ROYAL GOVERNMENT OF BHUTAN
NATIONAL CENTER FOR HYDROLOGY AND METEOROLOGY
(NCHM)

STANDARD OPERATING PROCEDURE
(SOP)

AVIATION METEOROLOGICAL SECTION
WEATHER AND CLIMATE SERVICES DIVISION
2020

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ABBREVATIONS

NCHM	National Center for Hydrology and Meteorology
OD	Organizational Development
MoIC	Ministry of Information and Communication
WMO	World Meteorological Organization
ICAO	International Civil Aviation Organization
DoAT	Department of Air Transport
AMSP	Aeronautical Meteorological Service Provider
BCAA	Bhutan Civil Aviation Authority
WCSD	Weather and Climate Services Division
PIA	Paro International Airport
AIP	Aeronautical Information Publication
HOID	Hydromet Operational and Infrastructure Division
MET	Meteorological
ATC	Air Traffic Control
AMHS	ATS Message Handling System
AMS	Aviation Met Section
ANS	Air Navigation Section
BIP-MT	Basic Instruction Package for Meteorological Technician
BIP-M	Basic Instruction Package for Meteorologist
AWOS	Automatic Weather Observation System
SOP	Standard Operating Procedure
FAT	Factory Acceptance Test

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1 ORGANISATION STRUCTURE

1.1 Introduction

1.1.1 National Center for Hydrology & Meteorology (NCHM) was established as an autonomous organization of the Royal Government of Bhutan for monitoring and understanding of hydrology, weather, climate and cryosphere, for timely provision of information and services to protect lives and property and support national needs for ecologically balanced sustainable development.

1.1.2 NCHM was established as an independent organization of the Royal Government vide cabinet approval of Organizational Development (OD) Exercise recommendations letter no: C/3/92 dated 25th December 2015 and subsequent approval of the staffing/structure by the RCSC vide letter no. RCSC/HRMD/26/2016/618 dated 10th August 2016. The Aviation Met Section under Department of Air Transport (DoAT), Ministry of Information & Communication (MoIC) was also merged with NCHM vide the same order.

1.1.3 Weather forecast continues to be a challenge in providing accurate forecasts for the aviation sector. In order to contribute towards the safety, economy and efficiency of air navigation, National Meteorological Services throughout the world make meteorological observations and forecasts through establishment of sustained monitoring and warning systems in their respective countries, as per the standards and guidelines provided by World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO).

1.1.4 The aviation met services came as an additional mandate to the center. The DoAT has transferred the mandates, functions, responsibilities and services of aviation met section to NCHM on 17th August 2017. NCHM is now the designated Aeronautical Meteorological Service Provider (AMSP) within Bhutan, which is responsible for all matters related to Aviation Meteorological Services. The NCHM has to enhance the capacity, expertise, technology, equipment and infrastructures for the safety of the flight operations.

1.1.5 Within the NCHM, AMS is a section under the Weather and Climate Services Division (WCSD) with the mandate to provide operational meteorological information for safe, regular and efficient air navigation as well as meteorological support to the activities of the aviation industry. It provides information to the Paro International Airport (PIA) and the three domestic airports in Gelephu, Bumthang and Yongphula.

1.1.6 The meteorological services provided in Bhutan are described in the Bhutan Aeronautical Information Publication (AIP) and are defined in GEN 3.5 Meteorological Services.

1.1.7 The organization structure of the center is as appended:

Figure 1: Organisational Structure of NCHM

1.2 Vision

1.2.1 Center for excellence in hydrology, meteorology and cryosphere science and services

1.3 Mission

1.3.1 Monitoring and understanding of hydrology, weather, climate and cryosphere, for timely provision of information and services to protect lives and property and support national needs for ecologically balanced sustainable development.

1.4 Core values

1.4.1 Commitment and loyalty in delivery of products and services;

1.4.2 Integrity;

1.4.3 Professionalism in support of science, research, objectivity, impartiality, and excellence;

1.4.4 Mutual respect, cultural sensitivity and non-discrimination.

1.5 Goals

1.5.1 Improve result-based decision support service for weather incidents and events that threaten lives and livelihoods;

1.5.2 Enhance climate services to understand and adapt to climate-related risks;

1.5.3 Develop capacity to provide integrated and coupled monitoring, detection and forecast services to support assessment and management of water resources and water-related hazards;

1.5.4 Build competence to provide sector-relevant information for socio-economic development, and support development of integrated environmental services to foster healthy communities and ecosystems;

1.5.5 Sustain highly skilled professional workforce equipped with training, tools and infrastructure to fulfil the mission.

