Australian Government
Bureau of Meteorology

Basic Observing System Study 2005

BOSS05

Summary Report

May 2006

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ATTACHMENTS

Foreword

Bureau Observing System Study 2005

The Bureau Observing System Study 2005 (BOSS05) is a timely attempt to take a good hard look from a multi-program perspective at the Bureau's observing systems, to assess how well they meet the Bureau's requirements for observational data and to look at how they might meet those changing needs into the future. In the context of the next 5-10 years, the study has set out to identify the essential elements of an efficient and effective observing system to deliver on the Bureau's agreed outputs to government, the end-to-end strategies for delivering that system and the logistics of making it happen.

Key drivers in commissioning the study were the increasing need to focus on national priorities in the Bureau's observing networks, in order to better understand how declining real resources can be utilised to best overall effect, and to consider how we might make better use of new scientific and technological solutions to observing challenges within an overall composite Bureau observing system. While the study team was charged with evaluating the extent to which the requirements for observational data could be met within the existing base resource envelope, they were also asked to identify a resource envelope that might be required to deliver a robust, effective and sustainable system into the future.

The biggest challenge of the study, and possibly its greatest achievement, was to obtain a comprehensive specification of the Bureau's services requirements for observations, and to define them in such a way that they can be used effectively to develop and assess systems requirements and specifications. In developing the system requirements, the study has arguably gone outside its mandate and has made a number of recommendations in relation to adjacent issues, such as data display and archival. However, I support the judgement of the study team that failure to address such issues impacts directly on the usefulness and effective value of observations to users.

The BOSS05 Summary Report distils the major issues and findings of the study. It is, however, just the tip of the iceberg, with the considerable amount of supporting material that underpins it accessible on the Bureau's intranet. As well as drawing out some recommended strategic directions for the Bureau Composite Observing System (BCOS), mapped into a four-step BCOS Strategy for the period 2006 to 2016, the report presents some 62 specific recommendations, initially for the consideration of Program Managers and ultimately for the Executive either directly or via specific proposals. Looking to the future, the BCOS strategy offers a more sustainable and effective program, with offsetting savings that will return much of the initial investment.

With broad participation across all relevant contributing and user programs, the study was conducted under the leadership of Dr Roger Atkinson. The list of co-authors and contributors (on the front page of the Summary Report) reflects the substantial effort, as well as the breadth of interests, perspectives and expertise, that the study has benefited from. Clearly, in any study such as this there will be contrary views and I will be pleased to hear them and take them into account in implementing the study's findings. As Chair of the Steering Committee (ADO, ADS, ADC, ADN, CSR), I wish to acknowledge the commitment and contribution of all those that have participated in the study, including others that are not named specifically, and to thank them for their considerable efforts.

Sue Barrell
Assistant Director (Observations & Engineering)

17 May 2006

Executive Summary

Introduction

1. The Basic Observing System Study 2005 (BOSS05) aims to identify the observing system necessary for the Bureau of Meteorology to deliver effectively and efficiently on its agreed outputs to Government over the next 5 to 10 years, as well as to develop end-to-end strategies for delivering that system, including strategies for migrating from existing to specified systems. Key requirements placed on the Study Team were that BOSS05 be strategic, pragmatic but thorough, that it draw on the work of previous similar studies, and that it involve a broad range of participants drawn from across the Bureau.

2. With a focus on the efficient delivery of the Bureau's overall national observations program, the study was broadened from the traditional 'basic' system to embrace the Bureau's overall (composite) multi-purpose observing system: that is, the system required to fulfill all of the Bureau's functions, including, inter alia, space-based observations, the observing networks previously considered to be 'special' rather than 'basic', such as Aviation, Defence and Atmosphere Watch, the new or more recently expanded areas of responsibility in the Bureau, such as National Tidal Centre and Australian Tsunami Warning System observing programs and networks, with consideration also given to inclusion of third party and shared observational data or systems.

3. The content of the newly titled **Bureau Composite Observing System (BCOS)** comprises all those components of the entire Bureau Observing System that are long term, robust and whose data and system performance are of known and suitable quality. In extent, it also includes components under developmental trial by the Bureau, which may not strictly satisfy the aforementioned three criteria, but which serve the primary purpose of attaining more effective BCOS performance. In depth, the boundaries of the BCOS are set by the point at which the end-to-end service delivery chain delivers observational data into the data handling or services systems. While the manner in which data are used and archived are thus technically outside the BCOS, the study team was well-equipped to offer some insights into how these could be improved to provide improved value for the Bureau from the BCOS.

Specification of Services Requirements for BCOS Data

4. Participation of a cross-program team in the conduct of BOSS05 facilitated the documentation of a comprehensive analysis of national and international service requirements. As well as being a milestone within the overall study, the analysis of national requirements was a significant achievement in its own right.

5. The effort required to complete this step, however, demonstrated that provision of quantified, scientifically objective and/or economically justifiable service specifications of data requirements are a key challenge for many service areas in the Bureau. A more analytical approach, assisted by targeted data impact studies and improved performance monitoring, would assist in developing and routinely updating specifications of services' requirements.

6. The study also revealed that some international specifications for data provision are too stringent to be scientifically achievable outside the laboratory, or, where scientifically achievable, to be economically impractical for countries other than the more densely populated and advanced nations of the northern hemisphere.

Adequacy and Value of the Current BCOS

7. The study provided a comprehensive description of the BCOS as it is currently configured and applied a number of methodologies to an assessment of its adequacy and value.

8. In some specific respects, particularly relating to the efficiency of operating the existing observations program, the current BCOS represents world's best practice. In scale and extent, the BCOS is similar to that of Canada, the country most like Australia in terms of economy, population and areal extent. At the same time, however, it was demonstrated that the BCOS falls short of meeting

national and international requirements for observational data, particularly in relation to spatial and temporal density, and adherence to climate monitoring principles.

9. The assessment highlighted many issues that have contributed to the increased difficulty in managing and operating the BCOS in recent years, with a key factor being the progressively tightening resource environment, in the face of growing user demands and a need for continuously increasing efficiency and accountability.

10. Key imbalances exist within the spatial distribution of observations, with a bias towards populated areas, and a climate requirement for a more even distribution of manual sites relative to AWS sites. The study identified specific deficiencies within individual user groups including more special purpose data for agriculture and more sophisticated measurements for aviation.

11. Automation has delivered some distinct benefits in coverage and frequency of data, but has also created some negative impacts such as a shortage of ‘visual’ element data, which are of particular value to climate and aviation service users. The demand for both AWS and weather radar coverage continues to outstrip the Bureau’s resources, with gaps in radar coverage identified over increasingly populous and industrialised provincial centres along the tropical coastline and at key inland locations.

12. The degree to which the BCOS represents ‘value for money’ in delivering outcomes is extremely difficult to assess and further work would produce valuable data to support current and future resourcing proposals. Nevertheless, it was apparent from existing studies and a number of proxy measures that investment in the BCOS provides excellent return on investment and contributes positively to service provision, including, inter alia, through improved assimilation of BCOS data, and especially satellite data, into NWP.

Trends in Requirements and Capabilities

13. BOSS05 documented trends and future expectations in service requirements over the coming decade and their implications for data requirements, and the opportunities that new and emerging technology may provide for the BCOS to deliver data more efficiently and effectively over the same time frame. The study also considered a range of operational and management issues likely to impact on the operation and effectiveness of the BCOS, including human and financial resource pressures, quality management, equipment lifecycle management, data handling and management, spectrum management, observational research and development, and shared or third party observing systems or data. Finding a sustainable balance between automated and manual systems, capitalising on efficiencies where possible but still meeting effectiveness criteria, will be an ongoing challenge.

14. Trends likely to impact on the design, operation and required deliverables of the BCOS in the future include:

- Service requirements are generally expected to become more demanding in all respects;
- Climate monitoring will demand significantly greater emphasis than it does today compared to weather service provision;
- Numerous opportunities are emerging for the implementation of more advanced and automated observing technology in the BCOS (wind profilers, AMDAR water vapour, video cameras, dual polarisation radar, hyper-spectral satellite sounders, redundant sensors, etc.), but many of these are yet to be proven as suitable for operational provision of data of adequate quality;
- Requirements for quality management are expected to increase, including the need for more formal accountability;
- Increasingly more stringent OH&S and regulatory environments will impose increased maintenance workloads and operational (human and financial) costs;
- Communications costs are expected to decrease as technology advances, and computing and communications security requirements are expected to increase;
- Increased demand and competition in relation to access to and protection of radiofrequency bandwidth;

- Need to explore more fully the scope for, and implications of, use of shared and third party data and systems.

Major Issues, Findings and Recommendations

15. In mapping out a proposed future strategy for delivery of the BCOS, based on extensive investigative and background analysis, the BOSS05 drew together a large number of major issues and individual findings which are submitted in the study report for the consideration of Program Managers. In many cases, they include specific recommendations, mostly for the consideration of ADO but given the cross-program involvement and end-to-end approach, some are also referred to other Program Managers for their consideration in planning their respective program activities over the coming decade.

16. Foremost amongst the findings of the study is a clear need for the Bureau to be making more effective and extensive use of satellite information, both to harness the intrinsic value and information of these data, and to explore the extent to which they can supplement and, in some circumstances, partially replace some more traditional surface-based systems, such as within the upper air network. There are proven benefits achievable in NWP assimilation of satellite data, but an increased effort in visualisation of data, such as for atmospheric temperature and moisture profiles, and in greater integration of satellite and in situ data in data display systems, will offer substantial advantages in data utilisation.

17. Operation of a robust and sustainable BCOS in the future requires a more structured long-term approach to the evaluation and implementation of new technologies. The study highlighted a number of emerging technologies at varying levels of maturity that may offer operational efficiencies and meet requirements more effectively. In assessing the potential value of new technologies, particularly automated systems, the full lifecycle cost must be taken into account, including operation, maintenance and end-of-life replacement. Some of the new systems already under development, such as the Next Generation AWS and SitesDb, have identified clear savings and operational efficiencies, and these should proceed on their development and evaluation tracks as soon as possible. The AMDAR program is also in this category and will benefit from high-level support for evaluation of humidity sensors and expansion of the national program. Wind profilers, while already implemented at several sites across the Bureau's network, require further evaluation with respect to their ability to replace wind-finding radar systems and deliver data appropriate to user requirements.

18. While there is an increased emphasis on automation and general assumptions about the ability of the program to operate with gradually decreasing staffing levels, the BOSS05 demonstrates that the Bureau has already achieved a high level of operational efficiency compared to many other national meteorological services and the scope for further real staff savings from automation requires careful consideration. There is an ongoing critical need for annual recruitment and training of TO (Observers) to refresh the skill levels and age mix of the program, especially considering the distributed nature of the field program and necessity for staff mobility. Similarly, engineering maintenance resources and staffing need to be consistent with the increasing reliance on automated system, with ongoing refreshment through TO (Eng) recruitment.

19. Perhaps not surprisingly, a clear message from services areas was the need for greater network coverage, particularly for surface observations and radar, and increased frequency of observations, particularly for surface and upper air observations. The extent to which more effective use of satellite data and application of some newer technologies can address these requirements requires more extensive investigation. There are some culture change issues to be addressed in increasing forecasters' confidence in a more composite network approach and reducing their reliance on more traditional data sources, such as manual visible observations and radiosondes. The study indicated an ongoing role for the latter, with a strong desire amongst users for restoration of a more extensive 12Z network, although some future rationalisation of the network may be possible once other sources, such as satellite derived profiles and AMDAR temperature and moisture profiles are operational.

20. The need for greater accountability in the operation of the BCOS was recognised through recommendations for more systematic performance reporting and introduction of a formal quality systems, preferably across the whole Bureau but at least within the Observations and Engineering Programs. Consistent information about system performance and operation would assist not only in

more effective whole-of-life planning, including operating, maintenance and replacement strategies, but also in assessing the value of observations.

21. Improved network design and quantification of impacts likely to flow, inter alia, from changes in observational coverage would benefit from the conduct of rigorous data impact studies. Currently, the Bureau is ill-served in this respect and a recommendation of the BOSS05 is the establishment of a data impacts group within BMRC.

22. To ensure seamless and high quality climate monitoring, any potential changes to the BCOS, such as new technology or revised techniques, should be fully evaluated prior to implementation and their introduction into operation should adhere to all elements of the climate monitoring principles, especially in respect of overlaps with existing systems.

23. To aid in focusing the study on the BCOS per se, the BOSS05 set the boundaries for when data effectively left the BCOS via various data handling routes. At the same time, the study took an end-to-end approach to ensure that any factors that impinged on how the data could be used more effectively were taken into account. This approach highlighted key deficiencies in the areas of data archival and retrieval, and data display. The former, data archival and retrieval, is an issue that tends to slip through the cracks in traditional program planning and there is no consistent Bureau policy that addresses it holistically. Multiple and diverse approaches exist, with little interoperability. Development and implementation of a standardised Bureau-wide policy is clearly an urgent requirement and would facilitate greater sharing and integration of data across the Bureau, especially if the concept of a data warehouse is to remain on the agenda.

24. Similarly, data display systems have traditionally been developed to meet the needs of individual observing and/or data processing systems, and there is no single display system that allows forecasters to compare or composite information from different sources, such as upper air data from satellites, profilers, AMDAR and radiosondes. For a composite observing systems to be used effectively, attention should be focused on such a universal data display concept.

25. The major issues, findings and recommendations captured in the BOSS05 vary in the degree of specificity, from those requiring an overarching corporate response to those focused tightly on single systems and/or users. These are expanded on in the full BOSS05 report and a list of the 62 recommendations to Program Managers, extracted from the full report, is annexed to this Executive Summary.

Proposed BCOS Strategy 2006-16

26. The study concluded that the BCOS could not be adequately maintained and developed over the coming decade within the currently-projected Observation and Engineering Program resource envelope. Such a resource constraint would render it impossible to meet services requirements for data and would lead to a corresponding decrease in service outcomes and, in particular, cause a long-term, negative impact on the national climate record.

27. The proposed strategy requires a significant short to medium term boost in investment to consolidate BCOS performance and enable development and implementation of alternative automated technologies. A more automated BCOS could then be implemented operationally and deliver, in the long term, significant and ongoing efficiency gains, in particular with regard to the human resource levels, enabling ongoing and sustainable operation of the BCOS into the future.

28. This new BCOS would be characterised by the supply of larger data volumes, but of reduced raw data quality. While automated systems appear unlikely to outperform manual systems in this respect, an upgraded BCOS quality management system and more optimal utilisation of data would at least maintain BCOS effectiveness at levels similar to those achieved today, in the face of expected increases in service demand.

29. Increases in short to medium term resource allocations required to test and implement more efficient solutions would be largely repaid through reductions in staffing and infrastructure. Modest ongoing savings should follow once the BCOS stabilises. The study suggests that there is no viable alternative to submission of one or more business cases to Government to acquire the additional resources required.

30. This recommended strategy for the evolution of the BCOS over the next ten years comprises four overlapping stages:

Stage 1: Consolidation of the existing BCOS (Years 1 to 4)

31. Stage 1 comprises a number of immediately practicable initiatives which address significant shortcomings in some key areas without making significant changes to the techniques and technology employed within the BCOS. It includes upgrades to satellite data reception, ingestion and applications software, immediate restoration of the 12Z radiosonde program, modest changes to surface observations networks and restoration of the Atmosphere Watch Program.

