Final Report
Road Weather Information Systems

SUMMARY REPORT:
WASHINGTON STATE
ROAD WEATHER INFORMATION SYSTEMS

by

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16. ABSTRACT

The Washington State Department of Transportation (WSDOT) has deployed advanced weather systems and products to support maintenance operations and to provide public information. The expanded system has tremendously improved the availability and quality of weather information for WSDOT crews and the traveling public. Use of current and forecast weather information has increased from nearly non-existent to an actively used, Department-wide resource.

This summary report overviews the various efforts, products, and reports generated since the beginning of the road weather project.

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The Washington State Department of Transportation (WSDOT) has deployed advanced weather systems and products to support maintenance operations and to provide public information. The expanded system has tremendously improved the availability and quality of weather information for WSDOT crews and the traveling public. Use of current and forecast weather information has increased from nearly non-existent to an actively used, Department-wide resource.

This summary report overviews the various efforts, products, and reports generated since the beginning of the road weather project.

A BRIEF HISTORY

WSDOT's weather system in 1999, at the beginning of the project, consisted of about 14 automated weather stations, all but a few of which were in poor repair. The weather sites were each polled from the local maintenance office, and as a result the data were not available beyond the local office. This greatly limited the usefulness of the weather system.

The project, as originally conceived, would install more weather stations, properly repair sites, and find a way to collect all the weather data into a central location. Centralized data would be useful across the state and could be provided to the public as traveler information. A Federal Highway Administration (FHWA) earmark grant and state matching funds were obtained to start the work.

Once project funding was obtained, the project lead was handed over to an intelligent transportation systems (ITS) intern within WSDOT. This individual's initiative was responsible for taking the project beyond the original goal of centralizing weather data toward a true information system. The University of Washington (UW) Department of Atmospheric Sciences was engaged to develop Internet screens (the original rWeather pages) to present the weather data in a meaningful way for both WSDOT users and the public. The rWeather pages included a road temperature page that showed highways that were at or below freezing in red and near freezing (33ºF to 37ºF) in yellow. Later, a page was developed to show current and predicted road temperatures over a 24-hour period for a few major routes within the state.

Subsequent funding was used to further expand and improve the Road Weather Information System (RWIS), including the use of NTCIP (National Transportation Communication for ITS Protocol) for communications between one vendor's weather stations and another vendor's server system. Funding also continued development work at the UW.

ARROWS (Automated Real-time ROad Weather System) is a UW product specifically designed to provide short-term (24-hour) weather and pavement forecasts to WSDOT maintenance groups. ARROWS forecasts include point forecasts along state and Interstate highways in both graphic and table formats. Statewide and zoomed in views show where precipitation is likely within 4-hour intervals throughout the 24-hour prediction period.

ENVIRONMENTAL SENSOR STATION NETWORK IMPROVEMENTS AND ADDITIONS

The single project element that enabled virtually all other aspects of the project was the deployment of a centralized server system to collect data from environmental sensor stations (ESS), automated roadside weather stations.

All pre-existing ESS had been purchased from Surface Systems Inc., so SSI's Scanweb was chosen for the central server. This occurred before the development of NTCIP protocols, so the ESS were all using proprietary protocols from the vendor. This limited the choice of vendor for the server system to SSI because it was not practical, and possibly a violation of SSI's proprietary code, to reverse-engineer a server system.

Initially, a server was placed in every region but one, which shared a server with another region. Each region server polled the sites within its area and replicated the data to the central server in Olympia.

The original server software was based on Windows '98 and SQL 6.0, both of which were already obsolete at the time. Problems associated with data replication between servers appeared to be related to the SQL version, which was so old that Microsoft no longer supported the product. Replication failures would interrupt the data flow and make portions of the system unavailable until the problem was corrected. This type of failure happened with disruptive frequency. Eventually, databases were eliminated at all but one region server (Spokane also supported city and airport ESS and required a local connection). Region servers continued to poll the sites, but the servers only temporarily stored the data until they could be pushed to the Olympia server. This eliminated many of the problems. In 2005, state funding upgraded the central server

software to a version that uses current operating system and SQL database software, and it replaced most all the server hardware.

Each of the above efforts to improve the weather server system resulted in a substantial reduction in network down time.