1.6 Organizational structure of AMS

1.6.1 The organization structure of AMS is as appended:

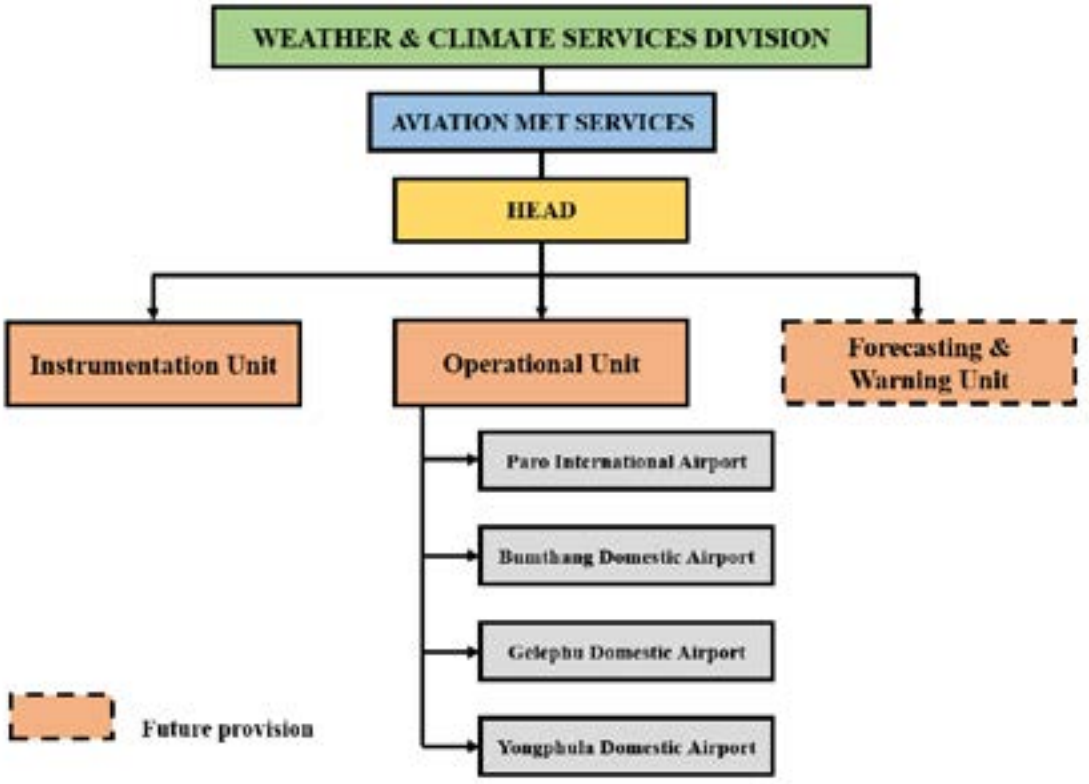


Figure 2: Organisational structure of AMS

1.6.2 The WCSD mainly comprises of four sections i.e. Weather Forecasting Section, Climate Information Management Section, Climate Research & Analysis Section and Aviation Met Section.

1.6.3 The AMS located at the Paro International Airport (PIA), together with its subsidiary meteorological stations at international and domestic airports, plays a central role in the aviation met service to carry out all the functions necessary to meet the needs of flight operations at the airports.

1.6.4 AMS is composed of the Headquarters (Paro) and three aviation met offices at respective domestic airports. There are three units namely, instrumentation unit, operational unit and forecasting & warning unit.

1.6.5 The WCSD is headed by the Chief. Roles and responsibilities of the chief and other post holders are detailed in the responsibilities section.

1.6.6 The operational flow of AMS is as appended:

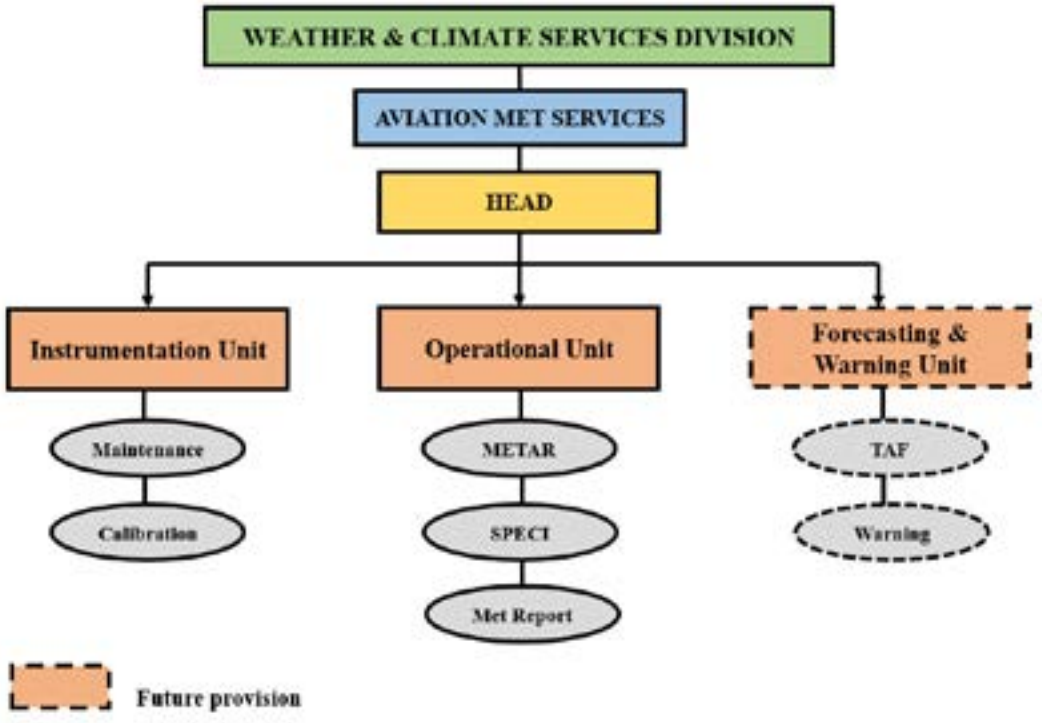


Figure 3: Operational flow of AMS

1.7 TECHNICAL/ACADEMIC QUALIFICATION AND EXPERIENCE

1.7.1 Chief (WCSD

- *The Chief should have a minimum qualification of Degree and should have served at least 10 years in relevant fields of hydrology & Meteorology.*

1.7.2 Hydro/Met Officer

- *Master/Bachelors in Civil/Electrical/Electronics & Communication Engineering OR Diploma in Civil/Electrical/Electronics &Communication engineering.*

1.7.3 Hydro/Met Technicians

- *Class XII passed with a science background OR technical institute graduate in civil.*

1.7.4 Support Staff

- *Personnel familiar with office equipment, computer operations, administrative procedures, record keeping, etc.*

1.8 FUNCTIONS AND RESPONSIBILITIES

1.8.1 Instrumentation Unit:

- *Prepare annual plans and budget in consultation with the head.*
- *Prepare drawing, cost estimate of works related to establishment and construction of aerodrome meteorological stations and related infrastructures as per BCAA and ICAO norms.*
- *Maintain inventory of aerodrome meteorological network stations and infrastructure.*
- *Operation and maintenance of stations and infrastructures as per BCAA and ICAO norms.*
- *Calibration of field instruments as per the required standard of BCAA and ICAO norms.*
- *Organize instrument evaluations and comparisons as per BCAA and ICAO norms.*
- *Coordination with Air Traffic Controllers and Air Traffic Services.*
- *Correspond and update with ICAO and WMO.*
- *Coordination with Hydromet Operational Infrastructure Division (HOID) of NCHM.*

