedent moisture conditions should exist due to the same general potential evapotranspiration

3. Soils and geology are more uniform within basins and similar among basins which minimizes the effects of these variables

1. The problem of the aggregation of many runoff processes due to multiple land uses, wetness, vegetation are minimized

2. Runoff as a function of land phase (infiltration capacities, instantaneous rates of runoff, overland flow) can be better assessed, i.e. the impacts of channel processes become less important

1. Parameter values such as soil water holding capacity can be more accurately determined

2. Response times are relatively short and permit evaluation of effects of land use and topography

1. Storages in the watershed, both surface and subsurface can be better defined and related to runoff

2. Ground water–surface water interactions can be addressed from water table data

3. A finer resolution can be applied for terrain and landscape analysis using a GIS based runoff model

1. Runoff processes and contributing versus non-contributing areas can be observed and compared.

Related research

The PI's are currently conducting research in on a project entitled "Assessment of the Applicability of Engineering Hydrologic Models in Connecticut" funded by the Bureau of Water Management, Connecticut Department of Environmental Protection which is scheduled to end March 31, 2000. As part of that project, the rainfall–runoff relationships are being studied for 17 basins that are gaged by the USGS. The basins range in size from about 4 to 30 square miles. The rainfall data for those basins must be interpolated from surrounding NCDC rain gages since there are no reliable recording rain gages in the basins. Preliminary results of the project involving the USGS gages can be found in technical reports (Tamayo et al., 1999; Warner et al. 1999a,b).

The lack of runoff data for very small basins and available coincident rainfall data led the PI's to the establishment of runoff monitoring systems on the five small basins indicated above. Recording rain gages were added to provide accurate temporal and spatial rainfall data to use in rainfall–runoff relationships and modeling efforts. These efforts were financed by limited supply monies in the project and other discretionary monies available to the PI's. In fact, three of the basins were chosen because of an existing weir (Dairy Mart, Pink Ravine and Route 44), not necessarily because of their watershed characteristics.

Saturation excess runoff production was first identified by Dunne and Black (1970) based on their observations at the Sleeper's River experimental watershed in Vermont. The saturation excess mechanism depends on three factors: 1) highly permeable soils; 2) shallow groundwater tables; and 3) convergence of flow lines due to concave hillslopes or converging topography. These three factors act in concert to produce runoff in swales or riparian areas. For highly permeable soils, rainfall easily infiltrates, raising the water table. The hydraulic gradient is small on flat tops of watersheds and at the toe of concave slopes compared to steep mid-slope areas. Convergence of flowlines (surface or sub-surface) accentuate the rise in the water table due to the increase in contributing area with decreases in elevation. The end result is a region where the surface becomes saturated from below by the rising water table. The saturated area then behaves hydrologically like an impervious surface, producing rapid runoff.

Vegetative cover plays a big role in saturation excess runoff. Dense vegetation and associated root growth, freeze/thaw cycles, and the large organic matter content of the soil all tend to increase the ability of the soil to absorb rainwater (Aubertin, 1971, Beven and German, 1982). Other research has shown that the presence of macropores and soil pipes permit shallow subsurface flow that not only keep water tables low on steep hillslopes, but also help feed SSA's lower in the landscape (Jones, 1978; Gilman and Newson, 1980; Warner et al., 1989, Warner, 1990; Nieber and Warner, 1991; Warner and Nieber, 1991).

Much of the runoff in the glaciated terrain of the Northeast has been shown to result from specific zones in the landscape that are temporally saturated even though the inherent infiltration capacity of the soil is very high (Dunne, 1978). Dunne et al. (1975) showed that SSA's are very variable in size and extent for Vermont and suggested that repeated field mapping is the best method for evaluation of the variability of SSA's.

Commonly used models for runoff and water quality prediction are usually based on the Hortonian runoff mechanism. The effort by Steenhuis et al. (1995) to estimate the CN for a watershed by a water balance approach for the shallowest water table soil showed some promise. The CN they estimated was calculated as the percent of SSA's to total area of the watershed. They did not actually measure SSA's areas in the field.

Methods, procedures, and facilities

The seven preliminary sites identified will be investigated for suitability for instrumentation. Most are on University land, but two or three may involve obtaining permission from adjacent landowners. All of the new potential monitoring sites are nested within the rain gage network previously established. One landowner has been contacted and agreed to have a weir installed on the boundary of his land and University land. Other potential sites will also be investigated. Efforts will be made to include each type of land use (agriculture, forest, and urban/suburban). All selected sites will be instrumented with weirs or flumes depending on the terrain. The location of the sites will fill in gaps among existing basins, both in terms of physical location and in representation of land uses and landscape positions. Each watersheds will be within about 1 km of a recording rain gages in order to provide accurate estimates of duration and intensities of events. The spatial-temporal distribution of rainfall has been shown to be important in runoff (Ogden and Julien, 1994; Ogden et al., 1995). Additional non-recording gages will be placed in the watersheds to measure amounts of rainfall and will be monitored after each significant rainfall to assist in quality control of recording rain gage data.

Weirs will be constructed of formed concrete or sheet steel, while flumes will be purchased. Flumes will be used where flow is confined to a narrow channel and where a weir is not suitable due to excessive ponding or potential debris problems. Pressure transducers will be connected to data loggers (Stowaway™ from Onset Computer Company) using custom-designed circuitry (by F.L. Ogden) and installed at each weir or flume to continuously monitor water levels at 6 minute intervals. The recorded voltage will be converted to stage and then a discharge through calibration and rating curves.

Piezometers will be installed at selected locations in the watersheds to monitor water table levels as appropriate. Piezometers will consist of sections of slotted pipe attached to PVC pipe installed to depths of about 0.5 and 1.0 meters. Some piezometers will be fitted with a pressure transducer–circuit board–datalogger arrangement similar to the weirs to continuously monitor water table levels. Due to cost, other piezometers will be monitored by hand on a selected time basis. Data from the data loggers will be downloaded to a portable computer (supplied by PI's) about every two weeks, and or more frequently if a major event occurs.

Periodic measurements of soil water content will be made at some sites using Time Domain Reflectometry (TDR). The TDR method, developed by (Topp et al., 1988) can easily and accurately measure in-situ soil water content. A Moisture-Point™ TDR instrument and probes with multiple segments (4 or 5 horizons at 15 or 30 cm increments) are available from previous research by G.S. Warner.

