Center for Water Resources Research

Annual Technical Report

FY 1999

Introduction

Abstract

In FY 99, the Utah Water Research Laboratory (UWRL) expended approximately $6 million in water research support. USGS Section 104 funds administered through the Utah Center for Water Resources Research (UCWRR) accounted for about one percent of this total and were used for outreach, information dissemination, and strategic planning with regard to water resources and environmental quality issues in the State of Utah.

Outreach within the UCWRR is a form of scholarship that is stimulated, supported, and rewarded. Outreach activities through the UCWRR, the UWRL, and Utah State University (USU) have had an impact on the technical and economic development of the State of Utah. As part of the UCWRR outreach activities supported by USGS Section 104 funds, there continues to be a vigorous dialogue and experimentation with regard to efficiency and effectiveness of outreach activities of the UCWRR. Faculty have been involved in regular meetings with State of Utah agencies, including the Department of Environmental Quality (DEQ) and the Department of Natural Resources (DNR), to provide on-site training, non-point source (NPS) pollution assistance, technology transfer, and development of water resources planning documents within the context of Utah issues.

Types of information dissemination partially supported by USGS Section 104 funds include: (1) research publications, (2) applied research summaries, (3) guidance manuals, (4) newsletters, and (5) database development. Research publications have traditionally been a very high priority and will remain a strong and dominant type of UCWRR outreach, with external (to USU) audiences consisting of other researchers in non-university settings, State of Utah agency personnel, consultants, and other specialists in government and private sector positions in the generation and application of new knowledge applied to water resources and environmental issues. Applied research summaries are provided to summarize findings in specific areas of concern, and include chemistry of contaminant transport and fate, and bioremediation of soils. Guidance manuals represent the use of research results for specific applications with regard to engineering or management to accomplish specified tasks. Guidance manuals and newsletters have been prepared by the UCWRR addressing on-site (septic tank) wastewater treatment for Utah environments, soil bioremediation, land treatment, and corrective action. A future video on on-site wastewater treatment for Utah is planned. A database is currently being prepared to assist the Utah DEQ with location and status on on-site systems for NPS assessments.

Strategic planning with regard to water resources and environmental quality issues in the State of Utah has continued to be a top priority in FY 99 due to the rapid growth in industry and population both in rural and urban areas. The UCWRR Director, Dr. Ronald C. Sims, is serving on the Utah Committee on Infrastructure for Quality Growth at the request of the Utah Governor's Office of Planning and Budget. Dr. Sims is providing input to the Committee on issues addressing water quality, wastewater treatment, and NPS pollution in rural areas. UCWRR faculty have been working along two parallel planning activities: (1) NPS assessments for source water protection, and (2) future water-related challenges to quality growth in Utah. Source water protection activities assist the

State of Utah DEQ with review, comment, and input regarding current water resources, NPS pollution, and projected water needs. Future water-related issues assist the State of Utah and the Intermountain West in identifying intra-state and inter-state water management scenarios and options as impacted by long-term trends in climate, population, land use, and transportation.

This USGS Fiscal Year 1999 Report represents another avenue for UCWRR outreach that is supported by Section 104 funds. This Report provides an opportunity to summarize the outreach, information dissemination, technology transfer, and strategic planning activities of the UCWRR and the UWRL.

Research Program

1.0 Water Problems and Issues of Utah

Utah has an arid and semi-arid continental climate. Mountain snowmelt waters feed lower valley areas where the flatter topography and milder temperatures attract development. Pioneers diverted mountain streams for culinary, agricultural, and mining uses; secured legal protection of water rights; and built an economy and a culture that values "full water development" and abhors "water waste."

The strong commitment of the State of Utah to water development is well demonstrated by the investment of nearly $260 million in almost 1,300 water development and conservation projects through the Utah Board of Water Resources since 1947. A State Water Plan 2000, completed in 1999, has been prepared by the State Water Plan Coordinating Committee and includes Utah Water Research Laboratory (UWRL) faculty members. It contains the foundation, guidelines, and principles for a continuing planning process, and addresses the various aspects of water resources supply, conservation, development, management, protection, and use that are critical to the future of the state.

Lake Powell is heavily used by Utah citizens, equivalent to over one million people spending one night between April and September, 1999 for swimming, boating, and camping. This has resulted in increased pressure on the water quality of the beaches of Lake Powell. A Technical Advisory Committee (TAC) was formed by the Utah Department of Environmental Quality to address issues of human and non-point source animal contamination, monitoring, and management to ensure protection of human health and the environment. Two UWRL faculty members, including the Director, serve as members of the Lake Powell TAC.

Unsewered areas of Utah, including both urban and rural environments, have experienced failure of decentralized on-site wastewater systems. UCWRR and UWRL faculty have teamed with the Utah Local Health Departments and with the Utah Department of Environmental Quality to address issues including establishing criteria, testing, and monitoring for decentralized systems.

New federal source water protection plan requirements require river-basin-wide characterization, assessment, and reevaluation with regard to risks of contamination of source water from near and far sources. Both point sources and non-point sources (NPS) need to be identified. Risks to Utah's source water include both point and non-point sources. Several UCWRR faculty are assisting the State of Utah water agencies in developing source water protection plans. The UCWRR has partnered with the Utah DEQ to assess NPS pollution as part of the Utah Source Water Protection Plan (SWPP). As part of this partnership, UCWRR is developing specific information concerning the location and status of on-site wastewater treatment systems in important watersheds in Utah.

With current and projected industrial growth and population trends in Utah, changing land use patterns, and transportation system expansion, the need exists in many areas of the State for evaluation of water quality issues. The Utah Water Quality Board, under the direction of the Utah Department of Environmental Quality, addresses issues and needs for the State of Utah. These include non-point sources of contaminants to Utah's rivers, lakes, and streams, abatement or elimination of impacts, alternative treatment systems, and expansion of existing wastewater treatment systems. The UWRL Director serves as a member of the Utah Water Quality Board.