1.8.2 Operational Unit:

- *Collect and maintain the records of meteorological observations of aerodromes in all airports.*
- *Collect weather information in a form of MET REPORT/SPECIAL REPORT at half-hourly intervals.*
- *Prepare and provide meteorological information (METAR/SPECI) at half-hourly intervals to the pilots, flight dispatchers, ATC etc.*
- *Dissemination of meteorological information (METAR/SPECI) to the originating aerodromes, Airlines, ATC and domestic airports through Automatic Message Handling System (AMHS).*
- *Monitoring of aerodrome weather conditions and reporting to ATC for updating the pilots for landing and take-off.*

- *Monitoring and operation of the aviation met infrastructure in respective airports for safe operation of flights as per Bhutan Civil Aviation Authority (BCAA) and ICAO norms.*
- *Coordination with Air Traffic Controllers and Air Traffic Services.*
- *Correspond and update with ICAO and WMO.*

1.8.3 Forecast & warning Unit:

- *Obtain METAR from all airports via AMHS.*
- *Prepare forecasts and other relevant information for flights.*
- *Prepare forecasts for the aerodromes.*
- *Maintain continuous survey of meteorological conditions over all airdromes.*
- *Prepare warnings, as necessary, for all aerodromes.*
- *Exchange meteorological information with other meteorological offices.*
- *Coordination with Weather Forecast Services of the Division for weather updates.*

1.9 JOB DESCRIPTION OF KEY MANAGEMENT AND TECHNICAL PERSONNEL

1.9.1 Job description of Chief Meteorological Officer

- *Manage and monitor all aspects of Aeronautical Met Services, with general oversight of all units under AMS.*
- *Advise Aviation Met Section on any matters relating to ANSP and Civil Aviation Act.*
- *Monitor the Aeronautical Meteorological Services provided by the section to ensure that such services meet ICAO requirements.*
- *Ensure that the MoU related to ANS are established, implemented and maintained.*
- *Ensure that all the protocol questions & memos raised by the Auditors of Regulatory are followed up and answered on time.*

1.9.2 Job description of Head

- *Assist in developing policies for Aviation Meteorology and recommend as necessary.*
- *Assist the Chief, WCSD in formulating policies on long- and short-term plans for the aviation sector and the responsibilities of WCSD, NCHM*
- *Assist to procure Aviation Meteorology equipment & delivery services in Bhutan with the assistance and guidelines from ICAO and WMO*
- *Plan and proposal of Met Officials and train/familiarize to upgrade the knowledge as per the ICAO norms & conditions.*
- *Recommend to the Chief, WCSD as per the DoAT/BCCA directives the procedures, Meteorology equipment & system*
- *Prepare annual Aviation Meteorology budget and implement the approved program*
- *Implement the provisions contained in the following Annexes and documents, issued by ICAO*
    - *Annex 3 – Meteorological Services for International Air Navigation*
    - *Annex 14 – Aerodrome*
    - *Doc 8896 – Manual of Aeronautical Meteorological Practice*
    - *Doc 9377 – Manual on coordination between Air Traffic Services, Aeronautical information Services and Aeronautical Meteorological Services.*
- *Perform any other duties assigned by the head of division.*

1.9.3 Job description of Assistant Hydro/Met Officer

- *He/she is the immediate supervisor of Aviation Meteorology unit and manages the daily activities under his/her control*
- *Ensure that all Met Equipment & system are properly maintained and serviceable all the time at all airports*
- *Maintain close interaction with ANSP, BCAA and neighbouring ATS units to provide and exchange information regarding the Air Traffic Services*
- *Ensure that Aviation Meteorology abide by ICAO and WMO recommendations & practices*

- *Keep in constant contact with day to day matters of Air Traffic Services, Air Traffic Control and report to the aviation met officer*
- *Plan trainings/OJTs required for the aviation meteorological assistants and to discuss with the Met Officer*
- *Monitor the staff of three domestic airports and ensure it is manned & available all the time for the safe flow of flight operations*
- *Endure and plan regular visits to 3 domestic airports for periodic maintenance of meteorological equipment & system check in order to keep the met services available all the time*

1.9.4 Job description of Meteorology Technicians

- *Collection of weather data and maintaining of the meteorological records of the aerodrome on half hourly intervals*
- *Coordination with ATC on weather conditions during the departure & arrival flight operations*
- *Assist the assistant Meteorological in day-to-day office works & activities.*
- *To check the serviceability of the Met equipment & systems to ensure in providing the meteorological information to the pilots, flight dispatchers, flight documentation, etc.*
- *Prepare METAR from the collected meteorological data of the aerodrome and transmit through Automatic Message Handling System (AMHS) to the originating airdromes and to Paro ATC*
- *Obtain & get METAR from each airport (Paro & 3 domestic airports) whenever there are flight movements*

1.10 TRAINING OF KEY OFFICERS

1.10.1 Initial training of key personnel

- *All the key personnel of AMS shall have in depth knowledge of various provisions of ICAO Annex 3 and Manual of Aeronautical Meteorological Practice, therefore, they shall have undergone a training course on ICAO Annex 3 and Manual of Aeronautical Meteorological Practice*

- *They shall have undergone a training course as specified by the Basic Instruction Package for Meteorological Technicians (BIP-MT) and Basic Instruction for Meteorologist (BIP-M).*
- *Components of the Basic Instruction Package for Meteorologists are:*
    - *Foundation topics in mathematics and physics plus complementary subjects dealing with other sciences and related topics, communications, and data analysis and utilization;*
    - *Topics in atmospheric sciences*
        - *Physical meteorology (i.e. atmospheric composition, radiation and optical/electrical phenomena; thermodynamics and cloud physics; boundary-layer meteorology and micrometeorology; conventional observations and instrumentation; remote sensing);*
        - *Dynamic meteorology (i.e. atmospheric dynamics; numerical weather prediction);*
        - *Synoptic and mesoscale meteorology (i.e. mid-latitude and polar weather systems; tropical weather systems; mesoscale weather systems; weather observation, analysis and diagnosis; weather forecasting; service delivery);*
        - *Climatology (i.e. global circulation; climates and climate services; climate variability and climate change).*

  Besides the basic requirement to successfully complete topics (a) and (b), individuals wishing to obtain a specialization may also study in greater depth such subjects as aeronautical meteorology, atmospheric chemistry, and climate monitoring and prediction.
- *Components of the Basic Instruction Package for Meteorological Technicians are:*
    - *Foundation topics in mathematics and physics plus complementary subjects dealing with other sciences and related topics, communications, and data analysis and manipulation*
    - *Topics in general meteorology: basic physical and dynamic meteorology; basic synoptic and mesoscale meteorology; basic climatology; and meteorological instruments and methods of observation.*

Besides the basic requirement to successfully complete topics (a) and (b), individuals wishing to obtain a specialization may also study in greater depth such subjects as specialized observations and measurements; data quality control and archiving; equipment calibration and maintenance; and communications and computing.

