The Atmospheric Technologies Group (ATG) of the Savannah River National Laboratory’s Non-proliferation Technologies Section (NTS) performs hydrological studies to assess the impact of Savannah River Site (SRS) operations and to support offsite customers. These hydrological studies may be predictive, statistical, or descriptive in nature. Predictive studies (i.e., modeling) include estimating flood levels; calculating temperature distributions from thermal discharges to streams, rivers, and ponds; and predicting pollutant concentrations and impacts from waste water releases. Water quality and flow statistics to support outfall permitting are developed from extensive NTS databases. Hydrological information is documented for environmental impact statements and safety analysis reports.
The Atmospheric Technologies Group develops, adapts and uses a variety of computer codes to model surface water hydraulics, pollutant transport and distribution, and water quality. This includes codes developed by NTS as well as by government agencies that are expert in, and responsible for, surface water hydrology and/or water quality, such as the U.S. Army Corps of Engineers (ACE), the U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS). NTS also performs dye tracer studies to characterize the transport and dispersion of pollutants in rivers, streams, swamps, and other surface waters. With these models and data, ATG supports SRS emergency response and facilities' safety analyses, operations and regulatory compliance.

Aquatic Emergency Response

The SRS emergency response plans include a stream/river emergency response model to predict pollutant travel times, maximum concentrations, and concentration distributions at selected locations downstream of each of the major SRS installations. ATG developed the STREAM-II code, a menu-driven aquatic emergency response model that contains a database of all the required stream information and thus requires only input data characterizing the release (e.g., location, date, time, type, duration, amount, and units of release). The release location could be specified by a facility identifier or by mouse-clicking at any location along the SRS main stream or Savannah River. The EPA Water Quality Analysis Simulation Program V. 5 (WASP5) has been adapted as the calculation module in STREAM-II. WASP5 uses finite difference methods to solve the one-dimensional advection-dispersion mass transport equation. A post-process module provides STREAM-II results in tabular and graphical form to show the impact of a release and to help design a plan to monitor the release.

Swamp Water Level Study for Wetlands Restoration

Hydrology models can provide useful information for environmental restoration projects. For example, ATG scientists participated in a wetland restoration project at SRS. The SRS wetlands (a 10,000 acre swamp) are in Barnwell County, South Carolina on the southwest boundary of SRS. Water levels within the swamp are determined by the Savannah River, local drainage, groundwater seepage, and inflows from four tributaries — Beaver Dam Creek, Four Mile Branch, Pen Branch, and Steel Creek. Historically, discharges of heated water from these tributaries scoured the stream beds, creating deltas in the adjacent wetland and killing native vegetation near the delta deposits. Future releases from these tributaries will be substantially smaller, closer to ambient temperatures. One goal of the restoration project is to reestablish indigenous wetland vegetation.
on the Pen Branch delta. ATG scientists used the FASTTABS modeling system to model the wetland and to predict long-term water levels within the swamp. Knowledge of these water levels is required to determine the characteristics of suitable vegetation. Figure 2 shows the calculated swamp water depth for a Savannah River flow of 12,000 cubic feet per second (cfs) and a downstream stage of 79.5 feet.

**Water Quality Studies and Regulatory Compliance**

ATG scientists perform calculations in support of water quality and permitting activities. For example, construction of a waste water treatment plant at SRS required a permit from South Carolina Department of Health and Environmental Control (SCDHEC). In support of the permit application, ATG used the EPA Enhanced Stream Water Quality Model, QUAL2E, to simulate the impact of the one million gallons per day sanitary waste water treatment plant effluent on the dissolved oxygen (DO) levels in the receiving stream (Four Mile Branch). The QUAL2E simulation showed that DO levels would remain above the regulatory lower limit of 5 mg/l if the flow in the Four Mile Branch remained above 3.3 cfs. QUAL2E also was used to study the impact of reactor cooling water on the receiving pond water temperature, providing data to help minimize environmental impacts such as fish kills.

To ensure compliance with regulatory limits, WASP5 was used to simulate the downstream pollutant concentrations for several proposed facility process scenarios. The scenarios involved different combinations of waste release times, durations, magnitudes, and locations. Figure 3 shows WASP5 results for the tritium concentration in the Savannah River for four proposed process scenarios. The analyses showed that only one release scenario would ensure that the concentration upper limit would not be exceeded.

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**Safety/Hazards Analysis**

ATG scientists perform engineering calculations to help answer questions about the safe operation of SRS facilities. On occasion these analyses address the consequences of hypothetical events such as earthquakes. For example, ATG analyzed the surface runoff of liquid radioactive waste following the postulated rupture of a large storage tank. The results showed that the runoff would flow to a storm sewer system and be delivered to a creek onsite, eventually reaching the Savannah River. The analysis also showed that the time required to reach the creek was small compared to the transport time from the creek to the river.