FIELD HARDWARE AND COMMUNICATIONS IMPROVEMENTS

The number of field installations has greatly increased since 1999. WSDOT started out with 14 ESS, some of which were shared with the City of Spokane.

Since 1999, federal earmark funding has been used to add 16 ESS to the WSDOT network. During that same period, WSDOT maintenance organizations and construction contracts have added another 43 WSDOT owned sites, and Yakima County has installed five ESS that are polled through the WSDOT weather server system. At the time of this report the system polls 82 sites through a single server system, and more will be added soon.

The Yakima County installations are being considered as a model for working with other local jurisdictions that wish to participate in the WSDOT weather system.

In 2001 WSDOT published a Request for Qualifications for ESS installations across the state. The specification was intended to allow competition between vendors in an attempt to minimize site costs. The effort resulted in a cost reduction of approximately $10,000 per ESS. To allow the existing server system to communicate with other vendors' ESS (or to avoid the need for a second server system), the procurement required NTCIP communications, which enabled multiple vendors to bid. The NTCIP requirement was easily met by the new vendor and did not cause any other problems.

In addition to the land-based ESS, WSDOT installed atmospheric ESS (measuring temperature and wind speed/direction) on seven ferry boats, a fraction of the 22-vessel ferry fleet operated by WSDOT as part of the state highway system. True wind speeds and directions are calculated by subtracting the vessel speed (based on an on-board GPS) from the measured wind speed and direction. A dedicated radio system relays the data to WSDOT.

UNIVERSITY OF WASHINGTON CONTRIBUTIONS

Collaboration with the University of Washington Department of Atmospheric Sciences was vital to the development of advanced weather products generated throughout the project.

The UW developed the original set of weather information pages for the WSDOT website. Most all of the features that make the WSDOT pages a huge success were generated by the UW team. All of the weather information products except ARROWS were produced in just the first two years of the project.

Weather Information

The original rWeather page developed by the UW team displayed data from both WSDOT ESS and several hundred non-DOT sources (already collected by the UW) to provide a complete weather picture across the state. The entry screen featured a map with representative air temperatures on it. Clicking on a temperature would bring up the most recent weather sensor data from the site, as well as a link to the National Weather Service forecast for that area. Weather stations could also be selected from a list. Originally, the location of a site selected from the list would be circled on the map, a feature not available on the new site. The original rWeather site has been replaced with a

new WSDOT-developed page that has retained all but a few of the features available on the original rWeather page.

Weather Data from Ferries

Along with the rWeather page, a special page was developed to display data coming from seven of WSDOT's ferry boats. Wind and air temperature sensors aboard the vessels are used in conjunction with GPS equipment to determine "true" wind speed. The speed of the ferry is subtracted from the apparent wind, as measured on the moving ferries to get the correct value. The UW team developed a Web page to display the data at the point collected as the vessels move across Puget Sound. A toggle selects wind or temperature data to be displayed. The original Ferry Weather page developed at the UW remains in use today.

Road Surface Data

Road surface temperatures are plotted on a third Web page. Surface temperatures are displayed across a state map. State highways on the map are color coded on the basis of the actual surface temperatures calculated with algorithms developed by the UW. Red coding indicates temperatures below freezing, yellow from 33°F to 37°F, and green above 37°F.

Road surface temperatures are also displayed for a few major routes. These are shown in cross-section and use the same color coding as the statewide Web page. In addition to current conditions, these "route" displays offer predicted pavement temperatures over 6-hour intervals over a 24-hour forecast period.

National Weather Service Forecasts

National Weather Service (NWS) forecasts are presented on yet another Web page. Moving the mouse across the state highlights the NWS forecast zones within Washington State. Clicking on one of the zones brings up the NWS forecast, which is augmented by weather symbols inserted by WSDOT.

ARROWS

ARROWS is the primary product that has been produced at the UW since the first efforts. ARROWS was developed specifically to support WSDOT's snow and ice control efforts. ARROWS provides statewide and zoomable map views that indicate precipitation, temperature, and wind forecasts across the state in 4-hour increments over a 24-hour forecast window. ARROWS also provides point forecasts for precipitation, air temperature, and pavement temperature for all state routes.