32. The incremental costs (over and above currently approved program) associated with this stage are +$7M Asset over 4 years, comprising $5.5M for Atmosphere Watch (principally the rebuilding of CGBAPS) and $1.2M for surface observing networks, plus $1.3M pa G&S and +10 ASL, primarily to enable restoration of the 12Z radiosonde program.

Stage 2: Overarching and underpinning initiatives (Years 1 to 4)

33. Stage 2 comprises initiatives mostly in program areas outside of the BCOS per se, which are aimed at indirectly improving BCOS effectiveness and data utilisation, and upgrading the Bureau's capacity to plan and provide for the BCOS. It includes upgrading the Bureau's performance, impact and value measurement capabilities, improved BCOS quality management and spectrum management, upgrading NWP, data display and data storage and retrieval systems, and developing means of utilising satellite data for climate analysis.

34. The incremental costs for this stage are +$1.4M Asset over 4 years, +$1.2M G&S pa reducing to $0.13M by Year 4, and +8.5 ASL for ongoing support of these initiatives.

Stage 3: Development and testing of new technology (Years 1 to 7)

35. Stage 3 comprises further development of satellite applications software, development and trialing of Next Generation AWS, WebConsole, SitesDb and an Input Observations Data Processing System, radar wind profilers, lightning sensors, automated evaporimeters, other advanced and automated sensors for providing visual element observations, new agrometeorological sensors, and unattended operation of the Autosonde. It also includes experimenting with a redundant sensor model for basic surface quantities, and investigating the needs for further expansion and upgrade of the weather watch radar network, and for multi-tiered networks, and third party and shared data and systems.

36. The incremental costs for all these initiatives include $1.4M Asset over 7 years, $0.4M G&S pa reducing to $0.2M after 4 years, and an additional 2 ASL.

Stage 4: Migration to a new and sustainable configuration for the BCOS (Years 1 to 9)

37. The last stage of the proposed strategy involves implementation of various new technologies, subject to their successful development and trialing, as a partial replacement for the manually-intensive technology currently employed. It includes:

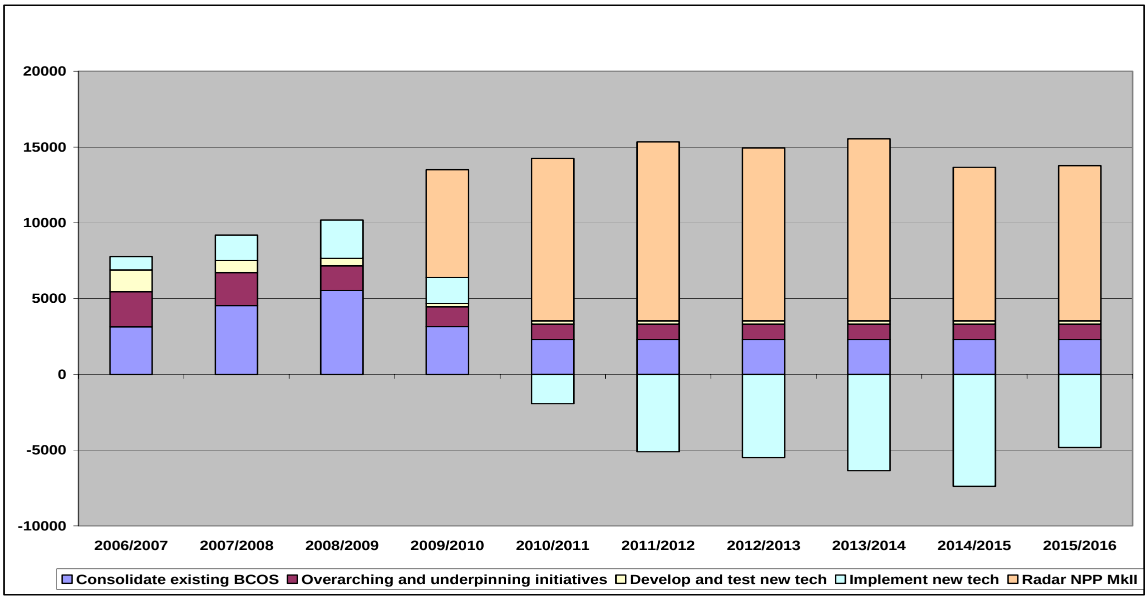
- Expansion of the AMDAR program, including deployment of advanced water vapour sensors on commercial aircraft;
- Deployment of boundary layer and stratosphere-troposphere profilers at many wind-only upper air sites and some existing radiosonde sites;
- Deployment of local lightning sensors on all AWS and the implementation of various other new technologies in the surface network;
- Establishment of a GPS water vapour network; and
- A major expansion and upgrade to the weather radar network.

38. The radar initiative alone may cost in the vicinity of $60M equity injection over 7 years (assuming 10 new radar sites, 4 high resolution Doppler radars, dual polarisation on all Doppler radars and digitisation of all radars in the network), incremental G&S expenses rising to $3M pa by year 10, and an additional 7 ASL by Year 10.

39. The remaining initiatives together are broadly costed at $23M incremental asset funding ($10M for wind profilers, $2M for AMDAR, and most of the remainder for various improvements to surface observing networks), incremental G&S increasing to $1.9M pa by Year 10, and incremental ASL peaking at +12 in Year 8 then reducing to an ongoing +8 by year 10.

40. Progressive implementation of all these initiatives should enable significant progressive field staff reductions during the period, enabling compensating savings as follows: $29M Asset (via reduced need for staff accommodation, meteorological office and observing system infrastructure), annual G&S savings of $0.2M, and a reduction of 70 field staff by year 10. The detailed structural changes to the Bureau's surface observing networks, including field office locations, were beyond the explicit scope of this study but the information in the study will provide a strong basis for development of this element of the strategy by the Program Manager.

41. The overall resource implications for all 4 stages are shown in the figure below.



42. In summary, excluding the radar initiative (the tan bars in the figure) for which a stand-alone NPP is suggested, the main implications are:

- The need for an additional injection of approximately $35M over the first five years, mainly in asset funds, $34M of which is required in the first 4 years;
- Significantly reducing costs from years 4 to 6, as compensating savings begin to take effect;
- Reduced net operating costs relative to current expenditure, from year 6 to 10 inclusive, due to further compensating savings (primarily in staffing and assets) achieved by the progressive migration of the BCOS to a more automated state, which should enable a payback of $12M over the five year period; and
- An ongoing steady state achieved by year 10 which provides an overall reduction of approximately $1.3M per annum in G&S and staff costs compared to present levels, potentially enabling a full refund of the remainder of the incremental expenditure incurred by approximately 2035.

Conclusion

43. The Basic Observing System Study 2005 (BOSS05) has identified an end-to-end strategy that will enable the BCOS to deliver effectively and efficiently on its agreed outputs to government over the next 5 to 10 years. The proposed strategy includes elements beyond the observing systems per se in order to ensure the data outputs of the BCOS are utilised effectively to deliver the specified service outcomes. The costed strategy requires a significant investment of resources but delivers partial offsets within the decade and more substantial offsets over an extended period. Executive support will be required for development of business cases for one or more New Policy Proposals. The strategy has considered whole-of-life costings for operation and support and for ongoing sustainability, and provides a sound framework for development of specific implementation plans within the Observations Program, such as network and field office configurations, and associated plans and strategies in other program areas, particularly Communications and all Services.

Recommendations to Program Managers

While the BOSS05 was initiated with the intent of providing advice to ADO, the inter-dependencies between programs, and the broad participation in the study, have identified a number of findings and recommendations which are presented for consideration by all Program Managers.

Recommendation 1
That more effective tools for quantitative assessment and monitoring of overall performance and impacts be developed and implemented. (All Program Managers)

Recommendation 2
That the removal of the efficiency dividend, and recognition of compensating factors, continue to be pursued. (ADE)

Recommendation 3
Continue to promote the ongoing free international exchange of data, particularly from satellites, including through active engagement in GEO/GEOSS. (ADE, ADO)

Recommendation 4
That the allocation of resources to the Observations Program, hence the delivery of BCOS outputs, be stabilized. (EXEC, ADO)

Recommendation 5
That the Observations Program be more fully enabled to utilise the ASL (or “Employee Expense”) resources allocated to it, including sustained annual recruitment of about 15 Observer trainees and short-term employment of non-ongoing staff to address current shortfalls. (EXEC, ADO)

Recommendation 6
That the Bureau continue to work with WMO and/or other international organisations who are responsible for specifying minimum standards for observation requirements of meteorological and related data such that the standards are sustainable and commensurate with the use of the data. (ADO, ADN)

Recommendation 7
That efforts be increased to measure performance, value and impacts, both of the BCOS as a whole and its various components, and of service outputs and outcomes. (All Program Managers)

Recommendation 8
That the need for installation of additional X-band ground receiving equipment be addressed to enable receipt of new generation satellite data at several key locations. (ADO)

Recommendation 9
That the Satellite Applications area(s) urgently upgrade existing applications software for ingestion of data from the new generation satellite platforms, including the retrieval of temperature and moisture profiles from satellite sounders, and develop new high priority applications as required. (ADO)

Recommendation 10
That data assimilation systems for the ingestion of satellite data from a wide range of new platforms be upgraded. (CSR)

Recommendation 11
That a flexible and universal data display system for the simultaneous display of data from multiple sources, including satellite retrievals, be developed and implemented within the AIFS/FSEP/GFE environment. (ADC)

Recommendation 12
That the Climate Services Program pursue the utilisation of new generation satellite data for climate monitoring and diagnostic purposes. (ADN)

Recommendation 13
That a detailed study be urgently commissioned into the impact on NWP of the recent 12Z radiosonde program reductions. (CSR)

Recommendation 14
That BMRC, in collaboration with the Observing Program, provide objective, scientifically based guidance on the use of adaptive sondes, to enhance the current manual synoptic assessment approach. (CSR, ADO)

Recommendation 15
That the radiosonde program be restored to pre-January 2005 levels, pending either partial replacement of the program by alternative technologies, or clear evidence from data impact studies of a lack of significant impact on NWP skill in critical weather situations. (ADO)

Recommendation 16
That the Observations and Engineering Programs work vigorously toward the reliable, unattended operation of the autosonde system. (ADO)

Recommendation 17
That reduced staffing at appropriate autosonde sites be trialled. (ADO)

Recommendation 18
That WVSS2 sensors be acquired for AMDAR-equipped commercial aircraft, subject to successful trialling of the instrument. (ADO)

Recommendation 19
That the expansion of the AMDAR program be accelerated to include the participation of additional airlines, and pursues the supply of AMDAR-type data by the commercial aviation sector. (ADO)

Recommendation 20
That the performance assessment of boundary layer wind profilers be expedited. (ADO)

Recommendation 21
That consideration be given to implementation of boundary layer wind profilers, including RASS equipped units where appropriate, in combination with AMDAR and satellite data, as a partial replacement for some sites in the radiosonde network, subject to suitable data quality. (ADO)

Recommendation 22
That a test-bed ST wind profiler for scientific and technical performance assessment be purchased. (ADO)

Recommendation 23
That consideration be given to implementation of ST profilers as a possible replacement technology at some upper wind only sites, subject to suitably reliable performance and data quality. (ADO)

Recommendation 24
That consideration be given to the installation of ART technology at sites where this will deliver a medium to long term cost saving, subject to the ART's ultimate commercial development and suitable operational performance. (ADO)

Recommendation 25
That the establishment of an operational program for acquiring GPS water vapour data, for assimilation in the Bureau's NWP models, be fast-tracked. (ADO)

Recommendation 26

That the proposed review of the weather radar network be carried out, with its primary focus on expansion of the existing network to include all areas deemed to be of high priority following extensive consultation with key stakeholders. It should also include consideration of needs for:

- Network-wide conversion of all existing radars to digital signal processing;
- Expansion of the doppler services network to include at least all major population centres, particularly the capital cities;
- Retention of back-up radars at capital city locations; and
- Implementation of dual polarisation capability at key locations. (ado)

Recommendation 27

That GPATS be urged to accelerate planned upgrades to its network, and to provide a more effective means for forecasters to monitor network status and data quality. (ADO)

Recommendation 28

That additional sources of lightning mapping data to supplement GPATS data be pursued. (ADO)

Recommendation 29

That the development of a real-time-reporting replacement for the aged LFC network, with the ability to discriminate between cloud-to-cloud and cloud-to-ground strikes, be expedited. (ADO)

Recommendation 30

That the Vaisala TSS928 lightning detection system be characterised, and its implementation continued at those locations where the detailed information can be beneficially utilised, particularly in support of aviation weather requirements. (ADO)

Recommendation 31

That current shortages of ‘visual’ element information accompanying surface observations be addressed, by accelerating the trialing and implementation of automated technology for providing this information. (ADO)

Recommendation 32

That the suitability of the current distribution of surface observing sites be reviewed, and changes made as opportunity permits, to ensure optimal effectiveness of the network in providing the data routinely required by all Bureau service programs. (ADO)

Recommendation 33

That consideration be given to provision of additional portable AWS units to each Region for emergency deployment in critical weather situations. (ADO)

Recommendation 34

That routine reporting frequencies from surface observing sites across the country be reviewed and standardised, to address current imbalances to the extent possible, given the differing requirements for data from one site to another. (ADO)

Recommendation 35

That the capability for provision of higher frequency data on demand in critical weather situations from automated surface observing sites be implemented. (ADO)

Recommendation 36

That the current shortage in the availability of information essential for delivery of services to the agricultural community and for water resource assessment, such as soil temperature, solar irradiance, evaporation, evapotranspiration, and soil moisture data, be addressed. (ADO)

Recommendation 37
That the current paucity of evaporation measurement in the BCOS be addressed, and the feasibility of deploying automated evaporimeters at strategic sites, and the feasibility and acceptability to users of relying more in future on derived evaporation data, be urgently investigated. (ADO)

Recommendation 38
That potential techniques for effective measurement of soil moisture at selected surface sites, and snow depth and cover at alpine sites, be investigated. (ADO)

Recommendation 39
That the development and implementation of the Next Generation AWS and WebConsole systems be fast-tracked. (ADO)

Recommendation 40
That significant resource increases be provided for specialised climate-only monitoring networks by:

- Ensuring that the Cape Grim BAPS building infrastructure is refurbished or rebuilt as planned in FY2008-09 and that its aged monitoring and analysis equipment is replaced; and
- Ensuring there are sufficient specialist staff to maintain on-going functions in atmospheric chemistry, ozone, radiation and metrology; and
- Restoring and then maintaining the Solar and Terrestrial Radiation, Ozone; and BAPMoN station numbers to those indicated in the Slatyer-Bonner Review. (ADO)

Recommendation 41
That current significant shortcomings in the provision of metadata associated with BCOS observational data be addressed. (ADO)

Recommendation 42
That a project development plan to address current and future needs for modernising meteorological codes used to transmit data, both domestically and internationally, be developed. (ADO, ADC)

Recommendation 43
That the development and implementation of a Next Generation SitesDb system, that can accommodate current and anticipated future requirements for all relevant Bureau metadata, be pursued. (ADO)

Recommendation 44
That development and implementation be pursued, in parallel with the Next Generation SitesDb system and revision of meteorological codes, of the Incoming Observations Data Processing (IODP) environment. (ADO)