1.10.2 Recurrent training of key personnel

- *The key personnel of the AMS require the continuing development of their knowledge and skills related to their respective responsibilities. This shall be accomplished through periodic training and refresher courses in all the disciplines for which the technical officers are responsible. They shall be required to undergo recurrent training/refresher training at the interval of every two years.*
- *Participation in seminars and workshops organized by ICAO, international/regional aviation related organizations and BCAA can also enable these personnel to widen their horizons and share experience with experts from other states or organizations.*
- *The key personnel shall attend the workshops, seminars and OJTs overseas within the region to understand and keep up with the new procedures and practices of ICAO annex and WMO recommendations in other busy International Airports.*

1.10.3 Training records of the key personnel

- *AMS shall maintain the training records of each key personnel in their respective files*
- *The Secretariat of NCHM is responsible for keeping the training records of the key personnel updated and secured.*

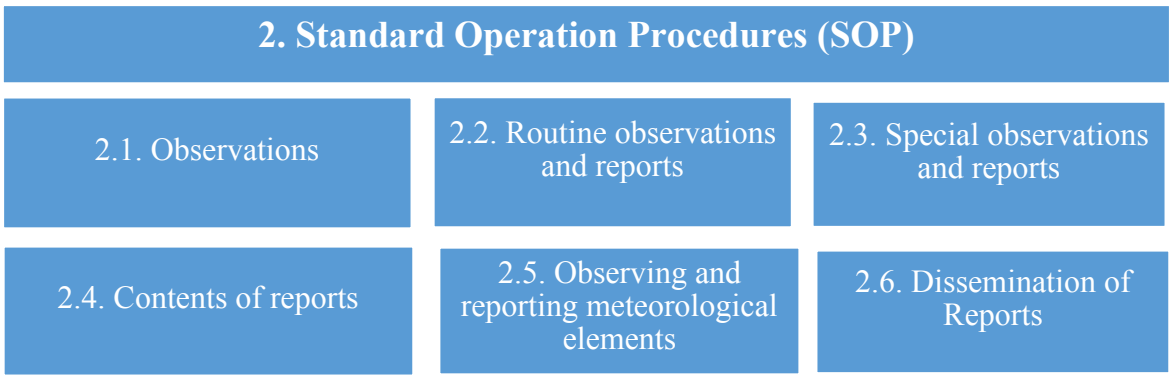
2 STANDARD OPERATING PROCEDURE FOR PREPARATION OF MET REPORT

AMS has installed automated equipment for measuring surface wind, air and dew-point temperatures and atmospheric pressure to support approach and landing and take-off operations. These devices are integrated automatic systems for acquisition, processing, dissemination and display in real time of meteorological parameters affecting landing and take-off operations. AMS provides METAR and SPECI at PIA and all domestic airports.

Table 1: Meteorological observation and report

Name of station/Location indicator	**Type & frequency of observation/automatic observation equipment**	**Type of MET report & supplementary information included**	**Observation system & site(s)**	**Hours of operation**	**Climatological**
PARO (VQPR)	Half hourly plus special observation	Plain language METAR SPECI	Surface wind sensor Temp. sensor Pressure sensor	HO	NIL
BUMTHANG (VQBT)	Half hourly plus special observation	Plain language METAR SPECI	Surface wind sensor Temp. sensor Pressure sensor	HO	NIL
GELEPHU (VQGP)	Half hourly plus special observation	Plain language METAR SPECI	Surface wind sensor Temp. sensor Pressure sensor	HO	NIL
YONGPHULA (VQTY)	Half hourly plus special observation	Plain language METAR SPECI	Surface wind sensor Temp. sensor	HO	NIL

			Pressure sensor		



2.1 Observations

2.1.1 Collection of data for surface wind & speed, temperature & pressure from the AWOS on half-hourly basis.

2.1.2 Collection of information regarding visibility, cloud amount & cloud base by visual estimation by the observer at half-hourly interval.

2.1.3 These data shall be maintained in a Met Report register.

2.1.4 Encode the Met Report for the preparation of METAR as specified in 6.5.

2.2 Routine observations and reports

2.2.1 At aerodrome, routine observations shall be made for 5 hours each day.

2.2.2 The observations shall be made at intervals of half-hour.

2.2.3 Reports of routine reports observations shall be issued as:

- *Local routine reports, only for dissemination at the aerodrome of origin, and*
- *METAR for dissemination beyond the aerodrome of origin*

2.2.4 METAR shall be issued prior to the aerodrome resuming operations.

2.3 Special observations and reports

2.3.1 Following are the list of criteria for special observations:

- *As and when significant changes place in any one or more of the visibilities, weather, cloud and surface wind*
- *After issuing SPECI, if a similar weather condition prevails at the same time of next routine observation, the report at routine observation will be METAR.*
- *If a SPECI is issued within a 10 minutes period of routine observation time, then at the time of routine observation, no weather report will be prepared. The observation will be entered in the current weather register only.*
- *If deterioration in one met element and improvement in another MET element takes place simultaneously, the SPECI for Deterioration will be issued immediately and it should include the improvement of other meteorological elements.*
- *When visibility changes to all processes by 5000M, 3000M, 1500M & 800M, SPECI is issued.*
- *For onset, cessation or change of intensity of the following weather phenomena, SPECI is issued.*
    - *Freezing precipitation.*
    - *Moderate or heavy rain, snow, snow pellets, Ice pellets, hail, small hail or their combination.*
    - *Thunderstorm with or without above precipitation.*
    - *Drifting/ Blowing dust, sand, snow.*
    - *Dust storm, Sand storm, Squall, Funnel cloud.*

2.3.2 Reports of special observations shall be issued as:

- *Local special reports, only for dissemination at the aerodrome of origin*
- *SPECI for dissemination beyond the aerodrome of origin*

