CHAPTER 12

ROAD METEOROLOGICAL MEASUREMENTS

12.1 GENERAL

12.1.1 Definition

Road meteorological measurements are of particular value in countries where the serviceability of the transport infrastructure in winter exerts a great influence on the national economy. In some countries there will be other road hazards such as dust storms or volcanic eruptions. Safe and efficient road transport is adversely affected by the following conditions which affect speed, following distance, tyre adhesion and braking efficiency: poor visibility (heavy precipitation, fog, smoke, sand storm), high winds, surface flooding, land subsidence, snow, freezing precipitation and ice.

12.1.2 Purpose

The role of a road network manager is to ensure the optimal, safe, free flow of traffic on arterial routes. Operational decisions on the issuing of road weather information and on initiating de-icing and snow clearing operations are dependent on road meteorological observations that are increasingly made by special-purpose automatic weather stations (AWSs). While these stations should conform as far as practicable to the sensor exposure and measurement standards of conventional AWSs (see Part II, Chapter 1) they will have characteristics specific to their function, location and measurement requirements.

The reliability of road meteorological measurement stations which supply data to a transport decision support system is critical: Each station will relate to the immediate environment of important high-density transport routes and may be responsible for feeding data to road meteorology forecast routines and for generating automatic alarms. Thus, equipment reliability and maintenance, power supply, communications continuity and data integrity are all important elements in the selection, implementation and management of the weather measurement network. These concerns point to the benefits of an effective collaboration between road management services and the National Meteorological and Hydrological Service (NMHS).

12.1.3 Road meteorological requirements

This chapter should assist in standardizing road meteorological measurements with a method that adheres to WMO common standards as closely as possible. However, those users who may wish to employ road measurements in other meteorological applications will be advised of important deviations, in sensor exposure, for example.

The needs of road network managers focus in four main areas (WMO 1997; 2003*a*):

(a) *Real-time observation of road meteorology*: The practical objective, on the one hand, is to inform road users of the risks (forecast or real-time) that they are likely to face on designated routes; and on the other hand, to launch a series of actions aimed at increasing road safety, such as scraping snow or spreading chemical melting agents;

(b) *Improvement of pavement surface temperature forecasting*: The measurements of road AWSs are the important input data for the temperature and pavement condition forecasting programmes which may be run by the NMHS. This authority has the capability of ensuring continuity and timeliness in the observations and in the forecast service. In practice, two tools are available to forecasters. The first tool is a computer model for the transposition of a weather forecast of atmospheric conditions to a pavement surface temperature forecast, taking account of the physical characteristics of each station. The second tool is the application of an algorithm based on a specific climatological study of the pavement surface;

(c) *Road climate database*: The establishment of a road climatological database is important because in many situations an assessment of current events at a well-instrumented location enables experienced road network managers to transpose the data using the climate model to other locations they know well. In some cases, thermal fingerprints can be taken in order to model this spatial relationship. The recording of road weather data will be useful for analysing previous winter disturbances and for carrying out specific road-dedicated climatology studies. National Meteorological and Hydrological Services can fill the data gaps and compare and provide quality assurance for measurements coming from different sources;

(d) *Reliable data*: Road managers do not need exceedingly accurate measurements (with the exception of road-surface temperature). Rather, they want the data to be as reliable as possible. That is to say the data must be a consistent reflection of the real situation, and the measuring devices must be robust. Communication and power supply continuity are often of prime importance.

12.2 ESTABLISHMENT OF A ROAD METEOROLOGICAL STATION

12.2.1 Standardized representative measurements

The general requirements for meteorological stations, their siting and the type and frequency of measurements are defined in WMO (1988; 2003*a*). It is recommended that these standards and other relevant material in this Guide should be adhered to closely when establishing road meteorological stations in order to make standardized, representative measurements that can be related to those from other road stations in the network and also to data from standard synoptic or climatological stations, except where the unique measurements for road meteorology demand other standards, for example, for the exposure of sensors. Advice on the optimum placement and density of stations may be obtained from the local branch office of the NHMS which will be able to access climatological data for the region.

