February 1999

STATE OF TEXAS

SOURCE WATER ASSESSMENT
AND
PROTECTION PROGRAM STRATEGY

Water Utilities Division

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PROTECTION PROGRAM STRATEGY

Prepared by

The Source Water Assessment and Protection Team
Public Drinking Water Section
Water Utilities Division

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Information About this Document

This version of the Texas Source Water Assessment and Protection Program is provided as an Adobe Acrobat PDF file. There may be some formatting or pagination shifts from the original document. If you notice any of these shifts, please contact the TNRCC SWAP team at (512) 239-6050.

This version only contains one appendix: ***Appendix A, Acronyms***. The subsequent appendices could not be included for download since they do not exist in electronic form. You may obtain a copy of these appendices by calling the TNRCC Public Drinking Water Section at (512) 239-6050 or writing to the following address:

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Overview of TNRCC's Source Water Assessment and Protection Program

INTRODUCTION

The 1996 Amendments to the Safe Drinking Water Act initiated a new era in cost-effective prevention of drinking water contamination, and in State flexibility and citizen involvement in drinking water programs. The new law strengthens protection for all members of the public, while allowing the Texas Natural Resource Conservation Commission (TNRCC) to focus on the highest risks to human health and to develop responsible solutions. Source water protection is the centerpiece of the Act's prevention focus and this Source Water Assessment and Protection (SWAP) Program Description reflects TNRCC's commitment to those values as we continue to implement our responsibilities.

The TNRCC's Source Water Assessment and Protection Program addresses all of the requirements placed on a State by the Act to identify the areas that are sources of public drinking water, determine potential contaminants, assess water systems' susceptibility to contamination, and inform the public of the results.

TNRCC's criteria for determining, and its form of expressing, relative susceptibility to different sources of contamination incorporates sound scientific principles which yield similar results under similar circumstances when applied by different people in different parts of the state, and provides for a level playing field for businesses throughout the state.

Texas' program not only meets the requirements of the Safe Drinking Water Act (SDWA), but provides local decision makers with a useable and understandable program which will assess and protect local drinking water supplies. It is a program which provides for a technically accurate analysis that will stand the test of public understanding.

Editorial note: A list of acronyms and glossary terms used throughout this document can be found in Appendix A. Major and minor aquifer maps, a geologic map, and a river basin map are included in Appendix L.

Purpose of this Document

Provisions of the 1996 Amendments require states to develop a Source Water Assessment Program and submit it to the U.S. Environmental Protection Agency (EPA) by February, 1999. Therefore, the primary purpose of this document is to describe the elements of TNRCC's SWAP Program. The document also provides an overview of how source water assessment and protection integrates with other SDWA programs and efforts.

The general scope of this program includes the development of a Source Water Assessment and Protection Program which: (1) identify the areas that supply public drinking water; (2) delineate the boundaries of the assessment areas; (3) inventory the potential sources of contamination within the assessment areas; (4) inform the public of the results; and (5) implement a Source Water Protection Program.

Background

Public drinking water supplies have always been key to the location and development of communities. The public water supply of a community often defines and directs its growth. Historically, the location of a good source of drinking water was a key factor in determining the location of centers of population. Indeed, safe drinking water is essential to the quality of community life because of the link between public health and the quality of the public water supply.

The 1986 Amendments to the Safe Drinking Water Act initiated a new era in cost-effective prevention efforts. A major component of those amendments was the Wellhead Protection (WHP) Program. Provisions of the act required states to develop a WHP Program and submit it to EPA by June 19, 1989. Texas developed a WHP Program and the program was approved on March 16, 1990.

However, under the 1986 Amendments, EPA and TNRCC emphasized ground water and wellhead programs to protect source waters. The new SWAP initiative, described within this document, expands assessment and protection efforts beyond ground water, strengthening protection for all members of the public.

Legislative Commitments

As a result of the 1996 Amendments, source water protection has become a high priority, both at the state and federal level. Source Water Protection is a high priority with the TNRCC and is demonstrated in our Strategic Plan to the Texas Legislature which states:

> *Objective 01-04.02: Percent of Texas Population served by public water systems, using vulnerable sources, protected by a source water protection program.*
>
> *Goals:*

1997	1998	1999	2000	2001
10 %	25 %	35 %	50 %	55 %

Fiscal Year 1998 Results:

Population served by vulnerable sources:	5,409,009
Population protected by SWP Program:	2, 454,977
Percent of population protected:	45.4 %

This ambitious goal will require TNRCC, water utilities, other state and federal program areas, associations, and the public to work cooperatively in conducting source water assessment and protection programs for all public drinking water supply systems. Altogether, there are 6,730 water systems (1,382 transient, non-community systems; 813 non-transient, non-community systems; and 4,535 community systems) in Texas serving over 19 million people.

The goal of TNRCC's Source Water *Assessment* Program is to develop information which enables public water supply systems, consumers, and others to initiate and/or promote actions to protect their drinking water sources.

The list of contaminants of concern must include raw water contaminants regulated under the Safe Drinking Water Act that have a maximum contaminant level (MCL), and cryptosporidium. MCL means the maximum permissible level of a contaminant in water which is delivered to any user of a public water supply system. Appendix B contains a list of contaminants that public water supply systems in Texas test for.

As part of the assessment, TNRCC will provide the following information to each of the state's 6,730 public water supply systems:

- The location of the public water supply well or surface water intake;
  A map of the wellhead protection area (WHPA) or delineated watershed area (DWA);
- A list of potential sources of contamination found in the database search and their locations shown on the WHPA or DWA map. Guidance and training is available to help the system conduct a more detailed "on-the-ground" contaminant source inventory;
- A vulnerability/susceptibility analysis;
- A list of options for protecting the source water; and,
- A list of options for making the material available to the public.

Authority

The Public Drinking Water Section of the Water Utilities Division administers the public drinking water system supervision program and has primary responsibility for the public water system aspects of the SDWA. The section executes all program activities with a central office staff in Austin, and with the cooperation of the sixteen regional offices administered by the Field Operations Division of the Office of Legal and Regulatory Services. State authority is granted under Chapter 341, Subchapter C of the Texas Health and Safety Code.

The program sets in place public health protection measures to ensure safe drinking water for Texans served by public drinking water supplies. These supplies are defined primarily as water systems serving at least 15 connections or at least 25 persons at least 60 days per year. Approximately 6,730 public water systems serve over 19 million Texans.

The *Rules and Regulations for Public Water Systems* (Title 30 *Texas Administrative Code*, Chapter 290.38-47) are established by the TNRCC and specify construction and operational standards for PWS systems. Additionally, there are *Drinking Water Standards* (Title 30 *Texas Administrative Code*, Chapter 290.101-121) set by the Agency which cover primary and secondary water quality standards. A copy of the *Rules and Regulations for Public Water Systems* is included as Appendix C.

Funding

The Drinking Water State Revolving Fund (DWSRF) was authorized under Section 1452 by Congress to assist public water systems (PWS) to finance the cost of infrastructure needed to achieve or maintain compliance with SDWA requirements and protect public health. In addition, states may use a portion of their capitalization grants to fund various state and local water systems management programs and projects including SWP activities.

Under 1452(k), up to 10 percent of the DWSRF can be set aside for delineation and assessments. States may issue these funds in the form of grants and there is no specific State match required for them. However, although these funds can be banked for four years, they were only available from the federal fiscal year 1997 appropriations.

The Texas Water Development Board (TWDB) administers the DWSRF in Texas. Through an inter-agency agreement, EPA provides the capitalization grant to the TWDB. The TWDB then coordinates with the TNRCC for further disbursement of the funds.

Texas developed an intended use plan (IUP) which described how the capitalization grant funds will be used. Texas elected to use $2.5 million of the DWSRF funds for source water assessment activities. The IUP described the source water assessment activities to be funded and was made available to the public for review and comment. The bulk of these funds were targeted towards a joint funding agreement with the U.S. Geological Survey (USGS) to develop a source water assessment strategy in cooperation with the TNRCC (Appendix D). While Texas could have elected to use additional DWSRF funds for SWAP, it was felt that the $2.5 million was adequate to develop a SWAP Program. By electing this option, additional dollars would be made available to the local level, providing additional funds for source water protection activities and improving system infrastructure.

TNRCC's Public Drinking Water staff will be using a combination of federal public water supply grant funds and DWSRF dollars to fund source water assessment and protection activities.

Past Accomplishments of TNRCC and its Partners

The State of Texas and the EPA have a long history of significant legislative actions and other landmarks in the public drinking water supply arena. Below is a chronology of the Texas Public Water Supply Regulatory Program.

YEAR	EVENT
1913	The Texas legislature outlined in detail a public health education program for which it made an appropriation to the State Board of Health. Education on the prevention of water borne disease was the primary reason for this legislation.
1915	The McFarland Water Law and the McNealus Stream Control Law were moving forces in implementing public health education programs in Texas. These laws were major factors in the beginning of training programs for water and wastewater operators and in the formation of the Texas Water and Sewage Works Association (later to become the Texas Water Works Association and eventually the American Water Works Association - Texas Section and the Texas Water Utilities Association)
1915	The State's first sanitary engineer was appointed by the governor to make inspections, investigations and reports of water borne disease epidemics. Mr. Vic M. Ehlers subsequently organized the Sanitary Engineering Division of the State Health Department. He was to guide and develop the state environmental programs for the next forty-four years.
1917	The Division of Sanitary Engineering was established in the State Department of Health.
1920	First Annual Water Works Short School for operators, system officials and engineers held in Austin. There were eleven registrants.
1937	The Division of Sanitary Engineering developed a publication entitled "Procedure for Submitting Plans Pertaining to Public Water Supplies - Water Purification Plants - Water Distribution Systems." This document was the forerunner of today's "Rules and Regulations for Public Water Systems."
1945	The Legislature enacted Article 4477 of Vernon's Texas Civil Statutes (Senate Bill 81). This law formalized the requirement for plans ans specifications submission prior to construction of a public water system, operator certification, requirement of monthly bacteriological sampling, sanitary surveys of public water systems, rating and recognition of "State Approved" programs for public water systems, as well as mandating complete treatment for surface water supplies.
1946	The U.S. Public Health Service adopts "Drinking Water Standards" for public water systems. These, with later revisions and amendments, will become the basis for the 1974 "Safe Drinking Water Act" standards.
1962	"drinking Water standards" are revised by U.S. Public Health Service.
1974	Congress promulgates the "Safe Drinking Water Act" which initiates national drinking water standards for 32 contaminants and federal/state oversight program.

1978	The Texas Department of Health becomes the primary enforcement authority for the “Safe Drinking Water Act” in Texas.
1986	“Safe Drinking Water Act” is amended by Congress mandating national drinking water standards for 83 contaminants and standards for 25 additional contaminants every three years.
1986	The Public Health Service Fee (PWS Fee) is adopted by the Board of Health to supplement the Federal Grant and General Revenue funding. The fee is dedicated to help support the various functions of the State Public Water Supply supervisory Program.
1991	State Legislature passes Senate Bill 2 which creates the TNRCC and mandates that the Public Water Supply Program shall combine with the Texas Water Commission on March 1, 1992.
1992	Transition to the Texas Water Commission takes place.
1993	Texas Water Commission and Texas Air Control Board combine to form the Texas Natural Resource Conservation Commission.
1993	Four bills are passed by the Texas legislature which are to be pivotal in improving plumbing practices and, as a result, increasing the level of public health protection in our state. **S.B.137** - Requires annual mandatory continuing education for plumbers; three hours of which are in subjects of health protection, energy conservation and water conservation. **S.B.812** - Prohibits the wholesale and retail sale and distribution of plumbing fixtures, pipe fittings or solders containing lead. **S.B.813** - Creates the “Water Supply Protection Specialist” classification within the plumbing code. This category can inspect residential plumbing in rural areas and areas not now covered by plumbing inspectors. **S.B.815** - Adopts standards plumbing codes for use in the State of Texas.
1993	The PWS Fee is amended by rule to increase revenue by $1.9 million. These fees are necessary to fund federally mandated sampling and implementation of the Lead/Copper Rule, Surface Water Treatment Rule, and Phase II/V Contaminant Monitoring and Waiver Program.
1996	“Safe Drinking Water Act” Amendments of 1996 adopted. Major new activities mandated by the amendments include consumer awareness, small systems technical assistance and technology development, water system capacity assurance and operator certification. A multi-million dollar Drinking Water State Revolving Fund is established. The amendments emphasize sound science and risk-based standard setting, monitoring relief for public water systems, small water system flexibility, and community empowered source water protection.

Prior to the 1996 SDWA, TNRCC emphasized ground water and wellhead protection (WHP) programs and the watershed protection approach to protect source waters. Texas' WHP Program was approved by EPA on March 16, 1990, and serves as a core component of this effort along with the formation of multiple partnerships with agencies and associations that have an interest in SWP, including:

- Local Cities and Communities
- Texas Rural Water Association
- Underground Water Conservation Districts
- River Authorities
- Retired and Senior Volunteer Program
- League of Women Voters
- The Groundwater Foundation
- Other State and Federal Agencies

From these partnerships grew public information networks and information sharing. The Sole Source Aquifer Program has been used to protect major underground sources of drinking water (Edwards Aquifer), and the Comprehensive State Ground Water Protection Program (CSGWPP) have been a vehicle for focusing contaminant source control programs on the protection of drinking water sources. Texas' watershed protection approach also has provided the critical means to better focus water pollution control efforts on the protection of drinking water supplies.

Texas' Vulnerability Assessment Program (VAP) was established in January 1991 with a statewide effort to locate and map all public water supply wells, springs, and surface water intakes. This water source location project has also established implementation of Phases II and V of the National Primary Drinking Water Regulations beginning in 1993. This rule gives Texas the option to use vulnerability assessments as a tool for determining drinking water monitoring requirements for organic chemicals and asbestos. Due to the success of this program, a total savings of over $50,000,000 has been realized through the implementation of the organic chemical waiver program for the 1996-1998 period.

The TNRCC's Public Drinking Water Section is implementing a program to recognize surface water treatment plants that are continuously achieving optimized performance. This program was developed by the TNRCC with the help and input of utilities as part of the Texas Optimization Program. This program is part of a statewide effort to improve water treatment plant performance and reduce the threat of waterborne disease in Texas. The program is voluntary and includes performance goals that are far more stringent than current regulatory requirements.

Through workshops, publications, on-site assistance, and direct consultation, the TNRCC's Office of Pollution Prevention and Recycling assists local communities and businesses in planning and implementing efficient and effective voluntary programs to reduce pollution. Examples of these programs include:

> TNRCC's Clean Industries 2000 voluntary hazardous waste reduction program has 179 participating ***industrial facilities*** that accounted for 82 percent of statewide reductions in releases and transfers of federal Toxics Release Inventory (TRI) chemicals between 1988 and 1996.

The Clean Cities 2000 voluntary waste reduction program for Texas ***municipalities*** has 78 member communities with a combined population of 7 million Texans. Member communities voluntarily diverted 981,819 tons of municipal solid waste from landfills, saving $24.5 million in 1997

The Clean Texas Star voluntary nonhazardous waste reduction partnership – with ***business, government, schools, and organizations*** – has 3,265 participating Texas facilities that together reduced the amount of waste sent to landfills by 410,000 tons, increased recycling by 134,000 tons, and purchased $260 million worth of recycled-content products in 1997 and 1998.

Based on information from a 1998 survey, respondents (industrial facilities that have received pollution prevention assistance from the TNRCC) achieved the following annual results: reduced hazardous waste 77,000 tons; reduced nonhazardous waste 145,300 tons; conserved 1.5 billion gallons of water; and saved $81 million in reducing disposal costs, labor, and raw material purchases.

At the request of the EPA and Mexico's environmental agency – the Mexican Secretariat for the Environment for the Environment, Natural Resources and Fisheries (SEMARNAP) – the TNRCC provides pollution prevention and recycling training and technical assistance projects on both sides of the Texas-Mexico border.

Since 1994, 19 maquiladoras have participated in site assistance visits conducted jointly by the TNRCC and PROFEPA (Mexican Attorney General for the Environment). Participating maquiladoras reduced hazardous waste generation by 8,558 tons and nonhazardous waste generation by 50,063 tons; and they conserved 31 million gallons of water and 10.9 million kilowatt-hours of electric energy. These projects saved participating facilities $7.8 million in avoided disposal costs and material savings. The program has also provided pollution prevention and recycling training to 1,000 representatives from maquiladoras, government, universities, and the general public along the border.

The TNRCC is continuing its partnership with the U.S. Natural Resources Conservation Service to conduct regional workshops for agricultural producers about composting animal waste. The TNRCC also conducts seminars for regional Texas Department of Transportation engineers, regional councils of governments, local governments, and other interested organizations on the benefits of using compost to reduce runoff from road construction and maintenance activities.

Improper storage of disposal of agricultural waste pesticides can contaminate groundwater and surface water, and present a health threat to persons and animals exposed to them. In response to these concerns, the TNRCC created the Agricultural Waste Pesticide Collection Program to offer agricultural areas the opportunity to dispose of unusable chemicals in a safe and environmentally sound manner at no cost. One-day collection events are conducted in agricultural areas throughout the state.

Since the program's inception in 1992, it has achieved the following results:

2,868 agricultural producers have participated in 36 collection events in which almost two million pounds of waste pesticides have been collected and properly disposed of.

A one-day collection event in Stanton, Texas resulted in the collection and proper disposal of almost 148,000 pounds of waste pesticides.

At one event in April, 1997, 130 participants dropped off 33 tons of waste pesticides at the Fort Bend County Fairgrounds.

At Plainview, Texas in October 1997, only 51 participants showed up for the collection, but they brought in almost 40 tons of waste pesticides, an average of 1,562 pounds per participant. All participants were agricultural producers.

The TNRCC developed a household hazardous waste collection and waste management program to provide communities with technical assistance on organizing collections and education about alternative products. Household hazardous wastes are regulated under Texas Household Hazardous Waste rules (Title 30, *Texas Administrative Code,* Chapter 335, Subchapter N).

Since household hazardous waste regulations took effect in 1985, 5,520 tons of household hazardous wastes have been collected for recycling or proper disposal during 287 events in which 175,759 Texans participated.

During fiscal year 1998, 22,011 Texans participated in 55 collection events. Five hundred seventy-eight tons of material were collected, including the following: 68,266 gallons of paint for recycling; 6,124 batteries; 6,128 gallons of antifreeze; 14,405 tires; 23,999 oil filters; and 21,468 gallons of used oil.

The Texas Country Cleanup Program offers rural residents a disposal outlet for properly rinsed pesticide containers. In 1994, the program was expanded to include waste oil, oil filters, tires, and automotive batteries. TNRCC staff assist communities with scheduling one-day collection events at temporary sites throughout the state – determining collection location, developing promotional materials, and arranging for recycling contractors. The program includes an educational component, which addresses proper procedures for rinsing containers and proper management of the containers, rinsewater, and pesticides.

Since the program began in 1991, 275 collections have been conducted in which 8,221 participants have brought the following: 389,194 pesticide containers (367.8 tons); 99,942 tires (934.6 tons); 148,485 gallons of used oil (536 tons); 213,018 used oil filters (245 tons); and 17,166 automotive batteries (171.7 tons).

There are many other equally successful programs within the TNRCC, all involving partnerships. These programs include: Texas Environmental Education Partnership, Teaching Environmental Sciences Program, Storm Drain Stenciling, Community Information Workshops, Texas

Environmental Excellence Awards, Lake and River Cleanup Program, Pollution Prevention and Recycling Programs, and the Border Pollution Prevention Program.

The TNRCC's Source Water Assessment and Protection Program coordinates with many of these programs assuring that efforts are concentrated in the more susceptible or vulnerable areas of the state.

Program Coordination and Integration

TNRCC - USGS PARTNERSHIP

The goal of the SWAP is to complete technical defensible source water assessments of all public water supplies in Texas. Therefore, early in the work plan formulation phase, the TNRCC decided to broaden and compliment its in-house technical expertise by partnering with knowledgeable scientists from the U.S. Geological Survey (USGS). Early in the summer of 1997, three technical work groups were established:

- Surface Water Work Group
- Ground Water Work Group
- Data Base and Software Work Group

Each work group was co-chaired by a senior scientist from the TNRCC Public Drinking Water Section and a counterpart from the USGS Water Resources Division. Membership on the work groups included selected staff from each agency having technical expertise in hydrology, geology, chemistry, geography, relational data bases, geographic information systems (GIS), and software development. The assignment given to each work group was (1) to evaluate all possible technical approaches for assessing the susceptibility of ground and surface source water supplies in Texas to contamination and (2) to recommend technically defensible alternatives that could be accomplished statewide with the best available data within the time frame outlined in the SDWA. Numerous technical approaches were proposed and considered by the TNRCC and USGS scientists. Some very complex approaches were not recommended by the technical work groups due to limitations of available data, limitations of current scientific knowledge, inability to apply the approach to all public water supplies, and (or) time or funding constraints. Conversely, some of the more simple approaches were not recommended as they would not provide the technically defensible assessments desired by the TNRCC. The preliminary recommendations of the scientists from the TNRCC and the USGS were then presented and reviewed by members of the SWAP Public Participation and Education Forum and in particular, its Technical Steering Committee (see Section 3, Public Participation). The assessment approach presented in this strategy document reflects the results of this extensive collaboration process.

SOURCE WATER ASSESSMENT AND PROTECTION AND OTHER PUBLIC WATER SUPPLY SUPERVISION PROGRAM IMPLEMENTATION EFFORTS

Preventing the contamination of and maintaining good quality drinking water supplies are the primary goals of Source Water Protection efforts under the SDWA. Reducing or preventing chemical and microbiological contamination of source waters could allow PWSs to avoid costly treatment or minimize monitoring requirements.

The TNRCC's Source Water Assessment and Protection Program is located within the Public Drinking Water Section of the Water Utilities Division and coordinates very closely with all public water supply program areas. The following sections identify those public water supply programs and activities and discusses how the programs coordinate to achieve the objectives of the Source Water Assessment and Protection Program.

Wellhead Protection Program

As discussed throughout this document, the Wellhead Protection (WHP) Program is a pollution prevention program designed to protect ground water sources of drinking water. This program has played a strong role in Texas' ground water protection efforts since 1988 and serves as the base ground water protection component of Texas' Source Water Assessment and Protection Program.

The U.S. EPA formally approved the program on March 19, 1990, making it one of the first programs approved in the United States. Since that time, Texas' WHP program has grown from protecting one system to providing an added level of protection to more than 600 PWS systems. Currently, 45% of all vulnerable Texas PWS systems are protected by a WHP program.

Interim Monitoring Relief

As allowed under section 1418(a) of the SDWA, Texas has an active interim monitoring relief program which may reduce monitoring requirements for most contaminants for an interim period if: (1) the initial sample fails to detect, at the time of greatest vulnerability, the presence of the contaminant; and (2) the hydrogeology of the area and other relevant factors are considered. In Texas, interim monitoring relief does not apply to microbiological contaminants, disinfection byproducts, or corrosion byproducts.

This program saves money for public water systems and their customers by reducing or eliminating unnecessary testing of drinking water. Since 1993, waivers issued by the vulnerability assessment staff have saved Texans more than $50 million in testing costs.

In 1990, the Texas Public Drinking Water Program began developing criteria to assess the vulnerability of PWS wells, springs, and watersheds to contamination. This program:

- Identifies drinking water treatment plants at high risk to contamination by the disease-causing protozoan *Cryptosporidium parvum*;
- Targets shallow or poorly constructed wells for microbiological testing, to decide whether their water needs additional disinfection or filtration;
- Evaluates the type and frequency of testing for pesticides, chemicals found in gasoline, industrial chemicals, and asbestos;
- Issues testing waivers where water supplies are not at risk to contamination;
- Provides computer mapping support to the Public Drinking Water Program;
- Targets public water supplies in need of wellhead or watershed protection;
- Reviews requests for exceptions to rules and regulations on the location and construction of public water supply wells, and on actions required to protect wells from contamination.

The existing interim monitoring relief program is administered through Texas' Source Water Assessment and Protection Program.

Drinking Water Monitoring

The Drinking Water Monitoring Team, located within the Public Drinking Water Section serves as a quality control mechanism to protect and maintain a specific quality of drinking water in each system and provide a readily available history of a given system's bacteriological and chemical record. Specific tasks include:

- Maintaining records on all water systems by scheduling for monitoring, receiving, evaluating, and recording sample analyses and water operational reports. Overseeing compliance sampling schedule for both TNRCC Field Staff and the sampling contractor;
- Notifying affected system and field offices by letter if the system:

    a. submits bacteriological samples that are positive for coliform organisms, or
    b. is in violation of the bacteriological MCL for a monthly monitoring period, or
    c. fails to submit routine monthly bacteriological samples, or
    d. fails to submit monthly reports of treated water turbidity or exceeds the turbidity MCL.

- Reviewing the chemical analyses for possible violations of the primary standards, notifying the affected systems and district offices, and insuring that follow-up samples are collected to confirm those violations. Enforcing system compliance for both primary and secondary standards to deter new noncompliance and to correct existing noncompliance;
- Updating the water system inventory as necessary including source names, production capacities, and treatment information for all systems;
- Compiling statistical system-specific data on all violations and enforcement actions;
- Providing data concerning all instances of significant contamination of sources of drinking water;
- Maintaining current information files on toxicological opinions for various coatings, linings, paints, sealants, treatment chemicals, and other water system related materials;
- Monitoring compliance with the lead/copper rule and initiating follow-up actions as appropriate; and,
- Monitoring trihalomethane analysis results for public water supplies above 10,000 population and use data collected for determining compliance.

The Source Water Assessment and Protection Team coordinate very closely with the Drinking Water Monitoring Team on monitoring issues, monitoring schedules, and development of vulnerability assessment policies.

Raw Water Coliform Monitoring

If a well is located adjacent to a surface body of water such as a lake, river, or stream there could be an impact on the quality of water in the well. The well could be under the influence of the nearby surface water and actually not be producing true ground water. Additionally, wells located in igneous and metamorphic rock areas can be influenced by surface runoff after a rain. This can create a hazard for customers if pathogenic organisms found in surface water are able to penetrate the well. Local ground water systems, which are suspected of being under the influence of surface water, are asked to collect samples of raw water each month for a period of six months. TNRCC has an active raw water monitoring program which coordinates very closely with the Source Water Assessment and Protection Program.

Surveillance and Technical Assistance

This program has primary responsibility for review of sanitary surveys of PWS systems. Program members work closely with the TNRCC Field Operations Division and the PWS systems to make sure they comply with state and federal regulations. Staff also address plumbing issues for PWS systems, specifically with regard to backflow prevention and cross-connection control.

Sanitary Surveys

The purpose of a sanitary survey is to evaluate and document the capabilities of a public water supply system to continually provide safe drinking water and identify any deficiencies. A system's treatment, storage, distribution network, operation, and maintenance are evaluated as part of a survey. Sanitary surveys provide a fundamental understanding of current and potential threats to water quality and system reliability.

TNRCC regulations require that a PWS exercise sanitary control over all property located within 150 feet of a public drinking water well. In cases where the PWS lacks the right of eminent domain, TNRCC will require the execution of a sanitary control easement on the property. In addition to this requirement for sanitary control, TNRCC regulations also require minimum separation distances of up to 500 feet between the well and certain sources of contamination. Specifics of this program include:

- Ground water sources shall be located so that there will be no danger of pollution from flooding or from insanitary surroundings, such as privies, sewage, sewage treatment plants, livestock and animal pens, solid waste disposal sites or underground petroleum and chemical storage tanks and liquid transmission pipelines, or abandoned and improperly sealed wells;
- No well site which is within 50 feet of a tile or concrete sanitary sewer, sewerage appurtenance, septic tank, storm sewer, or cemetery; or which is within 150 feet if a septic tank perforated drainfield, areas irrigated by low dosage, low angle spray on-site sewage facilities, absorption bed, evapotransporation bed, improperly constructed water well or underground petroleum and chemical storage tank or

liquid transmission pipeline will be acceptable for use as a public drinking water supply;

- ! No well site shall be located within 500 feet of a sewage treatment plant or within 300 feet of a sewage wet well, sewage pumping station or a drainage ditch which contains industrial waste discharges or the wastes from sewage treatment systems;
- ! No water well shall be located within 500 feet of animal feed lots, solid waste disposal sites, lands on which sewage plant or septic tank sludge is applied, or lands irrigated by sewage plant effluent;
- ! Livestock in pastures shall not be allowed within 50 feet of water supply wells; and,
- ! All known abandoned or inoperative wells (unused wells that have not been plugged) within one quarter mile of a proposed wellsite shall be reported to the TNRCC along with existing or potential pollution hazards. These reports are required for community and nontransient, noncommunity ground water sources;

This basic level of protection serves to protect the well from only specific sources of contamination and the Source Water Protection Program is an extension of this basic level of protection.

TNRCC uses the information collected in source water assessments to enhance sanitary survey information and to identify systems of concern that may receive priority for surveys.

Surface Water Plant Evaluation

The Surface Plant Evaluation Program provides analysis of disinfection strategies (CT studies), review of designs for treatability, regulatory guidance, and optimization activities. (CT is an acronym for concentration time. CT refers to the amount of time that some concentration of disinfectant remains in contact with the water. Obviously, the longer the disinfectant is in the water, the more opportunity it will have to inactivate microorganisms, including pathogens which could cause disease in humans. Likewise, if the concentration of the disinfectant is higher, it does not need as much time to inactivate the microorganisms.) CT studies are performed when a new plant is built, when a plant is changed significantly, or when a plant's disinfection strategy is changed. Internally, the program interacts with Plans Review to get information about new plants, sharing information with Chemical Monitoring regarding existing or potential or microbial exceedances, and the program gets information from the Source Water Assessment and Protection Program regarding systems treating ground water under the influence of surface water.

The program supports the Agency's surface water treatment plant optimization efforts. The program participates in comprehensive evaluations of treatment plants, assists with optimization training activities, provides technical and logistical support to utilities involved in the Texas Optimization Co-op Program, and administers the Texas Optimization Program and its recognition program.

The Surface Water Plant Evaluation and Source Water Assessment and Protection Programs interact and identify surface water treatment plants with drinking water sources which may be vulnerable to potential upstream contamination. These potentially vulnerable surface water treatment plants are identified as sites at which optimization activities would be most beneficial.

Capacity Development

The 1996 SDWA Amendments include requirements for states to obtain authority to prevent new non-viable systems, to develop a strategy to address the capacity of existing systems, and to ensure that potential SRF recipients have sufficient technical, managerial, and financial capacity prior to receiving loan funds.

TNRCC chose to develop a comprehensive Capacity Development Strategy that includes all of the SDWA-required elements. TNRCC's Capacity Development strategy includes preventing new non-viable public water systems from operating, assessing the capacity of existing public water systems, improving the capacity of the existing public water systems through assistance and assisting with the restructuring of non-viable existing public water systems.

All public water systems must assure the TNRCC they are financially stable and technically sound. Recent state law changes require certain new public water systems demonstrate they have financial, managerial, and technical (FMT) capacities to operate a viable system by submitting a business plan. Others must demonstrate they have FMT capacities when they submit an application for a certificate of convenience and necessity to delineate service areas.

FMT capacity and consolidation assessments of public water systems are being conducted by TNRCC staff and a contractor, Texas Rural Water Association. Public water systems that need assistance may be placed on a Corrective Action Plans to move the system toward compliance.

The Source Water Assessment and Protection Program coordinates with the Capacity Development Program by providing information directly relevant to determine source water adequacy, and, in turn, building of technical capacity and a capacity development strategy.

Operator Certification

The Operator Certification Program is administered by TNRCC's Operator Certification Section, Compliance Support Division, in the Office of Compliance and Enforcement. The Operator Certification program helps to ensure that PWSs have the technical and managerial capacity and training to provide safe water on a continuing basis.

In accordance with state law, Title 5 *Texas Health and Safety Code,* Chapter 341 and Title 30 *Texas Administrative Code*, Chapter 290, any entity furnishing drinking water to the public for a charge and any system utilizing surface water in the State of Texas, must at all times be under the direct daily supervision of a TNRCC Certified Waterworks Operator to oversee the production, processing, treatment, and distribution of safe and plentiful drinking water to the customer's tap. Certified Waterworks Operators are responsible for the operation of water treatment plants and all the activities that responsibility entails including the testing and treating of water, operation, and maintenance of plant equipment, and the filing of monthly operational reports.

Additionally, certified water operators, and members of other water related professional groups, such as engineers or sanitarians, passing the examination, and holding a valid endorsement issued by the TNRCC may conduct public water supply customer service inspections.

Customer service inspections shall be completed prior to providing continuous water service to new construction, or any existing service when the water purveyor has reason to believe that cross-connections or other unacceptable plumbing practices exist, or after any material improvement, correction, or addition to the private plumbing facility. The responsibilities of an Endorsed or Authorized Customer Service Inspector include cross connection identification and elimination, prevention of backflow and back siphonage, and the control or lead and improper usage of copper materials.

Because Texas' Source Water Assessment and Protection Program requires active involvement by PWS operators, close coordination of the programs is maintained. Presentations on source water assessment and protection are provided at most of the operator certification and training seminars. Certified operators also assist TNRCC in conducting both source water assessment and protection activities due to their familiarity and working knowledge of both the system as well as ground water and watershed protection problems in the area.

Plans Review

Texas statutes require the submission of plans and specifications to TNRCC prior to the construction of a new PWS. Plans, specifications, and related documents must be prepared by a registered professional engineer. The engineering report includes: statement of the problem or problems; present and future areas to be served, with population data; the source, with quantity and quality of water available; present and estimated future maximum and minimum water quantity demands; description of proposed site and surroundings for the water works facility; type of treatment, equipment, and capacity of the facilities; basic design data; the adequacy of the facilities with regard to delivery capacity and pressure throughout the system; the location of all abandoned or inactive wells within 1/4 mile of a proposed wellsite; a general map or plan of the municipality, water district, or area to be served; well log; raw water chemistry and microbiological report; and a PWS well intake location.

TNRCC's Source Water Assessment and Protection Program review and provide input into all plan reviews requiring geological and well construction technical assistance. This coordination provides the SWAP program with up-to-date information and records on all new PWSs.

Consumer Confidence Reporting

Again demonstrating its commitment to public health protection and the public's right-to-know about local environmental information, the TNRCC is working in partnership with water suppliers to put annual drinking water quality reports into the hands of their customers. These consumer confidence reports, which TNRCC developed in consultation with water suppliers, environmental groups, and other stakeholders will enable Texans to make practical, knowledgeable decisions about their health and their environment.

While water systems are free to enhance their reports in any useful way, each report must provide consumers with the following fundamental information about their drinking water:

- the lake, river, aquifer, or other source of the drinking water;
- a brief summary of the susceptibility to contamination of the local drinking water source based on source water assessments;
- how to get a copy of the water system's complete source water assessment;
- the level (or range of levels) of any contaminant found in local drinking water, as well as EPA's health-based standard (MCL) for comparison;
- the likely source of that contaminant in the local drinking water supply;
- the potential health effects of any contaminant detected in violation of an EPA health standard, and an accounting of the system's actions to restore safe drinking water;
- the water system's compliance with other drinking water-related rules;
- an educational statement for vulnerable populations about avoiding *Cryptosporidium*;
- educational information on nitrate, arsenic, or lead in areas where these contaminants are detected above 50 % of EPA's standard; and,
- Phone numbers of additional sources of information, including the water systems and EPA's Safe Drinking Water hotline.

The TNRCC formed a CCR Public Forum in February, 1998, comprising representatives of large and small water systems, public health advocacy groups, water associations, consumer groups, environmental groups, and individual consumers. The forum met three times to discuss the CCR rule, additional items for the rule and implementation of the rule.

The CCR Forum members met on July 9, 1998 to discuss additional items that systems could add to their reports. Additional elements that could be added to the CCRs were source water protection plan, cross connection control, water conservation plan, outages, drought management plan, taste, odor, and color. Out of all these additional elements, source water protection plan was voted number one.

Public water supply systems will be required to put in a statement in the CCR regarding the availability and completeness of their source water assessment, and also provide detailed instructions for obtaining a copy of the assessment. If a source water assessment is not yet available, the CCR report should indicate that such information will be available in the future and provide a time frame for when the information will be available to the public.

Database Integration Project

The TNRCC depends on a solid foundation of high quality, timely, and accessible information to support the full range of its business functions and day-to-day activities. One goal of TNRCC's Water Utilities Division is to provide Division and Agency management, staff, and interested stakeholders with timely and direct access to information that meets requirements for State and Federal legislative mandates. This integrated information system will fulfill this goal and is currently being developed. Among other objectives, this database will: (1) allow data sharing among all public water supply program areas as well as other Agency program areas; and, (2) provide data tracking and reporting systems that meet requirements of the SDWA National Primary Drinking Water Regulations as agreed to in the State/EPA primacy designation. This will include storage and management of data necessary to track the regulatory activities of water districts, utilities, and public drinking water systems, such as audits, surveys, assessments, and reports.

SOURCE WATER ASSESSMENT AND PROTECTION AND OTHER FEDERAL/STATE AGENCY PROGRAMS

Protecting ground and surface sources of drinking water supplies requires a wide array of actions ranging from establishing partnerships, assessing the vulnerability of critical water and biological resources, identifying and controlling sources of pollution, land use planning and management, monitoring for contaminants, nutrients, and other water quality parameters, and enforcement of various local, state, and federal laws. Any of these efforts benefit from coordination and communication across different levels of public and private interests, and reliance on a range of funding sources, regulatory/permit requirements, and voluntary agreements.

Delineating source water protection areas, inventorying significant potential sources of contamination in those areas, and making susceptibility determinations can benefit, and benefit from, other federal and state program areas. For example, delineating source water protection areas will enable other programs to identify where these areas are located and will allow these program areas to reset priorities for prevention efforts to reduce or eliminate contaminants flowing into public water supply wells or intakes. For some public water supply systems, this could mean significant increases in efficiency through both reduced monitoring and reduces need for new or more expensive treatment technologies. The delineated source water protection areas will also certainly increase the awareness of federal, state, and local managers of other programs that action in these areas may be a high priority for the protection of human health.

Similarly, the benefits that other state and federal programs can provide to state and local source water assessment and protection efforts are potentially very large. The information, authorities, and communication networks that these other programs have can be invaluable in helping the TNRCC and the public water supply systems conduct the assessments and implement protection measures.

TMDL Program

One example of coordination that provides useful information to each program is between the TNRCC's Total Maximum Daily Load (TMDL) Program and the Source Water Assessment and Protection Program. The federal Clean Water Act requires states to develop TMDLs for water bodies which do not meet state water quality standards. Water quality standards in Texas include requirements that water bodies used as a source of public drinking water should be free of harmful contaminants. TMDLs are quantitative analyses of water bodies and their contributing watersheds to determine how much pollutant loadings water bodies can receive and still meet their water quality standards. TMDLs result in watershed management plans which allocate the allowable pollutant loadings to individual sources in the watershed and provide for the implementation of water quality management measures necessary to achieve the load allocation.

During FY 98 the SWAP and TMDL programs began coordinating efforts for the first time in the Marlin and Aquila watersheds which have been placed on the 303(d) list due to concerns about atrazine concentrations in finished drinking water. These and other programs of the TNRCC have been working in cooperation with the Texas Agricultural Experiment Station (TAES), Texas Agriculture Extension Service (TAEX), Natural Resources Conservation Service (NRCS), and Texas State Soil and Water Conservation Board (TSSWCB) to develop an integrated approach for the implementation of BMPs to reduce atrazine contamination in these two watersheds. The SWAP program's main role in the effort is to ensure optimum participation on the part of the public water supplies, assist in the development of surface water management documents and workplans, involve the public and address their drinking water related concerns during the process, and lend technical and outreach assistance in order to avoid duplication of effort by developing a Source Water Protection Strategy independently.

The TMDL program will be updated on the progress of the source water assessments but the assessments themselves do not require close integration between the two programs. Due to the ongoing nature of the assessments, the SWAP program will incorporate any data collected through the TMDL process and may provide technical assistance with monitoring plan design. The coordination between the two programs will be taking place through integrated protection efforts to implement BMPs, develop demonstration and educational activities, increase involvement and environmental awareness of local residents, improve wellhead conditions and protect surface water from pollution sources.

UIC Class V Well Program

Underground Injection Control (UIC) Class V Injection Wells are typically shallow disposal systems that place a variety of fluids below the land surface, into or above underground sources of drinking water. Injection wells are regulated by EPA and TNRCC through the UIC program in order to protect underground sources of drinking water from contamination.

The 1996 Amendments to the SDWA establish source water protection as a national priority. Consistent with the national priority established by the SDWA, proposed Class V rule, 40 CFR 144, Subpart G - *Requirements for Owners and Operators of Class V Injection Wells,* focuses on high-risk Class V injection wells in source water protection areas, that are known to pose the greatest threat to underground sources of drinking water:

- motor vehicle waste disposal wells;
- industrial waste disposal wells; and,
- large-capacity cesspools.

The proposed Class V regulation would affect the owners and operators of these wells in source water protection areas delineated for community water systems and non-transient non-community water systems that rely on at least one ground water source.

Class V injection wells are regulated by the UIC program, whose governing regulations were promulgated under the authority of Part C of the SDWA. Under the existing federal and state regulations, Class V injection wells are "authorized by rule," which means they do not require a permit if they do not endanger underground sources of drinking water and comply with other UIC program requirements.

The conditions of the rule authorization are two-fold: first, basic inventory information about the Class V injection well must be submitted to EPA or the state primacy agency; second, the Class V injection well must be constructed, operated, and closed in a manner that protects underground sources of drinking water.

In a report to EPA dated September 1989, the TNRCC proposed to identify and give first priority to Class V injection wells through the WHP Program. TNRCC's Class V program staff, as a priority, have targeted shallow underground disposal wells in source water protection areas to ensure that the wells comply with the SDWA by having owners and operators implement management measures to avoid endangerment.

Comprehensive State Groundwater Protection Program

In evaluating the states' activities under the groundwater protection strategy initiative begun in the early 1980's, the EPA concluded that additional efforts were needed to protect the nation's groundwater. The EPA developed a new initiative to build core programs, which were termed comprehensive state groundwater protection programs (CSGWPPs).

Because groundwater protection programs tend to be a patchwork of federal, state, and local efforts that focus on individual sources of contamination rather than protection of the resource as a whole, the Texas Groundwater Protection Committee has begun to develop a comprehensive state groundwater protection program. The CSGWPP consists of six strategic activities:

- establishing a common protection goal;
- establishing priorities to achieve the most efficient and effective means of achieving the goal;
- defining roles and responsibilities in all program areas;
- implementing all necessary efforts to accomplish the goal;
- coordinating information; and,
- improving public education and participation.

Surface Casing Program

TNRCC's Surface Casing Program coordinates with the SWAP Program through data exchange and is responsible for the following major tasks:

- Provides ground water protection recommendations to the oil and gas industry;
- Provides ground water protection recommendations for seismic programs;
- Reviews and issues ground water protection recommendations to industry and the Texas Railroad Commission for Class II injection wells; and,
- Provides geologic analysis to TNRCC and other state agencies for ground water contamination investigations.

Hazardous and Solid Waste Program

The TNRCC establishes ground water protection standards for hazardous waste land disposal facilities permitted under the RCRA program. When contamination is detected, the Commission specifies additional monitoring and investigation, designated numerical concentration limits for individual contaminants and specifies remedial action to be taken if the limits are exceeded. Information from this program has been integrated into Texas' source water assessments. In turn, designated source water protection areas will be available to the hazardous and solid waste program for priority setting.

Petroleum Storage Tank Program

The Commission's PST program regulates the following: (1) underground storage tanks (USTs) which store petroleum substances and CERCLA-listed non-waste hazardous materials; and, (2) above ground storage tanks (ASTs) which store certain motor-fuel type petroleum products. Commission rules require UST systems to be equipped with leak detection, corrosion protection, and spill/overfill prevention systems. If a release is detected, the PST facility is required to notify the Commission and abate the release of the product. The responsible party is required to initiate an assessment of the extent and degree of subsurface contamination. If contamination is confirmed, a remedial action plan which presents the method of ground water restoration must be submitted to the TNRCC for review and approval.

The petroleum storage tank program serves as a key program area in assessing Texas' source water.

Abandoned Well Program

Improperly plugged or unplugged abandoned wells which penetrate an injection formation may provide a conduit for migration of injected fluids into fresh water formations. The Texas Water Well Drillers Program was created and charged by the Texas Legislature to help ensure the quality of the state's ground water through the licensing of water well drillers. Rules and regulations have been developed by the Texas Department of Licensing and Regulation to properly plug and complete water wells.

The Texas Department of Licensing and Regulation defines an abandoned well as "A well that has not been used for six consecutive months. A well is considered to be in use in the following cases: (A) a non-deteriorated well which contains the casing, pump, and pump column in good condition; or, (B) a non-deteriorated well which has been capped."

As abandoned wells are identified through Texas' source water assessment and protection program, the wells are immediately turned over to the Texas Department of Licensing and Regulation for proper closure.

Water Well Drillers Program

The Texas Water Well Drillers Program was created and charged by the Texas Legislature to help ensure the quality of the state's ground water through the licensing of water well drillers and assuring well construction standards are enforced. The program is administered through the Texas Department of Licensing and Regulation. The programs activities do not arise from any specific federal program, legislation, or delegation. The responsibilities of the program include establishing licensing procedures and qualifications for water well drillers and duties for licensed drillers.

The program continues to coordinate its activities with source water assessment and protection as well as other state ground water programs through the Texas Groundwater Protection Committee whose mission is to prevent contamination of the state's ground water resources.

Nonpoint Source Program

Under Section 319 of the 1987 Clean Water Act (CWA) amendments, Texas was: (1) required to conduct statewide assessments of their waters to identify those that were either impaired (did not fully support state water quality standards) or threatened (presently meet water quality standards but are likely not to continue to meet water quality standards fully) because of nonpoint sources (NPS); (2) required to develop NPS management programs to address the impaired or threatened waters identified in their nonpoint assessments; and (3) entitled to receive annual grants from EPA to assist in <u>implementing</u> the NPS management programs once EPA had approved it. EPA has approved Texas' assessments and management programs.

For over ten years, TNRCC has utilized funds from the NPS Program to fund source water protection activities. Additionally, information developed for the NPS Program serves as valuable information and data about land-based contamination sources which provide valuable input into the source water assessment process. An example of this coordination is the Regional Aquifer Protection Programs (e.g., Edwards Aquifer) which has provided a wealth of data for TNRCC's assessment and protection activities.

Sole Source Aquifer Protection Program

The Sole Source Aquifer Protection Program is authorized under Section 1424(e) of the SDWA. The provision allows EPA to declare that an aquifer is a "sole or principal drinking water source" for an area if contamination of the aquifer could create a significant hazard to public health.

The hydrogeologic and water usage information assembled during the designation process can aid in defining protection areas and determining vulnerability of water supplies. Project reviews can be a source of information on potential contaminant sources within source water protection areas. In turn, the information from source water assessment and protection can be used to help evaluate whether an area meets sole source aquifer designation criteria, and can provide useful information for project reviews, such as the location of delineated source water protection areas, potential or existing sources of contamination, and local variations in aquifer susceptibility.

