DEVELOPMENT OF A WINTER MAINTENANCE DECISION SUPPORT SYSTEM

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Summary

Maintenance of the Québec road network remains a major challenge for all operational personnel. In the early 2000s, given the difficulties presented by decision-making and the growing need to improve management of winter maintenance operations, the Ministère des Transports initiated a pilot project to develop a winter maintenance decision support system adapted to the specific needs of its operational personnel.

This decision support system was intended to give the personnel concerned continuous access to quality road weather information during the winter period.

To concretize this decision support system, a data acquisition system was created. This data acquisition system allows collection of data from weather and road sensors.

In addition, a website (the DVH-6024 system) was created to allow rapid dissemination of the road weather information collected. The information accessible via this website concerns both weather forecasts and weather and road observations. The system also allows extraction, processing and use of the data collecting in the past through the road weather station network. This last functionality allows users to perform post-event analyses, which can be very useful to validate the effectiveness of the treatments applied.

The DVH-6024 system is a sophisticated road weather data acquisition and processing tool. It allows complete and rapid analysis of all the road weather data necessary for winter maintenance decisions.

The Québec road network is spread over a vast and extensive territory, offering major topographic and hydrographic diversity, which causes considerable climatic and road variations. Obviously, these variations are more perceptible in winter. Road users thus are confronted with extremely varied weather events when they drive on the road network. These variations, sometimes local, have major impacts on winter maintenance operations.

Québec road network managers thus must deal with extremely variable local climate conditions, adding enormously to the complexity of decisions leading to activation and dimensioning of winter maintenance operations. Road users' growing expectations, the tightening of the financial framework in which they operate and management of human resources are all factors that make the decisions of road network managers more complex.

Constant pressure is therefore exerted on these managers who, until very recently, had little technological support to justify activating winter maintenance operations.

It was in this perspective that, in February 2000, the Ministère des Transports du Québec authorized the SADVH pilot project *(Système d'aide aux décisions en viabilité hivernale* – Winter maintenance decision support system*).*

The SADVH pilot project was initiated at the beginning of 2000. The goal of this project was to define the Québec winter maintenance decision support system and determine the accompanying measures necessary to implement this system in Québec.

EVALUATION OF NEEDS

This project thus was initiated by a complete review of the Québec situation, including identification of the problems and needs of operational personnel. This study was initially conducted with the personnel directly affected by winter maintenance operations and then with road network managers. It allowed identification of the close interrelationship between the road field and the science of meteorology, and the communication and comprehension problems of the leading players in these two disciplines.

This finding had major impacts on the level of winter maintenance, because this task did not only consist of spreading de-icing agents on the pavement. To a much greater degree, it involved recognizing and, ideally, even anticipating in the phenomena necessitating an intervention on the pavement and the factors which can limit or cancel out the action of de-icing agents, in order to optimize their use.

Major problems thus were revealed and, in particular, concerned the acquisition, treatment, validation and communication of data useful to the dimensioning of winter maintenance operations. The following problems were identified:

- flagrant lack of instrumentation in the road environment;
- lack of knowledge of the phenomena involved;
- several sources of weather information;
- lack of confidence in weather forecasts;
- decision-making based on erroneous data;
- lack of knowledge of how de-icing agents work and their limits of action.

Considering the importance of the problems raised, an enormous task was in store for the SADVH project's principal stakeholders.

To mitigate the principal problems identified, the Ministère des Transports du Québec initiated the design and development of a winter maintenance decision support system.

WINTER MAINTENANCE DECISION SUPPORT SYSTEM

The Québec winter maintenance decision support system was designed to meet the primary needs of the winter maintenance decision-makers of the Ministère des Transports. Following an evaluation of the needs, the engineers responsible for this project concluded that some of these needs could be met by the development of an information technology solution supported by a road weather data acquisition system.

To be effective, the proposed IT solution thus should meet two primary needs, in this instance the complete management of road weather forecasting data and management of road weather observation data.

To gather road weather information, a data acquisition system and an innovative road weather station concept were created. These two systems were designed according to an open architecture making it possible to gather both weather and road information.

DATA ACQUISITION SYSTEM

Through the specialized data acquisition system, all of the data collected from the different road weather stations are stored in real time in an SQL relationship database.

(Figure 1 - Data acquisition system)

Environment Canada FTP Server	Internet	Environment FTP Server	
LoggerNet 1.2a	LoggerNet Socket Data Export 1.2a	J2EE Web server and application	SQL databases
Ground Modem Weather station	Service Centre Modem NL-100 terminal server	MTQ network DGMO SQL server	Pavement Laboratory FTP server