The temporal variation in saturated areas will be determined by walking selected parts of the watersheds with a GPS available from Dr.Tom Meyer, Assistant Professor in NRME, UConn. The GPS system has a resolution on the order of centimeters so the extent of the saturated areas can be measured quite accurately. The edge of saturated areas will be determined visually and by feel, i.e. a "squish" test. Growth and decay of SSA's will be measured over the life of selected longer storms, e.g. every 6 to 24 hours. In general the SSA's to be monitored as part of this proposal will be located in the upper portion of watersheds. These SSA's are more varied in size throughout the year compared to SSA's in riparian areas or river floodplains, as shown by the examples of Dunne (1975). Land and channel slopes in the upper portion are relative gentle compared to the lower portion of the watershed. These SSA's are very variable in size and typically are unsaturated during summer months, but produce saturated overland flow during fall-winter-spring periods of high precipitation-low ET. The maximum size of individual SSA's is estimated to vary from about 0.1 ha to 1 ha.

The runoff data along with precipitation and estimated ET will provide the opportunity to develop a daily running water balance to calculate a relative storage parameter. The storage parameter is a way to quantify the antecedent moisture condition and will be related to the runoff–rainfall ratio, and can be used to estimate when saturated areas develop and runoff begins. The soil water content and water table levels can also be compared to the storage parameter. The meteorological data from the U.S. Weather Bureau station at the Agronomy Farm will be used to estimate potentialET. The potential ET will be adjusted to estimated actual ET using the soil water contents. Research at the Agronomy Farm has shown that shallow water tables provide substantial upward capillary flow to the soil root zone (Warner et al., 1997; Colombo, 1999). The TDR measurements and water table levels will help verify and calibrate this phenomenon and more accurately estimate actual ET. These data will also provide the opportunity to assess the amount of ground water recharge from these small watersheds. Steenhuis et al. (1995) used a similar approach to estimate the soil water balance for the shallowest soil types in watersheds in an attempt to relate CN's to SSA's.

Future support will be sought from State and Federal agencies to continue monitoring for 5 to 10 years, add water quality monitoring and to test various runoff models. The data base from the first year will help show the need for monitoring a concentrated network of gages and provide evidence of the importance of the monitoring efforts.

Principal Findings

Dozens of potential monitoring sites were reviewed and field inspected to determine accessability, land use, and feasiblity of measuring discharge and ground water levels. Five new sites having varying land uses (ag, turf, forest and impervious) were selected for monitoring of discharge. These range from about 1 ha to 250 ha in area. In addition, five sites being monitored as part of a previous study were evaluated for measuring ground water levels in order to study the influence of the water table on runoff. A total of 17 monitoring wells were installed at the new and existing sites. These wells range in depth from 1 m to approximately 4 m. V-notch weirs for the new sites were constructed from PVC. Equipment needs for each site were assessed, and compatible data loggers and pressure transducers were selected and purchased. Circuit boards were designed and built from electronic components to maximize the resolution of measurements for the water level ranges expected. Data loggers were programmed for multiple pressure transducers (weirs and wells). Data from the weirs and wells are being recorded and analyzed. A Global Position System was used to measure the saturated areas within two watersheds to determine the role of saturated source runoff. The boundaries of these saturated areas were walked after different hydrologic conditions (wet vs. dry) to evaluate the changes with time. A GIS was then used to determine the area of saturation.

References Cited

Aubertin, G.M. 1971. Nature and extent of macropores in forest soils and their influence on subsurface water movement. For. Serv. Res. Pap. NE(U.S.) 192. p.33.

Beven, K. and P. Germann. 1982, Macropores and water flow in soils, Water Resour. Res., 18, 1311-1325.

Dunne, T. and Leopold, L.B. 1978. Water in Environmental Planning. W.H. Freeman and Co., N.Y.

Dunne, T. 1978. Field studies of hillslope flow processes. in Hillslope Hydrology. (ed) Kirkby, M.J. John Wiley and Sons.

Dunne, T., T.R. Moore, and C.H. Taylor. 1975. Recognition and prediction of runoff-producing zones in humid regions. Hydrological Sciences Bulletin 20(3):305-327.

Dunne, T., and R.D. Black, 1970, Partial area contributions to storm runoff in a small New England watershed, Water Resources Research, 6(5): 1296-1311.

Gilman, K. and M.D. Newson. 1980. Soil pipe and pipeflow; a hydrological study in upland Wales. Geo. Abstracts. University of East Anglia, Norwich, England, p.110.

Jones, J.A.A. 1978. Soil pipe networks: distribution and discharge. Cambria 5: 1-21.

Julien, P.Y., B. Saghafian, and F. L. Ogden, Raster-based hydrologic modeling of spatially-varied surface runoff, Water Resources Bull., AWRA, accepted for publication, Jan. 1995.

Nieber, J.L. and G.S. Warner. 1991. Influence of a soil pipe on steady subsurface stormflow." Hydrological Processes Journal, 5:329-344.

Nieber, J.L. and M.F. Walter. 1981. Two-dimensional soil moisture in a sloping rectangular region. Water Resour. Res. 17(6): 1722-1730.

Ogden, F.L., and P.Y. Julien, 1993, Runoff sensitivity to temporal and spatial rainfall variability at runoff plane and small basin scales, Water Resources Research, 29(8): 2589-2597.

Ogden, F.L., and P.Y. Julien, 1994, Runoff model sensitivity to radar rainfall resolution, J. Hydrology, 158: 1-18.

Ogden, F.L., J.R. Richardson, and P.Y Julien, 1995, Similarity in catchment response 2: moving rainstorms, Water Resources Research, AGU, (in press).

Steenhuis, T.S., M. Winchell, J. Rossing, J.A. Zollweg, and M.F. Walter. 1995. SCS runoff equation revisited for variable-source runoff areas. J. Irrig. and Drainage Engr. 121(3):234-238.

Topp, G.C., M. Yanuka, W.D. Zebchuk, and S. Zegelin. 1988. Determination of electrical conductivity using time domain reflectometry: soil and water experiments in coaxial lines. Water Resour. Res. 24(7): 945-952.

Warner, G.S. 1990. "Characterization of soil macropores by computed tomography". Ph.D. Thesis. Univ. of Minnesota.

Warner, G.S. and J.L. Nieber. 1991. Macropore distributions in tilled vs. grass surfaced cores by computed tomography. Proceedings of National Symposium on Preferential Flow. December 16-17, 1991. American Society of Agricultural Engineers. Chicago, Illinois.

Warner, G.S., J.L. Nieber, I.D. Moore, and R.A. Geise. 1989. Characterizing macropores in soil by computed tomography. Soil Sci. Soc. Am. J. 53: 653-660.

C. Tamayo, G.S. Warner and F.L. Ogden. 1999. Investigation and Application of Spatial Rainfall Interpolation for Runoff Studies in Connecticut. Technical Report to Bureau of Water Management, Connecticut Department of Environmental Protection, May 28, 1999, 33 pp.