ARROWS forecasts, based on a 12-kilometer grid, have changed from a single numerical (computer-based) forecast to an ensemble forecast, that is, a forecast based on several separate numerical forecasts (ensemble members), which in turn may be based on different initial conditions or use different atmospheric physics. The ensemble members are compared, and agreement from most of them indicates a higher probability of an accurate forecast. Efforts continue to improve the quality of the forecasts.

The reader is referred to the ARROWS evaluation (Boselly and Senn 2002) for a detailed description of ARROWS implementation.

Continued Efforts

In addition to ARROWS, the UW has continued to maintain and supply WSDOT with weather data and has maintained a few of the Web pages. Recently, UW

Atmospheric Sciences developed a scheme to put quality flags on all the weather station data that it collects. Output from the system is being fed back into WSDOT's weather station maintenance to improve data quality.

RWIS PROJECT PRODUCTS

The RWIS project has resulted in many specific products, either through deployment or through research and development.   The products listed below maximize the value of the installed sensor station network and improve the quality and availability of weather and forecast weather information.

The following products were produced through this project:

- A fully deployed and integrated ESS and server network

- Access to the ESS network by all WSDOT employees

- A weather website that displays ESS and other weather station data for both the traveling public and WSDOT employees

- A weather forecast Web page that links to the National Weather Service zone forecasts

- A Ferry Weather Web page the shows winds and temperatures across Puget Sound

- A statewide pavement temperature Web page

- Specific route web pages showing current and forecast pavement temperatures

- The ARROWS weather forecasting Web page for WSDOT maintenance and construction use that supports winter snow and ice control, and paving and pesticide applications in summer

- Training for ESS maintenance technicians

- Training for maintenance and engineering personnel to help them interpret and maximize the value of the weather information for improving transportation operations.

RWIS PROJECT REPORTS TO DATE

This project has taken place over several years and at different times has generated a number of products. As a result, separate evaluation reports of the various project components covered the objectives addressed in specific efforts within the reporting time frame. The objective of this section is to list all the reports to date.

The following reports have been generated regarding various aspects of the project:

Boon, C.B., and Cluett, C., 2002. *Road Weather Information Systems: Enabling Proactive Maintenance Practices in Washington State*. WA-RD 529.1

Mass, C., and Steed, S., April 2005. *A Next Generation Land Surface Model for the Prediction of Pavement Temperature.* AN: 00942628

Boselly, E., and Senn, L., February 2002. *ARROWS Evaluation*. WARD 608.1

In addition, several rWeather newsletters were published. The newsletter reported on RWIS developments in Washington state, as well as on other RWIS news around the country. The latest rWeather newsletter is available on-line at:

http://www.wsdot.wa.gov/biz/atb/pdfs/rWeather_fall2004.pdf

WSDOT WEATHER ON THE WEB

Reports cannot describe the WSDOT public website as well as a simple visit to the site. All the public pages can be accessed through WSDOT's traffic and weather Web page at http://www.wsdot.wa.gov/traffic/ .

Specific Web pages and their locations are as follows:

∙   ESS and Weather data:

http://www.wsdot.wa.gov/traffic/weather/

∙   National Weather Service Forecasts:

http://www.wsdot.wa.gov/traffic/forecast/

∙   Statewide current pavement temperatures:

http://www.wsdot.wa.gov/traffic/RoadTemps/

∙   NexRad Doppler Radar composite:

http://www.wsdot.wa.gov/traffic/forecast/radar.aspx

∙   Link to NOAA Satellite photos:

http://www.wsdot.wa.gov/traffic/forecast/satellite.aspx

∙   Link to Highway Advisory Radio Broadcast (I-90 Snoqualmie Pass):

http://www.wsdot.wa.gov/traffic/passes/radio.aspx

∙   Ferry Weather:

http://www.atmos.washington.edu/maciver/Ferry/Ferryjs/mainframe1.htm

In addition, several links to other sites are included to aid the traveling public in obtaining traffic and weather information and to provide background information.

ARROWS is not currently a public website. Navigation through the ARROWs site is based on WSDOT's organization codes, as requested by WSDOT maintenance at

the start of the project. This makes it difficult for the uninitiated to navigate. It is hoped

that ARROWS can provide data to other public agencies across Washington State in the

future.