Edwards Aquifer

In 1975, the Edwards Aquifer was the first aquifer in the United States to receive the EPA sole source status. Geologically, the Edwards Aquifer developed in a faulted and fractured, Cretaceous dolomitic limestone, in which primary sedimentary features, along with structural deformation associated with the Balcones Fault Zone, ultimately yielded a karst environment in which recharge and transmissivity is rapid, and the potential for contamination can increase with the degree of development activity over the recharge zone.

The first Edwards rules were concerned with wastewater as a contaminant. Rather than allow indiscriminate installation of septic tanks for wastewater disposal, cities on the recharge zone were required to develop organized sewage collection systems to transport wastewater off the recharge zone. In 1974, construction of "subdivisions" on the recharge zone became regulated, as did installation of all underground hydrocarbon and hazardous substance storage. In 1977, placement of 1,000 gallons or more of hydrocarbons and hazardous substances in aboveground storage tank facilities became regulated. The next significant change in the rules came in 1986 with the inclusion of the "transition zone" in the Edwards Rules. Its purpose is to provide the Edwards with additional protection against leakage from hydrocarbon and hazardous substance storage facilities. In 1990, the rules required, "a description of the measures that will be taken to prevent pollution of storm waters originating on-site or upgradient from the site (and to) ... prevent downgrade pollution by contaminated storm water runoff from the site" during and after construction.

The Edwards Aquifer remains as a high priority with respect to source water assessment and protection in Texas. Further discussion on source water assessment and protection in the Edwards is included later in this document.

U.S. Department of Agriculture Programs

The U.S. Department of Agriculture (USDA), Soil Conservation Service (SCS), and Extension Service administer a number of programs that enhance source water assessments and protection including, state groundwater management plans, voluntary agricultural resource management plans, conservation reserve program, and the wetlands reserve program. The Environmental Quality Incentives Program (EQIP) is extremely active in Texas and plays a very strong role in Texas' source water protection activities.

Texas has used these programs to enroll and protect environmentally sensitive land that impacts drinking water supplies and to find cost-effective solutions to source water problems. Additionally, the Department of Agriculture provided input on Texas' Source Water Assessment Strategy.

Tex*A*Syst Program

Tex*A*Syst is a series of publications to help rural residents assess the risk of ground water contamination, and to describe best management practices that can help protect ground water. The Tex*A*Syst bulletins and related materials were developed from the national *Farm*A*Syst* ground water protection program. Tex*A*Syst is administered by the Texas Agricultural Extension Service.

The Tex*A*Syst Program has been in partnership with Texas' Wellhead Protection Program for a number of years. By bringing the private and municipal wellhead inventories together, a clearer picture of risks to ground water contamination can be made, and a more comprehensive plan to reduce such risks can be developed and implemented. This rural program will continue to assist the Source Water Assessment and Protection Program in developing a more comprehensive assessment of rural areas and implementing best management practices within those areas.

Groundwater Conservation Districts Programs

The Texas Groundwater Conservation Districts Association is the umbrella organization for special purpose districts, known as underground water conservation districts, created by the Texas Legislature or by the TNRCC with the purpose and responsibility to preserve and protect ground water. There are presently over 30 water conservation districts located around the state. These districts are local or regional in their jurisdiction and have, for the most part, elected boards of directors. Among their legislatively granted authorities is the power to monitor ground water quality. A number of districts also have the authority to bring civil court proceedings for injunctive relief against an entity causing ground water contamination.

Ground water protection programs that are typical of most districts include source water or wellhead protection, water quality monitoring, water quantity studies, well registration and permitting, well construction standards and water conservation efforts. Source water protection activities are closely coordinated with the appropriate ground water conservation district.

A map of existing ground water conservation districts is included in Appendix M.

Groundwater Guardian Program

Groundwater Guardian is an international program which supports, recognizes, and connects communities taking voluntary, pro-active steps toward comprehensive ground water protection. Groundwater Guardian allows local problems to be solved through local solutions by motivating citizens to take personal and community responsibility.

The TNRCC has been designated as a Groundwater Guardian Affiliate and fully supports the activities of the Groundwater Guardian Program. In 1997, 122 communities received Groundwater Guardian designation. Source water assessment and protection is an integral part of TNRCC's Groundwater Guardian Affiliation.

Other State and Federal Programs

The TNRCC has identified key state and federal program areas that are important in the development and implementation of Texas' SWAP program. On October 2, 1997, letters were sent to the various program areas inviting them to develop a partnership with source water assessment and protection. On October 7, 1997, a training session was held specifically for other program areas.

Many of the program areas have been contacted individually to obtain informational and data needs in order to conduct assessment activities. Several program areas (Superfund and Petroleum Storage Tank Programs) currently coordinate with the Source Water Assessment and Protection Program to help prioritize workloads. The TNRCC will continue to take advantage of every opportunity for integration of source water protection efforts with the vast array of federal and state programs.

TEXAS GROUNDWATER PROTECTION COMMITTEE

The Texas Groundwater Protection Committee was created by the 71st Texas Legislature in 1989 as a means to bridge the gap between existing state groundwater programs and to optimize water quality protection by improving coordination among agencies involved in groundwater activities. House Bill 1458 (codified as Sections 26.401 through 26.407 of the Texas Water Code) established the committee and outlined the powers, duties, and responsibilities of the committee.

A state groundwater protection policy was also adopted by the Legislature as part of the bill that created the committee. The policy sets out nondegradation of the state's groundwater resources as the goal for all state programs. The Policy recognizes the variability of the state's aquifers, the importance of maintaining water quality for existing and potential uses, the protection of the environment, and the maintenance and enhancement of the long-term economic health of the state. The policy states that discharges of pollutants, disposal of wastes, and other regulated activities be conducted in a manner that will maintain present uses of groundwater and not impair potential uses of groundwater or pose a public health hazard. The use of the best professional judgement by the responsible state agencies in attaining the goal and policy is also recognized.

The committee actively seeks to implement this policy by identifying opportunities to improve existing groundwater quality programs and promoting coordination between agencies. The committee also strives to improve or identify areas where new or existing programs could be enhanced to provide additional protection. Major responsibilities of the committee are:

- to improve interagency coordination in the area of groundwater protection;
- to develop and update a comprehensive groundwater protection strategy for the state;
- to study and recommend to the Legislature groundwater protection programs for areas in which groundwater is not protected by current regulation;
- to publish an interagency groundwater monitoring and contamination report; and
- to file with the governor, lieutenant governor, and speaker of the House of Representatives a report of the committee's activities during the biennium preceding each regular legislative session, including any recommendations for legislation for groundwater protection.

The committee's membership is composed of the following individuals or their designated representative:

- the executive director of the Texas Natural Resource Conservation Commission;
- the executive administrator of the Texas Water Development Board;
- a representative selected by the Railroad Commission of Texas;
- the commissioner of health of the Texas Department of Health;
- the deputy commissioner of the Department of Agriculture;
- the executive director of the Texas State Soil and Water Conservation Board;
- a representative selected by the Texas Alliance of Groundwater Districts;
- the director of the Texas Agriculture Experiment Station; and
- the director of the Bureau of Economic Geology, University of Texas at Austin.

The TNRCC is designated as the lead agency with the commission's executive director designated as the committee's chairman. The executive administrator of the Texas Water Development Board is designated as the committee's vice-chairman.

The Groundwater Protection Committee has been briefed on the SWAP Program submittal and will continue to receive updates as appropriate.

TEXAS SURFACE WATER PROTECTION COMMITTEE

In August 1997, the TNRCC's Public Drinking Water Program requested the formation of a "Surface Water Protection Committee." The initial purpose of the committee was to discuss and act on the numerous atrazine detects found in drinking water. Members of the committee include:

- Texas Department of Agriculture
- Texas Natural Resource Conservation Commission

- Texas State Soil and Water Conservation Board
- Texas Agricultural Extension Service
- Natural Resource Conservation Service
- Governor's Office
- Novartis Corporation
- Interested Members of the Public

The Committee was charged and developed a consensus "State of Texas Pesticide/Herbicide Action Plan" which allows the state to respond pro-actively before either a regulatory violation occurs or public anxiety grows.

The Surface Water Protection Committee actively seeks and identifies opportunities to improve existing surface water quality programs and promotes coordination between agricultural and surface water-related agencies. The Committee also strives to improve or identify areas where new or existing programs could be enhanced to provide additional protection. Examples of their expanded work include Source Water Assessment and Protection and the Total Maximum Daily Load Program. Meetings of the Committee are held once every two months.

SENATE BILL 1

Senate Bill 1 (SB1), passed by the 75th Texas Legislature, is a comprehensive reform of Texas water law, providing a framework for management of the state's water resources. Components of the legislation include drought planning, water rights regulation, financial and technical assistance, and data collection. Some have said the first article is the most important one in the bill since it changed how Texas plans for its long-term water supplies. The bill lays out that water plans, "...shall provide for the orderly development, management, and conservation of water resources and preparation for and response to drought conditions, in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural and natural resources of the entire state." Further, the bill creates a new planning process where local groups are to prepare regional plans that are to be incorporated into the state water plan. The regional plans are to be submitted to the Texas Water Development Board (TWDB) by September 1, 2000 with the state plan due one year later.

The state was divided into 16 regional water planning areas by the TWDB in February, 1997. In doing this, the TWDB considered factors such as river basins, aquifer delineations, water utility development patterns, socioeconomic characteristics, existing regional water planning areas, political subdivision boundaries, and public comment. Rules guiding the preparation of plans have been developed, and initial members of the regional water planning groups have been named. All 16 groups have adopted bylaws.

The requirements for the regional plans are that they describe the region, consider existing plans, describe the future demands for water (the planning period extends through 2050), describe current water supplies, identify water users with surpluses of water and those with needs, and plan ways to provide sufficient water to satisfy the needs.

Senate Bill 1 also provides that groundwater conservation districts are to develop a comprehensive management plan that address the following management goals, as applicable: (1) providing for the most efficient use of groundwater, (2) controlling and preventing waste of groundwater, (3) controlling and preventing subsidence, (4) addressing conjunctive surface water management issues, and (5) addressing natural resource issues.

Source Water Assessment and Protection activities will be coordinated with these 16 regional planning groups as appropriate.

MULTI-JURISDICTIONAL AREA COORDINATION

TNRCC will make the maximum practical effort to coordinate with surrounding states and Mexico in conducting assessment and protection activities in those watersheds or aquifers which cross state boundaries. There are a number of coordination activities and links already in place which serve as excellent mechanisms for source water assessment and protection activities.

Interstate Coordination

The TNRCC is committed to interstate coordination of all source water assessment and protection components through membership in national organizations such as American Water Works Association (AWWA), Association of State Drinking Water Administrators (ASDWA), Association for State and Interstate Water Pollution Control Administrators (ASIWPCA), Council of State Governments (CSG), and the Ground Water Protection Council (GWPC).

TNRCC, working through EPA Region VI, will continue to coordinate with the states of Arkansas, Louisiana, New Mexico, and Oklahoma through regularly scheduled State-EPA meetings. These meetings, held twice per year, provide an opportunity for data exchange, coordinate future interstate activities, and develop joint protection strategies.

Through these biannual meetings, any disputes can be addressed along with the resolution of issues always being resolved at the staff level.

The TNRCC SWAP Program has also agreed to participate in the Rio Grande Watershed Interstate Coordination Team, sponsored by EPA and coordinated by the State of Colorado. This coordination team establishes lines of communication between states along the Rio Grande River for exchange of water quality data, information on the individual state approaches to the various SWAP elements, and how the various states can work together in concert to protect the Rio Grande. TNRCC will participate in a series of interstate meetings and conferences; exchange data with bordering states; and produce GIS maps of the source water protection areas in each river basin.

The TNRCC is also committed to providing data to the Ground Water Protection Council's Source Water Protection Data Management System. This national database will assist adjacent states and communities with data sharing and consistency in susceptibility and protection activities.

This system is an interactive tool that provides source water assessment and protection programs with the following capabilities:

- The ability to compile and organize data from many sources (e.g. state agencies, EPA, USGS) into a unified structure;
- The ability to track and graphically plot water quality trend data;
- Use GIS technology to display information from these databases on a map with other land use activities;
- The ability to spatially analyze how different environmental factors interact with each other and impact water quality;
- The ability to publish and distribute data in a variety of useful formats;
- Is flexible and can combine additional databases for future program expansion;
- Can be made available via the Internet;
- Built-in quality control checks to assure the integrity of electronic data transfer;
- Water quality data can be evaluated with respect to other factors such as land use, geology, or demographics;
- Data can be published in various formats, including maps, statistical summaries, and electronic data downloads;
- GIS report options including thematic mapping of contaminant loading by source, by state, etc. or concentrations by individual well; and,
- Track source management activities.

Finally, when a WHPA or DWA extends into another state, the source water assessment will list the neighboring state contacts. TNRCC's Source Water Assessment and Protection web site also contains hot links to neighboring states' SWAP web sites (Louisiana, Arkansas, Oklahoma, and New Mexico). This vehicle allows interstate coordination at the local level to monitor activities within a watershed encompassing two states.

International Coordination

The unique border region shared by the United States and Mexico provides challenges and opportunities to the states and local communities which compose it. Four Mexican states are adjacent to the Texas border and include: Chihuahua, Coahuila, Nuevo León, and Tamaulipas.

All coordination activities with respect to Mexico must be coordinated through the International Boundary and Water Commission (IBWC). The IBWC was created more than a century ago by the governments of the United States and Mexico to apply the provisions of various boundary and water treaties, and settle differences arising from such applications through a joint international commission located at the border. The IBWC's jurisdiction extends along the U.S. - Mexico boundary, and inland into both countries where they may have international boundary and water projects. The IBWC has encouraged and coordinated the establishment of cooperative relationships with federal, state, and local agencies, both in the U.S. and in Mexico, in carrying out its border projects and activities. In the early stages of Texas' SWAP Program development all information and draft submittals were furnished to the IBWC for review, comment, and information. That coordination continues today. Upon final program approval, the TNRCC will coordinate with the International Boundary and Water Commission to brief the Republic of

Mexico on Texas' Source Water Assessment and Protection Program at an official and formal meeting of the two countries. All program activities which involve those watersheds or aquifers crossing into Mexico will be coordinated with the IBWC.

State-to-State Strategic Environmental Plans have been developed to serve as a framework for cooperation and communication. The intent of these plans is to provide a framework for cooperation for the state environmental agencies of Texas and Chihuahua, Coahuila, Nuevo León, and Tamaulipas. Each state has appointed a liaison who is responsible for the coordination of activities under the environmental plan. Annual meetings are held with the purpose of developing a twelve-month bi-state action plan with a calendar of prioritized activities, and mechanisms to ensure their fulfillment. Each of the states have committed to working together in the following six areas:

- Establish programs for reuse, reduction, and recycling, including water conservation;
- Develop a border-wide electronic environmental information sharing mechanism, support development of GIS databases and pursue compatible methods and measures to enable information sharing;
- Develop programs for volunteers (including professionals), and establish a recognition/award system;
- Collaborate with the maquiladoras and other industries as a source of technology and information exchange;
- Develop state-to-state environmental strategic plans; and,
- Develop and implement low-cost and clean technologies.

Through the "Transboundary Aquifers and Binational Ground-Water Data Base" study (completed in January, 1998), ground water data from the U.S. and Mexico have been integrated into one data base. The ground water databases were provided by the Texas Water Development Board and New Mexico State Water Resources Research Institute for the U.S. side, and Comision Nacional del Agua, Junta Muncipal de Agua y Saneamiento, Ciudad Juárez, and Servicios Nacionales de Estadistica, Geografia e Informatica for the Mexican side. The data exchanged includes: land use, well data (construction, ownership, well use, etc.), core descriptions, ground water levels in wells, results of ground water quality analyses, and pumping records. This data will be incorporated into source water assessments for those watersheds and/or aquifers crossing into Mexico.

Indian Tribes

No tribal land with public water supply systems exists in Texas.

PUBLIC PARTICIPATION

The following section addresses the requirements for public participation in developing Texas' Source Water Assessment and Protection submittal in relation to EPA'S SWAP Guidance Document (EPA 826-R-97-009).

The 1996 SDWA Amendments place a strong emphasis on public awareness and involvement. Involving the public in source water assessments and protection programs offers states and localities the opportunity to channel the energies of an increasingly informed public into efforts to protect their water supplies.

As stated in the Final Guidance document Section 1428(b) of the Safe Drinking Act requires that "to the maximum extent possible, each state shall establish procedures, including but not limited to the establishment of technical and citizens advisory committees, to encourage the public to participate in developing the protection program for wellhead areas and SWAPs under section 1453." Texas has fulfilled this requirement by meeting first with the Drinking Water Advisory Work Group (DWAWG).

Drinking Water Advisory Work Group

The DWAWG was established in 1992 by the TNRCC's Public Drinking Water Section. DWAWG is a voluntary group of participants that meet on a quarterly basis to discuss issues related to drinking water, with emphasis on compliance with state and federal regulations and improving customer service to the public. In other words, the Work Group serves the Public Drinking Water Program as a sounding board for policies, rules, and issues affecting both consumers and public water suppliers. Based on input from the group, TNRCC Drinking Water Section staff compile agendas for each quarterly meeting. DWAWG provides TNRCC with expanded knowledge and resources to help with existing and future drinking water issues. The DWAWG has been continually updated on all source water assessment and protection issues and progress since passage of the Amendments.

This group is a voluntary group and is open to the public, therefore anyone who wishes to join may attend the meetings. The group currently has representation from American Water Works Association, Texas Rural Water Association, Texas Water Utilities Association, Independent Water & Sewer Companies of Texas, Texas Municipal League, Clean Water Action, Consumers Union, League of Women Voters, Sierra Club, Texas Water Conservation Association, Association of Water Board Directors, Community Resource Group, Dow Chemical, attorneys, engineers, and individual citizens.

The responsibility of this group will continue as Texas makes program improvements over the next few years and as the program moves into more protection activities.

Public Participation and Education Forum

On September 26, 1997, the TNRCC met with representatives from the DWAWG to discuss implementation of statewide public participation. This *ad hoc* committee was provided with an overview of SWAP public participation and the requirements and responsibilities that would be expected from the members of the public forum. Through this *ad hoc* committee, over 70 groups and organizations (non-governmental organizations) were identified that would represent a broad representation on advisory groups and wide public involvement. The committee was provided a time line outlining the general steps of the SWAP public participation process. Committee members decided to convene one general public forum at the beginning of the SWAP process instead of starting with two separate ones (citizens and technical advisory committees). The committee felt it was important to educate both the technical representatives as well as citizens, so that everyone was in at the beginning, with the understanding that the committee had the option of creating separate committees later if needed. The Committee decided to name the public participation committee the SWAP Public Participation and Education Forum (PP&E). This Committee will remain in place through the implementation phase of Texas' Source Water Assessment Program.

One important step the committee felt was necessary before convening the entire PP&E Forum was to gather the state and federal programs and agencies together to provide them a "heads up" that the TNRCC was beginning the process of carrying out the mandate to identify the areas that are sources of public drinking water, assess water systems' susceptibility to contamination, and inform the public of the results. It was important that these agencies know that TNRCC intended to invite groups and organizations that represent hundreds of their constituents that may, in turn, be calling on them with questions concerning source water assessment and protection. This meeting was held on October 7, 1997.

Next, the TNRCC sent out two letters, one dated October 10, 1997 to the state and federal program areas encouraging them to continue their support by attending the first SWAP PP&E meeting and, a letter dated October 9, 1997 inviting over 150 individuals and non-governmental organizations to participate in Texas' SWAP PP&E Forum. Included with these letters was a packet containing an overview of SWAP, a brief description of the TNRCC's SWAP Program, a draft SWAP PP&E Time Line, and a map of the TNRCC complex.

The letter emphasized TNRCC's full commitment for their organization to have input in the SWAP process and offered complete scholarship funding for travel to the meetings that would be held in Austin, Texas. The meetings were held in Austin because of its central location in the state and therefore make it more convenient for all participants.

At the first SWAP PP&E meeting on November 3, 1997, the public was provided with a complete overview of the SWAP process, as well as the purpose, goals, milestones, and time lines for the SWAP project. The USGS discussed the joint partnership with the TNRCC and explained the roles and responsibilities of each party. The public was provided a copy of a draft summary work plan which outlined Texas' approach for conducting assessment and protection activities.

The PP&E Forum then held a Question and Answer session to validate and edit the SWAP approach. After lunch, the PP&E Forum was lead by an outside facilitator to work in four groups to help identify gaps and to identify resources to fill those gaps. Group One was assigned the topic "Identify Potential Sources of Contamination." Group Two's topic was "Gathering Information from Government Agencies." Group Three discussed "Assessing Public Drinking Water Susceptibility of Contamination." And Group Four discussed "Providing Information to the Public." Afterward, the groups came back to the Forum and reported their outcomes. After the reports were made, each person was given twenty dots to identify and vote for their priority issues in each topic. The prioritization of databases showed the stakeholders' concerns with potential sources of contamination around drinking water sources. Finally, the Forum was given homework consisting of fifteen questions concerning the SWAP process that would be returned at the next PP&E Forum meeting of November 17, 1997.

A thank you letter was sent out on November 7, 1997 to each SWAP PP&E Forum member thanking them for their attendance and participation. Included with the letter were the following enclosures: a list of participants at the November 3, 1997 meeting; an updated time line of SWAP activities; and the results of the individual priority votes from the group activities conducted at the meeting. TNRCC also felt it was important to send a "we missed you" letter and complete informational packet to the individuals and organizations that could not attend the November 3, 1997 meeting. This packet contained a copy of the homework questions, a list of participants from the meeting, an updated time line of SWAP activities, the results of the groups activities conducted at the meeting, and a draft summary work plan which outlined the assessment and protection components. Also included was a copy of a letter inviting them to attend the November 3, 1997 meeting. Both letters included an invitation to the next SWAP PP&E meeting to be held on November 17, 1997.

The second SWAP PP&E meeting was held on November 17, 1997. Topics included at this meeting were a brief SWAP overview, the compiled homework results, and a general discussion among forum members on the SWAP process. The USGS discussed existing databases which included agency names and their existing database information which would likely be incorporated into TNRCC's database for inclusion into the assessment and protection process.
After the USGS presentation, the forum was given five dots to vote for their priority databases. Also presented during the meeting was information on Total Maximum Daily Loads (TMDLs) and its relationship with SWAP.

The third and final formal SWAP PP&E meeting was held on December 15, 1997. Due to time constraints and the approaching holidays, a Fax was sent to every member to ensure high attendance at this important meeting. To demonstrate the effectiveness and importance of the public participation process, local and regional entities provided assessment and protection data and information which is available at the local and regional levels for incorporation into the statewide assessments. The results of the priority database exercise which was completed at the November 17, 1997 meeting was shared with forum members. A discussion followed on the homework questions and how the TNRCC would be incorporating the SWAP PP&E information, suggestions, and ideas to the SWAP plan. Discussions were also held concerning the 1997 State Revolving Fund. The USGS distributed and discussed with the Forum the latest draft version of the TNRCC/USGS work plan and invited additional comment and draft revisions. The meeting closed with a discussion of what will happen next along with a recommendation that a Technical Steering Committee be formed from members of this Forum.

On July 22, 1998, the members of the SWAP PP&E received an update letter from TNRCC. The letter updated the members on the status of the Technical Steering Committee and provided a web address to access additional information on the SWAP plan. Also included in the letter was a survey which requested public feedback on the public participation and education process. The TNRCC mailed out 40 surveys and received 10 responses. The overall response was very positive.

Correspondence with respect to the Public Participation and Education Forum can be found in Appendix D.

Technical Steering Committee

The PP&E Forum elected to create a technical advisory committee to assure the needs of the program would be met in the most efficient and technically sound way. This committee consisted of both internal and external technical individuals who could advise and guide the TNRCC on technical issues related to the assessment and protection process.

The technical steering committee will continue to meet to resolve issues through the implementation phase of Texas' Source Water Assessment Program. This steering committee also reviewed public comments received on the draft submittal for advice and concurrence on appropriate changes to the document.

The Technical Steering Committee met for the first time on April 14, 1998. The focus of the Technical Steering Committee was to review detail work plans generated by the TNRCC-USGS partnership, *Detailed Work Plans for Source Water Assessment Approach for Determining the Potential Susceptibility of Public Drinking Water Supplies to Contamination.* It was important this group keep a statewide perspective on the assessment and protection process and not let personal views or perspectives enter into the decision making process.

The Technical Steering Committee met again on August 12, 1998 to discuss TNRCC's plans for submitting the SWAP plan to EPA, software and hardware workplans, "Justification for Designations of Hydrologic Regions in Texas," "Justification for Selection of Period 1961-90 to Represent Long-Term Runoff," and, "Susceptibility to Pathogens." Discussions were also held on aquifer identification codes and PSOC database acquisition progress. Additional information on the Technical Steering Committee can be found in Appendix E.

Ongoing Public Outreach

Web Site

Through the TNRCC's Internet access, public involvement and input will continually be received on source water assessment and protection program activities. Information on program development, the strategic approach to conducting assessments, delineation of source water boundaries, information on regulated and certain unregulated contaminants, program funding information, hot link to other related sites, and the opportunity for public input has been and will continue to be available through the TNRCC's Source Water Assessment and Protection home page. The address is: **http://www.tnrcc.state.tx.us/water/wu/swap/swap.html**

Public Workshops, Conferences, Meetings

Further public involvement and participation has been achieved through the state's Groundwater Protection Committee and the newly created Surface Water Protection Committee. These committees are composed of representatives of state agencies whose programs affect ground and surface water. Public participation is an integral component of these committees and source water assessment and protection activities have been coordinated with the committees.

Significant public input was also received through the TNRCC's 12th Annual Source Water Protection Seminar which was held in June, 1998 in San Antonio, Texas. The overall theme of the seminar was implementing best management practices at the local level. A portion of the seminar was set aside for overview of the source water assessment and protection process as well as public input and participation.

The TNRCC also conducted several Public Drinking Water Workshops this past year where additional public input was received. The workshops provide water supply operators and any individuals who have an interest in their public water supply information on the TNRCC's Public Drinking Water Section's programs, goals, and time lines for various projects. SWAP was presented at each workshop with emphasis on public participation and involvement in protection activities.

At the 1998 Groundwater Foundation Symposium which was also held in San Antonio this past September, there was a special break out session specifically for source water assessment and protection. The agenda included SWAP requirements, the state revolving fund, SWAP time line, and activities underway in Texas with respect to source water. Citizen input was also received.

One significant component of the TNRCC's SWAP program is the partnership with Texas Rural Water Association (TRWA) in promoting source water protection workshops. TRWA conducted three workshops; April 16, 1998 in Midland, Texas, May 7, 1998 in Amarillo, Texas, and November 10, 1998 in Kerrville, Texas. The workshops provide an introduction to the SWAP program and deliver "hands-on," interactive training sessions concerning the procedures necessary to carry out a successful program.

A summary of all meetings and activities where outreach and input was received is summarized in Table 1.

Table 1

Source Water Assessment and Protection Public Outreach

EVENT	LOCATION	AREA OF OUTREACH	DATE
Texas A&M Water Quality Training	Weatherford, TX	Statewide	05/08/97
Lubbock WHP Task Force	Lubbock, TX	Regional	05/13/97
SWAP Seminar	Lubbock, TX	Statewide	05/19-20/97
Groundwater Training	El Paso, TX	Statewide	06/24-25/97
Environmental Sciences Training	Lubbock, TX	Statewide	07/16-17/97
TRWA Annual Meeting	Galveston, TX	Statewide	07/17/97
Public Drinking Water Seminar	Austin, TX	Statewide	07/22/97
Groundwater Foundation Meeting	San Francisco, CA	Interstate	09/03/97
DWAWG *	Austin, TX	Statewide	09/16/97
DWAWG	Austin, TX	Statewide	09/26/97
Surface Water Quality Monitoring Annual Workshop	Austin, TX	Statewide	09/29/98
Public Drinking Water Seminar	Houston, TX	Statewide	10/03/97
Austin Geological Society	Austin, TX	Regional	10/06/97
State & Federal Agencies Meetings	Austin, TX	Statewide	10/07/97
Border Environmental Conference	El Paso, TX	Border Region	10/15/97

Marlin SWP Advisory Committee	Marlin, TX	Regional	10/20/97
ASDWA	Savannah, GA	Interstate	10/20/97
Surface Water Protection Committee Meeting	Austin, TX	Statewide	10/24/97
Public Drinking Water Seminar	Corpus Christi, TX	Statewide	10/28/97
PP&E ◊	Austin, TX	Statewide	11/03/97
PP&E	Austin, TX	Statewide	11/17/97
TNRCC Commission Agenda	Austin, TX	Statewide	11/19/97
Statewide Groundwater Protection Committee	Austin, TX	Statewide	11/20/97
Groundwater Foundation Meeting	Oakbrook, IL	Interstate	11/22/97
Surface Water Protection Committee	Austin, TX	Statewide	12/05/97
DWAWG	Austin, TX	Statewide	12/09/97
PP&E	Austin, TX	Statewide	12/15/97
Border Environmental Conference	El Paso, TX	Border Region	12/17/97
Agricultural Activities Meeting	Temple, TX	Statewide	01/09/98
TMDL/Clean Rivers Program	Dallas, TX	Statewide	01/23/98
Marlin SWP Advisory Committee	Marlin, TX	Regional	01/26/98
TWDB Public Meeting on SRF	Austin, TX	Statewide	01/27/98
Public Drinking Water Seminar	Austin, TX	Statewide	01/30/98

Highland Village WHP Meeting	Highland, TX	Regional	02/09-10/98
Surface Water Protection Committee	Temple, TX	Statewide	02/18/98
Surface Water Protection Committee	Austin, TX	Statewide	02/19/98
EQIP Meeting	Italy, TX	North Central Texas Area	02/24/98
Aquilla Source Water Protection Committee	Hillsboro, TX	Regional	02/27/98
ASDWA Meeting	San Antonio, TX	Interstate	03/06/98
DWAWG	Austin, TX	Statewide	03/10/98
Surface Water Protection Committee	Austin, TX	Statewide	03/26/98
Non-Point Source Committee	Austin, TX	Statewide	03/31/98
TRWA SWP Seminar	Wichita Falls, TX		03/30/98
Technical Steering Committee	Austin, TX	Statewide	04/14/98
Surface Water Protection Committee	Marlin, TX	Statewide	04/14/98
League of Women Voters	Corpus Christi, TX	Statewide	04/17/98
SWAP Conference	Dallas, TX	Statewide Interstate	04/29/98
Statewide Environmental Trade Fair	Austin, TX	Statewide	05/4 - 8/98
Marlin SWP Advisory Committee	Temple, TX	Regional	05/13/98
TMDL Meeting	Austin, TX	Statewide	05/21/98
Statewide Source Water Protection Seminar	San Antonio, TX	Statewide	06/01-02/98

Surface Water Protection Committee	Austin, TX	Statewide	06/08/98
Source Water Protection Committee	Austin, TX	Statewide	06/12/98
Marlin SWP Advisory Committee	Marlin, TX	Regional	06/18/98
Surface Water Protection Committee	Temple, TX	Statewide	07/07/98
AWWA	Dallas, TX	Statewide	06/25/98
Border Environmental Conference	El Paso, TX	Statewide	07/30/98
Surface Water Protection Committee	Temple, TX	Statewide	07/31/98
Kerr County UWCD Meeting	Kerrville, TX	Regional	08/11/98
Technical Steering Committee	Austin, TX	Statewide	08/12/98
Surface Water Protection Committee	Temple, TX	Statewide	08/17/98
Public Drinking Water Seminar	Dallas, TX	Statewide	08/28/98
San Antonio Water System	San Antonio, TX	Central Texas	09/02/98
Groundwater Foundation	San Antonio, TX	Statewide Interstate	09/09/98
GWPC	Sacramento, CA	Interstate	09/21/98
TMDL Meeting	Dallas, TX	Statewide	09/28/98
Amarillo WHP Meeting	Amarillo, TX	Regional	09/29/98
Marlin SWP Advisory Committee	Marlin, TX	Regional	10/12/98
AWWA North TX Chapter Meeting	Dallas, TX	North Central Texas Area	10/15/98

Surface Water Protection Committee	Austin, TX	Statewide	10/21/98
Surface Water Protection Committee	Temple, TX	Statewide	11/10/98
TRWA SWP Seminar	Kerrville, TX	Central Texas Area	11/10/98
Clean Water Forum Meeting	Dallas, TX	Statewide	12/12/98

* Drinking Water Advisory Work Group
◊ Public Participation & Education Forum

Public Comment on Draft Submittal

Although Texas' program submittal follows the guidelines and suggestions provided by the Public Participation and Education Forum as well as the Technical Steering Committee and does not differ in policy from that originally suggested by the committees, the TNRCC posted this draft submittal for public comment on the internet in December, 1998. To further assure the public was aware of its availability, a statewide press release was sent to all major newspapers throughout the state. Copies of the submittal were all also provided to all non-governmental organizations originally invited to participate on the Public Participation and Education Forum.

Finally, on December 12, 1998, a statewide meeting/workshop of traditional environmental, conservation and watershed groups, volunteer monitoring groups, and grassroots based environmental groups met in Dallas, Texas. The workshop also sought to involve groups representing constituencies more vulnerable to waterborne diseases, such as AIDS service agencies and groups representing people with HIV/AIDS, senior citizen groups, cancer support groups, children's health advocates, and health care providers. Approximately 70 individuals attended the meeting. This workshop was hosted by the Clean Water Fund of Texas and funded by EPA. Copies of the latest draft submittal were provided to the group for discussion and comment.

ASSESSMENT COMPONENT

Overview

For the Texas SWAP, susceptibility of a PWS is the potential for a PWS to withdraw water containing a listed contaminant(s) at a concentration that would pose concern through any of the following pathways: (1) direct injection or discharge; (2) through soils; (3) through geologic strata including faults, fissures, or other types of secondary porosity; (4) overland flow; (5) up-gradient water or streamflow; and (6) through cracks in a well casing or intake pipe. Susceptibility of a water supply to contamination is related to (1) the physical integrity of the well or intake and the pipe transmitting water from the well or intake and to the treatment plant/distribution system; (2) the natural and man-altered physical, geologic, hydrologic, chemical, and biological characteristics of the source-water area over which, or matrix through which, water and contaminants will move to the supply point; (3) the type and number of potential sources of contamination (PSOCs) and land usage within the contributing area of a supply well, spring, or intake; and (4) the nature and quantity of contaminants that have been or potentially could be released within a contributing area, as well as measures in place to prevent such releases.

The Texas SWAP includes three major subject areas: assessment software and database structures, ground-water supplies, and surface-water supplies that contribute to a SWSA determination for each PWS in the State. A product of this program will be GIS-supported assessment software, providing batch-processed assessments for a large number of PWSs and interactive assessments of individual supplies. The first major subject area deals with the creation of this software. The Ground Water and Surface Water subject areas are further defined as sets of components, where each component deals with a major facet of the SWSA. These components (also called tasks or projects), are then broken down into a series of major subtasks which give a high level definition of the tasks required to accomplish the creation of the component or software module. The SWA components are listed below. The technical aspects of the GIS-supported software, databases, and each assessment component, including the summary susceptibility determination for a specific PWS, are described in Section IV. C, Source Water Assessment Approach.

1. Assessment Software and Database Structures

2. Ground Water

    a. Identification Component (Task 1)
        Locate public-supply wells and springs
        Determine aquifer category of the water source

    b. Contributing Area Delineation Component (Task 2)
        Unconfined isotropic aquifers
        Confined isotropic aquifers
        Alluvial aquifers
        Conjunctive delineation--ground water under the influence of

surface water (GUIs)
Edwards aquifer
Conjunctive delineations--GUIs
Unknown aquifers

c. Non-Point Source Component (Task 3)

d. Point-Source Component (Task 4)
Development of Possible Source of Contamination (PSOC)
Databases

e. Contaminant Occurrence Component (Task 5)

f. Attenuation of Contaminants (Task 6)
Soil zone
Vadose zone
Aquifer matrix

g. Susceptibility Summary Determination Component (Task 7)

3. Surface Water

a. Delineation Component (Task 1)
Locate public-supply intakes
Delineate contributing watershed

b. Intrinsic Characteristics Component (Task 2)
Runoff
Soil erodibility
Beneficial effects of reservoirs
Time-of-travel

c. Non-Point Source Component (Task 3)

d. Point Source Component (Task 4)

e. Contaminant Occurrence Component (Task 5)

f. Area-of-Primary-Influence Component (Task 6)

g. Susceptibility Summary Determination Component (Task 7)

TIME EXTENSION

SWSAs (phase I) for all community and non-community PWSs in Texas will require the full 3.5 years (from the date of USEPA's approval of the Texas SWAP) to complete. Therefore, the 18-month extension period as allowed for by the SDWA is requested. The justification for the request for the extension includes the technical complexity of the proposed assessment approach, the time required to develop the business rules, databases, and GIS-supported assessment software, and the time required to coordinate with adjacent states, as well as with Mexico, SWSAs for the numerous multi-jurisdictional source waters along Texas' borders.

SOURCE WATER ASSESSMENT PHASES AND PRIORITIES

Assessment Phases

Initial Assessments—Phase I

Initial (phase I) SWSAs for all community and non-community, non-transient PWSs in Texas will be performed and released to the PWS and the public within 3.5 years after USEPA's approval of the Texas SWAP. Phase I assessments will be based on available, statewide data and information. The assessment approach, including detailed descriptions of the databases to be used for phase I assessments, business rules, and the GIS-supported software for batch (phase I) and interactive (phase II) processing of SWSAs, is outlined in Section IV. C, Source Water Assessment Approach.

Initial (phase I) SWSAs for non-community, transient PWSs in Texas will involve differential assessment with the SWSAs limited only to selected, priority contaminants**.** As with the other PWSs, the initial assessments will be performed and released to the PWS and the public within 3.5 years after USEPA's approval of the Texas SWAP. The phase I assessments also will be based on available, statewide data and information using the same assessment approach outlined in Section IV. C, Source Water Assessment Approach, but for a fewer number of contaminants.

A systems susceptibility will be considered as "undetermined" until a Phase I assessment is released. This does not mean or imply that a system has a high or low susceptibility to specific contamination. It simply infers that a determination of susceptibility cannot be made at that time.

Updating Assessments—Phase II

Phase II SWSAs will be performed for specific PWSs when new data or information are provided to TNRCC that could substantially change the initial (phase I) SWSA. Initial SWSAs will be released to the PWS; interested local, regional, State, and Federal agencies; and the public for information, review, and comment. This review may result in new or refined data or information being made available justifying up-dating of the database(s) and re-assessment of the source water. Also, with the implementation of Source-Water Protection Programs, new data or information will be collected that could warrant up-dating the initial assessments. Examples include refinement of the PSOC database for a contributing area, more accurate chemical or pesticide usage data, and the availability of local, current, high-resolution land-use information. If these data and information are made available to TNRCC, the assessment software can be used in an interactive mode to up-date the SWSA. However, up-dates of the initial assessments must be deferred until the initial assessments for all PWSs are completed. It is anticipated that phase II assessments could not be processed until after the 3.5 year phase I assessment period.

PRIORITY FOR COMPLETING PHASE I ASSESSMENTS

PWSs in Texas will be assessed as separate, aquifer or reservoir/stream specific, batch processes in the following sequence:

1. Community supplies,
2. Non-community, non-transient supplies, and
3. Non-community transient supplies.

Community supplies will be batch processed in the following sequence to allow for early review of SWAs for many of the potentially, more susceptible supplies:

Community supplies obtaining water from selected unconfined aquifers, such as the Ogallala and Seymour aquifers;
All community surface-water supplies;
Community ground-water supplies under the influence of surface water (GUI) (selected Edwards and alluvial aquifer supplies);
Other community supplies obtaining water from unconfined, Edwards, or alluvial aquifers;

Community supplies obtaining water from confined aquifers; and
Community supplies obtaining water from unknown aquifers.

SOURCE WATER ASSESSMENT PROGRAM MAINTENANCE

Databases

Databases created or modified for use in SWAP are being developed using the most up-to-date RDBMS software technology. This technology contains complete maintenance, backup, and security tools making maintenance of SWAP databases very efficient. The SWAS software is being developed with extensive file and database tools, which in turn, make use of industry standard SQL-language commands. All software created will be fully documented, and extensive help files will be available. Finally, the software is being developed on common hardware and software platforms, and should be stable, as well as easily enhanced or modified for the foreseeable future.

Assessment of proposed water supplies

The software and databases developed for SWAP should be useful with few if any modifications for assessing proposed water supplies. Modifications required would involve adding a software module to interactively locate the water supply either from maps, photos, etc., or by entering the location coordinates, and accepting analyst input for required database fields in the various SWAP database tables.

Updating assessments of existing supplies

The software system being created for the Texas SWAP will be capable of re-assessing a water supply at any time. As stated above, assessments may need to be updated, as new data sets become available.

SOURCE WATER ASSESSMENT APPROACH

Background

Groundwater supplies can be considered susceptible if a potential source of contamination (PSOC) exists in the contributing area for the public supply well field or spring, the contaminant's time-of-travel to the well field or spring is short, and the soil zone, vadose zone, and aquifer-matrix materials do not adequately attenuate the contaminants associated with the PSOC. In addition, the existence of particular types of land use/cover within the contributing area may cause the supply to be deemed more susceptible to contamination. Finally, detection of various classes of constituents in water from wells in the vicinity of public supply wells may indicate susceptibility of the public supply well.

Surface water supplies are by their nature susceptible to contamination. The degree of susceptibility of a public surface water supply to contamination can vary and is a function of the environmental setting, water-management practices, and land use/cover within a water supply's contributing watershed area. For example, a public water supply intake downstream from extensive urban development is obviously more susceptible to contamination than an intake in a forested, relatively undeveloped watershed. Surface water supplies are also susceptible to contamination from point sources.

The development of a scientifically-defensible methodology for assessing the susceptibility of Texas' public water supplies to contamination, based on the most accurate, readily available hydrologic, hydrogeologic, land use/cover, point-source, and other natural-resource and environmental data, will better enable the Texas Natural Resource Conservation Commission (TNRCC) and specifically the Public Drinking Water Section (PDW) Source Water Assessment Program (SWAP) staff to:

- focus its source-water protection efforts on surface-water supplies that are more susceptible to contamination:

- potentially reduce monitoring costs associated with ensuring safe, public-drinking-water supplies;

- assist the public in developing an improved understanding of the source of their water supply;

- support the implementation of best management practices needed to protect source waters.

ASSESSMENT SOFTWARE AND DATABASE STRUCTURES

Statement of Problem

Source Water Susceptibility Assessments (SWSA) are technically complex activities involving numerous specialized, comprehensive, computer databases and programs. SWSA are dependent on spatial analysis techniques that may consist of one or more lower-level computer algorithms. In general, these lower-level algorithms are available in commercial Geographic Information Systems (GIS) software as macros or “commands,” but require specialized expertise to use in order to combine them into usable software components capable of performing the various high-level analysis of SWSA. In addition, commercial GIS software packages utilize complex data structures and database formats requiring specialized expertise to design and use. Business rules governing the assessment of water-supply susceptibility must be encoded and made available so that they may be applied to data derived from spatial analysis, as well as to relational database tables accessed from internal PDW and external TNRCC databases. In some cases, these rules are simple yes/no tests; in other cases, a series of logic tests involving several relational database files must be applied. This, in turn, requires that the various databases to be accessible real time, to PDW staff.

The software system developed should be easy to use by the PDW Source Water Assessment Team, and should be compatible with TNRCC’s existing databases. Specialized training in GIS technology should not be required. Due to the volume and variety of required data and the level of technical detail of SWSA, the PDW staff requires access to software documentation and help files, metadata describing databases and GIS coverages, references to external publications, and background or other supplementary information. The most efficient system would place these data files and a reference at the fingertips of the analyst at all times. Due to the large number (>16,000) of assessments which must be completed, SWSA software must be capable of supporting unattended (batch) processing of SWSA. As larger-scale data sets are produced for Texas, SWSA will be repeated, hence the ongoing requirement for unattended processing. In cases where a single assessment (a new water supply) or a small number of assessments are to be completed however, an interactive version is required. It is anticipated that, as SWSA become more technically complex and larger-scale datasets come on-line, assessments are likely to require interactive rather than batch processing. A computer system specifically designed to meet the above requirements does not exist at this time.

Objectives and Scope

The objectives of this project are to design and develop database structures, assessment software, and technical documentation specifically designed to support PDW staff in performance of SWSA on TNRCC computers; and, to coordinate this effort with TNRCC’s Office of Administrative Services, Information Resources (IR) to the extent possible, in order to ensure the long-term compatibility and usability of the databases and software created. The project scope will include requirements analysis, design, development, testing, and documentation of database structures and assessment software, for the following:

- SWSA project database - based on a comprehensive data object model, which defines overall database structure, data tables, data elements within tables, data-entity relations, and includes a data dictionary.

- Software used to retrieve records from, manage, and interact with the various spatial and non-spatial databases required for each SWSA component.

- Software used to display input and/or output datasets, and allow user interaction with these datasets. For example, GIS coverage display, database query, hard copy output, or report generation.

- Software that performs spatial analysis such as delineation of contributing areas; calculation or determination of variables, characteristics, threshold values, etc., based on the results of the analysis; or other analysis as required for the various SWSA components.

- Software that assists the user in applying appropriate business rules for determining susceptibility within the various SWSA components and determining overall susceptibility once the required components have been completed.

- Software modules that provide access to on-line help and documentation for the SWSA.

- A graphical user-interface, which provides organization of and user access to databases and assessment software for the various SWSA components.

- Software which supports interactive processing of SWSA

- Software which supports batch processing of SWSA

Approach

The software development methodology followed will conform to the general principles of information engineering, that is to conduct Joint Requirements Planning (JRP) sessions and Joint Application Design (JAD) sessions for requirements definition and systems design, with a series of review points during the process. The specific approach to be taken regarding SWSA software is the development of a custom application using GIS software Arc/Info, v7.2 and v8.0 (when available) from ESRI, Visual Studio (v6.0) from Microsoft Corporation for interface programming, Access database software from Microsoft Corporation, and Oracle Server data base software from Oracle Corporation. The Arc/Info and Oracle database software and databases will reside on a server running the Windows NT Server 4.0+ Enterprise Edition operating system. This approach, based on the use of the upcoming Arc/Info Open Development Environment (ODE), will produce software with very specific functionality, compiled into a executable program which may be run on any sufficiently-outfitted hardware platform running Windows NT 4.0 Workstation. Access to the Arc/Info license and to the SWSA databases is provided over standard network protocols. The interface application is installed and run on client machines.