Recommendation 45
That the Observations Program clearly reflect within its longer term strategic plans the impact of significant staff reductions in the program, so that planning and implementation of adjusted program deliverables may be effected in a timely fashion. (ADO)

Recommendation 46
That a working group be established, under the leadership of the Observations Program, to further consider the draft recommendations of the BOSS05 Task Team on Quality Management, and specifically to develop a project to identify and implement a formal quality management system that suits the Bureau's needs and those of its users. (ADO)

Recommendation 47
Ensure that, wherever operational observing techniques are modified in any way, provision is made for suitable periods of parallel operation of old and new techniques, so that the overlapping measurements can be used to provide adequate data traceability from one measurement system to the next. (ADO)

Recommendation 48
Ensure that equipment purchase and design takes into account the need to minimise maintenance requirements while maximising data quality and continuity, using appropriate technology, and that these factors in addition to more accurate and transparently linked equipment lifetime depreciation, lifecycle maintenance costs and funds allocation be properly accounted for within the Asset Replacement Program and the routine operational budget. (ADO)

Recommendation 49
That engineering maintenance requirements for new automated equipment are fully ascertained prior to installation and that the implied human resource expenses are factored into implementation plans.(ADO)

Recommendation 50
That the trend towards standardising service level requirements for outages of all equipment is continued. (ADO)

Recommendation 51
That implementation of new generation communications technology in the existing AWS network, to achieve greater economy of communications in the short term, is pursued. (ADO)

Recommendation 52
That the Bureau take a greater lead in national spectrum management for and through WMO, ACMA, the APT and ITU-R to minimise the risk of future loss of spectrum. (ADO)

Recommendation 53
That high priority be given to exploring more fully the merits of involvement in shared and/or third party data or systems, and that policy for Bureau involvement in these systems be developed to reflect the current situation and possible future initiatives. (ADO, ADN, ADS)

Recommendation 54
That high priority be given to exploring more fully the merits of adopting a tiered network model for the BCOS. (ADO, ADN)

Recommendation 55
That a trial of the redundant sensor model for some basic quantities measured by AWS, be initiated to assess suitability of the model for operational implementation. (ADO)

Recommendation 56
That a ‘rolling’ BOSS model for observing system planning be adopted. (ADO)

Recommendation 57
That improved measurement and routine monitoring of the impact of observing system upgrades on outcomes, including data quality and performance of services, be pursued. (ADO, ADS, ADN)

Recommendation 58
Conduct a detailed study into its needs for data storage and retrieval, and implement an appropriate system which enables ready access to all data types by all data users. (ADC)

Recommendation 59
Urgently address current significant limitations in our ability to simultaneously display data from a wide range of different sources. (ADC)

Recommendation 60
That a dedicated group be established to strengthen efforts in assessment of data impacts. (CSR)

Recommendation 61
That the Observations, Engineering, Hydrological Services and Training Programs perform a detailed assessment of the potential operational benefits and training implications of cross-program

collaboration for field equipment maintenance and inspection, and implement more formal and widespread arrangements as appropriate. (ADO, ADN, ADE)

Recommendation 62

That the Observations, Engineering and Hydrological Services Program examine the potential for utilising the combined resources available for network management and operation more effectively and efficiently in achieving desired Bureau outcomes. (ADO, ADN)

1 Introduction

1.1 Background

In recognition of the need for a thorough review of the Bureau's Observing System, ADO advised of the intention to carry out the Basic Observing System Study 2005 (BOSS05) in a minute to the Bureau Executive of 24 November 2004 (see Attachment 1). Accompanying that minute was a Concept Paper laying out the requirements of the study: its aim, scope, participation and draft Terms of Reference (also at Attachment 1). The key requirements of BOSS05 were that it be strategic, pragmatic but thorough, that it draw on the work of previous similar studies, and that it involve a broad range of participants drawn from across the Bureau.

Set within the context of the next five to ten years, BOSS05 was to identify the observing system necessary to deliver effectively and efficiently on the Bureau's agreed outputs to government, to develop end-to-end strategies for delivering that system, and to recommend strategies for migrating from existing to specified systems.

The Bureau Executive endorsed ADO's proposal at its meeting 2004/20 of 09-10 December 2004 (see Item 2 of Attachment 2). After further scoping by the Study Leader during December 2004 - see the BOSS05 website at:

http://oebwiki.bom.gov.au/twiki/bin/view/OEB/BasicObservingSystemDevelopment

- the study itself was carried out between February and October 2005, under the guidance of the BOSS05 Steering Committee. BOSS05 was performed by a Study Management Team chaired by the Study Leader and comprising 12 senior officers from across the Bureau, assisted by numerous other contributors from key Bureau program areas. Further details of how the study was performed are at Attachment 3.

1.2 Report Structure

The full report for BOSS05 comprises a collection of individual detailed task reports by respective Task Teams which can be accessed, by those seeking more detail of the work performed than is included in this summary report, on the BOSS05 website (as detailed above).

BOSS05 commenced with a review of previous similar studies, which are detailed in Section 2 below. Section 3 discusses the concept of the Basic Observing System in its more recent, expanded, context, and how for this study the term Bureau Composite Observing System (BCOS) is used, rather than Basic Observing System (BOS), to avoid confusion with historical meanings and to stress the necessarily composite nature of the Bureau's observing system today. Section 3 also describes where the boundaries between the Observing System and the Data Handling and Service Provision Systems were drawn for BOSS05.

Of the more important services provided to the Australian community by the Bureau are its roles in fulfilling Australia's obligations for the international exchange of meteorological and related data under WMO Resolution 40, and in participating with the rest of the world in a number of international scientific programs. Australia is obliged to make data available to other countries and to those international programs, to agreed specifications drawn up by, e.g., WMO (through its GOS), and UNEP (through GCOS). Section 4 lists these international specifications and guidelines, which have implications for the requisite shape and size of our BCOS. In Section 5 our own national requirements for the BCOS are summarized, as dictated by the service provision process for the range of services the Bureau delivers to the Australian community.

Section 6 contains a summary description of the existing BCOS: what it comprises today. This includes both the observing networks and platforms owned and used by the Bureau and also the data sourced to supplement our own from other organisations or through cooperative arrangements. The analysis includes consideration of data quality and radiofrequency spectrum management, data handling and communications, and the equipment lifecycle management strategies currently employed.

Section 7 examines the adequacy of the existing BCOS in satisfying the Bureau's total requirements for service provision. It first addresses how well the existing BCOS satisfies both international requirements as described in Section 4, and the Bureau's own requirements for data described in Section 5. Lastly, it gains a different perspective on BCOS adequacy by comparing and contrasting Australia's BCOS with those of some other countries.

Section 8 examines the value of the BCOS. It first endeavours to assess 'value for money' in delivering outcomes by summarising what we know of the economic value of the BCOS to the Australian community, then turns to an examination of the impact of some of its individual components or program elements on outputs products, such as NWP. Last, it attempts to gauge the impact on outputs of previous changes to the BCOS.

Section 9 turns to the future. It deals with recent trends and expected changes in service requirement over the coming decade and their implications for data requirements, and the opportunities that new and emerging technology may provide for the BCOS to deliver its data more efficiently and effectively. It considers expected changes in requirements and opportunities for quality management, equipment lifecycle management, data management and communications and spectrum management, and it briefly discusses the prospects for future involvement in shared or third party observing systems or data.

Section 10 specifically highlights the more critical issues, either existing or anticipated, identified in the course of BOSS05 and details 62 specific recommendations for the BOSS05 Steering Committee to consider to ensure the future integrity and effectiveness of the BCOS. Section 11 then takes these into account in discussing options for the future evolution of the BCOS, and laying out a plan for the next decade. It describes a realistic pathway to overcome existing BOS shortcomings in the next few years, looks ahead at the broad makeup of the BOS we will need to have in place by the year 2015, and proposes strategies for achieving that target state during the coming decade. It provides approximate funding and staffing implications for each initiative, and discusses the main advantages and disadvantages of the recommended strategy overall.

2 Previous Studies Related to the BOS

Since the early 1980s the Bureau has performed a number of studies concerned, at least in part, with observing system design and requirements. The more notable of these studies are:

- 'The Year 2000 Basic System: An Infrastructure Specification', Coleman et al, 1990 (BS90).
- 'Defining the Basic Observing System', Sharp et al, 1995 (BOS95).
- 'Report to ADO on the 2001 Observing System Study for Staffed Observing Offices of the Bureau of Meteorology', Stickland et al, 1996 (OSS96)
- 'The Basic Observing System', Sharp et al, 1995- (BOS2)

These studies together provide a great deal of useful background to BOSS05, though none is entirely relevant to the present study either due to the passage of time, or because their focus was somewhat different to that of the present study. A brief commentary on each is provided as Attachment 4.

3 BOS/BCOS Concept

3.1 Breadth of the BOS/BCOS

Each of the previous studies listed above examined a particular sub-set or aspect of the Bureau's overall observing system. In BS90 the word 'Basic' meant that part which should be publicly funded, as opposed to those primarily to be funded on a 'user pays' basis. In BOSS95 and BOS2, 'Basic' carried a more hybrid meaning. As well as excluding 'specialised' networks, such as aviation (user pays), it also meant 'minimum': the aim of that study was to describe the minimum tolerable surface-based observing system, or that which the Bureau would 'be willing to die in the trenches' to protect from further erosion or degradation. OSS96 had a different focus again and was concerned almost solely with ways to rationalise and modernise the observing programs at the Bureau's staffed observing stations, in order to cope with lower field staff numbers and enable the sale of some Bureau housing, rather than a study of the service-oriented observing networks and programs per se.

As is clear from the ADO-specified Scope and Terms of Reference for BOSS05 (see Attachments 1 and 2), the present study was to have a much broader focus than each of the previous studies. It concerns the Bureau's entire, overall (composite), multi-purpose (integrated) observing system: the system required to fulfill all of the Bureau's functions, including, inter alia, space-based observations, the observing networks previously considered to be 'special' rather than 'basic', such as Aviation, Defence and Atmosphere Watch, the new or more recently expanded areas of responsibility in the Bureau, such as NTC and ATWS observing programs and networks, and explicitly includes third party and shared observational data or systems used by the Bureau.

To avoid potential confusion as to what is meant by the term Basic in the context of this study, and to stress the composite view that must be taken of the Bureau's observing system today, the term 'Basic Observing System (BOS)' was replaced with 'Bureau Composite Observing System (BCOS)' in this study. Herein, the term BCOS refers to all those components of the entire Bureau Observing System that are long term, robust (well-supported) and whose data and system performance are of known and suitable quality. It also includes components under developmental trial by the Bureau which may not strictly satisfy the aforementioned three criteria, but where the primary purpose of the trial/research is on attaining more effective BCOS performance (via, e.g., use of new observing technology or techniques, increased observing system performance, or improved observational data quality).

3.2 Boundary of the BCOS

At what point along the end-to-end service delivery chain is the boundary of the BCOS? i.e. At what point does a data stream make the transition from the Observing System into the Services System, or the sometimes fuzzy middle ground perhaps separate to both that might be referred to as the System?

In BOSS05 the boundary between the Observing System and the Data Management and/or Services Systems in the end-to-end service delivery chain was chosen after first describing the end-to-end functions of the overall Bureau service-driven product delivery process: from the initial recognition of a service need, through planning for, and implementation, operation and lifecycle management of the necessary observing infrastructure and program required to deliver the data needed for that service, through to output data transmission, processing and storage, then product preparation, display, dissemination and storage. Many of these functions fit either wholly within the Observing System or wholly within the Services System, but there are a number which might be viewed as either, or both, or perhaps neither, and lie in the domain of the Data Handling System instead. To resolve these uncertainties for the sake of the present study, the boundary of the BCOS was somewhat arbitrarily defined as that point at which the output data stream from a particular observing instrument, platform or network first splits into multiple data streams enroute to the service areas utilising the data.

It is of particular note that neither the development nor management of data display systems is considered to be part of the BCOS for the purposes of BOSS05, nor, necessarily, is data archiving, though clearly the BCOS is an important stakeholder in each of these processes, and each is of particular importance to the BCOS. Hence they are both considered further in what follows (see, e.g., Section 10.6 below).

4 International Requirements for Data

As a member nation of WMO and participant in a number of international meteorological and related programs, Australia is obliged to satisfy a range of internationally-specified requirements for the international exchange of data. For some of the more recently evolved or evolving observing system components, firm guidelines on what is expected of member nations have yet to be agreed. For most observing system components, however, detailed specifications are available which provide useful guidance on the minimum and target requirements for the BCOS to fulfill these international obligations.

Because such international specifications carry the authority of WMO and reflect the consensus of leading international scientists, they can provide a sound foundation for mapping the minimum requisite characteristics of the BCOS.

Of the numerous international specifications available, the primary reference document is the Manual on the Global Observing System (WMO No 544), which specifies 'what is to be observed where and when in order to meet the relevant observational requirements of WMO Members'. A related publication, the Guide on the Global Observing System (WMO No 488) provides detailed guidance on how to establish, operate and manage networks of stations to make these observations.

Other relevant documents containing guidance material on the requirements for specific component networks, or on requisite instrumentation and observational information, include: the Guide to Meteorological Instruments and Methods of Observation (WMO No 8), the International Cloud Atlas (WMO No 407), the Manual on Codes (WMO No 306), the Guide on Meteorological Observation and Information Distribution Systems at Aerodromes (WMO No 731), the Guide to Marine Meteorological Services (WMO No 471), the Guide to Climatological Practices (WMO No 100), the Guide to Agricultural Meteorological Practices (WMO No 134), the Manual on the Global Data Processing System (WMO No 485), the Guide to Hydrological Practices (WMO No 168), the Guide to GCOS Surface and Upper Air Networks: GSN and GUAN (WMO GCOS Report No 73) and the Global Atmosphere Watch Measurements Guide (WMO TD No 1073).

5 Bureau Service Requirements for Data

Additional to the international requirements for data from the BCOS are Australia's own incremental requirements. These are primarily driven by the need for the Bureau to fulfill its service obligations to the Australian community, so are in turn dictated by the data needs of the various Bureau output service programs.

To construct an overall specification of Bureau requirements of the BCOS, each of the Bureau's output service program areas was consulted to obtain information on the range of service products provided by that service and the service provision process involved in each case, hence the observations required to deliver those services, with particular focus on the quantities to be measured, allowable measurement uncertainty, temporal and spatial resolution, and reliability and timeliness of delivery. The resulting specifications for each service area (see the BOSS05 website for details) were then composited to provide a summary specification, which is presented as Attachment 5.

6 The Current BCOS

The current BCOS is summarized below. As with each of the other BOSS05 topics, more complete details can be found on the BOSS05 website at:

http://oebwiki.bom.gov.au/twiki/bin/view/OEB/BasicObservingSystemDevelopment.

6.1 Observing Networks and Platforms

Most BCOS networks and platforms are currently administered by the Bureau's Observations Program with support from the Engineering Services Programs, though some smaller, more specialised components come under the Hydrological (most of the hydrological networks) and Ocean (tidal and tsunami networks) Services Programs and the Research Program (e.g. the proposed CP2 radar). Those managed by the Observations Program, with the notable exception of satellite platforms, are generally fully owned and operated by the Bureau, whereas, e.g., the hydrology networks include many shared sites or use sites managed and operated by external organizations, either government or commercial, as is much of the tidal network.