A meteorological station site is chosen so that it will properly represent a particular geographic region. A road meteorological station will be sited to best represent part of the road network or a particular stretch of important roadway that is known to suffer from weather-related or other hazards. The station must therefore be adjacent to the roadway so that road-surface sensors may be installed, and therefore some compromise on "ideal" meteorological siting and exposure may occur. The sensors are installed so that their exposure enables the best representation in space and time of the variable being measured, without undue interference from secondary influences. In general, the immediate site adjacent to the roadway should be level, with short grass, and not shaded by buildings or trees.

12.2.2 Station metadata

In every case it is important that the location and characteristics of the site and the specification of equipment and sensors are fully documented, including site plans and photographs. These metadata (Part I, Chapter 1 and Part III, Chapter 1) are invaluable for the management of the station and for comparing the quality of the measurements with those from other sites.

12.3 OBSERVED VARIABLES

12.3.1 Road meteorological measurements

The important measurements at road weather stations for forecasting roadway conditions include air temperature and humidity, wind speed and direction, precipitation amount and type, visibility, global and long-wave radiation, road-surface temperature and road-surface condition. Some of the measurements, for example, temperature and humidity, will be used to forecast conditions of concern to road users, while others (wind and visibility) may indicate impending or real-time hazards; yet others (meteorological radiation, road-surface temperature and condition) are specific to predicting the performance of the road surface.

The sensors will be selected for their accuracy, stability, ease of maintenance and calibration, and for having electrical outputs suitable for connecting with the automatic data-acquisition system. The choice of sensors and their exposure should conform to standard WMO practice and recommendations (see the relevant chapters in Part I of this Guide), except when these are incompatible with the specific requirements of road meteorology. Measurement accuracy should generally conform to the performances quoted in Part I, Chapter 1, Annex 1B. Note also the recommendations on the measurements at AWSs in Part II, Chapter 1.

12.3.1.1 Air temperature

The sensor may be an electrical resistance thermometer (platinum or stable thermistor). The air-temperature sensor, its radiation shield or screen and exposure should conform to the guidelines of Part I, Chapter 2, with the shield mounted at a height of 1.25 to 2 m over short grass or natural soil.

Measurement issues: The sensor and screen should not be mounted above concrete or asphalt surfaces that could inflate the measured temperature. The placement of the shield should ensure that it is not subject to water spray from the wheels of passing traffic, which might cause significant sensing errors.

12.3.1.2 Relative humidity

The hygrometric sensor may be one of the thin-film electrical conductive or capacitive types (Part I, Chapter 4). A wet-bulb psychrometer is not recommended on account of the continual contamination of the wick by hydrocarbons. The sensor may be combined with or co-located with the air-temperature sensor in its radiation shield as long as the sensor thermal output (self-heating) is very low, so as not to influence the temperature measurement.

Measurement issues: Note the same water spray hazard as for the temperature sensor. Humidity-sensor performance is subject to the effects of contamination by atmospheric and vehicle pollution. Functional checks should be made regularly as part of the data-acquisition quality control, and calibration should be checked at least every six months, particularly before the winter season. A sensor that is not responding correctly must be replaced immediately.

12.3.1.3 Wind speed and direction

These variables are usually measured by either a pair of cup and vane sensors or by a propeller anemometer (Part I, Chapter 5) with pulse or frequency output. The sensors must be mounted at the standard height of 10 m above the ground surface and in a representative open area in order to carry out measurements not influenced by air-mass flow disturbances due to traffic and local obstacles.

Measurement issues: The freezing of moving parts, water ingress and corrosion and lightning strike are potential hazards.