The software will incorporate a three-tier object framework. User Services-, Business Services-, and Database Services-tiers will be developed as separate, but integrated components, which serve to isolate the various software functions, and allow the software components to be used and reused in a more flexible manner. This is a particular advantage in this application where future corporate database decisions will need to be accommodated with minimum impact. This approach satisfies the functional requirements outlined above, and allows for easier maintenance, upgrade, and enhancement of software. The software developed under this approach will integrate the extensive database information and maps required for SWSA on the analyst's desktop. In addition, this approach will provide very fast tabular data search and spatial analysis capabilities, without incurring the typical overhead penalties associated with running scripts such as AML against Arc/Info, through the use of Arc/Info's ODE.

The software will be compatible with anticipated software and hardware directions at TNRCC, that is use of ESRI Spatial Data Engine (SDE) to access Oracle databases, and growth in the use of desktop hardware platforms. Access to databases residing outside of the SWSA software system will be facilitated using Structured Query Language (SQL). Access to databases inside of SWSA will be provided to other applications also using SQL, or as applicable using Oracle Objects.

Under this approach, the requirement for support of unattended (batch) assessment sessions will be designed into the software. Batch assessment capability will be provided through software "wizards" which are a common to most modern software applications on Microsoft Corporation's Windows platform. Essentially the user is led through multi-step processing by on-screen dialogs boxes. These "wizards" commonly present the user with various choices and then build an input stream from these choices, which is in turn directed to the required software modules. The user is then freed to work on other tasks. Typically, a status or progress bar is displayed on the screen while the process is under way. The user is notified when the process is complete.

Support for interactive assessment sessions will be provided through the graphical user interface. The user will be able to conduct a single interactive assessment or multiple interactive assessments simultaneously. This capability will be based on the Multiple Document Interface (MDI) (Microsoft, 1995) programming techniques. An example of the MDI as implemented in commercial software would be the ability of users of Microsoft Office applications to open and simultaneously work on multiple documents in Word, or multiple spreadsheets in Excel. The number of interactive assessment sessions is limited only by the hardware on which the SWSA software is run. In this view of the problem, based on principles of Object-Oriented Programming (OOP), each assessment is seen as a separate project (object). In turn, these project objects are comprised of the various database query objects, geospatial objects, custom views of various data objects, and reports or summaries objects produced for a particular public-water-supply susceptibility assessment. The "look and feel" of the application will be closely coordinated with

PDW staff and will conform to TNRCC's Graphic User Interface Design Guidelines document (TNRCC, 1996).

The primary objective of this project is to create software to support SWSA, however the system will likely be only one of a number of software systems that will be used by PDW. Ongoing discussions within the Data Management/GIS Workgroup have and will focus on how the SWSA software can interact with other PDW software and with TNRCC's corporate database structure. Every effort will be made to ensure that the SWSA software will be compatible with existing systems at TNRCC, primarily through the use of Oracle database software, providing SQL-compliant access to databases, and by enabling the user to "cut and paste" the various maps, tables, reports, etc., produced with SWSA software, to other desktop applications.

Task 1.1: Acquire and Install Application Development, Professional GIS, and Database Software and Licenses

Under this task, software used to design, develop, and run SWSA software will be obtained. Software and licenses for Arc/Info V7.2+ for Windows NT (upgrading to V8.0 when available) will be obtained from the vendor under an existing U.S. Geological Survey (USGS) contract. This contract provides substantial discounts over regular vendor prices and allows transfer of the license to TNRCC. Maintenance and upgrade of software, printed software documentation, and user assistance is also available under this contract and will be obtained. Software and licenses for Visual Studio 6.0 Enterprise Edition, Oracle 7, (upgrading to Oracle8 Server v8.0.3) database software for Windows NT, Windows NT Server V4.0, Enterprise Edition, and Windows NT Workstation V4.0 will be obtained from commercial sources. Additional development tools or components such as help/documentation tools or graphics/statistics modules will be obtained as needed. All commercial software obtained specifically to develop and run SWSA software will be transferred to TNRCC as requested.

The development, database, and operating system software will be installed on USGS computers at the Austin office. The software will be setup and tested, and logs of the procedures followed will be kept and provided to TNRCC. As the Oracle database software, Arc/Info for Windows NT, and Arc/Info's ODE environment are new to USGS, some time will be spent becoming familiar with these software packages. Some formal training may be required.

Task 1.2: Conduct Database Requirements Analysis

This task will include a requirements analysis focused on database and database software needs for SWAP components. A series of JRP sessions will be held in order to identify relevant processes and data entities within the SWAP program. A high-level object data model will be developed describing SWSA, in database terminology, representing database requirements as specified by TNRCC/USGS under the various component workplans. The model will include a data dictionary, which defines all data elements used in SWSA and database entity-relationship diagrams portraying the relations between various database tables, data elements associated with GIS coverages, and detailed descriptions with data flow diagrams for all software modules. During this phase, efforts will be closely coordinated with TNRCC OWRM's Water Utilities Database Integration Project so that the SWAP program may benefit from these efforts, and be integrated with Water Utilities Division's overall database plan (Farooq, 1998).

Standardized naming conventions, to be used throughout SWSA databases, will be specified under this task as will standard computer directory-tree structures to be used in SWSA. Further, exchange standards for GIS and relational data tables will be defined. The recommended standard for GIS datasets is the Spatial Data Transfer Standard (SDTS), however datasets will be made available in other formats as required. TNRCC (TNRCC, 1997) and Texas Geographic Information Council Standards for GIS (Texas DIR, 1994) and the draft of TNRCC's Oracle Database Administrator Guide, dated 12/11/97, will be followed as to specification of geographic standards such as scale and projection, naming conventions, etc. Access protocols for external databases required for SWSA will be identified under this task.

Task 1.3: Design and Develop Database Structures

Under this task, the results of the database requirements analysis in task 1.2 will be translated to a database structure. The data dictionary will be used to create database table templates, which will be populated with SWSA data as the data are made available. Data elements within these tables will be defined as specified in the data dictionary. The data tables will be named according to conventions specified in the data dictionary, and the tables will be located in specified directory-tree structures. Also, under this task, database queries, special data input forms, or database reports will be programmed. Software scripts and/or SQL syntax will be developed for access to data tables in external databases as required. The GIS database structure will be developed under this task. The structure will comply with established principles of GIS database design and be compatible with SDE. The tiling structure of the database will be defined and documented under this task and content standards for digital geospatial metadata (FGDC, 1994) will be provided for all GIS coverages created. Unique identifier numbers (GIN or equivalent) will be established for relating water supplies to their contributing recharge- or watershed-areas. Standard projection files, tic files, boundaries, etc., will be developed under this task. Also, explanation (key files, symbol sets, etc.) developed specifically for SWSA will be prepared here.

Task 1.4: Design and Develop Software for Ground-Water Supply Assessment Components

Under this task, software classes, methods, and events used to support SWSA of ground-water supplies will be designed and developed from specifications outlined in the detailed workplans. All subtasks will include documenting, testing, and debugging of code. JAD sessions will be held as necessary in order to accomplish this task.

Task 1.4.1: Design and Develop Identification Component (1) – software capable of performing overlay analysis using the water-supply well or spring location and the Major Aquifer Category (MAC) region coverage as input. The output consists of the water supply’s major aquifer category and various hydrologic characteristics. The output will be stored and used in delineation component.

Task 1.4.2: Design and Develop Contributing Area Delineation Component (2) – software capable of delineating contributing recharge area to water supplies, which have been identified as being in one of five major aquifer categories. Each of the aquifer categories requires a unique delineation method and therefore each will require a slightly different software method. Aquifer properties derived from the MAC; location of the water supply; flow direction, and flow accumulation grids (lattices), are used as input. The contributing recharge-area and time-of-travel are output datasets. This component is one of the most technically complex of all in the SWSA due to the number of datasets to be referenced and to the number of tests to be performed on aquifer properties. The contributing recharge-area coverage will be stored for use in subsequent analysis and for future graphic display and reporting.

Task 1.4.3: Design and Develop Non-Point Source Component (3) – software capable of performing overlay analysis using the contributing recharge-area coverage for the water supply, land use/cover coverage within the contributing area. The output of the process will be the load of contaminants leached into the subsurface from the contributing area for selected chemicals. This output is used by the contaminant attenuation component.

Task 1.4.4: Design and Develop Point-Source Component (4) – software capable of performing overlay analysis using the contributing recharge-area coverage and the PSOC coverage as input to determine the presence of these sites within the contributing recharge-area. The output of this process will be a database of PSOC site identifiers and list of possible 120 listed contaminants associated with the PSOC.

Task 1.4.5: Design and Develop Contaminant Occurrence Component (5) – software capable of identifying water-quality wells or springs identified as having detections of 120 listed contaminants within a given radius of the water- supply well. Output of this component will be run through the Component 6 to determine if contaminant is attenuated.

Task 1.4.6: Design and Develop Contaminant Attenuation Component (6) –software capable of performing overlay analysis using the contributing recharge-area coverage and generalized soil, vadose, and aquifer matrix characteristic coverages as input. Based on these characteristics, each contaminant group associated with the PSOC or with non-point sources, will be assessed as to its potential for attenuation within the contributing recharge-area, within established times-of-travel to the water supply. Output of this component is determination of attenuation/non-attenuation of contaminant groups associated with PSOC locations within the contributing recharge-area as identified in Component 4.

Task 1.4.7: Design and Develop Determination of Susceptibility Component (7) – software used to compile results of the various individual components and output an overall susceptibility determination for the water-supply well or spring. Software will be based on an assessment decision matrix developed by PDW staff. Software output will include report(s) as defined by PDW staff under requirements analysis (Task 1.1).

Task 1.5: Design and Develop Software for Surface-Water Supply Assessment Components

Under this task, software classes, operations, methods, and events used to support SWSA of surface-water supplies will be designed and developed from specifications outlined in the detailed workplans. All subtasks will include documenting, testing, and debugging of code. JAD sessions will be held as necessary in order to accomplish this task.

Task 1.5.1: Design and Develop Contributing Area Delineation Component (1) – software capable of delineating the six types of contributing watershed areas to water supplies as defined in the detailed workplan. Each of the watershed-area types requires a unique delineation method and therefore a slightly different software method. Locations of water supplies, reservoir outlet points, and other locations; flow direction and flow accumulation grids (lattices); and stream segments are used as input. Up to six coverages of contributing watershed areas to water are the output datasets. The contributing watershed-area coverage(s) will be stored for use in subsequent analysis and for graphic display and reporting. Software methods for calculation of watershed characteristics used in susceptibility assessments will be developed.

Task 1.5.2: Design and Develop Intrinsic Characteristics Component (2) – software methods to use established regression equation parameters to estimate mean-annual runoff and mean-seasonal runoff for contributing watershed areas to surface-water supplies. The software will use a coverage of hydrologic regions (Asquith and Slade, 1996), the contributing watershed area(s) and watershed characteristics from the Delineation Component (1), a relational database table containing regression equation parameters (developed under Component 2.A.1), and a coverage of mean-annual precipitation as input. The software will then calculate ratios of mean-annual runoff to mean-annual precipitation, mean-seasonal runoff to mean-seasonal precipitation, contributing area size to basin slope, and total reservoir storage to runoff. The software will use these estimates and PDW-established threshold values to determine and output the intrinsic susceptibility of the water supply.

Task 1.5.3: Design and Develop Non-Point Source Component (3) – software methods to use relational database table of established threshold values (developed under Non-Point Source Component – Project 3), the contributing watershed area for the water supply, land use, population density, oil and gas production well fields, and other point-source information as input. The software will determine environmental characteristics for the contributing watershed area, apply threshold values or regression parameters from the table, and output the intrinsic susceptibility of the water supply to non-point source contamination.

Task 1.5.4: Design and Develop Point Source Component (4) – software methods to use the truncated watershed coverage, the area-of-primary-influence coverage, and the contributing watershed-area coverage; point-source discharge locations, permitted instantaneous loads, and estimates of 7Q2 at ungauged sites as input to estimate concentrations and loads for the stream or reservoir. The software will apply PDW business rules and output the intrinsic susceptibility of the water supply to point-source contamination.

Task 1.5.5: Design and Develop Contaminant Occurrence Component (5) – software methods used to assess contaminant occurrence in the contributing watershed area will be developed under this task.

Task 1.5.6: Design and Develop Area-of-Primary-Influence Component (6) – software methods to assess the area-of-primary-influence will be developed under this task.

Task 1.5.7: Design and Develop Determination of Susceptibility Component (7) – software used to compile results of the various individual components and output an overall susceptibility determination for the water supply. Software will be based on an assessment decision tree developed by PDW staff. Software output will include report(s) as defined by PDW staff under requirement analysis (Task 1.1).

Task 1.6: Design and Develop Graphical User-Interface

This task will include design and development of the user interface. The user interface can be thought of as the glue which binds together the various assessment components, databases, GIS coverages, business rules, and documentation into a cohesive application. The analyst is presented with an easy-to-use yet powerful environment in which to perform susceptibility assessments. JAD sessions will be held as necessary in order to accomplish this task.

Initially, standard windows software functions will be developed such as menus including file, edit, copy/paste, view, etc. Next, graphic elements such as tabs, data controls, status bars, scroll bars, data grids, and other elements will be added. Finally, underlying code will be developed which responds to software-, user-, or system-initiated events or messages. The potential events are numerous, but in general consist of responding to user input, opening files or databases, calculating variables, loading/unloading software components, obtaining licenses, printing reports, saving files, modifying the graphic display, etc. A prototype design for the interface has been developed, but it is anticipated that ongoing close coordination between PDW and USGS staff will result in a high-quality user-interface design which meets TNRCC needs as closely as is possible with current available technology and conforms to TNRCC's Graphic User Interface Design Guidelines document (TNRCC, 1996).

The graphic user interface will undergo continuous review and improvement throughout the development process. This task will include documenting, testing, and debugging of code. The user-interface development platform, recommended in the approach section above, is well suited to this type of flexible development process, and this in turn will facilitate the development of a quality product. This task also will include development of batch capabilities for SWSA (software wizards). This component will be fully integrated into the application, but also may be designed and coded to run from a system command line, which will accept parameters such as an input file name of water supplies to be assessed, an output file name, etc.

Task 1.7: Design and Develop On-line Help System

This task will include design and development of software comprising an on-line help system. The system will be context sensitive, that is, depending on which command, form, dialog box, or menu currently has focus, help will be available about the use or action of the object, by clicking the right mouse button. Further, help on the overall SWSA process will be available, as will guidelines and tips for use of the program. This task will include documenting, testing, and debugging of code. JAD sessions will be held as necessary in order to accomplish this task.

Task 1.8: Design and Develop On-line Documentation System

Under this task, development of the help system will continue with the design and coding of software which will present detailed information such as the data dictionary, metadata for GIS coverages, schematic diagrams of the flow of information through the assessment, and a bibliography of relevant documents. This area of the help system will be written in HTML, allowing the user to view the documentation both inside of the application as well as by internet browsers such as Netscape or Internet Explorer. This documentation also can be made available over the Internet from TNRCC's web page for Source Water Assessments. This task will include documenting, testing, and debugging of code.

Task 1.9: Compile Final Code, Create Installation Programs

Under this step, final code modules will be compiled into executable programs and tested. An installation program will be created and tested. Completed software, help files, and documentation will be written to CD-ROM and other media as requested.

Quality-Assurance Plan

Software development process will adhere to established programming principles as well as additional requirements of TNRCC PDW. During development, all software modules will be tested to determine proper function, as well as proper interaction with other software modules. USGS staff or contractors having experience with GIS software development will perform work. Work will be under the supervision of a senior GIS specialist experienced with software development and GIS programming. Software developed will be tested and submitted for internal and/or external peer review as required. All software developed will be year 2000 compliant.

All database and GIS programming will be written with enough embedded narrative in order to fully document the thought process behind the programming. At a minimum, each script or computer program developed by USGS or contractors will contain the following elements:

- Name of program or script
- Author
- Purpose
- Date created
- Calls, routines or arguments within program or script
- Type of script or program and version
- Date modified
- Specific system dependencies

Maintenance/Enhancements and Support Requirements

The recommendations made here for development, application, and database software have been carefully considered in light of our best understanding of TNRCC's and PDW's future corporate computing environment. It is anticipated that the software and databases developed will be fully compatible with that environment and that maintenance of software and databases will be no more than will be required for other areas of TNRCC's computing environment. Database size estimates for databases specific to SWAP are between 5 and 10 GB total, well within capabilities of currently available servers with arrayed SCSI disk drives. Storage estimates for corporate databases such as the hydrologic derivatives will be on the order of 100 GB. The software is expected to run exceptionally well on currently available desktop computers with 128 to 256 Mb ram and 5 GB disk storage. The recommended server configuration should be a dual to quad processor 300 MHZ or greater with 1 GB ram, 250 GB disk storage, and 8 MB or greater graphics video cards. Disk storage requirements are estimates and may be higher. Other equipment, such as color printers, plotters, CD-ROM jukeboxes, etc., may be required. Standard, high-speed network connections will be required between the server and client computers.

Because of the close collaboration of PDW and USGS staff on the project, especially during JAD sessions, PDW staff will be familiar with the software and database structures developed and should be capable of maintaining and enhancing the system. PDW's support requirements are expected to be mainly in the areas of maintaining the Windows NT operating systems, and providing guidance and support for compatibility issues with TNRCC's other operating systems and databases, and hardware support.

Deliverables

- Quarterly Reports
- Logs of Software Installation and Tuning, as Requested
- Software Object Model
- Database Structures
- Miscellaneous Data Files
- Software for Ground-Water Supply Assessments
- Software for Surface-Water Supply Assessments
- Graphical User Interface,
- On-line Help System,
- On-line Documentation System,
- Installation Programs
- All Source Code and Executables

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GROUND WATER

Identification Component (Task 1)

Statement of Problem

Source Water Susceptibility Assessments (SWSA) require that the contributing recharge area to each public water supply well or spring be determined so that PSOCs that occur within may be identified and assessed as to their potential impact. An initial step will be to identify which aquifer the wells derive their water from, as all subsequent determinations in SWSA are based on aquifer type and hydrologic characteristics of the aquifer. In Texas, nine major and 20 minor aquifers have been mapped (Texas Water Development Board (TWDB) Report 345). These 29 aquifers have been subdivided into 450 aquifer codes (UM-50 Ground Water Data System Dictionary, Texas Water Development Board, rev. 1998), each having its own geologic, hydrologic, and water-quality characteristics. These aquifer codes have been developed for several uses, including public drinking water, however the 29 major and minor aquifers do not provide sufficient detail for the purposes of the SWAP. Alternatively, data requirements for 450 aquifers are beyond the scope of this work. Thus, agreement must be reached between the various stakeholders, including representatives of TNRCC, TWDB, and U.S. Geological Survey (USGS), regarding a workable number of aquifers that still provide adequate detail. Texas aquifers, for the purposes of SWSA, will be categorized as follows:

- unconfined isotropic aquifers, (e.g., Ogallala)
- confined isotropic aquifers, (e.g., Gulf Coast)
- alluvial aquifers along major rivers, and (e.g., Colorado River Alluvium)
- anisotropic karst aquifers (the Edwards aquifer).
- unknown aquifer

Additionally, there are some public ground water supplies in Texas that do not obtain water from the 29 mapped major and minor aquifer systems or where an aquifer determination cannot be made. Thus, designation of the fifth aquifer type is required for the susceptibility-assessment purposes.

Goal and Objectives

The goal of this project is to create a database and software useful to conduct SWSA on public-supply ground-water wells or springs. Specific objectives include:

- Create GIS coverage of public-supply ground-water wells or springs.
- Develop aquifer category coverage(s)
- Develop and provide documentation (metadata)

Approach

The approach will consist of conducting a literature review to determine sources of aquifer information and maps, preparing GIS coverages of public-supply wells or springs, categorizing Texas aquifers into one of five aquifer categories or types, obtaining source materials and maps or digital files, preparing GIS coverages of aquifer properties from source maps or digital files, and preparing metadata for the datasets produced. The aquifer regions or coverages will be used in combination with the Public Water Source (PWS) well coverage to conduct SWSA. The process will result in a georeferenced well dataset that also contains pertinent aquifer information, which will be input to the Ground-Water Contributing Area Delineation Component (2).

Task 1.1: Conduct Literature Review

A Senior USGS Geologist will conduct a literature review in order to determine status and availability of reports and maps describing Texas aquifers. The result of this effort will be a definitive list of source reports and maps to be used to construct GIS coverages of Texas aquifers.

Task 1.2: Create GIS Coverage of Public Supply Ground Water Wells or Springs

The PWS database maintained by the TNRCC will be accessed to retrieve information regarding all public-supply wells and springs within the State of Texas. It is estimated that there are over 12,500 active water sources in the PWS database with a considerable amount of attribute data, therefore this will be a significant contribution to ground-water related databases in Texas. Table 1.1 lists the minimum required attributes to be included in the coverage.

Table 1.1: List of attributes for PWS coverage

[B, binary; I, integer; N, numeric; dms, degrees, minutes, seconds; dd, decimal degrees; LSD, land surface datum; C, character; gpd, gallons per day; mgd, millions of gallons per day; ft3/d, cubic feet per day]

Attribute	**Type (INFO Types)**	**Description**
Numeric Well Identifier	B	PWS-ID
Latitude	I	Latitude in dms
Longitude	I	Longitude in dms
Elevation of screen top (first screened interval)	I or N	LSD minus screen top
Elevation of screen bottom (last screened interval)	I or N	LSD minus screen bottom
Spring elevation	I or N	
Estimate pumping rate	I or N	Pumping rate in consistent units (gpd, mgd, or ft3/d)

Well depth	I or N	LSD - well depth
Confinement	True or False	True means >30 ft. of clay confined. False means <30 ft. of clay - treat as unconfined.

The PWS data will be used to create a coverage of water-supply sites and will be projected into a TSMS map projection (Texas Department of Information Resources, 1992), coordinate units in feet, NAD83 datum (Allison, B., TNRCC IR, Interoffice Memorandum, 1/26/1998). USGS will conduct gross quality assurance checks on data sets generated from TNRCC files. USGS staff will advise TNRCC PDW staff of discrepancies and attempt to correct location and attribute information where possible.

Task 1.2.1: Update Database, Add Missing Locations for Public-Supply Ground-Water Wells or Springs. USGS will locate water-supply sites from source materials and add to the coverage created under task 1.2.

Task 1.2.2: Obtain Depth of Well Values from Digital Elevation Models for all Public Supply Ground-Water Wells or Springs.

Task 1.2.3: Obtain and Computerize Well Construction Data. USGS Staff will obtain and computerize well construction data from TNRCC files.

Task 1.2.4: Obtain and computerize water well annular cement data to evaluate well construction integrity. The majority of this information is complete, however the TNRCC staff will complete data entry of missing information.

Task 1.3: Develop Aquifer Categories Coverage

The determination of aquifer category is needed to define which method to be used in the Ground-Water Contributing Area Delineation Component (2). Aquifer categories include unconfined isotropic, confined isotropic, alluvial, anisotropic karst, and unknown. The first step in this task will be to convene a group of individuals that share a common role in the SWAP ground-water program to redefine aquifer boundaries within the State. The new aquifer boundaries will be used as a basis for decision for all further SWAP analyses. If data are not available in digital format, hard copy aquifer maps that define aquifer category will be digitized or scanned. The specific subtasks are as follows:

Task 1.3.1: Establish a committee of stakeholders, including representatives of the USGS, TNRCC, and TWDB, to redefine names and boundaries of major and minor aquifers within the State. Names will conform to TWDB nomenclature.

Task 1.3.2: Establish a look-up table (in INFO and in hard copy) indicating where each of the 450 aquifers falls within the new aquifer definition. Supply a definition of where these aquifers fall into the 41 major- and minor-aquifer regime.

Task 1.3.3: Create (by digitizing or scanning) GIS polygon coverages of each of the new aquifer boundaries, showing the full extent of the aquifer at the surface and subsurface. Attributes for these coverages are listed in Table 1.2.

Table 1.2: List of attributes for aquifer boundary coverages. [C, character]

Attribute	**Type**	**Description**
Polygon attributes		
Aquifer ID	I	One of 41 potential aquifer codes (Task 1.3.1)
Aquifer Type	I	Unconfined (an aquifer may be confined or unconfined in different areas), confined, alluvial, Edwards, other
Aquifer	I	1= confined area, 1= outcrop area, 0 = “hole”
Aquifer Name		Name as determined in Task 1.3.1
Line attribute		
Source	C	Source of the information
Contact type	C	Definition of aquifer contact type: updip limit, downdip limit, lateral boundary, etc.

Task 1.3.4: Create graphic check plots of aquifer coverages and compare to source materials. USGS and TNRCC (as available) staff will review draft plots of aquifer boundaries. USGS staff will make corrections where necessary.

Task 1.3.5: Create a single, GIS regions (ESRI, 1994) master aquifer coverage (MAC) or multiple polygon coverages showing the boundaries and outcrop areas of all of the new aquifers. The purpose of this coverage is to identify the aquifer(s) that the well could potentially be screened within.

Task 1.4: Prepare Metadata

USGS staff will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata (FGDC, 1994) for the well and springs coverages and for the aquifer categories coverage. Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial datasets and information about the resultant dataset including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994).

Deliverables

The following are to be delivered:

- GIS coverage of public-supply wells and springs
- GIS coverages of aquifer boundaries
- Relational database table of aquifer definitions
- MAC regions coverage
- FGDC-Compliant content-level metadata

References

Environmental Systems Research Institute, Inc. (ESRI), 1994, ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.11.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.12: Global Positioning System.

<u>Contributing Area Delineation Component (Task 2)</u>

Statement of Problem

Determination of the contributing area for water to enter the ground-water system for a specific well field or spring is complicated by: (1) complex geologic structure, (2) ground-water/surface-water interaction, (3) heterogeneous aquifer matrix material resulting from the depositional environment of the aquifer, and 4) a general lack of site-specific aquifer information.

There are several methods for determination of contributing areas of a water-supply well or spring: deterministic numerical models, such as MODFLOW; analytical boundary element calculations, such as WHPA 2.2; or the use of observed data in the development of a flow net. A 2-dimensional flow net can be developed for most aquifers in Texas for the determination of contributing areas. Flow-net analysis is valid for most aquifers for the following reasons. Aquifers will be evaluated on a regional scale. The length of most aquifers in Texas is several orders of magnitude longer than the aquifer thickness, therefore, flow in the aquifer can be approximated as 2-dimensional along the length of the aquifer. The dip of most aquifers in Texas is very slight (less than 40 feet per mile), therefore the flow can be considered horizontal. It will be assumed that aquifers in Texas are: homogeneous in composition, horizontally isotropic (the Edwards aquifer is an exception), are laterally extensive on a regional scale, and flow in the aquifer is laminar (Darcy's law is valid).

For flow-net analysis, a regional water table map (unconfined aquifer) or potentiometric surface map (confined aquifer) initially must be developed for each aquifer. The flow net for an unconfined isotropic media is developed by defining the lines perpendicular to the water table map (flowpaths). A flow net is a combination of the water table contours and the flowpaths. Once specific data layers are developed for each aquifer type, spatial analysis tools can be used to develop the portion of a flow net that defines the contributing area to the water-supply well or spring. Additional calculations can be made to determine time-of-travel and amount of discharging water from the well in all aquifer categories except the anisotropic karst aquifer (Edwards aquifer). The characterization of the aquifer is such that the vertical movement of water to the water table is not approximated; only the horizontal movement. Thus, the assumption is that the contributing area to a well in an unconfined system is the area directly above the flowpaths for a specified end time (2, 5, 10, 20, and 100 years). In a confined system, the contributing area would be that area terminating in the outcrop of the aquifer for similarly specified end times.

Some PSOCs, such as oil and gas production wells, wastewater or brine injection wells, domestic and irrigation water-supply wells, and abandoned wells, may penetrate or breach a confining unit above a confined aquifer. These wells may be poorly-constructed or deteriorated and could allow vertical flow from the land surface through the confining unit into the water-supply aquifer. Therefore, the area directly above the flowpaths that extend to a 2-, 5-, 10-, 20-, and 100-year time-of-travel from the well or spring also will be delineated as a contributing area even if this area is not within the outcrop of the confined aquifer. This contributing area will be used to search for PSOCs that may penetrate or breach the confining unit (Ground-Water Component 6).

Delineation of contributing recharge areas, by the method proposed here, requires that several input parameters be defined for equations that solve for drawdown due to a pumping well. A goal of this component will be to determine the sensitivity of the size and shape of the contributing recharge areas to variations in input parameters. The sensitivity analysis will involve changing each variable in the drawdown and velocity equation within reasonable limits and statistically evaluating the results. The overall goals of the sensitivity analysis are to:

- evaluate the level of precision required to obtain reliable and reproducible results,

- determine which parameters significantly influence the size and shape of the contributing recharge areas, and

- define data deficiencies that may be addressed with future hydrologic investigations.

Prototype software will be developed during the early stages of the SWAP Software Development Component to evaluate which variables have the most and least effect on the contributing recharge areas. Additionally, development of the prototype software will allow for testing and experimentation to determine the best and most efficient way of conducting calculations.

Goal and Objectives

The objective of this project is to delineate contributing areas to public water-supply wells or springs deriving their water from five categories of aquifers as follows:

- Flow net, time-of-travel, and contributing area for wells or springs in unconfined isotropic aquifers
- Flow net, time-of-travel, and contributing area for wells or springs in confined isotropic aquifers
- Flow net, time-of-travel, and contributing area for wells or springs in alluvial aquifers
- Contributing area for wells or springs in the Edwards aquifer
- Contributing area for wells or springs in unknown aquifers

Scope of the project includes delineation of the above contributing areas for approximately 16,000 water-supply wells or springs.

Approach

The approach will vary dependent on the aquifer category of the water-supply well or spring, and whether ground water in a specified time-of-travel capture zone for the well or spring is under the influence of surface water. The discussion that follows describes how contributing recharge areas of supply wells will be calculated using methods appropriate to the aquifer type identified in Component 1. The five aquifer types (unconfined isotropic, confined isotropic, alluvial, Edwards, and "other") are discussed here as separate tasks.

<u>Task 2.1: Develop Database For Flow Net And Time-Of-Travel For Unconfined Isotropic Aquifers</u>

Task 2.1.1: Compile Data and (or) Digital Map Datasets.
Data regarding unconfined aquifers in hard (paper) copy and digital format will be compiled and reviewed. Hard-copy maps will be assessed regarding their scale, accuracy,

and applicability to SWAP. Some datasets in digital format already exist for unconfined aquifers. These formats include existing Geographic Information System (GIS) coverages in various forms and Computer Aided Drafting and Design (CADD) drawing files. It is common for public-supply wells to be screened in (or open to) more than one aquifer, therefore data also are required for underlying confined aquifers. Compilation of data for confined aquifers will be addressed in Task 2.2.1, below. Only transmissivity data for confined aquifers will be required as part of Task 2.1.1

Task 2.1.2: Acquire or Construct Digital Maps. Based on results of Task 2.1.1, hydrologic data for unconfined aquifers will be acquired from all available sources. If in a GIS format, coverages may require further processing. Other type files will require further processing to ensure line or polygon topology and correct attribution. Hard-copy maps will either be scanned or digitized. Both scanning and digitizing will require input of attributes associated with map features. If available, digital versions of contour maps showing spatial distribution of aquifer characteristics such as the base of the aquifer, hydraulic conductivity, porosity, water table, and transmissivity of underlying aquifers will be converted into a three-dimensional representation (tin or lattice data structure), so that interpolation of contour values can be performed at the well location. Table 2.1 lists aquifer characteristics and attributes that are necessary for calculation of the contributing recharge area in unconfined aquifers. Table 2.1 also indicates whether interpolation is desirable, based on the availability of contour maps for that specific hydrologic characteristic. If digital or hard-copy maps of these data are not available, a constant value will be inserted into the appropriate field in the Master Aquifer Coverage (MAC) (Component 1).

Table 2.1: Hydrologic data required for calculation of contributing recharge areas in unconfined aquifers

[L, line; P, polygon; X, point; ft, feet; ft/d, feet per day; PWS, Public Water Source]

Hydrologic Characteristic	**Coverage Type [a]**	**Interpolation desirable?**	**Description/ attributes**
Base	L	Yes	Contours of elevation (ft) 1
Extent	P, L	No	Created as part of Component 1
Hydraulic conductivity (K)	L	Yes	Contours, in consistent units (ft/d)
Porosity (n)	L	Yes	Contours, in consistent units (percent)
Regional potentiometric Surface (water table)	L	Yes	Contours of elevation (ft)

Hydrologic Characteristic	Coverage Type [a]	Interpolation desirable?	Description/ attributes
PWS wells	X	No	Created as part of Component 1
Saturated thickness	L	Yes	Contours (ft); if unavailable calculate (water table – base)
Transmissivity (T)	L	Yes	Contours, in consistent units (ft^2/d)

[a] Coverage may contain more than one type of feature to allow for both polygon and arc attributes.

Although the overall project uses a regional approach, there is also an abundance of local-scale data from aquifer tests and smaller-scale projects. For areas where no map data are available, local-scale data will be a key element providing the required data for contributing recharge area delineation. Thus, a major focus of this task will be to assess local-scale data and create a database describing availability and types of data that are available. Incorporation of this data into the SWA program will require evaluation on a site-by-site basis, but it is anticipated that a point coverage will be created to hold these data and statistical measures or regionalization of aquifer parameters will be conducted whenever possible.

Task 2.1.3: Determine Contributing Recharge Areas for Public-Supply Well or Springs in Unconfined Aquifers. There are several steps involved in defining the contributing recharge area for a pumping well. Each step will be programmed into a series of computer programs that will use data obtained from overlay analyses. The initial testing of the software will include sensitivity analyses to evaluate the degree to which changes in input variables alter the contributing recharge area. The individual subtasks for computation of the contributing recharge area are discussed below.

Task 2.1.3.1: Calculate drawdown using the modified Theis equation (Cooper and Jacob, 1946).

$$s=(0.183Q)/Kb)(\log(2.25Kbt/(r^2Sy)) \quad (1)$$

where, *s* equals drawdown, *Q* is the pumping rate, *K* is hydraulic conductivity, *b* is the saturated thickness, *t* is time, *r* is the radial distance from the pumping well, and *Sy* is the specific yield. Drawdown will be calculated at each grid cell within the flow field to determine the resulting head distribution in task 2.1.3.2. If drawdown is expected to be a significant part of the saturated thickness, a different technique will be employed.

Task 2.1.3.2: Subtract drawdown from water-table surface. Drawdown will be calculated in all adjoining grid cells deemed to have a potential influence from the pumping well. The grid size will have to be of small enough spacing so that a smooth cone of depression is generated. Using the principal of superposition, drawdown will be subtracted from a grid of the water-table surface to derive a new surface showing the influence of pumping.

Task 2.1.3.3: Compute flowpaths and velocity. Flowpaths will be computed using hydrologic modeling tools that draw flowpaths perpendicular to the modified water-level contours. Velocity (*V*) along each flowpath will be calculated by multiplication of the gradient (*i*) within a grid cell by the hydraulic conductivity (*K*) divided by the effective porosity (*n*), as in equation 2, below.

$$V=iK/n \qquad (2)$$

Task 2.1.3.4: Compute 2-, 5-, 10-, 20-, and 100-year time-of-travel. Times-of-travel will be calculated by multiplying velocity by the specified time period giving a total length. This length will be measured from the well along a flowpath and terminated at the 2-, 5-, 10-, 20-, and 100-year times-of-travel. Computing similar lengths along each flowpath contributing water to a well will result in a series of points that have the similar times-of-travel. Connecting all points for the 20-year time-of-travel will often result in an elliptical area. The contributing area to a well is that area defined by the terminations of the flowpaths.

Task 2.1.3.5: Conduct sensitivity analyses on input variables. Because much of the data that will be used for these calculations is approximated or interpolated, a sensitivity analysis will be performed to examine the influence of variations in input variables. Each variable will be varied within a reasonable range and statistical measures will be used to compare the effect on the contributing recharge area to a representative sample of public-supply wells or springs.

Task 2.2: Develop Database For Flow Net And Time-Of-Travel For Confined Isotropic Aquifers

Task 2.2.1: Compile Data and (or) Digital Map Datasets. This process will be identical to that described in Task 2.1.1, except that data regarding confined aquifers will be compiled and reviewed.

Task 2.2.2: Acquire or Construct Digital Maps. This process is identical to that described in Task 2.1.2, except that slightly different hydraulic data are needed for the confined aquifer determinations. These data are listed in Table 2.2.

Table 2.2: Hydrologic data required for calculation of contributing recharge areas in confined aquifers
[L, line; P, polygon; X, point; ft, feet; ft/d, feet per day; PWS, Public Water Source]

Hydrologic Characteristic	**Coverage Type [a]**	**Interpolation desirable?**	**Description/ attributes**
Base	L	Yes	Contours of elevation (ft)
Extent	P, L	No	Created in Component 1
Top	L	Yes	Contours of elevation (ft)
Hydraulic conductivity (K)	L	Yes	Contours, in consistent units (ft/d)
Porosity (n)	L	Yes	Contours, in consistent units (percent)
Regional potentiometric surface (water table)	L	Yes	Contours of elevation (ft)
PWS wells	X	No	Created in Component 1
Storage coefficient	L	Yes	Contours of storage (dimensionless)
Thickness	L	Yes	Contours (ft)
Transmissivity (T)	L	Yes	Contours, in consistent units (ft^2/d)

[a] Coverage may contain more than one type of feature to allow for both polygon and arc attributes.

Task 2.2.3: Determine Contributing Recharge Areas for Public-Supply Well or Springs in Confined Aquifers. Most details of the contributing recharge area calculation are similar to those of the unconfined aquifer, however the Theis (1935) equation will be used.

Task 2.2.3.1: Calculate drawdown using Theis equation. For confined conditions, the Theis (1935) equation with subsequent revisions by Cooper and Jacob (1946) will be used. Equation 3 can be used for large values of *t* and calculates the drawdown at any point in the flow field.

(3)

$$s=(0.183Q)/Kb)(\log(2.25Tt/(r^2Sy))$$

where *s* equals drawdown, *Q* is the discharge rate of the well, *T* is transmissivity, *t* is time, *r* equals the radial distance from the pumping well, and *S* equals the storage coefficient. It will be assumed that the cone of depression has reached steady state, therefore a time of 20 years (7,300 days) will probably be adequate.

Task 2.2.3.2: Subtract drawdown from potentiometric surface. This task will be identical to Task 2.1.3.2.

Task 2.2.3.3: Compute flowpaths and velocity. This task will be identical to Task 2.1.3.3.

Task 2.2.3.4: Compute 2-, 5-, 10-, 20-, and 100-year time-of-travel and project to surface. This task will be identical to Task 2.1.3.4.

Task 2.2.3.5: Conduct sensitivity analyses on input variables. This task will be identical to Task 2.1.3.5 for a representative sample of public-supply wells or springs.

<u>Task 2.3: Develop Database For Flow Net And Time-Of-Travel For Alluvial Aquifers</u>

Task 2.3.1: Compile Data and (or) Digital Map Datasets. This process will be identical to that described in Task 2.1.1, except that data regarding alluvial aquifers will be compiled and reviewed.

Task 2.3.2: Acquire or Construct Digital Maps. This process will be identical to that described in Task 2.1.2, except that slightly different hydraulic data are needed for the alluvial aquifer determinations, namely, the location and stage of rivers. River location and stage are necessary because wells in alluvium commonly induce infiltration from a nearby river. Additionally, the assumption that the aquifer is of greater extent than the radius of influence of the pumping well is invalid because bedrock walls are often encountered as a boundary condition. Data required for computation of a flow net and time-of-travel for alluvial aquifers are listed in Table 2.3.

Table 2.3: Hydrologic data required for calculation of contributing recharge areas in alluvial aquifers
[L, line; P, polygon; X, point; ft, feet; ft/d, feet per day; PWS, Public Water Source]

Hydrologic Characteristic	**Coverage type**	**Interpolation desirable?**	**Description/attributes**
Base	L	Yes	Contours of elevation (ft)
Extent	P, L	No	Created in Component 1
Top	L	Yes	Contours of elevation (ft)
Hydraulic conductivity (K)	L	Yes	Contours, in consistent units (ft/d)
Porosity (n)	L	Yes	Contours, in consistent

Hydrologic Characteristic	**Coverage type**	**Interpolation desirable?**	**Description/attributes**
			units (percent)
Regional potentiometric surface (water table)	L	Yes	Contours of elevation (ft)
PWS wells	X	No	Created in Component 1
Boundary location	L	No	Created in component 1
River location	L	No	Location of river reaches
Saturated thickness	L	Yes	Contours (ft)
Transmissivity (T)	L	Yes	Contours, in consistent units (ft^2/d)

Task 2.3.3: Determine Contributing Recharge Areas for Public-Supply Well or Springs in Alluvial Aquifers. Most details of the contributing recharge area calculation are similar to those of the unconfined aquifer, however image-well theory will be used to simulate boundary conditions.

Task 2.3.3.1: Calculate drawdown at the pumping well using image wells and the modified Theis (1935) equation (Cooper and Jacob, 1946). For alluvial aquifers, this calculation is complicated by the boundary conditions imposed by the river (a source of water) and the limited extent of the alluvium (a barrier to the flow of water). Therefore, image-well theory will be used to simulate the effects of these boundaries on the drawdown observed in the pumping well. The river is a source of water and will therefore be simulated as a recharging image well with the recharge rate equal to the pumping rate of the pumping well with opposite (-) sign, The image well for the stream will be placed at a distance 2 times the distance between the well and the stream. The limited extent of the alluvium will be simulated by adding a discharging well with a pumping rate equal to the pumping rate of the pumping well at a distance 2 times the distance between the well and the aquifer boundary.

Task 2.3.3.2: Subtract drawdown from potentiometric surface. This process will be identical to that described in Task 2.1.3.2 except that drawdown will be added or subtracted from the drawdowns that result from the recharging (river) and discharging (alluvial aquifer) boundary conditions.

Task 2.3.3.3: Compute flowpaths and velocity. This process will be identical to that described in Task 2.1.3.3.

Task 2.3.3.4: Compute 2-, 5-, 10-, 20-, and 100-year time-of-travel. This process will be identical to that described in Task 2.1.3.4.

Task 2.3.3.5: Conduct sensitivity analyses on input variables. This task will be identical to Task 2.1.3.5

Task 2.4: Delineate Contributing Areas for the Edwards Aquifer

Task 2.4.1: Determine recharge area in the outcrop using existing USGS Finite-Element Model.

The USGS has constructed a finite-element model of the Edwards aquifer (Kuniansky and Ardis [in press]). This model already incorporates much of the data required to determine recharge areas for public-supply wells. The only additional data required to rerun the model would be to include the locations and pumping rates of wells within the model area. Data requirements supplied by the calibrated model or other sources are listed in Table 2.4. The model will be used to determine flowpaths from public-supply wells back to the recharge areas in the outcrop.

Table 2.4: Hydrologic data required for calculation of contributing recharge areas in the Edwards aquifer
[PWS, Public Water Source]

Data needed	**Source and (or description)**
Flux vectors	From calibrated model
Aquifer outcrop areas	From calibrated model; areas of high stream loss, stream recharge rates, and estimates of inter-stream recharge rates
PWS wells	Created as part of Component 1

Task 2.4.2: Analysis of the Watershed Area Providing Direct Recharge to the Aquifer Where Surface Water Flows Over the Outcrop Area. Because the flow of ground water in the Edwards aquifer is closely related to flow of surface water and travel times can potentially be very short, the watershed supplying recharge to the public-supply well will also be delineated for evaluation as outlined in task 2.7. The complex karst hydrology of the Edwards aquifer and the potential for multiple porosities to take effect at various water levels (e.g. the intersection of a conduit as water levels increase) require that all times-of-travel for PSOCs are assumed to be within the limits of concern.

Task 2.5: Delineate Contributing Areas For Unknown Aquifers

For wells that are screened or open to aquifers that have been categorized as unknown aquifer the Identification Component, a fixed radius of ½-mile for nonpoint source PSOCs and ¼-mile radius for point source PSOCs will be used. The following process will be used to delineate the contributing recharge area.

Task 2.5.1: Create two circular contributing areas around each PWS site that is identified as an unknown aquifer. The ½-mile radius will be used with non-point PSOCs and the ¼-mile radius will be used for point PSOCs. These polygons can then be used for an overlay with PSOCs. The data in Table 2.5 are necessary to complete this task.

Table 2.5: Data required for calculation of contributing areas in unknown aquifers
[PWS, Public Water Source; PSOC, potential source of contamination; X, point]

Hydrologic Characteristic	**Coverage type**	**Interpolation desirable?**	**Description/attributes**
PWS wells	X	No	Created as part of Task 1.1

Task 2.6: Delineate Contributing Areas

The USGS will process the estimated 16,000 public-supply wells and springs according the approach outlined above, using the software developed under the Software Development Component.

Task 2.7: Conjunctively Delineate Contributing Areas Under The Influence Of Surface Water

There are four basic categories of public-supply wells that may be determined to be under the influence of surface water. These categories include: 1) wells in a karst aquifer system, most notably the Edwards aquifer, 2) wells in an alluvial hydrogeologic setting where the capture zone of the well intersects a surface-water body, and 3) wells that have been determined to be under the influence of surface water by an MPA (microparticulate analysis) test, and 4) wells in unconfined areas where the capture zone (as determined in task 2.6) intersects major surface-water bodies.

Task 2.7.1: Define the surface-water body contributing water to the well.

Task 2.7.2: Define the latitude and longitude of the downstream point of the watershed to be defined.

Task 2.7.3: Analysis of the watershed area providing direct recharge to the aquifer. Once a downstream point or “pour point” has been determined for the watershed within the capture zone of the public supply well, a surface-water assessment approach will also be required. Specific needs of the analysis of the watershed area are given below:

- Contributing watershed delineation (where major stream crosses downstream of outcrop area or capture zone)
- Intrinsic characteristics assessment

- Non-point source assessment
- Point-source assessment
- Contaminant occurrence assessment
- Area-of-primary-influence assessment

Details of each of these needs are discussed further in the workplans for the surface-water assessments.

Task 2.8: Prepare Metadata

The USGS will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata (FGDC, 1994) for all developed aquifer coverages and the contributing area coverages. Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial datasets and information about the resultant dataset including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994). All coverages created or modified in this project will be quality control checked. In addition, the information will be peer reviewed by a Senior Ground-Water Hydrologist.

Deliverables

Deliverables for this project will be as follows:

- GIS coverage of contributing areas for public-supply wells or springs in unconfined isotropic aquifers
- GIS coverage of contributing areas for public-supply wells or springs in confined isotropic aquifers
- GIS coverage of contributing areas for public-supply wells or springs in alluvial aquifers
- GIS coverage of contributing areas for public-supply wells or springs in the Edwards aquifer
- GIS coverage of contributing areas for public-supply wells or springs in unknown aquifers
- FGDC-Compliant content-level metadata
- GIS coverages of aquifer properties

References

Cooper, H.H., and Jacob, C.E., 1946, A generalized graphical method of evaluating formation constants and summarizing well field history: Trans. Amer. Geophys. Union, v. 27, p. 526–534. Edwards aquifer reference

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Kuniansky, E.L., and Ardis, A.F., in press, Hydrogeology and Ground-Water Flow in the Edwards-Trinity Aquifer System, West-Central Texas, USGS Professional Paper, 1421–C

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.11.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.12: Global Positioning System.