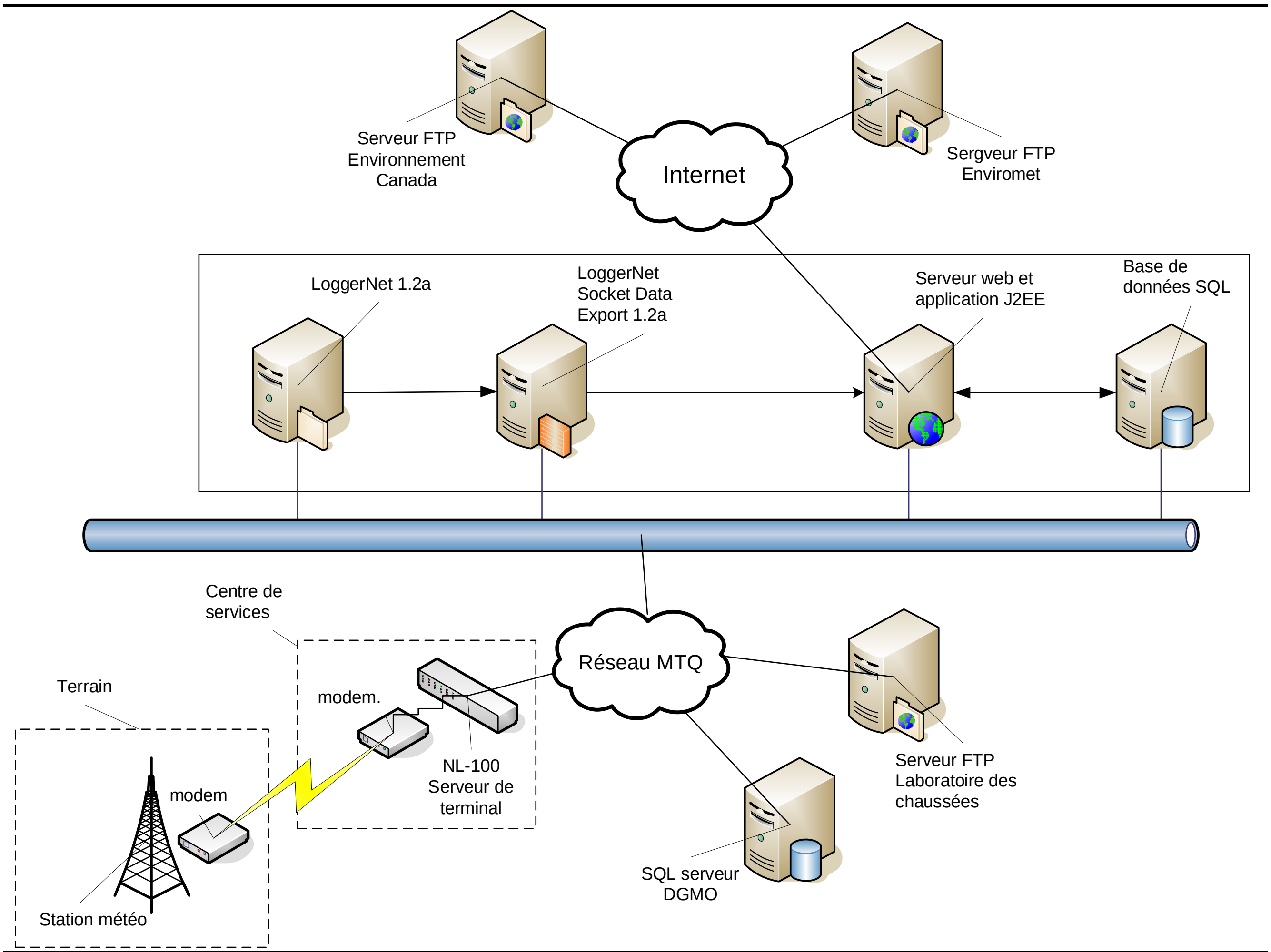


Figure 1-
Data acquisition system

The system can store data from any type of weather or road sensor, without any database programming.

The data collected by a sensor are saved in the weather station's memory in the same way as in a spreadsheet table, in which each line of the table corresponds to a new record every 10 minutes and where each column corresponds to a different variable measured or calculated for this sensor. The database, for each measurement, stores the time stamp, the table name, the column name and the value measured.

For the different viewing applications, a table of the published elements matches the variable to be displayed, such as the air temperature, with the origin of the data in the database. Thus, if a sensor fails, the air temperature display variable can be assigned quickly to another sensor by editing the table of published elements if, of course, the weather station has another sensor measuring the air temperature.

STATIONARY ROAD WEATHER STATIONS (OBSERVATION DATA)

In the winter maintenance context, these devices serve as "electronic sentinels". They not only are the more sophisticated decision-making tool, but also the principal reliable source of weather and road information.

They thus represent the basic element of a winter maintenance decision support system. The implementation and especially the importance of the deployment of this equipment represent a challenge. How sophisticated should the system be and how many stations should be deployed? The MTQ has favoured an approach in which the decision-makers themselves define the nature, number and location of these stations.

The deployment of road weather equipment has been oriented according to a precise implementation plan based on the real needs of the local authorities. According to this plan, the territory managed by the Ministère des Transports du Québec is divided into 90 homogeneous climate zones, each of which must be assigned a road weather station *(Federal Highway Administration FHWA-HOP-05-026)*.

Such a division of the province makes it possible both to limit and improve the targeting of the needs for implementation of stationary road weather stations. The division into homogeneous climate zones was accomplished in collaboration with Environment Canada meteorologists, accounting for the observations of the MTQ's operational personnel, who have a detailed knowledge of the territory under their responsibility. Figure 2 shows the geoclimatic division as produced.