G.S. Warner, F.L. Ogden and C.Tamayo. 1999a. Review of the NRCS Runoff Curve Number (CN) and its application to Connecticut conditions. Technical Report to Bureau of Water Management, Connecticut Department of Environmental Protection, April 29, 1999, 23 pp.

G.S. Warner, D.R. Hodgson and F.L. Ogden. 1999b. Review and Application of Base Flow Separation Methods for Runoff Determination for Small Connecticut Streams. Technical Report to Bureau of Water Management, Connecticut Department of Environmental Protection, May 28, 1999, 28 pp.

Basic Information

Title:	A Study of Vernal Pool Ecosystems in Southern New England
Project Number:	B-06
Start Date:	3/1/1999
End Date:	2/28/2000
Research Category:	Biological Sciences
Focus Category:	Wetlands, Ecology, Conservation
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	

Publication

PROBLEM AND OBJECTIVES

Problem

Vernal pools are a type of ephemeral wetland found throughout the world. Vernal pools possess many aspects of independent ecosystems differing from surrounding terrestrial environments, permanent wetlands, or permanent ponds. The pools represent a unique system which alternates between aquatic and terrestrial within any given year (Wetzel 1983). In addition, the major carbon source for forested pools is not in-pool photosynthesis but leaf litter from the surrounding forest thus creating a detritus based system (such as found in first and second order streams (Allan 1995)).

The primary identifying characteristic of vernal pools is that they are dry for some part of the year, usually in summer and early autumn. Therefore, they do not, in our region, harbor fish populations which, in permanent ponds, act as predators. Thus, organisms (or their larvae) which would not survive fish predation are able to survive. In north temperate zones, vernal pools are critical to the survival of several amphibians such as spotted, marbled, and Jefferson salamanders, wood frogs, and eastern spadefoot toads (Klemens 1993). These organisms, some of which are endangered, deposit their eggs in the pools where the larvae develop, metamorphose, and leave the ponds for the surrounding woodlands. Certain invertebrates, the best known of which are fairy shrimp, survive only in vernal pools, probably because of a combination of low predation rates and eggs which require freezing and/or drying to be viable (Pennak 1989). The pools also serve as habitat for hundreds of organisms which may spend all (e.g. crustaceans, mollusks) or part of their life cycle (e.g. insects with aquatic larvae) as part of the pool ecosystem. Species may survive the drying of the pool by aestivating (Jokinen 1978), by having rapid life cycles, or by leaving the pool when mature.

Because southern New England forests are becoming fragmented by suburban and recreational development, there has been an increased interest in the preservation of vernal pools as unique wetlands (Donahue 1996; Kenney 1995; Colburn 1991; Fellman 1998). Legislation defining temporary pools almost always includes the presence/absence of specific amphibians (listed above) and/or fairy shrimp because these organisms are highly visible and often fall into endangered or rare categories. Dearth of real data on the rest (95%) of the pool community the habitat as defined by physical/chemical parameters, and the cyclical trends and patterns is forcing government groups to resort to anecdotal and oversimplified information which may result in eliminating many vernal pools from potential protection. Our observations over the past two years have noted a number of pools which do not have the "proper" amphibians, fairy shrimp, wetland vegetation, wetland soils, nor confined basins. The uniqueness of vernal pools requires comprehensive assessment at all levels: biology, chemistry, hydrology, physical characteristics (e.g. duration of drought and what controls it), and surrounding terrain.

With increased forest land development, it is important to be able to locate and protect vernal pools. However, vernal pools can require intensive field reconnaissance to locate, a time consuming element which will discourage planners and permitting agencies from locating pools prior to development. If an easier method (model) can be developed to shorten the time required to locate pools, planners and agencies will be encourage to direct development away from vernal pools.

Objectives

A. Biological/Chemical Aspects: Since February 1997, we have gathered the following field information from 26 vernal pools in southern New England: 1) Diversity data (benthos+plankton): for each sampling period and for total pond season; 2) Dominant species (or taxa) for each pond for each period and the changes in the community structure through a season; 3) Density of organisms as proportional to number of individuals caught in each pond at each sampling period (numbers of animals large enough to be caught by a fine-meshed plankton net and a dip net); 4) Length of time each pool is active (holds water) and patterns of pool filling and drying (ice and water depths); 5)Seasonal temperature changes; 6)Maximal depth and ara of each pond; 7) Initial chemistry values as measured in the field (dissolved oxygen, conductivity, pH); 8) Ongoing water analyses for cations (Ca, Mg, Na, k), conductivity, total phosphorus, ammonia/nitrate, sulfur, alkalinity, dissolved inorganic carbon, total organic matter, tannins, and lignins); 9) Whether pools are confined to basins without inlets or whether they are formed by intermittent streams; 10) Soil samples from beneath the pools with no inlets to indicate nature of subsoil and Presence/absence and nature of aquatic vegetation; 12) Nature of surrounding terrestrial vegetation and resultant allochthonous leaf litter; 13) Aerial photos and GPS locations; 14) Groundwater wells in place at two locations.

The above data will be used (a) to describe in-pool community dynamics, and (b) to test whether types of taxa (copepods, cladocerans, ostracods, mollusks, et.) total diversity (number of taxa) and community structure of the ponds are determined by a suite of physico-chemical factors.

B. GIS-based landscape profiles. The objective of this aspect of the research is to determine whether or not the general areas in which vernal pools are found are significantly different from the average conditions in the larger landscape as assessed by GIS analysis.

METHODS

A. Biological/chemical: The field work on 26 ponds will be competed by February 1999 . Field studies on six ponds will continue as part of two graduate degree studies not included in this proposal. Data from all 26 ponds will be used for statistical analyses.

Identification manuals used to identify the invertebrates include Belk (1975), Henderson (1990), Jokinen (1983 and 1994), Means (1979) Merritt and Cummins (1996), Peckarsky *et al*. (1990), Pennak (1989), Smith (1995), Thorp and Covich (1991), Wiggins (1996), and Wood *et al.* (1979).

Water samples were taken from the ponds on each trip (every two weeks in spring, once/month during winter in one liter poly bottles. Additional samples are collected for dissolved inorganic carbon (DIC). Water is being analyzed by standard methods: Cations by atomic absorption and emission with a Perkin Elmer Atomic Absorption Spectrophotometer Model 306; conductivity on a YSI Model 16 conductivity bridge, cell constant-0.1; total phosphorus by the ascorbic acid method; ammonia by the Nesslerization method; nitrate by the cadmium reduction method; sulfide by the methylene blue method; alkalinity by titration to a fixed endpoint (pH=4.5); dissolved inorganic carbon (DIC) by MSA infra-red analyzer; total organics from ash-free dry weight at 550° C; pH by Corning Model 10 pH meter and combination electrode; and tannins and lignins colorimetrically. All equipment necessar for analyses is available at the University of Connecticut.