Theis, C.V., 1935, The relation between the lowering of the piezometric surface and rate and duration of discharge of a well using ground water storage: Trans. Amer. Geophys. Union, v. 2, p. 519–524.

Non-point Source Component (Task 3)

Statement of Problem

The susceptibility of a public-water supply to non-point source contamination is primarily dependent on the hydrogeologic and land-use characteristics of the contributing area to the supply. Numerous studies have shown relations between the occurrence of contaminants in both surface- and ground water and the land-use practices within the contributing area. For example, Ulery and Brown (1995), demonstrated significant correlations between pesticide detections in surface water, and land use. Ferrari and others (1997), and Land and Brown (1996), demonstrated that the occurrence of pesticides in surface water is greater in urban and agricultural settings than in rangeland, forest, or other relatively undeveloped areas. Vowinkle and others (1996) determined vulnerability of public-supply wells to pesticide contamination in agricultural areas, and Land and others (1998) suggested that urban land-use within the aquifer outcrop could be associated with nitrate and pesticide detections in sampled wells. An impartial, scientific approach for assessing public ground-water supplies as to their susceptibility to non-point source contamination is not available at this time. Such an approach could help reduce monitoring costs where susceptibility is low; focus necessary monitoring on areas and compounds of more concern; and help guide remediation and pollution control efforts.

Objectives

The project will provide scientific input to the overall SWAP for the assessment of the susceptibility of ground-water supplies to non-point sources of contaminants. Sources originating from major human land uses, such as urban, agricultural, range, etc., will be considered. Natural environmental factors that can affect water quality will also be evaluated, including hydrologic characteristics of the soil and aquifer. Together, these human and natural factors comprise the environmental characteristics of the capture zone for a public-supply well. Existing water-quality data collected by the USGS, TNRCC, TWDB, USEPA, and others will be used in the analysis. Specific objectives include:

- Develop an updated statewide land use/cover coverage
- Develop database table with land use/cover class, associated contaminants, and estimates of quantities available from each land use/cover class other than agriculture
- Develop database table for agricultural land use with associated contaminants and estimates of quantities available
- Develop a database containing constituents with available water-quality data and selected environmental characteristics of sampled ground-water sites
- Determine, to the extent possible, statistical relations between environmental characteristics of the sites and the occurrence of contaminants
- Provide the SWAP with threshold values of environmental characteristics that indicate susceptibility of ground-water supplies to contamination (a threshold value is a measure

of the type of intensity of land use of other environmental characteristic (such as depth to water) that correlates with contaminant occurrence

- Develop and provide documentation (metadata)

Approach

The susceptibility of ground-water supplies to non-point sources of contaminants will be assessed with threshold values for constituents of concern developed from selected environmental characteristics. Statistical relations between the occurrence of contaminants in ground water and the environmental characteristics of the capture zone contributing the water (e.g. land use, clayey soil, depth to water, chemical load, etc.) will be used to determine the threshold values.

Task 3.1: Develop or Acquire a Statewide Census Coverage

USGS staff will acquire the 1990 census tract coverage from state or federal sources and format for use within SWSA components. Staff will also derive population density coverages as required from the census coverage.

Table 1: List of data attributes for Census and Population Density Coverage

Data Element	**Description or example**
State Fips Code	Federal Information Processing Standard Code
County Fips Code	Federal Information Processing Standard Code
Census Tract/Block Numbering Area	Cluster of census block groups
Census Block Group	Census block group
Population90	Census block population, 1990 Census
Population95	Estimated 1995 census block population
Population00	Estimated 2000 census block population (replace with actual census figures when available
Population Density90	Population density, 1990
Population Density95	Population density, 1995
Population Density00	Population density, 2000
Housing Density	Dwelling Units Per Acre
Narrative	Description of relevant information

Task 3.2: Develop Enhanced Statewide Land Use Coverage

The GIRAS (Mitchell and others, 1977) land-use dataset developed by the USGS National Mapping Division during the 1970s and early 1980s (Anderson and others, 1976) will be acquired, reformatted as necessary, and updated to include new urban areas, using the 1990 Census data coverage prepared under Task 3.1, using the method developed by EPA (Mynar and Hewitt, 1989) and enhanced by USGS (Hitt, 1994).

Table 2: List of data attributes for Land Use GIS Coverages

Data Element	**Data Description**
Land Use Code	USGS Land-Use Level Code
Land Use Class	Land Use Class
Area	Area in square miles

Task 3.3: Develop a Database Table with Land-Use Class and Associated Contaminants

Working from the list of regulated contaminants and contaminant groups prepared under a separate project USGS staff will prepare two database tables to be used in linking contaminants to land use class. Table 3 (below) will serve as the relational link between the land use/cover coverage and the contaminants table (Table 4) by contaminant group id, making possible the association of the various chemical groups or individual chemicals with land use/cover polygons, within the contributing area to the public water-supply well.

Table 3: List of suggested data elements for land-use class-associated contaminants database table

Data Element	**Description**
Contaminant Group Id	Unique identifier relating to contaminants database
Land Use Code	USGS Land Use/Cover Level Code
Narrative	Description of relevant information

Table 4: List of suggested data elements for contaminants database table

Data Element	**Description**
Contaminant Group ID	Unique identifier
Contaminant Group	Pesticides, metals, nutrients, etc.
Contaminant Name	Contaminant name
Chemical Properties Variables	Multiple elements containing relevant properties
Environmental Process Variables	Multiple elements containing relevant properties
Estimated Amount	Estimated amount associated with

	land-use type and area
Narrative	Description of relevant information

The SWSA software will reference these tables in order to evaluate the occurrence and relative amount of contaminants from non-agriculture land use/cover within the contributing area.

Task 3.4: Develop Agricultural Chemical Loss Database and Coverage

The Blackland Research Center, Temple, Texas will use the GLEAMS model (Knisel, 1993) to estimate pesticide loss due to runoff and leaching. Pesticide runoff is defined as movement beyond the edge of the field and will be estimated as pesticide in solution and pesticide adsorbed to soil material and organic matter. Pesticide leaching is leaching beyond the bottom of the root-zone. These estimates will, in turn, be used to develop a GIS coverage for agricultural land use that contains the average load of pesticides and recharge that is available to be leached into the ground water (written comm. Don Goss, Blackland Research Center, July, 1998). The resultant loads could still be subject to attenuation processes before reaching the ground water, however, the calculated pesticide yields will provide an environmental characteristic that will be used in the statistical analyses discussed above. Runoff and leaching estimates for pesticides used in Texas from clustered groups of soils will be averaged for 50 years from each of several clustered climates distributed throughout Texas. The pesticides used in Texas will be selected from a group of 335 pesticides for which data is known. These data come from a recent search of pesticide use and characteristic data in the United States, and represent the known best estimates for Texas.

The National Resource Inventory (NRI) is a data collection by the National Resource Conservation Service (NRCS) at 76,338 points in Texas. The data is collected on all points every ten years with an anniversary year ending in 2. One third of the points are sampled every ten years with an anniversary year ending in 7. Many attributes dealing with soils, crops, and conservation practices are collected at those points. The crops selected for these simulations will be the major row-crops identified at NRI points in Texas. The NRI point identifies the cultivation practice, i.e., contouring, terracing, or straight row farming.

Pesticide application timing will be based on the planting date, harvest date and purpose of the application. The planting and harvest date will be estimated using the climatic record from the station selected for each cluster and the growing days for the crop. This information will be verified and enforced with planting and harvest dates from existing data on farming practices developed at Blackland Research Center. A planting and harvest date will be estimated for each of the climate clusters based on mean daily high and low temperatures.

Pesticide application method will be based on planting date and purpose. The insecticides used as foliar application will be applied at label recommended frequency. Model simulations for all pesticides in the NRCS database will be used on appropriate crops. Parameters required for the selected model will be selected from the NRCS database. The Insect Control Guide or the Weed Control Guide will be used to determine the action of each compound when applied, how frequently, recommended rates, and methods of application. Those herbicides with application designations as 'all methods' will be considered pre-emerge herbicides. Some herbicides are designated only for pre-plant application and some only for post-plant. The Insect Control Guide includes the frequency of application, i.e. 3-5 days, 5 days, or 7 days. The selected model will apply the insecticide every 3 days for the 3-5 day recommendation 5 days for the 5-day recommendation and every 7 days for the 7-day recommendation. Some soil insecticides and nematicides are incorporated in the soil; some surface applied, and some applied over-the-top of foliage. The NRCS database also includes growth regulators and defoliants, both of which are applied on foliage.

The following describes how pesticide application dates are calculated from the planting date (PD) and harvest date (HD). All dates are Julian.

Preplant pesticides will be simulated with application on

$$(PD - 7)$$

Pre-emerge pesticides will be simulated with application on

$$PD$$

This list also includes soil insecticides and nematicides, both surface applied and incorporated.

Post-plant pesticides will be simulated with application on

$$(PD + 14)$$

There will be no repeat application of post-plant herbicides.

Over the top insecticides, fungicides, miticides and aracides, will be simulated in 3 repeat applications beginning at 1/3 of the growing season after planting date

$$NDAYS = (HD - PD) / 3.$$

The first application and each subsequent application will be as follows:

PD + NDAYS	First application of all repeat periods
PD + NDAYS + 3	1st 3-day repeat
PD + NDAYS + 5	1st 5-day repeat
PD + NDAYS + 6	2nd 3-day repeat
PD + NDAYS + 7	1st 7-day repeat
PD + NDAYS + 9	3rd 3-day repeat
PD + NDAYS + 10	2nd 5-day repeat
PD + NDAYS + 14	2nd 7-day repeat
PD + NDAYS + 15	3rd 5-day repeat
PD + NDAYS + 21	3rd 7-day repeat

Application of growth regulators will be at 1/4 the growing season before harvest,

$$GRD = HD - [(HD - PD)/4].$$

Growth regulators will be not applied before the last repeated pesticide application date shown above, even in short growing-season locations. To prevent this the application will be extended by one day from the last pesticide application. Defoliants in the NRCS pesticide database will be assumed to be applied 5 days before harvest date.

$$DEFDAY = HD - 5$$

Task 3.4.1: Establish Soil Clusters. The soils used in clustering will be the NRI points that have row crops growing. The soils will be clustered and tested for similarity of results within a cluster using the selected model. The soils selected for clustering are those unique soil phases from the NRI data that grow crops. This selection will reduce the number of soil phases from the total number NRI points growing soils. The selected soil phases will be clustered using a procedure after Sanabria and Goss (1997). Soil grouping is based on linear combinations of soil properties. The coefficients in the linear combinations will come from a multivariate factor analysis performed on the standardized matrix of soil characteristics. The number of clusters selected will reduce the variability within the clusters to a level at which the entire suite of soils in the cluster would be expected to behave similarly when used in the GLEAMS model. One soil near the centroid of a soil cluster will be chosen to represent all the soils of the cluster when running the GLEAMS model.

Task 3.4.2: Establish Climate Clusters. Climate stations used in the clustering will be the 79 climatic stations developed for use by climate generators in GLEAMS. The climate stations within a cluster will be tested for similarity of pesticide loss. Climatic stations with sufficient length and completeness of data have been developed from other modeling efforts. A technique similar to clustering soils will be used for climate. The number of climate clusters will reduce variability within the clusters to a level at which the entire suite of climate stations within a cluster will produce similar results when used in the chosen model. One climatic station per cluster will be chosen to represent all climatic stations in the cluster when applying the data to the model of choice.

Task 3.4.3: Establish Soil/Climate Clusters. GIS will be used to confirm intuitively reasonable soil and climate distributions for all clusters. Mapping the soils and climate by a geographic attribute will require associating the climate to a spatial area common to soils. An attempt will be made develop this association with three spatial attributes at NRI points. These are county (CO), Major Land Resource area (MLRA) and eight-digit Hydrologic Unit Areas (HUA8). Success has been accomplished by using only the HUA8 spatial areas, but greater detail could be derived from combining the three spatial areas mentioned above. This process will also define what climate clusters will be run with what soil clusters. Also the crops grown in each of the soil/climate cluster combinations will be defined. One climate cluster may have several soil clusters and several crops.

Task 3.4.4: Develop System to Automate Process. A system to automatically run all combinations of climate-soil-crop-pesticides will be developed. This will be a 'batch' process that will automatically choose soils and crops for each climate, and apply appropriate pesticides and copping practices.

Task 3.4.5: Run Gleams Model. The Model runs will be made to generate the data for all possible combinations required to estimate pesticide loss at each of the NRI points.

Task 3.4.6: Re-distribute Results. Distribution of the results back to NRI points will be accomplished by identifying the climate and soil for each NRI point with the cluster it is a member. The climate and soil cluster data and NRI point crop and cropping practice will then be related to a table of results. Each NRI point has a variable that relates that NRI point to areal distribution. This value may be required to determine how much of an area within the HUA8 or larger unit the NRI point occupies.

Task 3.4.7: Map Pesticide Loss to HUA and Land Use. Pesticide loss for important pesticides will by mapped to the HUA8 and agricultural Land Use polygons. Maps will be produced for distribution. The large output database will be placed on CD-ROMs and a system for retrieving this data will be developed. The CD-ROMs will be distributed to TNRCC and Texas USGS.

Task 3.5: Compile Available Water-Quality Databases

Water-quality data for ground-water sites will be compiled from available sources to be used in the correlations between contaminant occurrence and environmental characteristics of the capture zone. Data will include information collect by the USGS National Water Quality Assessment Program's (NAWQA) Trinity River Basin study (Land and others, 1998). This study includes water quality data for wells sampled from different aquifers with multiple land uses. Water quality data available from TWDB's water-quality and infrequent constituents databases, TNRCC's TRACs and PDWS databases, USGS' NWIS databases, and USEPA's STORET, and other available sources will be used.

Task 3.6: Determine Environmental Characteristics of Ground Water Sampling Sites

Environmental characteristics including human and natural factors known or suspected of influencing ground-water quality will be estimated for each sampling site. Natural factors include items such as the clay and organic carbon content of soils, depth to the water table, rainfall, aquifer matrix material, etc. Human factors include items such as land use type, population density, chemical loads, etc. Databases developed in tasks 3.1-3.3, soils data available from the NRCS's STATSGO (USDA, 1983) database, as well as databases developed in other SWAP projects will be compiled, reformatted, or created as necessary to develop statewide environmental characteristics databases that will be used in the characterization of the sites as well as in the overall SWSA.

Task 3.7: Relate the Occurrence of Water-Quality Constituents to Environmental Characteristics

The first step in the analysis will be to correlate statistical summaries of water-quality variables (e.g., median and 90th percentiles, percent detections, number of pesticides detected, etc.) to environmental variables (e.g., percent urban land use, depth to water, etc.). Depending on the strength of the relations and on the availability of data, a number of more sophisticated statistical techniques might be utilized, such as multiple regression analyses or a logistic regression. If data for a given parameter are simply unavailable or are so sparse as to preclude developing statistically valid relations, published reports from localized areas in Texas and from other parts of the country and best professional judgment will be used. The objective of these analyses is to identify the relations of environmental characteristics that lead to a conclusion that a ground-water supply is susceptible to contamination from a constituent. Once determined, these relations will allow the SWSA software to assess statewide environmental characteristics databases and determine if the capture zone of a public-supply well is vulnerable to non-point source contamination.

Task 3.8: Develop Metadata for Non-Point Source Databases

USGS staff will prepare FGDC-compliant content-level metadata (FGDC, 1994) for all coverages except the Pesticide Loss Coverage. Blackland Research Center staff will prepare Pesticide Loss Coverage and database table documentation to FGDC standards.

Quality-Assurance Plan

USGS and Blackland Research Center will conduct quality-control checks on all datasets generated. Established State standards and guidelines for GIS will be followed (Texas DIR, 1994). USGS staff or Blackland Research Center will deliver all coverages in the Texas Statewide Mapping System (TSMS) projection (Texas DIR, 1992), coordinate units in feet, NAD83 datum (Allison, B., TNRCC, IR, Interoffice Memorandum, 1/26/1998).

Deliverables

The statistical results of this study will identify the relations (or thresholds) of environmental characteristics that will allow the SWSA software to assess statewide environmental characteristics databases and determine if a ground-water supply is susceptible to contamination from a non-point source constituent. Deliverables for this project will consist of:

- Population density coverage
- Updated statewide land use/cover coverage
- GIS Coverage of Pesticide Loss by Agricultural Land-Use Class
- Database table with land use/cover class, pesticide losses to runoff estimates, the quantity of water run-off, pesticide losses to leaching estimates, the quantity of water leached, and the mass of sediment in runoff, by month or year
- Environmental characteristics databases
- Metadata

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Attachment - Ground Water Non-point Source Component (Task 3)

Using MODELS to Estimate Pesticide Loss for a Variety of Soils and Climates IN TEXAS

Don W. Goss
Blackland Research Center
Temple, Texas
Friday, July 10, 1998

Leaching and runoff estimates for pesticides used in Texas from clustered groups of soils will be estimated for 50 years from each of several clustered climates distributed throughout Texas. The pesticides used in Texas will be selected from a group of 335 pesticides for which data is known. The model to estimate the pesticide loss data will be GLEAMS. Pesticide runoff is movement beyond the edge of the field. Pesticide runoff will be estimated as pesticide in solution and pesticide adsorbed to soil material and organic matter. Pesticide leaching is leaching beyond the bottom of the root-zone.

NRI

The National Resource Inventory (NRI) is a data collection by the National Resource Conservation Service (NRCS) at 76,338 points in Texas (3&5). The data is collected on all points every ten years with an anniversary year ending in 2. One third of the points are sampled every ten years with an anniversary year ending in 7. Many attributes dealing with soils, crops, and conservation practices are collected at those points. The data available at each NRI point and code definitions for coded data are presented in attached documents.

CROPS

The crops selected for these simulations will be the major row-crops identified at NRI points in Texas.

CONSERVATON PRACTICE

The NRI point will have one of the cultivation practices dealing with contouring, terracing and straight row farming identified.

PLANTING AND HARVEST DATES

A planting and harvest date will be estimated for each of the climate clusters based on mean daily high and low temperatures.

PESTICIDE APPLICATION

Pesticide application timing will be based on the planting date, harvest date and purpose of applying the pesticide. Pesticide application method will be based on planting date and purpose. The insecticides used as foliar application will be applied at label recommended frequency.

SOIL CLUSTERS

The soils selected for clustering are those unique soil phases from the NRI data that grow crops. This selection will reduce the number of soil phases from the total number NRI points growing soils. The selected soil phases will be clustered using a procedure after Sanabria and Goss (6). Soil grouping is based on linear combinations of soil properties. The coefficients in the linear combinations will come from a multivariate factor analysis performed on the standardized matrix of soil characteristics. The number of clusters selected will reduce the variability within the clusters to a level the entire suite of soils in the cluster would expect to behave similarly when used in the GLEAMS model. One soil near the centroid of a soil cluster will be chosen to represent all the soils of the cluster when running GLEAMS.

CLIMATE CLUSTERS

Climatic stations with sufficient length and completeness of data have been developed from other modeling efforts. These 198 stations will be selected for clustering. A technique similar to clustering soils will be used for climate. The number of climate clusters will reduce variability within the clusters to a level the entire suite of climate stations within a cluster will produce similar results when used in the chosen model. One climatic station per cluster will be chosen to represent all climatic stations in the cluster when applying the data to the model of choice.

PLANTING AND HARVEST DATES

The planting and harvest date will be estimated using the climatic record from the station selected for each cluster and the growing days for the crop. This information will be verified and enforced with planting and harvest dates from existing data on farming practices developed at Blackland Research Center.

PESTICIDE APPLICATION

Model simulations for all pesticides in the NRCS database* will be used on appropriate crops. Parameters required for the selected model will be selected from the NRCS database. The *Insect Control Guide* (1) or the *Weed Control Guide* (4) will be used to determine the action of each compound when applied, how frequently, and recommended rates and methods of application.

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* The NRCS pesticide database contains the basic pesticide properties. Assembled by Wauchope et al. 1992 (3) with foliar characteristics added by R.A. Leonard in (2) using the procedure by Willis and McDowell, 1987. (5)

Those herbicides with application designations as 'all methods' will be considered pre-emerge herbicides. Some herbicides are designated only for pre-plant application and some only for post-plant.

The *Insect Control Guide* (1) includes the frequency of application, i.e. 3-5 days, 5 days, or 7 days. The selected model will apply the insecticide every 3 days for the 3-5 day recommendation 5 days for the 5-day recommendation and every 7 days for the 7-day recommendation. Some soil insecticides and nematicides are incorporated in the soil; some surface applied, and some applied over-the-top of foliage. The NRCS database also includes growth regulators and defoliants, both of which are applied on foliage.

A table at the end of this proposal lists all the pesticides for we have data and the crops they are used on for the state of Texas. This data comes from a recent search of pesticide use and characteristic data in the United States. It is doubtful if we could locate sufficient data to run any pesticides not located in this table.

The following description indicates how pesticide application dates are calculated from the planting date (PD) and harvest date (HD). The dates are Julian dates.

Preplant pesticides will be simulated with application on

(PD - 7)

Pre-emerge pesticides will be simulated with application on

PD

This list also includes soil insecticides and nematicides, both surface applied and incorporated.

Post-plant pesticides will be simulated with application on

(PD + 14

There will be no repeat application of post-plant herbicides.

Over the top insecticides, fungicides, miticides and aracides, will be simulated in 3 repeat applications beginning at 1/3 of the growing season after planting date

NDAYS = (HD - PD) / 3.

The first application and each subsequent application will be as follows:

PD + NDAYS	First application of all repeat periods
PD + NDAYS + 3	1st 3-day repeat
PD + NDAYS + 5	1st 5-day repeat
PD + NDAYS + 6	2nd 3-day repeat
PD + NDAYS + 7	1st 7-day repeat
PD + NDAYS + 9	3rd 3-day repeat
PD + NDAYS + 10	2nd 5-day repeat
PD + NDAYS + 14	2nd 7-day repeat
PD + NDAYS + 15	3rd 5-day repeat
PD + NDAYS + 21	3rd 7-day repeat

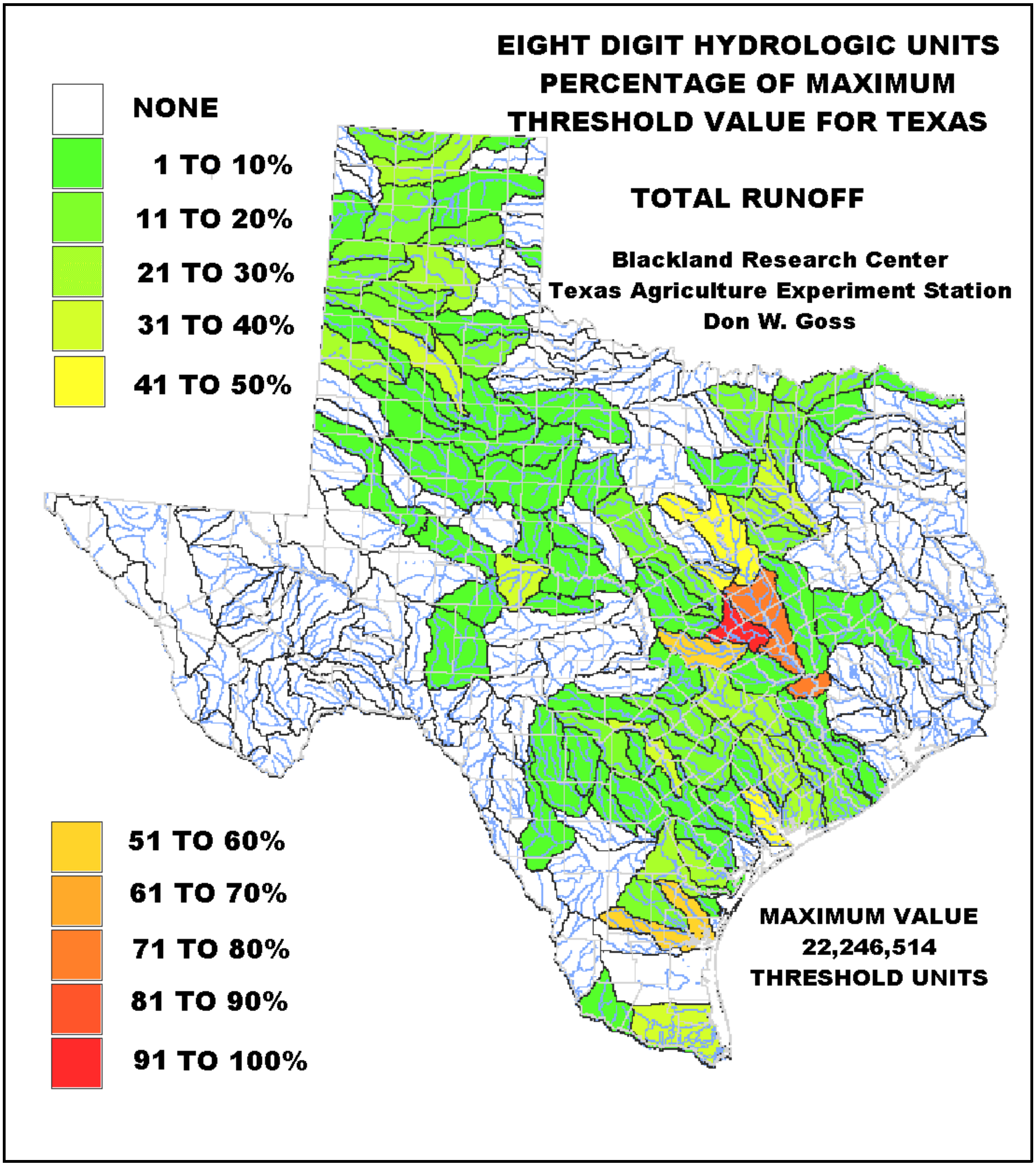
Application of growth regulators will be at 1/4 the growing season before harvest,

$$GRD = HD - [(HD - PD)/4].$$

Growth regulators will be not applied before the last repeated pesticide application date shown above, even in short growing-season locations. To prevent this the application will be extended by one day from the last pesticide application. Defoliants in the NRCS pesticide database will be assumed to be applied 5 days before harvest date.

$$DEFDAY = HD - 5$$

Below is an example of the pesticide loss data that can be produced in GIS form. This is from a study done for the National Resource Conservation Service to estimate pesticide hazards in United States. The example shows only Texas from this national study. The data is atrazine runoff in acre units times the ratio of runoff concentration to EPA's health advisory limit concentration. This is a threshold value used for planning purposes. The plotted value is the percent that the eight-digit-hydrologic unit is of the eight-digit-hydrologic unit with the greatest threshold value sum. Data can be presented in many forms. The particular form chosen will depend on the needs to be demonstrated. The primary data will be the mass of pesticide in runoff or leaching losses, the mass of water in run off, the mass of sediment in runoff, and the mass of water in leaching by month or year. The data presented in the figure is based on the average concentration of runoff water by year.


EIGHT DIGIT HYDROLOGIC UNITS
PERCENTAGE OF MAXIMUM
THRESHOLD VALUE FOR TEXAS
TOTAL RUNOFF
Blackland Research Center
Texas Agriculture Experiment Station
Don W. Goss
NONE
1 TO 10%
11 TO 20%
21 TO 30%
31 TO 40%
41 TO 50%
51 TO 60%
61 TO 70%
71 TO 80%
81 TO 90%
91 TO 100%
MAXIMUM VALUE
22,246,514
THRESHOLD UNITS

PESTICIDES AND CROPS FOR TEXAS

Common Name	Trade Name	CASRN	Use	New	Crops
2,4-D Acid	Dacamine	94-75-7	H		CR, GS
2,4-D Ester	Aqua Kleen	1928-38-7	H	*	CR,GS,SC,WW
2,4-D Amine	Weedar	2008-39-1	H		CR, GS,SC
2,4-DB Acid	Embutox	10433-59-7	H	*	SB,PN,WW
2,4-DB Ester	Butyrac Ester	32357-46-3	H		
2,4-DB Sodium Amine	Butyrac	94-82-6	H		PN,SB
2,4,5-T Acid	Ded-Weed	93-76-5	H	*	
2,4,5-T Amine	Weed-B-Gon	93-76-5	H		SC
2,4,5-T Ester	Weedone	2545-59-7	H	*	
2,4,5-TP	Silvex	?	H		
3-CPA Sodium Salt	Fruitone CPA	101-10-0	G		
Abamectin	Dynamec	65195-55-3	I,M	*	CO
Acephate	Orthene	30560-19-1	I		CO,SB
Acifluorfen	Tackle	62476-59-9	H		SB,PN,WW
Acrolein	Aqualin	107-02-8	H	*	
Alachlor	Lasso	15972-60-8	H		CR,CO,PN,SB,SC
Aldicarb	Temik	116-06-3	I,N		CO,GS,PN,SB,SC
Aldoxycarb (Aldicarb Sulfone)	Standak	1646-88-4	I,N		
Aldrin	Aldrin	309-00-2	I		
Ametryn	Evik	834-12-8	H		CR,SC
Amidochlor	Limit	?	?		?
Aminocarb	Matacil	2032-59-9	I		CR,CO,SB
Amitraz	Mitac	33089-61-1	A,I		CR,CO,PN,SB
Amitrole	Amitrol T	61-82-5	H		
AMS	Ammate	773-06-0	H	*	
Ancymidol	A-Rest	12771-68-5	G		
Anilazine	Dyrene	101-05-3	F		WW
Arsenic Acid	Dessicant L-10	1327-53-3	D		CO
Asulam Sodium Salt	Asulox	3337-71-1	H		SC
Atrazine	Aatrex	1912-24-9	H		CR,GS,SC
Azinphos-Methyl	Guthion	86-50-0	I		CO,SB,WW
Barban	Carbyne	101-27-9	H	*	WW
Benalaxyl	Galben	71626-11-4	F	*	
Bendiocarb	Tattoo	22781-23-3	I		
Benefin	Balan	1861-40-1	H		PN
Benodanil	Calirus	15310-01-7	F	*	WW
Benomyl	Benlate	17804-35-2	F		All
Bensulfuron Methyl	Londax	83055-99-6	H		

Bensulide	Prefar	741-58-2	H		CO
Bentazon	Basagran	50723-80-3	H		CR,PN,SB
BHC	Benzex	?	?		?
Bifenox	Modown	42576-02-3	H		CR,GS,SB,WW
Bifenthrin	Talstar	82657-04-3	I,M		CO
Bromacil	Hyvar	314-40-9	H		
Bromoxynil Octan. Ester	Buctril	1689-99-2	H		CR,GS,WW
Common Name	Trade Name	CASRN	Use	New	Crops
Butachlor	Machete	23184-66-9	H	*	
Butylate	Satan	2008-41-5	H		CR
Captafol	Happen	2425-06-1	F	*	
Captain	Orthocide	133-06-2	F		PN
Carbaryl	Seven	63-25-2	I		All
Carbendazim (M.C.)	Bavistin	10605-21-7	F	*	
Carbofuran	Furadan	1563-66-2	I,N		CR,CO,GS,PN,SB, SC
Carbon Disulfide	Carbon Disulfide	75-15-0	I	*	
Carbophenothion	Trichion	786-19-6	A,I	*	
Carbolic	Vitavax	5234-68-4	F		CR,CO,GS,PN,SB, SC,WW
CAA (Allidochlor)	Randox	93-71-0	H	*	CR,SB,SC
Chloramben Salts	Amiben	133-90-4	H		SB
Chlorbromuron	Maloran	13360-45-7	H	*	SB
Chlordane	Octa-Klor	57-74-9	I		
Chlordimeform Hydrochloride	Fundal	19750-95-9	I		CO
Chlorimuron-ethyl	Classic	90982-32-4	H		SB
Chlorobenzilate	Acaraben	510-15-6	A,M		CO,SB
Chloroneb	Terraneb	2675-77-6	F		CO,SB
Chloropicrin	Telone C-17	76-06-2	N,S		
Chlorothalonil	Bravo	1897-45-6	F		PN,SB
Chloroxuron	Tenoran	1982-47-4	H		SB
Chlorpropham CIPC	Sprout Nip	101-21-3	H		CR,CO,GS,PN,SB
Chlorpyrifos	Lorsban	2921-88-2	I		
Chlorpyrifos-methyl	Reldan	5598-13-0	I	*	
Chlorsulfuron	Glean	64902-72-3	H		WW
Chlozolinate	Serinal	72391-46-9	F	*	
Cimethylin	Cinch	87818-31-3	H	*	CO,SB,PN
Clofentezine	Apollo	74115-24-5	M	*	CO
Clomazone	Command	81777-89-1	H		SB
Clopyralid	Lontrel	1702-17-6	H		WW
Cryolite	Prokil	15096-52-3	I	*	
Cyanazine	Bladex	21725-46-2	H		CR,CO,GS
Cycloate	Ro-Neet	1134-23-2	H		

Cyfluthrin	Baythroid	68359-37-5	I		CO,PN
Cyhexatin	Plictran	13121-70-5	A	*	
Cypermethrin	Ammo	52315-07-8	I		CO
Cyromazine	Larvadex	66215-27-8	I		
Dalapon	Dowpon	?	?		?
Dalapon Sodium Salt	Dalapon	127-20-8	H		CR,SC
Daminozide	Alar	1596-84-5	G		
Dazomet	Basamid	533-74-4	S	*	
DBCP	Fumazone	96-12-8	N		
DCNA (Dicloran)	Botran	99-30-9	F		
DCPA	Dacthal	1861-32-1	H		CO,SB
DDD (TDE)	Rothane	72-54-8	I	*	
DDE	DDT (o,p')	3424-82-6	DP	*	
Common Name	Trade Name	CASRN	Use	New	Crops
DDT	DDT	50-29-3	I		
Demeton	Systox	8065-48-3	A,I	*	
Desmedipham	Betanex	13684-56-5	H		
Diazinon	Spectracide	333-41-5	I,N		All
Dicamba	Banvel	1918-00-9	H		CR,GS,SC
Dichlobenil	Carsoron	1194-65-6	H		WW
Dichlone	Phygon	117-80-6	F	*	
Dichlormid	Eradicane	37764-25-3	H	*	GS
Dichloropropane	D-D	78-87-5	N,S	*	
Dichloropropene	Telone II	542-75-6	N,S		All
Dichloroprop Ester	Weedone	120-36-5	H		
Diclofop-Methyl	Hoelon	51338-27-3	H		SB,WW
Dicofol	Kelthane	115-32-2	M		CO
Dicrotophos	Bidrin	141-66-2	I		CO
Dieldrin	Octalox	60-57-1	I		
Dienochlor	Pentac	2227-17-0	A	*	
Diethatyl-Ethyl	Antor	58727-55-8	H		
Difenzoquat	Avenge	43222-48-6	H		CR,WW
Diflubenzuron	Dimilin	35367-38-5	I		CO,SB
Dimethipin	Harvade	55290-64-7	D		CO
Dimethirimol	Milcurb	5221-53-4	F	*	
Dimethoate	Cygon	60-51-5	I,M		
Dimethylarsinic Acid	Cotton Aide HC	75-60-5	H	*	CO
Dinitromine	Cobex	29091-05-2	H	*	
Dinocap	Karathane	39300-45-3	F,M		
Dinoseb Phenol	Dinitro	88-85-7	H		CR,CO,PN,SB,WW
Dinoseb Salts	Dinitro	88-85-7	H		CR,CO,PN,SB,WW
Dioxycarb	Elecron	6988-21-2	I	*	
Diphenamid	Enide	957-51-7	H		CO,PN

Dipropetryn	Sancap	4147-51-7	H		CO
Diquat Dibromide	Diquat	80-00-7	D,H		GS,SB,SC
Disulfoton	Di-Syston	298-04-4	I		CR,CO,GS,PN,SB, WW
Diuron	Karmex	330-54-1	H		CR,CO,GS,SC,WW
DNOC Sodium Salt	Elgetol	534-52-1	F		
Dodine Acetate	Cyprex	10/3/39	F		
DSMA	Clout	144-21-8	H	*	CO
Endosulfan	Thiodan	115-29-7	I		CO,WW
Endothall Salt	Accelerate	145-73-3	D,H		CO
Endrin	Endrex	72-20-8	I	*	CO,GS,SC
EPN	EPN	2104-64-5	A,I		CO,GS
EPTC	Eradicane	759-94-4	H		CR,CO
Esfenvalerate	Asana	66230-04-4	I		CR,CO
Ethalfluralin	Sonalan	69481-52-3	H		SB
Ethephon	Cerone	16672-87-0	G		WW
Ethion	Ethanox	563-12-2	A,I		
Ethofumesate	Norton	26225-79-6	H		
Common Name	Trade Name	CASRN	Use	New	Crops
Ethoprop	Mocap	13194-48-4	I,N		CR,PN,SB,SC
Ethylene Dibromide (EDB)	Bromofume	109-93-4	I	*	
Etridiazole	Terrazole	2593-15-9	F		
Fenac	Fenatrol	2439-00-1	H		SC
Fenamiphos	Nemacur	22224-92-6	I,N		
Fenaminosulf	Lesan	140-56 7	F	*	
Fenarimol	Rubigan	60168-88-9	F		
Fenbutatin Oxide	Vendex	13356-08-6	M		
Fenfuram	Pano-Ram	24691-80-3	F	*	
Fenitrothion	Fenitox	122-14-5	I		CR,CO,GS,PN,SB, SC,WW
Fenoxaprop-Ethyl	Acclaim	66441-23-4	H		SB
Fenoxycarb	Logic	72490-01-8	I		
Fenpropathrin	Danitol	64257-84-7	A,I	*	
Fensulfothion	Dasanit	115-90-2	I		CO,WW
Fenthion	Baytex	55-38-9	I		CO,SC
Fenuron	Dybar	101-42-8	H	*	
Fenvalerate	Pydrin	51630-58-1	I		CR,CO,PN,SB,SC
Ferbam	Carbamate	14484-64-1	F		
Fluazifop-Butyl	Fusilade	69806-50-4	H	*	CO,SB
Fluazifop-P-Butyl	Fusilade	69335-91-7	H		CO,SB
Fluchloralin	Basalin	33245-39-5	H	*	CO,PN,SB
Flucythrinate	Pay-Off	70124-77-5	I		CR,CO
Flumetralin	Prime	62924-70-3	G		
Fluometuron	Cotoran	2164-17-2	H		CO

Fluridone	Sonar	59756-60-4	H		
Fluvalinate	Mavrik	69409-94-5	I,M		
Fomesafen Salt	Reflex	72178-02-0	H		SB
Fonofos	Dyfonate	944-22-9	I		CR,GS,PN
Formetanate Hydrochloride	Carzol	23422-53-9	I,M		
Fosamine Ammonium Salt	Krenite	25954-13-6	H		
Fosetyl-Aluminum	Aliette	39148-24-8	F		
Glufosinate Ammonium	Final	77182-82-2	H		
Glyphosate Amine	Roundup	1071-83-6	H		CR,CO,GS,PN,SB, SC,WW
Haloxyfop-Methyl	Verdict	69806-40-2	H	*	
Heptachlor	Heptagram	76-44-8	I	*	GS,WW
Hexachlorobenzene (HCB)	Anticarie	118-74-1	F	*	WW
Hexazinone	Velpar	51235-04-2	H		
Hexythiazox	Savey	78587-05-0	A,I		CO
Hydramethylnon	Amdro	67485-29-4	I		
Imazalil	Bromazil	35554-44-0	F	*	CO,WW
Imazamethabenz-m	Assert	81405-85-8	H		WW
Imazamethabenz-p	Assert	81405-85-8	H		WW
Imazapyr Acid	Arsenal	81334-34-1	H		
Imazapyr Amine	Chopper	81334-34-1	H		
Imazaquin Acid	Sceptor	81335-37-7	H	*	SB
Imazaquin Ammonium Salt	Scepter	81335-47-7	H		SB
Iprodione	Rovral	36734-19-7	F		PN
Common Name	Trade Name	CASRN	Use	New	Crops
Isazofos	Miral	42509-80-8	I		CR,CO
Isofenphos	Oftanol	25311-71-1	I		CR
Isopropalin	Paarlan	33820-53-0	H		
Isoxaben	Knockout	82558-50-7	H	*	WW
Lactofen	Cobra	77501-63-4	H		SB
Lambda-Cyhalothrin	Karate	91465-08-6	I		CO
Lindane	Isotox	58-89-9	I		
Linuron	Lorox	330-55-2	H		CR,CO,GS,SB
Malathion	Cythion	121-75-5	I		CR,CO,GS,SB,WW
Maleic Hydrazide	Royal Slo-Gro	123-33-1	G		
Mancozeb	Dithane	8018-01-7	F		CR,CO,GS,PN,WW
Maneb	Maneb	12427-38-2	F		GS,SB,WW
MCPA Amine	Dedweed	94-74-6	H		WW
MCPA Ester	Stampede	94-74-6	H		WW
MCPB Sodium Salt	Thistrol	94-81-5	H		
Mecoprop Amine	2 Plus 2	7085-19-0	H		
Mefluidide	Embark	53780-34-0	H	*	
Mepiquat Chloride Salt	Pix	24307-26-4	G		CO

Metalaxyl	Ridomil	57837-19-1	F		
Metaldehyde	Metaldehyde	9002-91-9	L		
Methamidophos	Monitor	10265-92-6	I		CO
Metham Sodium	Vapam	137-42-8	F,I,H,N		
Methanearsonic Acid Sodium Salt	DSMA	2163-80-6	H		CO
Methazole	Probe	20354-26-1	H		CO
Methidathion	Supracide	950-37-8	I,M		CO,GS
Methiocarb	Slug-Geta	2032-65-7	I,L,R		
Methomyl	Lannate	16752-77-5	I		CR,CO,GS,SB,WW
Methoxychlor	Marlate	72-43-5	I		CR,CO,GS,PN,SB,SC,WW
Methyl Bromide	Brom-O-Sol	74-83-9	S		
Methyl Isothiocyanate	Vorlex	556-61-6	F		
Methyl Parathion	Penncap-M	298-00-0	I		CR,CO,GS,SB
Metiram	Polyram	9006-42-2	F		
Metolachlor	Dual	51218-45-2	H		CR,CO,GS,PN,SB
Metribuzin	Sencor	21087-64-9	H		CR,SB,SC,WW
Metsulfuron-Methyl	Ally	74223-64-6	H		WW
Mevinphos	Phosdrin	7786-34-7	I		CR,GS
Mexacarbate	Zectran	315-18-4	I	*	
Molinate	Ordram	2212-67-1	H		
Monocrotophos	Azodrin	6923-22-4	I		CO,PN,SC
Monolinuron	Aresin	1746-81-2	H	*	
Monuron	Telvar	150-68-5	H	*	
MSMA	Arsonate	2163-80-6	H		CO,SC
Myclobutanil	Rally	88671-89-0	F	*	
NAA Amide	Amid-Thin W	86-86-2	G		
NAA Ethyl Ester	Tre-Hold	86-87-3	G		
Common Name	Trade Name	CASRN	Use	New	Crops
Naled	Dibrom	300-76-5	I		CO
Napropamide	Devrinol	15299-99-7	H		
Naptalam Sodium Salt	Alanap	132-66-1	H		PN,SB
Napthaline	Napthalene	91-20-3	F,I	*	
Neburon	Kloben	555-37-3	H	*	
Nicosulfuron	Accent	111991-09-4	H	*	GS
Nitrapyrin	N-Serve	1929-82-4	B,X		
Nitrofen	Tok	1836-75-5	H	*	WW
Norflurazon	Evital	27314-13-2	H		CO,SB
Oryzalin	Surflan	19044-88-3	H		SB
Oxadiazon	Ronstar	19666-30-9	H		CO,SB
Oxamyl	Vydate	23135-22-0	I,N		CO,PN,SB

Oxycarboxin	Plantvax	5259-88-1	F		
Oxydemeton-Methyl	Metasystox	301-12-2	I		CR,CO,GS
Oxyfluorfen	Goal	42874-03-3	H		CR,CO
Oxythioquinox	Morestan	1/2/39	F,I,M		
Paclobutrazol	Bonzi	76738-62-0	G	*	
Paraquat	Prelude	1910-42-5	H		
Parathion (Ethyl)	Phoskil	56-38-2	I		CR,CO,GS,PN,SB, SC,WW
PCNB	Terrachlor	82-68-8	F		CO,PN,WW
Pebulate	Tillam	1114-71-2	H		
Pendimethalin	Prowl	40487-42-1	H		CR,CO,GS,PN,SB
Pentachlorophenol	Pentacon	87-86-5	I	*	
Perfluidone	Destun	37924-13-3	H	*	CO
Permethrin	Pounce	52645-53-1	I		CR,CO,SB
Petroleum Oil	Volck Oils	-	I,H,M		
Phenmedipham	Betanal	13684-63-4	H		
Phenthoate	Cidial	2597-03-7	I		CO
Phorate	Thimet	298-02-2	T		CR,CO,GS,PN,SB, WW
Phosalone	Zolone	2310-17-0	I		
Phosmet	Imadan	732-11-6	I		CR,CO
Phosphamidon	Swat	13171-21-6	I		CO
Picloram Salt	Tordon	1918-02-1	H		WW
Piperalin	Pipron	?	F		
Pirimicarb	Pirimon	23103-98-3	I	*	WW
Pirimiphos-Ethyl	Fernex	23505-41-1	I	*	
Pirimiphos-Methyl	Actellic	29232-93-7	I		
Primisulfuron-Methyl	Beacon	86209-51-0	H	*	GS
Prochloraz	Octave	67747-09-5	F		
Procymidone	Sumisclex	32809-16-8	F	*	WW
Prodiamine	Barricade	29091-21-2	H	*	CO,SB
Profenofos	Curacron	41198-08-7	I,M		CO
Profluralin	Tolban	26399-36-0	H		CO,SB
Promecarb	Carbamult	2631-37-0	I	*	
Prometon	Pramitol	1610-18-0	H		
Prometryn	Caparol	7287-19-6	H		CO
Pronamide	Kerb	23950-58-5	H		
Common Name	Trade Name	CASRN	Use	New	Crops
Propachlor	Ramrod	1918-16-7	H		CR,GS
Propamocarb	Banol	25606-41-1	F		
Propanil	Stam	709-98-9	H		WW
Propargite	Comite	2312-35-8	M		CR,CO,GS,PN
Propazine	Milogard	139-40-2	H		GS
Propham (IPC)	Chem-Hoe	122-42-9	H		

Propiconazole	Tilt	60207-90-1	F		SC,WW
Propoxur	Baygon	114-26-1	I		
Pyrazon	Pyramin	1698-60-8	H		
Pyrethrins	Pyrethrum	800-3-34-7	I	*	
Quizalofop-Ethyl	Assure	76578-14-8	H		SB
Resmethrin	Benzyfluroline	10453-86-8	I	*	
Rotenone	Derris	83-79-4	I	*	
Secbumeton	Etazine	26259-45-0	H	*	
Sethoxydim	Poast	74051-80-2	H		CO,PN,SB
Siduron	Tupersan	1982-49-6	H		
Simazine	Princep	122-34-9	H		CR
Simetryn	Gy-bon	1014-70-6	H	*	
Sodium Chlorate	Drop-leaf	7775-09-9	H	*	CO
Sulfometuron-Methyl	Oust	74222-97-2	H		
Sulprofos	Bolstar	35400-43-2	I		CO,SB
TCA	Varitox	76-03-9	H	*	SC
Tebuthiuron	Spike	34104-18-1	H		
Temephos	Abate	3383-96-8	I		
Terbacil	Sinbar	5902-51-2	H		SC
Terbufos	Counter	13071-79-9	I,N		CR,GS
Terbutryn	Terbutrex	886-50-0	H		GS,WW
Tetrachlorvinphos	Gardona	22248-79-9	I	*	CO,SB
Thiabendazole	TBZ	148-79-8	F		
Thidiazuron	Dropp	51707-55-2	D		CO
Thifensulfuron-Methyl	Harmony	79277-27-3	H		WW
Thiobencarb	Bolero	28249-77-6	H		
Thiocyclam-hydrogen Oxalate	Evisect	31895-22-4	I	*	CO,SC
Thiodicarb	Larvin	59669-26-0	I		CR,CO,GS
Thiophanate-Methyl	Topsin	23564-05-8	F		PN,SB
Thiram	Thiram	137-26-8	F		
Tolclofos-methyl	Rizolex	57018-04-9	F	*	CO
Toxaphene	Phenatox	8001-35-2	I		CR,CO,GS
Tralomethrin	Scout	66841-25-6	I		CO,SB
Triadimefon	Bayleton	43121-43-3	F		WW
Triadimenol	Bayton	55219-65-3	F	*	CR,WW
Triallate	Far-Go	2303-17-5	H		WW
Tribenuron methyl	Express Herbicide	101200-48-0	H	*	WW
Tribufos	DEF	78-48-8	D		CO
Trichlorfon	Dylox	52-68-6	I		CR,CO,WW
Trichloronat	Agrisil	327-98-0	I	*	
Common Name	Trade Name	CASRN	Use	New	Crops
Triclopyr Amine	Turflon	55226-06-3	H		

Triclopyr Ester	Crossbow	55335-06-3	H		
Tricyclazole	Beam	41814-78-2	F	*	
Tridiphane	Tandem	58138-08-2	H		CR
Triflumizole	Trifmine	99387-89-0	F	*	WW
Trifluralin	Treflan	1582-09-8	H		CR,CO,GS,PN,SB, SC,WW
Triforine	Funginex	26644-46-2	F		
Trimethacarb	Broot	2686-99-9	I		CR
Triphenyltin Hydroxide	Du-ter	76-87-9	F		
Vernolate	Vernam	1929-77-7	H		CR,PN,SB
Vinclozolin	Ronilan	50471-44-8	F	*	
Zineb	Dithane Z-78	12122-67-7	F	*	
Ziram	Aaprotect	137-30-4	F	*	

Use Codes:
A = Acracide
B = Bacteriacide
D = Defoliant

F = Fungicide
G = Growth Regulator
H = Herbicide
I = Insecticide

L = Molluscocide

M = Miticide
N = Nematicide
R = Bird Repellant
S = Soil Fumigant
T = Seed Treatment
X = Nitrification Inhibitor
DP = Degradation Product

Crop Code:
CR = Corn
CO = Cotton
GS = Grain Sorghum
PN = Peanuts
SB = Soybeans
SC = Sugarcane
WW = Winter Wheat
includes Barley
Oats, & Rye

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PROCEDURE

Month 1
Soil clustering will be accomplished first. The soils used in clustering will be the NRI points that have row crops growing. The soils will be clustered and tested for similarity of results within a cluster using the selected model.