Overall the BCOS comprises approximately 8100 surface-based observing sites plus a number of satellite platforms, with many of these contributing to at least several Bureau output service programs.

The surface-based sites comprise:

- 58 Bureau staffed observing stations on the mainland, surrounding islands and Antarctica, each fulfilling a composite function and contributing to each of the surface, upper air, hydrology and climate networks;
- ~500 cooperative observer sites at which the observer is remunerated either for the observations made or for maintaining equipment (approximately 220 of these are equipped with an Automatic Weather Station, or AWS);

- ~330 unstaffed AWS sites (about 20 or these are owned by external organizations, with the Bureau receiving the data in realtime);
- ~6800 volunteer observer sites, most observing rainfall (and/or river height);
- ~100 ships of the Australian Volunteer Observing Fleet, several deploying Expendable Bathy Thermographs in addition to making regular synoptic observations;
- ~300 other unattended 'sites' on land or at sea equipped with a weather radar, lightning sensor, drifting buoy, or other specialized observing equipment.

The space-based observations component of the BCOS involves

- Direct reception of satellite data via a network of 19 ground-based antennae;
- Provision of systems for accurately positioning geostationary satellites (a small but important contribution from australia to international satellite operations);
- Derivation of physical parameters from received satellite data; and
- Acquisition of processed data from sources external to the bureau.

6.2 Staff Resources

Weather observation was historically an inherently manual activity, requiring the interpretation and description of prevailing conditions as well as reading values off measuring devices. The Bureau's operations are now more automated but still require manual involvement for some observations, for at-source quality management, for system operation and general station management, plus the supporting network and systems planning and management. Current staff level requirements for the operational program are 203 observers to maintain Field Office operations, 32 Regional Observations Section staff to maintain site inspections, quality management and network management activities, plus a number of observers in RFCs and in Head Office, as well as regional engineering services staff. Additional staff numbers in Head Office fulfill program planning and management functions.

6.3 Quality Management

To gauge the status of quality systems in the BCOS, a survey was conducted, as part of BOSS05, of a majority of groups in the Bureau involved in the provision of observational data to internal and external users. The survey gathered information related to an end-to-end quality framework covering six main quality processes: specification, design, implementation, measurement, assurance, auditing and internal feedbacks (see the Flow Diagram at Attachment 6).

Overall, the survey indicated that although most of the data streams within the BCOS involve some form of quality management, the treatment of quality in the BCOS tends to be more ad hoc than formal, and highly variable from one data stream to another.

There is confidence in the specifications for data provided either by data users or the professional judgement of data providers. Similarly, most providers are confident that their data come from well-controlled measurement systems, and that the data quality is assured to some quantitative level. On the other hand, about half of the data streams examined are provided with no accompanying indication of quality. Notably, more than half of the providers reported that essential components of their quality system are handled either by other Bureau groups or externally, a reflection of the Bureau's matrix management structure. A significant number of providers reported that WMO guidelines contribute to the documentation of their quality system. About two thirds have confidence that their quality system is effective: one third do not. According to the survey, less than 60% of data streams employ audit processes within the quality system. Of those that do, the overwhelming majority employ only professional judgement and/or field trips as the audit method. There is little apparent use for auditing of end-to-end data tracing or reference to user requirements. Almost 40% of respondents indicated that they receive only very infrequent feedback from users on data quality.

6.4 Equipment Lifecycle Management

A number of Bureau programs are responsible for the observation equipment and the supporting communications equipment in the networks comprising the BCOS.

For the replacement of these network assets, the Bureau is appropriated funds that are linked explicitly to the estimated depreciation expense. The internal Bureau resource allocation process for the asset replacement is an integral component of the annual and 5-year planning cycles and is based on an ongoing assessment of needs and priorities through all elements of the organisation including consideration of costed multi-year Project Development Plans for all major new projects.

Equipment replacement procurement strategies include purchase of existing equipment, and development through in-house, contract or collaborative arrangements. In some instances equipment may be provided by outside organisations in a mutually beneficial arrangement. Equipment procurement is undertaken by staff within each program. The Engineering and Management Programs manage the installation of larger equipment and facilities such as radars and field offices.

The primary objective of the ongoing maintenance strategies is to maintain the BCOS networks' equipment and related infrastructure in a cost effective and timely manner to ensure their availability to meet the operational requirements of Bureau programs. Equipment maintenance strategies include preventative maintenance and repair / replacement on failure, including refurbishment of equipment and major components. Maintenance activities are carried out by Head Office and Regional staff, or by external contract. Quantitative and qualitative performance of the equipment and its maintenance is recorded and monitored to a greater or lesser degree by the programs, primarily through use of the SitesDb system, which is a very useful tool but is in need of updating.

A mix of specialist program staff, mainly from the Engineering and Observations Programs, and other program staff carries out maintenance activities. It is mostly restricted to business hours maintenance due to limited staff resources. However, there are some instances where emergency callout is used to repair essential equipment. Key influences are:

- The lack of formal specified service levels which affects the scope of, and availability of resources for, emergency maintenance;
- The want of a clear sustained link in the funds allocation process, especially for G&S, to the maintenance and asset requirements of the network. Funding levels (Assets and G&S) are key influences on both field maintenance and stock levels; and
- The increasing imposition on maintenance workloads and staff responsibilities by the changing OH&S and the Regulatory environment.

6.5 Reporting, Communications and Data Management

The individual observing systems reviewed in this study were radars, wind profilers, radiosondes, AWSs, EFB, ROCS, flood warning networks (including external agencies), the rainfall intensity (pluviograph) network, the daily rainfall network, GPATS, satellite reception (GMS, NOAA, FY), climate observations, AMDAR, drifting buoys and ship reports. Basic communications and data flow information were sought from respective observing program areas for each system and the responses received are summarized in the Table at Attachment 7.

There are variations between each observing system, and within some systems, with respect to the systems and parameters being monitored, the communications methods, the frequency of observations and data volumes. There are however, some similarities in the AWS and EFB systems in that the parameters being measured are similar.

As a result of these differences, each of the observing systems has tended to be developed independently, with communications systems established to suit the particular system's requirements.

All observing systems rely on communications systems to relay their data from the observation point to a collection point (usually at HO or the ROs) and after processing and archiving, are distributed as various products, bulletins and/or graphic presentations. Communications methods are many and varied, and include distribution via international GTS links, radio telemetry, PSTN, satellite links, direct data lines and connections to the Bureau's private communications network and Weathernet. Where possible, commercial communications systems are used, but a number rely on specific arrangements (eg. specific VHF frequency allocation for flood warning systems, specific provision made by the ITU for wind profilers, etc.)

6.6 Spectrum Management

The main uses of the electromagnetic (radiofrequency) spectrum by the Bureau of Meteorology are for meteorological observation (monitoring) and meteorological communication (collection and dissemination of meteorological data, forecasts and warnings). The meteorological observation systems utilising the electromagnetic spectrum include radars, radiosondes, meteorological satellites and wind profilers.

The Bureau, through its Spectrum Management Working Group, protects its use of the electromagnetic spectrum by maintaining close contact with the Australian Communications and Media Authority (ACMA) on all matters affecting meteorological radiofrequency issues. The Bureau is represented by ADO on the ACMA-sponsored International Radiocommunications Advisory Committee (IRAC), and other Bureau officers on various Australian Radiocommunications Study Groups (ARSGs) which provide expert advice to the ACMA on issues that might affect the Bureau's operations. In turn, Australia influences the direction of international radio regulations through membership of the Asia-Pacific Group of the International Telecommunication Union's (ITU) World Radiocommunications Conference (WRC) and by direct representation at the 4 yearly WRCs. The Bureau is also represented on the WMO CBS Steering Group for Radio Frequency Coordination, which helps to ensure a more global approach to protection of meteorological spectrum. The diagram at Attachment 8 illustrates these spectrum management activities.

7 Adequacy Assessment

7.1 How Well the BCOS Satisfies International Requirements

The current BCOS was assessed against the international specifications for Climate Services, Atmosphere Watch, Weather Services, Hydrological Services and Oceanographic Services referred to in Section 4 above. Attributes such as uncertainty, horizontal and vertical network resolution, observation frequency and data timeliness were considered. Generally, the current BCOS does not fully meet the international guidelines for any of the Programs considered.

The current BCOS follows all long-term climate monitoring principles to some degree. Almost all are supported by current Bureau policy, but resource deficiencies sometimes mean they are not fully implemented.

Australia's GCOS Surface (GSN) and Upper-Air Network (GUAN) stations generally meet the minimum requirements for station selection criteria, as well as some of the more stringent target requirements. However, an examination of the draft GCOS requirements for Essential Climate Variables reveals that the surface temperature and dewpoint networks fail to meet the minimum spatial density through much of inland Australia. Upper-air temperature and wind networks almost meet the minimum spatial separation in coastal regions but are lacking in the interior. These networks also fail to meet observation frequency requirements. There are 16 terrestrial climate variables for which no national network exists. While it is probably inappropriate at present for the Bureau to take responsibility for most of these variables, there are some (eg. soil moisture) that might be considered for future inclusion in the BCOS.

GCOS uncertainty guidelines for most surface and upper-air Essential Climate Variables are generally not met. However, it appears that some of the recommended targets have little theoretical basis and it is assumed that they have been developed with future technological advances in mind. Nevertheless, this failure highlights the need to utilise technological advances to improve uncertainty in the field wherever possible.

Global Atmosphere Watch specifications are mostly met but Cape Grim Baseline Air Pollution Station does not meet specifications for ozone sondes and total column ozone. Also, due to difficulties with representativeness of sites, the current BCOS does not include the measurement of surface radiation budget at all.

The BCOS surface networks generally do not meet the minimum requirements for the Global Observing System. Coverage is better in populated regions, but there are large gaps inland. The upper-air networks also fail to meet requirements, both in terms of horizontal resolution and observation frequency. Similarly, the Bureau's networks generally fail to meet spatial density guidelines for the Hydrological variables through many inland parts.

Oceanographic requirements are being addressed by the phased implementation of the Ocean Observing System. Implementation levels of the Australian components are generally similar to, or more advanced than, the overall global status. However, even with full implementation of current projects, distribution of some components, such as drifting buoys, is likely to remain inadequate in waters surrounding Australia.

Horizontal spatial resolution requirements are generally not satisfied in the interior, underlining the importance of preserving remote stations and looking for opportunities to use satellite data. However, these results not only point to inadequacies in the networks, but also requirements that are clearly not realistic. In such cases there is a need for more realistic international guidance. Routine data impact studies to measure the consequences of departures from the standard are also needed. Requirements related to observation frequency are generally not met for manual and upper-air components of the observation system. Where assessed, the timeliness of data generally meets international requirements.

7.2 How Well the BCOS satisfies Bureau Requirements

The adequacy of the existing BCOS was assessed by comparing it against the Bureau's own service-based requirements, which were considered in Section 5 above. In most respects and for most services, the Bureau's service program requirements for data mimic those of the international specifications discussed above; these are not further elaborated upon here. For the provision of some services, however, the Bureau's own requirements for some particular data types are more stringent than the international requirements.

In general, the data provided by the existing BCOS are considered to be inadequate for the optimal delivery to the Australian community of the high quality meteorological and related services expected of the Bureau. Whereas data uncertainty, reliability and timeliness of delivery tend to be viewed by most service provision areas as generally satisfactory, attesting to ongoing efforts made by the Bureau to implement and operate robust, high quality observing systems, available data resolution (both spatial and temporal) tends to fall short of the expectations of most service areas.

For a number of service areas (e.g., public weather, agriculture, water resources, climate), the distribution of existing surface observing sites tends to be too heavily weighted towards populated areas, with too little data available from the remoter or less populated areas. Climate services require a more even distribution of manual observing sites relative to AWS sites. Agricultural services require more special purpose data (soil temperature, moisture, wind run, sunshine duration, evaporation) from agriculturally sensitive areas, and the hydrological services require more observing sites inland.

Surface data over coastal waters are lacking, leading to too great a dependence on observations from more than 50m inland from the shoreline for the provision of services over coastal waters.

Observational data for aviation services are considered insufficient, particularly at smaller aerodromes which can lack basic information on surface conditions, but also at major airports, where there is a perceived need for much more detailed meteorological information, such as that obtained from wind profiler and Doppler radar systems.

The relatively recent trend towards use of automated, rather than manual, surface observing techniques, has created a clear shortage of visual element data (visibility, cloud type, present and past weather) for most service areas, notably aviation and climate.

Disaster mitigation services identify a currently unfulfilled need for access to more data from portable AWS units that can be located as required, particularly during fire events.

Although the Bureau's weather radar network has grown considerably over recent decades, in both the quality and extent of coverage, most service areas identify an urgent need for further improvement to the network. New radars are required to cover additional densely populated provincial areas and to fill gaps in coverage along coastlines affected by tropical cyclone activity. Significant extension of Doppler radar coverage is seen as a high priority, to include more densely populated areas and, as noted above, the major airports.

Available information on lightning occurrence across the country is considered by most service areas to be inadequate, particularly in the north and west of the country.

Weather service areas, in particular, consider the volume of available upper air data to be inadequate, in particular the observational frequency and spatial density of upper air temperature and moisture data.

The climate services area requires closer adherence than currently achieved by the BCOS to the ten climate monitoring principles adopted by the United Nations Framework Convention on Climate Change in 2003 (see Attachment 9). The Bureau has had difficulty in meeting the first and foremost of these principles: "impact of new systems or changes in existing systems should be assessed prior to implementation", pointing to a lack of adequate change management in the BCOS.

Further shortcomings in the BCOS that impact on climate service provision are:

- Some very poor quality data;
- Too much missing data;
- Poor density of observations, including large spatial gaps;
- Lack of metadata with which to address inhomogeneity issues (e.g. changes in algorithms);
- Lack of knowledge about performance of our networks and systems;
- Inability to attach an appropriate assessment of 'uncertainty' to an observation; and
- The relatively poor state of terrestrial-based climate observations for Australia (e.g. snow, soil moisture).

7.3 How the BCOS Compares with Those of Other NMHSs

An additional measure of adequacy was obtained by comparison of the BCOS with the observing systems of several other countries, both developed and developing. The countries selected for this comparison, and the main reasons for their inclusion, are:

- USA: A well-resourced nation of similar geographical size to Australia;
- Canada: A country of similar size, demography, development and prosperity;
- UK: Represents a typical small European nation;
- South Africa: Represents Africa, albeit at the prosperous end of the spectrum;
- South Korea: Represents a rapidly developing Asian nation; and
- Indonesia & New Zealand: Our nearest neighbours.

Demographic information was obtained for each country where available, and the following observation parameters and platforms were selected to represent a relatively broad view of the various nations' observing systems.