Graphical and statistical analyses:

(1). The community structure of each pool for each collection date will be graphed as a percentage of each taxon as part of the whole sample comunity. This illustrates the community dynamics of each pool (dominant species, changes in dominance through time, predators, etc.). From the diagrams we can compare and contrast pools for community structure. Statistical analyses (arcsine transformation on specific dominant taxa (e.g. harpacticoid copepods, daphniid cladocerans) between ponds (for specific dates) and within ponds (over a series of dates) will test whether the perceived differences are significant.

(2). Multivariate and principal components analyses (Harris 1975, Orloci e5t al. 1979) will be run using the software program Statistical Analyses Systems (SAS, SAS Institute 1982). Analyses will determine which factors may be influential in structuring the taxonomic diversity and presence/absence of species. Data to be used in the statistical analyses will include: presence/absence of taxa; mean water chemistry values, maximum depth and area, presence/absence of in-pool vegetation, hydrological status (is pool groundwater controlled or is it part of an ephemeral stream system), and number of months of standing water.

(3). The hypothesis that vernal pools will fall into categories defined by basin type, carbon source, water flow, duration of standing water, chemistry, and community dominants will be tested by cluster analysis (Pielou 1984).

B. GIS-based landscape profiles. A set of 25 vernal pools documented in the 1997-1998 funded project (U.S. Geological Survey Report No. GR-02661-2, 1998) will be used to develop profiles of general areas in which vernal pools are likely to be found. (These pools are not identical with the set of pools used for the biological/chemical part of this project, although there is some overlap).

The study area will be the area covered by the Spring Hill and Coventry, CT, 7 1/2 minute U.S. Geological Survey topographic quadrangles. Global Positioning System (GPS) points have been gathered in Coventry for pools being studied by middle school students (Ken Goodale, personal communication). GPS points for the other pools were gathered in conjunction with analyses of pools from the 1997-98 project.

To develop a profile of general areas in which vernal pools are likely to be found, Geographic Information System (GIS) data sets will be amassed an analyzed for the 25 vernal pools using personal computer (PC) ArcInfo and ArcView (Environmental Systems Research Institute 1990-1995, 1996). Variables chosen to be included in the GIS profile will be those for which a significant relationship with the presence of vernal pools is found. Two approaches to analyzing the significance of the variables will be taken.

Chi-square goodness of fit analysis will be done for class variables. The proportions of the pools in which the variable is present will be tested against an expected value derived from calculation of the proportion of the study area in which the variable is present. The chi-square goodness of fit analysis will involve the following variables: (1) soil types, (2) surficial geology, and (3) forest cover type.

T-tests will be done for continuous variables, the value of which will be measured for the vernal pool locations and for 25 randomly located points in the study area. The t-tests will involve the following variables: (1) mapped slope (calculated from Digital Elevation Model [DEM] data), (2) roughness of topography (calculated from DEM data), (3) distance form any perennial water body, (4) distance from the nearest major (Class III or greater) stream, (4) distance from nearest area of wetland soil, and (5) proportion of the area covered by wetland soils within a circle around the pool or the randomly located point.

Principal Findings

The findings will be described in the final report, which is being prepared.

REFERENCES

Allan, J.D. 1995 Stream ecology, structure and function of running waters. Chapman & Hall, London. 388 pp.

Belk, D. 1975. Key to the Ahostraca (fairy shrimp) of North America. Southwestern Naturalist 20:91-103.

Colburn, E.A. ed. 1991. A citizen's guide to protecting vernal pools. massachusetts Audubon Society. 107 pp.

Donahue, D. 1996. A guide to vernal pool wetlnad of Connecticut. University of Connecticut Cooperative Extension System Forest Stweardship Program. 18 pp.

Fellman, B. ed. 1998. Our hidden wetlands. Proceedings of a symposium on vernal pools in Connecticut 1998. Yale University & connecticut Department of Environmental Protection, Hartford. 62 pp.

Henderson, P.A. 1990. Freshwater ostracods. Synopsis of the British Fauna (New Series), No. 42. Linnean Society of London and The Estuarine and Coastal Sciences Association. Universal Book Services, Oegstgeest, The Netherlands. 228 pp.

Jokinen, E.H. 1978. The aestivation pattern of a population of Lymnaea elodes (Say). American Midland Naturalist 100: 43-55.

Jokinen, E.H. 1983. The freshwater snails of Connecticut. State Geological and Natural History Survey of Connecticut, Department of Environmental Protection Bulletin 109. 83 pp.

Jokinen, E.H. 1994. The freshwater mollusks of the inland waters of the Indiana Dunes National Lakeshore. Indiana Dunes National Lakeshore Research Program Report, Porter, Indiana. 16 pp.

Kenney, L.P. 1995. Wicked big puddles. A guide to the study and certification of vernal pools. U.S. Environmental Agency, U.S. Government Printing Office. 58 pp.

Klemens, M.W. 1993. Amphibians and reptiles of Connecticut and adjacent regions.. State Geological and Natural History Survey of Connecticut. Bulletin No. 12:1-318.

Means, R.G. 1979. Mosquitoes of New York. part I. The genus Aedes Meigen. New York State Museum Bulletin No. 430a, Albany. 221 pp.

Merritt, R.W. and K.W. Cummins, eds. 1996. An introduction to the aquatic insects of North America, 3rd Ed. Kendall/Hunt Publishing Co., Dubuque, Iowa. 862 pp.

Peckarsky, B.L., P.R. Fraissinet, M.A. Penton, D.J. Conklin, Jr. 1990. Freshwater macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca. 442 pp.

Pennak, R.E. 1989. Fresh-water invertebrates of the United States, 3rd ed. John Wiley & Sons, Inc. New York. 628 pp.

Smith, D.G. 1995. Keys to the freshwater macroinvertebrates of Massachusetts, 2nd Ed. Privately printed, D.G. Smith, Sunderland, Massachusetts. 243 pp.

Thorp, J.H. and A.P. Covich, eds. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, Inc. San Diego. 911 pp.

Wetzel, R.G. 1983. Limnology, 2nd Ed. Saunders College Publishing, Fort Worth. 767 pp.

Wiggins, G.B. 1996. Larvae of the North American caddisfly genera (Trichoptera), 2nd Ed. University of Toronto Press, Toronto. 457 pp.