Rapid and sustained growth predicted for both rural and urban areas of Utah have placed increased stress on infrastructure systems and resources, including water quantity and quality. The UCWRR currently serves as a member of the Ad Hoc Committee on Infrastructure, created by the Governor of Utah to address these issues and develop quality growth tools for use by State planners.

Utah's water supply is highly variable, responding to large swings in precipitation, characteristic of semi-arid climates. This variability has accentuated water disagreements and disputes, increased interest in moving existing water rights to other locations and uses, and heightened concern about the over-appropriation and degradation of groundwater quality in many Utah basins. This provides incentive for water conservation, a new level of cooperation among water users working together to find valley-wide solutions to water supply problems, growth of conjunctive use and artificial groundwater recharge projects, and an increasing emphasis on water quality maintenance and improvement.

Agriculture continues to contribute significantly to the Utah economy. It is, however, vulnerable to the erratic water supply, and is a major contributor to non-point source water pollution, including salinity from irrigation return flows and pesticides in ground water. Also, agriculture will be impacted by the implementation of the state dam safety program, which is expected to require costly dam rehabilitation measures.

Water rights are being transferred from agricultural water use to municipal and industrial use through the free market process. Some are concerned that large transfers may lead to unacceptable environmental or social costs which cannot be satisfactorily mitigated, and believe that administrative controls may be needed to limit the future impact of these transfers.

Alterations to natural streams now must be evaluated to ensure that adequate protection of riparian habitat and stream channel integrity will be provided. There is, however, concern about deterioration in water quality in some major reservoirs.

Prevention of continual degradation of limited surface and groundwater supplies, and remediation and renovation of soil and water resources impacted from historical and on-going industrial, mining agriculture, and military activities are high priorities. An aggressive UCWRR program for the detection and remediation of releases of fuels, agricultural chemicals, and other hazardous materials has supported the Utah Department of Environmental Quality.

2.0 Program Goals and Priorities

The Section 104 program facilitates the important functions of linking water research programs throughout Utah, linking Utah programs with those in the region and nationally, and supporting seed projects. Utah Section 104 funds have been used in FY 99 to support information transfer, program management, and statewide regional, and national research coordination activities.

The objectives of the research, information transfer, and program management/coordination aspects of the Utah Section 104 program are discussed in Subsections 2.1 and 2.2.

2.1 Information Program

The information transfer activities of the Utah Section 104 program are limited to those managed directly by the Utah Center for Water Resources Research (UCWRR)/UWRL.

Our information transfer activities include our World Wide Web (WWW) site, the Utah Water Atlas, The Utah Water Journal, The Utah WaTCH (Wastewater Training Center Happenings), conferences, workshops, training for U.S. and international professionals, publications' production support and sales, publications of all types, general education, availability of faculty to share their expertise with users, and brochures. The UCWRR/UWRL library has been integrated with the main university library to make UCWRR/UWRL publications and holdings more widely available to users across the campus and throughout the state.

The UWRL is involved in efforts to increase the amount of water research information available to the general public. The UWRL World Wide Web (WWW) pages (http://www.engineering.usu.edu/uwrl) include information on UWRL staff and full text of major publications. It is easy for users to download and print the information they are looking for. Currently we have provided links to The Utah Water Atlas, which is a comprehensive work covering all aspects of water in the State of Utah. Users are able to quickly link to our experts and obtain information on issues of interest using our searchable database publications and reports.

2.2 Program Management/Coordination

Administration of the Section 104 program in FY 99 involved the UCWRR Director, Dr. Ronald C. Sims; UCWRR Acting Associate Director, Mac McKee; UCWRR Administrative Assistant, Jan Urroz; UCWRR Information Dissemination Coordinator, Ivonne Harris, and the UCWRR Business Office Supervisor, Tamara Peterson, and her staff. Coordination activities can be divided into state, regional, and national activities. At the state level, we administer the Section 104 Program, publish an annual report that summarizes UCWRR research, co-sponsor the Utah Section AWRA Annual Meeting, and keep UCWRR associates informed through various mailings.

At the regional level, the UCWRR Director participates in meetings of the Powell Consortium of Water Research Institutes in the Colorado River Basin states. The UCWRR Director also participates as a member of the Lake Powell Technical Advisory Committee composed of representatives of the State of Utah, State of Arizona, and the National Park Service.

At the national level, the UCWRR Director participates in the National Institutes for Water Resources (NIWR) Annual Meeting and either the Director or the Associate Director attends the Annual Meeting of the Universities Council on Water Resources Research (UCOWRR).

2.3 Individuals Cooperating in Program Development

Utah Water Research Laboratory and Utah Center for Water Resources Research

Ronald C. Sims, Director
Upmanu Lall, Associate Director (on leave July, 2000 - June, 2001)
Mac McKee, Acting Associate Director (September, 1999 - June, 2001)
R. Ryan Dupont, Head, Environmental Division
Steve Iverson, Manager, Utah On-Site Wastewater Treatment Training Center
David G. Tarboton, Head, Water Division
Geoffrey G. Smith, Manager, International Office for Water Education

Utah State University Water Resources Research Council

A. Bruce Bishop, Dean, College of Engineering (Chair)
Ronald C. Sims, Director, Utah Water Research Laboratory/ Utah Center for Water Resources Research
Rodney J. Brown, Dean, College of Agriculture
Fee Busby, Dean, College of Natural Resources
Peter F. Gerity, Vice President for Research
James A. MacMahon, Dean, College of Science
Stan L. Albrecht, Dean, College of Humanities, Arts, and Social Sciences
H. Paul Rasmussen, Director, Agricultural Experiment Station
Martyn M. Caldwell, Director, Ecology Center

Representatives from Other Utah Universities

Danny Vaughan, Weber State University
Larry DeVries, University of Utah
A. Woodruff Miller, Brigham Young University