APPENDIX A

Road and Weather Information Systems Projects
Funded Through the Traffic Operations –Capital Program

FUNDING HISTORY

99-01 Biennium

Federal FY 1999 – ITS Earmark for Statewide Road and Weather Information System. $1,253,000 federal funds and $315,000 state matching funds.

Additional state matching funds = $150,000

01-03 Biennium

Additional work on Statewide Road and Weather Information System

$978,000 state matching funds

$150,000 federal Target Zero safety funds

03-05 Biennium

Federal FY 2004 – ITS Earmark for Statewide Road and Weather Information System Expansion

$250,000 federal funds and $250,000 state matching funds.

Total of all funds = $3,346,000

Federal = $1.653,000

State = $1,693,000

RESULTS RECEIVED FROM INVESTMENT MADE

The initial project funded the following:

- Installation of 12 new environmental sensor stations (ESS), at least one in each WSDOT region. These stations collect data on atmospheric and roadway conditions such as wind speed, air temperature, road temperature, and precipitation.

- Consolidation of pre-existing ESS, which had independently reported only to local maintenance offices, into a single Road Weather Information System that enables access to all sites from any WSDOT office with access to the WSDOT intranet.

- Upgrade of servers at the University of Washington Department of Atmospheric Sciences to enable its weather model to provide more frequent and more detailed weather forecasts.

- Integration of the data from WSDOT's ESS into a database, maintained at the UW, that combines the weather data from almost 400 (now over 700) stations operated by agencies around the state.

- Construction of a Web page to display the data from these weather stations, thereby giving WSDOT maintenance personnel access to this weather information from office or home, around the clock, via the Internet. The Web page also provides this information to the public to aid in travel planning.

- Development of a road surface temperature model to display current and predicted road surface temperatures so that WSDOT Maintenance and the public will be warned of potential problems with road conditions. Because it is not possible to observe the road conditions on all 7,000 miles of state

highway in real time, it was decided to rely on modeling to predict surface temperatures, which can give the best indication of what conditions are like.

- Construction of a Web page to display road surface temperature information as well as "corridor views" that integrate all available road condition information and roadside camera views into one Web page for the major travel corridors in the state.

- Development of the Condition Acquisition Reporting System (CARS) website, which allows statewide accidents, road conditions, and construction or maintenance closures to be displayed on a Web page. This system also supports the 511 travel information phone line.

The 20001-2003 Biennium Project funded the following:

- Installation of four additional ESS and hardware, including additional cameras and sensors, and upgrade of software in both the field and server systems.

- Support for two project FTEs from WSDOT's Office of Information Technology for development work on the website for one year. (The weather related websites were originally developed at the UW, and further work was needed for WSDOT to be able to support them in-house.)

- Development of ARROWS, which is a web-based system that provides information that is specifically tailored to WSDOT winter maintenance managers to assist with keeping highways safe and passable during the winter. The information is organized by WSDOT maintenance areas. Forecasts are

provided in 4-hour increments.   Warnings of localized snow, frost, fog, or other weather conditions that will adversely affect highways are provided. ARROWS is designed to give maintenance managers a way to anticipate when freezing pavement or air temperatures will occur, when snow or rain is likely to occur, when to expect a transition between rain and snow, and if frost is likely to occur. This information is critical if WSDOT is to successfully use proactive methods of snow and ice control, such as anti-icing treatments. An evaluation after its first season indicated that field personnel generally like ARROWS, but more development work is needed.

The 2003-2005 Biennium Project funded the following:

- The installation of six additional Road and Weather Information System stations around the state.   Along with other sites being installed by WSDOT, approximately 90 of the planned 130 stations will be installed.

- Further development work on ARROWS to respond to the improvements requested in the evaluation conducted after the first winter of operation.

FULL-TIME EMPLOYEES

All FTEs associated with this work have been project FTEs. Work has been done by FTEs at the University of Washington Department of Atmospheric Sciences, WSDOT's Office of Information Technology, and WSDOT's Advanced Technology Branch (project management).

At one time, the project proposed to hire a meteorologist to provide training to maintenance workers in basic weather terminology and interpretation of the information

provided by various weather websites and forecasting services. In addition, the position would evaluate the accuracy and usefulness of the information that ARROWS was providing to Maintenance. The position would help improve the application by working as a liaison between maintenance managers and the UW system developers. This position was never filled.