ATG scientists also perform analyses to address safety concerns about proposed facilities and processes. For example, a large lake that formerly received cooling water from two nuclear reactors was partially drained to repair a deteriorating earthen dam. The sediments at the bottom of this lake were known to contain some radioactive contamination. Concerns were raised that refilling the lake might stir up these contaminated sediments, and that some of the radioactivity might be transported from the lake to a tributary of the Savannah River. ATG scientists calculated that some resuspension would likely occur but natural settling processes would remove all but the tiniest particles, preventing any significant radioactivity from escaping the lake. This analysis helped justify the process that eventually was used to refill the lake.

ATG scientists have also contributed to hazards analyses for critical facilities at SRS. One such hazard, flooding, can cause structural and nonstructural damage and interrupt critical functions resulting in potentially huge economic losses. More importantly, if the affected facility contains hazardous or radioactive materials, flooding may result in a significant environmental and health hazard. DOE Order 420.1, Facility Safety, outlines the requirements for Natural Phenomena Hazard (NPH) mitigation for new and existing DOE facilities. Specifically, NPH includes flood events. An important element of NPH flooding analyses is the determination of facility-specific probabilistic flood hazard curves. These curves define as a function of water elevation the annual probability of occurrence or the return period in years. ATG scientists developed a method combining an ACE precipitation-runoff model (HEC-HMS) and a USGS water surface profile hydraulic model (WSPRO) to calculate facility-specific probabilistic flood hazard curves. Using these facility-specific probabilistic flood hazard curves, facility managers assess the magnitude of the flooding hazard and then design permanent or temporary devices to prevent the propagation of flooding on site, as well as develop emergency preparedness plans to mitigate the consequences of floods.

**Remote Sensing/Thermal Imaging**

ALGE is a 3-D hydrodynamic code developed by NTS that solves the momentum, mass, and energy conservation equations to predict the movement and dissipation of thermal plumes within cooling lakes, rivers and estuaries. Cooling lake simulations include recirculation and buoyancy-driven flow. Estuarine simulations include prediction.
of tidal current speeds and directions. ALGE also simulates wind-driven circulations, and can combine wind stress effects with tidal and buoyancy forces. Energy is exchanged with the model atmosphere through turbulent sensible and latent heat transfer, and by short-wave (solar) and longwave (thermal) radiation transfer, including the effects of clouds. The model coordinates are Cartesian. ALGE was designed to produce high-resolution simulations for analysis of aircraft or satellite thermal imagery. Recent applications of ALGE include:
1. assessment of cooling lake performance in several locations across the U.S.;
2. analysis and simulation of thermal bar development in Lake Ontario using remote sensing data;
3. analysis and simulation of thermal and turbidity plumes from an Oak Ridge Reservation stream flowing into and mixing in the Clinch River; and
4. analysis and simulation of transport and mixing in a flooded Savannah River swamp of tritium from SRS.

Dye Tracer Studies
Dye tracer studies are performed periodically in SRS streams. Dye study data are used to determine stream velocities and dispersion coefficients and to benchmark water quality models (e.g., WASP5, QUAL2E). For example, in the past, ATG joined with the EPA, SCDHEC and Georgia Department of Natural Resources to conduct dye tracer studies on the Savannah River. The purpose of these studies was to develop a waste load model for the Savannah River.

In a dye tracer study, a known quantity of fluorescent dye is released into a stream. At downstream sampling locations, manual and/or automatic samplers are used to take samples as a function of time. The water samples are then brought back to the laboratory for analysis. A fluorometer is used to measure the sample fluorescence intensity. To obtain the sample concentration, the measured fluorescence intensity is compared with readings for standards of known concentrations on the same fluorometer under the same instrumental and environmental conditions.

Some of the SRS dye study data have been used to benchmark the WASP5 code. These benchmark results provide confidence in WASP5 as the computational module for the STREAM-II aquatic emergency response system.

Development Areas
The monthly average flows based on historical records are used in the STREAM-II code for pollutant transport analysis. One area of development of the STREAM-II is to include an option of using the real-time flows for the pollutant transport analysis, when the real-time flows are available.

For more information on Hydrology and Surface Water Modeling, contact:
Kuo-Fu Chen, Fellow Engineer
Phone: (803) 725-7122; E-mail: kuo-fu.chen@srnl.doe.gov
A. J. Garrett, Senior Advisory Engineer
Phone: (803) 725-4870; E-mail: alfred.garrett@srnl.doe.gov
C. H. Hunter, Manager, Atmospheric Technologies Group
Phone: (803) 725-2953; E-mail: chuck.hunter@srnl.doe.gov
R. P. Addis, Manager, Nonproliferation Technologies Section
Phone: (803) 725-3325; E-mail: robert.addis@srnl.doe.gov

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