12.3.1.4 Precipitation

(a) *Accumulated precipitation*: The tipping-bucket recording gauge (Part I, Chapter 6) where increments of usually 0.2 mm of precipitation are summed, is commonly used at automatic stations. Heated gauges may be employed to measure snow or other solid precipitation. A rate of precipitation may be estimated by registering the number of counts in a fixed time interval.

   Measurement issues: The gauge must be kept level and the funnel and buckets clean and free from obstruction. The tipping-bucket gauge is not satisfactory for indicating the onset of very light rain, or in prolonged periods of freezing weather. Totals will be lower than the true values because of wind effects around the gauge orifice, evaporation from the buckets between showers, and loss between tips of the buckets in heavy rain;

(b) *Precipitation occurrence and type*: Sensors are available which use electronic means (including heated grids, conductance and capacitance measurement) to estimate the character of precipitation (drizzle, rain or snow) falling on them. Optical sensors that determine the precipitation characteristic (size, density and motion of particles) by the scattering of a semiconductor laser beam offer better discrimination at much greater expense.

   Measurement issues: These sensing functions are highly desirable at all stations, but existing types of sensors are lacking in discrimination and stable reproducibility. Provisions must be made (heating cycles) to remove accumulated snow from the surface. The regular cleaning of sensitive elements and optical surfaces is required.

   Only sensors that are well documented and that can be calibrated against an appropriate reference should be installed. If any system uses an algorithm to derive a variable indirectly, the algorithm should also be documented.

12.3.1.5 Meteorological radiation

(a) *Global radiation*: The solar radiation (direct and diffuse) received from a solid angle of 2π sr on a horizontal surface should be measured by a pyranometer using thermoelectric or photoelectric sensing elements (Part I, Chapter 7). The sensor should be located to have no significant nearby obstructions above the plane of the instrument and with no shadows or light reflections cast on the sensor. Although the location should be such as to avoid accidental damage to the sensor, it should be accessible for inspection and cleaning. Global radiation measured “on site” is particularly relevant to the road manager. It expresses the quantity of energy received by the road during the day. The relationship of incoming radiation to surface temperature and road inertia will depend on the constituent materials and dimensions of the pavement mass.

Measurement issues: Obstructed sensor horizon, sensor not level, surface dirt, snow or frost obscuring the glass dome or sensing surface, and water condensation inside the glass dome;

(b) *Long-wave radiation*: A pyrgeometer may be used which measures radiation in the infrared by means of a thermopile, filtering out the visible spectrum. Mounted with the sensor facing upwards and a sufficiently unobstructed horizon, it determines the long-wave radiation received from the atmosphere, in particular at night, and gives an indication of cloud cover and therefore of roadway radiative cooling. A sensor sensitive to a spectrum from 5 to 50 μm, with a maximum sensitivity of 15 $\mu V/Wm^{-2}$ and a response time lower than 5 s is adequate for road weather forecasting purposes.
Measurement issues: See those for global radiation.

12.3.1.6 Visibility

Transmissometers and forward scatter meters may be applicable (Part I, Chapter 9).

Measurement issues: Road managers are interested in visibilities below 200 m (the danger threshold). Maintaining sensor windows and lenses clean is important. Some systems will compensate for a degree of window contamination. An appropriate calibration procedure should be carried out during routine maintenance.

12.3.1.7 Road-surface temperature

Active sensors based on a 100 ohm platinum resistance and providing serial digital transmission are available, and may be imbedded in the road surface. The manufacturer's instructions for the installation of the sensor and cabling and bonding to the road surface should be followed. The sensor has to be positioned out of the line of tyre tracks, otherwise the sensor surface will be soiled and measurements affected by friction heating. The sensor must lie in the road surface plane with no depression where water could gather and affect the measurement. The sensor's correct position must be checked on a regular basis.

Measurement issues: The thermal lag (time-constant) of the sensor and the imbedding material should match that of the road-surface composition. The sensor should have a surface finish with low absorptance in the infrared to minimize radiation error. For long connecting cable lengths (over 20 m), cable resistance compensation is recommended.