Month 2
Climate clustering will be accomplished second. The climate stations used in the clustering will be the 79 climatic stations developed for use by climate generators in GLEAMS. The climate stations within a cluster will be tested for similarity of pesticide loss.

Month 3&4
Geographic Information Systems (GIS) will be used to confirm intuitively reasonable soil and climate distributions for all clusters. Mapping the soils and climate by a geographic attribute will require associating the climate to a spatial area common to soils. An attempt will be made develop this association with three spatial attributes at NRI points. These are county (CO), Major Land Resource area (MLRA) and eight-digit Hydrologic Unit Areas (HUA8). Success has been accomplished by using only the HUA8 spatial areas, but greater detail could be derived from combining the three spatial areas mentioned above.

This process will also define what climate clusters will be run with what soil clusters. Also the crops grown in each of the soil/climate cluster combinations will be defined. One climate cluster may have several soil clusters and several crops.

Month 5
A system to automatically run all combinations of climate-soil-crop-pesticides will be developed. This will be a 'batch' process that will automatically choose soils and crops for each climate, and apply appropriate pesticides and copping practices.

Month 6-7
The model runs will be made to generate the data for all possible combinations required to estimate pesticide loss a each of the NRI points.

Month 8-10
Distribution of the results back to NRI points will be accomplished by identifying the climate and soil for each NRI point with the cluster it is a member. The climate and soil cluster data and NRI point crop and cropping practice will then be related to a table of results. Each NRI point has a variable that relates that NRI point to areal distribution. This value may be required to determine how much of an area within the HUA8 or larger unit the NRI point occupies.

Month 11-12
Pesticide loss for important pesticides will by mapped to the HUA8 and maps produced for distribution. The large out-put database will be placed on CD-ROMs and a system for retrieving this data will be developed. The CD-ROMs will be distributed to TNRCC and Texas USGS

Point Source Component – PSOC Coverage Development (Task 4.1)

Statement of Problem

A primary step in assessing the susceptibility of a ground-water supply to contamination is locating PSOCs that are within the contributing area of a supply. Selected categories of PSOCs that may contribute contaminants to the source water of a public-water-supply well or spring are as follows:

Potential Source of Contamination	Source of Information
Petroleum Storage Tanks	Texas Natural Resource Conservation Commission
Superfund Sites	Texas Natural Resource Conservation Commission
Industrial and Hazardous Waste: Treatment, Storage, and Disposal Facilities	Texas Natural Resource Conservation Commission
Potential Source of Contamination Files from Wellhead Protection Studies in Texas	Texas Natural Resource Conservation Commission
Candidate Sites for State Lead Cleanup	Texas Natural Resource Conservation Commission
Active and Abandoned Municipal Solid Waste Facilities	Texas Natural Resource Conservation Commission
Class I Injection Wells	Texas Natural Resource Conservation Commission
Class III Injection Wells	Texas Natural Resource Conservation Commission
Class V Injection Wells	Texas Natural Resource Conservation Commission
Toxic Release Inventory	Texas Natural Resource Conservation Commission
Water Quality Permits (Confined Animal Feeding Operations; Municipal Wastewater discharges)	Texas Natural Resource Conservation Commission
Ground Water Well Database	Texas Water Development Board
Major Roads in Texas (Interstate, Highway, Farm-to-Market and Ranch Road)	Texas Department of Transportation
Railroads	Texas Department of Transportation
Airports	Texas Department of Transportation
Oil and Gas Production Wells	Railroad Commission of Texas
Class II injection wells (Disposal of Oil and Gas Production Saltwater)	Railroad Commission of Texas
Petroleum and Refined Product Pipelines	Railroad Commission of Texas
Abandoned Mined Lands in Texas	Railroad Commission of Texas
Confined Animal Feeding Operations (CAFOs)	Texas State Soil and Water Conservation Commission

Beginning in the 1970s, the TNRCC (and its predecessor agencies) have developed a variety of independently constructed and maintained computerized PSOC databases for Texas, which provide data on the various categories as listed above. At this time, there are records for an estimated 65,000 known PSOCs held in the various databases. While locational information for the majority of these sites is available from the databases, the information is not accessible with Geographic Information System (GIS) software as is required for spatial analysis within the various Source Water Susceptibility Assessments (SWSA) components.

Approximately 6,000 PSOCs have no computerized locational information (latitude/longitude) as is required for SWSA. Locational information for these sites may be available from a physical review of paper files maintained by TNRCC's various PSOC programs. In some cases, PSOCs may have been located on photocopies of U.S. Geological Survey (USGS) topographic maps whereas in other cases only paper engineering reports, site drawings, or field sketches may exist. In still other cases, only street address information may be available in the file.

A large amount of work by both TNRCC and USGS staff will be required to provide accurate locational data for PSOCs that could affect contributing source waters to a supply well. Interviews with pertinent TNRCC staff that manage PSOC programs will be required to better determine data type, attributes, locations, quality, availability, and documentation. The SWAP staff has developed a comprehensive flowchart and list of interview questions to facilitate this process (Attachment 1). Simply stated, for each PSOC that locational data are required, its file will need to be physically pulled, reviewed, and pertinent information extracted, to allow the PSOC, if possible, to be located on a USGS topographic map or equivalent. An additional problem is that of out-of-date USGS topographic maps may not contain streets where PSOC could be located by address. Supplemental maps or commercial databases with address/location information will be required to locate some PSOCs.

Once the locational information is obtained, a GIS database must be developed for use by the SWAP. The database will need to provide a variety of information on PSOCs including the TNRCC program that collects and manages the PSOC data, the source material for the data, descriptions of data quality, and minimal accuracy standards (or needs) for PSOC locations. The database also will need to be linked to the list of regulated contaminants (and contaminant groups) and to Standard Industrial Codes (SIC). The list of regulated contaminants and contaminant groups will be prepared under a separate project and linkages will be facilitated through the software developed under a separate project.

Goal and Objectives

The goal of this project is to develop PSOC databases for use in SWSA. Specific objectives include:

- Develop a statewide coverage for each category of PSOC for which digital location information is currently available.
- Supplement the PSOC coverages developed under Task 4.1.1 to include PSOCs for which location information is not available, and
- Develop and provide documentation (metadata)

The PSOC coverages and associated metadata will be provided for display and analysis during SWSA. The design of the SWSA database structure will be flexible so as to accommodate periodic update, as when new facilities are permitted or as more accurate location information is obtained from other TNRCC programs, State or Federal agencies, or the public.

Approach

The tasks outlined below will proceed as a team effort by SWAP and USGS staff. However, for budgeting purposes only tasks, that are to be performed by USGS staff are presented. A preliminary review of some of TNRCC's PSOC files was conducted by the USGS during January-February 1998 to provide an indication of types of information available; the general quality of that information; the ease of data location, collection, and processing; the type of staff and training required to collect data; and timeframes to collect and process data. This information was used to develop proposed budget and timelines for tasks to be performed by the USGS for this project. After some experience with the proposed approach, alternative data-collection processes may need to be evaluated and tested, and the workplan appropriately adjusted.

Task 4.1.1: Develop PSOC Statewide Coverage for Each Category of PSOC for Which Digital Location Information is Available

TNRCC staff will retrieve, from TNRCC databases, computer files containing location, identification information (facility id), and other attribute information as listed in Table 1, for all available PSOC categories and provide to the USGS. USGS staff will convert these files to GIS point coverages and project these coverages to the Texas Statewide Mapping System (TSMS) projection (Texas Department of Information Resources, 1992), coordinate units in feet, NAD83 datum (Allison, B., Texas Natural Resources Conservation Commission, Information Resources, Interoffice Memorandum, 1/26/1998). USGS will conduct quality-control checks on datasets generated from TNRCC files. USGS staff will advise TNRCC's PDW staff of discrepancies and attempt to correct location information where possible.

Task 4.1.2: Supplement PSOC Coverages with Sites having no Available Digital Location

Constraints on both time and funding will control the amount of work expended to collect accurate PSOC location data. For PSOCs where accurate location data can not be readily obtained, GIS software will be used to develop a buffer zone surrounding the PSOC to take less accurate locations into account. TNRCC PDW staff will provide to the USGS a list of PSOCs to be researched. USGS staff will review PSOC paper files at TNRCC's office in Austin and extract relevant information required to locate PSOC sites. USGS personnel will use this information to estimate the location of the sites on the most up-to-date paper USGS 7.5-minute quadrangle topographic maps available. Proceeding on a quadrangle-by-quadrangle basis, USGS staff will digitize the PSOC sites, the TNRCC facility number will be assigned as a unique identifier in the database, and other attributes, as listed in Table 1, will be encoded in the database. Digitizing will be "heads-up" with the site being located on a Digital Raster Graphic (DRG) image loaded from CD-ROM within ArcView 3.x, on a computer workstation specifically outfitted with digitizer and CD-ROM reader. This process will eliminate errors associated with digitizing from paper maps.

PSOC sites, which cannot be located on 7.5-minute topographic maps, will be digitized based on information extracted from source documents, if possible. Sites which have no usable source document maps will be located on Texas State Department of Transportation maps or from commercial location information on CD-ROM, through address or zip code information. Graphic plots will be produced in order to check the location of the point in the database with the available paper maps or reports.

Latitude/longitude coordinates will be output to a file from the GIS and provided to TNRCC. The PSOC coverages will be projected to the Texas Statewide Mapping System (TSMS) projection (Texas Department of Information Resources, 1992), coordinate units in feet, NAD83 datum (Allison, B., Texas Natural Resources Conservation Commission, Information Resources, Interoffice Memorandum, 1/26/1998). The PSOC coverages will be merged with the PSOC coverages created under the previous task.

Table 1: List of data attributes for PSOC GIS Coverages

Data Element	Description
PSOC location	Latitude, longitude, address, zip code, county
Facility identifier	Unique facility identifier
Specific type of contaminant(s)	TCE, BTX compounds, lead, chlordane, atrazine
Contaminant group	Organic, inorganic, trace element, pesticide
Method of introduction into environment	Spill, leak, injection, etc.
Quantity of spill or leak	Estimated or known quantity
Date of spill or leak	Estimated or known date
Narrative	Description of relevant information or extenuating circumstances that make this site more of a concern than others

Task 4.1.3: Develop Metadata for PSOC Database

USGS staff will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata for the PSOC database (FGDC, 1994). Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial datasets and information about the resultant dataset including data elements such as scale, projection, and author.

Quality-Assurance Plan

For PSOC sites with available location information, USGS staff will review the coverages produced from TNRCC files and conduct gross quality-control checks to determine, to the extent possible, whether sites are in the correct location. These tests will consist of plotting of the points and checking that they fall within the correct political boundary. To the extent possible, PSOC sites without locational information will be located on USGS topographic maps (or DRG) by referencing source maps, addresses, and other information obtained from TNRCC documents. The accuracy of the latitude/longitude obtained will be dependent on the quality of the paper file information, however comparisons of check plots to source documents will afford a high level of quality control. Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994).

Deliverables

- USGS 7.5-minute quadrangle maps with PSOC site locations
- Arc/Info coverages of PSOC locations with associated attributes
- FGDC-Compliant content-level metadata
- Computer file of PSOC facility numbers and latitude/longitudes
- Standard operating procedures for determining PSOC locations from source maps and TNRCC documents

References

Environmental Systems Research Institute, Inc. (ESRI), 1994: ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.11.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.12, Global Positioning System.

Point Source Component – Contaminant Groups Database (Task 4.2)

Statement of Problem

The susceptibility of water supplies must be assessed for all contaminants listed in the U.S. Environmental Protection Agency (USEPA) publication titled "Drinking Water Regulations and Health Advisories" (USEPA, 1996). Many of these contaminants undergo similar environmental processing in surface-water and ground-water systems, and can therefore be grouped according to these similarities. A relational database that provides technical data of the environmental behavior and fate of these contaminants must be developed to assist evaluation of a potential contaminant or group of contaminants in a source-water assessment scenario.

Goal and Objectives

The goal of this project is to develop a database of contaminant groups and individual contaminants as appropriate for use in SWSA. Specific objectives include:

- Determine Environmental Processing Similarities of Each Contaminant (USEPA, 1966) and Assign Each Contaminant to a Contaminant Group.
- Develop a Relational Database of Contaminants, Contaminant Groups, and Associated Chemical Properties Relevant to Environmental Processing.
- Develop Metadata for the Contaminant Group Database

Approach

Task 4.2.1: Develop a Set of Contaminant Groups and Assign Each Contaminant to a Contaminant Group
A senior USGS geochemist will compile a list of contaminants from the document "Drinking Water Regulations and Health Advisories" by USEPA, October 1996. Additional research of recent scientific literature will provide information pertinent to the processing of contaminants in surface-water and ground-water environments, leading to data useful in determining the persistence of the contaminants in the various environments. Based on these technical details, contaminants will be grouped according to similarities in chemical properties and environmental behavior as appropriate.

Task 4.2.2: Develop a Relational Database File of Contaminants, Contaminant Groups, and Associated Chemical Properties
With the assistance of a student intern, the senior geochemist will develop a relational database consisting of the contaminants, contaminant groups, and associated chemical properties and descriptions. The database will be designed for easy access to environmental processing variables by the source-water assessment

software to assess fate and transport of a contaminant of concern in a source-water assessment scenario developed by the user.

Task 4.2.3: Develop Metadata for Contaminant Database

USGS staff will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata for the PSOC database (FGDC, 1994). Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial datasets and information about the resultant dataset including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994).

Deliverables

Relational contaminant database FGDC-Compliant content-level metadata

References

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

U.S. Environmental Protection Agency, 1996, Drinking Water Regulations and Health Advisories: Office of Water 4304, EPA 822–B–96–002.

Contaminant Occurrence Component (Task 5)

Statement of Problem

Some aquifers have naturally occurring contaminants that render the water less desirable for human consumption. Thus, an analysis, both spatially and temporally, of existing ground-water and PWS entry-point monitoring data is needed to determine if the occurrence of a contaminant(s) in water from an aquifer is due to natural or manmade conditions. Additionally, it is certain that every abandoned well or other potential breach of a confining unit cannot be identified as part of Component 4. Thus, this analysis also may uncover sources of contamination due to breaches of the confining unit for a confined aquifer. Several databases exist that contain ground-water quality data for this analysis, such as TWDB's water-quality and infrequent constituents databases, TNRCC's TRACs and PDWS databases, U.S.G.S.' NWIS databases, and USEPA's STORET. Using spatial analysis techniques, these data will be identified within a 1-mile search radius around each public-supply well and spring. If detections of contaminants within this area were found, then the PDWS would be assessed as being susceptible to contamination to either man-made or naturally occurring contamination. The goal of this project is to compile, into one or more databases, location and selected water-quality data from existing water-quality databases. This data will be used, with software developed under a separate project, to identify sites with contaminant occurrences exceeding designated thresholds for specific constituents within a 1-mile search radius of the public-supply ground-water well or spring identified in Component 1. This analysis will lead to a determination of the susceptibility of the public-supply ground-water well or spring to contamination. Specific objectives include:

- Compile relational data file of water-quality information
- Create Geographic Information System (GIS) coverage of water-quality wells or springs
- Develop and provide documentation (metadata)

Approach

The approach will consist of assessment of the five existing water-quality databases listed above as to format and suitability for Source Water Susceptibility Assessments (SWSA), compilation of water-quality database table(s), location of water-quality wells or springs and creation of GIS coverages, and creation metadata.

Task 5.1: Assess Water-Quality Databases

Each of these databases contain vital information for the assessment of existing water quality, however, they also contain information that is not required to fulfill the goals of the SWAP. Thus, the formats and contents of each database will be reviewed. At the time of this writing, it is anticipated that the focus of this task will be to collect data with regards to the 120 chemical constituents on the USEPA's primary drinking water standards maximum contaminant level (MCL) list.

Task 5.1.1: The existing water-quality databases contain thousands of records. These databases will be queried to obtain only those records that exceed some threshold value of a contaminant. The TNRCC will establish the threshold value for each contaminant for this task. The threshold value will vary per contaminant, and will be based on one of several methods such as: the maximum contaminant level (MCL); a value such as half the MCL; or reflect a confirmed detection above the analytical limit.

Several contaminants may not have a threshold value prepared. These will include contaminants that TNRCC tests, but do not have an established MCL (for example, calcium). Other contaminants will have a threshold established that may reflect a specific type of contamination source, such as high sodium from oil field saltwater disposal.

Task 5.2 – Download All Pertinent Data from Databases

Only chemical quality data concentrations collected within the past 10 years that exceed a predetermined threshold level will be downloaded for incorporation into the SWAP water-quality database(s). A list of data that are required for the successful completion of this task are listed in Table 5.1

Table 5.1: List of attributes required for the water-quality database(s)

Attribute	**Description**
Locational data	Latitude and longitude
Date	Date of analysis
Chemical constituent (approximately 120)	Chemical abbreviation of constituent name
Symbol	Less than, greater than
Class	Class of constituent (organic, inorganic, VOC, pesticide, etc.)
Well identifier	Unique identifier; also should include county code
LSD	Land surface datum, in feet above sea level
Depth	Screen interval
Database code	Source of data
STORET code	Value of contaminant
Treatment	Y/N Boolean
Aquifer code	Should come out of database

Each of the water-quality databases is quite large and will require a significant amount of time and effort to reduce the data into a usable form. USGS will conduct gross quality-assurance checks on datasets generated from the various databases. The initial database developed will include all constituent hits above the thresholds assigned by TNRCC in Task 5.1.1.

Task 5.2.1: Develop Table Assessing Lab Procedure Changes and Detection Limits

Task 5.3: Develop Water-Quality Wells And Springs GIS Coverage

A GIS point coverage of water-quality wells and springs will be constructed from the locational data retrieved under task 5.2. A thorough check of the locations of these sites is beyond the scope of this project, however gross quality- assurance checks of the data will be performed on the location data.

Task 5.4: Prepare Metadata

USGS staff will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata (FGDC, 1994) for the well and springs coverages and for the aquifer categories coverage. Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial datasets and information about the resultant dataset including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994). USGS will perform gross quality-assurance checks on locational and attribute information, advise PDW staff of errors or inconsistencies, and revise data where possible.

Deliverables

- Threshold values list
- GIS coverage of water-quality wells and springs
- Relational database table(s) of water-quality data
- FGDC-Compliant content-level metadata

References

Environmental Systems Research Institute, Inc. (ESRI), 1994, ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

Attenuation of Contaminants Component (Task 6)

Statement of Problem

Contaminants released from a point source or area that enter aquifers as solutes in ground water undergo physical and chemical processes that lower their concentrations in the ground water. If the behavior of the contaminant is conservative (no chemical interaction with soil and sediment and no chemical or biochemical degradation), lowering of the concentration is accomplished by advective, dispersive, and diffusive processes (transport) as the water moves through the aquifer. If the behavior of the contaminant is non-conservative (sorption to soil and sediment and/or chemical or biochemical degradation), lowering of the concentration is accomplished by both the physical processes and chemical processes that occur as the contaminant moves through the aquifer.

Inorganic contaminants such as metals often have greater affinity for soil and sediment (sorption) rather than as solutes in the water phase. Many organic compounds can be lowered in concentration in ground water by both sorption processes and chemical and biochemical degradation processes. As a result, it is necessary to consider these processes for each contaminant as it is transported through the soil, vadose zone, and aquifer, to some point of exposure, for example, a drinking-water supply.

The concentration of a contaminant in ground water and time-of-arrival at the point of exposure are thus determined by the physical, chemical, and biochemical processes that lower (attenuate) the concentration of the contaminant in ground water. Conservative behavior could mean that a contaminant might exceed maximum contaminant levels within the 20-year time-of-travel period of consideration at some point of exposure. Non-conservative behavior could mean that a contaminant might be attenuated in the soil, vadose zone, or aquifer matrix, depending on its specific properties, perhaps never arriving to a point of exposure, or arriving at concentrations below levels of concern. Thus, it is important to include computations of fate and transport based on behavioral data of each contaminant, and physical properties of soil, unsaturated (vadose) zones, and aquifer matrices.

Goal and Objectives

The goal of this project is to assess attenuation properties of the soil zone, vadose zone, and aquifer matrix within the contributing area of public-supply wells or springs with respect to selected contaminant groups. Specific objectives include:

- Assessment of attenuation properties of the soil zone
- Assessment of attenuation properties of the vadose zone
- Assessment of attenuation properties of the aquifer matrix
- Develop and provide documentation (metadata)

Approach

Although the time-of-travel is more critical in the evaluation of public-water-supply susceptibility, an assessment of the attenuation property of the soils, vadose zone, and aquifer matrix in the contributing area should be considered in the decision. Soil type and thickness can be obtained from the STATSGO soils database which is already in Geographic Information System (GIS) format. The STATSGO database contains a level of detail that is beyond the scope of this study, but the data can be simplified by an agronomist, which will improve the speed of the analysis of the soils over the contributing zones. The most important properties of the soil zone affecting contaminant fate and transport are permeability, thickness, and total organic carbon content. Additionally, the greater the depth to water, the longer the travel time to the aquifer through the vadose zone. The rock type of some aquifers may also inhibit the transport of some contaminants. A decision matrix will be developed for these properties alone to assess the "intrinsic" capability of these zones to attenuate contaminants.

Task 6.1: Soil Type and Attenuation Properties

Soil characteristics have a major influence on whether or not attenuation of organic compounds can occur. This project only will be applied to wells in unconfined aquifers, alluvial, or unknown aquifers.

Task 6.1.1: Simplify STATSGO data. The STATSGO database contains information that goes well beyond the scope and needs of the SWAP. An important first step in this project will be to simplify the numerous soil types. This will involve the expertise of an agronomist. The Texas Agricultural Research Station’s Blackland Center has already created a regionalized soil data layer for the United States. This dataset will be reviewed in order to assess its potential value to the SWAP.

Task 6.1.2: Create a polygon coverage indicating soil areas that can and cannot attenuate specific chemical groups. As with all coverages created or modified in this project, QA/QC procedures, metadata, and peer review also will be part of this task. Initially, some thresholds could be established in a conservative manner as follows:

If soil thickness < x, no attenuation
If soil permeability > x, no attenuation
If total organic carbon < x, no attenuation

Task 6.1.3: Intersect the soil data with public-water-supply contributing zones and PSOC locations. An overlay analysis will yield information regarding the soils and PSOCs within the contributing recharge area. Data required for this task are given in Table 6.1.

Table 6.1: List of data required for estimation of soil attenuation

[P, polygon; X, point; PWS, Public Water Source]

Data requirement	**Coverage type**	**Description/attributes**
STATSGO (or replacement) soils data	P	Type or name,Thickness Permeability Total organic carbon content (weight percent)
PSOC locations	X	Created in Project 4, Attributes include type of compound and date of spill or application
PWS contributing recharge area	P	Created in Project 2

Task 6.2: Vadose Zone Attenuation Properties

This project only will be applied to unconfined aquifers. Vadose zone water movement and chemical processes are complex. A threshold decision process also will be employed as an initial screening tool. If site-specific information is available, additional processing may be employed to determine attenuation. When information is not available, a worst-case scenario of instantaneous contaminant transport with no chemical interaction will be used.

Task 6.2.1: Create coverages of unsaturated zone thickness. If available, this data will be digitized or scanned. In absence of such data, the thickness of the vadose zone can be approximated by subtracting the elevation of the water table from the elevation of land surface. Table 6.2 lists data needs for this Task.

Table 6.2: List of data required for estimation of vadose zone thickness
[P, polygon; L, line; ft, feet; X, point; PWS, Public Water Source]

Data requirement	**Coverage type**	**Interpolation desirable**	**Description/attributes**
PWS contributing recharge area	P	No	Created in project 2
Vadose zone thickness	L,P	Yes	Thickness in feet
If the above are unavailable	N/A	N/A	N/A
Land surface elevation	L,P		Elevation in feet above sea level
Water table elevation	L,P		Elevation in feet above sea level

Task 6.2.2: Determine areas where the vadose zone is thick enough to foster attenuation by establishing a threshold value:

If thickness of the vadose zone < x, no attenuation.

The polygons of the contributing recharge area where the depth to water is less than the threshold value will be developed to indicate more susceptible areas of the contributing area.

Task 6.2.3: Determine time-of-travel through vadose zone. If the vadose zone is of sufficient thickness, the time-of-travel (infiltration rate) could be estimated by assuming a vertical hydraulic conductivity one order of magnitude less than the hydraulic conductivity of the aquifer. This calculation could be done simply by adding an additional data field to the hydraulic conductivity coverages established in Ground-Water Component, Project 2.

Task 6.3: Aquifer Matrix Attenuation Properties

This task will be applied to the aquifers developed in Task 1.. In order to assess the attenuation capability of an aquifer, the following properties are important: bulk density, porosity, and organic carbon content. A table of these properties for each major and minor aquifer will be compiled. If data are not available for a particular aquifer, a conservative approach will be applied assuming that no attenuation occurs in the aquifer.

Task 6.3.1: Determine availability and compile information about each major and minor aquifer for items listed in table 6.3

Table 6.3: List of data required for estimation of aquifer matrix attenuation
[P, polygon; L, line; ft, feet; PWS, Public Water Source]

Data requirement	**Coverage type**	**Interpolation desirable**	**Description/attributes**
PWS contributing recharge area	P	No	Created in project 2
Aquifer properties			
Bulk density	L,P	Yes	Contours of density in consistent units
Porosity	L,P	Yes	Created in Project 2
Organic carbon content	L,P	Yes	Contours of organic carbon content, in weight percent

Task 6.3.2: Depending on results of the literature search, either a single lookup table or polygon coverages for each aquifer will be developed. Threshold values of density, porosity, and organic carbon content will be established in a manner similar to Task 6.1.2.

Task 6.3.3: Perform overlay analysis to determine aquifer properties within contributing recharge areas. Aquifer properties will be determined from GIS coverages developed under Ground-Water Components 1 and 2. Many organic contaminants degrade in the environment and are attenuated by natural degradation. For some contaminants, microbially-mediated degradation can take place rapidly in the soil.

Although significant contamination might occur at the site of the PSOC, the fate and transport of the contaminant(s) could be of short duration with perhaps no effect on water supplies. On the other hand, many other contaminants are resistant to natural attenuation processes and could threaten ground-water supplies within the 20-year time-of-travel. A decision matrix will be developed to consider each contaminant group in order to assess their potential for transport to nearby ground-water wells or springs. Some contaminants will be treated individually, such as glyphosate, as they possess unique characteristics.

Task 6.4: Prepare Metadata

USGS staff will prepare FGDC-compliant content-level metadata (FGDC, 1994) for all coverages.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas DIR, 1994). All coverages created or modified in this project will be quality control checked. In addition, the information will be peer reviewed by a Senior Ground-Water Hydrologist.

Deliverables

- GIS coverage of re-categorized soil areas that are capable of attenuating contaminants(6.1.2)
- GIS coverage of unsaturated-zone thickness
- Decision matrices and threshold values
- FGDC-Compliant content-level metadata

References

Environmental Systems Research Institute, Inc. (ESRI), 1994, ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

United States Department of Agriculture, Soil Conservation Service, 1983, State Soil Geographic Database (STATSGO) Data Users Guide.

Susceptibility Summary Determination Component (Task 7)

Statement of Problem

When the geographic area defining a capture zone to a raw water source (well, spring, surface intake) is intersected with the potential source of contamination (PSOC) geographic information system (GIS) coverages, zero to many PSOCs will be identified that may affect the water system. This project will determine the susceptibility of the water system to each contaminant of a PSOC. This susceptibility determination will be automated using software developed under a separate project, that will populate a table with unique codes; each code will reflect one piece of information about the well, aquifer, contaminant, etc. The software will then compare the codes generated for each water system with a “master matrix” table that includes every possible combination of codes with a pre-defined susceptibility determination. Essentially, this “master matrix” table would contain the “business rules” regarding the potential impact of a contaminant to a water system. This method has been used for the last several years within the TNRCC Vulnerability Assessment Program and will provide a simple, objective, rapid, and automated evaluation. The master matrix table can be easily edited as new information is developed regarding source water contamination; expensive and complicated software editing is eliminated.

There are many parameters that may be considered for susceptibility. This information will be collected as part of many projects within this document. These parameters include those that describe the water system, surface- and ground-water hydrologic setting, PSOC(s) and their contaminant(s), environmental attenuation of a contaminant, and so on. These parameters will need to be analyzed, when available, for each contaminant at each PSOC for each raw water source (well, spring, surface water intake) in a water system. The amount of information available for each PSOC will be highly variable not only between different types of PSOCs, such as landfills versus petroleum storage tank sites, but even within the same class of PSOCs, such as abandoned landfills. This project will be designed to take advantage of any and all information that is available. This complex information will need to be synthesized into a form easily comprehended; that is the purpose of the matrix table.

Goal and Objectives

The goal of this project is to determine the susceptibility of a public water supply to contamination from potential sources of contamination. Objectives of the project include:

- Define the parameters and their standard codes that will be used to define a susceptibility determination
- Develop a database table to contain the codes used to formulate a susceptibility determination
- Define the “business rules” and incorporate these into the master matrix table so that a susceptibility determination can be defined for each combination of parameter codes
- Develop the methods to populate the matrix tables from raw data obtained through GIS and database queries
- Develop the methods to populate matrix tables when there is interaction between different PSOCs that could lead to contamination
- Develop the method to summarize the susceptibility determination for a water system

The software to support the automation of this process will be developed in Source Water Susceptibility Assessment Software and Database Structures, Tasks 1.4.7 and 1.5.9.

Approach

Task 7.1: Develop Susceptibility Determination Database Tables, Methods, and Data Collection

Task 7.1.1: Define the parameters and their standard codes that will be used to define a susceptibility determination. There will be several parameters acquired during the susceptibility analysis that will characterize the relationship between a contaminant and the water system. An example of some of these parameters include:

Contaminant: All inorganic, organic, radiological, and microbiological contaminants presently tracked by Texas. (This information will be collected under Ground Water Susceptibility Assessment, Task 4.2)

PSOC Type: These include Underground Storage Tanks (UST), Above Ground Storage Tanks (AST), Permitted Landfills, Abandoned Landfills, Highways, Railroads, etc. (This information will be collected under Ground Water Susceptibility Assessment, Tasks 3 and 4)

PSOC ID: The unique id for each PSOC will be retained during the GIS and database analysis. This id will only be used to create maps of PSOCs and contaminants. This parameter will not be used for susceptibility determination.

PSOC BMPs: Specific PSOC's will have Best Management Practices (BMPs) in place to mitigate the release of a contaminant into the environment. This would be a Boolean field with "Yes\No" or "True\False". (This information will be collected under Ground Water Susceptibility Assessment, Task 4)

Time-of-Travel: The time-of-travel from a PSOC site to a well will be calculated. The actual time in years may be determined, or a time range (0-2 years; 2-5 years) will populate this field. (This information will be collected under Ground Water Susceptibility Assessment, Task 2)

Well Integrity: The field tracks if the well annulus is cemented to the top of the water-producing interval. This would be a Boolean field with "Yes\No" or "True\False". (This information will be collected under Ground Water Susceptibility Assessment, Task 1.2.3)

Aquifer Type: Confined, Alluvial, Edwards, Unconfined, Unknown. (This information will be collected under Ground Water Susceptibility Assessment, Task 1)

PSOC Interaction: An analysis of PSOC interaction will populate a field within the matrix. This field may be simple, such as a boolean, or more complex, related to which type of PSOC may be acting as a conduit for contaminant migration.

Attenuation: Is attenuation of the contaminant predicted in the soil zone, vadose zone, or aquifer matrix. This would be a Boolean field with “Yes\No” or “True\False”. (This information will be collected under Ground Water Susceptibility Assessment, Task 6.

This is not a complete list of parameters; additional parameters or modifications to the list provided will be finalized during the completion of this task. Each parameter will have a standard set of codes assigned. The list of codes per parameter will be kept as small as possible, thereby limiting the size of the master matrix table. A limited set of codes per parameter will also facilitate quality assurance \ quality control of the database.

Task 7.1.2: Develop a database table to contain the codes used to formulate a susceptibility determination.

A relational database table will be designed once the parameters and their codes have been defined. The table structure will be the same for the matrix table (used to store the codes for a water system) and the master matrix table (explained in Task 7.1.3).

Task 7.1.3: Populate the master matrix table with parameter codes and susceptibility decisions. The master matrix table will store every possible combination of codes in addition to the susceptibility determination represented by those codes. The master matrix table will literally have thousands of records. Some parameter code combinations will be impossible, such as wells drawing water from an unknown aquifer with unknown well construction, -- these wells will not have time-of-travel designations. Impossible code combinations will not be loaded into the master matrix table.

It is anticipated that there will be a simple, subjective, and gradational coding of susceptibility determinations for a water system. Attempting to determine an objective, numerical coding is virtually impossible for the scope of this project. A final decision on susceptibility coding will be made during the development of this project. Initial ideas include a range from “Not Susceptible - to - Low - Medium - High” or “ Not Susceptible - Low - High”.

Early in the deliberations resulting in the proposed SWA approach, it was determined that a numerical rating system with value ranges and weights assigned to each SWA component was impractical. This decision was based on the extensive time and resources that would be required to develop a rating system, to complete the degree of sensitivity testing required to ensure that proper results could be achieved for the wide variety of hydrologic systems in Texas, and to have the rating system reviewed by the Technical Steering Committee. Further, concern was expressed about the limited information that a numerical rating provides to the public. Rather, a descriptive presentation (in matrix format) of the output from each individual assessment component was selected for communicating the susceptibility determination. The use of an assessment matrix would more clearly convey the water supplier and public, specific information about their source water and its watershed (or contributing area) most relevant to their future efforts in source-water protection.

The following table is a partial example of the master matrix table, with a few records related to benzene:

Contaminant	PSOC Type	PSOC BMPs	Time of Travel (years)	Well Integrity	Aquifer Type	Atten	Atten	Atten	
						Soil	Vadose	Aquifer	Susc
Benzene	UST	No	0-2	True	Confined				No
Benzene	UST	No	2-5	True	Confined				No
Benzene	UST	No	5-10	True	Confined			Yes	No
Benzene	UST	No	10-20	True	Confined			Yes	No
Benzene	UST	No		True	Edwards				Low
Benzene	UST	No	0-2	True	Alluvial				High
Benzene	UST	No		False	Unknown				Low
Benzene	UST	No	0-2	False	Unconfined				High

Task 7.1.4: Develop the methods to populate the matrix tables from raw data obtained through GIS and database queries. The methods to populate the matrix table with information obtained through GIS analysis and subsequent database queries will be developed. The amount of information that needs to be analyzed for each PSOC for each water system is highly variable and complex. Each PSOC database will be examined in detail to determine what data is available, what does it mean, and how can it be synthesized into a uniform set of codes per parameter. The contaminant(s) at each PSOC site will either be derived (based on PSOC type, such as a UST site having benzene, xylene, toluene, etc.,) or an actual contaminant list obtained directly from the PSOC database (such as contaminants from a superfund site). These contaminants will also be loaded into the attenuation module (Ground Water Susceptibility Assessment, Task 6) and the output of this module will be loaded into the matrix table.

Task 7.1.5: Develop the methods to populate matrix tables when there is interaction between different PSOCs that could lead to contamination. There will be many situations where there is potential interaction between different types of PSOCs that could lead to contamination. An example would be an underground storage tank which, individually, could not impact an aquifer that is located beneath a thick layer of clay. However, should a contaminant plume reach an abandoned or deteriorated well, the well could act as a conduit for contaminant migration to a lower aquifer. Scenarios where interaction of PSOCs could cause contaminant migration to a water system will be defined and a process to recognize them during the GIS analysis will be developed. This will be a very complex task. A field will be placed in the matrix table to record this decision.

Task 7.1.6: Develop the method to summarize the susceptibility determination for a water system. The matrix table for a water system will be queried against the master matrix table to determine susceptibility for a water system. A moderately complex water system may have hundreds of records, each representing a contaminant and a susceptibility determination. There may be several records with a “Not susceptible” decision; these records will need to be extracted from the database. The remaining records will be summarized into a manageable format. For example, the water system does not need 50 records indicating that it is susceptible to benzene. A special susceptibility summary can be used as a basis for setting the TNRCC chemical and microbiological sample schedule. This table will be tied to the water system raw water source(s) and entry point(s) information to be effective.

Task 7.1.7: Develop a relational database that correlates derived contaminants with PSOCs. When the geographic area defining a capture zone to a raw water source (well, spring, surface water intake) is intersected with the potential sources of contamination (PSOC) geographic information system (GIS) coverages, zero to many PSOCs will be identified that may affect the water system. The contaminant(s) from each PSOC will be identified and incorporated into the matrix table. The relationship between PSOC and contaminant may be either *derived* (gas station = benzene, toluene, xylene, and so on) or *actual* (Superfund Site ### has a plume of chromium waste). *Derived* contaminants will be assigned on a global basis for a specific class of PSOC where insufficient information exists about the site (or where there is insufficient time to review each and every file). *Actual* contaminants will be obtained from digital or paper record information maintained on the site.

Databases will be created for the derived contaminants: one for gas stations, another for municipal landfills, etc. These small databases are necessary to limit the size of the PSOC tables to practical limits. For example, if there are 45,000 gas stations that have, on average, three contaminants (benzene, xylene, toluene) then it is more practical to store the contaminant data in a derived table than expanding the gas station table by a factor of three (135,000 records). The information available from the original PSOC databases will need to be pre-processed to extract, where possible, the contaminants at the site, the BMPs at the site, whether a spill or leak has occurred, etc. The data can be summarized into standard PSOC tables to allow rapid insertion into the matrix tables and into the attenuation process modules. The matrix table for a water system will be populated with PSOC type and contaminants, and the contaminants will either come from the PSOC data tables or, in some cases, from the derived contaminant tables.

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994) for the creation of GIS coverages under this and other tasks. Standard database techniques will be followed for creation of all tables.

Deliverables

- Database of parameters and their standard codes that will be used to define a susceptibility determination
- Database table to contain the codes used to formulate a susceptibility determination
- Business rules incorporated into the master matrix table so that a susceptibility determination can be defined for each combination of parameter codes
- Methods to populate the matrix tables from raw data obtained through GIS and database queries
- Methods to populate matrix tables when there is interaction between different PSOCs that could lead to contamination
- Method of summarizing the susceptibility determination for a water system

SURFACE WATER ASSESSMENTS

Delineation Component (Task 1)

Statement of Problem

In order to assess the susceptibility of a surface water supply, five types of watershed delineations are required but not available. Watershed delineations must be determined at surface water intakes or outlets of public-supply reservoirs so that PSOCs within the contributing watershed may be identified and evaluated. Additionally, the land use/cover types within the contributing watershed must be determined in order to assess their impact on the water supply. Characteristics such as rainfall, runoff, and reservoir storage must be obtained for the contributing watershed in order to assess the intrinsic susceptibility of each surface water supply. Watershed delineations are required for approximately 500 surface water-supply intakes, of which approximately 176 are unique (due to multiple intakes in various reservoirs). Watershed delineations for an estimated 90 additional reservoirs located within the contributing areas of public- supply reservoirs must be delineated. Finally, areas-of-primary-influence for all public water supplies must be delineated.

Source hydrologic-derivative data sets including Digital Elevation Models (DEM), flow direction and flow accumulation data sets, and hydrography (streams and reservoirs) coverages used in the watershed delineation process must be acquired for use in this project.

Objectives and Scope

The objective of this project is to delineate six types of watersheds to be used in SWSA as follows:

- Contributing watershed to the intake (delineated at the public-water-supply reservoir outlet or at the mapped location of the intake on the stream)
- Monitored watersheds (as required) - the contributing area to a stream, reservoir, or municipal storm water water-quality monitoring site
- Contributing watershed for all non-public-water-supply reservoirs with normal storage capacity of greater than 1,000 acre-ft, which are located within the contributing area of the public-water-supply intake
- Truncated watershed - the area within the contributing watershed to the intake but excluding any contributing watersheds of non-public-water-supply reservoirs with normal storage capacity of greater than 1,000 acre-ft
- Area-of-primary-influence - the area within 1,000 feet of a reservoir boundary, and, for all streams discharging directly to the reservoir, the area within 1,000 feet of the center of the stream channel of the 3-mile stream reach immediately upstream from the reservoir. For intakes on streams, the area-of-primary-influence is the area with 1,000 feet of the 3-mile stream reach upstream from the intake.
- Multi-jurisdictional area - a watershed area that crosses state or international boundaries, such as the Red River and Rio Grande.

Scope of the project includes delineation of the above watersheds, as required, for approximately 176 water-supply reservoirs.

Approach

The approach here will be to obtain the locations of all surface water intakes, hydrologic derivative and hydrography data sets; convert the data sets to usable form; delineate the contributing watershed boundaries; assign identification and other attribute information; review the data sets and make corrections; and prepare metadata.

Task 1.1: Obtain Locations of Surface Water Intakes and Prepare GIS Coverages

USGS staff will work with PDW staff to obtain locations of public-water-supply intakes either as text files or as GIS coverages, with unique identification number and other pertinent attribute information as specified by TNRCC. In the case of files, the location information will be used to create GIS coverages. In the case of coverages, no conversion should be necessary. USGS staff will review the sites and identify any anomalies or duplicate information. If not already available as an attribute of the intake coverage, USGS staff will determine the source stream or reservoir providing water to the intake and record this information as an attribute of the intake coverage under Task 2.1.3.

TNRCC staff will determine the type of surface water intake (river, reservoir, canal, distal end of a pipeline, etc.). Certain types of intakes will not have a watershed assigned, such as the distal end of a pipeline or a terminal reservoir. The watershed will be defined on the surface water body that provides the water to the intake.

TNRCC staff will determine the point on a surface water body for which a watershed will be determined for ground water wells that may be influenced by surface water. These include wells drawing water from alluvial aquifers, wells classified as “ground water under the influence of surface water”, and wells completed in the Edwards aquifer (Balcones Fault Zone Segment).

Task 1.2: Obtain 60-Meter Hydrologic Derivative Data sets for Texas

USGS-WRD, Austin office will contract with USGS-NMD, Eros Data Center, Sioux Falls, SD, for completion of hydrologic derivative data sets for Texas (See SW-Attachment 1, Draft Statement of Work). These data sets will meet known TNRCC data standards and requirements as well as meet National Map Accuracy Standards and Federal FGDC standards. These data sets will be placed in the National Elevation Database (NED), making Texas the first State to have these data sets completed (see SW-Attachment 3). As the NED database will be logically seamless, Texas data will match exactly with data for other states along Texas borders. This is particularly important for hydrologic applications where the contributing watershed or recharge area to a public water supply may include areas from other political entities (as in multi-jurisdictional areas).

Task 1.3: Obtain Hydrography Data set for Texas

Complete hydrography data sets for Texas are available only at 1:100,000-scale at this time. The USGS staff will obtain the 1:100,000-scale NHD (see SW-Attachment 2) in draft or final version from the USGS, NMD, USEPA, Region 6. As development of the NHD is a work-in-progress, availability of the final NHD for Texas is estimated to be FY 1998. At a minimum, vector information will be available to the project but depending on the status of the database at the time, attribute information as listed in Attachment 2 may not be available. Primarily, SWSA are dependent on the vectors (streamlines and water-body polygons) and not on attribute information, however, names of reservoirs may need to be assigned to the water-bodies coverage. The data set will be projected to the TSMS projection (Texas DIR, 1992), coordinate units in feet, NAD83 datum (Allison, B., TNRCC Interoffice Memorandum, 1/26/1998).