Wood, D.M., P.T. Dang and P.A. Ellis. 1979. The insects and arachnids of Canada, Part 6. The mosquitoes of Canada, Diptera:Culicidae. Biosystematic Research Institute Publication 1686, Ottawa. 390 pp.

Basic Information

Title:	An Assessment of the Transferability of Habitat Suitability Criteria for Brown Trout in Southern New England Streams
Project Number:	G-03
Start Date:	9/30/1998
End Date:	9/29/2000
Research Category:	Biological Sciences
Focus Category:	Ecology, Methods, Management and Planning
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	Richard Jacobson, Robert Neumann

Publication

1. Strakosh, T. R., R. M. Neumann, and R. A. Jacobson. 2001. Development of habitat suitability criteria (HSC) for adult brown trout and assessment of HSC transferability between southern New England rivers. Final Report, Fisheries Division, Connecticut Department of Environmental Protection, Hartford.
2. Strakosh, T. R., and R. M. Neumann. 2001. Final Report: Development of habitat suitability criteria (HSC) for adult brown trout and assessment of HSC transferability between southern New England rivers. Connecticut Institute of Water Resources, University of Connecticut, Storrs, CT
3. Strakosh, T. R., R. M. Neumann, and R. A. Jacobson. 2001. Development of habitat suitability criteria for adult brown trout in a southern New England river and assessments of transferability. in Annual Meeting, Kansas Chapter, American Fisheries Society, Pittsburg, Kansas.
4. Strakosh, T, and R. M. Neumann. 2000. Development and assessment of habitat suitability criteria for brown trout in a southern New England river. in 130th Annual Meeting of the American Fisheries Society, St. Louis, MO.

PROBLEM AND RESEARCH OBJECTIVES

Water allocation and instream flow have risen to the forefront of environmental concerns in New England. Managing water diversions to avoid resource degradations requires access to effective tools to define instream flow needs; the instream flow incremental methodology (IFIM) has generally been recognized as the most useful tool. The physical habitat simulation (PHABSIM), a component of IFIM, uses habitat suitability criteria (HSC) to translate structural and hydraulic characteristics into descriptions of habitat suitability for different fish species and life stages. The HSC describe microhabitat preferences for individual species and life stages as measurable variables (e.g., depth, velocity, substrate, and cover) that change with the quantity of water in a stream. In spite of the widespread acceptance of the IFIM and PHABSIM, concerns have been expressed regarding the transferability of species-specific HSC among streams and regions. The transferability of HSC should be tested before they are used to assess discharge and microhabitat relationships. This has never been done in New England; in each application of PHABSIM, previously developed HSC were used.

The objectives of this research are to develop HSC for depth, velocity, substrate, and cover for adult brown trout in one Connecticut stream, and to assess transferability of HSC for adult brown trout in another stream. The HSC will be developed for adult brown trout in the Farmington River. Development of HSC will be based on microhabitat utilization data determined by underwater observation. The HSC developed for brown trout in the Farmington River will be tested for transferability to brown trout in the Westfield River, MA. This study will result in the first set of HSC developed from direct underwater observations in New England. The HSC and transferability test results will be useful to managers throughout New England to improve confidence in future instream flow studies.

METHODOLOGY

Development of Habitat Suitability Criteria

The source stream for which habitat suitability criteria (HSC) will be developed will be an approximate 6.0-km reach of the west branch of the Farmington River (National Wild and Scenic River). Habitat suitability criteria will developed by observing and measuring the characteristics of microhabitats (e.g., depth, velocity, substrate, and cover) used by many individuals of a target organism. We will use an equal effort sampling design (Thomas and Bovee 1993) to develop HSC in this study.

Direct underwater observation (Li 1988; Dolloff et al. 1996) will be used to locate the positions of brown trout at representative sites of each habitat type during midsummer 1999. At each fish location, the following microhabitat measurements will be recorded: water depth, mean water column velocity (measured at 0.6 of the depth), nose velocity (velocity at depth fish was observed), cover type, and substrate composition. Water depths will be measured with a top-setting graduated wading rod. Water velocities (mean column and nose) will be measured with either a Marsh-McBirney or a pygmy-Gurley current velocity meter (McMahon et al. 1986). Cover type and substrate measurements will utilize the same codes used in a previous instream flow assessment on the Farmington River (Normandeau Associates 1992).

Habitat suitability criteria for depth, mean column velocity, nose velocity, substrate heterogeneity, substrate particle size, and cover type will be developed for both life stages of brown trout based on the optimum and suitable range approach of Thomas and Bovee (1993). Non-parametric tolerance limits (Bovee 1986) will be used to develop HSC for depth, mean column velocity, nose velocity, substrate heterogeneity, and substrate particle size.

Testing Transferability of Habitat Suitability Criteria

The destination stream to which HSC are to be applied and tested in the Westfield River, MA. A two-person team will observe fish at each site by snorkeling (Li 1988; McMahon et al. 1986) during early summer 2000 when water temperatures are similar to those in the Farmington River when HSC were developed. Locations occupied by brown trout will be marked with a weighted, numbered tag. At the conclusion of the dive, microhabitat variables at each location will be measured using the same methods outlined for the Farmington River. We intend to achieve microhabitat measurements for at least 100 occupied locations (combined among the four study sites) of each life stage of brown trout. Immediately after microhabitat measurements are taken for all fish locations, microhabitat will be measured at locations where fish were not observed. Microhabitat data from unoccupied locations will be systematically sampled along a series of transects laid perpendicular to the stream flow. Microhabitat measurements of depth, velocity, substrate composition, and cover will be taken at equal increments (preliminary increment = 3 m) along each transect resulting in microhabitat measurements for approximately 200 unoccupied locations sampled systematically throughout each study site. Transferability of depth, velocity, substrate, and cover HSC from the Farmington River to the Westfield will be tested based on a variation of the methods outlined in Thomas and Bovee (1993) and Groshens and

Orth (1993); transferability tests will be conducted for both life stages of brown trout. Transferability will be tested for each HSC separately, and for composite suitabilities calculated for each location.