12.3.1.8 Road-pavement temperature

Temperatures of the pavement at 5, 10 and 20 cm below the road surface may be determined by sinking appropriately sheathed electrical resistance sensors at corresponding depths and using suitable bonding material.

Measurement issues: See those for road-surface temperature.

12.3.1.9 Road-surface condition and freezing temperature

This sensor estimates the road-surface condition (dry, wet, frost, ice) and the freezing temperature of residual surface water. The sensor control circuit heats the sensor before cooling it, using the Peltier effect. The rate of cooling is a function of the surface condition and freezing temperature. See also Part I, Chapter 6, regarding ice on pavements. The sensor output should give road managers an indication of the chemical de-icing agent's persistence at the specific location and enable them to optimize chemical spreading operations.

Measurement issues: The sensor must not be covered by foreign matter or when road re-surfacing. The sensor requires regular cleaning. It is difficult to ensure a sensor response that is representative of the true road-surface condition because of the small sample size, the location on road surface and variable imbedding practices. Measurement depends on traffic density and is otherwise not very stable with time. This sensor, of which there are few alternative makes, may be difficult to obtain. The remote sensing of road-surface temperature by thermal infrared sensors is generally not practical because of the interference caused by water spray from vehicle tyres. Road-surface frost risk estimation may be improved through better measurement of temperature, air humidity and temperature in and on the road surface, namely, improved sensor exposure and reduction of systematic and random errors.

12.3.1.10 Video surveillance

Video surveillance is a component of what have come to be called intelligent transport systems. They are principally used for road-incident detection, but also give a useful indication of present weather for transport management. Image processing algorithms will aid the discrimination between different weather conditions.

12.4 CHOOSING THE ROAD WEATHER STATION EQUIPMENT

Part II, Chapter 1, gives information that may be applied to road meteorological measurement applications. In what follows, attention is drawn to the particular issues and concerns from the experience of road network managers, in particular the need for high performance where public safety is a primary issue.

12.4.1 The road environment

A road weather station is subject to considerable stress due to the vicinity of the roadway: vibration, vehicle ignition interference, exhaust pollution, corrosion from salt spray, and unwelcome attention from members of the public. In some respects the station may be considered to operate in an industrial environment, with all that that implies for the robustness of the design and concern for data integrity. Frequently met problems are: lack of protection against over-voltage on sensor interface circuits; inadequate electrical isolation between sensors, sensor cables and the data-acquisition unit; variable connector contact resistance causing calibration drift; measurement failure; and extended maintenance attention.

12.4.2 Remote-station processing capability

There is a move in AWS design to include increased data-processing capacity and storage at the remote data-acquisition unit in order to employ processing algorithms that act on several sensor signals to give complex outputs; to provide for some level of quality assurance on the data; to provide two-way communications between the control centre and remote units for diagnostics of both the sensor and unit performance; and to provide for downloading new algorithms and software updates to the remote units. On the other hand, a network of remote stations which are not more complex than necessary for reliable data acquisition, and a central control and data-acquisition computer where the more complex algorithms, quality assurance and code translation is carried out as well as the higher level processing for road management decisions, may provide a more reliable and less costly overall system. Those planning for the implementation of a road meteorological measurement network are encouraged to consider flexible and extendable equipment solutions with powerful programming options for sensor data processing and system control.

The station data processing may include: control of the measurement cycle (initiation, frequency, time and date); complex sensor management (power on/off, sampling regime); sensor signal processing (filtering, conversion to scientific units, algorithms); data quality checks; alarm generation (variables outside pre-set limits, partial system failure, station integrity breached); data storage (short-term storage and archiving); output message generation (code form, communications protocol); communications management; and station housekeeping (power supply, sensor checks, communications).