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Source Water Protection Assessment Tools Development
Project Number	B-01
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Water Quality
Focus Category #1	Water Supply
Focus Category #2	Water Quality
Focus Category #3	Water Quantity
Lead Institution	Utah State University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Darwin L. Sorensen	Associate Professor	Utah State University	01
Mariush Kemblowski	Associate Professor	Utah State University	02
David G. Tarboton	Associate Professor	Utah State University	03
R. Ryan Dupont	Professor	Utah State University	04
David K. Stevens	Professor	Utah State University	05
Donald T. Jensen	Associate Professor	Utah State University	06

James P. Dobrowolski	Associate Professor	Utah State University	07
Ronald C. Sims	Professor	Utah State University	08
Gilberto E. Urroz	Associate Professor	Utah State University	09

Problem and Research Objectives

An approach to inventorying and managing potential sources of drinking water contamination that sets fixed distance assessment boundaries on a source water stream may not include available information, extensive professional experience, and state-of-the-art technology that could be used in contamination risk management. It is important that a source water protection assessment approach not be constrained with respect to appropriately addressing contamination sources for which transport of contaminants crosses the interface between ground water and surface water; the so called conjunctive sources. About 40 percent of stream baseflow in the US is groundwater (USEPA 1997). In addressing this situation, the draft final Utah plan (Utah Division of Drinking Water 1999) states:

> Protection of the groundwater component of surface water sources has been indirectly incorporated through delineation of the assessment zones upstream of and surrounding the surface water source... Ideally, site-specific data would allow one to determine how long it would take for a contaminant to reach a surface water body through groundwater contributions. Since site specific data are not available for most streams, assessing PCSs in zones 1 through 3, and inventorying larger sources and non-point sources throughout the watershed…, will provide advance warning of possible impacts to groundwater contributing to a surface source. The use of conjunctive delineation does provide a larger assessment and protection area for the system and is more protective of the drinking water source than either a ground or surface water delineation alone. If necessary, individual sources may be conjunctively delineated based on site-specific factors. This would most likely occur in an area where the adjacent up-gradient aquifer is known to be contaminated.

The present research project is focused on developing source water assessment tools that decrease the reliance on arbitrary boundary setting and improve the use of scientific information and professional experience. This is particularly important in the assessment of conjunctive sources but it is true for all kinds of drinking water sources.

Diffuse sources of contamination present a major challenge to source water protection management. Nonpoint source pollution is seen as the nation’s largest water quality problem (USEPA 1996) and it is a major focus of water quality management in Utah. Runoff water and infiltration water contaminated with nitrate, other nutrients, and pesticides from agricultural operations, construction site runoff, highway runoff, and urban stormwater and infiltration water are nonpoint pollution sources that add to the contaminant burden of watersheds. Utah’s Total Maximum Daily Load (TMDL) Program (Sec. 303 (d) of the federal Clean Water Act) recognizes the difficulty in implementing controls for these kinds of sources (Utah Division of Water Quality 1998). Both public and private water quality managers are expending considerable effort and financial resources toward controlling these "traditional" nonpoint sources of pollution to surface and ground water in Utah . Source water protection assessment and management efforts may use what is being done and what has been learned from these efforts. Less has been done in inventorying and managing on-site wastewater treatment (e.g., septic tanks and drainfield) as relatively diffuse sources of contaminants to groundwater and surface water. Utah Division of Water Quality personnel have expressed concern about this source of contaminants and they have suggested that a systematic approach to management of these sources is greatly needed in the state. They have suggested that a database inventory of on-site wastewater treatment systems in the state would be an important first step in a management approach (Kiran Bhayani, personal communication, 1998).

Another "non-traditional" diffuse source of pollution may be petroleum and hazardous materials contaminated soils and aquifer materials left in place while risk based management and remediation approaches are applied. There is a growing trend toward risk-based closures of sites contaminated with a variety of chemical releases from underground storage tanks (USTs), landfills, surface impoundments, etc. Higher and higher levels of contamination are being left in place in the soil and ground water environment. The health and ecological risks of this residual contamination are generally determined based on existing or impending exposures to adjacent receptors, and only infrequently is extensive exposure pathway analysis carried out. Analysis of surface source water protection is rarely carried out at a scale larger than that of the site, and only crude evaluation of potential groundwater impacts is considered, i.e., "are there culinary wells within 1 mile of the site boundary?" These kinds of sources are being carefully considered in the source water assessment tool development underway in this project.

A systematic approach to applying available, state-of-the-art scientific information, including expert understanding of contaminant transport in natural systems, to the assessment and management of potential drinking water source contamination is needed. This approach should capture the level of uncertainty in the available information and present to risk managers both an indication of the contamination risk and the uncertainty associated with that risk determination. Contaminant risk assessors and risk managers should be able to use the system to improve their understanding of information needs so that uncertainty associated with the protection of surface water supplies can be reduced in a cost effective way. A new scientific investigation methodology for analyzing complex, multi-process, stochastic systems called probabilistic networks (Castillo et al. 1997) has been developed over the past decade. We are using this methodology to develop a source water assessment approach that will have the properties and meet the needs listed above.

The principal objective of the project is to develop a probabilistic network methodology for integrating watershed information to evaluate the susceptibility of Utah drinking water sources to unacceptable contamination. The project effort will focus principally on creating knowledge-based and computationally simple Bayesian networks to connect physical (transport) and biogeochemical (fate) processes using existing process models. The approach will recognize the variable, stochastic and uncertain nature of watershed-scale processes and input data. We are also exploring the potential for creating a hybrid approach that combines Bayesian Analysis and Neural/Functional Nets to facilitate learning about system structure and behavior from environmental data (Freeman 1994; Gallant 1995; Müller and Reinhardt 1990; Neal 1996). Our specific, practical objectives are to:

1. Develop a methodology for evaluating data needs and information value in the context of watershed-specific source susceptibility analysis. The following data characteristics will be considered:

    - Type of data
    - Temporal measurement frequency
    - Spatial distribution of sampling locations
    - Measurement techniques.