2.4 Contents of reports

2.4.1 Local routine and special reports (METAR and SPECI) shall contain the following elements:

- *Identification of the type of reports*
- *Location indicator*
- *Time of the observation*
- *Identification if an automated or missing report, when applicable*
- *Surface wind direction and speed*
- *Visibility*
- *Runway visual range, when applicable*
- *Present weather*
- *Cloud amount, cloud type and height of cloud base, or, where measured vertical visibility*
- *Air temperature and dew-point temperature*
- *QNH and, when applicable QFE*

2.5 Observing and reporting meteorological elements

2.5.1 Surface Wind	2.5.2 Visibility	2.5.3 Runway visual range	2.5.4 Present weather	2.5.5 Clouds	2.5.6 Air temp and dew-point	2.5.7 Atmospheric pressure

2.5.1 Surface wind

- *Wind shall be coded as direction in degrees true followed by the average speed. Eg: 24015KT-indicates that the wind is blowing from southwest at 15kts*

- *If the wind is gusting this shall be coded by a further group of figures preceded by the letter G. Eg: 24015G27KT*
- *If the wind is calm then 00000KT shall be coded.*
- *A variable wind direction shall be coded by VRB. Eg: VRB02KT shall indicate that the wind was only 2KTs but would not be blowing from any fixed direction.*
- *If the wind is greater than 3KT and the direction is varying by 60 degrees or more than the actual values be coded. Eg: 31015G27KT 280V360 which indicates that the wind is blowing from northwest at 15 KTs with gusts to 27KTs but that the wind direction is varying from 280 to 360 degrees.*

2.5.2 Visibility

- *Visibility shall be coded as a four-figure group in meters (2000 meters is roughly 1 nm). If 0000 is coded for the visibility less than 50 meters. If 9999 is coded for the 10 km visibility or more*

2.5.3 Runway Visual Range (RVR)

- *RVR is an indication of the real visibility as measured down the runway either electronically or manually. RVR is taken when the Met visibility drops below 1500 meters and it shall therefore only be shown occasionally in METAR reports. RVR visibility shall always be prefixed by the letter R followed by the runway for which has been taken*

  Eg: R24/1200 – RVR for runway 24 is 1200 meters

2.5.4 Present weather

- *Weather shall be coded by one or more two letter groups as shown in table below*

2.5.5 Clouds

- *Usually clouds are coded in six figure groups. The group consists of three letters that describe the cloud cover followed by three figures for cloud height above aerodrome level.*
- *Cloud amount shall be coded as;*

  FEW Few indicating 1 or 2 oktas of cloud

  SCT Scattered indicating 3 or 4 oktas cloud

  BKN Broken indicating 5 to 7 oktas of cloud

OVC Overcast indicating 8 oktas (solid cloud cover)

- *Cloud height shall be coded in the next three figures which shows the altitude in hundreds of feet. i.e. 040 for 4000ft, 004 for 400ft, 200 for 20,000ft.*

  Eg; SCT020 Scattered at 2000ft
  BKN005 Broken cloud at 500ft
  OVC250 Overcast at 25,000ft

- *A METAR may contain several cloud layers like SCT025 BKN070 BKN120, indicating scattered cloud at 2500ft, broken cloud at 7000ft and again at 12,000ft.*

  SKC Sky clear, if no cloud layers are observed
  CAVOK If no cloud exists below 5000ft and the visibility > 10km
  CB Cumulonimbus formation
  TCU Towering CB formation

2.5.6 Air temperature and dew-point temperature

- *Temperature and dew-point shall be measured in centigrade. A minus value shall be preceded by the letter M.*

  Eg; 25/12 Temp 25°C, Dew-point 12°C, or
  00/M02 Temp 0°C, Dew-point -2°C

2.5.7 Atmospheric pressure

- *QNH shall be rounded to the next whole millibar and coded as a four figure group preceded by Q. For values < 1000mbs then the first digit shall be 0.*

  Eg;
  Q0996 QNH 996mbs
  Q1030 QNH 1030mbs

2.6 Putting it all together

2.6.1 METAR VQPR 1050Z 24015KT 9000 RA SCT025 BKN040 10/09 Q1010 NOSIG

2.6.2 The report was measured at 1050 UTC and it shows that PARO was reporting a wind of 240 at 15KTs, the visibility was 9KM (9000m), it was raining, cloud was scattered at 2500ft and broken at 4000ft. Temperature was 10℃ and dew-point of 9℃, the sea level pressure (QNH) was 1010mb and there was no significant change expected in the next two hours.