12.4.3 Network configuration and equipment options

The selection of station equipment, communications and network control (the network infrastructure) should reflect the particular demands of road meteorology and the road network management decision-making. These choices will be materially affected by the relationship between the road network authority and the local NMHS. For example, the road network authority might contract the NMHS to provide road meteorology forecasting services and specified road data, to which the road network managers apply their physical criteria to make operational decisions. In this case, it would be logical for the road network stations to be an extension of the NMHS AWS network employing common station hardware, communications and maintenance service, with particular attention to network reliability, and including the special sensors, algorithms and software for the road meteorological task. However, if such close integration is impractical, the road authority may still wish to adopt some commonality with NMHS systems to take advantage of operational experience and the supply of hardware and spare parts.

If an entirely new or separate network is required, the following guidelines are recommended for the choice of data-acquisition equipment and communications. Rather than develop new hardware and software for road meteorological measurement, it is wise to employ existing proven systems from reputable manufacturers and sources, with only necessary adaptation to the road network application, and taking advantage of the experience and advice of other road network administrations. The equipment and its software should be modular to allow for future added sensors and changes in sensor specifications. To facilitate the extension of the network after a few years it is most helpful if the hardware is sourced from standardized designs from a sound manufacturing base where later versions are likely to maintain technical compatibility with earlier generations.

12.4.4 Design for reliability

Data-processing modules should be of industry-standard architecture with robust standard operating systems with a well-managed upgrade process. Application software should be written in a standard language and well documented. To achieve the desired reliability, special industrialized components and modules may be selected. A cheaper alternative may be to use standard commercial designs with redundant parallel or back-up systems to ensure system reliability. The design of the remote-unit power supply needs particular attention. An uninterruptible power supply may be recommended, but it should be recognized that communications systems will also depend on a functioning local power supply.

Whatever the system design, housing the electronics in a robust, corrosion-resistant, secure, even temperature, dust- and moisture-free enclosure will add much to its reliability. Connectors carrying the sensor signals should be of high-quality industrial or military grade and well protected against cable strain, water ingress and corrosion. Sensor cabling should have an earth shield and a robust, waterproof insulating sheath and be laid in conduit.

Special attention should be given to obviating the effect of electrical noise or interference introduced into the data-acquisition system through sensor cables, the power supply or communications lines. These unwanted electrical signals may cause sensor signal errors and corrupt data, and cause electronic failure, particularly in sensitive interface circuits. Great care needs to be given to: the design of sensor and communication line isolation and over-voltage protection, including an appropriate level of protection from atmospheric electricity; the adequate earthing or grounding of sensors, power supplies, communications modems and equipment cabinets; and to earth shielding all parts of the measurement chain, avoiding earth current loops which will cause measurement errors.

Good standardized installation and maintenance practices will contribute much to system reliability. System reliability is also related to the “mean time to repair”, which involves the call-out and travel time of maintenance staff to make equipment replacement from whole unit and module stock.

12.5 MESSAGE CODING

12.5.1 Coding functions

The message transmitted from the remote road meteorological station will contain a station identifier, the message time and date, sensor channel data, including channel identification, and some “housekeeping” data which may include information on station security, power supply, calibration and other data quality checks. This message will be contained in the code envelope relating to the communications channel with an address header, control information and redundancy check characters to provide for error detection. The road meteorological data part of the message may be coded in any efficient, unambiguous way that enables the central control and data-acquisition computer to decode and process before delivering intelligible guidance information to the network managers for their decision-making.

12.5.2 WMO standard coding

Designers of road meteorology measurement networks should also consider the value of WMO standard message coding (see WMO, 1995) which enables other users like NMHSs to receive the data by some arrangement and employ it in other meteorological applications. This message coding may be carried out at the remote AWS, which places demands on station software and processing, or, as is more likely, in the central control and data-acquisition computer after the completion of any quality assurance operations on the data.