Principal Findings

During summer 1999, habitat suitability criteria (HSC) were developed for adult brown trout *Salmo trutta* on the West Branch Farmington River, Connecticut. Snorkeling was used to collect microhabitat observations for 144 brown trout based on an equal effort habitat sampling design. Habitat suitability criteria for depth, mean velocity, nose velocity, substrate, embeddedness, and cover were developed using nonparametric tolerance limits. Transferability of previously developed HSC to the West Branch Farmington River was assessed. West Branch Farmington River HSC were recreated using the same HSC development techniques as each source. Frequency distributions of suitability index (SI) values calculated from the West Branch Farmington River HSC and other sources were compared using K-S test. Distributions of SI values between the West

Branch Farmington River and other sources were significantly different *P* in all tests but one. Transferability of West Branch Farmington River HSC to another river in southern New England was then tested. Microhabitat use of adult brown trout and habitat availability were determined in a section of the East Branch Westfield River, Massachusetts. First, observations in the East Branch Westfield River were assigned SI values based on the West Branch Farmington River HSC. The K-S test was used to test for differences in frequency distributions of SI values between rivers. Second, a chi-squared test was used to test for selection of optimum habitat use over usable habitat and for suitable over unsuitable habitat use based on composite SI values. Third, a multivariate profile analysis was used to test transferability between rivers. In each test only total depth, fish depth, and mean velocity HSC successfully transferred from the West Branch Farmington River to the East Branch Westfield River. The lack of transferability between rivers may have been due to differences in fish communities and river morphology. A standardization of HSC development and microhabitat classifications is recommended. Further investigation is needed into the chi-squared test, the K-S test, and the profile analysis use in assessing HSC transferability.

REFERENCES

Bovee, K. D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream flow incremental methodology. U.S. Fish and Wildlife Service Biological Report 86(7). U.S. Fish and Wildlife Service, Washington, D.C.

Dolloff, A., J. Kershner, and R. Thurow. 1996. Underwater observation. Pages 533-554 in B.R. Murphy and D. W. Willis, editors. Fisheries techniques, second edition. American Fisheries Society, Bethesda, Maryland.

Groshens, T. P., and D. J. Orth. 1993. An assessment of the transferability of habitat suitability criteria for smallmouth bass. Virginia Water Resources Research Center Bulletin 180.

Li, S. K. 1988. Measuring microhabitat in swift water. Pages 392-407 in K. D. Bovee and J. R. Zuboy, editors. Proceedings of a workshop on the development and evaluation of habitat suitability criteria. U.S. Fish and Wildlife Service Biological Report 88(11). U.S. Fish and Wildlife Service, Washington, D.C.

McMahon, T. E., A. V. Zale, and D. J. Orth. 1996. Aquatic habitat measurements. Pages 83-120 in B.R. Murphy and D. W. Willis, editors. Fisheries techniques, second edition. American Fisheries Society, Bethesda, Maryland.

Thomas, J. A., and K. D. Bovee. 1993. Application and testing of a procedure to evaluate transferability of habitat suitability criteria. Regulated Rivers: Research and Management 8:285-294.

Information Transfer Program

The Connecticut Institute sponsored one information transfer project through its competitive base grant award program:

B-12: Developing an online data dissemination system for the state of Connecticut. Yang.

Base grant funds were also used to support our CTIWR seminar series, and to co-sponsor a conference entitled, 8th National Nonpoint Source Monitoring Workshop.

The DEP has recently awarded the IWR a $30,000, two-year grant to conduct information transfer activities related to golf course water management. Information provided to the DEP thought this grant will be used in developing Best Management Practices for golf course water supply, demand and quality.

Basic Information

Title:	Developing an Online Data Dissemination System for the State of Connecticut
Start Date:	3/1/2000
End Date:	2/29/2001
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	Xiusheng Yang

Publication

Statement of critical regional or State water problems

Connecticut is an urbanized state. Urban planning and development requires accurate assessment of climatic data regarding available water resources and quality. For example, Fairfield County in southwest Connecticut is largely dependent on reservoirs for drinking water supply. The amount and variation of precipitation in the related watersheds are critical for management and planning, especially during abnormal climate conditions. This year, Connecticut experienced very bad drought that not only caused severe damages to agricultural crops but also threatened the water supply for a large area of the State. Unfortunately, the State does not have an information system that could quickly respond to many inquires from the local government agencies, industry, and concerned groups and individuals regarding the climate data, including the historical statistics, trends, current conditions, and future expectation. Such deficiency in dissemination of climate data and information may affect the efficiency in water management and planning for the region

Statement of results or benefits

This project proposes to establish an online climate center for the State of Connecticut to provide the basic climate data for water management and planning. The center will be a web-based information dissemination system that is open to the public to provide the basic yet relevant climate data of the State. Thirty-year descriptive statistics of monthly climate data will be provided based on the data collection and analysis recently done at the University of Connecticut. Daily climate data for selected stations and current meteorological conditions will be included by linking the site to the national and regional and climate centers. Direct linkages to official information sources will also be established for those who need specific data sets.

Nature, scope and objectives of the research

The overall objective of the study is to develop a web-based expandable platform of an online climate data dissemination system for the State of Connecticut. The system is to be hosted at the University of Connecticut and administrated by the office of the Connecticut State Climatologist. The first phase of the project will establish online services to disseminate historical climatic statistics and current meteorological conditions, focuing on precipitation and water resources related parameters. Linkages will be established for users to obtain special climatic date from national and regional climate centers.

Related research

The faculty of University of Connecticut has done a wide range of research that is related to atmospheric and hydrological sciences (Miller, 1998; for example). An online service center, however, is largely an outreach project that intends to provide information support for the State, general public, and to some extent, research and education. The PI strongly believes that such an information dissemination system is badly needed, extends the university research, and fits the overall objectives of the Water Resources Institute.

Similar products are available in federal agencies and other States. Attached are two sample pages from the National Climatic Data Center and the Office of the Delaware State Climatologist, for reference.

Methods, procedures, and facilities

The data dissemination system

A web site is to be established on a server of the University of Connecticut to provide the proposed online climate information service to the State of Connecticut government agencies, industry, and general public. The home page will be administered by the Office of the Connecticut State Climatologist, Department of Natural Resources Management and Engineering, University of Connecticut. The interface is to be designed visible, informative, and elegant but simple, expandable, and easy to access. For the first phase, the system will include the following major components:

Introduction and disclaimer
Statewide climate data, 30-year monthly means, variation ranges, and extremes
Daily climate data for Storrs, Hartford, and Bridgeport
National, regional, and local climate data sources (links)
Current weather information (links)
Special data request form

Introduction and disclaimer. This is to provide users a general description of the function, scope, and usage of the data system, including products, sources of data, accuracy and liability, contact information, feedback comments, as well as a brief introduction of the general climate conditions and historical extremes of the State.

Monthly climate data. Monthly climate data of the State for the past 30 years will be provided for reference of normality and trends. The former Connecticut State Climatologist Dr. David R. Miller of the University of Connecticut has been working on updating the climate data for the State for many years. With data analyzed and provided by the Northeast regional Climate Center (DeGaetano, 1996), state-wide precipitation data have been completely rejuvenated (Miller et al., 1997; Ogden, 1998). Updating other climatic parameters is also planned. The monthly descriptive statistics are based on observations from 2 primary stations and 37 cooperative observation stations across the State of Connecticut. The computation will be comparable with those published at the national level for a unified 3-tiered (national, regional, and local) climate system.