Task 1.4: Revise Stream Segments to Match Flow Accumulation and Pour Point Locations

Selected stream segments from the 1:100,000-scale NHD hydrography will be revised, as required, to ensure conformance of stream or reservoir locations to pour point locations, for all streams or reservoirs required by SWSA. This revision consists of physically moving selected stream-segment vectors on the computer screen to where they visually match the flow accumulation data set.

Task 1.5: Establish Pour Points for Intake Locations at Downstream Flow Accumulation Cell

USGS staff will establish coincident flow accumulation pour-points, as required, for each site in the intake coverage created under Task 1.1. In addition, flow accumulation pour points will be established at other locations required for SWSA. These will include:

- Outlet point of water-supply reservoirs
- Outlet point of other reservoirs within the contributing area to the water-supply reservoir (used in defining the truncated watershed)
- Location of the surface water intake on the stream
- Location of a stream, reservoir, or municipal-stormwater water-quality monitoring site as required

Total number of pour points required is estimated at 250, based on the number of public-supply reservoirs.

Note: *A pour point is the lowest point along the boundary of a watershed boundary. As such it is the point at which water would pour out of a watershed area.*

Task 1.6: Delineate Watershed Boundaries at Pour Points

At each pour point location, established under Task 1.5 above, USGS staff will delineate watershed boundaries using software developed under the Software Development Component.

Task 1.7: Calculate Watershed Characteristics as Required

USGS staff will calculate watershed characteristics for the delineated watershed. Characteristics required for SWSA are listed in Table 1.1.

Table 1.1: List of required watershed characteristics to be determined for each contributing area

Abbreviation	Description	Units
BS	Basin Slope	feet/mile
BSF	Basin Shape Factor	none
BL	Basin Length	miles
CDA	Contributing Drainage Area	square miles
STO	Normal storage volume	acre-ft

Task 1.8: Produce Graphic Check Plots and Review

Graphic check plots will be produced in order to compare the delineations against such as USGS drainage-area maps. A USGS staff hydrologist will review delineations. Needed corrections or changes will be incorporated into the watershed coverage.

Task 1.9: Append Watersheds to Regions Coverages

Individual contributing watershed coverages will be appended into region (ESRI, 1994) coverages for each water-supply reservoir or surface water intake. A unique TNRCC GIN number will be assigned to the watershed boundary as the unique identifier for the region. The GIN number will facilitate the relation of the water supply to the contributing watershed(s) region. Regions are specialized GIS coverages that contain groupings of polygons with assigned unique identifiers. In the case of watersheds, regions allow all of the various types of contributing areas delineated for a particular surface water intake to be addressed as a single unit.

Task 1.10: Prepare Metadata

USGS staff will prepare FGDC-compliant content-level metadata for the PSOC database (FGDC, 1994). Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial data sets and information about the resultant data set including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for Geographic Information Systems will be followed (Texas DIR, 1994).

Deliverables

- 60-meter digital elevation model data for use with GIS for the entire State of Texas
- Hydrologic derivative data sets including flow direction, flow accumulation, and shaded relief, as derived from digital elevation model, at 1:100,000 scale for use with GIS for the entire State of Texas
- Arc/Info coverages of pour point locations
- Arc/Info coverages of contributing watersheds to the intake (delineated at the public-water-supply reservoir outlet or at the mapped location of the intake on the stream), including required attributes
- Arc/Info coverages of contributing watersheds for all non-public-water-supply reservoirs with normal storage capacity of greater than 1,000 acre-ft, which are located within the contributing area of the public-water-supply intake, including required attributes
- Arc/Info coverages of truncated watersheds, including required attributes
- Arc/Info coverages of areas-of-primary-influence watersheds, including required attributes
- Arc/Info coverages of multi-jurisdictional areas, including required attributes
- Arc/Info region coverages for all public-water-supply reservoirs or stream intakes, including required attributes
- FGDC-Compliant content-level metadata for each coverage type

References

Environmental Systems Research Institute, Inc. (ESRI), 1994: ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee. Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.11.

Texas Natural Resource Conservation Commission, 1997, TNRCC Operating Policies and Procedures 8.12, Global Positioning System.

<u>Delineation Component - Attachment 1 – Statement of Work For 60-Meter Digital Elevation Models</u>

Statement of work to be performed for the USGS Water Resources Division, Texas District, Contact person: Randy Ulery (512-873-3058)

Work to be performed by USGS Earth Resources Observation Systems Data Center (EDC), National Mapping Division, Contact person: Sue Greenlee (605-594-6011)

Reimbursable cost: $100K FY 1998 - deliverables 1 through 4, $25K FY 1999

Deliverables

I. A logically seamless elevation database of Texas, assembled from USGS 7.5-minute digital elevation models (DEMs). The DEMs will be processed in the following manner in order to produce the seamless database:

- Production artifacts will be minimized with a two-pass filter process as described by Oimoen, 1997 (in review).
- A smoothing filter will be applied to minimize edge effects where edge matching between source files is insufficient.
- Metadata will be assembled that will provide information about the source data that was used and how it was processed, including the name references and original metadata for the 7.5-minute files. This metadata will be accessible through spatial Arc/Info coverages.
- The data will be screened for errors in consistency such as unit of measure, and a shaded-relief representation will be visually screened and problems noted and corrected.
- The seamless elevation database will be assembled with a 1 arc-second cell size in a Plate Carree (lat/long) projection. This database will be delivered to Texas and retained by EDC as the first complete state having the NED assembled. This database is the basis for the additional deliverables. It will be available for future Texas projects that require the full 1 arc-second resolution.

2. The seamless elevation database in (1) above also will be provided to Texas in the TSMS projection with a cell size of 60 meters.

3. Three hydrologic derivative data sets will be delivered. The database in (2) above will be processed in Arc/Info with the Grid tools that fill depressions, calculate flow directions, and calculate flow accumulation to build the three derivatives. Depressions that can be identified by Texas as authentic rather than spurious (closed basins) will not be filled. This process of identifying closed basins may require several iterations with the responsible parties in Texas, but will speed the watershed processing that will be done subsequently in Texas. The filtering and edge-matching procedures described in (1) make corrections in the elevation data that produce significantly higher-quality hydrologic derivatives.

II Three additional derivatives of slope, aspect, and shaded-relief will also be computed from (2) above. The algorithmic parameters selected by Texas for slope calculation, illumination angle and exaggeration will be used.

5. The elevation database and derivatives described in 2 through 4 above will be supplied in the Albers map projection also. The parameters for this projection are listed in below. The version of the database in this projection also will have a cell size of 60 meters. This database version will be produced after the TSMS version and is the deliverable item corresponding to the FY 1999 $25K reimbursable.

Distribution Format and Method

All files will be created in Arc/Info and will be delivered to Texas as Arc grids and/or images as they deem most useful. While the databases are logically seamless, Texas may opt to receive the data subdivided into tiles for easier handling. EDC has reserved room for these products on an ftp server. The products also will be supplied on CD or 8mm media if requested.

Timetable

All products for the first deliverable will be completed by 11/30/98. All products for the second deliverable will be completed by 2/20/99.

Related activities at EDC, information note:

This agreement gives EDC the opportunity to produce a large piece of the NED and work directly with collaborators in a major application. Along with NED, the EDC plans to produce nationally consistent elevation-derived hydrology, termed NED-H. The NED-H will contain flow accumulation and watershed delineations at a 30 meter or smaller resolution. If NED and NED-H were completed, Texas could have used them directly without this agreement. This activity will aid EDC's design of the NED and NED-H. While not called out as deliverables in this plan, the efficient calculation of flow networks and watersheds, and the internet browser and distribution of the data will be active areas of development this fiscal year at EDC, and will hopefully enhance the near-term utility of the data for Texas.

Projection parameters for data sets to be completed in FY 1998:

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units: Decimal Degrees
Planar:
Map_Projection:
Map_Projection_Name: Lambert Conformal Conic
Texas State-wide Mapping System

Standard_Parallel: 34d 55m 00s
Standard_Parallel: 27d 25m 00s
Longitude_of_Central_Meridian: -100d 00m 00s
Latitude_of_Projection_Origin: 31d 10m 00s
False_Easting: 1,000,000 meters
False_Northing: 1,000,000 meters
Other_Projection's_Definition:
The projection used also is known as the Texas Statewide Mapping System (TSMS) defined in the Texas GIS Planning Council's GIS Data Standards.
Grid_Coordinate_System:
Grid_Coordinate_System_Name: Texas Statewide Mapping System
Other_Grid_System's_Definition:
The coordinate system used corresponds to the Texas Statewide MappingSystem (TSMS) defined in the Texas GIS Planning Council's GIS Data Standards. TSMS uses measurement units of meters.
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Projection parameters for data sets to be completed in FY 1999
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units Decimal Degrees
Planar:
Map_Projection:
Map_Projection_Name: Albers Equal Area
Standard_Parallel: 34d 55m 00s
Standard_Parallel: 27d 25m 00s
Longitude_of_Central_Meridian: -100d 00m 00s
Latitude_of_Projection_Origin: 31d 10m 00s
False_Easting: 1,000,000 meters
False_Northing: 1,000,000 meters
Other_Projection's_Definition:
The projection system uses the same parameters as the TSMS.
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80

Delineation Component - Attachment 2

An Overview of the National Hydrography Data set (Downloaded from http://nhd.fgdc.gov/nhdpgs/nhdoview.htm on 6/98)

The National Hydrography Data set (NHD) is the culmination of recent cooperative efforts of the USEPA and USGS. It combines the best of the USEPA Reach File Version 3.0 (RF3) and USGS Digital Line Graph (DLG) hydrography files: hydrologic ordering, hydrologic navigation for modeling applications, and a unique identifier (reach code) for surface water features from RF3; and the spatial accuracy and comprehensiveness of DLG hydrography.

In response to their own needs and those of other users, USGS and USEPA formalized their commitment to merging RF3 and DLG hydrography in a Memorandum of Understanding in 1994. This merger of complementary systems also coincided with the FGDC led efforts to develop the NSDI. Consequently, the NHD incorporates the NSDI framework criteria set out by the FGDC. The NHD is designed to provide comprehensive coverage of hydrologic data for the US. While based on 1:100,000-scale data, the NHD is designed to incorporate—and encourage the development of—higher-resolution data required by many users. It also will facilitate the improved integration of hydrologically related data in support of the application requirements of a growing national user community and will enable shared maintenance and enhancement. The NHD is a natural evolutionary step that combines the extensive previous work of USGS, USEPA, and others. By incorporating these systems and data, the NHD is immediately more comprehensive, powerful and useful than any of its components and it is designed for continual expansion and improvement by user-contributors. As part of the dynamic nature of the NHD, it will be available on-line (with some initial limitations.)

An integral feature of the NHD is that it incorporates a two-way exchange of data between the National level and the State and local level. States, localities, and other users are expected to benefit from the NHD and to contribute to the data set as well. The NHD supersedes RF3 and DLG by incorporating them, not by replacing them. Users of RF3 or DLG will find the same data in a new, more flexible format. They will find the NHD both familiar and greatly expanded and refined.

Characteristics of the NHD

The primary entity in the NHD will be a basic feature. There are 53 different types of basic features.

- For 1:100,000-scale data, there are 43 basic features types. 10 additional feature types are added for 1:24,000-scale data. Additional feature types may be added in the future to accommodate data of higher resolution.
- The NHD will be housed in an ORACLE/SDE database called the Feature Operational Database (FOD).
- The FOD will be available on the Internet through the USGS. Initially, retrievals by USGS cataloging unit will be supported. Over time, retrievals will be supported through queries of metadata and by user-specified geographic extent. User updates will be incorporated into the FOD.

- Graphically features can be a collection of points, a collection of lines, or a collection of polygons.
- Features may be grouped, regardless of dimensionality, into compound features.
- There are two types of compound features defined: Reach and Named Watercourse
- Reaches will be compound features composed of 12 basic feature types. They will have unique ids which are 14 digit reach codes: Catalog Uniting (8) + Segment (6).
- Named Watercourses will be compound features, which may be composed of reaches or of basic features. They will have unique ids, which come from the USGS Geographic Names Information System (GNIS).
- All basic features, which do not belong to a reach, will have a unique feature id.

Characteristics of the Reach File Subset of the NHD

- The "reach file" will be a subset of the NHD.
- Approximately 81 percent of the NHD’s basic features will belong to reaches.
- In the first release of the FOD, a linear network will graphically represent the “reach file.”
- In subsequent releases of the FOD, a linear network and a 2-dimensional (polygon) network will graphically represent the “reach file.”
- Reaches will have topologic connectivity through the use of connector basic features.
- Reaches will have attribute connectivity through the implementation of "flows to" relationships.
- Reaches will have a stream level attribute.

NHD - Basic Feature Types

Basic Features that are Reach Components:

1. Area of Complex Channels
2. Artificial Flow Path
3. Canal/Ditch
4. Connector
5. Estuary
6. Ice Mass
7. Lake/Pond
8. Pipeline
9. Reservoir
10. Stream/River
11. Swamp/Marsh
12. Wash

Basic Features that are not Reach Components:

1. Anchorage
2. Area To Be Submerged
3. Bay/Inlet
4. Bridge
5. Crevasse Field
6. Dam/Weir
7. Fish Ladder
8. Flume
9. Foreshore
10. Fumarole
11. Gaging Station
12. Gate
13. Geyser
14. Hazard Zone
15. Inundation Area
16. Lock Chamber
17. Mile Marker
18. Mud Pot
19. Non-earthen Shore
20. Playa
21. Post
22. Rapids
23. Reef
24. Rock
25. Sea/Ocean
26. Shoreline
27. Sink/Rise
28. Snag/Stump
29. Sounding Datum Line
30. Special Use Zone
31. Special Use Zone Limit
32. Spillway
33. Spring/Seep
34. Submerged Stream
35. Tunnel
36. Underpass
37. Wall
38. Water Intake/Outflow
39. Waterfall
40. Well
41. Wreck

<u>Intrinsic Characteristics Component – Mean Annual and Mean-Seasonal Streamflow (Task 2.1)</u>

Statement of Problem

The USGS has monitored streamflow and maintained continuous streamflow data for about 603 streamflow-gaging stations in Texas. Approximately 334 of these stations have at least 8 years of data for natural basins. A natural basin is defined as a rural and non-urbanized basin with less than 10 percent of its contributing drainage area consisting of impervious cover or controlled by reservoirs. The USGS continuous streamflow data provide the State with information to evaluate and plan for the availability, development, appropriation, conservation, and protection of surface water resources which are owned and managed by the State through State, regional, and local agencies. The estimation of mean runoff is requisite for managing the water supply and water quality of the State's surface water resources.

As part of the Texas SWAP, an efficient method for estimating statewide runoff for ungaged water-supply intakes within natural basins is needed. Factors affecting mean runoff potential, such as climate, topography, geology, soil characteristics, and vegetative cover, vary considerably across Texas. Assessment of each of these factors requires very detailed, site-specific data which in many cases are not readily available, and if the data were available, accounting for each of these components would result in a runoff assessment tool being too complex for statewide estimation of runoff. In 1995, Asquith and Slade delineated eleven hydrologic regions based on areas of the State with similar climate, geology, soil characteristics, vegetative cover, topography, drainage-basin boundaries of large basins, and areal density of streamflow gaging stations (fig. 2). The hydrologic regions provide for the development of an efficient regional runoff assessment tool for statewide estimates of mean runoff from ungaged natural basins.

Variability of mean-annual streamflow also can be attributed partly to the temporal variability of the climate over the State. Precipitation depths and intensities that affect the amount of runoff change with the seasons. To address the variability associated with seasonal precipitation characteristics and to improve the temporal resolution of estimated mean runoff, mean seasonal estimates of runoff must be used.

Goal and Objectives

The goal of this project is to provide a set of regional regression equations for estimating the mean-annual and mean-seasonal runoff of ungaged natural basins in Texas. Specific objectives for this project include:

- Assemble long-term (1961–90) data sets of mean-annual and mean-seasonal streamflow and their associated basin characteristics
- Develop regional regression equations for estimating mean-annual and mean-seasonal streamflows from ungaged natural basins in Texas

- Document and describe regional regression equations for estimating streamflows for natural basins in Texas

Approach

Task 2.1.1: Assemble Database of Mean-Annual Streamflow and Basin Characteristics for Natural Basins. The USGS will assemble a database of long-term (1961–90), mean-annual streamflow and basin characteristics, such as contributing drainage area, basin shape factor, stream slope, and stream length for natural basins in Texas. The 1961–90 mean-annual streamflow for stations with less than 30 years of record data (short-term stations) will be included in the database. The long-term flow for the short-term stations will be estimated based on statistical comparison of the common period of record for each short-term station and a nearby long-term station.

Task 2.1.2: Develop Regional Regression Equations to Estimate Mean-Annual Runoff for Natural Basins. Regional equations will be developed for each of eleven hydrologic regions in Texas (Asquith and Slade, 1995) using weighted least-squares regression analysis of long-term (1961–90), mean-annual streamflow and basin characteristics data from stations in natural basins. The multiple regression analysis will establish the statistical relations between streamflow (dependent variable) and basin characteristics (independent variables) using methods similar to Asquith and Slade (1996). For each regression equation, standard errors will be determined.

Task 2.1.3: Assemble Database of Mean-Seasonal Streamflow and Basin Characteristics for Natural Basins. The USGS will assemble a database of long-term (1961–90), mean-seasonal streamflows for each of four seasons—winter (January–March); spring (April–June); summer (July–September); and fall (October–December); and integrate it with basin characteristics developed in Task 2.1.1 above. The 1961–90 mean streamflow for stations with less than 30 years of record will be included in the database, by using the method described in Task 2.1.1 above.

Task 2.1.4: Develop Regional Regression Equations to Estimate Mean-Seasonal Runoff for Natural Basins. The USGS will develop regional equations for the estimation of mean-seasonal streamflow for natural basins in Texas. Weighted least-squares regression analysis will be done for each season and for each of eleven hydrologic regions using long-term (1961–90), mean-seasonal streamflow and basin characteristics data from stations as described in the tasks above. For each regression equation, standard errors will be determined.

Task 2.1.5: Prepare USGS Report to Document Development and Limitations of the Regional Equations. The USGS will prepare a Water Resources Investigation Report, consisting of 50 to 100 pages of text and illustrations, to document the development, limitations, and use of the regional equations.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas DIR, 1994). All coverages developed during this project will be quality-control checked. In addition, the information will be peer reviewed by the District Surface water Specialist.

Deliverables

- Regression equations for estimating mean-annual runoff within each of eleven hydrologic regions of Texas
- Regression equations for estimating mean-seasonal runoff for each season within each of eleven hydrologic regions of Texas
- USGS Water-Resources Investigations Report

References

Asquith, W.H., and Slade, R.M., Jr., 1995, Documented and potential extreme peak discharges and relation between potential extreme peak discharges and probable maximum flood peak discharges in Texas: U.S. Geological Survey Water-Resources Investigation Report 95–4249, 58 p.

Asquith, W.H., and Slade, R.M. Jr., 1996, Regional equations for the estimation of peak-streamflow frequency for natural basins in Texas: U.S. Geological Survey Water-Resources Investigation Report 96–4307, 68 p.

Texas Department of Information Resources, 1994, Standards and guidelines for geographic information systems in the State of Texas.

<u>Intrinsic Characteristics Component – Runoff, Soil Erodibility, Beneficial Effects of Reservoirs and Time of Travel (Task 2.2)</u>

Statement of Problem

Surface water supplies are all to some degree "intrinsically" susceptible to contamination because contaminants released at the land surface can potentially reach supplies in relatively short time frames. There are several factors that can affect the relative magnitude of susceptibility. The geology, soil characteristics, and vegetative cover affect the amount of runoff and the attenuation of contaminants in watersheds. Eroded soil may carry, adsorbed on the surface of the sediment particles, organic chemicals and pesticides, nutrients, and heavy metals. The dilution capacity and contaminant degradation capability of a stream, or reservoir, each affect the fate, transport, and degradation of contaminants. Finally, the slope of the land controls the time-of-travel of contaminants in runoff. Assessment of each of these factors requires very detailed, site-specific data which in many cases are not readily available, and if the data were available, adding each of these components would result in the susceptibility assessment tool being too complex for statewide source-water assessment purposes. Rather, the following four broad measures will be used to assess the intrinsic susceptibility of a source water-supply:

> Task 2.2.1: Ratio of Mean-Annual and Mean-Seasonal Runoff to Mean-Annual Precipitation. Generally speaking, if precipitation falls on a watershed having shallow soils and steep slopes, as contrasted to an area with deep soils and less relief, there is greater potential for point and non-point contaminants on the land surface to reach a water-supply intake. This is primarily due to the fact that deeper soils and decreased relief increase the potential for attenuation of contaminants. Stated another way, if two watershed areas receive similar amounts of precipitation, the watershed area that generates a larger amount of runoff intrinsically has less potential for attenuation of a contaminant. To assess a watershed area's intrinsic susceptibility associated with surface runoff, the ratio of the mean-annual runoff to mean-annual precipitation will be calculated. Low values of this ratio indicate less susceptibility; higher ratios indicate increased susceptibility. Variability of mean-annual streamflow can be attributed partly to the temporal variability of the climate over the State. Precipitation depths and intensities that affect the amount of runoff change with the seasons. To address the variability associated with seasonal precipitation characteristics, estimates of mean-seasonal runoff must be used. To assess a watershed area's intrinsic susceptibility associated with the seasonal variability of surface runoff, the ratio of the mean-seasonal runoff to mean-seasonal precipitation will be calculated. Low values of this seasonal runoff-precipitation ratio indicate less susceptibility; higher ratios indicate increased susceptibility.
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> Task 2.2.2: Intrinsic Susceptibility Associated With Soil Erodibility. The quality of surface water supplies is affected by soil-forming processes or reactions that occur within the soil zone. Sediment, that is, eroded soil, reduces the storage capacities of reservoirs. Sediment also carries, adsorbed on the surface, organic chemicals and pesticides, nutrients, and heavy metals. The processes of soil erosion and sediment

transport by rain and runoff are selective in terms of grain size and weight. In general, the coarser sediments deposit first and the finer ones move further downstream. As a consequence, suspended sediments tend to contain more of the finer, less dense particles. Because these fine particles may contain adsorbed chemicals it follows that an enrichment of any sorbed chemical in eroded sediment must be considered in an assessment of surface water susceptibility. The STATSGO database for Texas contains a soil erodibility factor which will be used to develop a Geographic Information System (GIS) coverage of soil erodibility. Based on the erodibility factor contributing watersheds with higher soil erodibility potential will be considered to be more susceptible to soil associated contaminants.

Task 2.2.3: The Beneficial Effects of Reservoirs on Reducing the Concentration of Contaminants. Studies have documented how reservoirs can integrate the variable water quality of their contributing streams. The effectiveness of a reservoir's integrating capacity is a function of the reservoir’s storage characteristics. Contaminants will enter a reservoir either as intermittent slugs of runoff (non-point sources) and as relatively continuous inflows (point sources). Within the reservoir the following processes can work together or separately to reduce a contaminant’s concentration or convert/degrade the contaminant to a less threatening form: dispersion, dilution, sedimentation, chemical/biological conversion and degradation, and biological uptake. To assess the potential beneficial effect of reservoirs within a watershed, the ratio of reservoir storage in the watershed to its runoff will be used to represent the processes listed above. Reservoir storage is the summation of the normal storage for each reservoir in the watershed. There are about 205 reservoirs in Texas with a normal storage capacity exceeding 5,000 acre-ft and more than 4,500 reservoirs with a normal storage capacity between 5,000 and 200 acre-ft. Only those reservoirs with a normal storage capacity greater than 1,000 acre-ft will be used in this assessment. This will include all public-water-supply reservoirs (about 176 reservoirs). High values for the ratio indicate less susceptibility at the intake due to reservoir storage (e.g., their beneficial processes); low values for the ratio indicate increased susceptibility.

Task 2.2.4: Intrinsic Susceptibility Associated With Time-Of-Travel. Within a stream, the following processes can work together or separately to reduce a contaminant’s concentration or convert/degrade the contaminant to a less threatening form: dispersion, dilution, sedimentation, chemical/biological conversion and degradation, and biological uptake. However, time must be provided for these processes to occur. Generally, there is less potential for the concentration of a contaminant to be reduced when there is a shorter time-of-travel between the point where the contaminant enters the stream and the intake point. To assess a watershed’s intrinsic susceptibility associated with time-of-travel, the ratio of the size of watershed to the basin slope will be calculated. High values of the size-slope ratio indicate longer time-of-travel and thus less susceptibility; lower ratios indicate shorter time-of-travel and thus increased susceptibility.

Goals and Objectives

The goal of this project is to provide scientific input to the overall SWAP by developing tools to determine the “intrinsic” susceptibility of a stream or reservoir to potential sources of contamination in a public-supply watershed. Specific objectives include:

- Assess a watershed’s intrinsic susceptibility associated with mean-annual surface runoff by using the ratio of estimated mean-annual runoff to mean-annual precipitation for contributing watershed’s of water-supply intakes,
- Assess a watershed’s intrinsic susceptibility associated with mean-seasonal surface runoff by using the ratio of estimated mean-seasonal runoff to mean-seasonal precipitation for contributing watersheds of water-supply intakes,
- Assess a watershed’s intrinsic susceptibility associated with soil erodibility for contributing watersheds of water-supply intakes,
- Indirectly assess the potential beneficial effects of reservoirs within a watershed on reducing the concentration of contaminants by using the ratio of total reservoir storage to mean-annual runoff,
- Assess a watershed’s intrinsic susceptibility associated with time-of-travel within the watershed by using the ratio of the size of the contributing watershed to basin slope, and
- Document and describe spatial data generated from above tasks by developing metadata for GIS coverages.

Approach

The majority of the ratios used in the following tasks will be generated using software developed under the Software Development Project. Nevertheless, these ratios require spatial GIS databases and threshold values to establish degrees of surface water susceptibility. Contributing watershed delineations and basin characteristics used in the following tasks will be developed under Surface water Component 1.

Task 2.2.1.1: Develop mean-annual and mean-seasonal precipitation coverages.
Digital contour maps for mean-annual precipitation and mean-seasonal precipitation will be developed using available 1961–90 precipitation data. Each contour map will be entered into a GIS database. The mean-seasonal precipitation data will be entered as four separate GIS coverages: winter (January–March); spring (April–June); summer (July–September); and fall (October–December).

Task 2.2.1.2: Use ratios of mean-annual runoff to mean-annual precipitation to develop threshold values to determine surface water susceptibility associated with annual-runoff.

The regional equations developed in Project 3.1 will be used to estimate mean-annual runoff for each contributing watershed and entered as an attribute into a GIS database. Using these database attributes the estimated mean-annual runoff to mean-annual precipitation for each contributing watershed will be created. These ratios will be used to develop threshold values for assigning degrees (low to high) of surface water susceptibility to contamination associated with annual-runoff.

Task 2.2.1.3: Use ratios of mean-seasonal runoff to mean-seasonal precipitation to develop threshold values to determine surface water susceptibility associated with seasonal-runoff.

The regional equations developed in Project 3.1 will be used to estimate mean-seasonal runoff for each contributing watershed and entered as an attribute into a GIS database for each of the four seasons: winter (January–March); spring (April–June); summer (July–September); and fall (October–December). Using these database attributes the estimated mean-seasonal runoff to mean-seasonal precipitation for each contributing watershed will be created. The ratios, for each season, will be used to develop threshold values for assigning degrees (low to high) of surface water susceptibility to contamination associated with seasonal-runoff.

Task 2.2.2.1: Develop soil erodibility coverage based on simplified STATSGO data.

A polygon GIS coverage representing soil erodibility will be created using attributes from the STATSGO database for Texas.

Task 2.2.2.2: Use soil erodibility index values to develop threshold values to determine surface water susceptibility associated with soil erosion. The contributing watershed for each intake will be overlaid by the soil erodibility coverage. Corresponding erodibility index values will be summed for the contributing watershed resulting in an erodibility index value. These erodibility index values will be entered as an attribute into a GIS database. These index values will be used to develop threshold values for assigning degrees (low to high) of surface water susceptibility to soil erosion.

Task 2.2.3.1: Use ratios of total reservoir storage to mean-annual runoff to develop threshold values to determine the beneficial effects of reservoirs on reducing the concentration of contaminants. A database table will be developed of normal storage area for reservoirs greater than 1,000 acre/feet. Ratios of the total reservoir storage to mean-annual runoff for each contributing watershed will be calculated using the database table assembled in preceding Task 2.2.1.2. The ratios of total reservoir storage to mean-annual runoff will be used to develop threshold values for assigning degrees (low to high) of surface water susceptibility accounting for the beneficial effects of reservoirs on the attenuation of potential contamination.

Task 2.2.4.1: Use ratios of watershed area to basin slope to develop threshold values to determine susceptibility associated with time-of-travel. The contributing watershed for each intake will be used to estimate the ratio of basin area to basin slope. The basin characteristics of area and slope are being calculated for each contributing watershed under Surface water Component 1. These ratios will be used to develop threshold values for assigning degrees (low to high) of surface water susceptibility associated with time-of-travel.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994). All coverages developed during this project will be quality-control checked. In addition, the information will be peer reviewed by the District Surface water Specialist.

Deliverables

- GIS coverage of mean-annual precipitation for 1961–1990
- Four separate GIS coverages of mean-seasonal precipitation for 1961–1990
- GIS coverage of soil erodibility
- Database table containing mean-annual runoff to mean-annual precipitation
- Database table containing mean-seasonal runoff to mean-seasonal precipitation
- Database table containing watershed size to basin slope
- Database table containing total reservoir storage to mean-annual runoff
- Threshold values to be used by the overall SWAP
- FGDC compliant, content-level metadata for the GIS coverages

References

Texas Department of Information Resources, 1994, Standards and guidelines for geographic information systems in the State of Texas.

Non-point Source Component (Task 3)

Statement of Problem

The susceptibility of a surface water supply, usually a reservoir in Texas, to contamination is a function of the hydrologic and geographic setting of the supply. For example, a reservoir downstream from a large urban area is obviously more susceptible to contamination than a reservoir in a forested or rangeland watershed. An impartial, scientific approach for categorizing reservoirs and other water-supply intakes for their susceptibility to contamination, however, is not currently available. Such an approach could help reduce monitoring costs where susceptibility is low; focus necessary monitoring on areas, seasons, and compounds of more concern; and help guide remediation and pollution control efforts. In addition, the results of this project may be applied for other purposes in Texas as well as being transferrable to other parts of the country.

Objectives

This project will provide scientific input to the overall SWAP for the assessment of the susceptibility of surface water supplies to non-point sources of contaminants. Sources originating from all major human land uses will be considered. These include urban, agricultural, range, and mining land uses. Natural environmental factors that can affect water quality also will be evaluated including hydrologic characteristics and soil properties. Together, these human and natural factors comprise the environmental characteristics of sampling sites and water-supply intakes. Existing water-quality data collected by the U.S. Geological Survey (USGS) and by the TNRCC will be used in the analysis. Specific objectives include:

- Develop a database containing constituents with available water-quality data and selected environmental characteristics of water-quality monitoring sites and water-supply intakes
- Determine, to the extent possible, statistical relations between environmental characteristics of sites and the occurrence of contaminants
- Provide the SWAP with threshold values of environmental characteristics that indicate susceptibility of surface water supplies to contamination (a threshold value is a measure of the type or intensity of land use or other environmental characteristic that correlates with contaminant occurrence either in the watershed or in treated drinking water).

Approach

The susceptibility of surface water supplies to non-point sources of contaminants will be assessed with threshold values for constituents of concern developed from selected environmental characteristics. Statistical relations between the occurrence of contaminants in water (streams, reservoirs, and treated drinking water) and the environmental settings of those contributing water to a site will be used to determine the threshold values. The environmental characteristics will consist of human and natural factors.

Task 3.1: Compile Available Water-Quality Databases

Surface water-quality data are available from a number of agencies, at a variety of locations, and for a large number of constituents. Three types of data are available and will be utilized: (1) ambient monitoring data for streams and reservoirs, (2) event-based monitoring data (mostly urban stormwater), and (3) treated drinking-water testing data (known as "entry point" data) from TNRCC. Because this analysis is driven by concern for human health from drinking water and is statewide in scope, four water-quality data sets have been identified that will be of value. Other data sets could be identified and obtained during the project. The four are:

- USGS stream and reservoir ambient monitoring data-available digitally and most sites are already associated with watersheds and some of the above land-use data sets.
- TNRCC Surface Water Quality Monitoring (SWQM) data-available digitally and many sites are already associated with watersheds and some of the land-use data sets.
- USGS National Water-Quality Assessment Program (NAWQA) data-excellent pesticide data sets for two parts of the State, the Trinity River Basin (43 sites) and the Edwards Plateau. Available digitally and associated with land use.
- TNRCC "entry point" data-available digitally.

Although each of these data sets is in digital form, and some of the sites are already associated with environmental characteristics, each is in a different format and each is missing some of the environmental characteristics. A (very) considerable amount of database cleanup, reformatting, and GIS overlay and manipulation will need to be done before data analysis can proceed. Initially, the data will be screened to determine selected constituents with an adequate number of analyses to relate to environmental factors. The water-quality data also will be evaluated for seasonal variations. If seasonal variations are present, the data for the selected constituent will be aggregated by season. Several major studies or specific reports have been identified that also could be useful for this analysis. These include:

- Various USGS NAWQA study reports (e.g., Land and Brown, 1996).
- The USGS mid-continent (Mississippi) study reports that relate pesticides and nutrients to agricultural land use over the midwestern United States (Scribner and others, 1996).
- The statewide analysis of water quality done by the USGS for the TNRCC Clean Rivers Program (CRP) and published in their 1994 Summary Report (TNRCC, 1994).

Task 3.2: Assemble and Reformat Existing Watersheds

The contributing watersheds for most historical water-quality sampling locations (sites) have been delineated using the 1:250,000 scale Digital Elevation Models (DEMs) processed by the USGS for the CRP (Tan, 1997). The coverages will be reformatted and projected into the standard SWAP projection. Selected environmental characteristics will be overlain with the contributing watersheds digital coverages.

Task 3.3: Determine Environmental Characteristics Of Sampling Sites and Drinking Water Intakes

Environmental characteristics including natural and human factors known or suspected of influencing water quality in watersheds will be estimated for each sampling site and water-supply intake. The natural factors affect the efficiency of transport of potential non-point source contaminants from the land surface to streams or from the stream to a downstream reservoir or water-supply intake. Natural factors include hydrologic characteristics (ratio of runoff to rainfall, average and seasonal flow, watershed size, watershed slope, and extent of regulation by a reservoir) and soil properties (soil permeability and soil organic content). The human factors affect the occurrence of contaminants in streams and reservoirs. Human factors include land use and point sources. Land use includes a number of more detailed data layers. Several that will be evaluated in this analysis are: (1) population density; (2) percentages of urban, agricultural, range, forest, and wetlands; (3) agricultural crop acreage; (4) urban and agricultural pesticide use; (5) animal densities and concentrated animal feeding operations (CAFOs); and (6) detail within urban land use such as residential, commercial, and industrial categories. It is not possible to separate point sources from non-point sources in instream monitoring data. Therefore, the relative contribution of the point-source flow to the non-point- source streamflow must be addressed.

Natural Factors - The relation between rainfall and runoff indicates the fraction of rain falling on the land surface reaching streams and is also an indicator of the efficiency of transport of non-point source contaminants on the land surface for reaching streams. This relation varies seasonally and with antecedent conditions. In areas with low rainfall and high soil permeability, proportionally little rain becomes runoff and proportionally less of the land-surface applied contaminants, like a pesticide, will reach the streams. At a national scale, statistical analysis of USGS water-quality data, Smith and others (1997) used stream density as a measure of transport efficiency from the land to streams and found it to be a significant variable. The runoff to rainfall relation is preferred because it is a more direct measure of transport by water from the land surface to streams. Annual, monthly, or other seasonal divisions and antecedent factors will be used to account for regional variations in runoff generation and correlate with seasonal variations in constituent concentrations.

If the watershed is large, has a low slope, and (or) has reservoirs between source areas and the intake or sampling site, travel time will be longer, dilution will probably be greater, and instream and intra-reservoir processes, including uptake, conversion, and breakdown of the contaminant and volatilization could be greater. All of these factors can reduce the efficiency of contaminant transport within a watershed. Also, for reservoirs, the trapping of sediment and associated contaminants is an additional factor that reduces the transport of contaminants downstream (Smith and others, 1997; Van Metre and Reutter, 1994). These variables are being determined for Texas streams for use in this analysis and in the overall SWAP as part of Project 3 (surface water) and will be determined for the contributing watershed of each historical sampling location and each intake using basin characteristics developed at the 1:250,000 scale (Tan, 1997).

Digital soils data also are available from the Natural Resources Conservation Service STATSGO database. Aggregation presents a separate problem that will need to be addressed. How for example is a soil characteristic (e.g., organic carbon content) for a site on the Brazos River, with a drainage area of thousands of square miles, over multiple physiographic provinces, characterized? The current conceptual approach will be to overlay large-scale polygons of agricultural lands (e.g., GIRAS) with the soils data and average soils characteristics for just those areas identified as agriculture. This should lead to less variability in soils than basinwide and be more appropriate for assessment of agriculture-related compounds. A similar approach can be followed for watersheds containing urban areas by averaging soil properties only for the built-up parts of the watershed. Alternative soils databases for Texas are being explored with the Texas Agricultural Experiment Station (TAES).

Human Factors - With the exception of some trace elements in mineralized settings, the contaminants of concern for this study are either anthropogenic in source (e.g., man-made organic compounds) or their occurrence is enhanced by human activities (e.g., trace elements and polycyclic aromatic hydrocarbons (PAHs)). Their occurrence is, therefore, largely controlled by human land usage. For example, the occurrence of pesticides in streams is greater in urban and agricultural settings than in rangeland, forest, or other relatively undeveloped areas as demonstrated in a number of studies in Texas and elsewhere (e.g., Ferrari and others, 1997; Land and Brown, 1996).

Five land-use data sets have been identified that could be used in this analysis. All are available digitally but require some modification or clean up. They are:

GIRAS—land-use data set is the only national digital land-use coverage as developed by the USGS National Mapping Division during the 1970s and early 1980s. Its strength is that it covers the whole country and is available for display and manipulation using ARC/INFO. The weaknesses are that it is dated and has limited detail in agricultural areas. GIRAS will be overlaid with contributing watersheds to determine percent land use for categories including urban, agricultural, forest, and range.

TAES—Available agricultural crop acreage, and agricultural fertilizer and pesticide use data have been discussed with the TAES. The data currently are available at the 8-digit Hydrologic Unit Code (HUC) and county level. This resolution is probably sufficient for sampling sites and intakes with larger contributing watersheds (e.g., several hundred square miles or larger); however, some errors in soils and land-use definition could result for smaller watersheds. Some manipulation of the data at the HUC scale may be necessary and useful for more accurately parameterizing sites and intakes where HUC boundaries do not coincide with site locations. Although pesticide and fertilizer use is variable from season to season, year to year, or on the same field, an estimate will be made to quantify average use in the watershed.

Population—The 1990 census is currently available digitally and will be overlaid with watersheds to determine population density.

Oil well—Available digital location data for oil and gas production well fields will be overlaid with contributing watersheds to determine "density of wells" as a variable, particularly for contamination by salinity, some metals, and organics that can be precursors for the formation of trihalomethanes (THM) or other disinfection by products.

Point sources—A set of programs developed by National Oceanic and Atmospheric Administration (NOAA) have been modified and used nationally to make a preliminary assessment of point-source discharges of selected contaminants. A draft version of this database is available for Texas. This will be obtained and possibly updated with more recently available data. It will be overlaid with contributing watersheds and, minimally, the proportion of flow from different types of point sources will be calculated. If the data seem to support more detailed analyses, loads of individual contaminants also will be estimated.

Task 3.4: Relate Occurrence and Magnitude of Water-Quality Constituents to Environmental Characteristics

The first step in the analysis will be to correlate statistical summaries of water-quality variables (e.g., median and 90th percentiles, percent detections, number of pesticides detected, etc.) to environmental variables (e.g., percent urban land use, the ratio of runoff to rainfall, etc.). This correlation will be done graphically and numerically. Depending on the strength of the relations and on the availability of data, a number of more sophisticated statistical techniques will be utilized. One possibility is multiple regression analysis, for example, predicting the 90th percentile concentration of fecal coliform as a function of population density and soils or runoff characteristics. Another possibility, that is likely for some of the pesticides and VOCs (characterized by small, highly variable concentrations and sparse data sets statewide), is to use logisic regression in which the probability of some "class" variable outcome is predicted instead of a concentration. For example, the probability of a detection or a value above some concentration level (maximum contaminant level (MCL), for example) could be predicted for a pesticide or group of pesticides as a function of the percent urban or agricultural land usage in the watershed.

Finally, if data for a given parameter are simply unavailable or are so sparse as to preclude developing statistically valid relations, published reports from localized areas in Texas and from other parts of the country and best professional judgment will be used. The objective of these analyses is to identify environmental settings that lead to a conclusion that a surface water supply is susceptible to contamination. These settings will probably be characterized by gradients in land usage and either gradients or ranges of intrinsic variables. For example, in an analysis of stream water quality for the TNRCC CRP (TNRCC, 1994), the USGS showed graphically that, on average, a population density greater than about 1.5 people per square kilometer led to 90th percentile fecal coliform concentrations greater than the CRP guideline of 400 colonies per 100 milliliters. That analysis further showed that the 90th percentile concentrations of fecal coliform were about an order of magnitude greater on the Edwards Plateau than on the Gulf Coast Plain at the same population density. Carrying this example one step further for SWAP purposes, it could be concluded that population densities of greater than about 1.5 people/km^2 in a contributing watershed suggests a water supply is susceptible to fecal coliform contamination. If it could be demonstrated statistically, this relation would be varied based on physiographic province, soils, or runoff characteristics.

Task 3.5: Prepare Report

A USGS Water-Resources Investigations (WRI) report will be prepared, reviewed, and published under this task.

Task 3.6: Determine Susceptibility Threshold Values

Threshold values for the constituents will be established by the TNRCC to assess the susceptibility of water-supply intakes on the basis of the results of the statistical relations of the occurrence and magnitude of the constituents to selected environmental characteristics identified in Task 4. Susceptibility thresholds could be based on a variety of water-quality measures and will, by design, be conservative. These measures will include:

- MCLs or some fraction thereof,
- the percentage of detections for a toxic compound (e.g., greater than 10 percent detections of a pesticide), and,
- the number of toxic compounds detected even at low concentrations (e.g., more than five pesticides detected).

Measures of susceptibility other than those based on MCLs and HA levels, will be relative. Because data on many toxic compounds are geographically and temporally limited, a determination of relative susceptibility may be required. For example, if on average, 5 to 10 pesticides are detected in reservoirs in urban or agricultural areas and from zero to 2 are detected in rangeland and forested areas, it could be concluded that all sites in the former settings are relatively more susceptible to pesticide contamination than the latter, even if no MCLs are known to be exceeded. Also, the relative magnitude of susceptibility in relation to the threshold value might be determined by the TNRCC. A site might be assessed with no, low, moderate, or high susceptibility to a selected constituent depending upon how the site’s environmental characteristics relate to the threshold values of that constituent. For example, a site in an urban watershed might be highly susceptible to a selected trace metal but only marginally susceptible to a selected pesticide.

Task 3.7: Determine Susceptibility Of Selected Water-Supply Intakes

Susceptibility determinations will be made using TNRCC's business rules as coded into software developed under a separate project.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994). USGS will perform gross quality-control checks on locational and attribute information, advise PDW staff of errors or inconsistencies, and revise data where possible.

Deliverables

Numerical and statistical results of this study will be used by the overall SWAP to develop thresholds for decisions by TNRCC on the susceptibility of surface water supplies to contamination. The analysis will be documented in a USGS Water-Resources Investigations Report. Databases containing water-quality and environmental characteristics of monitoring sites and intakes will be provided to TNRCC.

References

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Point Source Component (Task 4)

Statement of Problem

Discharges from municipal sewage treatment plants (STP), industrial wastewater treatment plants (IWTP), and concentrated animal feeding operations (CAFOs) within the watershed of an intake can affect the quality of the supply's source water. The susceptibility of a surface water supply, usually a reservoir in Texas, to contamination from point-source discharges is a function of the number of point sources in the intake's contributing watershed, the mass of pollutants released in the treated wastewater, and the proximity of the outfall with respect to the supply's intake. An approach for assessing the susceptibility of supply intakes on reservoirs and on flowing streams to contamination from point sources is not currently available.

Goal And Objectives

The goal of this project is to provide the information needed to assess the susceptibility of surface water supplies to contamination from point-source discharges. Specific objectives include:

- Develop a spatial database and GIS coverages of all National Pollution Discharge Elimination System (NPDES) permitted, point-source discharges in Texas having an effluent limitation for a toxic pollutant (toxic pollutant as listed in Appendix D of 40 CFR Part 122);
- Develop a spatial database and GIS coverages of all permitted STPs, IWTPs, and CAFOs in Texas (for subsequent use in the "Area-of-Primary-Influence" (API) Component, Surface water Project 6);
- For every reservoir having a public-water-supply intake, develop an estimate of the concentration of toxic pollutants in the reservoir based on permit effluent limitations for NPDES discharges in the contributing watershed, mean-annual streamflow from tributaries providing water to reservoir, and statistical estimates of low-flow reservoir storage;
- For intakes on flowing streams, develop an estimate of the concentration of toxic pollutants at the intake during low-flow conditions based on permit effluent limitations for NPDES discharges in the contributing watershed.

The databases and toxic pollutant estimates developed from this project will be used to assess the susceptibility of source waters to contamination. Because the universe of point-source discharges is not static, the design of the databases will be flexible thus allowing for periodic updating of the databases by the TNRCC Public Drinking Water Section (PWD) as new point-source discharges are permitted or existing permits modified.

Approach

A simplified approach will be used to assess the susceptibility of surface water supplies to point-source discharges during low-flow conditions. Although point-source discharges may be included in the environmental setting variables used statistically above, the existing water-quality data sets may not adequately represent low-flow conditions, when point sources have their greatest influence on the water quality of the receiving water body. Therefore, theoretical concentrations of point-source-associated-toxic pollutants at low stream flow and low-flow reservoir storage conditions will be calculated based on permitted releases of toxic pollutants from point-source discharges in the contributing watershed (or truncated watershed) of the surface water intake or supply reservoir. The truncated watershed is the part of the watershed for an intake (or supply reservoir) that is downstream from major reservoirs. Parts of the watershed that are upstream from major reservoirs relative to the intake (or supply reservoir) are not part of the truncated watershed. This approach is based on U.S. Geological Survey (USGS) research that supports the assumption that reservoirs upstream of an intake will greatly reduce the downstream transport of most pollutants as a result of in-reservoir physical, chemical, and biological processes (Smith and others, 1997; Van Metre and Reutter, 1994).