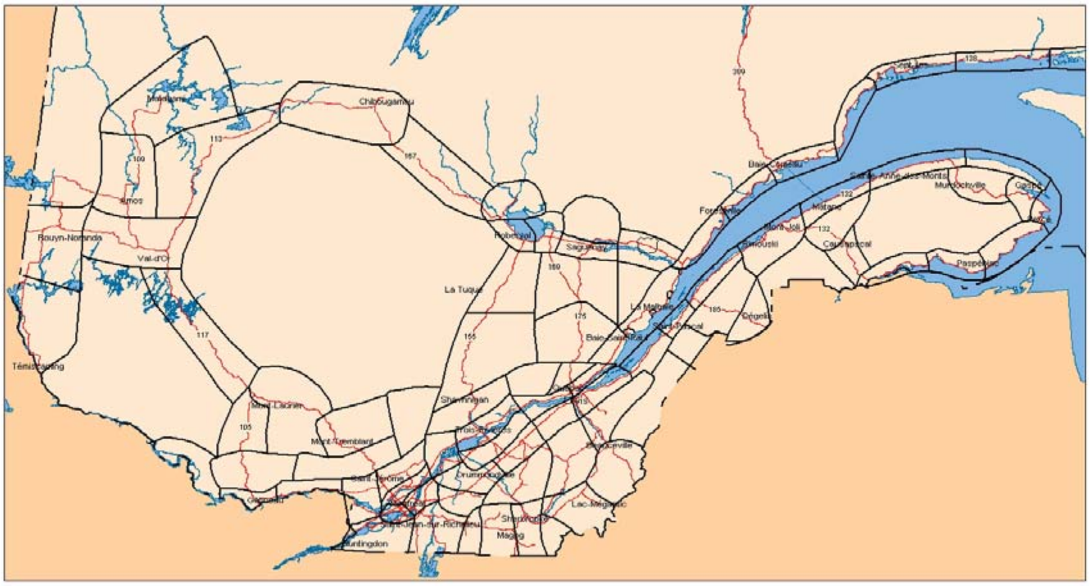


Figure 2
Geoclimatic division of Quebec's territory

A projected total of 90 stationary road weather stations should allow coverage of all of Québec.

These road weather stations were designed by the Ministère des Transports for its specific needs based on an open architecture, which allows addition or removal of a sensor according to the requirements of the operational personnel or to meet research and development needs. This architecture offers the MTQ the full latitude it requires and assures that it will not be the captive of a single weather or road equipment manufacturer. Currently, the Ministère des Transports du Québec has 21 road weather stations and plans to add 15 more over the next two years.

In general, these stations are equipped with devices that allow collection of all the necessary information to identify and measure the weather and road parameters. These parameters are essential when the road network manager wants to identify and dimension the type of treatment required. These two types of information *(road parameters and weather parameters)* are very revealing for the personnel assigned to road maintenance. It is first important to be able to differentiate the road parameters and weather parameters so that the importance of these data on operational efficiency is clearly understood.

Weather parameters are those that particularly concern the atmosphere and that generally influence the road environment, in this instance:

- air temperature;
- dew point temperature;
- relative humidity;
- atmospheric pressure;
- wind speed and direction;
- presence of precipitation and type of precipitation.

These parameters make it possible to anticipate short and medium-term weather changes.

Road parameters more specifically concern the road environment, and thus the pavement. They make it possible to identify and quantity the importance of weather events which can have an impact on winter pavement conditions.

These parameters are as follows:

- pavement surface temperature;
- pavement surface condition;
- freezing temperature of residual brine on the pavement;
- foundation temperature;
- paved surface albedo;
- vehicle traffic flow.

Given the importance of these data in the decision process leading to dimensioning of operations, it became essential to invest considerable efforts in the development and deployment of instrumentation, allowing precise measurement of these parameters.

WEATHER FORECASTING DATA

Given the importance of weather forecasting data in the decision process leading to dimensioning and activation of winter maintenance operations, the MTQ's representatives decided to control the quality of this information. Within this perspective, only one source of information has been identified and officialized as the provider of this type of service for Québec as a whole. Moreover, constant efforts are invested in evaluating the quality of the data, with the aim of improving the quality of the product throughout the territory, in partnership with the private service provider.

Three weather forecasts are sent to the MTQ by the private service provider very day. These three forecasts, which are transmitted at fixed times – 6 a.m., 3 p.m. and 9 p.m. – are produced for specific forecasting points. In Québec, more than 70 forecasting points are routed to the MTQ’s operational personnel each day. In each of these three periods of the day, the MTQ’s operational personnel are fed with weather forecasting data for the short term (0 to 12 hours), the medium term (12 to 48 hours) and the long term (48 to 120 hours). These weather forecasts present the parameters which have an influence on road conditions and operational efficiency.

UTILIZATION OF DATA

A data utilization system has been created (DVH-6024 system) to allow quick and efficient utilization of all of the data which have an impact on the variation of winter road conditions.

Thus, users can have quick access to the weather forecast data and the observation data from the stations that particularly concern their region. Also, users can have access to the data from regions near the region under their management, allowing them to anticipate difficult climate events.

Figure 3 presents the host environment of the DVH-6024 system.