- Synoptic stations (land based and ships)
- Upper Air Stations
- GCOS Networks

- Satellite hardware and support infrastructure
- AMDAR
- Rainfall networks
- Atmospheric watch stations
- Weather Watch Radar coverage, and
- Marine Buoys and Argo Floats

Attachment 10 provides a summary of the statistics obtained. The comparison suggests:

- Networks in Europe are excessively dense;
- Network densities within developed and strongly developing nations are strongly correlated with population density distributions as is the case in Australia;
- AMDAR and Ship-based networks are constrained to transport routes, and are generally most comprehensive in the Northern hemisphere, particularly North America, North Atlantic and Europe;
- The observing systems of Australia and Canada, the most similar country to Australia overall, compare well with each other. (The greater density of the Australian hydrological network attests to the greater importance attributed to water resources in Australia);
- The UK observing system has a far greater density than the Australian BCOS.
- Australia's limited contribution to satellite technology suggests that current arrangements are well in our favour;
- The weather watch radar network in Australia is substantially less dense, on average, than most other nations. Excluding consideration of our sparsely populated areas, radar network density in Australia compares unfavourably with the UK, USA & South Korea. Not noted in Attachment 10 is that Doppler capability exists on most of the radars in the more developed countries examined; and
- AMDAR numbers in Australia are somewhat lower than for the developed nations of the Northern Hemisphere.

Overall, The BCOS rates poorly when compared with the observing systems of the geographically much smaller European nations and with that of the far more populous USA. It is in many respects similar in scale and extent to that of Canada, the country most like Australia in terms of economy, population and areal extent. This suggests that while service-specification-based measures of adequacy rate the existing BCOS rather poorly, this comparative assessment gauges it more favourably.

8 Value Assessment

8.1 The Economic Value of the BCOS to the Australian Community

A significant shift has occurred world wide over the last few decades towards reduced government expenditure, with increasing demands on government organizations in Australia to realise potential efficiencies and to demonstrate return on investment in meeting desired outcomes. It is important that the Bureau position itself strategically to address these pressures by developing the capacity to demonstrate the value it provides to the community for the public investment expended. This type of information serves as persuasive evidence in negotiating future global organizational budgets and in one off-bids for special project funding, yet there is a scarcity of such information available relating to the Bureau's activities.

The first rigorous economic study to be undertaken in Australia, and one of the few internationally that applied economic methods to the evaluation of actual (rather than hypothetically perfect) meteorological services, was carried out jointly by the Bureau and Macquarie University between 1994 and 1997 under an ARC Research Grant. The general findings from this study showed:

i. The Bureau's services are valued by the community;

ii. An indication that the overall services of the Bureau have a positive benefit-cost ratio;

iii. Benefit-cost ratios among the specific services studied varied between 1.7:1 and 66:1;

iv. Generally, the ratio was higher the more user specific, location specific and application specific the meteorological information;

v. The economic categorization (free-cost recovery-commercial) of the services studied was sound;

vi. Economic methods spanning econometric modeling, cost loss decision modeling, and contingent valuation all have applicability in the valuation of various meteorological services, suggesting other methods may also be applicable;

vii. A multidisciplinary approach to valuation that includes both economists and meteorologists will yield the most scientifically robust results.

Selected services ranging from free to commercial, and from publicly accessible to restricted access were evaluated in the study. A summary of the individual cost-benefit ratios found by the study for selected meteorological service provision areas is tabulated at Attachment 11.

8.2 Data Impact Studies

An assessment of the contribution provided by particular components of the BCOS was attempted via a survey of the results of data impact studies previously carried out either within the Bureau or overseas.

No evidence was found of any previous study into optimum network design: it has never been established what observing system is necessary to provide a given level of service, or to objectively provide guidance as to the optimum observing system design for a given budget.

With respect to NWP, the following are important general considerations for network design:

- There is an overwhelming body of evidence that all observing system components contribute positively to NWP model skill;
- Redundancy between different observing platforms or sites can diminish individual impacts, but enables cross-validation of data within a data assimilation system, and so has value in itself;
- Data assimilation systems respond best to a series of small corrections of the background state, rather than large corrections. Given that error growth in an NWP system generally monotonically increases, this suggests that more frequent rather than less frequent data insertion is desirable;
- Data assimilation systems are better behaved when the observation distribution is relatively homogeneous, rather than highly variable in density; and
- Data assimilation systems are designed to use the complementary nature of different observing systems in order to optimize the information content of these different data types. Thus it is not simply the impact of one observation type that needs to be addressed if the "optimum" (affordable) observing network for NWP is to be addressed, but rather the optimum combination of all data types.

From the large body of published and unpublished studies on Observing System Experiments (OSEs), some more specific findings for the southern hemisphere are:

- The surface pressure observations that are shown to have maximum impact on analysis in the GASP data assimilation system (NMOC Quarterly Reports) are those from isolated drifting buoys, isolated oceanic islands, and Antarctic stations;
- For the Australian surface-based upper air network, the sites in northern Australia have the strongest impact;
- A Bureau data denial experiment to assess the impact of radiosonde temperature and humidity data on NWP system performance showed that, on average (over 10 forecasts),

withholding radiosonde data led to ~1 S1 skill-score point reduction in forecast skill over the Australian region. While this cannot be translated directly into a significant reduction in weather forecast accuracy, in two of these cases clear sub-regional scale deterioration in weather forecasts would have resulted;

- It has been demonstrated that the addition of moisture data from surface observations improved NWP forecasts of rainfall in the 24-36 hour timeframe over the Australian region;
- A large number of Australian data impact experiments has demonstrated positive impact of Atmospheric Motion Vectors (AMV's) on short-range NWP performance in the Australian region;
- There is direct evidence from recent BMRC experiments into the utility of GPS estimates of vertically integrated precipitable water (PW) in NWP, that these data have a positive impact, and indirect evidence that GASP analyses of PW are some 50% more in error at Alice Springs in the absence of radiosonde observations;
- ECMWF has demonstrated that, for its NWP system, the impact of satellite data in the southern hemisphere is an additional 3 days of predictability. Given that ECMWF uses data from a much wider range of satellite sensors than the Bureau, this suggests great potential gains, for the utility of the Bureau's NWP systems at least, through increased emphasis on and use of satellite data by the Bureau;
- ECMWF OSEs also show that, while radiosonde data have a positive impact on global forecasts in the Northern Hemisphere, this impact is hard to detect in the Southern Hemisphere. This suggests that, were the Bureau to make similar use of satellite data, the value of Australian radiosonde data for NWP should then diminish;
- AMDAR data have positive impact on regional NWP, with the impact on forecast wind errors greatest in the short-range, but also in individual weather events;
- Surface pressure and wind data have positive impact, serving to "anchor" remotely sensed tropospheric data;
- Rain-rate assimilation, be it from SSMI, TRMM, or radar data, has positive impact on very short-range precipitation forecasts; and
- Most recent OSE's have assessed impact on global, medium range forecasts. The impact on regional NWP is less developed, but there are frequent references in the literature to "occasional significant" forecast impacts, some of which are attributed to radiosonde data, and there are a few well-documented cases of a few key observations of one sort or another having a critical impact on the NWP forecast of a high-impact event (such as the October 1987 storm over UK).

NCC research has shown that if long-term climate monitoring is to be satisfactorily maintained, those surface-based stations identified as being high quality climate monitoring sites should be flagged as priority stations within the network, and regularly maintained to ensure a specified level of observation availability and accuracy.

Data impact studies require significant human and computing resource expenditure. Without a Bureau group dedicated to such studies, data impacts cannot be effectively gauged, especially when measures are required such as the impact of network changes on forecasts of particular high-impact weather phenomena.

8.3 Impact on Services of Previous Changes to the BCOS

Whereas previous OSEs provide some guidance on the impact of individual observing system components on, e.g., NWP, they yield very little information on downstream impacts on service provision itself. To address this, a brief examination was made of the impact on Bureau service provision, per se, of previous changes, either positive or negative, to the BCOS.

The extent of this examination was necessarily limited, and ultimately uncovered little in the way of hard and objective evidence of impacts. This is most likely partly attributable to the complexity of the relationships between trends in the type and amount of available data, computing resources, modeling capabilities, and theoretical understanding of the atmosphere, which clouds the attribution of service improvements to a specific cause. But this study finds that it is also likely to be at least partly attributable to current shortcomings in performance monitoring in both services and systems areas of the Bureau.

Despite a lack of clear and objective evidence, the examination found copious evidence, based on the professional opinions of many Bureau staff, that past negative impacts on the BCOS (e.g. 12Z radiosonde reductions, loss of visual observations) have led either to an increase in the difficulty of providing high quality services, or to a deterioration in service quality itself, or both. On the other hand, improvements to the BCOS (e.g., the weather radar network) have led to noticeable improvements both in service product quality and, e.g., forecasters' "comfort levels" via increased confidence in their output.

9 Future Requirements and Capabilities

9.1 Implications for the Future of Current Trends in Service Requirement

A brief analysis of current trends in service requirements was performed to identify likely changes in data requirement between now and the year 2015.

In summary, by 2015 the Bureau is likely to be operating in an environment characterised by:

- Greater emphasis placed on the monitoring of climate variability and change, and on the long term homogeneous data sets needed to support that;
- Greater reliance on automated systems, and on remotely sensed data (e.g., satellite, weather radar);
- Tighter regulatory frameworks;
- Greater reliance on model output (such as OCF);
- Greater emphasis on providing information in such a way that users can make their own decisions;
- Greater emphasis on users 'pulling' information as required, as opposed to the current 'push' situation;
- Greater emphasis by emergency management on mitigation through planning rather than response;
- Greater emphasis on risk management;
- Increased demand for high quality, higher resolution data (both spatially and temporally);
- Increased demand for observational metadata and for data and product uncertainty information; and
- Increased demand for data and product availability in geospatial format.

In this changed environment, the Bureau will generally be required to provide:

- Higher resolution forecasts, both temporally and spatially;
- Reduced product uncertainty (greater accuracy);
- More extended period coverage;
- New products – for hydrological and disaster mitigation services in particular;
- More sophisticated graphical display of output products, including observational data;
- Probability forecasts and uncertainty estimates; and
- Service Level Agreements for the reliability of data and forecast supply, and data quality.

More specifically, the Bureau will likely be required to provide:

- Extended weather radar coverage, and higher quality (quantitative) weather radar data (most probably via greater use of digital, doppler and/or dual polarization radars);
- More high quality and higher resolution climate and hydrological data in realtime or near-realtime;
- More comprehensive observational information from the vicinity of airports, in particular the major airports;
- More observations of weather phenomena (hail, lightning, fog, etc.)
- Quantitative flood warnings from an increasing number of catchments/locations;
- Seasonal streamflow outlooks for agricultural production and water resource management;
- Soil moisture mapping for agricultural production, water resource management and flood watch;
- Continuous streamflow forecasting for water resource management; and
- Significantly improved archiving and access systems (including web services etc).

9.2 New and Emerging Observing Technology

A survey of new and emerging observing technology and techniques was carried out as part of this study to explore opportunities likely to arise during the coming decade for increasing the efficiency and effectiveness of the BCOS, in particular through greater use of automation. The full range of these opportunities and their details can be accessed on the BOSS05 website: those with more promise are listed below, and a summary of the main characteristics of each is provided in Attachment 12.

Space-Based Observations

- Advanced Satellite Sounders
- Advanced imagers
- Scatterometers

Surface-Based Observations: System Management

- Next Generation SitesDB
- Incoming Observations Data Processing (IODP) environment

Land-Based Surface Observations

- Next Generation AWS and WebConsole
- AWS Sensors:
    - Sky Cameras
    - IR Sky Camera Coupled with Ceilometer
    - Automated Evaporimeter
    - Present Weather Sensor
    - Lightning Sensor
    - Throw-away Redundant Sensors for Basic Parameters
- Long path transmission systems for visibility observations (e.g., RVR)
- Stand Alone Thunderstorm/Lightning Sensors
- Replacement for Mercury-in-Glass Inspection Thermometers
- Mobile Nowcasting Sensors
- Tiered Rainfall Network Sensors

Marine Observations

- New generation Ship based AWS

- Moored Buoys
- Devil XBT

Surface-Based Upper Air Observations

- AMDAR:
  - TAMDAR
  - WVSS2 (Water Vapour)
- Advanced Radiotheodolite
- Wind Profiler
- Surface-based GPS Water Vapour Measurement

Surface-Based Remote Sensing Observations

- Weather Radar: Dual Polarization
- Weather Radar: Digital Signal Processing
- Networked Thunderstorm/Lightning Sensors

Atmosphere Watch Observations

- Total Ozone
- Fourier Transform Interferometer Radiometers (FTIR)

9.3 Staff Resources

The greater use of automation ultimately requires a balancing reduction in the number of field observers. This implies a continuing shift in the role of observers from making meteorological observations to a greater proportion of their role covering station management and frontline real-time or near real-time observations data quality monitoring and control. The direct manual observation itself will become limited more and more to specific specialized and demanding applications such as the description of cloud and weather at major airports, and long term continuity of some climate elements.

The required number of field observers will depend on the rate of uptake and the capabilities of future automation. In any case, it is likely the number of observers will continue to decline under the current more pragmatic approach of recruiting new observers in numbers far lower than the rate of natural attrition.

9.4 Quality Management

National and international needs for data have changed relatively slowly over the last few decades, but how they are assessed as met is now changing rapidly. The aviation industry is moving towards a competitive market in the provision of data and services, where providers will be required to demonstrate competence quantitatively. The Boxing Day tsunami has prompted the creation of a multi-agency warning system with at least one partner mandating that a quality system will be a requirement. State Governments are now requiring their authorities and contractors to provide accredited services based on an audited quality system. Private environmental monitoring organisations and companies are increasingly moving towards accreditation as a means of providing their clients with assurance about service provision. Within the WMO there has been a move to make accreditation via an international quality system a requirement of national meteorological services.

Human resource and knowledge bases of the Bureau are declining. Previously the Bureau's paper-based information system was a core component of its knowledge base, but that role has diminished with the increasing use of informal electronic storage of information. New technologies and the expanding electronic communications network mean that data rates and volumes will increase. These factors together highlight the growing importance of retaining and securing end-to-end corporate and professional knowledge.

As was noted in Section 6 above, various components of the BCOS have many elements of a quality system, and there is an apparent strong commitment to quality of products and services in the majority of data streams. But this comprises more a collection of disparate devices based on professional preference, rather than an organisation-wide quality system. This study views such an ad hoc collection of systems, based largely on professional judgement, as unlikely to provide the base for the BCOS in future.

9.4.1 Documentation of End-to-End Processes

End-to-end process documentation for most BCOS data streams is either poor or obscure, so that understanding by individual Bureau employees of the data stream(s) they manage tends closely to reflect their length of service in the Bureau. Auditing, either internal or external, is an important quality process apparently little utilized and poorly understood in the Bureau. The most basic interpretation of this suggests that data streams are not currently documented to a level that is consistent with a clear communication of process and there is a heavy reliance on professional expertise and judgement to sustain them. This situation will need to change in the future BCOS.

9.4.2 User Feedback

A substantial amount of quality assurance and control of data is performed downstream of the BCOS boundary by users of the data, yet there is little evidence of useful feedback into the BCOS. To improve effective quality processes feedback mechanisms will in future need to be regular, documented and useful to both the provider and the user.

9.4.3 Formal Experience in Quality Systems

There is little experience in end-to-end quality systems in the Bureau. This study was able to locate only a handful of Bureau employees with training or experience in formal quality systems (e.g. ISO 9000, ISO 17025, Business Excellence, Sigma etc). This situation will need to be addressed in the future.