2. Based on, and in connection with, the methodology developed in Objective 1, design a goal- and data-availability-based procedure for selecting diagnostic process models of water quality to evaluate source susceptibility to contamination.

3. Combine the procedures developed in Objectives 1 and 2 with a Bayesian Belief Network (BBN) approach to develop a methodology for evaluating source susceptibility in Utah watersheds, and to design efficient monitoring systems for source protection in these watersheds.

Diffuse pollution sources are more difficult to manage and present challenges to the method development. Therefore, management of two kinds of nonpoint pollution sources are being given special emphasis in this project: 1) on-site wastewater treatment systems, and 2) petroleum and hazardous materials contaminated soils. Databases for managing on-site wastewater treatment system inventories, including soils and other site characteristics, will be evaluated with emphasis on their application to Source Water Assessments and use in Bayesian networks. The potential influence of risk based management of contaminated soils and groundwater in Source Water Assessments will be evaluated.

Methodology

The research activities in this project consist of the development of an integrated methodology that combines physical and biogeochemical models and data uncertainty into one cohesive, analytical framework. Specific tasks being completed are:

<u>Bayesian Network Conceptual Framework Development</u>

We are setting the source susceptibility analysis in the framework of a probabilistic BBN (Berger 1985; Hawson and Urbach 1993; Lee 1989) in which conditional probabilities of source state (such as contamination levels or contamination indices) can be determined from the information flow combined with marginal probabilities of watershed antecedent conditions and transfer functions (links) that relate conditions at a downstream node to those at more upstream nodes (Smith 1988). Once the problem is formulated in this way, optimal source protection monitoring networks can also be designed to yield the most information from a minimum use of resources (least cost) (Mockus et al. 1997). The relationships between nodes (transfer functions) are being established from historical data, water quality models, or combinations of the two.

<u>Probabilistic Network Design</u>

This portion of the project is concerned with developing a procedure for creating knowledge-based and computationally efficient Bayesian networks to connect process states via local models (network edges). The Bayesian network approach is being used as the integrating "glue" for the overall source susceptibility analysis. This work consists of the following steps.

- Creating computationally efficient BBNs.

- Checking the network for its coherence. The purpose of the coherence control is to help the user to avoid giving inconsistent facts.

- Develop understanding for estimating the initial marginal probability distribution (subjective priors), i.e., probability before any new evidence is collected.

- Select computationally efficient techniques for evidence propagation in Bayesian networks.

Physical and Biogeochemical Models

A simplified hydrologic and pollutant transport modeling approach is being developed that uses ArcView GIS computer software as the programming environment for the model. This approach allows direct visualization of the watershed geography and the surface and subsurface flow paths for water and pollutants.

The surface water hydrologic model being developed for "average" conditions hydrology simplifies the physical system by using annual precipitation (Px,y) data. Annual precipitation data for Utah watersheds are available from the Utah Climate Center (http://climate.usu.edu/). The surface runoff time fraction (w) is simply the number of hours that surface runoff occurs divided by the number of hours in a year. Overland flow, C_oP, is modeled using a runoff coefficient C_o. Both w and C_oP are estimated from hydrograph baseflow separation. C_oP is the annual volume of storm hydrographs and w is the time fraction that flow is above baseflow. C_sP is the subsurface flow derived using an infiltration coefficient, C_s, and is estimated as the annual volume of baseflow. For each unit area, the fraction of time that "steady state" overland flow occurs is assumed to be equal to C_oP/w. Subsurface flow, per unit area input, is C_sP. Schematically, water in a watershed, or portion of a watershed, is routed as shown in Figure 1.

For surface contamination, the contaminant contributing area (As) may be defined at each point on a stream. A specific catchment area (a = A/b) may also be defined for each point on a smooth hillslope (Figure 2). The mass of contaminant per unit area (mass/length^2) may be assigned to a weighting field, r (x,y). Then the accumulation of r at each point on the stream would be:

See Formula (1)

The functional dependence on r may be denoted by using $Ar_s(r)$ or $Ar_s(r(x,y))$.

The accumulation of r per unit width of each point on the hillslope may be evaluated as:

See Formula (2)

This is called specific accumulation and also has functional dependence on the field r, denoted ars(r) or ars(r(x,y)).

A numerical GIS calculation is used to simulate pollutant transport. Each cell on a square grid, representing a designated area of the watershed, is assigned a set of one or more flow proportions, representing flow directions (Figure 3). There is a single value of r(i, j) associated with each grid cell. The accumulation value Ars(i,j) for each cell is evaluated.

See Formula (3)

The condition (See 3a) is required to ensure ‘conservation’ of mass. Directions must be assigned to ensure that there are no loops. Usually directions are assigned based on topography (Tarboton 1997). The specific accumulation is evaluated as:

See Formula (4)

Assuming that base flow originates uniformly over the watershed and given Qs, As, r can be estimated as:

See Formula (5)

with units of L/T. With this r, the discharge at any point is:

$$Q_s = Ar_s$$

and specific discharge is:

$$q = ar_s$$

This amounts to an assumption of steady state hydrology as a first approximation where runoff yield equals a net or effective water input rate. It can also represent the assumption that flow rates are proportional to the contributing area. The per unit area water input rate or yield is quantified as r and Q_s and q the discharge and per unit width discharge at a point.