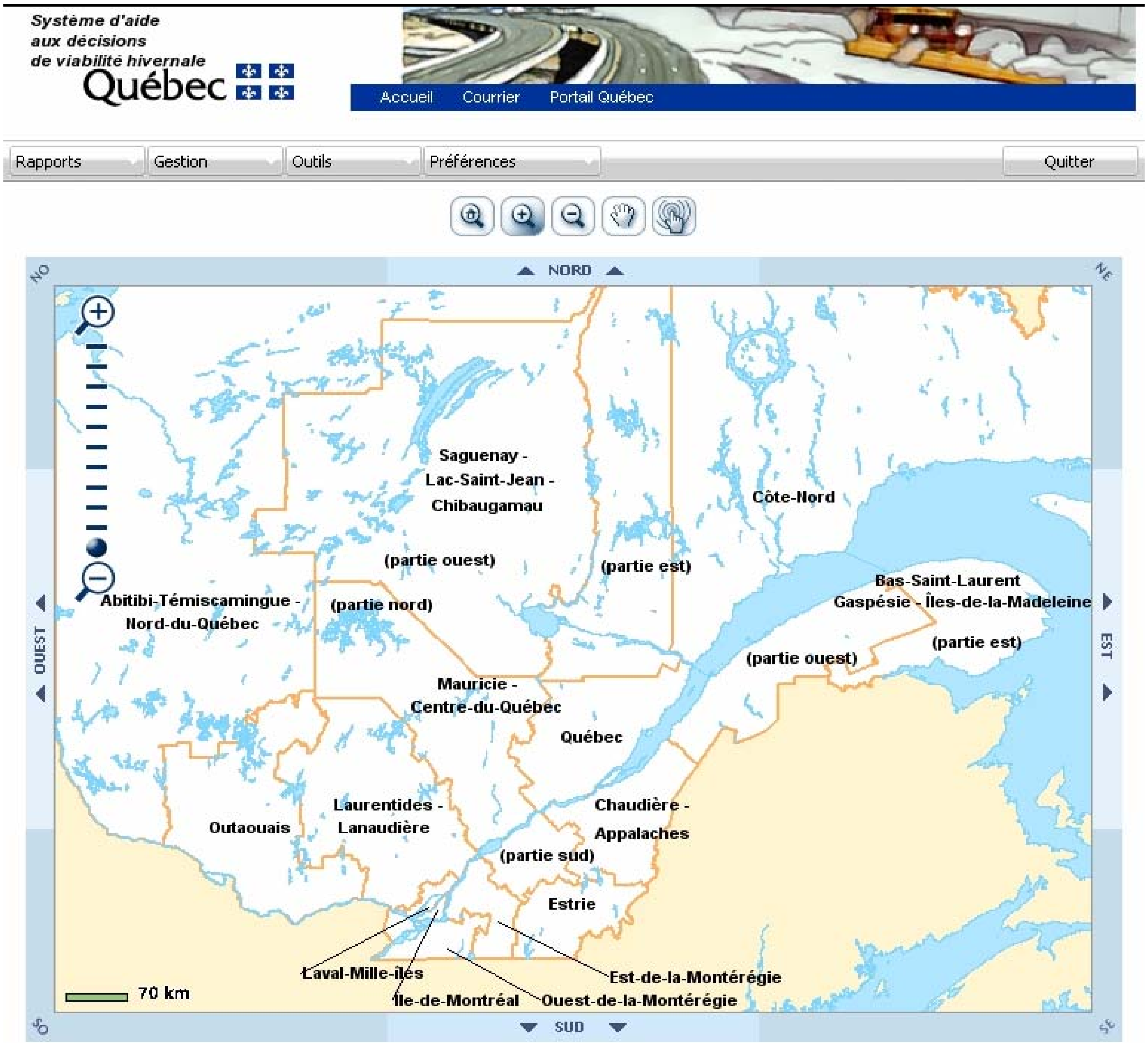


Figure 3
Host environment of the DVH-6024 system.

After selecting a specific region, the user has the possibility of consulting the forecast data only or simultaneously consulting the observation and forecast data at the road weather stations.

In Figure 4, the red circles represent the locations where the MTQ has weather forecasting points and the red stars represent the road weather stations.