9.4.4 Documentation of OEB Business Processes

OEB plays a central role in the BCOS in designing, implementing and maintaining significant system components for the majority of the observational data streams. However, the matrix nature of responsibility in the Bureau means that for a significant number of data streams under the leadership of the Observations Program, their quality components are compartmentalised into other Branches and Regions. Given that this compartmentalization is likely to remain in a future environment of reduced staffing and more regular staff turnover, improved interaction will be required between groups in OEB and between OEB and the wider Bureau community to enable optimal performance of the BCOS, pointing to a need for more formal documentation and Bureau-wide dissemination of the OEB business process.

9.5 Asset Lifecycle Management

Current asset maintenance and replacement strategies have served the Bureau well in the past and continue to evolve, but a there are number of needs currently not being met for equipment maintenance and replacement strategies and these will need to be addressed in the future. The main drivers of these future needs are expected to be:

- Depreciation funds for asset replacement approaching more realistic levels;
- The lack of robust and sustainable linking of replacement and lifecycle costs to depreciation funding;
- The continuing downward pressure on staff resources, and the move to an increasing use of technology and numbers of equipment;
- The consequent emerging imbalance between the resources available to meet the increasing replacement and maintenance workloads and the desire to satisfy rising public demands for services;

- Somewhat ad hoc integration of replacement and maintenance strategies;
- A dearth of formal service level agreements; and
- An increasing imposition on maintenance workloads and staff responsibilities by the changing OH&S and the regulatory environment.

9.6 Communications and Reporting

As noted in Section 6 above, most of the observing systems in the BCOS have been developed independently, with the respective communications systems established to suit their particular requirements. In future, many existing communications methods may continue to be used, including radio telemetry, PSTN, satellite links, direct data lines and connections to the Bureau's private communications network, Weathernet. While there may be some rationalisation of communications methods used, commercial systems will continue to be used where appropriate. The main object will therefore be to continue supporting the current observing systems, but providing greater freedom in terms of site location, the number of reporting sites, the number of parameters reported, data volumes and frequency of reporting.

Particular trends anticipated over the coming decade are as follows:

- **Communications costs** are likely to continue to remain a limiting factor for a number of observing systems. While the costs may reduce for some systems, it is likely that the number or reports, reporting sites and/or the type of report will increase, which results in similar communications costs for the overall observing system. Economies may be achieved by sharing the communications infrastructure (eg. A national VSAT network for AWS, tide gauges and other data loggers).
- **Security** will remain a major issue. This will be in terms of ensuring the systems are not vulnerable to data mutilation and/or virus attacks. Systems may be deployed which can quarantine viruses and other malicious code and reduce the frequency and urgency of ensuring PC based systems have their operating system and antivirus software kept up to date.
- **Reliability** may be affected in several ways:
    - Depending on the density of observing points, the reliability of communications from specific sites may need to be considered. The value of back-up communications methods may need to be weighed up against denser network observing points.
    - Reliability of radio based systems can be affected by the sharing of the radio spectrum with other systems or interference from other equipment.
    - Reliability can also be affected by unstable interfaces or termination devices, particularly if protocol translation or interface conversion is required, placing an additional link in the communications path.
- **Data integrity.** As the number of sensors at particular sites increases, there is greater importance in ensuring that the error protection mechanisms are built into the data transfer process. Normally with modern systems this is taken care of by the protocol.
- **Communications techniques.** The availability of more widespread and versatile communications systems (eg. DSL) may cause a rationalisation of the type of communications systems used to support the observing systems. This may influence the observing system design, particularly if greater volumes, more frequent reporting and extra observing sites are added to the network, but the Bureau will continue to exploit commercial communications systems to obtain the most cost effective method of obtaining observation data. To minimise network maintenance, the Bureau will need to restrict the types of interfaces offered on Weathernet. As observing systems are developed, they will need to support these interfaces, including the ability to incorporate back-up communications at strategic locations.
- **Technology changes**.
    - From time to time changes made to commercial communications systems may affect the observing systems designed to use it. (A recent example is ROCS. Telstra, in replacing DRCS infrastructure in more remote areas with CDMA wireless local loop (WLL) technology, the infrastructure could no longer carry the full DTMF character

set (16 characters) required by the ROT. Despite months of testing and evaluation of alternative approaches, Telstra ultimately conceded that their new WLL system could not support the ROT and the Bureau was forced to redesign the communications protocol for the ROT).

    - As technology changes and new techniques evolve, some communications interfaces or protocols (eg. async) may become unsupportable. However, the Ethernet LAN connection is likely to remain a "standard" for some time, providing reliable error protected communications connections.
    - Technological changes with the design of the observing system too will impact on the type of communications required (e.g, Next Generation AWS, WebConsole).

- **Data exchanges and volumes**. Efficient use of expensive and/or limited communications links will still remain an important issue. The monitoring of the frequency of reporting, the volume of individual reports and the number of sites providing reports will remain a necessary administrative task.
- **Sharing of data.** As well as validation issues, the sharing of data can introduce additional communications links, security and cost considerations. Observing systems could be affected if communications links or the agreed provision of data from other organisations were no longer available or viable.
- **Data duplication with multiple sensors.** The future use of redundant sensors may lead to reports with an apparent duplication of data for the same parameter. If the data for each parameter is important, there will need to be a mechanism to distinguish between them. Otherwise there may be data integrity problems or a loss of data if the value for one parameter overwrites the other. It should be noted in this regard that a system of sensor numbering has been devised for implementation through SitesDB.
- **Accessibility**. Selection of sites has often been limited by the availability of communications facilities. As the communications infrastructure and/or options improve, this limitation may be eased.

9.7 Data Management

In the future CCSB will ideally supply an Ethernet Port or LANs to observing sites, into which OEB, for example, can connect observing sensors or systems to communicate between sites or to centralised systems. Centralised OEB observing equipment would be run as applications on the supplied CCSB infrastructure in the same way as other operational systems like ADAM or AMDISS. OEB would have Service Level Agreements (SLA) with CCSB, such as for data volumes, scalability, data retention and other requirements.

New data streams or sites will have defined requirements, including archiving needs, which CCSB can cost in advance to ensure ongoing funding and sustainability. OEB and other branches would still use their own hardware in the field (such as radar consoles and EFBs) and these would be treated as a part of the observing system. However, any systems plugging into the network would need to conform to security standards as normal CCSB-managed equipment such as servers and managed PCs.

It is envisaged the Bureau will move to a central data repository and warehouse model. This is quite different to the present situation with a range of custodian models. Data Management Section (DMS) will ensure data management practices across the Bureau, and system and hardware replacement strategies, create the flexible and scalable environment to enable this data warehouse model.

Regardless of where the final data warehouse lies, it will be necessary to consider where data leave and re-enter the BCOS. It is clear that, as OEB builds more sophisticated data capture systems, data of varying processing levels will be much more mobile across our networks than present systems, before being accessible to data users. It is also likely that some CCSB applications will form part of the OEB system. For instance, CMSS presently creates various synoptic observations from automatic weather station METARS to meet international Synoptic Reporting requirements.

In summary, CCSB will most likely continue to ascertain its user requirements and build the required capability into its systems, allowing systems to be optimised to current funding and to gain synergy from multiple users. The line separating the BCOS from the Data Management System will always remain grey, but the simplistic view described here can go a long way to helping clarify roles. The BCOS will be encouraged to define its requirements and allow CCSB to meet those requirements under SLAs, rather than dictating its own technical solution. The BCOS will make optimum use of the powerful, high availability communications and computing systems in place in the Regions and CCF to move data around and to run applications, while the Data Management System manages data traffic and storage.

9.8 Spectrum Management

The Bureau is becoming increasingly more reliant on radiofrequency spectrum to collect and disseminate meteorological information. The future will see Bureau dependence on radiofrequency spectrum increase as the organisation continues to embrace new and changing technologies. The Bureau will also face other challenges that may require additional or better use of radiofrequency spectrum to fulfill its obligations. Overall these challenges will require the Bureau to better manage and resource its use of radiofrequency spectrum.

Radiofrequency spectrum-based technology is evolving at an extraordinary rate. Keeping up-to-date with these changes and new developments and how they are likely to impact on operational meteorological systems will require a dedicated team of experts in engineering and physical sciences, with a capacity to access legal expertise. A Bureau spectrum management team will need to keep closely abreast of developments by monitoring relevant scientific literature, Australian and International radiofrequency regulations and documentation from the Australian Communications and Media Authority (ACMA) and other regulatory bodies, for timely identification of issues of concern to the Bureau.

The ACMA is currently evaluating the concept of leasing or selling blocks of spectrum to third party organisations, or “Private Band Managers”. There is great uncertainty at present as to how these arrangements might affect the Bureau’s use of spectrum. Private Band Managers would likely comprise commercial organizations with a focus on profit rather than public good, so the Bureau will need to monitor these developments closely, and be proactive in liaising closely with ACMA and other band users to protect our turf.

As demand for additional spectrum increases while availability remains static, bandwidth will become increasingly precious, and pressure will increase on spectrum users to become more efficient and flexible with its use. The future will likely see more commercial attempts to acquire additional bandwidth to meet consumer demand for new technology, such as onboard car radars, ultra-wide band devices, etc. Potential misuse of spectrum will become more heavily scrutinized, with increased penalties for breaches, so the Bureau will need to more closely monitor its use of spectrum, not only for identifying external interference with its systems, but also to prevent its unauthorized interference with other users.

9.9 Shared and Third Party Data and Systems

A number of the components of the BCOS involve extensive use of shared or third party data and/or systems (e.g. satellite observations, ocean services networks and hydrological networks): others involve only limited use of these data/systems.

In the former case (e.g. Hydrology), data and equipment sharing tends to have been undertaken under formal cooperative arrangements covered by explicit agreements with external parties, and few difficulties have been experienced as a result.

For the latter cases, arrangements have tended to be more ad hoc, and have been undertaken on an opportunity basis. With these, various complications can arise, such as:

- A third party requires data from a site for which the Bureau has no direct requirement, so funding is provided to the Bureau by the third party for purchase of equipment, and the Bureau installs and operates the equipment on behalf of the third party. There is often no compensation provided for communications, maintenance or depreciation costs, leaving the Bureau with a financial legacy;

- The Bureau installs and operates externally-funded equipment on behalf of a third party, then ultimately becomes dependent on it. When the third party's need for the data ceases, again the Bureau is left with an unanticipated and unbudgeted financial legacy; and
- The Bureau utilizes external data from a third party, but difficulties can be encountered in ensuring continuous data supply, obtaining metadata, data quality assurance, etc., and lack of ownership can impose restrictions on the Bureau's use of the data, particularly for onward distribution beyond the Bureau.

Despite the difficulties, there have been numerous cases where the Bureau would not have had the capability to undertake certain critical activities if sharing arrangements were not undertaken (both with respect to equipment and data) and past experience has resulted in greater awareness, and so some avoidance, of the potential pitfalls. Nonetheless, there will be a need in future for the Bureau to protect itself more formally against these traps, and a clear need exists for formal policy regarding these relationships.

Improved access to shared data through the internet and improvements in data communication technology is likely to result in more widespread data sharing between various agencies and to the community in general.

It seems likely that, if the current tight economic climate continues through the next decade, there will be merit in a more systematic and proactive approach to engagement in these third party or shared data arrangements, if the surface-based component of the BCOS is to continue to grow significantly.

9.10 Observational Research

There are a number of issues relevant to research and the future that need to be considered in planning for the BCOS:

- A recognition of the role that observational research has played in developing and supporting service requirements;
- BCOS support (fixed percentage of resource base) for strategic observational research supporting the needs of the forecast process and service requirements;
- The need to focus part of the observational research within the BCOS in a nowcasting test bed focused on delivery of severe weather, aviation and hydrological program requirements;
- That the observational research program include system development and quality assurance activities and integrated use of new and emerging observational platforms of relevance to forecast processes that meet current and anticipated service requirements; and
- That major ad hoc observational research programs be encouraged to provide demonstrations of observational capabilities that will enhance the overall capacity and expertise of the Bureau in the future.

10 Major Issues, Findings and Recommendations

10.1 Preamble

Information collected under Tasks 1 to 8, and additional input sourced by Team Leaders from all relevant parts of the Bureau, have highlighted numerous issues and priorities for consideration in the forward planning of the Bureau's observing system. Those with significant implications for the future of the BCOS are detailed here. Accompanying most of these are specific recommendations for the members of the BOSS05 Steering Committee to consider in planning future program activities and developments that may impact on the BCOS. While most directly concern the BCOS itself, some concern either overarching or underpinning areas expected to impact significantly on the future evolution of the BCOS.

10.2 The External Environment

In recent years the Bureau has faced an increasingly unfavourable external resource environment, as Government has imposed increasingly tight controls on public sector spending. While acquisition of one-off resources for new initiatives has been possible, these typically leverage substantially off base resources, especially staffing. As a result, and with a combination of salary and other cost increases and ongoing application of the efficiency dividend, it is increasingly difficult to meet existing needs and commitments for systems and services. Injection of funds for new development, which can often deliver future efficiencies, has become nearly impossible.

Increasing demands on available resources has exacerbated the situation. There is an increasing number of regulatory requirements to satisfy, such as Occupational Health and Safety standards, Service Level Agreements, and the demand for employee accreditation, and there is an increasing community expectation for more sophisticated services of higher quality.

Together these point to a need for the Bureau to become even cleverer in the way it operates. This is despite enormous gains in efficiency and effectiveness over the last few decades, as evidenced by significant increases in outputs achieved in the face of large staff reductions, and noted in the 2001 Output Pricing Review.

As well as continuing to focus on more efficient and effective use of available resources, the Bureau needs to demonstrate these gains more effectively. Increased Bureau attention to the provision of quantitative performance metrics and robust analyses of economic benefits, that clearly demonstrate to government and the community how the Bureau in general represents ‘value for money’ and provides a tangible return on investment, should then lead to a more receptive environment, not only for securing ongoing funding, but also for carefully planned and quantitatively justified funding bids for new initiatives.

Recommendation 1: That more effective tools for quantitative assessment and monitoring of overall performance and impacts be developed and implemented. (Program Managers)

For more than twenty years the Bureau has faced increasing and particular pressure on staff numbers as a result of the continuously ‘sinking lid’ imposed by the annual efficiency dividend, together with un-supplemented wage increases. In recent years the Bureau has found it increasingly difficulty to absorb these pressures. Continued imposition of the efficiency dividend on a widely distributed and operational organisation like the Bureau is neither sensible nor practicable, and will continue to seriously degrade operational performance.

Recommendation 2: That the removal of the efficiency dividend, and recognition of compensating factors, continue to be pursued. (ADE)

The particular pressure on staffing levels suggests that, where automation is feasible and efficient, it should be implemented more fully to reduce reliance on manual inputs. To the extent that space-based systems can meet expressed requirements for data and can do so at much lower costs to the Bureau than our own surface-based systems, the Bureau should maximise its use of space-based systems as long as it remains freely available.

In recent years the traditional free exchange of meteorological data from satellites has come increasingly under threat. This is due to the growth in commercial satellite providers, the increasing commercial orientation of governments, and the looming possibility of deregulation of Spectrum Management. Considering the serious implications for meteorology, both locally and internationally, the continued free exchange of meteorological data from satellites is of critical importance. In this regard, the GEOSS (Global Earth Observation System of Systems) initiative provides both an opportunity and a threat, and the Bureau needs both to maintain its advocacy for free data exchange and to work with GEO to ensure the principles of WMO Resolution 40 are enshrined in all aspects of GEOSS.