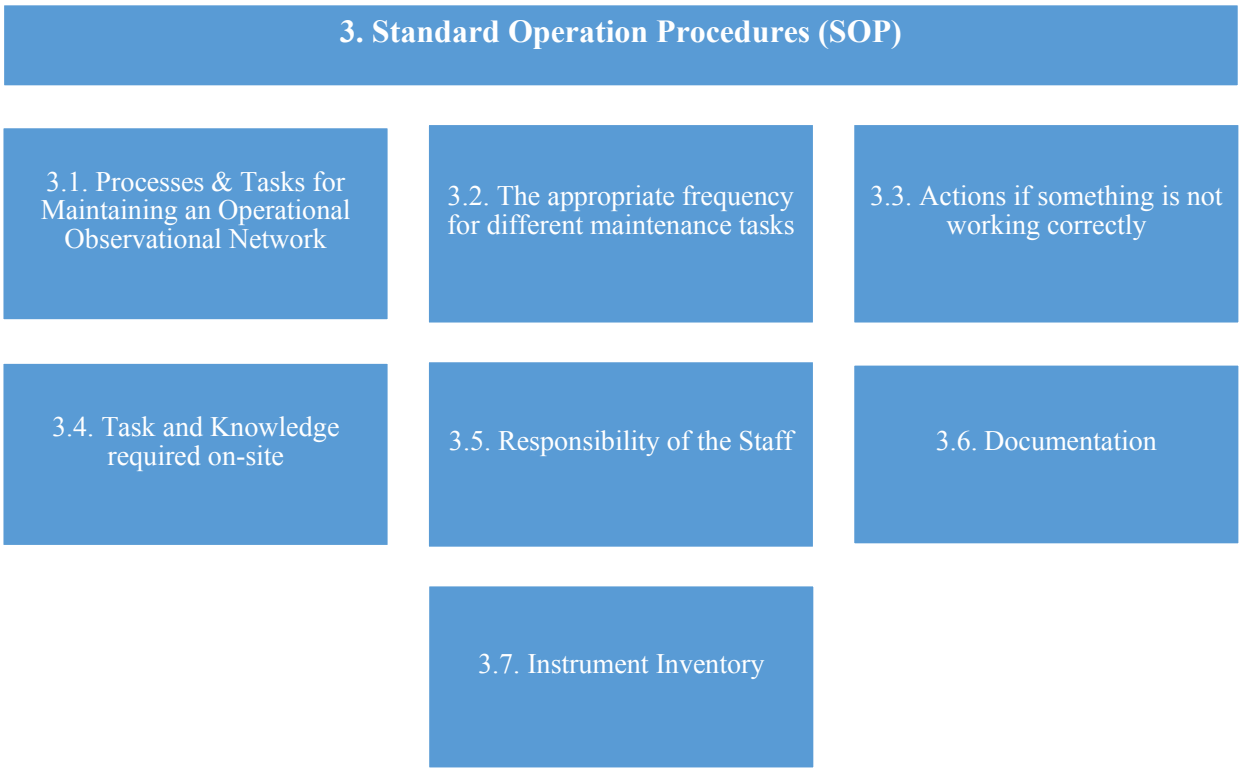
2.7 Dissemination of report

2.7.1 These Aerodrome Reports shall be transmitted through ATS Message Handling System (AMHS) to the originating aerodromes and to Paro ATC.

3 STANDARD OPERATING PROCEDURES FOR STATION MAINTENANCE

Standard Operating Procedures (SOP) consists of seven parts:

1. Process & tool for maintaining as operational observation network
2. The appropriate frequency for different maintenance tasks
3. Actions if something is not working correctly
4. Tasks and knowledge required on site
5. Responsibility of the staff
6. Documentation
7. Instrument Inventory



3.1 Processes and tasks for maintaining an operational observational network

3.1 Processes and task for maintaining an operational observational network				
3.1.1 Establishing new or moving existing weather observation stations	3.1.2 General maintenance and service	3.1.3 Monitoring of data transmission	3.1.4 Calibration and adjusting	3.1.5 Instrument updates, including configuration and testing

3.1.1 Establishing new or moving existing weather observation stations

- *ATC personnel should be included in the selection of new weather station locations and it should be at aerodromes in its territory.*
- *Representativeness of the new location should be in accordance with ICAO and WMO norms.*

3.1.2 General maintenance and service

- *Grass cutting.*
- *Cleaning of instruments.*
- *Main office information for field observer:*
    - *Dos and don'ts for field observers regarding things that affect the representativeness of the station.*
    - *Updating the station logbook with the help of station inspection forms etc.*

3.1.3 Monitoring of data transmission

- *It is convenient to automatize the status messaging of a large modern observation network, because manual monitoring is impossible to implement efficiently. Monitoring regarding data flow and data quality can be automatized. In addition, station fault diagnostics can be monitored (warnings, alarms etc.).*

3.1.4 Calibration and adjusting

- *Planning and maintaining calibration procedures and systems.*
- *Laboratory calibrations.*
- *Technical quality assurance.*
- *Maintain traceability of calibration reference equipment.*

3.1.5 Instrument updates, including configuration and testing

- *Replacement of instruments before their calibration lifetime expires.*

3.2 The appropriate frequency for different maintenance tasks

3.2 The appropriate frequency for different maintenance tasks				
3.2.1. Once a year (technician)	3.2.2. Every month (field observer)	3.2.3. Weekly (field observer)	3.2.4. Daily (field observer)	3.2.5. Maintenance schedule

3.2.1 Once a year (technician)

- *Visiting and inspecting all stations. Replacing the sensors as planned. The required instrument replacement schedule depends on the used instrumentation and the environmental conditions.*
- *Checking the sensor leads and cables for cracking, deterioration and proper routing. Replacing the sensor cables if necessary.*

3.2.2 Every month (field observer)

- *Need for cutting of grass is determined.*
- *Keeping an eye out for any changes in the surroundings (new buildings, planted areas etc.). Reporting these immediately.*
- *Monitoring for any unauthorized visits or vandalism.*

3.2.3 Weekly (field observer)

- *Cleaning of instruments.*

3.2.4 Daily (field observer)

- *Cleaning of manual rain gauges and checking if the automatic rain gauge container is full.*

NOTE: Important to update the station logbook (metadata) with the help of station inspection forms etc.

3.2.5 Maintenance schedule

- *Temperature and humidity - every year.*
- *Wind sensors - every second year. Positioning of the wind vane will be checked in every year.*
- *Ultrasonic wind sensor (after mechanical damage or any specific problems).*
- *Pressure - every three years.*
- *Solar radiation sensor (if available).*
- *Data logger every 10 years.*
- *If major deviation or mechanical damage in sensors are observed.*

3.3 Actions if something is not working correctly

3.3. Actions if something is not working correctly	
3.3.1. In case all parameters are unavailable	3.3.2. In case only individual parameters are unavailable

3.3.1 In case all parameters are unavailable

- *A remote connection first used, if available. If the remote connection procedures (resetting logger, checking date, checking power supply etc.) does not fix the problem or it is not available, the local contact person contacted for checking station abnormalities and asked if the field observer is able to fix the problem.*
- *Checking the station with the following procedures:*
    - *Electricity (power supply).*
        - *The electricity provider contacted, if an electricity issue can be identified.*
    - *Communication module (modem).*
        - *Resetting of modem.*
        - *The service provider contacted, if a connection issue can be identified, but resetting the modem does not work.*
    - *Data logger.*
        - *The data logger errors read (incl. communication errors).*
        - *Reset the logger.*
    - *Assembly's cable connections.*
- *If a resolution is not found, a technician will be requested from the main office. The field observer asked to help to make a list of the required maintenance spare parts etc. if extra service needed.*
- *An error report always documented and filed. In addition, also progress updates are included in the report.*