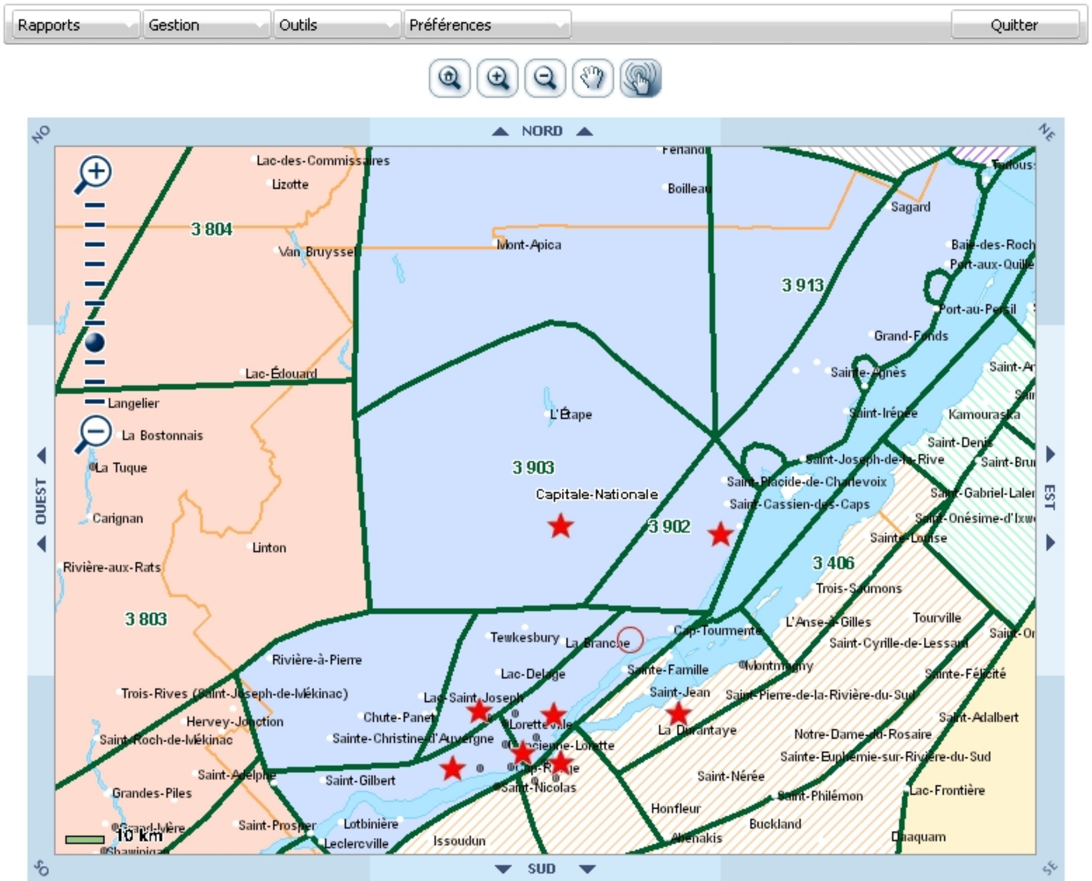


Figure 4
Visualization of a territorial division

Certain data play a more crucial role in winter maintenance and are followed more closely both in forecasting and in observation. These data are: *air temperature, dew point temperature, pavement surface temperature, foundation temperature, relative humidity, wind intensity and direction, and precipitation type and intensity.*

Some parameters will have a direct effect on the road environment. This is the case for air temperature, dew point temperature and pavement surface temperature. The interaction between the air and pavement surface temperatures and the dew point temperature conditions the formation of condensation in the air or on the pavement. This condensation can occur in liquid or solid form. Figure 5 presents a summary of the situations that may arise, depending on the variations of these three temperatures.

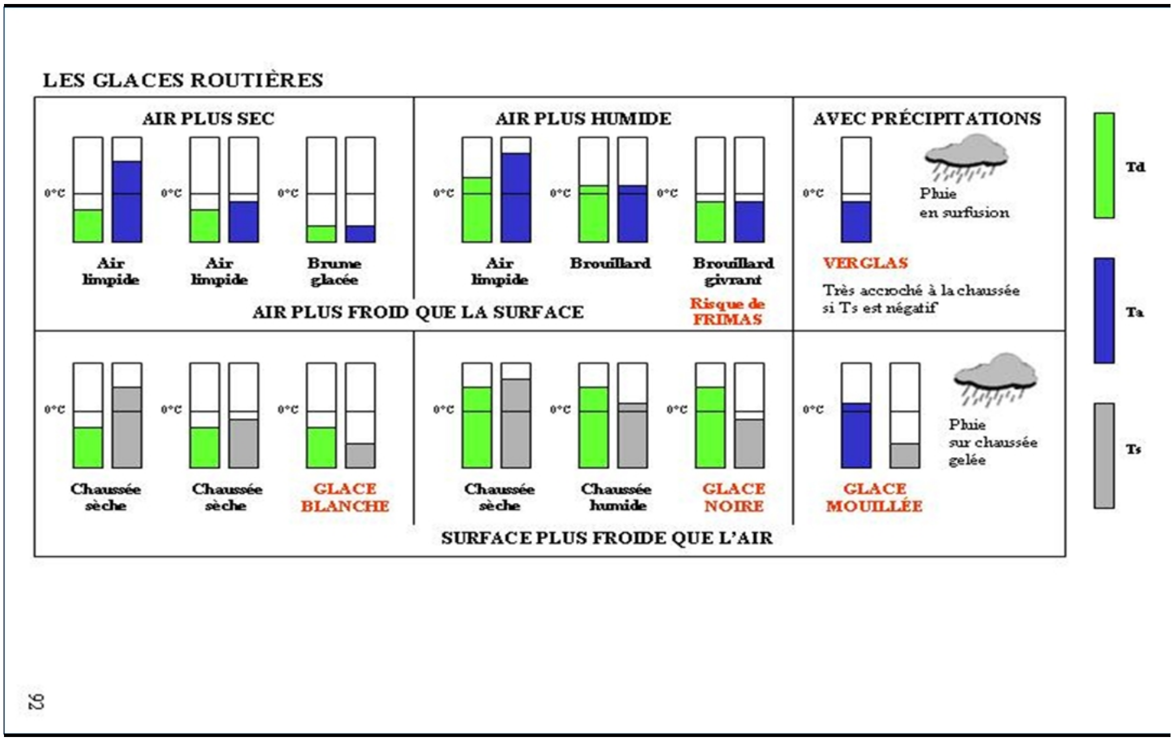


Figure 5
Road ice formation

ROAD ICE

DRIER AIR			MOISTER AIR			WITH PRECIPITATION	
Clear air	Clear air	Icy mist	Clear air	Fog	Freezing fog	FREEZING RAIN	Supercooled rain
AIR COLDER THAN THE SURFACE					Risk of FROST	Sticks to the pavement if Ts is negative	
Dry pavement	Dry pavement	WHITE ICE	Dry pavement	Wet pavement	BLACK ICE	WET ICE	Rain on frozen pavement
SURFACE COLDER THAN THE AIR							

The road network manager, based on reliable measurements of the air temperature, the pavement surface temperature and the dew point temperature, can quickly identify the formation of certain types of road ice *(white ice, black ice, wet ice, frost and freezing rain)*.

The road weather stations thus make it possible to identify and even anticipate situations which can lead to deterioration of road conditions. Quick identification of certain phenomena allows more effective intervention on the road network.

Figure 6 makes it possible to verify the accuracy of the theory. Indeed, when the dew point temperature (represented by the green curve) falls below the pavement surface temperature (represented by the black curve), then white ice forms on the pavement. At that time, without any precipitation having fallen, the surface condition changes from dry to icy.