To simulate the movement of a conservative contaminant, an assumption is made that the mass loading rate is the product of contaminant concentration times the water input rate:

$$C(x,y)r_w$$

with units of $[M/L^3 *L/T=M/T/L^2]$ and where $r_w = Q_s/A_s$ is the assumed spatially uniform effective water input rate. Taking

$$r = C(x,y)r_w$$

the mass flux and specific mass flux are given by:

$$M = Ar_s(r) = Ar_s(C(x,y)r_w)$$

$$m = ar_s(r) = ar_s(C(x,y)r_w)$$

Concentrations are:

$$C(x,y)=M/Q_s=m/q$$

Overland flow under storm conditions is modeled, simply, by neglecting downstream infiltration and assuming a runoff generation function g(x,y) with units of L/T that accounts for rainfall rate, infiltration and other runoff processes, i.e., a runoff coefficient

$$g(x, y) = CP(x, y)$$

where P is precipitation. Another simple storm overland flow function is:

See Formula (13)

where See (13a) is an infiltration rate capacity that depends on the soil type. A third would be:

$$g(x, y) = p(x, y), \text{ for } (x, y) \text{ such that } a/s > \text{threshold}; 0, \text{ otherwise.}$$

Some combination of these simple approaches will probably be selected for the final modeling approach. Now with:

$$r = g(x, y)$$

the overland discharge at each point is:

$$Q_0 = Ar_s(g(x,y))$$

$$q_0 = ar_s(g(x,y))$$

Again we have used a steady state approximation.

Subsurface velocity may be estimated using:

$$v(x, y)=q(x, y)/Bn$$

where B is a flow thickness and n is effective porosity. Implicitly this amounts to, via Darcy's Equation

$$KI = q/B$$

where K is hydraulic conductivity and I hydraulic gradient. The hydraulic gradient (I) may be close to the topographic gradient.

For overland flow with depth h we may use Mannings equation and estimate:

$$v = q/h = R^{2/3} S^{1/2}/n$$

where R is the hydraulic radius. For wide (i.e., non rilled flow) R = h. Using this above gives:

$$h = (qn/S^{1/2})^{3/5}$$

then:

$$v(x, y) = q/h$$

Numerically on a grid, the travel time through a grid cell is See 21A along grid lines or See 21B along diagonals.

Assuming a mass loading, m(x, y) with units of M/L^2, that moves in a flow v(x,y) and is subject to first-order decay at rate See 22a The accumulation of m at each point can be numerically evaluated:

See Formula (22)

The specific accumulation is:

See Formula (23)

A simplification is to write the term:

See Formula (24)

This is a combined decay and velocity reduction factor field representing the factor by which the substance decreases due to decay (or reactions) in the time spent in a grid cell. We can now evaluate

See Formula (25)

On-Site Wastewater Treatment Database Evaluation

Drainfields and other systems used to treat and dispose of septic tank effluents may discharge into ground water. The effectiveness of these treatment systems in removing pathogens, nitrate, and other chemical contaminants sufficiently to allow other beneficial uses including drinking water, is highly variable. Effective treatment depends on appropriate design and installation of the system relative to site and soil properties including depth to ground water. The number and distribution (density) of these systems in watersheds supplying drinking water is critical to source water protection. With few exceptions, there is little information available about on-site wastewater treatment system density in Utah watersheds. Information about relatively recent installations of these systems has been collected by local health departments but is not available to environmental managers in formats, such as GIS maps, that are readily usable. Records do not exist for many older systems. Appropriate source water protection management requires information about on-site wastewater systems including their location, size, and functionality.

Commercially available on-site wastewater treatment management software (e.g., Septic Information Management System (SIMS), Stone Environmental, Inc., Montpelier, VT; Septic System Tracking Lite, Groundwater Database, Inc., Belleville, Ontario) provide an opportunity to capture on-site wastewater treatment information in a GIS compatible format making it readily usable and easy to interpret by environmental managers. Available database programs have been evaluated for cost effective use in Utah. Special attention is being paid to evaluating the use of these database programs in source water assessments and how they might be incorporated into the Bayesian network system.

Principal Findings and Significance

Stake Holder Coordination

Coordination of the Source Water Assessment Tools Development project has focused on capturing the insights of three groups of major stakeholders in source water assessments: a major water supply organization, the Weber Basin Water Conservancy District; the state drinking water management and regulation agency, the Utah Department of Environmental Quality, Division of Drinking Water; and the state water quality management and regulation agency, the Utah Department of Environmental Quality, Division of Water Quality.

Michael L. Miner, Ph.D., Laboratory Director for the Weber Basin Water Conservancy District, has major responsibility for water quality management programs within the Weber and Ogden River basins in northern Utah. The Weber Basin Water Conservancy District provides drinking water source water to Ogden City and other municipalities. Dr. Miner has helped establish the direction and approach of the project. He has emphasized the need to incorporate sound science into the assessment tool development. Providing tools that cost-effectively allow the identification and management of potential pollutant sources while accounting for the mountainous topography and hydrology of Utah's watersheds was identified as a need. Dr. Miner continues to provide suggestions for the direction of the project.

Ms. Kate Johnson of the Utah Division of Drinking Water is the surface water source protection coordinator for the Division. She has met with the project staff and expressed encouragement for developing the assessment tool described above. Because of regulatory time schedules, the Utah Division of Drinking Water has promulgated guidance and draft regulations that are focused on using the management corridor and zone method. Water suppliers are allowed to use other methods deemed acceptable by the Utah Drinking Water Committee.

The watershed management and Total Maximum Daily Load (TMDL) section of the Utah Division of Water Quality is directed by Mr. Harry Judd. Mr. Judd has had a lower level of involvement with the project but has, in principle, endorsed the objectives and approach of the project toward source water protection.

The Test-Case Watershed Description

The Ogden River basin near Ogden, Utah, was selected as the test-case watershed for the project. This watershed is an important source of drinking water for Ogden City. Ogden has a population of approximately 66,500 people. Ogden draws water from Pineview Reservoir at the dam and from Wheeler Creek into a 56.8 m^3 (15 million gallon) per day drinking water treatment plant. This plant is operated only during summer months to meet peak demands. On an annual basis, this plant provides Ogden City with approximately 13% of its culinary water supply.

The Ogden River basin above Pineview Reservoir Dam has an area of 832 km^2 (321 mi^2). It ranges in elevation from approximately 1450 to 2960 m (4760 to 9710 ft) above mean sea level. The mean annual discharge of the Ogden River below Pineview Reservoir is 9.95×10^7 m^3. The town of Huntsville, with a population of about 650, is located on the South shore of Pineview Reservoir. The unincorporated, populated areas of Liberty and Eden are located to the North of Pineview Reservoir.