3.3.2 In case only individual parameters are unavailable

- *A remote connection first used, if available. If the remote connection procedures (resetting logger, checking date, checking power supply etc.) does not fix the problem or it is not available, the local contact person contacted for checking the individual instrument and asked if the field observer is able to fix the problem.*
- *Checking the individual sensor with the following procedures:*
    - *Connections.*
    - *General conditions of the instrument.*
    - *Obstructions (blocking of radiation sensor etc.).*

- *If a resolution is not found, the same procedures as with all parameters are unavailable and can be tried, before a technician is requested from the main office. The field observer asked to help to make a list of the required maintenance spare parts etc. if extra service needed.*
- *An error report always documented and filed. In addition, also progress updates are included in the report.*

3.4 Tasks and Knowledge required on-site.

3.4 Tasks and Knowledge required on-site		
3.4.1. Field observer	3.4.2. Technician	3.4.3. Calibration

3.4.1 Field observer

- *Basic operation and maintenance knowledge.*
- *Civil and electricity works knowledge.*
- *Basic knowledge about the instruments.*

3.4.2 Technician

- *Background in electronics and instrumentation.*
- *Certificate level technicians with electrical engineering background.*
- *Computing (IT) knowledge.*
- *Communication knowledge.*
- *Troubleshooting knowledge.*

3.4.3 Calibration

- *This depends on the instrumentation. Analog instrumentation needs the calibration of the logger. For digital instruments, only replacement is required. Therefore, digital instrumentation will be highly recommended for the future updates. This way, the required maintenance knowledge at the station level is minimal and all the calibration is focused on the calibration laboratory and the key personnel in the main office.*

3.5 Responsibility of the Staff.

3.5. Responsibility of the Staff		
3.5.1. Field observer	3.5.2. Regional office	3.5.3. Main office

3.5.1 Field observer

- *Overall operation and maintaining of the station (ensure that station is functioning).*
- *Responsibility of maintaining the station logbook and providing the updates to the main office.*

3.5.2 Regional office

- *Requirements for new instruments and sensors.*
- *Scheduling of maintenance.*
- *Support in maintenance.*
- *Maintaining regional inventory.*
- *Propose and plan development of the network.*

3.5.3 Main office

- *Overall monitoring of stations.*
- *Minor calibration.*
- *Procurement of spare parts.*
- *Major maintenance.*
- *Updating the logbook metadata to the database.*

Later on, after the AWS network is bigger, and field observers are not enough, personnel from the main office can be appointed to be responsible for specific stations or specific areas of stations.

3.6 Documentation

3.6 Documentation	
3.6.1. Metadata	3.6.2. Major database elements

3.6.1 Metadata

- *Metadata is essential and should be kept current and be easily obtainable. A station logbook and station inspection form should be used for documenting the station metadata. The updates should also be delivered to the main office for updating the metadata database.*
- *Any significant changes should be recorded in the station logbook and dated.*
- *Photographs are useful if they have been taken at sufficient distance to show the instrument and its terrain background. Such photographs are should be taken from all cardinal direction*
- *Station information (incl. Site acceptance test).*
- *Instrument information (incl. FAT).*
- *Contact person.*
- *Network (communication) information.*
- *Observations (type etc.).*

Inspection forms (changes, maintenance etc.). Maintenance and service documents, calibration documents, metadata database, instrumentation database (serial numbers etc.)

3.6.2 Major database elements

- *Network information.*
- *Station information:*
    - *Station name and station index number(s).*
    - *Geographical coordinates.*
    - *Elevation above mean sea level.*
    - *Types of soil, physical constants and profile of soil.*
    - *Types of vegetation and condition.*
    - *Local topography description.*
    - *Type of AWOS, manufacturer, model, serial number.*
    - *Observing program of the station: parameters measured, reference time, times at which observations/measurements made and reported.*
    - *The datum level to which atmospheric pressure data of the station refer.*

- *Contact information, such as name and mailing address, electronic mail address, and telephone numbers.*
- *Complete history of the station with dates and details of all changes.*
- *Establishment, interruptions and closure of the station.*
- *Inspection information: comments about the site, exposure, quality of observations and station operation.*

- *Individual instrument information:*
  - *Sensor type, manufacturer, model, serial number.*
  - *Principle of operation.*
  - *Method of measurement/observation.*
  - *Type of detection system.*
  - *Performance characteristics.*
  - *Unit of measurement and measuring range.*
  - *Resolution, accuracy (uncertainty), time constant, time resolution, output averaging time..*
  - *Siting and exposure: location, shielding, height above ground (or level of depth).*
  - *Date of installation.*
  - *Data acquisition: sampling interval, averaging interval and type.*
  - *Correction procedures.*
  - *Calibration data and time of calibration.*
  - *Preventive and corrective maintenance.*
    - *Recommended/ scheduled maintenance.*
    - *Calibration procedures including frequency.*
    - *Procedure description.*
- *Data-processing information regarding each individual meteorological element:*
  - *Measuring/observing program: time of observations, reporting frequency, data output.*
  - *Data-processing method/procedure/algorithm.*
  - *Formula to calculate the element.*

- *Mode of observation/measurement.*
- *Processing interval.*
- *Reported resolution.*
- *Input source (instrument, element, etc.).*
- *Constants and parameter values.*

- *Data handling and transmission information*
  - *Quality control procedures/algorithms.*
  - *Quality control flag definition.*
  - *Constants and parameter values.*
  - *Processing and storage procedures.*
  - *Method of transmission.*
  - *Data format.*
  - *Transmission time.*
  - *Transmission frequency.*

3.7 Instrument inventory

3.7 Instrument inventory	
3.7.1 Instruments etc.	3.7.2 Tools

3.7.1 Instruments etc.

- *Data loggers.*
- *Communication modules (modems).*
- *Sensors (min. 10 % in stock).*
- *One extra maintenance toolkit.*