A review of NPDES permits issued in Texas reveals that effluent limitations for discharges from STPs commonly are limited to a few conventional pollutants (biochemical oxygen demand (BOD), suspended solids, and pH and non-conventional pollutants (total residual chlorine and ammonia). Under a general NPDES permit, CAFOs are prohibited from discharging process wastewater pollutants to receiving water bodies except during catastrophic or chronic rainfall events (U.S. Environmental Protection Agency, July 11, 1998). From a public-drinking-water perspective, the greatest concern for the susceptibility of source waters is generally not associated with the discharge of BOD, suspended solids, and nutrients, but rather the release of toxic pollutants and pathogens. Quantitative effluent limitations for pathogens are not provided for in NPDES discharge permits. Therefore, development of theoretical concentrations of pollutants in municipal and industrial point-source discharges will have to be limited to toxic pollutants.

As stated above, quantitative effluent limitations for pathogens are not provided for in NPDES discharge permits. Further, when discharged upstream of an intake, dilution and pathogen die-off each contribute to a reduction of pathogen densities in surface waters. In addition, results from the analysis of specific pathogens in water are problematic, and can be highly variable for several analyses conducted on the same sample. Therefore, the susceptibility of a source water to Cryptosporidium, sp.; Giardia, sp.; and other pathogens will be assessed using “indirect” methods included in the approaches for the Applications Programming Interface (API) component (Surface water Project 6) and non-point source component (Surface water Project 4.1). For the API component, a spatial database of all permitted STPs and CAFOs within the API will be developed. STPs and CAFOs have the potential to bypass, spill, or release untreated or inadequately treated human or animal wastewater. Being within the API, these facilities also are in closer proximity to the intake which reduces the potential for dilution and die-off of pathogens. This spatial database of STPs and CAFOs will be used to assess the susceptibility of the source water to human and animal wastes based on the density of such facilities in the API for an intake. For the non-point source component, statistical relations will be developed between the occurrence of fecal coliform in surface water and pertinent human or animal variables, such as population density. These relations also will be used to assess the susceptibility of the source water to pathogen contamination from human and animal wastes.

Task 4.1: Develop Point-Source Pollutant Spatial Databases

Information on NPDES discharge permits is contained in the Permit Compliance System (PCS), the U.S. Environmental Protection Agency's (USEPA) national computerized management information system. This system automates the entry, update, and retrieval of NPDES data and tracks permit issuance, permit limitations, and monitoring data. Data needed for this project will be obtained directly from the USEPA PCS system or from a comparable database maintained by the TNRCC.

Task 4.1.1: Develop Point-Source, Toxic Pollutant Spatial Database. The USGS will retrieve from the USEPA's PCS database the facility identification number, location, and effluent limitations for point-source discharges of toxic pollutants in Texas. Because CAFOs do not discharge toxic pollutants, discharges will be limited to selected IWTPs and STPs. USGS staff will convert these files to GIS point coverages and project these coverages to the Texas Statewide Mapping System (TSMS) projection (Texas Department of Information Resources, 1992), coordinate units in feet, NAD83 datum (Allison, B., Texas Natural Resource Conservation Commission, Information Resources, Interoffice Memorandum, January 26, 1998).

Task 4.1.2: Develop STP, IWTP, and CAFO Spatial Database. The USGS will obtain from the PCS database the facility identification number and location of all STPs, CAFOs, and IWTPs in Texas. USGS staff will convert these files to GIS point coverages and project these coverages as outlined in task 4.1.1. This spatial database will be used in the API component (Surface water Project 6).

Task 4.1.3—Develop Metadata for Point-Source Spatial Databases. The USGS will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata for the point-source spatial databases (FGDC, 1994). Content-level metadata is defined in the above referenced publication. Metadata is information about the source documents or databases used to produce spatial data sets and information about the resultant data set including data elements such as scale, projection, and author.

<u>Task 4.2: Estimate of the Concentration of Point-Source Associated Toxic Pollutants at Intakes on a Flowing Stream During Low Streamflow Conditions</u>

For intakes on flowing streams, calculate the ratio of the mass of each toxic pollutant discharged under NPDES permits within the truncated watershed to the 7-day, 2-year (7Q2) low flow of the stream at the intake site. This will involve the following sub-tasks.

Task 4.2.1: Statistical Estimation of 7Q2. Both the USEPA, for NPDES permitting purposes, and the TNRCC, for State discharge permit purposes, use the 7Q2 low flow to evaluate the effects of treated wastewater on the receiving stream, e.g., will the discharge of the point-source pollutant load result in a violation of the applicable water-quality standards for the stream segment. The 7Q2 discharge (in ft3/s) at each intake located on a flowing stream will be estimated using associated basin characteristics and proven statistical techniques. For SWAP purposes, the definition of a flowing stream will include run-of-the-river reservoirs, such as Town Lake in Austin. Basin characteristics will include contributing drainage area, main channel length, and stream slope for each contributing watershed of an intake. One of the three methods below will then be used to determine 7Q2 low flows.

> Method 1—For intake sites located on streams with nearby USGS streamflow-gaging stations (gaged sites), the 7Q2 determined at the streamflow station will provide the basis of the analysis.
>
> Method 2—For intake sites with streamflow measurements located on streams that are ungaged (ungaged intake), a graphical, statistical, or other suitable relation between concurrent low flows at gaged sites and ungaged intakes will provide the transformation of the gaged 7Q2 to the ungaged 7Q2. A basic requirement of the ungaged 7Q2 determination is that a sufficient number of essentially uncorrelated (in time) low-flow measurements for the ungaged intake site be available to adequately define the gage/ungaged low-flow relation. A sufficient number of measurements could be as few as 4 to 5, although for some sites defensible identification of a gaged site for low-flow comparison might require more measurements. Measurements at the same flow (even if widely spaced in time) are unsuitable for analysis; a large range in the low-flow measurements is needed. Low-flow measurements made close together in time are expected to be highly correlated; highly correlated measurements are unsuitable for analysis. Low-flow measurements separated by seasons (possibly months) or separated by brief to long periods of high flow could be considered uncorrelated and suitable for analysis (personal comm., W. H. Asquith, USGS, 1998).
>
> Method 3—For ungaged intake sites that have a insufficient number of or no low-flow measurements, statistical comparisons of the basin characteristics between the ungaged intake site and nearby gaged sites will be used to adjust the 7Q2 values for the gaged sites in order to estimate the 7Q2 at the ungaged intake.

Task 4.2.2: Summation of Instantaneous, Maximum Permitted Mass of Toxic Pollutants. Instantaneous mass of toxic pollutants discharged from IWTPs and STPs under an NPDES permit in the truncated watershed will be summed. The maximum instantaneous permitted mass of each toxic pollutant will be calculated from effluent limitations contained in each NPDES permit in the PCS database for the truncated watershed.

Task 4.2.3: Determination of Susceptibility of Intakes on Flowing Streams From Point Sources Discharges of Toxic Pollutants. For each toxic pollutant, a theoretical maximum instantaneous concentration will be calculated using (1) NPDES effluent limitations for all toxic pollutant discharges in the truncated watershed and (2) the estimated 7Q2 for the stream at the intake site. TNRCC will determine concentrations of a toxic pollutant that will indicate less susceptibility; high concentrations, such as maximum contaminant level (MCL), will indicate increased susceptibility.

Task 4.3: Estimate of Concentration of Point-Source Associated Toxic Pollutants in Water-Supply Reservoirs

The concentration of toxic pollutants in water-supply reservoirs will be estimated using (1) the mass of a toxic pollutant that can be discharged over specified number of days (14 days) under an NPDES permit for discharges within the truncated watershed of the reservoir, and (2) a statistical measure of low-flow contents of the supply reservoir. A second estimate of the toxic pollutant concentration will be made using the mass of toxic pollutants discharged over a full year and a statistically-based estimation of the mean-annual inflows from streams providing water to the reservoir. The two estimates will provide a "range" of toxic pollutant concentrations to be used for SWAP purposes. This will involve the following tasks.

Task 4.3.1: Toxic Pollutant Concentration Estimates Based on Low-Flow Storage Conditions in Water-Supply Reservoirs

Task 4.3.1.1: Statistical estimation of low-flow storage conditions in water-supply reservoirs. TNRCC's PDW files for surface water supplies indicate that there are 348 permitted suppliers obtaining raw water from 176 reservoirs in Texas. These reservoirs have a combined normal storage capacity of about 29-million acre-feet of water and supply a population of 5,774,053 people. The storage contents of each supply reservoir during low-flow conditions must be estimated in order to develop an estimate of the toxic pollutant concentration during these storage conditions. The USGS has current or historic daily storage-content data for 73 of these reservoirs, which represent only 41 percent of the total public-supply reservoirs. However, the reservoirs with such data represent 212 permitted suppliers and 4,088,582 people (71 percent of the total population served). For the reservoirs with daily storage data, a statistical assessment of the data will be performed to estimate storage conditions during low-flow conditions. A statistical distribution of the data will be used to indicate, for each reservoir, the storage contents that are exceeded 96 percent of the time. This storage value will be equivalent to that occurring during the lowest 14 days of a typical year.

For water supply reservoirs without daily storage data, one or both of two procedures will be used to estimate low-storage conditions. The reservoir owners will be asked to provide an estimate of the storage conditions during the lowest 2-week period of a typical year. The other procedure involves the hydraulic and hydrologic factors affecting low-storage conditions. These factors will include, for each reservoir, an evaluation of the conservation storage contents and contents associated with release gates and valves. Such assessments also might include an evaluation of the reservoir inflows and outflows (withdrawals, evaporation, and releases) during dry conditions.

Task 4.3.1.2: Summation of maximum permitted mass of toxic pollutants. The mass of toxic pollutants discharged from IWTPs and STPs under an NPDES permit in the truncated watershed will be summed for a 14-day period. The mass of each toxic pollutant will be calculated from effluent limitations contained in each NPDES permit in the PCS database for the truncated watershed.

Task 4.3.1.3: Determination of susceptibility of water-supply reservoirs during conditions of low reservoir contents. For each toxic pollutant permitted for discharge by IWTPs and STPs in the truncated watershed of a water-supply reservoir, the theoretical maximum permitted concentration will be calculated. This value represents the permitted mass of a toxic pollutant released over 14 days diluted by the estimated reservoir storage volume during low-flow conditions. TNRCC will determine concentrations of a toxic pollutant that will indicate less susceptibility; high concentrations, such as the MCL, will indicate increased susceptibility.

Task 4.3.2: Toxic Pollutant Concentration Estimates Based on Mean-Annual Tributary Inflows

Task 4.3.2.1: Statistically based estimation of the mean-annual flow from tributary streams. The tools required to estimate mean-annual flow from tributary streams will be provided as part of Project 3.A.1. The regional regression equations developed by the USGS will be used to estimate mean-annual flow from streams providing water to the reservoir.

Task 4.3.2.2: Summation of maximum-annual permitted mass of toxic pollutants. The mass of toxic pollutants discharged from IWTPs and STPs under an NPDES permit in the truncated watershed will be summed for a full year time period. The mass of each toxic pollutant will be calculated from effluent limitations contained in each NPDES permit in the PCS database for the truncated watershed.

Task 4.3.2.3: Determination of susceptibility of water-supply reservoirs based on mean-annual flow from tributary streams. For each toxic pollutant the discharge of which is permitted for IWTPs and STPs in the truncated watershed of a water-supply reservoir, the maximum permitted annual concentration will be calculated based on the mean-annual flow from tributary streams. This value represents the largest permitted mass of a toxic pollutant discharged over a full year diluted by the mean-annual flow from all tributary streams providing water to the supply reservoir. This will provide a lower-range estimate of the concentration of point-source associated toxic pollutants in a water-supply reservoir. TNRCC will determine concentrations of a toxic pollutant that will indicate less susceptibility; high concentrations, such as the MCL, will indicate increased susceptibility.

Quality-Assurance Plan

The USGS will perform quality-control checks of the data sets generated from PCS or TNRCC files. USGS staff will advise TNRCC PDW staff of discrepancies and attempt to correct location information where possible. Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994).

Deliverables

- Digital database and GIS coverages providing the location and effluent limitations for NPDES permitted point sources that discharge toxic pollutants (will include a sub-set of all IWTPs and STPs in Texas)
- Digital database and GIS coverages with the location of all STPs, CAFOs, and IWTPs in Texas
- Statistical estimation of 7Q2 low-flow stream flow discharge at ungaged stream sites where an public-water-supply intake is located
- Statistical estimation of the low-flow contents of all water-supply reservoirs in Texas
- For intakes on flowing streams, an estimate of the point-source associated concentration of toxic pollutants at an intake during low-flow conditions
- For water-supply reservoirs, an estimate of the point-source associated concentrations of toxic pollutants using statistical estimates of low-flow reservoir storage and mean-annual stream flow from tributaries providing water to supply reservoirs

Numerical/statistical results of this project will be used by the SWAP as the basis for decisions on the susceptibility of source waters to point sources of contamination.

References

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

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Contaminant Occurrence Component (Task 5)

Statement of Problem

Some watersheds have naturally occurring contaminants that render the water less desirable for human consumption. Thus, an analysis, both spatially and temporally, of existing surface water and public-drinking-water supply point-of-entry (POE) monitoring data is needed to determine if the occurrence of a contaminant(s) in water is due to natural conditions in the watershed. Several databases exist that contain surface water quality data for this analysis, such as TNRCC's TRACs and POE databases and U.S. Geological Survey's (USGS) NWIS databases. Using spatial analysis techniques, these data will be identified within each watershed containing a public-water supply intake or a public-supply reservoir. If detections of naturally occurring contaminants within a watershed were found, then the contributing watershed would be assessed as being susceptible to contamination from naturally occurring contaminants.

Detections will also serve as a confirmation check of the methodology for assessing the degree of susceptibility of source water to contamination. Stream, reservoir, and PWS entry-point monitoring data will be used to verify assessment decisions. If a surface water source is determined to be of low susceptibility to a particular contaminant then the monitoring data should not reveal detections. Yet, if the monitoring data reveals detections, then the assessment model needs to be re-evaluated. If a surface water source is determined to be of high susceptibility, data may or may not support the assessment. The lack of detection may only mean that the stream, reservoir, and PWS entry-point monitoring data were not collected at the appropriate "hydrologic" time (e.g., time of greatest vulnerability, during or just after a runoff event or during baseflow conditions).

Goal and Objectives

The goal of this project is to compile, into one or more databases, location and selected water-quality data from existing water-quality databases. This data will be used, with software developed under a separate project, to identify sites with naturally occurring contaminants exceeding designated thresholds for specific naturally occurring contaminants within each contributing watershed of a public-water supply intake or a public-supply reservoir delineated in Component 2. This analysis will lead to a determination of the susceptibility of the public-supply surface water intake or public-supply reservoir to naturally occurring contaminants. Specific objectives include:

- Compile relational data file of water-quality information
- Create Geographic Information System (GIS) coverage of water-quality sample sites

- Perform confirmation check of methodology used in determining susceptibility of source water to contamination
- Develop and provide documentation (metadata)

Approach

The approach will consist of creation of GIS coverages, and creation of metadata.

Task 5.1: Assess Water-Quality Databases

Each of these databases contain vital information for the assessment of existing water quality, however, they also contain information that is not required to fulfill the goals of the SWAP. Thus, the formats and contents of each database will be reviewed. It is anticipated that the focus of this task will be to collect data with regards to pre-defined naturally occurring chemical constituents.

Task 5.2: Download all Pertinent Data from Databases

Pertinent, chemical quality data concentrations that exceed a predetermined threshold level will be downloaded for incorporation into the SWAP water-quality database(s). A list of data that are required for the successful completion of this task are listed in Table 5.1

Table 5.1: List of attributes required for the water quality database(s)

Attribute	Description
Location data	Latitude and longitude
Date	Date of analysis
Chemical constituent	Chemical abbreviation of constituent name
Symbol	Less than, greater than
Class	Class of constituent (organic or inorganic)
Sample identifier	Unique identifier; also should include county code

Each of the water-quality databases is quite large and will require a significant amount of time and effort to reduce the data into a usable form. USGS will conduct gross quality-assurance checks on data sets generated from the various databases.

Task 5.3: Develop Water-Quality Sample Site GIS Coverage

A GIS point coverage of water-quality sample sites will be constructed from the location data retrieved under task 5.2. A thorough check of the locations of these sites is beyond the scope of this project, however gross quality- assurance checks of the data will be performed on the location data.

Task 5.4: Perform Confirmation Check.

Overlay the GIS point coverage of water-quality sample sites with the GIS contributing watershed of a public-water supply intake or a public-supply reservoir delineated in Component

1. Using software developed under a separate project, determine conformity or non-conformity with the initial assessment of susceptibility.

Task 5.5: Prepare Metadata

USGS staff will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata (FGDC, 1994) for the sample site coverages. Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial data sets and information about the resultant data set including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994). USGS will perform gross quality-assurance checks on location and attribute information, advise PDW staff of errors or inconsistencies, and revise data where possible.

Deliverables

- GIS coverage of water-quality sample sites
- Relational database table(s) of water-quality data
- FGDC-Compliant content-level metadata

References

Environmental Systems Research Institute, Inc. (ESRI), 1994, ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

Texas Department of Information Resources, 1994, Standards and Guidelines for Geographic Information Systems in the State of Texas.

Area-of –Primary-Influence Component (Task 6)

Statement of Problem

The proximity of a surface water intake to a point-source discharge, threatening land usage, a major transportation corridor, or pipeline can result in the source water being susceptible to contamination. The relatively short time-of-travel of a chemical spill, continuous release, or runoff to the intake minimizes the opportunity for reducing a contaminant's concentration or converting or degrading a contaminant to a less threatening form.

Goal and Objectives

The goal of this project is to prepare data sets required to assess, for an area-of-primary-influence, (1) all PSOCs and associated contaminant groups and (2) Land use and associated contaminant groups, and (3) point-source discharges and associated contaminants. These data sets will be constructed from the following databases or coverages:

- PSOCs database as (compiled under the Ground Water Point Source Component)
- Land-use classifications - GIRAS land-use data (compiled under the Ground Water Non-point Source Component)
- Land Resource Units – flood prone areas
- Transportation and pipelines coverages
- Point-source discharges -- Location and maximum permitted pounds per day of contaminants discharged from both municipal and industrial wastewater point sources in Texas, as retrieved from the TNRCC's TRACs database (compiled under Surface Water Point Source Component)
- Boundaries of all water-supply reservoirs under normal storage conditions (compiled under the Surface Water Delineation Component)
- GNIS – Geographic Names Information System contains geographic names for landmarks from USGS Topographic Maps.
- CAFOs – Confined Animal Feeding Operations (compiled under Surface Water Point Source Component)

Approach

The approach will consist of compilation and/or creation of GIS data sets as necessary to support area-of-primary influence assessments using software developed under a separate task. For intakes in reservoirs, an area-of-primary-influence will initially be defined as the area within 1,000 feet of a reservoir boundary, and, for all streams discharging directly to the reservoir, the area within 1,000 feet of the center of the stream channel of the 3-mile stream reach immediately upstream from the reservoir. For intakes on streams, the area of primary influence is the area with 1,000 feet of the 3-mile stream reach upstream from the intake. On an as-needed basis, the area-of primary influence will be tailored to the specific water supply by the incorporation of ancillary data sets such as flood-prone areas, and/or time-of-travel where flow characteristics are readily available.

Within the area-of-primary-influence, all PSOCs, land uses, and the existence of transportation corridors or pipelines will be identified along with their associated contaminant groups. As needed, the analyst will "manually" examine in more depth the type and age of the PSOC, and contaminants associated with each PSOC in the area-of- primary influence. A qualitative determination of susceptibility (less susceptibility to increased susceptibility) will be assigned based on the presence of PSOCs, potential for releases or spills of contaminants, and the contaminants associated with each specific PSOC in the area-of-primary-influence. The susceptibility determination will be guided by the number of PSOC sites, the total amount of area dedicated to activities known to generate contaminants, and the contaminants and amounts potentially generated by the various activities within the area of primary influence.

Task 6.1: Retrieve and Format Pertinent Data from TRACs Database as required

Task 6.2: Obtain statewide transportation and pipeline coverages and format for use in SWAP

Statewide coverages of transportation and pipeline coverages will be obtained from USGS or Texas Natural Resource Information System archives depending on availability. Other sources of high-quality transportation coverages will be researched. Develop database table of contaminants associated with the transportation corridor or pipeline.

Task 6.3: Develop GIS Point Landmarks Coverage

A GIS point coverage containing locations and names of landmarks on USGS Topographic maps will be prepared. This cover will be useful in identifying marinas, or other features not contained in other coverages. Develop database table of contaminants associated with the feature.

Task 6.4: Develop Land Resource Units Coverage

A GIS coverage of Land Resource Units will be created from source materials available at USGS.

Task 6.5: Prepare Metadata

USGS staff will prepare Federal Geographic Data Committee (FGDC)-compliant content-level metadata (FGDC, 1994) for the all coverages. Content-level metadata, defined in the above referenced document, is information about the source documents or databases used to produce spatial data sets and information about the resultant data set including data elements such as scale, projection, and author.

Quality-Assurance Plan

Established State standards and guidelines for GIS will be followed (Texas Department of Information Resources, 1994). USGS will perform gross quality-assurance checks on location and attribute information, advise PDW staff of errors or inconsistencies, and revise data where possible.

Deliverables

- GIS coverage of Land Resource Units
- GIS coverage of Transportation and Pipelines
- GIS coverage of Landmarks
- FGDC-Compliant content-level metadata

References

Environmental Systems Research Institute, Inc. (ESRI), 1994, ARC/INFO users guide, version 7.0: Redlands, CA.

Federal Geographic Data Committee, 1994, Content standards for digital geospatial metadata (June 8): Federal Geographic Data Committee, Washington, D.C.

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Susceptibility Summary Determination Component (Task 7)

Statement of Problem

When the geographic area defining a capture zone to a raw water source (well, spring, surface intake) is intersected with the potential source of contamination (PSOC) geographic information system (GIS) coverages, zero to many PSOCs will be identified that may affect the water system. This project will determine the susceptibility of the water system to each contaminant of a PSOC. This susceptibility determination will be automated using software developed under a separate project, that will populate a table with unique codes; each code will reflect one piece of information about the well, aquifer, contaminant, etc. The software will then compare the codes generated for each water system with a "master matrix" table that includes every possible combination of codes with a pre-defined susceptibility determination. Essentially, this "master matrix" table would contain the "business rules" regarding the potential impact of a contaminant to a water system. This method has been used for the last several years within the TNRCC Vulnerability Assessment Program and will provide a simple, objective, rapid, and automated evaluation. The master matrix table can be easily edited as new information is developed regarding source water contamination; expensive and complicated software editing is eliminated.

There are many parameters that may be considered for susceptibility. This information will be collected as part of many projects within this document. These parameters include those that describe the water system, surface- and ground-water hydrologic setting, PSOC(s) and their contaminant(s), environmental attenuation of a contaminant, and so on. These parameters will need to be analyzed, when available, for each contaminant at each PSOC for each raw water source (well, spring, surface water intake) in a water system. The amount of information available for each PSOC will be highly variable not only between different types of PSOCs, such as landfills versus petroleum storage tank sites, but even within the same class of PSOCs, such as abandoned landfills. This project will be designed to take advantage of any and all information that is available. This complex information will need to be synthesized into a form easily comprehended; that is the purpose of the matrix table.

Goal and Objectives

The goal of this project is to determine the susceptibility of a public water supply to contamination from potential sources of contamination. Objectives of the project include:

- Define the parameters and their standard codes that will be used to define a susceptibility determination
- Develop a database table to contain the codes used to formulate a susceptibility determination
- Define the "business rules" and incorporate these into the master matrix table so that a susceptibility determination can be defined for each combination of parameter codes
- Develop the methods to populate the matrix tables from raw data obtained through GIS and database queries

- Develop the methods to populate matrix tables when there is interaction between different PSOCs that could lead to contamination
- Develop the method to summarize the susceptibility determination for a water system

The software to support the automation of this process will be developed in Source Water Susceptibility Assessment Software and Database Structures, Tasks 1.4.7 and 1.5.9. See additional details under Ground water Section 2g, Susceptibility Summary Determination Component (Task 7)

LINKING SOURCE WATER ASSESSMENTS TO OTHER WATER QUALITY ASSESSMENT AND PROTECTION EFFORTS

Source water assessments can provide better, locally-focused data that tie into a comprehensive state water quality management program that includes ambient water quality standards and monitoring, nonpoint source controls, watershed planning, watershed assessments, and other elements of water quality protection. By doing so, Texas has learned that source water assessment and protection can become more than a programmatic end in itself; it can become a “lens” by which we look at our priorities in other programs, and focus on drinking water as a central element in overall water quality management.

The linkages and program areas described in this section are important for building a strong base of information for source water assessments, as well for initiating and evaluating mitigation, protection and restoration strategies, contingency planning, and emergency response.

Total Maximum Daily Load Program

The Total Maximum Daily Load (TMDL) Program at TNRCC is responsible for three major tasks stemming from §§303(d) and 303(e) of the Clean Water Act:

1) <u>Identifying and listing impaired surface water bodies in the state.</u> These are water bodies that do not meet, or in the near future are not expected to meet, water quality standards. The list is called the 303(d) list and is developed in Texas on a yearly basis with an extensive focus on one-fifth of the state. These water bodies are also ranked and scheduled for the development of TMDLs. TNRCC has set the goal of developing TMDLs for all listed water bodies in ten years, which is slightly shorter than the 11-13 year time frame set by EPA.

   The 1998 303(d) list, which includes 146 water bodies, was submitted in April 1998 and has been approved by EPA. The SWAP Program coordinated data with the TMDL Program for listing one impaired and seven threatened water bodies in the state. TNRCC is currently developing the 1999 list.

2) <u>Developing TMDLs.</u> A TMDL is an estimate of the maximum amount of pollution a water body can receive and still meet water quality standards. A TMDL must address the specific pollutant or pollutants causing the impairment, whether originating from point or nonpoint sources. A watershed action plan must also be developed to detail how the load allocation will be achieved.

   Members of the SWAP and TMDL Programs are in the process of developing best management practices that address both drinking water needs and surface water needs in affected watersheds, thus avoiding duplication of effort.

3) Implementing TMDLs. A TMDL is only a plan. Once the TMDL has been approved, it must be implemented in order to achieve the pollution (or loading) reduction and to attain water quality standards.

Through the TMDL Program, regulatory controls are available which may provide reinforced assistance to drinking water protection enforcement within the watershed. These activities are closely coordinated between the TMDL and SWAP Programs.

All three tasks require extensive public involvement at the local (watershed) level. TNRCC is working closely with the Texas Clean Rivers Program and their basin level partners to enhance public input.

Texas Clean Rivers Program

The Clean Rivers Program (CRP) uses a watershed management approach to identify and evaluate water quality issues, and to establish priorities for corrective action. Watershed management is a way to coordinate operations of existing water resource programs to better achieve water resource management goals and objectives. The goal of the CRP is to maintain and improve the quality of water resources within each river basin in Texas through an ongoing partnership involving the TNRCC, other state agencies, river authorities, local governments, industry, and citizens.

The TNRCC initiated the CRP in 1991 by contracting with regional entities, including river authorities, municipal water authorities, and councils of government, to conduct regional water quality assessments for the river and coastal basins throughout the state. In those basins, each existing contractor is identified as the lead agency with primary responsibility for the river/coastal basin assessment.

Texas Unified Watershed Assessment

The Clean Water Action Plan is designed to provide a mechanism for attainment of the original goals of the federal Clean Water Act (CWA) and other natural resource goals. These goals were set to ensure that all waters are fishable, swimmable, and safe. Although not required by the federal CWA, the Plan strengthens the foundation of a watershed-based approach for protecting and restoring surface freshwater, coastal and estuarine waters, groundwater, wetlands, and other natural resources which impact water quality and public health.

A key element of the Plan relies on collaboration between regional and local governments, state, and federal entities to identify existing watersheds with water quality problems and other natural resource goals. By identifying watershed priorities, interested parties in each watershed can work to mitigate known problems and develop the means to protect the water quality of those watersheds which are unimpaired. State and federal partners, working with local stakeholders and interested citizens in individual watersheds, can secure and target resources to develop and implement strategies in priority watersheds which restore water quality and meet other natural resource goals. The identification of watershed priorities has been established through the Texas Unified Watershed Assessment.

The Assessment in Texas is jointly led by the USDA - NRCS, TNRCC, and the Texas State Soil and Water Conservation Board (TSSWCB). Other state and federal partners who assisted in the development of this Assessment include the Texas Parks and Wildlife Department (TPWD), the Texas A & M University System (TAMU), USGS, the Texas office of the United States Fish and Wildlife Service (USFWS), and the Texas office of the United States Army Corps of Engineers (USCOE). This group of state and federal partners formed the working group for completing the Assessment.

The national guidelines for preparing the Assessment recommended that each state delineate watersheds using the eight-digit hydrologic unit codes (HUCs). There are 210 eight-digit watersheds in Texas. Each watershed is categorized into one of four categories based on the evaluation of existing and readily available data. The categories used include:

***Category I**: Watersheds in need of restoration.*

This includes watersheds that at the present time do not meet clean water and other natural resource goals which are summarized in the Clean Water Action Plan.

***Category II**: Watersheds in need of preventive action to sustain water quality.*

This consists of watersheds that meet clean water and other resource goals and standards, and support healthy aquatic systems. Such watersheds require the continuing implementation of core clean water and natural resource programs to maintain water quality and conserve natural resources.

***Category III**: Watersheds with pristine/sensitive aquatic system conditions on lands administered by federal, state, or tribal governments.*

This consists of watersheds with exceptionally pristine water quality or other sensitive aquatic system conditions that are located on lands administered by federal, state, or tribal governments.

***Category IV**: Watersheds with insufficient data to make an assessment.*

This includes watersheds that lack significant information, critical data elements, or the data density needed to make a reasonable assessment at this time.

On July 20, 1998, the collaborating agencies met to determine the data and information which would be used to prioritize watersheds throughout the state. The following outline summarizes the types and sources of data and information evaluated to identify watersheds for each of the four categories. This Assessment is not intended to indicate that sufficient water quality data exists for all water bodies in each category. It depicts current understanding of water quality conditions based on an evaluation of readily available data. The Assessment is considered a dynamic process and therefore, category designations for individual watersheds may change as new data an information become available. The Assessment is not intended to replace the TNRCC's reliance on the 303(d) list for establishing its water quality priorities.

Category I*: Watersheds in need of restoration include:*

- all impaired water bodies on the Texas 1998 CWA Section 303(d) List;
- agricultural nonpoint source priority watersheds of the TSSWCB which have 303(d)-listed water bodies within them; and,
- watersheds in the NRCS 1998 Environmental Quality Incentive Program (EQIP) priority areas which have 303(d)-listed water bodies within them.

It should be noted that if a watershed is designated as a Category I watershed, it does not mean that every water body (reservoir, stream, river, estuary) within the watershed is in need of restoration.

Category II*: Watersheds in need of preventive action to sustain water quality include:*

- all threatened water bodies from the 1998 CWA Section 303(d) list;
- TSSWCB agricultural nonpoint source priority watersheds and/or watersheds designated as 1998 EQIP priority areas which do not have 303(d)-listed water bodies within them; and,
- all other watersheds which do not have 303(d) listed water bodies within them and where sufficient data is available to the TNRCC or TSSWCB to adequately assess the water quality conditions.

Category III*: Watersheds with pristine/sensitive aquatic system conditions on lands administered by federal, state, or tribal governments include:*

- those water bodies of exceptional quality that reside within federal, state, or tribal lands. Fifteen percent of the total stream miles within each hydrologic unit area must be considered pristine for the watershed to fall in this category. The 15 percent criterion was chosen based on discussion and consensus of the committee.

Category IV*: Watersheds with insufficient data to make an assessment include:*

- those watersheds where less than nine samples are available from a sampling location over a five-year period from which to conduct an assessment of designated uses. These watersheds were unassessed because they did not fit the committee's criteria for a sufficient quantity of recent data to adequately characterize water bodies or portions of water bodies within the HUC watershed.

The main sources of data which were evaluated to prepare the Texas Unified Watershed Assessment are the TNRCC's 303(d) list, the list of agricultural nonpoint source pollution priority watersheds, and the NRCS-EQIP priority watersheds. Involvement from federal, state, regional, and local agencies, public interest groups, and concerned citizens has led to a general acceptance of the validity of these three sources of data. This inclusive involvement has garnered support for the use of these data as the primary tools for setting water quality restoration priorities in the state of Texas.

Texas has established a process for defining watershed restoration priorities through its watershed management approach. This approach is a resource-centered method of coordinating operations of existing water resource programs to better achieve water quality goals in a specific watershed. Watershed restoration priorities are set in response to existing state and federal programs, geographic targeting each year in a different portion of the state, available resources, and local concerns. The assessment is used to reinforce the restoration priorities and schedule already established through existing state and federal programs. The programs under which watershed restoration priorities have been established are the CWA Section 303(d) list, the CWA TMDL process, the Clean Rivers Program, the **Source Water Assessment and Protection Program**, the EQIP Program, and the Groundwater Protection Program.

AREA WIDE ASSESSMENTS

Area wide assessments as part of the Texas SWAP will be limited to the following situations:

- When more than one PWS intake withdraws water from a reservoir.
- When more than one supply well shares a common contributing area.

The SWSA determination for the reservoir or common contributing area will be issued for all PWSs obtaining water from the source-water “area” assessed. The assessment approach will be the same as described in Section IV. C, Source Water Assessment Approach.

DELEGATION OF ASSESSMENTS

The TNRCC's Public Drinking Water Section is responsible for conducting assessments of all public water supply systems. TNRCC will assume the responsibility for completing delineations. Delineations completed by other sources other than TNRCC (such as Texas Rural Water Association) will be used whenever applicable. Each PWS will be provided with their delineation as they are completed.

The Public Drinking Water Section is also responsible for providing technical assistance, ongoing oversight and implementation of a statewide source water protection program. In accordance with the state's approved Wellhead Protection Program, detail "on-the-ground" potential contaminant source inventories are the responsibility of the local system. Therefore, most refined assessments will be delegated to the local level.

TNRCC will work with the local PWS operator, Texas Rural Water Association representative, or other designated entity to assure quality assurance/quality control of obtained data. Source Water Assessment partners are chosen by the TNRCC according to formal contract bidding procedures established by Texas procurement law. This bid process is designed to select those vendors who are most qualified to provide services requested at the best price. A key part of this process is to identify and remove those vendors who are unqualified or do not have the financial capacity to perform the task requested. When the state considers a vendor for a contract, it must have evidence of financial capacity. The vendor must, in essence, provide access to financial records and demonstrate their solvency. If the vendor is unable to meet this test, then it is removed from the bid process. Vendors that do meet the financial capacity test and are awarded contracts must also be bonded. Purchase of this bond protects the state's financial investment in case the vendor's financial capacity becomes compromised or unable to meet their contractual obligations. Any subcontractors hired by the TNRCC's primary contractor must comply with the same rules and regulations as the primary contractor. In addition, U.S. EPA Headquarters has negotiated an agreement with National Rural Water Association (NRWA) for its state affiliates to implement Source Water Protection activities. In negotiating and awarding this agreement, EPA Headquarters presumably investigates and confirms NRWA's (and its state affiliates) financial capability.

All refined assessment work completed by anyone other than TNRCC will be reviewed by TNRCC for completeness and adequacy prior to acceptance. By TNRCC performing or reviewing all refined assessments, statewide consistency will be maintained.

MAKING ASSESSMENTS AVAILABLE TO THE PUBLIC

Information in a Source Water Assessment

When a source water assessment goes to a public water supply system, it will contain the following:

- A map of the wellhead protection area (WHPA) or the delineated watershed area (DWA);
- A list of potential sources of contamination found from the database search as well as their locations shown on the WHPA/DWA map mentioned above;
- A vulnerability rating; and,
- A list of options for making the information available to the public.

When an individual SWAP is complete, TNRCC will provide access to the completed assessment through the internet. A hard copy of the assessment will also be provided to the Public Water Supply System (PWSS).

TNRCC feels it is very important for PWSSs to have a large range of options for making the assessments available to the public. PWSSs already reach their consumers in different ways, therefore, a number of options have been developed:

TNRCC's Source Water Assessment and Protection Web Site

The TNRCC's Source Water Assessment and Protection web site will provide public access to Source Water Assessment information. Figure 1 illustrates how the site may function and Figure 2 shows a web page mockup. While the actual site may differ due to software and hardware capabilities, the overall concept should not change appreciably.

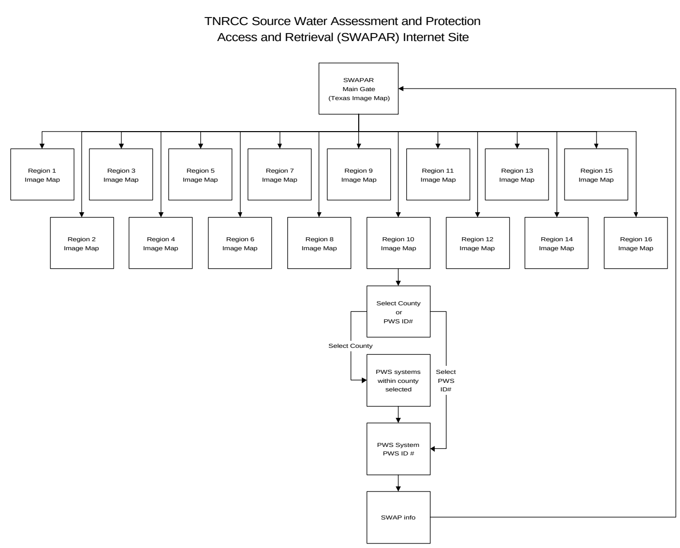

Figure 1 - Web Site Navigation

Web pages will be built using HTML and JavaScript. These pages will be tied to database fields populated by the assessment data. When specific water systems are queried by a browser, the internet server will access the appropriate database fields and project that information to the screen. Effectively projecting the susceptibility maps will probably involve an internet map server. Without a map server, maps will have to be converted to graphic files and then housed on the internet site.

Information accessible from the web site will include susceptibility maps, assessment information, a susceptibility determinations, plus supporting data. The information will be accessible 24 hours a day, free of charge, and will provide universal access.

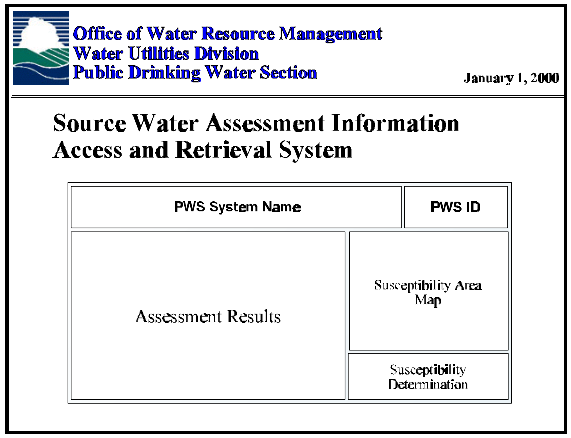

Figure 2 - Web Page Example

Consumer Confidence Reports

PWSSs are already required to distribute a Consumer Confidence Report (CCR) to all water consumers by October 1999. PWSSs will be required to put a statement in the CCR regarding the availability of the assessment. This statement will briefly explain that an assessment on the source of the drinking water for this system has been done. The system can relay where the location of the full assessment is located and how the consumer can obtain a copy.

Water Bills

Many communities send water bills to consumers; therefore, adding a statement about SWAP and where the completed assessment can be found is an option.

Television

Some communities have access to public television stations. Notice of the availability of the completed assessments can be made through this public media.

Posters and Flyers

Many systems may have consumers that can only be notified by posting completed assessments. These systems may want to post a notice with the actual assessment at the facility, or post a notice stating where it can be found and who to contact if they have questions. Locations such as public schools, businesses, and the nearest post office could be options.

Press Releases

Some PWSSs may feel that the best way to reach their consumers is in the newspaper. A press release or paid public notice on the assessment is an option for these systems.

Internet

The internet is another option PWSSs may post completed assessments. Many communities, businesses, or schools within a community host an internet homepage. These sites can be used to notify the public of the assessment or show the entire assessment.

Public Meetings

Holding a public meeting is an option that would allow consumers to ask questions and clear up any confusion on the completed assessment. This meeting must be advertised so the public has advance notice to attend. Alternately, a community could place a discussion of the assessment on their regularly scheduled board or council meeting.

Newsletters

PWSSs or utility departments may already send out a newsletter to their consumers. A newsletter is a good option that would allow enough room to give an explanation of SWAP, as well as list contacts, availability, and locations of the assessment.

Examples of Where to Have the Assessments Available

Anywhere that is easily accessible to the public is a good location to have completed assessments. TNRCC recommends assessments be in a location where someone is available to answer questions or help consumers understand what SWAP is. Examples of locations are: the city utility office, local library, county extension office, etc.

SOURCE WATER PROTECTION

The 1986 Safe Drinking Water Act Amendments, Section 1428, created the Wellhead Protection (WHP) program and gave states the flexibility in establishing their own programs. Texas adopted a voluntary approach and successfully tested its implementation model in the nation's first WHP case study, Del Rio, Texas. Since that time, the state has been actively implementing a statewide WHP program. The U.S. EPA formally approved the program on March 19, 1990, making it one of the first programs approved in the United States. Since that time, Texas' WHP program has grown from protecting one system to providing an added level of protection to more than 600 PWS systems. Currently, 45% of all vulnerable Texas public water supply (PWS) systems are protected by a WHP program.

The 1996 Safe Drinking Water Act Amendments expanded the WHP program to include both ground and surface waters. Given the success of its WHP program, Texas will expand and modify, where applicable, established WHP program functions and apply them to surface water protection. Where new program functions are required, the state will develop them based upon technically defensible processes and best professional judgement.

The state's overall goal is to establish SWP programs for 55% of all vulnerable PWS systems by 2001. Participation by vulnerable PWS systems will be increased over the next three years until this goal is reached. The following illustrates the participation goal for each year along with the actual participation level:

Year	Goal	Actual Participation
1997	10%	23.1%
1998	25%	45.1%
1999	35%	45.1% (as of 10/31/98)
2000	50%	
2001	55%	

In conjunction with these protection programs, the TNRCC oversees Water Quality Standards (Title 30, Chapter 307 of the Texas Administrative Code) that establish explicit water quality goals throughout the state. The adoption and revision of the standards by the Texas Natural Resource Conservation Commission is a very public and sometimes controversial process. Diverse sources have shaped standards development including cities, industries, environmental interests, and the U.S. EPA, which has approval authority over state water quality standards.

Regional hydrologic and geologic diversity is given consideration by dividing major river basins, bays and estuaries into defined segments (referred to as classified or designated segments). The standards rule contains (1) general standards which apply to all surface water in the state, and (2) segment-specific standards which identify appropriate uses (aquatic life, contact or non-contact recreation, drinking water, etc.) and list upper and lower limits for common indicators (criteria) of water quality such as dissolved oxygen, temperature, pH, dissolved minerals, and fecal coliform bacteria.

The Texas Drinking Water Standards (Title 30, Chapter 290.101 - 290.120 of the Texas Administrative Code) establish the drinking water quality and reporting requirements designed to ensure the safety of public water supplies with respect to microbiological, chemical and radiological quality. The US EPA is the lead agency in establishing drinking water standards and has approval authority over state drinking water quality standards.

SOURCE WATER PROTECTION AREA DELINEATION

Designation of a restricted use area around a public drinking water well or intake is one way of protecting public drinking water supplies. This area is referred to as a Source Water Protection Area (SWPA). SWPAs may be delineated for both ground and surface water sources. Source Water Protection areas (SWPA) identify the areas surrounding PWS wells and intakes considered to be most susceptible to contamination. The Source Water Assessment process will delineate these areas for PWS systems statewide. For most systems, these delineations will prove adequate. However, in some instances improved delineation models may be employed to refine or enhance the delineations for especially susceptible areas. However, the methodologies involved in the delineation process will differ between ground and surface waters.

SWPA's identify the areas surrounding PWS wells and intakes considered to be most susceptible to contamination. The source water assessment process will delineate these areas for PWS systems statewide. For most systems, those delineations will prove adequate. However, in some instances improved delineation models may be employed to refine or enhance the delineations for especially susceptible areas.

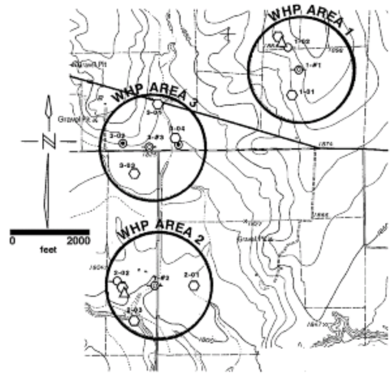

Figure 5

<u>Groundwater Delineation</u>

Source Water Protection areas will be delineated around public water supply wells or springs based upon a five year time-of-travel. Five years is believed to provide a PWS system adequate time to respond to a potential contamination event and has been almost universally adopted nationwide in other Wellhead Protection programs.

Computer models will be employed to accurately delineate the SWPAs. Texas currently uses two models to complete this task: the Calculated Fixed Radius and the WHPA 2.2 model. Delineating SWPAs with these methods requires information about a PWS system's individual water wells. This information includes:

- Maximum anticipated pumpage
- Screened or slotted interval
- Large scale map showing accurate well locations

Delineation of a SWPA for groundwater systems using the calculated fixed radius method (Figure 1) involves an analytical equation. The equation is based on the volume of water that will be drawn to a well in a specified time. The input data required by this method includes the well's pumping rate and screened interval and the average porosity of the aquifer. The calculated fixed radius method is an ideal tool for a single well or no more than two wells which are closely spaced and represent a large pumpage center.

The WHPA 2.2 model determines SWPAs by delineating the capture zones around PWS wells (Figure 2). This is accomplished by means of a particle tracking technique. Time related capture zones are obtained by tracing the pathlines formed by a series of particles placed around the pumping wells. The program uses both forward and reserve particle tracking in determining these pathlines. Once groundwater velocities are determined, pathlines may be delineated. The location of particles after a five year period defines the boundary of the capture zone. This becomes the SWPA.

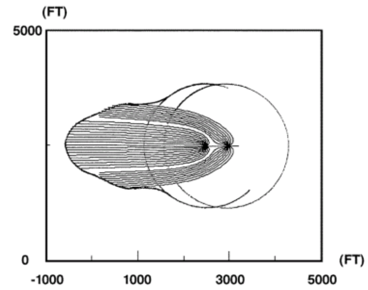

Figure 6

In the event that PWS well information is unavailable or incomplete, information from a nearby well, similar in construction, may be used in completing the delineation. In situations where a nearby well does not exist or is too dissimilar, a minimum quarter mile radius will be delineated around the PWS well. This area will then be adopted as the SWPA. If information becomes available that will allow a more accurate delineation, then the area will be redelineated. However, no delineation ever be smaller than one quarter mile radius.