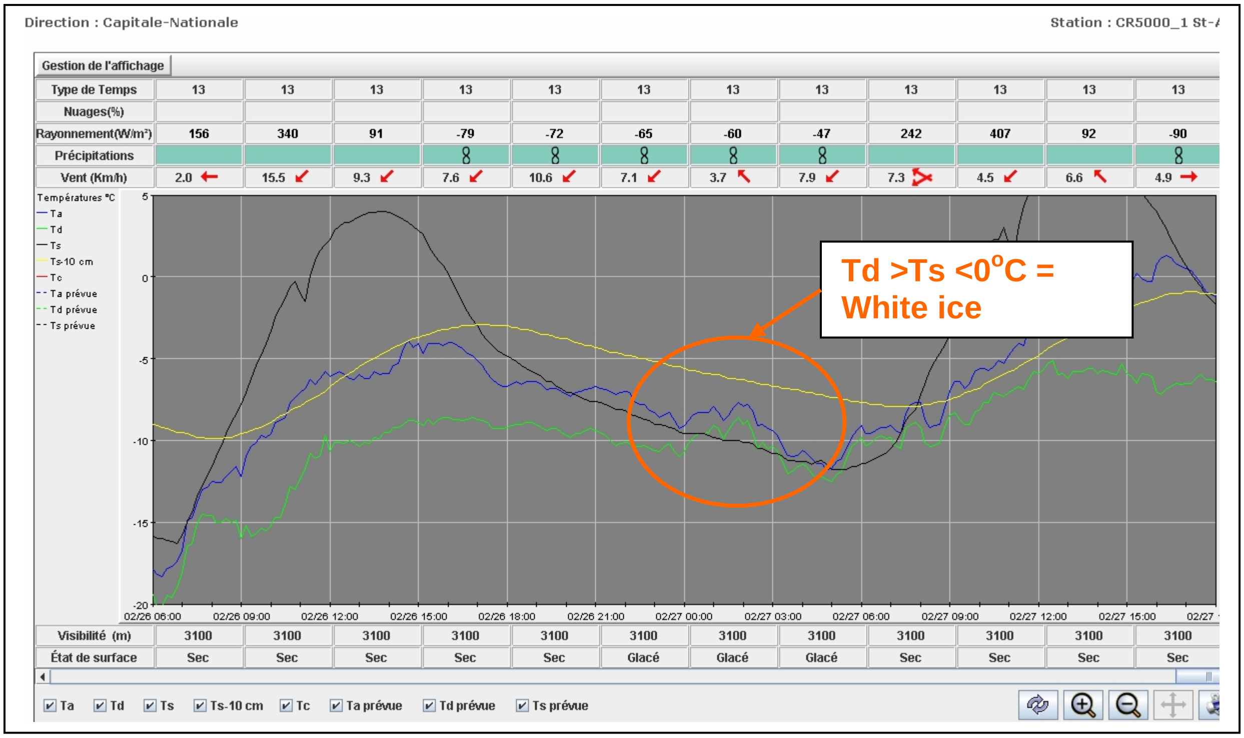


Figure 6
Decision support graph of the DVH-6024 illustrating white ice formation.

Rigorous monitoring of these parameters is thus essential throughout the winter season. Specialized tools have therefore been designed to facilitate monitoring of these parameters at several locations in the same territory.

Figures 7 and 8 represent functionalities which allow the users to have simultaneous access to complete information throughout the territory under the user's management. It is important to note that these two ways of viewing the information allow access to the parameters that influence winter maintenance operations.