12.6 CENTRAL CONTROL AND DATA-ACQUISITION COMPUTER

The functions of the central computer (or computers) have already been mentioned. The functions are to manage the network by controlling communications (see below), receive reports (road meteorological messages, AWS housekeeping messages and quality information), and process the road measurement data to give the road network managers the operational information and decision-making tools that they require. The network architecture may be designed to enable the central computer to act as an Intranet or Web server to enable ready access to this information by regional managers and other users of the meteorological data.

A separate computer will probably be allocated to manage the road network climate database and to produce and distribute analyses and statistical summaries. In a sophisticated network the central computer will manage certain maintenance and calibration operations, change AWS operating modes and update AWS software.

12.7 COMMUNICATIONS CONSIDERATIONS

A reliable telecommunications service that enables the network of stations to be effectively managed while it delivers the requisite data on time is vital. Since communications charges will make up a large proportion of the annual operating cost, the analysis of communications options is important, so that the cost per message can be optimized with respect to the level of service required. A detailed review of telecommunications options for the data collection and management of the road AWS is beyond the scope of this chapter (see Part II, Chapter 1, for guidance on data transmission). The communications solution selected will depend on the management objectives of the road meteorological measurement network and the services offered by the telecommunications providers of the country, with their attendant tariffs.

12.8 SENSOR SIGNAL PROCESSING AND ALARM GENERATION

12.8.1 Signal processing algorithms

The raw signal data from sensors must be processed or filtered to produce representative average values. This is either done in some active sensors, in the sensor interface in the data-acquisition unit, or in the higher level data processing of the station. The specifications for averaging the sensor outputs may be found in Part I, Chapter 1, Annex 1B.

Algorithms which are applied to sensor outputs (or groups of outputs) either at the remote station or in the central computer should be from authoritative sources, rigorously tested and preferably published in the open literature. Any in-house algorithms adopted by the road network management should be well defined and recorded in the station metadata or network manuals.

12.8.2 Alarm generation

Alarm indications may be generated from sensor outputs when values exceed preset limits to initiate alarm messages from the AWS. The choice of alarms and limit tests will depend on national or regional practice. Some examples of alarms from road AWS follow. Note the use of the logical "and" and "or" combinations in the algorithms.

Examples of alarms include:

Alarm 1: T(air) OR T(road surface) 3°C
AND
T(extrapolated road surface)[a] ≤ 1°C
Alarm 2: T(air) ≤ 0°C
Alarm 3: First condition
T(road surface) ≤ 1°C
OR T(extrapolated road surface) ≤ 0°C
OR T(pavement at –5 cm) ≤ 0°C
OR T(pavement at –10 cm) ≤ –1°C
OR T(pavement at –20 cm) ≤ –2°C
AND
Second condition
Carriage-way is not dry
OR at least one precipitation count in the past hour
OR relative humidity ≥ 95%
OR T(road surface) – T(dewpoint) ≤ 1°C
Alarm 4: T(road surface) ≤ 0°C AND detected state: frost or black ice
Alarm 5: First condition
Detected precipitation = snow or hail
AND
Second condition
T(air) ≤ 2°C
OR T(road surface) ≤ 0°C
Alarm 6: Wind average ≥ 11 $m\ s^{-1}$
AND
Wind direction referred to road azimuth, between 45° to 135° OR 225° to 315°
Alarm 7: Visibility ≤ 200 m

a Extrapolated road-surface temperature is calculated with an algorithm that takes account of the last measures and creates a quadratic equation. This can be ued to calculate estimates of temperatures over the next 3 h.

Other alarms may be set if faults are detected in sensors, message formats, power supplies or communications.

12.9 MEASUREMENT QUALITY CONTROL

Good decision-making for road management is dependent on reliable measurements so that, when sensors, their cabling or their interfaces in the AWS develop a fault, the defective unit is detected and repaired without undue delay. It is very difficult for a road manager to detect erroneous measurements. Reference should be made to the guidance on quality control provided in Part II, Chapter 1 and in Part III, Chapter 1. Gross sensor faults may be detected by the AWS system software, which should then generate an alarm condition.