A quarter mile radius will also be delineated around each proposed PWS well. This area will serve in all respects as the SWPA until such time as the PWS well is completed and information becomes available. At that time, the PWS system will submit this information to the state. The state will then delineate a SWPA using one of the models defined above. If the area is larger than the quarter mile radius, then it will be incumbent upon the PWS system to expand its inventory and submit the results to the state for review and inclusion in the SWP report.

Surface Water Delineation

Surface water supplies are by their nature susceptible to contamination. The degree of susceptibility can vary and is a function of the environmental setting, water management practices, and land uses within a water supply's contributing watershed area. The method of SWPA delineation for a surface water supply will follow the same delineation approach as outlined for the Source Water Susceptibility Assessments. The entire watershed of a surface water supply will be delineated. The approach will consist of compilation of GIS datasets as necessary to support area of primary influence assessments using software developed under a separate task of this SWAP. For intakes in reservoirs, an area-of-primary influence will be defined as the area within 1,000 feet of a reservoir boundary, and for all streams discharging directly to the reservoir, the area within 1,000 feet of the center of the stream channel of the three mile stream reach immediately upstream from the reservoir. For intakes on streams, the area of primary influence is the area with 1,000 feet of the three mile stream reach upstream from the intake. Areas of primary influence may be tailored for individual watersheds using ancillary data such as time of travel flow characteristics and geographic information such as areas prone to flooding.

Datasets required for the assessment and protection of the area of primary influence are: (1) all PSOCs and associated contaminant groups; (2) land use and associated contaminant groups and; (3) point source discharges and associated contaminants. These datasets will be constructed from the following databases or coverages:

- PSOCs database (as compiled under the Ground Water Point Source Component of this SWAP);
- Land use classifications- GIRAS land use data (compiled under the Ground Water Nonpoint Source Component of this SWAP);
- Transportation and pipelines digital line graphs;
- Point source discharges- Location and maximum permitted pounds per day of contaminants discharged from both municipal and industrial wastewater sources in Texas, as retrieved from the TNRCC's TRACs database (compiled under the Surface Water Point Source Component of this SWAP);
- Boundaries of all water supply reservoirs under normal storage conditions (compiled under Surface Water Delineation Component of this SWAP);
- GNIS- Geographic Names Information System contains geographic names for landmarks from USGS Topographic Maps;
- CAFOs- Confined Animal Feeding Operations (compiled under the Surface Water Point Source Component of this SWAP);
- Flood prone areas.

Within the area of primary influence, all PSOCs, land uses, and the existence of transportation corridors or pipelines will be identified along with their associated contaminant groups. The susceptibility assessment will be based on the presence of PSOCs, potential for releases or spills of contaminants, and the contaminants associated with each specific PSOC in the area of primary influence. The surface water protection efforts will focus on the contaminates and the associated land use activities determined to be a potential threat to the water supply. Any major PSOCs outside this area of primary influence may be included in the protection efforts. Examples of major PSOCs are industrial sites, pipe lines, and other sources that could contribute large volumes of contaminants in a short period of time. Protection efforts will be focused on the PSOCs in the area of primary influence unless the assessments indicate the water supply is vulnerable to contaminants generated outside this area.

Mapping Tools

Delineated SWPAs will be mapped using standard mapping tools. Hard copy USGS 7.5 minute quadrangle maps are readily available and have been employed by the Wellhead and Source Water Protection programs since 1988. Source Water Protection areas are delineated directly onto the maps and copies made for inventory purposes. The PSOCs are digitized directly off of the finished maps. While this option is slow and requires physical storage space, it can be implemented for any water source, surface or ground. It is, therefore, a failsafe mapping solution that can be employed anytime more advanced technologies are either unavailable or dysfunctional.

In most cases, however, the preferred Source Water Protection mapping tool will be geographic information system (GIS) technology. GIS offers flexibility and enhance mapping capabilities lacking in hard copy maps. Accurately mapping SWPAs in GIS is contingent upon accurate base map data. TIGER data developed by the United States Census Bureau does not possess the level of accuracy required for performing these delineations. The most universally available base map data which meets the TNRCC's accuracy standards are digital raster graphics. Digital Raster Graphics (DRGs) are scanned images of USGS topographic maps. The scanned image includes all standard map collar information. The image inside the map neatline is georeferenced to the surface of the earth, making it possible to use DRG as a map layer or theme in many GIS software packages.

Hard copy maps produced from DRGs look very much like the original quad sheets, except they can be at different scales, overlap quad boundaries, and include any other type of GIS data. The TNRCC has loaded all of the DRGs for Texas and portions of surrounding U.S. states, as well as about 80, 1:50,000 scale Dirección General de Geografía del Territorio Nacional/Instituto Nacional de Estadística Geográfica e Informática maps in Mexico along the border with Texas.

Digital Orthophoto Quarter Quadrangles (DOQQs)

The Texas DOQQ Project utilizes National Aerial Photography Program (NAPP) color infrared (CIR) data products. NAPP photography are acquired at 20,000 feet above mean terrain with a 6 inch focal length lens. The flight lines are quarter quad-centered on the 1:24,000-scale USGS maps.

NAPP photographs have an approximate scale of 1:40,000, and in this project, are flown in color infrared.

The NAPP photography captured for the DOQQ project is high quality, cloud free and quad-based. The photography can be integrated into Geographic Information Systems (GIS) as base images through high resolution scanners or they can be used to manually interpret land use, land cover, and feature changes when compared to other photography or satellite imagery acquired from earlier or later time periods. The NAPP film can be used to resolve objects as small as one to two meters in size.

However unlike maps, unrectified NAPP photography has inherent distortions due to camera tilt and relief of terrain. Until this distortion is removed by differential rectification, the photography will not have the properties of an orthographic projection. In other words, the photos will not have the geometric qualities of a map.

Basics of Orthophotography

The term "digital orthophoto" is used throughout this document to refer to both the "digital orthophoto quadrangle" (DOQ) and "digital orthophoto quarter-quadrangle" (DOQQ) products. A digital orthophoto is a digital image which has the properties of an orthographic projection. It is derived from a digitized perspective aerial photograph by differential rectification so that image displacements caused by camera tilt and relief of terrain are removed. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map.

This program is oriented toward the production of 1-meter digital orthophoto quarter-quadrangles from 1:40,000-scale color infrared (CIR) National Aerial Photography Program (NAPP) photography. NAPP photographs are quarter-quadrangle centered (3.75 minutes of longitude and latitude in geographic extent), which makes them perfectly suited for a quarter-quadrangle-based digital product. From the primary 1-meter data, a variety of standard resampled products will be produced, including 2.5-meter, 10-meter and 30-meter digital images.

The digital orthophoto is created by scanning an aerial photograph diapositive transparency with a precision image scanner. The scanned data file is then digitally rectified to an orthographic projection by processing each image pixel through photogrammetric space resection equations. This process requires, as input, ground control points acquired from ground surveys or developed in aerotriangulation, camera orientation parameters, and a digital elevation model (DEM). The rectified digital image is then archived with the USGS and distributed to project contributors via tape and CD.

The photography is scanned at 25 micrometers (microns), or 1000 dpi. Each 240- by 240-millimeter (9- by 9-inch) CIR aerial photograph scanned with an aperture of 25 microns yields approximately 276 megabytes of raw data. Using 1:40,000-scale photographs, a 25-micron scan equates to a ground resolution of 1 meter. A CIR quarter-quadrangle digital orthophoto generated and cropped from a 240- by 240-millimeter photograph, scanned at 25 microns, with the requisite 300-meter overedge and header records produces a rectified file of approximately 158 megabytes.

The archive and distribution format for this project is tagged inline format (TIFF) with an associated "world" or projection file. The digital orthophoto is cast on the Universal Transverse Mercator (UTM) projection on the North American Datum of 1983 (NAD 83). Digital orthophotos are archived and distributed so that when displayed on a computer graphics terminal, projection grid north is at the top.

Accuracy

The Texas digital orthophoto quarter-quadrangles meet horizontal National Map Accuracy Standards (NMAS) accuracy requirements at 1:12,000 scale. The NMAS specify that 90 percent of the well-defined points tested must fall within 33.3 feet (1/30 inch) at 1:12,000 scale. The vertical accuracy of the source DEM must be equivalent to or better than a level 1 DEM, with root-mean-square-error (RMSE) of no greater than 7.0 meters. A planar-DEM (sloped-plane substitute grid) may be used for areas where the relief difference (high to low elevation) does exceed 150 feet. All remaining inputs and processes (i.e. aerotriangulation control and methodology, scanner calibration, and sensor calibration) used in digital orthophoto production must be sufficiently accurate to ensure that the final product meets NMAS.

POTENTIAL CONTAMINANT SOURCE INVENTORY

The participating PWS system will be responsible for inventorying all potential sources of contamination located in the delineated SWPA. The TNRCC will supervise and/or provide technical guidance as necessary or assist in the inventory process. The agency has adopted a standardized inventory form (Appendix H) which must be used in conducting the inventory. Standard operating procedures have been written to facilitate the use of the form and ensure a quality inventory.

The inventory of all potential contaminant sources inside a Source Water Protection Area provides a PWS with the information it needs to protect its public water supply and provides the TNRCC with additional detail information in assessing susceptibility to contamination. The results of this inventory form the foundation of the Source Water Protection report and determine what best management practices should be implemented by the participant. This activity is typically carried out by the PWS upon receipt of the Source Water Protection Area delineations.

Other local entities may also coordinate potential contaminant source inventories subject to the oversight and guidance of the TNRCC. Experience in the WHP program from 1988 to 1998 has demonstrated that the following entities have proven themselves in conducting these inventories:

- Boy Scouts of America
- Camp Fire, Inc.
- Councils of Governments
- Texas Rural Water Association
- Underground Water Conservation Districts

PWS systems will be provided inventory forms by the state in addition to the Source Water Protection Area maps. The PWS system must then schedule and complete the inventory.

The inventory seeks to identify any activity which may present a threat to the entity's public drinking water wells. Table 1 includes those activities which may be inventoried.

Table 1

Water Quality Problems that Originate on the Land Surface

- Infiltration of polluted surface water
- Land disposal of either solid or liquid wastes
- Stockpiles
- Dumps
- Disposal of sewage and water-treatment plant sludge
- De-icing salt usage and storage
- Animal feedlots
- Fertilizers and pesticides
- Accidental spills
- Particulate matter from airborne sources
- Grain storage bins and silos (including rice dryers)
- Industrial activities
- Aboveground storage tanks
- Urban runoff

Water Quality Problems that Originate in the Ground Above the Water Table

- Septic tanks, cesspools, and privies
- Holding ponds and lagoons
- Sanitary landfills
- Waste disposal in excavations
- Leakage from underground storage tanks
- Leakage from underground pipelines
- Artificial recharge
- Sumps and dry wells
- Graveyards

Water Quality Problems that Originate in the Ground Below the Water Table

- Waste disposal in well excavations
- Drainage wells and canals
- Well disposal of wastes
- Underground storage
- Secondary recovery
- Mines
- Exploratory wells
- Abandoned wells
- Water supply wells
- Ground-water development

For PWS systems that employ the services of volunteers, the TNRCC will provide them with Source Water Protection volunteer identification shirts and/or caps. These shirts/caps identify volunteers to law enforcement and the public and are highly visible.

Upon completion of the inventory, the completed forms and maps will be returned to the TNRCC so that a site-specific Source Water Protection Report may be written to the community. The information will also be used to refine the susceptibility assessment process.

Considering that land uses change over time, the Source Water Protection Program recommends that PWS systems reinventory their SWPAs every 2 to 5 years. This inventory would be submitted to TNRCC upon completion. The TNRCC would then revise, update, and publish a new report for the PWS system.

SITE SPECIFIC REPORT

Proper management of a local Source Water Protection program requires adequate information about a PWS system's water supply, PSOC inventory, and recommended best management practices (BMPs). This information must be conveyed accurately and concisely without overloading the reader with unnecessary terminology or extraneous information. These doctrines will guide the development of site-specific reports for SWP participants. Given Texas' broad diversity of regions, different water supply sources, and issues, the TNRCC will prepare a site-specific report for each PWS system participating in the SWP program. This report will be compiled after the PWS system has completed and submitted its PSOC inventory and will contain the following information:

- Program Overview
- Delineation Methodology
- Water Source/Hydrogeology
- PSOC Summary
- Contingency Planning
- Recommended Best Management Practices

In addressing the PSOC inventory, the report will identify those sources which were surveyed, the quantity, and the associated hazards with each. It will then recommend best management practices that can eliminate or reduce these associated hazards.

The report will be formally presented to the PWS system's representative to fully explain the program, inventory, and recommended BMPs. The PWS system will be given the opportunity to ask questions and fully understand the program. At that point, it will be the PWS system's responsibility to implement the BMPs.

When addressing the link between the site-specific report and the overall SWAP process, one must remember that the Source Water Assessment and Protection Program encompasses two primary phases:

- Assessment; and
- Protection

The assessment phase serves to determine the susceptibility of all PWS sources statewide. Those PWSs that are assessed to be especially sensitive to contamination are given priority for establishing a SWP program. The site-specific report provides the SWP-participating PWS system with assessment information, PSOC inventory data, and recommended BMPs. The purpose is to provide the PWS system with the information it needs to protect its drinking water supply from contamination. The PSOC information obtained from the inventory process is placed in the SWAP database to update and refine the assessment process.

Best management practices (BMPs) will be implemented by the PWS system participating in the Source Water Protection Program. These BMPs will fall into one of two categories: Regulatory and public education/outreach. The general recommendations contained in the report identify actions the PWS systems should to take to prevent contamination. Since each PWS system is different, BMP implementation will differ from system to system. The Source Water Protection program recognizes these differences and encourages PWS system to implement BMPs according to their own infrastructure and authorization. Generally speaking, only home rule authorities may take regulatory actions. Most PWS systems in Texas are either water supply corporations, municipal utility districts, or investor-owned utilities and do not have this authority. Counties are not considered home rule entities. Therefore, most PWS systems participating in the program will base their BMP efforts on public education and outreach (Appendix I). A key component of this effort will be the erection of roadside markers (Figure 4) and adoption of contingency plans (Appendix K).

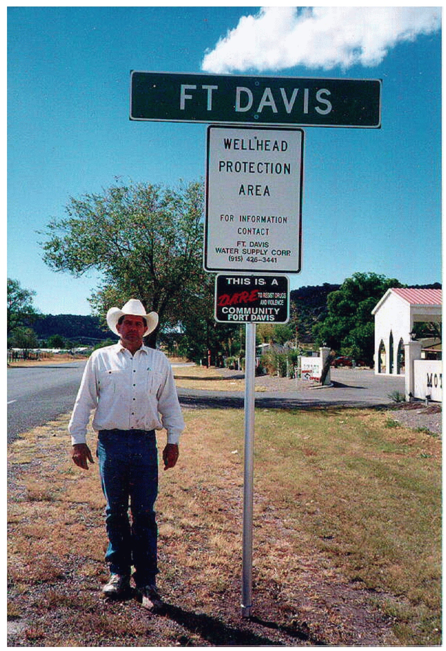

Figure 7

Contaminated drinking water can be very expensive and sometimes economically impossible to remediate. In cases of contamination from point sources, where the origin of the pollutant can be identified and addressed, the pollutant can be contained around the contamination point and there by protecting or at least minimizing the threat to finished drinking water. Contamination of surface waters derived from nonpoint sources tend to be intermittent and diffuse and as a result remediation may not be technologically or economically feasible for most contaminates. Therefore the importance of preventative measures which are much more economical to implement than drinking water plant renovations, will be the corner stone of the surface water protection program.

Reduction of nonpoint source pollution in source water supplies is dependent upon management of vulnerable areas. Preventative measures will be encouraged through education which will be based on community awareness by linking daily activity impacts on the local surface water supply. When voluntary efforts are unsuccessful, mandatory use restrictions or BMPs may become mandatory.

Contamination Prevention Measures

- *General Education*: General information will be shared statewide to raise the awareness of the potential for surface water contamination through activities contributing to nonpoint source pollution. A general information brochure, display, and slide presentation will be developed. These materials will be available to cooperating agencies and entities for distribution and presentation throughout the state.

- *Education Focused on Vulnerable Areas*: Educational efforts will be intensified in any area surface water supply is identified as vulnerable to contamination by specific contaminants. This effort will be applied based on the Source Water Susceptibility Assessments and the criteria used to define high priority protection areas even if monitoring data is unavailable. Education materials may be modified to address the specific PSOCs in the vulnerable areas.

- *Education and Voluntary Application of Best Management Practices*: When monitoring has revealed surface water contamination either through raw or finished water samples, but the concentrations are lower than the MCL , a voluntary BMP program will be encouraged. Education materials may be modified to address the specific contaminants found in the source water.

- *Education and Mandatory Application of Best Management Practices*: In areas where monitoring has revealed nonpoint source contamination of surface water by a contaminant at levels greater than the MCL or HAL, a voluntary educational and BMP program will be initiated as described above. If there is no evidence of improvement, a mandatory BMP program may be implemented or the appropriate regulatory option pursued.

BMP Implementation Methodology

Identification of Existing BMPs: The Source Water Protection staff and local partners will identify existing BMPs which can be applied to prevent nonpoint source contamination of surface water supplies. The staff will identify the agencies and other entities which have developed or collected pollution preventative management practices. The primary sources of this information will be the Natural Resource Conservation Service (NRCS), Texas State Soil and Water Conservation Board (TSSWCB), Texas Department of Agriculture (TDA) Texas Agricultural Experiment Station (TAES), Texas Agricultural Extension Service (TAEX), the Alliance for a Clean Rural Environment (ACRE) and others. The NRCS document “National Handbook of Conservation Practices” has a thorough list and descriptions of BMPs (see list of protection documents)

The Selection of Appropriate BMPs: The Source Water Protection staff will coordinate with other groups involved in BMP selection and work to establish a local task force to select the BMP for their targeted protection area. The task force will be responsible for determining which BMPs are feasible for the surface, geological, and climatological conditions, while having a attenuating effect on the contaminant.

Implementation of BMPs: The local task force will not only focus on which BMPs to utilize but also determine when a BMP program should be implemented. It will be important to have clear evidence of nonpoint source pollution that is either contaminating or threatening source waters before voluntary application of BMPs be suggested to the local communities. Determination of the periods of highest vulnerability will also be sought in order to implement BMPs at the most opportune times. Mandatory application of BMPs will only be implemented when it has been determined that the drinking water supply is contaminated by a known nonpoint source contaminate and all voluntary efforts have proven ineffective. This does not preclude any educational efforts.

Texas has been erecting Source Water Protection roadside markers since 1995. The Texas Department of Transportation approved the design at that time and has allowed erection of these signs along Texas highway rights-of-way (ROW). This approved design is provided to participating PWS systems to help them produce the signs correctly. When funding is available, the TNRCC may produce a quantity of signs and provide them to PWS systems upon request. Other BMPs approved for the SWP program are listed in Appendix J.

In situations were regulatory or enforcement actions are warranted, non-home rule PWS systems may refer issue to the appropriate state agency.

Public Health Protection: Preventing Microbial Contamination

The ultimate goal of any source water protection program is to protect public health by ensuring the source water is as free of contaminates as possible. Source water protection is the first barrier to drinking water contamination. Without the development of an effective protection plan, greater dependance will be placed on the treatment process and the distribution system to deliver safe drinking water to the consumer. While the goal of source water protection is designed to protect against all sources of contaminates, microbial contaminants often pose a more immediate threat to public health and will be a priority in the Texas SWP program. Protection of source waters from microbial contamination will be separated into three groups; protection, management, and monitoring.

Protection

Some states have implemented rigorous watershed regulations to control measures that influence coliform counts. Such measures include restricted grazing in watersheds and in some cases grazing and domestic animals are not permitted at all. Body contact, swimming and bathing have been prohibited in many source water lakes and reservoirs. Other strategies include land purchase programs which have been in place in watersheds with supporting communities.

These types of watershed policies must be pursued with strong community input and support in order to be implemented successfully. Watershed and water contact restrictions are easiest to initiate in an undeveloped watershed where there isn’t an established history of uses. Many Texas source waters already have long histories of contact recreation where it would be unrealistic to expect community support of restrictions of these uses. The TNRCC’s SWAP program will maintain these local regulation initiatives as potential protection approaches for newly developed surface water sources and for watersheds with the community support for such programs. Most of the Texas protection plans will be based on improved watershed management of existing and developing practices with the aim of improving or protecting the average quality of the source water.

Management

The implementation of BMPs throughout source water areas will be the main focus of protection activities when addressing microbial vulnerability. BMP identification, selection, and implementation will follow the method outlined previously in this document. This process will be tailored to develop BMPs strategies that prevent microbial contamination of surface water. They may include developing buffer strips, livestock fences bordering streams, and sequestering calves from the rest of the herd to minimize the potential of the entire herd becoming infected with Cryptosporidium and other pathogens.

While domesticated and non-domesticated animals will be a major management focus for microbial prevention, the issue of pathogens in wastewater effluent and combined sewer overflows will also be addressed. Urban areas where combined sewer overflows during storm events is know to be contributing raw sewage into a source water supply will be a main focus of protection activities especially if the urban storm water system discharges into the area of primary influence. These efforts will be coordinated with the municipalities, TNRCC staff involved with the Texas Pollution Discharge Elimination System, and other agencies and organizations.

Monitoring

Monitoring systems are often developed to provide an early indication of raw water quality so that operators and managers of water utilities can make effective treatment decisions to ensure the production of safe drinking water. These early warning systems can be used by water treatment personnel to optimize treatment performance in the event of especially poor raw water quality or allow for other responses such as taking the plant off line before contaminates reach the distribution system.

The greatest challenge is the need to monitor raw water for contaminants of concern in an accurate, timely and economical manner. Ideally early warning monitoring should be sensitive enough to detect changes in raw water quality during normal conditions. This, however may not be possible and as a minimum an effective early warning system must be able to detect abnormal situations that could impact human health, due to adverse weather conditions, high loading of contaminants, or spill situations. PDW staff will continue researching early warning systems and help further develop raw water monitoring procedures as well as participate in the on going bacteriological indicator studies.

Effective Source Water Protection program implementation across Texas will involve voluntary partnerships with local entities. Given the scope and site-specific nature of the program, it will be necessary to involve other organizations. This network will ensure that the Source Water Protection program is implemented according to state minimum standards but will allow for a more aggressive and proactive approach, especially in targeted vulnerable areas.

Such outsourcing initiatives are not without precedence. TNRCC (and its predecessor agency) has a long successful record of outsourcing Source Water Protection and Wellhead Protection activities. The following entities have contracted with the TNRCC to facilitate Source Water and Wellhead Protection activities:

Year	Entity
1990	North Central Texas Council of Gov'ts
1990	Panhandle Regional Planning Commission
1991	Retired and Senior Volunteer Program
1995	Texas Rural Water Association
1996	Springhills Water Management District
1997	Lubbock, City of

These examples aside, the TNRCC embarked on its most ambitious outsourcing effort in 1997. An open market contract was awarded to the Texas Rural Water Association (TRWA) to establish Source Water Protection programs in vulnerable aquifer areas identified by TNRCC. The contract required TRWA to assume responsibility for all aspects of the program under direct TNRCC oversight. Quality and productivity have been excellent (Figure 4) and all work has been done within budget. This partnership provides Texas with the ability to project Source Water Protection activities in specific geographic areas without adding additional FTEs or increasing costs. While TRWA is focusing solely upon groundwater systems, their focus will be expanded to include surface water PWSs as well.

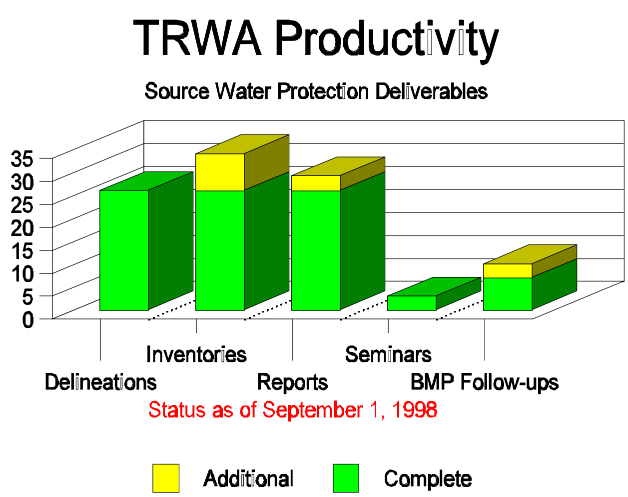

Figure 8

Source Water Assessment partners are chosen by the TNRCC according to formal contract bidding procedures established by Texas procurement law. This bid process is designed to select those vendors who are most qualified to provide services requested at the best price. The key part of this process is to identify and remove those vendors who are unqualified or do not have the financial capacity to perform the task requested. When the state considers a vendor for a contract, it must have evidence of financial capacity. The vendor must, in essence, provide access to financial records and demonstrate their solvency. If the vendor is unable to meet this test, then it is removed from the bid process. Vendors that do meet the financial capacity test and are awarded contracts must also be bonded. Purchase of this bond protects the state's financial investment in case the vendor's financial capacity becomes compromised or unable to meet their contractual obligations. Any subcontractors hired by the TNRCC's primary contractor must comply with the same rules and regulation as the primary contractor.

Local voluntary partnerships will also used to conduct the PSOC inventories. PWS systems have, for ten years, requested help completing their PSOC inventories. The TNRCC has consistently advocated the use of volunteers for this task, especially senior volunteers. This concept was clearly demonstrated in the El Paso Wellhead Protection Volunteer Project in 1990. Since that time, the Retired and Senior Volunteer Program (RSVP) has been routinely included in Source Water Protection inventory projects requiring assistance and will continue in this role. In fact, Texas G.O.L.D. (Guarding Our Local Drinking water), a Texas panhandle project, is based upon RSVP and is included as a demonstration project in EPA's Mentor Program. The project volunteers are trained Source Water Protection inventory volunteers available to assist PWSs complete their PSOC inventories. School students may also be involved in PSOC inventories as situations warrant.

The TNRCC provides volunteers with the appropriate training necessary to conduct the PSOC inventories. Such training provides a measure of quality assurance and also ensures compliance with program requirements and consistency. Examples of training provided to volunteers includes:

- Source Water Protection Delineation
- Using the PSOC Inventory Form
- Source Water Protection Area Map Interpretation
- Examples of PSOCs
- Inventory Techniques
- Emergency Procedures

All of these training procedures serve to provide a high quality inventory effort plus guard the safety of the volunteers. As a final measure, the volunteer are taken on a controlled field exercise where they are provided an opportunity to apply the inventory training they have received, ask questions, and receive additional instruction until they are capable of the inventory task.

Volunteers associated with Source Water Protection (SWP) activities have historically provide quality services unobtainable any other way. This synergistic association has been a hallmark of the program since the 1990 El Paso Wellhead Protection (WHP) Pilot Project. Since that time, literally hundreds of individuals have served as WHP/SWP volunteers. These volunteers typically carry out the potential contaminant source inventories necessary for completing local programs.

Although no one associated with the Texas SWP program has ever been injured or been subject to a liability claim as part of their volunteer activities, many people have become fearful of lawsuits pursuant to their volunteer services. Nationwide, governmental and nonprofit organizations have seen sharp decreases in the level of volunteerism because of this. Such fears ultimately end up costing taxpayers because volunteers help keep costs down while keeping projects on schedule.

These effects and the ramifications thereof were addressed by the 105th Congress in 1997 with the passage of the Volunteer Protection Act. This act protects individuals from frivolous claims and limits liabilities that can be placed on them while performing volunteer duties. Obviously, if an individual willfully commits a crime or an act that is grossly negligent then they can be held accountable. However, for those individuals who are performing necessary voluntary services they now have federal protection from unwarranted claims.

As the Source Water Protection program expands to surface water sources, partnerships with Senate Bill 1 Regional Planning groups will also be sought. These groups, created by the Texas Legislature with the passage of Senate Bill 1, will allow Source Water Protection program implementation while reducing duplication of effort.

IMPLEMENTATION TIMELINES

Source Water Protection (groundwater) implementation will be predicated on Source Water Assessment results. Criteria developed in the assessments will be employed to target which aquifers should receive implementation priority. Once this has been determined, the TNRCC and its contractors will focus their efforts on the PWS systems located in these areas according to the following priorities:

XCII. Community PWS Systems
XCIII. Community Non-transient PWS Systems
XCIV. Non-community Non-transient PWS Systems

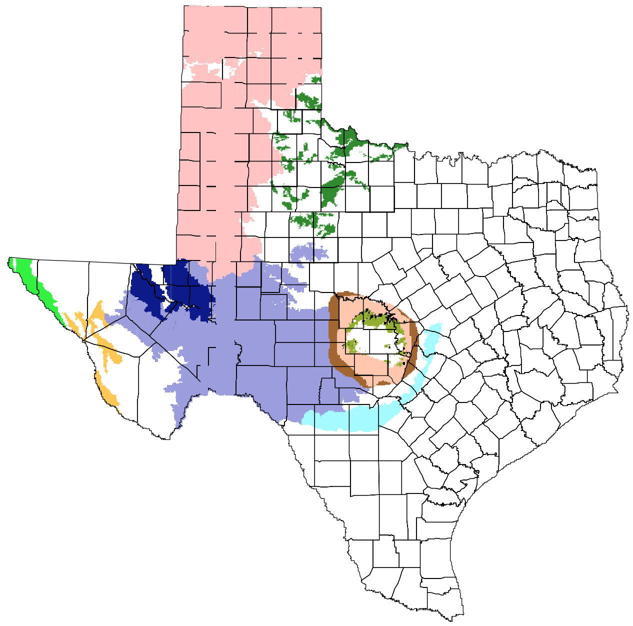

Figure 9 - Designated Implementation Project Areas

However, sufficient information exists about several aquifers such that implementation efforts can commence ahead of the assessment activities. These susceptible aquifers include the Ogallala, Edwards, Seymour, and the alluvial aquifers of west Texas. Table 3 shows those aquifers which have been given initial SWP implementation priorities:

Table 2 **Source Water Protection Implementation in Vulnerable Aquifer Areas**	
Aquifer	**Implementation Year**
Ogallala	1998
Seymour	1998
Cenozoic	1998
Edwards	1998
West Texas Alluvium	1998
Edwards Plateau	1999
Ellenburger-San Saba	1999
Hickory	1999
Marble Falls	1999
Additional aquifer areas will be added to the Source Water Protection implementation priority list in subsequent years based, in part, upon susceptibility assessment results.	

GROUND WATER PROTECTION (WHP)

In the ten years since the Texas Wellhead Protection Program was established, 600 PWS systems have been enrolled on a voluntary basis. These systems include both community and non-community water systems from across the state. The majority of participants have been centered around the Dallas/Fort Worth metroplex, the Houston-Galveston area, central and east Texas. Partnerships with local organizations in these areas contributed to the increase participation, further demonstrating the benefits of networking at the local level.

The Wellhead Protection program's implementation focus was changed in 1997. Instead of recruiting PWS systems statewide, the TNRCC began systematically targeting specific geographic regions for implementation. Known susceptible aquifers are used as the basis for each geographic region. The collective participation of PWS systems in each of these areas will have a greater impact on public health and water quality than in areas with susceptible water resources. Since this implementation shift, over 70% of the Ogallala aquifer community systems and 90% of the alluvial aquifer community systems have been protected by a Wellhead Protection program. Statewide, 23% of all vulnerable PWS systems were to be protected by a Wellhead Protection program at the end of FY1998. Texas exceeded this goal by 22%.

The implementation of protection plans for surface water systems will be prioritized based on the results of the Source Water Susceptibility Assessments and plant performance based on MCL violations. Due to the public participation component and other technical issues, surface water protection efforts will also be coordinated with other state watershed initiatives such as the Total Maximum Daily Load (TMDL) process and the Clean Rivers Program. All public water systems associated with segments on the Clean Water Act Section 303(d) list of impaired and threatened water bodies, will have source water protection activities coordinated in conjunction with TMDL evaluations.

Source Water Protection is the first line of defense designed to ensure public drinking water supplies are safe for human consumption. All Texas public water supplies are responsible to sample for total and fecal coliform bacteria which act as indicators of potential sewage or animal waste contamination and the related pathogens associated with sewage.

From 1995 to October 1998 there were 113 surface water systems reporting total coliform MCL violations (this includes acute fecal and non fecal violations). Of these systems there were 31 that had multiple violations (violations in more than one month). The graph indicates the number and type of systems reporting coliform violations during this time frame.

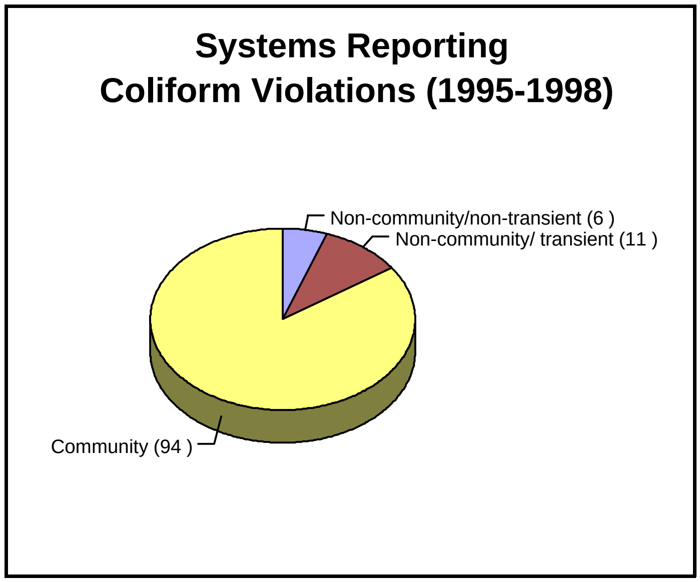

Figure 10

Community systems make up 83% of the MCL violations and represent a larger population than the other system types and will therefore be the main focus of protection activities when addressing plant MCL violations. Of the these systems reporting violations, 79 (70%) of the systems purchase surface water from another system. Clarification of these relationships will be made prior to any protection efforts. The combined population of a surface water supply, within and outside the watershed, if applicable, will be calculated and the largest populations will be will be a higher priority.

The criteria for prioritization follows:

High Protection Priority

- Community public water supplies that are determined to be highly susceptible to contamination that could have a human health impact;
- Community public water systems that have had MCL violations and are determined to be highly susceptible to that contaminant;
- Any water supply placed on the 303(d) list as a high priority or highly threatened due to violations of Texas drinking water standards; and,
- Community public water systems that have had an acute coliform MCL violation.
- Community public water supplies that do not have a complete source water assessment in place.

Medium Protection Priority

- Community public water supplies that are determined to be moderately susceptible to contamination that could have a human health impact;
- Any community water supply placed on the 303(d) list as moderately threatened due to contamination of finished drinking water;
- Community public water systems that have had a total coliform violation-no fecal; and,
- Non-community, non-transient public water systems that are determined to be susceptible to contamination that could have a human health impact.

Low Protection Priority

- Community public water supplies that are determined to have a low susceptibility to contamination;
- Non-community, transient public water systems that are determined to be susceptible to contamination that could have a human health impact; and,
- All public water supplies drawing from segments that are listed on the 303(d) list for reasons other than violations of finished drinking water standards.

Potential Funding for Source Water Protection

TNRCC Source Water Protection staff will provide information and assistance on potential sources of funding for source water protection activities. This will include on-going research on programs and legislation that can provide financial support to public water systems wishing to establish source water protection programs. Staff will ensure this information is made available to PWS and also offer technical assistance in the development of funding proposals.

In October 1998, congress passed the Clean Water Action Plan in which EPA appropriated $145 million. Within this plan, funds have been designated for groundwater and source water protection. The conference report states:

> Within the amounts provided for the Clean Water Action Plan, $3,500,000 is intended to support groundwater and source water protection efforts in priority watersheds that primarily encompass small communities and/or rural areas. These resources should support source water assessment and protection activities at the local level, integration of groundwater concerns into watershed assessment and restoration plans, implementation of wellhead protection programs locally, and/or field technicians supporting communities considering new groundwater/source water ordinances targeted at high risk watersheds.

Funding for source water protection projects on agricultural land is available through several USDA programs. The Environment Quality Incentives Program (EQIP) provides cost share payments of up to 75% of the cost of certain conservation practices as well as incentive payments for the implementation of land management practices. The 1996 Farm Bill requires that 50% of EQIP funding must be directed to practices related to livestock production.

The USDA's largest conservation program is the Conservation Reserve Program (CRP) which had funding for fiscal 1998 of nearly $2 billion. This program offers long-term land rental payments and cost-share assistance to farmers in exchange for converting agricultural land to less intensive, resource conserving uses. Eligible land must be highly erodible, located in a conservation priority area as determined by the Source Water Vulnerability Assessments, or meet other requirements.

Two programs within the CRP are potential sources of funding for livestock producers. The first is the National Buffer Strip Initiative which was announced by USDA in 1997. This initiative provides payment covering up to 50% of the total cost for the establishment of riparian buffers on marginal pasture land, and an estimated 20% incentive payment over and above the rental rates paid under the regular CRP.

The second program, the Conservation Reserve Enhancement Program (CREP), is a joint federal-state land conservation retirement program authorized by the 1996 Farm Bill. One of the advantages of CREP over the regular CRP is that greater funding is available to address resource needs since CREP pools funding from state and federal sources. This can be particularly important in areas where payments under the regular CRP do not provide sufficient incentive to farmers and ranchers to participate.

There are a variety of other federal program for protection funding. Table 3 summarizes some of these and includes recent funding levels and eligibility requirements.

	Table 3 **SELECTED FEDERAL FUNDING SOURCES FOR SOURCE WATER PROTECTION**	
PROGRAM FY 98 funding Level	DESCRIPTION	ELIGIBILITY Beneficiaries
	U.S. DEPARTMENT OF AGRICULTURE (USDA) PROGRAMS	
Conservation Reserve Program (CRP): $1,928 million	Voluntary program that offers long-term rental payments and cost-share assistance to establish long-term resource conserving cover on environmentally sensitive cropland or marginal pasture land.	Owners or operators of highly erodible or environmentally sensitive cropland
Wetlands Reserve Program (WRP): $163 million	Restoration and protection of farmed and prior converted wetlands, and riparian buffer areas through monetary incentives and technical assistance. Payments for environmental easements and cost-share payments of up to 75% for restoration activities are available.	Owners of farmed wetlands, converted wetlands, riparian areas, and buffer areas.
Environmental Quality Incentives (EQIP): $200 million	Provides technical, financial, and educational assistance to farmers and ranchers to address natural resource needs, with half of it targeted to livestock-related resource concerns. Cost sharing of up to 75% of cost and incentive payments of up to 100% for 3 years.	Non-federal agricultural landowners with eligible land
Watershed Protection and Flood Protection Program: $40 million	Provides cost sharing (50-100%) and technical assistance for projects such as watershed protection, flood prevention, erosion and sediment control, water quality, and wetlands creation and restoration in watersheds of 250,000 or fewer acres.	State and local entities Indian Tribes or nonprofits involved in watershed protection
Water and Waste Disposal for Rural Communities: Loans: $810 million Grants: $484 million	Provides funds for new and improved rural water and waste disposal systems.	Municipalities, counties, districts, nonprofits, Indian Tribes.
	U.S. EPA PROGRAMS	
Nonpoint Source Management Program $100 million	Assists states in implementing EPA approved Section 319 nonpoint source management programs. Nonfederal matching funds of at least 40% of project cost required.	State and local governments, Indian Tribes, and nonprofits.
CWA State Revolving Funds (CWA SRF): $1,075 million	Financing for construction of wastewater treatment plants, funding for water quality management activities including NPS and estuary management programs. State must provide 20% matching funds.	Municipalities and local agencies.
SDWA State Revolving Fund (SDWA SRF): $750 million	Loans for drinking water supply related projects, including source water protection. State must provide 20% matching funds.	Public water systems, agencies, nonprofits, Indian Tribes, and Individuals.
Water Quality Cooperative Agreements: $20 million	Supports creation of unique and new approaches to meeting stormwater combined sewer outflows, sludge, and pretreatment requirements.	State and local govts. Indian Tribes, nonprofit, private orgs, and individuals.
Pollution Prevention Grants: $ 6 million	Assistance for implementing pollution prevention projects, consistent with EPA's National Criteria. States must provide 50% matching funds.	States and local govts, nonprofits, and Indian Tribes.
Wetlands Protection Develop. Grants: $ 15 million	Financial assistance to support wetlands development or enhancement of existing programs. State or Tribes must provide 25% match.	States, local governments, and Indian Tribes.

UPDATING/REFINING ASSESSMENTS AND PROTECTION PROGRAMS

Assessments

Assessments will be updated on a case-by-case basis as additional site-specific (detail) protection data is obtained or submitted to TNRCC. As communities submit additional data or changes are made by the system, assessments will be updated or refined.

Susceptibility determinations will also be used to refine sampling (both chemical and microbiological) schedules. Every system will be re-analyzed once every three years. This policy is consistent with both the vulnerability assessment and sampling schedule.

New water systems or significant changes in existing systems (e.g. change in raw water source) will result in a re-evaluation of the assessment.

Protection Activities

Public water supply systems participating in the Source Water Protection Program will be updated every two to five years. This interval is consistent with the EPA-approved Texas Wellhead Protection Program. New information will be incorporated into the Source Water Assessment database and, where applicable, new Source Water Protection reports will be generated and distributed.

REPORTING TO EPA

TNRCC's Source Water Assessment and Protection strategy shares information with EPA in a number of ways. Online electronic access is provided to EPA for a number of databases (bacteriological, inventory, and enforcement). The TNRCC will provide training to EPA on access and data manipulation within its databases. TNRCC will continue to provide hard and/or electronic copies of traditional reports to EPA during this learning phase. Online access to source water assessment and protection data will also be provided as databases are migrated to software platforms compatible to EPA. The databases will be updated routinely; at a minimum, once every three months. The percentage of water systems (and population served) that provide drinking water standards will continue to be reported electronically on an annual basis to EPA.

The 1996 amendments to the Safe Drinking Water Act did not change the biennial reporting requirements for the Wellhead Protection Program authorized by Section 1428. TNRCC will expand its WHP Biennial Status Report to include reporting of all source water protection efforts. An update of susceptibility determinations will also be included in the report.

APPENDIX A
List of Acronyms

APPENDIX A

List of Acronyms

API	Applications Programming Interface
ASDWA	Association of State Drinking Water Administrators
AWWA	American Water Works Association
BMP	Best Management Practice
CADD	Computer Aided Drafting and Design
CAFO	Concentrated Animal Feeding Operations
CCR	Consumer Confidence Report
CMR	Chemical Monitoring Reform
CRP	Conservation Reserve Program
CSGWPP	Comprehensive State Ground Water Protection Program
CT	Contact Time
CWS	Community Water System
CWA	Clean Water Act
DBMS	Database Management System
DBP	Disinfection By-Products
DEM	Digital Elevation Models
DLG	USGS Digital Line Graph
DOQ	Digital Orthophoto Quadrangle
DOQQ	Digital Orthophoto Quarter-Quadrangle
DRG	Digital Raster Graphic
DWAWG	Drinking Water Advisory Work Group
DWSRF	Drinking Water State Revolving Fund
EDC	USGS EROS Data Center
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EROS	Earth Resource Observation Systems
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management System
FGDC	Federal Graphic Data Committee
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FOD	Feature Operational Database
GIN	TNRCC Numbering System Number
GIRAS	Geographic Information Retrieval and Analysis System
GIS	Geographic Information System
GNIS	USGS Geographic Names Information System
GPS	Global Positioning System
GUI	Ground Water Supplies Under the Influence of Surface Water
GWCD	Ground Water Conservation District
GWPC	Ground Water Protection Council
HA	Health Advisory
HTML	Hypertext Markup Language

APPENDIX A
List of Acronyms
(cont'd)

HUC	Hydrologic Unit Code
IR	Information Resources (TNRCC's Office of Administration Services)
IUP	Intended Use Plan
IWTP	Industrial Wastewater Treatment Plants
JAD	Joint Application Design
JRP	Joint Requirements Planning
LSD	Land Surface Datum
MAC	Master Aquifer Coverage
MCL	Maximum Contaminant Level
MDI	Multiple Document Interface
NAPP	National Aerial Photography Program
NAWQA	National Water-Quality Assessment Program
NCWS	Non-community Water System
NED	National Elevation Database
NED-H	Hydrologic Derivatives Database
NHD	National Hydrography Dataset
NOAA	National Oceanic and Atmospheric Administsration
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint Source
NRCS	National Resource Conservation Service
NRWA	National Rural Water Association
NSDI	National Spatial Data Infrastructure
NWIS	National Water Information System
ODE	Open Development Environment
OLE	Objective Linking and Embedding
OOP	Object-Oriented Programming
PAH	Polycyclic Aromatic Hydrocarbons
PCE	Perchloroethylene
PCS	Permit Compliance System
PDW	Public Drinking Water
PDWS	Public Drinking Water Supply
PP&E	Public Participation and Education
PSOC	Potential Source of Contamination
PST	Petroleum Storage Tank
PWS	Public Water System
PWSS	Public Water Supply Supervision Program
RCRA	Resource Conservation and Recovery Act
RDBMS	Relational Database Management System
RSVP	Retired and Senior Volunteer Program
SCS	Soil Conservation Service
SCSI	Small Computer Systems Interface

APPENDIX A
List of Acronyms
(cont'd)

SDE	Spatial Database Engine
SDTS	Spatial Data Transfer Standard
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SIC	Standard Industrial Codes
SMP	State Management Plan
SOC	Synthetic Organic Chemicals
SQL	Standard Query Language
SSA	Sole Source Aquifer
STORET	STOrage and RETrieval U.S. Waterways data system
STP	Sewage Treatment Plants
SWA	Source Water Assessment
SWAP	Source Water Assessment and Protection
SWAS	Source Water Assessment Software
SWP	Source Water Protection
SWQM	TNRCC Surface Water Quality Monitoring
SWSA	Source Water Susceptibility Assessments
TAES	Texas Agricultural Experiment Station
TAEX	Texas Agricultural Extension Service
TCE	Trichloroethene
TDA	Texas Department of Agriculture
TDH	Texas Department of Health
THM	Trihalomethanes
TIFF	Tagged Inline Format
TMDL	Total Maximum Daily Load
TNRCC	Texas Natural Resource Conservation Commission
TOT	Time-of-Travel
TRACS	TNRCC Regulatory Activities and Compliance System
TRI	Toxic Release Inventory
TRWA	Texas Rural Water Association
TSMS	Texas Statewide Mapping System
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
UIC	Underground Injection Control
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	Underground Storage Tank
UTM	Universal Transverse Mercator
UWCD	Underground Water Conservation District

APPENDIX A
List of Acronyms
(cont'd)

VAP	Vulnerability Assessment Program
VOC	Volatile Organic Compound
WHP	Wellhead Protection
WHPA	Wellhead Protection Area