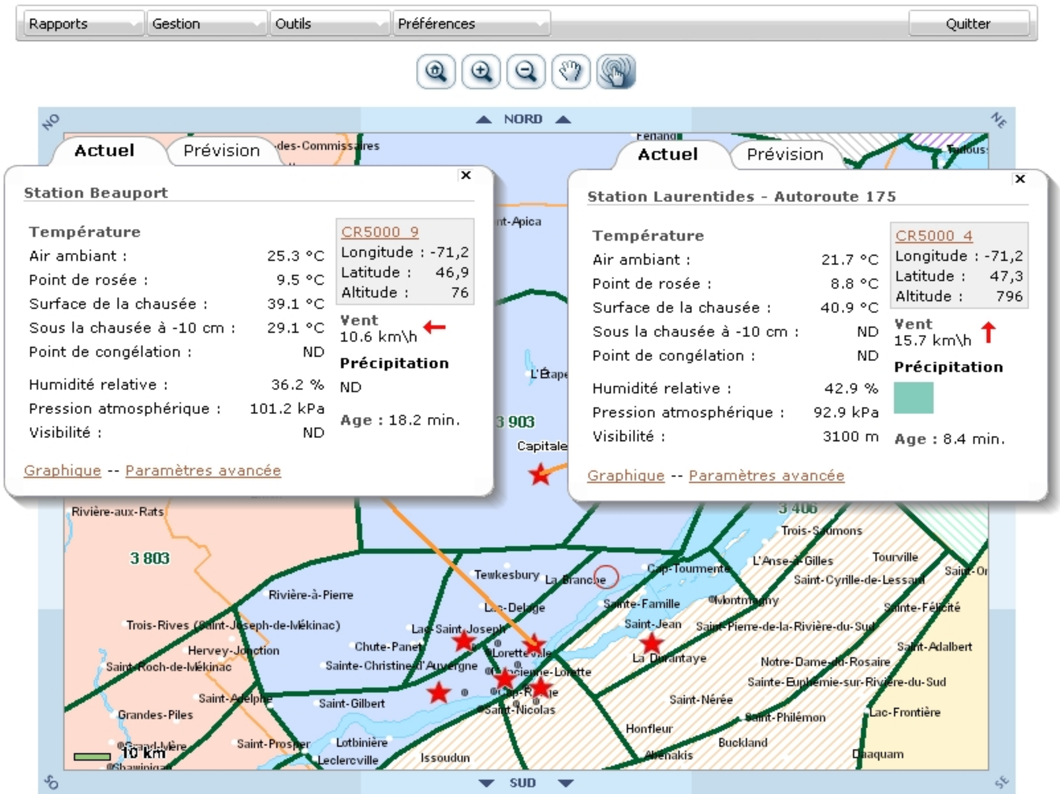
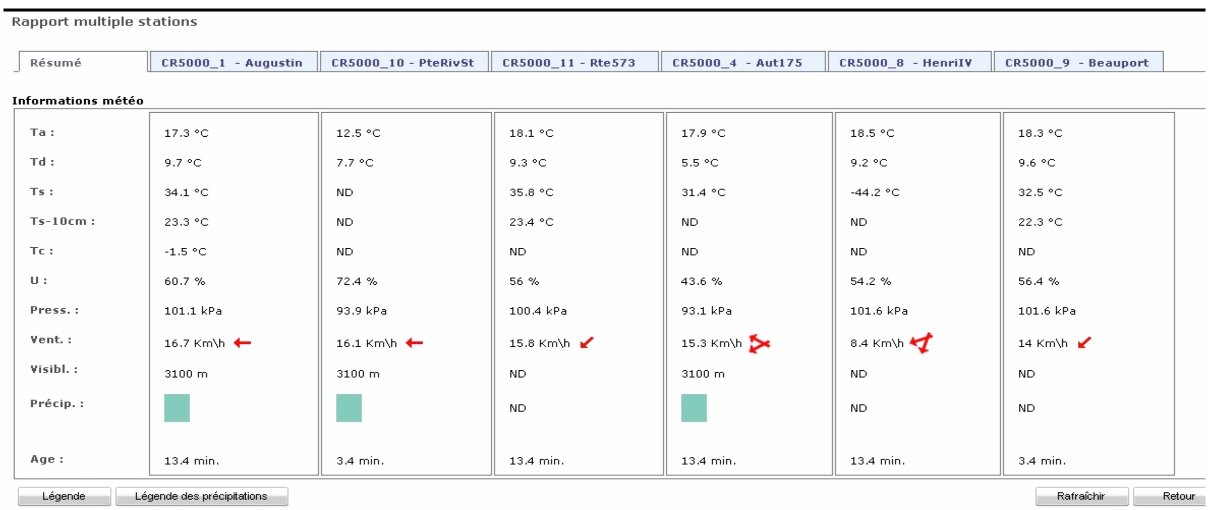


Figure 7
Functionality of the DVH-6024 system allowing consultation of the latest data collected by the road weather stations.



Rapport multiple stations

Résumé | CR5000_1 - Augustin | CR5000_10 - PteRivSt | CR5000_11 - Rte573 | CR5000_4 - Aut175 | CR5000_8 - HenriIV | CR5000_9 - Beauport

Informations météo

	CR5000_1 - Augustin	CR5000_10 - PteRivSt	CR5000_11 - Rte573	CR5000_4 - Aut175	CR5000_8 - HenriIV	CR5000_9 - Beauport
Ta :	17.3 °C	12.5 °C	18.1 °C	17.9 °C	18.5 °C	18.3 °C
Td :	9.7 °C	7.7 °C	9.3 °C	5.5 °C	9.2 °C	9.6 °C
Ts :	34.1 °C	ND	35.8 °C	31.4 °C	-44.2 °C	32.5 °C
Ts-10cm :	23.3 °C	ND	23.4 °C	ND	ND	22.3 °C
Tc :	-1.5 °C	ND	ND	ND	ND	ND
U :	60.7 %	72.4 %	56 %	43.6 %	54.2 %	56.4 %
Press. :	101.1 kPa	93.9 kPa	100.4 kPa	93.1 kPa	101.6 kPa	101.6 kPa
Vent. :	16.7 Km\h	16.1 Km\h	15.8 Km\h	15.3 Km\h	8.4 Km\h	14 Km\h
Visibl. :	3100 m	3100 m	ND	3100 m	ND	ND
Précip. :			ND		ND	ND
Age :	13.4 min.	3.4 min.	13.4 min.	13.4 min.	13.4 min.	3.4 min.

Légende | Légende des précipitations | Rafraîchir | Retour

Figure 8
Functionality of the DVH-6024 system allowing simultaneous consultation of the latest data collected by several road weather stations.

To facilitate simultaneous utilization of observation and forecast data, the decision support interface has been adjusted. As illustrated in Figure 9, the user has the possibility of viewing both the road weather station observations *(on the left of the screen)* and the weather forecasts *(on the right of the screen)*. Such a representation allows better anticipation of the weather situation.