Recommendation 3: Continue to promote the ongoing free international exchange of data, particularly from satellites, including through active engagement in GEO/GEOSS. (ADE, ADO))

While the purpose of the current study, and its intent up to this stage, has been to ascertain the requirements for the BCOS based on need, rather than cost, the above external issues have been taken into account in what follows, to propose a sensible path forward for the BCOS over the coming decade.

10.3 Internal Environment

Given the overall pressure on resources across the Bureau, a key factor in shaping the future of the BCOS will be the priority given to Observations Program outputs relative to the outputs of other programs. Over the past two years the Observations Program has been called upon to find large savings in its Goods and Services expenditure, to significantly reduce its staffing levels (through large natural attrition with small recruitment) and to postpone a large part of the normal cycle of asset replacement.

Recommendation 4: That the allocation of resources to the Observations Program, hence the delivery of BCOS outputs, be stabilized. (EXEC, ADO)

Staffing levels across the Bureau are managed through two concurrent and overlapping processes, annual ASL allocations and external recruitment quotas. The latter process is essentially the means of implementing the Bureau's policy of relying on natural attrition to reduce its staffing levels, which disadvantages the Observations Program at present due to the age profile and high departure rate of observers. For example, in 2004-05 the departure of 24 field observers was balanced by zero observer-course graduates, while in 2005-06 approximately 40 observer departures will be balanced by only 9 new graduates from the observer course.

There is effectively a cross-subsidisation of staffing from the Observations Program to other Programs to enable those Programs to avoid facing departures other than through natural attrition.

Recommendation 5: That the Observations Program be more fully enabled to utilise the ASL (or "Employee Expense") resources allocated to it, including sustained annual recruitment of about 15 Observer trainees and short-term employment of non-ongoing staff to address current shortfalls. (EXEC, ADO)

10.4 Data Requirements

The following are issues identified in relation to the requirements for data, per se. Because it is in many cases difficult to separate the requirements for data per se from the means used to provide that data, both are considered here. Other issues, such as underpinning requirements, are considered later. A notable exception to this is the consideration of space-based data in Section 10.4.3 below, where data issues and underpinning issues are considered in sequence to better demonstrate the close inter-dependence between the BCOS and other 'downstream' program areas.

10.4.1 Specifications of Data Requirement: International Standards

The existing BCOS fails to meet most of the internationally specified minimum requirements for surface-based data, let alone target requirements, particularly across the interior of the continent. However, some of these specifications are perhaps too stringent to be economically realistic for a relatively well-developed, but geographically large and sparsely-populated country like Australia. The minimum international requirements appear to mimic closely the existing surface-based network densities only across the smaller or more populous, well-developed nations of the Northern Hemisphere, while many of the target requirements are so demanding that they will probably only ever be achieved in future years through optimal use of data from new generation meteorological satellites. In several cases internationally-specified standards for data quality and resolution are barely achievable in the laboratory, let alone economically feasible in the field; yet they are specified for field observations.

Recommendation 6: That the Bureau continue to work with WMO and/or other international organisations who are responsible for specifying minimum standards for observation requirements of meteorological and related data such that the standards are sustainable and commensurate with the use of the data. (ADO, ADN)

10.4.2 Specification of Data Requirement: Bureau Requirements

While the existing BCOS has served the Bureau usefully in the past, there is strong evidence that it is no longer adequate to meet the full and growing array of services required to be provided nationally. This is particularly evident over rural and coastal areas, where the spatial and/or temporal resolution of observations for most data types falls well short of specified requirements.

At issue, however, is the difficulty of adequately and objectively defining these requirements. The specification of Bureau requirements for data was unquestionably the most demanding task of this study. It required more time and effort than any other task to complete. Yet it proved difficult in many cases to provide firm specifications supported by rigorous scientific evidence. In some cases, needs were reasonably based on sound professional judgement, but could not be supported with solid reasoning or other hard evidence. In others, solid reasoning was provided but lacked supporting service performance data. In general, it was the existing lack of hard supporting evidence, resulting from insufficient attention to measurement of impact on service, rather than supporting evidence to the contrary, which limited the value of the specifications provided.

Increased attention to the measurement of impacts and outcomes, via data impact studies, cost-benefit analyses and socio-economic studies, are essential if valid cases are to be built.

Recommendation 7: That efforts be increased to measure performance, value and impacts, both of the BCOS as a whole and its various components, and of service outputs and outcomes. (All Program Managers)

10.4.3 Shortcomings in Data Provision and Utilisation: Space-Based Data

This study has found that the utilisation of space-based data in the Bureau is seriously inadequate. It has led to the Bureau becoming over-dependent on the more classical and familiar types of surface-based data, particularly those from the conventional upper air sounding network. This binds the Bureau unduly to maintaining conventional data networks, greatly limiting the scope for modernising the BCOS.

This weakness appears to stem from a number of causes: some related to data capture, others to data usage.

Satellite sounding data have grown to serve today as a fundamental and highly-valued input for global NWP, but have continued to be viewed by other areas of the Bureau, particularly the weather and climate services, with suspicion and doubt as to data quality and usefulness. These doubts were well-founded in relation to the early generation satellite sounders, which, though providing unprecedented areal coverage and horizontal resolution, produced data of only very coarse vertical and temporal resolution, and of large uncertainty in the lower troposphere, where the data were most critical. More recently, however, data from the newer generation sounders have improved markedly in quality and quantity, yet the same perceptions seem to remain. Now we are witnessing the latest generation hyper-spectral sounders coming into operation, with effective vertical resolution of the order of a kilometre or two throughout much of the troposphere, temperature uncertainties down to about one degree, and systems being put into place to enable data traceability from one satellite in a series to the next. Yet the same skepticism remains in most service provision areas, and this is exacerbated by the relative inaccessibility and difficulty of use of satellite-derived information for application to routine work in the Bureau.

This continuing culture of scepticism within the Bureau, coupled with an inadequate allocation of resources has caused:

- The BCOS to capture less of the newer generation data than it can for the Bureau's use. Today the Bureau receives data from only a handful of satellites, and few of these are of the latest generation;
- Underutilization of the available data by our NWP systems, let alone the data we do not capture. The ECMWF, which receives data from approximately 55 distinct satellite sources,

has shown that optimal data usage impacts positively on model performance by increasing predictability over the southern hemisphere by 2.5 days;

- Underperformance of our NWP systems: sub-optimal model predictive skill due to the aforementioned under-utilisation of satellite data. This has likely contributed significantly to a relative lack of trust in our NWP products, which otherwise might be depended upon more in the forecast process, and so has reflected undue dependence back onto the availability of 'raw' surface-based observational data;
- The Bureau's recent focus on using satellite sounding data almost exclusively for NWP. The advent of multi-dimensional variational assimilation of raw radiance data has eliminated the NWP need for pre-processing of retrieved satellite vertical profiles, which might otherwise be usefully provided to service areas as an additional 'raw' data input; and
- The relative inaccessibility and difficulty of use of the available data, coupled with a lack of suitable integrated data display systems in the Bureau for retrieved satellite profiles to be viewed and utilised alongside similar data from other sources. This has diminished the operational use and demand for satellite-based information. Were forecasters and climatologists alike regularly and routinely able to see how well the quality of the new generation data matches that of the conventional data, the overall culture of distrust should diminish.

So there is a clear, urgent and growing need for the Bureau to gear up for the ingestion of high spatial resolution, hyper-spectral data from more of the newest generation GEO and LEO platforms, by installing the necessary ground receiving equipment, by accelerating the adaptation of existing software, and by development of new applications systems, as required, for producing high demand specialist products based on the new data streams. Examples of such products include AMVs, Antarctic sea-ice cover monitoring and volcanic ash detection to meet international obligations, fog detection, thunderstorm identification, enhanced SST and wave height observations, wind change tracking, fire spot identification and plume tracking.

Recommendation 8: That the need for installation of additional X-band ground receiving equipment be addressed to enable receipt of new generation satellite data at several key locations. (ADO)

Recommendation 9: That the Satellite Applications area(s) urgently upgrade existing applications software for ingestion of data from the new generation satellite platforms, including the retrieval of temperature and moisture profiles from satellite sounders, and develop new high priority applications as required. (ADO)

Together, the above two initiatives address the current shortage of available satellite data and products. There is also a clear and urgent need for the Bureau to address the shortcomings discussed above in areas downstream of the BCOS itself.

Recommendation 10: That data assimilation systems for the ingestion of satellite data from a wide range of new platforms be upgraded. (CSR)

Recommendation 11: That a flexible and universal data display system for the simultaneous display of data from multiple sources, including satellite retrievals, be developed and implemented within the AIFS/FSEP/GFE environment. (ADC)

Recommendation 12: That the Climate Services Program pursue the utilisation of new generation satellite data for climate monitoring and diagnostic purposes. (ADN)

The above five initiatives, taken together, should enable the Bureau's weather and climate services program areas to increase their overall usage and dependence on space-based data, complementing and easing, to some extent, the current critical dependence on conventional surface-based data sources. This in turn will then enable greater flexibility to be applied in reconfiguring the BCOS for more efficient and effective delivery of its outputs.

10.4.4 Shortcomings in the Provision of Surface-based Upper Air Data

10.4.4.1 Radiosondes

There is ample evidence demonstrating that the current BCOS fails to meet Bureau and international requirements for upper air temperature, humidity and wind data, particularly over the Australian land mass, where the satellite data presently available in the Bureau are of little direct use to forecasters and climatologists alike.

The current surface-based network fails to meet the specified minimum network density inland, and to meet the specified minimum temporal resolution at most sites. Of particular concern is the preliminary and unpublished BMRC evidence that recent (January 2005) cuts to the 12Z program have impacted upon the 12Z NWP model run, the output of which is relied upon for setting Regional forecast policy, generating severe weather threat maps, and morning issues of fire danger ratings.

Recommendation 13: That a detailed study be urgently commissioned into the impact on NWP of the recent 12Z radiosonde program reductions. (CSR)

Although the use of limited ‘adaptive’ sondes has been recommended, and provided for, to help counter the effects of the 12Z program cuts, there is a need for scientifically based guidance on when and where to deploy adaptive sondes to enhance the current manual synoptic assessment approach.

Recommendation 14: That BMRC, in collaboration with the Observing Program, provide objective, scientifically based guidance on the use of adaptive sondes, to enhance the current manual synoptic assessment approach. (CSR, ADO)

The recent reductions in the radiosonde program have introduced a significant risk of compromising the climate data set for future generations, and of a major and embarrassing forecast failure in a critical weather situation. The potential exists for effective and economical partial replacement of the radiosonde program in the 5 to 10 year timeframe using alternative technologies, and this will be discussed further below. However, in the short term, there appears to be no acceptable alternative to restoring the radiosonde program to its previous pre-January 2005 level.

Recommendation 15: That the radiosonde program be restored to pre-January 2005 levels, pending either partial replacement of the program by alternative technologies, or clear evidence from data impact studies of a lack of significant impact on NWP skill in critical weather situations. (ADO)

Restoration of the radiosonde program to its pre-2005 level will be difficult without first changing operational procedures at some field stations, due to the growing observing staff shortages in the field. At the same time, staff savings opportunities exist. At autosonde stations as many as three observing staff are employed, whose main tasks are overseeing a single autosonde flight each day and making synoptic observations. (It is noteworthy that autosonde is not a cost-efficient solution at a one-flight per day station: the units were installed to perform two flights per day.) Were cooperative observers employed at these sites to make synoptic observations, two autosonde flights could be performed per day while reducing the requirement for Bureau station staff to one, at some sites at least. This model is soon to be implemented by OEB at one field station.

Recommendation 16: That the Observations and Engineering Programs work vigorously toward the reliable, unattended operation of the autosonde system. (ADO)

Recommendation 17: That reduced staffing at appropriate autosonde sites be trialled. (ADO)

Notwithstanding the need to immediately restore the radiosonde program to previous levels, the gap between available financial resources and the cost of staffing, infrastructure and consumables to support this program has increased to the extent that it is imperative for the Bureau to find alternatives for the provision of surface-based upper air data. Several options exist with potential for operational implementation over the next several years. Strategically used, these could in time supplement a core network of radiosonde stations, which would continue to be required for high quality, high resolution baseline upper air monitoring. These options are satellites (discussed above), AMDAR, wind profilers, radiotheodolite, and GPS water vapour.

10.4.4.2 AMDAR

AMDAR offers the opportunity to gather high quality data very cheaply. Its three main limitations are:

- Data are restricted to the troposphere, to major air routes and airports;
- It does not currently include humidity data; and
- Its long-term and continuous supply is at risk in the event of airline collapse and global terrorism.

The Bureau was the first organisation in the world to establish an AMDAR program, yet growth of the Australian program has been slow due to a lack of resources. The use of AMDAR has grown internationally in recent years to the point that it has recently come to be recognized as a key component of WMO's GOS, and AMDAR programs are rapidly expanding in many countries.

This year a new high quality moisture sensor, the WVSS2, has undergone operational trials in USA and Europe, and preliminary results are very promising. If the instrument's reliability and data quality ultimately prove acceptable, installation of sensors on all AMDAR-equipped aircraft would greatly increase the value of AMDAR data.

Expansion of the AMDAR program to include other commercial airlines, in particular those servicing major provincial centres, will help to minimize risks in relation to the extent of coverage and long-term continuity of supply.

The introduction by ASA of the ADS-B communications and navigation system into the general aviation sector may soon provide the opportunity to receive additional AMDAR-type data from more remote locations and from the mid-troposphere, further enhancing the program.

Despite its limitations, AMDAR provides the opportunity to supplement, and potentially partially replace, the Bureau's existing upper air program in the next 5 or so years. The limited vertical extent of AMDAR data means they will never, of course, be a useful replacement for the upper air climate network.

Recommendation 18: That WVSS2 sensors be acquired for AMDAR-equipped commercial aircraft, subject to successful trialling of the instrument. (ADO)

Recommendation 19: That the expansion of the AMDAR program be accelerated to include the participation of additional airlines, and pursues the supply of AMDAR-type data by the commercial aviation sector. (ADO)

10.4.4.3 Radar Wind Profilers

Wind profilers show promise as an economical replacement for rawinsonde observations at some of the Bureau's upper wind only sites. If used in combination with AMDAR and new generation satellite data, or additionally if also equipped with RASS, they also provide an opportunity to supplement, and possibly provide a partial replacement for radiosonde observations.

Boundary layer wind profilers have now been implemented at several Bureau observing sites, with mixed success. Although further investigation of performance is required to fully assess the quality of profiler data, the data have to date been invaluable to aviation forecasters, and the units can operate remotely and, once operational, appear to require very little maintenance. High frequency, near-real time measurement of low to mid-level winds at airports has greatly enhanced forecasters' nowcasting ability, especially for low level turbulence, sea breeze onset and so forth, that are either an aviation hazard, or are phenomena that require runway changes and greatly affect the rate of airport traffic throughput.

Limited operational experience gained with RASS equipped profilers has shown these to be of some use, though, as with wind only profilers, the adequacy of data quality as a substitute observation method for radiosondes is yet to be scientifically established.