Daily climate data for selected weather stations. Daily climate data for Storrs, Hartford, and Bridgeport are available from automated measurements monitored by the University of Connecticut and National Weather Service Offices. Data can be processed and uploaded at the University of Connecticut within a reasonable time lag.

National, regional and local climate data. The proposed data dissemination system does not intend to repeat the work done by the national and regional climate centers (Northeastern Regional Climate Center, 1997, for example). Links will be provided for those who need the climate data beyond the scope of the site. A brief description of the corresponding products will be provided for the users.

Current weather information. Current weather information is to be accessed from the site through pertinent links to sites of the official weather service offices and major media.

Special data request form. A data request form is to be provided for online use or download for obtaining special data sets, in case the user wants additional help from the Office of the Connecticut State Climatologist.

Procedures

The project is to be conducted in three steps, information collection, web site development, and refining.

Data collection. The first step is to locate data sources, collect the accurate data for the State, process the data toward the desirable format, and describe and summarize the megadata. Water related climatic parameters will be the focus of the proposed study. Effort will be made not to duplicate what have been done at national and regional level.

Web site development. Technical development and testing of the web site will be done by a graduate student with help from on-campus web design specialists.

Refining. This is the fine tuning phase of the project, and will be conducted according to peer reviews of fellow colleagues and users.

Maintenance. The maintenance of the web site is not included in this proposal. Once the online service is set up, the PI will seek additional funds for maintenance and expansion.

Schedule

The overall schedule of the project is shown below:

Year 2000
M A M J J A S O N D J F
Data collection and processing
System development
Refining ----------------------

Facilities

The university of Connecticut has state-of-the-art facilities for internet communication. The College of Agriculture and Natural Resources and the University Library have enough storage for the operation of the proposed data dissemination system. Some development software and supplies are the only items need to purchase.

Principal Findings

The project has been completed with an online data distribution system established for public to access climatic data for the State of Connecticut. The system is now hosted by University of Connecticut CANR server ({ HYPERLINK http://www.canr.uconn.edu/nrme/cscc } http://www.canr.uconn.edu/nrme/cscc) for comments and improvement. The web site provides processed climatic data for 17 stations across the State, numerous links to regional and national sources, and much other relevant information. The system is graphically driven, well designed, consistent with UConn style, and open to any user who can access the university homepage. The site was created and tested by Mr. Junming Wang and Mr. Yuzhou Luo, to whom the grant was provided as partial support for their study at University of Connecticut toward advanced degrees.

References

DeGaetano, A. T., 1996. Extreme Precipitation Analysis for the State of Connecticut. Cornell University, Ithaca, NY.

Miller, D. R., H. F. Thomas, G. S. Warner, F. L. Ogden and A. T. DeGaetano, 1997. Update and publish climate statistics for the State of Connecticut. University of Connecticut, Storrs, CT.

Northeastern Regional Climate Center, 1997. Program, Products and Services. Cornell University, Ithaca, NY.

Ogden, F. L., 1998. Intensity-frequency analysis of 15 minute precipitation records in Connecticut. University of Connecticut, Storrs, CT.

NCDC and NERCC web samples (attached).

Basic Information

Title:	CTIWR Seminar Series
Start Date:	3/1/2000
End Date:	2/30/2001
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	Glenn Warner, Patricia Ann Bresnahan

Publication

Connecticut

Institute of Water Resources

2000 - 2001 Seminar Series

October 11, 2000. **"Connecticut's Evolving Water Quality Program."** *Robert Smith, Chief, Bureau of Water Management, CT Department of Environmental Protection*.

November 8, 2000. **"Cooperative Extension Connecticut River Watershed Projects."** *Leslie Kane, CT River Projects Director, UCONN Cooperative Extension.*

February 14, 2001. **"Using a paleolimnological approach as a tool for understanding aquatic ecosystems."** *Peter Siver, Botany Department, Connecticut College.*

March 14, 2001. **"Norwalk Watershed Action Plan: Implementation."** *Tess Gutowski, Management Analyst III, Bureau of Water Management, CT Department of Environmental Protection, and Walter Smith, Water Quality Coordinator, USDA Natural Resource Conservation Service.*

April 11, 2001. **"An Analysis of DOT Constructed Wetlands and Ponds."** *Steve Ladd, Senior Transportation Planner, CT Department of Transportation*.

Seminars are held on **WEDNESDAYS**, are FREE and open to the public.
Time: 3:30 Refreshments, 4:00 Seminar
Location: Rm 207 W.B. Young Building
University of Connecticut, Storrs Campus.

For Additional Information Call**: (860) 486-2840** or see ***www.ctiwr.uconn.edu***

Basic Information

Title:	Golf Course Compliance Assistance Project
Start Date:	11/30/2000
End Date:	11/29/2002
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	Glenn Warner, Patricia Ann Bresnahan

Publication

Problem and Objectives

In consultation with the Connecticut Department of Environmental Protection's Bureau of Water Management/Division of Inland Water Resources, the Connecticut Institute of Water Resources (IWR or Institute) shall conduct public outreach and coordination regarding water diversion compliance assistance, pollution prevention and water conservation issues concerning federal/state/local environmental programs.

Methods

1. Conference on Golf Course Water Resource Issues: In collaboration with CTDEP, IWR will host a conference focused on golf course water resource issues. The major tasks involved are listed below:

> **1A. Date and location:** The date and location will be determined by CTDEP and IWR based on facilities available and other events that may conflict with attendance.
> **1B. Target audience**. The target audience will be 100-200 golf course owners, managers, superintendents, wetland agents and golf course design professionals.
> **1C. Content and Speakers**. The content of the conference presentations will be developed by IWR in close collaboration with CTDEP. CTDEP and IWR staff will contact representatives of the target audience, water management professionals, and academic researchers to develop a conference program that will both attract the interest of the target audience and present state-of-the-art information they need for environmentally sound water management. Major program content areas will include:
>
> > **Problem Scope**: an overview of the magnitude of the turf water management problem; why turf water managers need to be concerned.
> > **Hydrology**: a thorough review of concepts involved in turf water management
> > **Regulatory Issues:** a review of current regulations and compliance assistance available through CTDEP.
> > **Water Conservation:** current techniques and issues.
> > **Water Quality and Pollution Prevention**: current techniques and issues.

Golf Course Design and Redesign: case studies and principals of environmentally friendly golf course design.