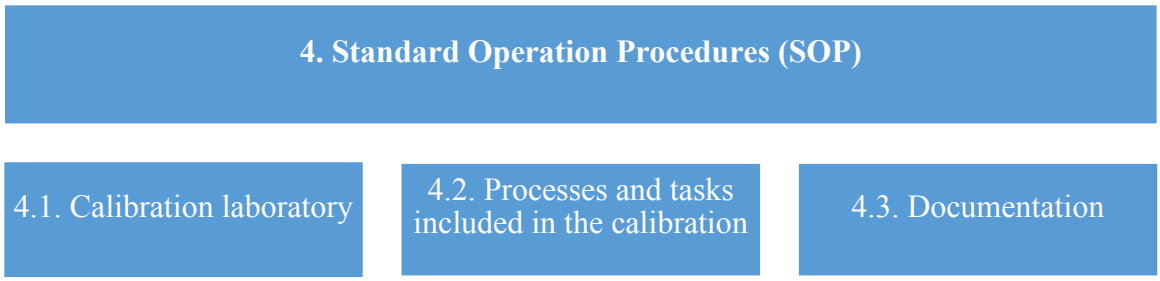
3.7.2 Tools

- *Multimeters.*
- *General tools for maintenance and electrical works.*

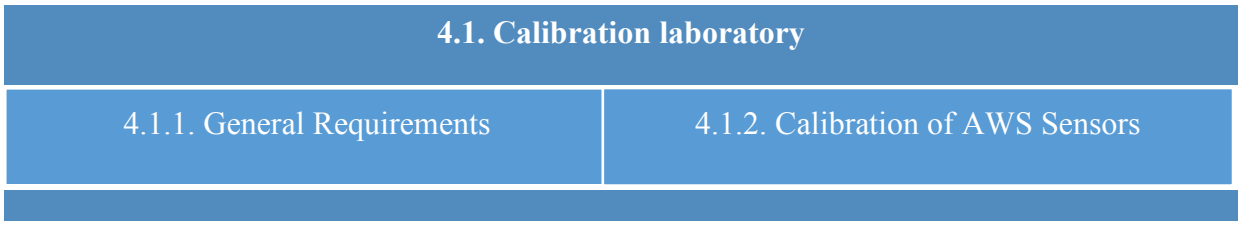
4 STANDARD OPERATING PROCEDURES FOR STATION CALIBRATION

Standard Operating Procedures (SOP) described in this document consists of three part:

1. What parts of the calibration processes should be in-house and what should be outsourced?
2. Processes and tasks included in the calibration
3. Documentation that must be done



4.1 What parts of the calibration processes should be in-house and what should be outsourced?



4.1.1 General Requirements

- *Laboratory rooms:*
    - *Constant temperature (20-25 °C) e.g. LiCl salt solution used in RH-calibration will be permanently damaged at temperatures much below 20 °C.*
    - *Preferably no windows. The solar radiation causes uncontrollable temperature effects.*
    - *Laboratory security standards, instruments and documents should be stored safely.*

- *Calibration of AWS Sensors*
    - *Humidity.*
    - *Temperature.*
    - *Pressure.*
    - *Wind.*
    - *Solar radiation.*
    - *Precipitation.*

4.2 Processes and tasks included in the calibration

4.2.1. Book-Keeping for Regional Instruments and Sensors	4.2.2. Functionality Checks and Cleaning	4.2.3. Pre-Calibration (in received condition)	4.2.4. Analysis of Pre-Calibration results	4.2.5. Adjustments of Instrument or Sensor	4.2.6. Final Calibration	4.2.7 Analysis of Final Calibration results	4.2.8. Accepted as Calibrated Instrument	4.2.9. Book-Keeping for Regional Instruments and Sensors

4.2.1 Book-Keeping for Regional Instruments and Sensors

- *All instrument and sensor meta-data (is data which includes, manufacturer, serial numbers, model numbers, last calibration date etc.) located in the network.*
- *Primary focus will be placed on the instrument or sensor identification, last calibration date (where applicable) and results of any calibrations that have been done on the instrument or sensor.*

4.2.2 Functionality Checks and Cleaning

- *Instrument or sensor integrity observed and a determination made whether the device is suitable for calibration.*
- *The device then cleaned and prepared for the calibration process.*
- *In the event that the device is not suitable for calibration, it will have to be repaired, either in-house or returned to the manufacturer.*
- *When these options do not bring the device to a suitable state, it may have to be removed from service. This decision is then recorded in the Book-Keeping database.*

4.2.3 Pre-Calibration (in received condition)

- *This is a full calibration process of the instrument or sensor prior to any adjustments.*

4.2.4 Analysis of Pre-Calibration results

- *At this phase, a determination will be made whether to make adjustments based on predetermined acceptance limits or if the instrument or sensor can be left as it is.*
- *When an adjustment is not possible on the instrument or sensor, the relevant corrections are recorded in the calibration documents.*

4.2.5 Adjustments of Instrument or Sensor

- *During this stage, the instrument or sensor adjusted to be as reasonably close to the reference.*

4.2.6 Final Calibration

- *This is a full calibration process of the instrument or sensor after all adjustments have been carried out. After this phase, no adjustments shall be conducted.*

4.2.7 Analysis of Final Calibration results

- *At this stage, a determination will be made whether the instrument or sensor is now within acceptable limits.*
- *If the instrument or sensor is not within acceptable limits, the instrument or sensor has to be returned to the adjustment stage.*

4.2.8 Accepted as Calibrated Instrument

- *At this stage, the calibration documents are issued for the instrument or sensor.*

4.2.9 Book-Keeping for Regional Instruments and Sensors

- *The calibration results are stored and the relevant areas in the book-keeping database are updated.*

General flow chart of the calibration process is appended in the figure below:

Figure 4: General flow chart of the calibration process

4.3 Documentation

4.3. Documentation		
4.3.1. Traceability documents	4.3.2. Documents of laboratory activities	4.3.3. Laboratory diaries

4.3.1 Traceability documents

- *Documents or certificates of the traceability of the main and laboratory standards.*

4.3.2 Documents of laboratory activities

- *Calibrations and other laboratory activities should be systematically documented. A calibration document should include the following:*
    - *Sensor (serial number).*
    - *When received and from which station (station and MAWS numbers).*
    - *Calibration results, adjustments made, faults, errors, etc.*
    - *When returned and to which station.*
    - *Person responsible, date.*

4.3.3 Laboratory diaries

- *To maintain security, it is also recommended that laboratory diaries should be kept. In the diaries should be documented:*
    - *Who has been in the laboratory?*
    - *When?*
    - *Which instruments and standards have been used?*

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Printed at United Printing Press