12.9.1 Checking for spurious values

Measurements that fall outside the expected operating range for the sensor, for example, 0° to 359° for a wind vane, and dewpoint not greater than air temperature, may be rejected by setting limits for each variable. Where there has been a faulty zero output, a rapid drift or step change in sensor response, invalid measurements may be rejected by software that performs statistical analysis of measurements over time, either in the AWS if it has sufficient processing power, or in the central data acquisition computer. In some of the examples that follow, the standard deviation of the last *n* values is compared with a parameterized threshold.

Examples of check algorithms (only for road meteorological measurements) include the following:

(a) *Test for all temperatures*: Accept data only if standard deviation of the last 30 values is ≥ 0.2°C;

(b) *Test for wind speed*: Accept data only if standard deviation of the last 20 values is ≥ 1 km hr^{-1};

(c) *Test for wind direction*: Accept data only if standard deviation of the last 30 values is ≥ 10°;

(d) *Test for liquid precipitation*: Check for consistency of amount with previous day's count;

(e) *Test for snow precipitation*: Check data if T(air) > 4°C;

(f) *Test for atmospheric long-wave radiation (AR) (related to cloud cover)*: Refuse data if AR > 130 W m^{-2}, if relative humidity > 97% and AR > 10 W m^{-2}, and if relative humidity ≥ 90% and AR >10 W m^{-2}, for four successive hours.

12.10 ROAD WEATHER STATION MAINTENANCE

12.10.1 The road environment

Reference should be made to Part I, Chapter 1 and Part II, Chapter 1 for the sections on inspection, maintenance and calibration. The chapters of Part I include advice on the maintenance and calibration of specific sensors. Note, however, that the road AWS exists in an environment with peculiar problems: vulnerability of the AWS and its sensors to accidental or intentional damage; exposure to severe vehicle exhaust pollution; electrical interference from vehicle ignition and nearby high-tension power lines; corrosion from salt spray; and vibration (affecting connections between sensors and cables).

12.10.2 Maintenance plans and documentation

Because operational decisions affecting road safety may critically depend on reliable AWS data, there are stringent requirements for maintenance of specific stations at particular times of the year. These considerations are outlined in the maintenance management plan for the network, which should include scheduled routine preventive maintenance as well as effective response to known fault conditions.

The road network administration should have its own maintenance manual for its road meteorological stations, based on the manufacturer's recommendations, information gleaned from this Guide and from its own experience. A good manual contains checklists to aid inspection and the performance of maintenance tasks. The administration may decide to contract out inspection and maintenance work to the local NMHS, which should have experience with this kind of instrumentation.

12.10.3 Inspections and work programmes

Each station should undergo a complete maintenance programme twice a year, consisting of site maintenance (cutting grass and vegetation which could affect sensor exposure); checking enclosures for water ingress and replacing desiccants; treating and painting weathered and corroded enclosures, screens and supports; checking cable and connector integrity; cleaning and levelling sensors (noting the measurement issues referred to previously); and calibrating or replacing sensors and the AWS measurement chain.

Road managers should maintain a physical inspection programme to check for the integrity and proper operation of their stations once a month in winter and once every two months in the summer. When conducting any work on the road surface, the regulation warning signs must be set out and approved safety clothing must be worn.

12.11 TRAINING

To manage, operate and maintain a network of road meteorological stations in order to obtain a continuous flow of reliable data and to interpret that data to give fully meaningful information requires personnel with specific training in the necessary disciplines. Some of these areas of expertise are: the roadway environment and operational decision-making for the safe and efficient movement of traffic; remote data acquisition, telecommunications and computing; the selection, application and maintenance of meteorological sensors and their signal processing; and the interpretation of meteorological and other data for the operational context. The administration responsible for the road network should collaborate with other agencies as necessary in order to ensure that the optimum mix of knowledge and training is maintained to ensure the successful operation of the road meteorological measurement network.

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