The principal industries in the basin are agriculture and recreation. Some, relatively small, confined animal feeding operations are located in the basin. Two major ski areas, Snow Basin and Powder Mountain, are located within the basin. Other major recreational attractions include boating, water skiing, and fishing on Pineview Reservoir.

Contaminant Properties

Contaminants of concern in drinking water source management have been divided into inorganics, volatiles, and pesticides and non-volatiles categories (State of Utah 2000). Tables 1, 2, and 3 list the compounds regulated under Utah primary drinking water standards along with some of their properties that influence their transport in the environment. The physical/chemical properties of these compounds will be used to develop chemical fate components of the assessment system. Inorganic anionic contaminants will be modeled as conservative compounds. The available mass of volatile compounds on surface soils or in groundwater will be reduced with time in proportion to their volatility. The transport of hydrophobic compounds in soil and aquifers will be retarded and degradation will remove degradable compounds over time.

Non-Point Source Pollutant Loading Rates

Loading rates for fecal contamination indicator organisms; i.e., total coliforms, fecal coliforms and fecal streptococci; from various land uses are being compiled. The majority of data available for these pollution indicators come from agricultural source studies and include various kinds and intensities of grazing, various crops, and some confined feeding land uses.

Loading rates for nitrogen and phosphorus, as nutrients, from various land uses are also being compiled. Excessive nutrient loads and the resulting eutrophication of lakes and reservoirs can affect the drinking water treatment process and treated water quality. Particulate matter concentrations and qualities associated with suspended algae can affect pathogen or indicator organism removal efficiency in many water treatment plants. Filter fouling and taste and odor problems associated with eutrophication are common. It is anticipated that the assessment system developed will help alert watershed managers to the potential for excessive nutrient loading from activities in the watershed.

On-Site Wastewater Database Evaluation

The procedure for locating suitable database software was a thorough search of the Internet, direct recommendations from Utah State University faculty and a search through the National Small Flows Clearinghouse. The faculty recommended two non-commercial databases and one of the commercial database programs. The National Environmental Training Center for Small Communities supplied a list of commercial database programs that may or may not be applicable to the needs of the project. One database program was found by performing a search on the Internet.

The septic system database programs identified include:

- Septic Information Management System (SIMS) by Stone Environmental, Inc., Montpelier, VT.
- Computer Aided Septic System Tracking (CASST) by AppliTech, Inc., Dallas, TX.
- SS Tracking Lite by WaterWeb Database, Inc. by Waterweb Groundwater Database, Inc., Belleville, Ontario, Canada.
- The Teton Survey for the Idaho National Engineering Environmental Laboratory (INEEL) which is an Excel spreadsheet
- CAMEO by the U.S. EPA National Service Center for Environmental Publications, Cincinnati, OH.

The five possible computer applications for the database were evaluated based on the following criteria:

- System identification number on every page
- Parcel identification number on every page
- Drag-down data insertion screens
- Ability to sort or query
- Ability to perform calculations for system design criteria
- Ability to perform calculations for future dates such as the next inspection due date
- Ability to store and display images
- GIS compatibility/ArcView compatibility
- Map or description of leach field location
- Legal description
- Percolation test data calculated
- Attention to special areas (e.g., wetlands or endangered species)
- Ability to print reports, permits, permit lists, ranking reports, et al.
- Detailed septic information
- Detailed soil information
- Detailed design parameters and design calculations
- User friendliness – Setup
- User friendliness – Short learning curve
- User friendliness – Simple instructions
- Ability to merge files
- Cost
- Time for data input
- US spellings
- English measurement unit compatibility

The datum in each evaluation spreadsheet cell was usually a "yes/no" answer. In the case of timeframe elements, the data options were: poor, moderate, efficient and excellent. The SIMS software and the SS Tracking Lite software were given equal, excellent ratings.

The Teton Survey for the INEEL was too site specific and inflexible for general health department use. CAMEO was too general and would require considerable programming. Both of these applications were deemed not suitable.

The CASST software was rated low because of difficulties in operating the sample program. After receiving a CD-ROM and the a floppy disk from the manufacturer, two separate electronic files had to be sent to execute the program. When the program was moved from one computer to another it would not run again. In addition, the database was highly specific for the residents and regulators of Texas and would require major modifications for application in Utah.

The Wasatch City-County Health Department was asked to give a preliminary evaluation of the SIMS software and of the SS Tracking Lite software. Their appraisal of the SIMS software was as follows:

1. Parcel ID and Permit ID would both need to be unique for each county.
2. Is there a way to zoom on the images? If not, large or small images would be difficult to review.
3. Is there a way to maximize the screens to higher resolution?
4. There is not a print preview option.
5. Items noted that deal with the programmability of the database:
    - How easily can reports be changed?
    - Can we actively change print forms as the need arises?
    - Would we be allowed to change and re-program or would we have to work through the program creator (Stone Environmental, Inc.)? It may be cumbersome if we have to get minor changes in letters done through them.
    - If they have to make changes, how much will it cost? Or is it covered in the purchase of the package.
6. Search-ability? How easily can queries be made for tracking, reporting, inventory, etc?
7. The people section does not group individuals by topics. For example, if someone wanted to know who the homeowners were, or all of the design engineers, or installers, etc. All contacts are grouped into one list.
8. How are the images stored in the database? Are they embedded or linked? They should be embedded for organizational purposes. If linked images are accidentally moved or deleted the database will not find them.

9. Overall, the biggest question is how changeable is the program? It is understood that they will tailor the program to our needs. How much will that cost? After we have a working product, how much can we change it for ongoing changes or queries?

The Wasatch City-County Health Department could not effectively download the SS Tracking Lite software from the Internet, thus, in their opinion, making it not user friendly.