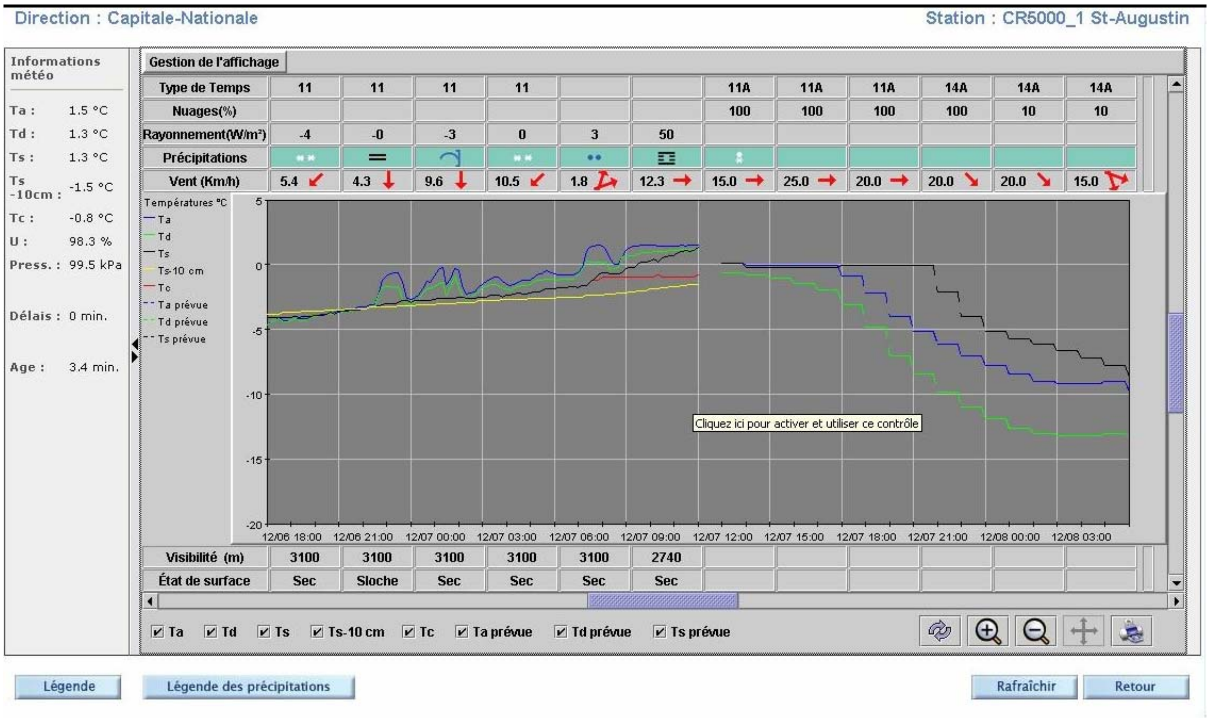


Figure 9
Consultation of the observation and forecast data on the decision support screen

The system also allows post-event analyses. In fact, the observation data are stored in an Oracle database, which allows them to be consulted at any time after a specific event. Intensive sodium chloride spreading is also identifiable on such an interface. Figure 10 allows the user to visualize spreading of de-icing agent on the pavement.

This de-icing operation can be identified by the sudden variation in roadway surface temperature. This functionality allows the users to validate the different parameters following an operation with an unsatisfactory result, out of a concern for continuous improvement of the quality of interventions.

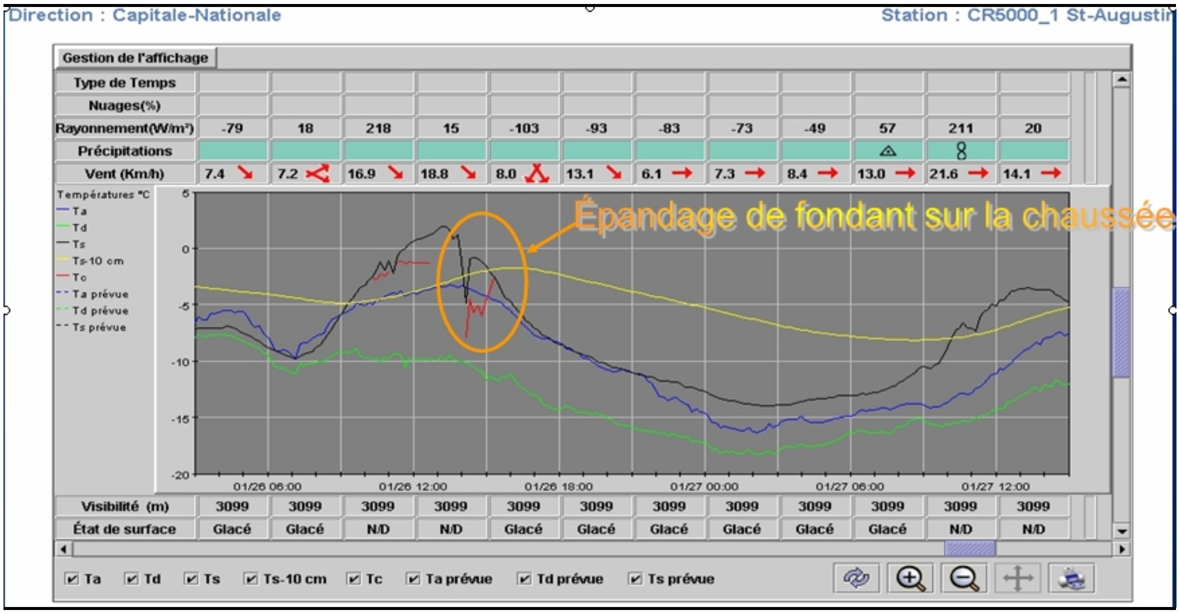


Figure 10
Consultation of data after an event

By way of conclusion, it is important to specify that the quality of winter maintenance operations is closely linked to the quality of the data used to support decision-making leading to dimensioning of these operations. Consequently, the Ministère des Transports has invested and continues to invest considerable efforts in the collection, analysis, processing and use of the data most meaningful to winter maintenance.

In this perspective, the SADVH project made it possible to change the perception of several industry workers and thus integrate the use of data essential to winter maintenance – the pavement surface temperature. This project and the work that followed it made it possible to relate several types of road and weather data and to make connections between these data and the weather phenomena observed.

Following this project, the employees of the Ministère des Transports du Québec remain convinced that optimization of winter maintenance operations depends on integration of road weather data into the decision-making process.