1D. Publicity. IWR will administer the publicity and conference mailings. CTDEP will help locate and provide relevant mailing lists, professional newsletters and other target media.

1E. Registration. IWR will administer conference registration either in-house, or through a subcontract to UCONN's Bishop Center conference facilities.

2. Conference Publications: The Institute will prepare and make available to conference attendees, various publications such as:

the conference abstracts
lists of relevant web sites
fact sheets and brochures related to turf grass, irrigation techniques and the permitting process

3. Ongoing public outreach and education: Additional outreach activities will be conducted, as time and resources permit, throughout the project period.

Principal Findings

Project Tasks: Status and Next Steps:

Task 1. Conference on Golf Course Water Resources Issues.

1A. Select conference date and location

Status Update: The conference will be held on October 18^{th} at the Farmington Country Club.

Next Steps: Finalize details concerning conference logistics and execute contract.

1B. Choose a target audience.

Status Update: Complete. The target audience will be 100-200 golf course owners, managers, superintendents, wetland agents and golf course design professionals.

Next Steps: Compile and gather list of invitees. Prepare mailing lists.

1C. Choose Content Areas and Speakers.

Status Update: A IWR/CTDEP planning committee has been meeting monthly since the fall of 2000. The Planning Committee consists of Glenn Warner (Director, Institute of Water Resources), Pat Bresnahan (Associate Director, Institute of Water Resources), Christie O'Neill (graduate student, Department of Plant Science, University of Connecticut) and Carla Feroni (DEP, Inland Water Resources). Tessa Gutowski of the DEP Water Bureau participated in the Committee meetings but as of March is now solely a member of the subcommittee working on the "Supply" BMP. A draft agenda has been developed and some speakers have been identified and confirmed. Other speakers need to be identified; the CTDEP is taking the lead in identifying and soliciting speakers. See attachment for the draft revised agenda dated June 20, 2001.

Next Steps: Obtain CTDEP management approval of the final draft agenda. Identify the remaining speakers. Finalize the agenda.

1D. Publicity. IWR will administer the publicity and conference mailings.

Status Update: The Planning Committee has briefly discussed various ways to publicize the conference and to compile mailing lists. An outreach to the existing golf course network will be conducted.

Next Steps: Develop a list of potential advertisers (newsletters); mailing lists; web sites.

1E. Registration. IWR will administer conference registration either in-house or through a subcontract to UCONN's Bishop Center conference facilities.

Status Update: Preliminary cost estimates were obtained from Bishop Center. Various announcement/registration flier formats are being collected and considered.

Next Steps: Develop a draft announcement/registration flier. Decide whether or not to use Bishop Center or a similar organization or have the Institute perform this function. The Conference announcement and registration form needs to be developed.

Task 2. Conference Publications. The Institute will prepare and make available to conference attendees various publications such as: the conference program and abstracts; lists of relevant web sites; fact sheets and brochures related to turf grass, irrigation techniques and the permitting process.

Status Update: No specific publications have been discussed by the Planning Committee except for the BMP's being developed under Task 3 below. As a part of this process, a web site containing links to golf course water sites (and other information) has also been established and will be maintained throughout the lifetime of this project. IWR is also preparing a literature review of scientific studies relevant to golf course water.

Next Steps: Decide what publications will be distributed at the conference.

Task 3 . Ongoing public outreach and education. Additional outreach activities will be conducted, as time and resources permit, throughout the project period.

3A. Coordinate the development of Best Management Practices for golf course water.

Status Update: The Institute and DEP have formed a BMP Advisory Committee that consists of golf course superintendents and owners, members of the DEP staff, consultants and University of Connecticut faculty and staff (see attachment). The committee has met the first Thursday of each month since February. The committee was divided into three working subcommittees, each responsible for writing BMPs related to water quality, supply and demand, respectively. Meetings are chaired by Pat Bresnahan, Associate Director, Connecticut Institute of Water Resources and Carla Feroni, Environmental Analyst II, CTDEP. See attachment for the BMPs that have been developed (final drafts, drafts). IWR established a public web site for this project that contains links to BMPs available on the internet and other relevant sites (*http://www.ctiwr.uconn.edu/Projects/proj_golf.htm*). In addition, a private web site was established through UCONN's Distance Learning WebCT program, to facilitate collaboration among the BMP Advisory Committee Members and the document revision management process.

IWR performed an initial web-search of existing BMPs, and distributed relevant documents to the committee. IWR has also begun a literature review of published, peer-reviewed studies relevant to the

BMP topics, and will make copies of these studies available to the Advisory Committee so that they may be referenced in the final BMPs.

Christie O'Neill, a graduate student employed by IWR for this project, is participating in the writing of the BMPs related to water quality. IWR Director Glenn Warner is also extensively involved in the water quality BMP, and is also responsible for reviewing, editing and commenting upon the other BMPs related to water supply and demand.

Other document preparation functions performed by the IWR office include incorporating the various subcommittee drafts into one document, with a consistent format, copying and mailing the drafts to the BMP Advisory committee, and posting revisions on the private web site.

Next Steps: The Institute has submitted to the CTDEP for their review and comment the Fourth Draft of the BMPs for Golf Courses- Introduction, Water Quantity Management/Supply, Distribution Management, and Water Quantity Management/Demand. The Water Quality BMP will be submitted after a scheduled July 12th Water Quality Subcommittee meeting.

Project Management Comments

IWR has hired a graduate student, Christie O'Neill, to help with the BMP development and conference planning process. Ms. O'Neill's working schedule consisted of 10 hours/week during the UCONN fall semester and 20 hours/week during the summer term.

The Institute is pleased with the attendance, participation and work products of the BMP Committee Members. The Committee has stayed on task and has submitted a substantial amount of their work products to the CTDEP for their review and comment. The Institute expects the CTDEP to provide their comment back to the Institute the last week in July and a subsequent meeting will be held with the BMP Committee fort he purpose of finalizing the BMPs and submittal to the CTDEP.

Basic Information

Title:	8th National Nonpoint Source Monitoring Workshop
Start Date:	9/10/2000
End Date:	9/14/2001
Descriptors:	
Lead Institute:	Institute of Water Resources
Principal Investigators:	John Clausen

Publication

Project Description

The Connecticut Institute of Water Resources was pleased to co-sponsor the 8th National Nonpoint Source Monitoring Workshop. The workshop was held September 10-14, 2000 in Hartford, Connecticut and was attended by over 200 people from around the country.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	1	0	0	4
Masters	3	1	0	1	5
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	8	2	0	1	11

Notable Awards and Achievements

None

Publications from Prior Projects

None