The Tri-County Health Department was also asked to give a preliminary evaluation of the SIMS software. Their appraisal of the SIMS is similar to that of the Wasatch City-County Health Department. Their evaluation of the SIMS software was as follows:

1. Can the user modify the reports (to be printed)?

2. Can the software be linked to existing WordPerfect documents? Tri-County Health Department has their own reports on WordPerfect that they want to use.

3. How changeable (prior to purchase) is the program and for how much money?

4. Can each health department make their own small modifications in the software?

    - Then how compatible will the software be with the same software from other health agencies?

5. The SIMS software looks good and has a lot of options that would be nice to have.

6. Each health department has different parcel identification numbers. How will it be possible to have separated sequences of ID numbers from other health departments?

7. Information from the County Assessors' Office is incorporated into the Tri-County Health Department's reports. Is it possible to link data from the county assessors' offices and input them into the SIMS program?

A Utah State University graduate student not familiar with SIMS and SS Tracking Lite, reviewed both database programs. He didn't like either program but he felt that the SS Tracking Lite software was more user-friendly. His underlying concern was that neither program guides the user through the data inputting process in a step-by-step progression. In addition, the "locate" command on the SIMS program did not effectively work all of the time.

Plans for Project Completion

GIS based contaminant fate and transport models will continue to be developed. Models will simulate the movement of distributed, nonpoint source contaminants (e.g., coliforms, nitrate) under "average" steady state conditions. Contaminant transport from spills or releases will be simulated under both average and reasonable worst case hydrologic conditions. Spills or releases from transportation accidents, industrial accidents, agricultural sources, and construction sources will be considered The fate and transport models will be integrated into the probabilistic network. The selected on-site database will be populated with information from on-site wastewater treatment systems within the Ogden River basin above Pineview Dam and the utility of these data in source water protection assessments will be evaluated.

The Bayesian network of models and expert decision nodes will be applied to the test case watershed. This application will be reviewed by water purveyor and regulator stakeholders. Modifications to the approach will be made based on this review. The modified assessment tool will be applied again to the test case watershed and to another drinking water supply watershed in Utah.

The results of these efforts will be reported in the professional scientific literature and through the Utah Water Research Laboratory's web site in addition to the report to the US Geological Survey.

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Descriptors

Drinking Water

Source Water

Pollution Sources

Watershed Management

Articles in Refereed Scientific Journals

None.

Book Chapters

None.

Dissertations

None.

Water Resources Research Institute Reports

None.

Conference Proceedings

Sorensen, D.L., M.W. Kemblowski, J.P. Dobrowolski, R.R. Dupont, D.T. Jensen, R.D. Ramsey, R.C. Sims, D.K. Stevens, D. Tarboton, G.E. Urroz. (1999). Source Water Protection Assessment Tools Development. In: Annual Meeting of the Intermountain Section of the AWWA, September 15-17. St. George, UT.

Sorensen, D.L., R.C. Sims, M.W. Kemblowski, J.P. Dobrowolski, R.R. Dupont, D.T. Jensen, R.D. Ramsey, D.K. Stevens, D. Tarboton, G.E. Urroz (1999). On-Site Wastewater Treatment Systems and Source Water Protection. In: Fifth Annual Water Planning Conference, October 18-19. Springdale, UT. Utah League of Cities and Towns, Salt Lake City, UT.

Other Publications

None.

Information Transfer Program

4.0 Information Transfer Activities

To promote the application and dissemination of current, past, and related research results, the following principal activities were carried out during the fiscal year.

4.1 Formal Gatherings

Each fall, the UWRL participates in the Governor's Banquet on Water Education that is held in Salt Lake City, Utah. To promote K-6 water education throughout the state, the UWRL and the Department of Water Resources conduct a poster contest among students at elementary schools to reinforce the statewide program of in-service training and to support water education in the elementary schools.

The following workshops have been conducted by UWRL Faculty:

- Quantitative Evaluation of Natural Attenuation Processes for Site Remediation.

  This five-day workshop is taught each summer to provide participants with tools for the quantitative description of natural attenuation processes taking place in contaminated groundwater and soil systems. Basic principles of groundwater movement, sorption, biodegradation, field sampling and analysis, and fate and transport modeling were provided, and classroom instruction was augmented with hands-on computer laboratory sessions and field sampling activities. Individuals that participated in this workshop represented state and federal environmental regulatory agencies, Department of Defense site management personnel, private consulting firms, USU environmental engineering and water resources graduate students, and USU faculty members.

- On-Site Wastewater Treatment Training

  Over 350 people in Utah received training regarding important site characterization information that is necessary to select sites, size systems, and protect public health. These training workshops were offered across the State of Utah.

- Physical Habitat Simulation Model

  The Institute for Natural Systems Engineering has developed a Windows-based implementation of the Physical Habitat Simulation System that includes several enhancements in addition to an expanded module for time series analysis. This advanced modeling system is supported by technical documentation and training opportunities provided by the UWRL as part of its technology transfer commitment.

4.2 Principal Information Transfer Publications

Principal information transfer items include the Comprehensive Water Education Grades K-6 manual (several thousand copies of the manual have been distributed throughout the country), newsletters addressing the on-site wastewater issues (The Utah WaTCH), and a Mineral Lease Report to the Utah Office of the Legislative Fiscal

Analyst.

UWRL's International Office for Water Education (IOWE) produced and distributed a regional water education calendar to elementary schools in Arizona, California, Colorado, Nevada, New Mexico, Wyoming, Alaska, Hawaii, Idaho, Montana, Oregon, and Washington. The calendar featured the winning posters from the K-6 poster contests conducted in the seven Colorado River and Columbia River states. It also included lessons, questions with answers, and facts about water. A separate water education calendar was produced and distributed to all elementary school classrooms in Utah.

UWRL has prepared two water education manuals for elementary school teachers. More than 20 in-service workshops were conducted. Preservice training workshops were completed at universities throughout the state. The Program is expanding into other states. More than 200 elementary school teachers received water related training through UWRL/UCWRR-sponsored credit workshops.

4.3 Professional Publications

Technical publications in FY 99 that were partially supported by the cooperative program described in this report are listed below. Other publications from the Utah Water Research Laboratory appear regularly as technically reviewed project reports, professional journal articles, other publications and presentations, theses and dissertation papers presented at conferences and meetings, and project completion reports to other funding agencies.

Sims, J.L. (Editor) (2000). The Utah WaTCH (Volume 2, No. 1). The newsletter addressing on-site wastewater treatment issues in Utah. Utah Water Research Laboratory, Utah State University, Logan, UT.

Sims, J.L. (Editor) (1998-2000). The Utah WaTCH (Volume 1, Nos. 1-4). The newsletter addressing on-site wastewater treatment issues in Utah. Utah Water Research Laboratory, Utah State University, Logan, UT.

Sims, J.L. and M. Cashell (1998-2000). Basic Site Evaluation Techniques for On-Site Wastewater Treatment. Utah Water Research Laboratory, Utah State University, Logan, UT.

Smith, G.G. (2000). Utah Water Education Calendar. International Office for Water Education, Utah Water Research Laboratory, Utah State University, Logan, UT.

Smith, G.G. (1999-2000). Powell States and Columbia Water Education Calendar. International Office for Water Education, Utah Water Research Laboratory, Utah State University, Logan, UT.

Smith, G.G. (2000). Substitute Teacher Handbook (Elementary IV Edition). International Office for Water Education, Utah Water Research Laboratory, Utah State University, Logan, UT.

Smith, G.G. (2000). Substitute Teacher Handbook (Secondary IV Edition). International Office for Water Education, Utah Water Research Laboratory, Utah State University, Logan, UT.

Smith, G.G. (2000). SubJournal, Best Practices in the Management of Substitute Teaching. Substitute Teaching Institute, Utah State University, Logan UT.

Utah Water Research Laboratory (1999). Mineral Lease Fund Report. Utah State University, Logan, UT.

5.0 Cooperative Arrangements

The UCWRR maintains a List of Center Associates and distributes mailings on research opportunities to faculty on the campuses of Utah State University, the University of Utah, Brigham Young University, and Weber State University. Program coordinators have long been established on each campus.

The UCWRR/UWRL works with the regional group of Center Directors (Powell Consortium of Water Institute Directors, in Arizona, California, Colorado, Nevada, New Mexico, and Utah) in maintaining a current statement of regional research priorities and developing collaborative research of regional significance. Also UCWRR/UWRL participates in annual National Institutes for Water Resources (NIWR) and Utah State University Water Resources Research Council meetings.

The UCWRR interacts with federal (National Forest Service, U.S. EPA), and state agencies (Utah DEQ, DNR, Water Rights) involved in water resources planning and management, water quality control, and environmental protection. The research response to state needs is coordinated with other universities through established interactive and iterative processes.

The UCWRR/UWRL's current cooperative studies with governmental agencies and private sector firms include: 1) a research agreement with the United States Department of Agriculture - Agricultural Research Service on *Scaling up spatially distributed models of arid water sheds;* 2) an agreement with U.S. Department of the Interior - Fish and Wildlife Service on *Habitat and flow requirements study for the Comal Ecosystem;* 3) research agreement with U.S. Department of the Interior - Bureau of Reclamation on *Study of water yields on semi-arid environments under projected climate change and impact of global climate change on urban water demand;* 4) joint effort with U.S. Bureau of Reclamation, State of Utah, Division of Water Quality, and Weber Basin Water Conservancy District on *Weber Basin water quality study*. In addition, several faculty have worked on IPAs with the National Science Foundation, Hill Air Force Base, and U.S. Army Corps of Engineers.

Other cooperative arrangements were: 1) U.S. Department of the Interior - Geological Survey on *Distribution of Water Education Calendars to Students;* 2) with Utah State Board of Regents and various Utah school districts on *Retraining Teachers in Science and Math Using Water Concepts;* 3) with Utah Department of Environmental Quality on *On-site Wastewater Treatment-Site Characterization;* 4) with U.S. Department of the Interior - Bureau of Land Management on *Seasonal Use of the Virgin River Gorge by Protected Fish;* 5) with Utah Division of Water Rights on *Poster Contest and Teacher Inservice/Assemblies/Classroom Demonstrations;* 6) with U.S. Department of Agriculture - Agricultural Research Service on *Water Quantity and Quality Analysis of Mining Areas Located Within Wasatch Plateau of Central Utah;* 7) with Department of Natural Resources - Utah Division of Water Resources, U.S. Department of the Interior - Bureau of Reclamation, and Cache County Commission on *Cache County Municipal Water Demand Model;* and 8) with Utah local health departments and the Utah Department of Environmental Quality on *Soil Percolation Testing and Evaluation.*

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	N/A	N/A	N/A	N/A	N/A
Masters	5	N/A	N/A	N/A	5

Ph.D.	N/A	N/A	N/A	N/A	N/A
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	5	N/A	N/A	N/A	5

Awards & Achievements

6.0 Notable Achievements

- The UCWRR received recertification of the Center's eligibility to receive grants under the provisions of Section 104 of the Water Resources Research Act of 1984, as amended. The evaluation panel indicated that the UCWRR is one of the top centers nationally.
- The UWRL was awarded an additional $500,000 as part of a $2 million competitive contract from the Idaho National Engineering and Environmental Laboratory (INEEL) for research development, and technology transfer related to water resources planning and management at the river-basin scale. The project involves the development and implementation of a user-driven decision support system for water resources development.
- Dr. William J. Doucette was nominated and appointed as Associate Editor of the Journal of the Society of Environmental Toxicology and Chemistry (SETAC).
- The UCWRR Director, Dr. Ronald C. Sims, was nominated and appointed to a second term on the Utah Water Quality Board by the Governor of the State of Utah.

Publications from Prior Projects

Articles in Refereed Scientific Journals

None.

Book Chapters

None.

Dissertations

None.

Water Resources Research Institute Reports

None.

Conference Proceedings

None.

Other Publications

None.