Recommendation 20: That the performance assessment of boundary layer wind profilers be expedited. (ADO)

Recommendation 21: That consideration be given to implementation of boundary layer wind profilers, including RASS equipped units where appropriate, in combination with AMDAR and satellite data, as a partial replacement for some sites in the radiosonde network, subject to suitable data quality. (ADO)

Until now, the Bureau has installed and operated low-powered profiler units (so-called boundary layer profilers). The potential also exists, again subject to data quality considerations, for the Bureau to supplement or partially replace some of the current, relatively labour-intensive, upper wind only network with high-powered stratosphere-troposphere (ST) wind profilers.

Recommendation 22: That a test-bed ST wind profiler for scientific and technical performance assessment be purchased. (ADO)

Recommendation 23: That consideration be given to implementation of ST profilers as a possible replacement technology at some upper wind only sites, subject to suitably reliable performance and data quality. (ADO))

10.4.4.4 Advanced Radiotheodolite (ART)

The ART promises potential savings at some Bureau upper air stations. Subject to suitable performance, it would circumvent the need to use expensive GPS radiosondes at some sites where autosondes are installed, and may serve as a more economical solution than the use of dual mode radars for windfinding at others. The ART device is still under development and testing by its manufacturer in collaboration with the Bureau. **[Recent advice suggests that this development has been discontinued by the manufacturer.]**

Recommendation 24: That consideration be given to the installation of ART technology at sites where this will deliver a medium to long term cost saving, subject to the ART's ultimate commercial development and suitable operational performance. (ADO)

10.4.4.5 GPS Water Vapour

Ground-based GPS receiver networks offer an opportunity for the Bureau to obtain total precipitable water data from receiver sites. The relatively recent proliferation of GPS technology has led to the implementation of several ground-based GPS receiver networks across Australia. These receivers are equipped to record the time-of-arrival of GPS satellite signals, which, with a detailed knowledge of the emitting satellite's location, the time-of-transmission of the satellite signal, and the atmospheric temperature profile, can be used to calculate the delay in receipt due to signal passage through the atmospheric water vapour column, hence to estimate the total precipitable water column itself. Recent NWP experiments, both by BMRC and overseas, have found a positive impact on NWP skill of assimilating these data into models, suggesting potential for using the data as a cheap and effective supplement to the upper air humidity network. This suggests that analysed water vapour profiles obtained after assimilation of GPS water vapour information, used in combination with AMDAR, profiler and satellite data, may in future serve as a useful substitute for radiosonde profiles at some locations.

Recommendation 25: That the establishment of an operational program for acquiring GPS water vapour data, for assimilation in the Bureau's NWP models, be fast-tracked. (ADO)

10.4.5 Shortcomings in the Provision of Surface-based Remotely Sensed Data

10.4.5.1 Weather Radar

This study has identified significant inadequacies in the Bureau's current weather radar network which limit the quality of weather services for many areas. The Bureau-specified requirements for radar coverage of the entire country and its coastal waters are clearly economically unrealistic. Nonetheless, the Bureau's existing network, even taking into account currently planned enhancements to it, does not compare well with those of many overseas countries, including some less-developed nations. It is important that the Bureau more fully exploit the diagnostic and early warning capabilities of weather radar.

This study acknowledges the commitment the Bureau has made to the Parliamentary Secretary to conduct a detailed review of the weather radar program in the near future. That review should primarily focus on the requirements for new installations that provide coverage of high population density locations and strips of tropical coastline currently beyond current radar range. But it should also consider the needs for replacement and upgrade of existing infrastructure.

Recommendation 26: That the proposed review of the weather radar network be carried out, with its primary focus on expansion of the existing network to include all areas deemed to be of high priority following extensive consultation with key stakeholders. It should also include consideration of needs for:

- ***Network-wide conversion of all existing radars to digital signal processing;***
- ***Expansion of the doppler services network to include at least all major population centres, particularly the capital cities,***
- ***Retention of back-up radars at capital city locations, and***
- ***Implementation of dual polarisation capability at key locations. (ado)***

10.4.5.2 Lightning Mapping

This study has identified significant inadequacies in the Bureau's current provision of Australia-wide lightning detection and location information. High quality lightning information is required by most service areas of the Bureau. This requirement is at present partly fulfilled for weather services by the real-time commercial GPATS network, and for climate services by the Bureau's aged and non-real-time LFC network. A growing network of sophisticated TSS928 systems is being sponsored by the Aviation Weather services program at larger airports.

GPATS detection efficiency and location accuracy is inadequate, particularly over the north and west of the country. The commercial arrangement between the Bureau and GPATS leaves the Bureau prohibited from passing the data on to third parties. Bureau forecasters have difficulty in monitoring GPATS network status and data quality due to the lack of detection network "health" info and integrated data display capabilities.

The LFC network is ineffective, cannot discriminate between cloud-to-cloud and cloud-to-ground flashes, and involves obsolete technology and manual transmission of data at the end of each month.

The TSS928 system provides detailed information requiring monitoring and interpretation. The performance of the system is not yet well understood or characterised by the Observations Program.

This study acknowledges the work underway in the Observations Program to work with GPATS to expand their existing network to better suit the Bureau's requirements. It also acknowledges the collaborative project underway to develop a cheap, new generation sensor (CGR4) to replace the existing LFC network with a real-time system able to discriminate different lightning types. There is a need to accelerate this work, and to investigate alternative sources of data to supplement the existing supply.

Recommendation 27: That GPATS be urged to accelerate planned upgrades to its network, and to provide a more effective means for forecasters to monitor network status and data quality. (ADO)

Recommendation 28: That additional sources of lightning mapping data to supplement GPATS data be pursued. (ADO))

Recommendation 29: That the development of a real-time-reporting replacement for the aged LFC network, with the ability to discriminate between cloud-to-cloud and cloud-to-ground strikes, be expedited. (ADO)

Recommendation 30: That the Vaisala TSS928 lightning detection system be characterised, and its implementation continued at those locations where the detailed information can be beneficially utilised, particularly in support of aviation weather requirements. (ADO)

10.4.6 Shortcomings in the Provision of Surface-Based Surface Data

10.4.6.1 Visual Observations

The availability of surface observations that include comprehensive 'visual' element information is inadequate. A progressive reduction has occurred over the last decade in the density of the cooperative observer network and the frequency of cooperative observations received from most stations. At the same time, a progressive decrease in the number of manual observations from Bureau staffed stations has occurred, due to decreasing staff numbers at field stations. This downward trend in the overall density and frequency of manual observations has been compensated by an increase in automated observations. However, the automated observations have not provided sufficient information on many 'visual' elements, such as cloud type, and present and past weather, yet this information is critical for effective delivery of weather and climate services, especially for aviation.

There is a clear need for automated observations to include more 'visual' element information. The reversal of the trend in manual observations is unlikely due to downward pressure on TO(Obs) staff numbers and funding for cooperative observations. Although the technology has not been available in the past, new opportunities have recently emerged and are emerging, which offer the potential to address this issue via automated technology. Examples of these are present weather sensors, lightning sensors, and video cameras.

Recommendation 31: That current shortages of 'visual' element information accompanying surface observations be addressed, by accelerating the trialing and implementation of automated technology for providing this information. (ADO)

10.4.6.2 Spatial and Temporal Distribution of Surface Observations

There is a bias in the distribution of surface observing sites towards areas of high population density. Historically, sites were located where the needs were greatest, and where cooperative observers were available to make the observations. More recently, the advent of automated observing technology, though at first enabling the establishment of additional observing sites in some key remote locations, has been primarily employed to replace existing cooperative sites.

Today the Bureau's emphasis has shifted and it is expected to provide a much wider and more extensive range of services across the country. Information is required for agricultural communities, for climate monitoring, country-wide severe weather warnings, and more comprehensive information is required from rural and remote areas for the provision of flood warnings and drought assessments. Together with the increasing need for the Bureau to be more efficient in its operations, i.e. to do more with less, this suggests a need to optimise the distribution of surface networks to ensure adequate information is provided for all service programs.

Any changes to the current distribution of observing sites must be made on the basis of comprehensive data impact studies that address multiple user needs and cost-benefit issues. The specific requirements for such data impact studies are discussed later, in Section 5.3.

Recommendation 32: That the suitability of the current distribution of surface observing sites be reviewed, and changes made as opportunity permits, to ensure optimal effectiveness of the network in providing the data routinely required by all Bureau service programs. (ADO)

The Bureau's weather service areas have also identified a pressing need for an increased capacity to establish temporary observing sites, on demand and at short notice, in key areas in critical weather situations, to provide valuable supplementary information needed in these situations, e.g. fire weather. It is suggested that this need could be suitably fulfilled by the provision of more portable AWS systems to each region for instant deployment in critical weather situations.

Recommendation 33: That consideration be given to provision of additional portable AWS units to each Region for emergency deployment in critical weather situations. (ADO)

There is a significant imbalance in current reporting frequencies for surface observations from different locations, and a more standardised approach is required to ensure consistency in service provision. It is acknowledged that required routine reporting frequencies will vary from site to site, as dictated by the service requirements for data from those particular locations (e.g., more frequent reports are routinely required at major airports for aviation operations than from many other sites).

Recommendation 34: That routine reporting frequencies from surface observing sites across the country be reviewed and standardised, to address current imbalances to the extent possible, given the differing requirements for data from one site to another. (ADO)

There is also a need for greater flexibility in reporting frequencies from automated sites, to enable provision of higher frequency observations in critical weather situations.

Recommendation 35: That routine reporting frequencies from surface observing sites across the country be reviewed and standardised, to address current imbalances to the extent possible, given the differing requirements for data from one site to another. (ADO)

10.4.6.3 Agro-Meteorological and Water Resource Observations

This study has identified a clear shortfall in the Bureau's provision of essential information for agricultural and water communities, such as soil temperature, solar irradiance, evaporation, evapotranspiration, and soil moisture. The demand for these data is being driven by a combination of State Agricultural Agencies, and directly from agricultural communities themselves, particularly those in drought prone areas where detailed information is required to underpin claims for Exceptional Circumstances financial support.

Recommendation 36: That the current shortage in the availability of information essential for delivery of services to the agricultural community and for water resource assessment, such as soil temperature, solar irradiance, evaporation, evapotranspiration, and soil moisture data, be addressed. (ADO)

A particular shortcoming identified in current provision of agro-meteorological and water resource data is that of evaporation reporting. Evaporation is arguably the least accurately reported and recorded meteorological variable in our network. Wholesale numerical derivation, with support from a ground truthing network of automated evaporimeter sites should be pursued. Cursory evidence suggests that derived evaporation fields, corrected to a high precision ground-truthing network, would yield more reliable results than the current network and would allow generation of derived evaporation figures for all synoptic and AWS sites. Automated evaporimeters are now commercially available, and a prototype model is currently being performance tested by the Observations Program. There is a need to purchase a commercially available instrument for detailed testing, and subject to suitable performance, priority deployment in the field.

Recommendation 37: That the current paucity of evaporation measurement in the BCOS be addressed, and the feasibility of deploying automated evaporimeters at strategic sites, and the feasibility and acceptability to users of relying more in future on derived evaporation data, be urgently investigated. (ADO)

10.4.6.4 New Measurements

A significant particular failing of the BCOS identified by this study is the current lack of soil moisture measurement by the Bureau. These data are important for the derivation of satellite data for the lower troposphere, for improvements in NWP capability, and for the effective provision of services to the agricultural community, for fire weather and for the water resources sector. Although it is acknowledged that the useful measurement of soil moisture is a challenging area, there is nonetheless a strong need to address this shortcoming.

Another variable for which there is scope for improved measurement by the Bureau is snow depth and cover, an important climate variable which is not observed well.

Recommendation 38: That potential techniques for effective measurement of soil moisture at selected surface sites, and snow depth and cover at alpine sites, be investigated. (ADO)

10.4.6.5 Next Generation AWS and WebConsole

The technology on which the Bureau’s current AWS system is based is becoming rapidly outdated. The CPU/console/communications elements of many AWS units are approaching the end of their operational lives. Data communications techniques employed are outdated. Many units are operating at or near capacity, with little scope for additional sensors. Data quality assurance is problematic, and equipment maintenance is labour-intensive. In short, there is a pressing need for urgent replacement of the existing technology to achieve significant gains in management efficiency and effectiveness of data delivery.

Most of the existing shortcomings and many significant improvements in efficiency and effectiveness are achievable with new technology and alternative approaches to system architecture. The more promising of these are currently being explored by the Observations and Engineering Programs.

Recommendation 39: That the development and implementation of the Next Generation AWS and WebConsole systems be fast-tracked. (ADO)

10.4.7 Shortcomings in the Provision of Atmosphere Watch Data

The Bureau has historically had difficulty in maintaining its specialised climate-only networks due to the implicit higher priority of mainstream real-time activities.

The Slatyer-Bonner climate initiative of the early 1990s aimed at restoring Bureau observations in general and focussed on returning the solar and terrestrial (S&T) radiation network to mid-1980s levels, namely 20 odd stations. The resources provided to the S&T radiation and other specialist areas like ozone, Cape Grim BAPS and the precipitation chemistry network began to suffer significantly at the end of the 1990s. The S&T radiation network reached 16 stations out of 20 by 2000, but even then resources to sustain such a specialist network were declining, and with currently planned resource allocations, by June 2006 only 9 of the 16 stations will remain. Ozone sonde stations doubled to two by 1996, but now poor resource levels have forced the reduction in observations at one of the two sites, and if resources are maintained at current levels could force the closure of ozone sonde observations at Melbourne or Macquarie Is. If a total column ozone Dobson spectrophotometer fails there is no replacement. The precipitation chemistry network (BAPMoN) has been reviewed and found to be in a poor state, as the expertise to maintain the observations has not been available.

Perhaps the worst case is the Cape Grim BAPS station, the premier WMO/GAW station in the Southern Hemisphere. The building has been the subject of a number of OH&S issues and has needed replacement since 1998, and asset funding to sustain the measurement program has been very low since 2000. If there is no significant injection of funding into the Cape Grim BAPS infrastructure and measurement program in the next 2-3 years, some of Australia’s core contributions to the WMO/GAW Programme and monitoring for the Montreal Protocol will cease. While insufficient asset and G&S funding is part of the problem, the principle issue is the inability of the Bureau to maintain specialist expertise outside of the Bureau mainstream monitoring and service areas.

Recommendation 40: That significant resource increases be provided for specialised climate-only monitoring networks by:

- ***Ensuring that the Cape Grim BAPS building infrastructure is refurbished or rebuilt as planned in FY2008-09 and that its aged monitoring and analysis equipment is replaced;***
- ***Ensuring there are sufficient specialist staff to maintain on-going functions in atmospheric chemistry, ozone, radiation and metrology; and***
- ***Restoring and then maintaining the Solar and Terrestrial Radiation, Ozone, and bapmon station numbers to those indicated in the Slatyer-Bonner Review. (ADO)***

10.4.8 Shortcomings in the Provision of Metadata

The current BCOS fails substantially to satisfy a globally increasing need for observational data to be accompanied by comprehensive metadata.

Increasing pressure on the Bureau is expected from international developments such as the WMO Information System. To maximise the benefits from the system, participating NMHSs will need to support various standard protocols, and in particular a standard approach to metadata to enable efficient data discovery.

Recommendation 41: That current significant shortcomings in the provision of metadata associated with BCOS observational data be addressed. (ADO)

Many code types still employed by the Bureau for data transmission to the international meteorological community, such as the upper air TEMP code, are archaic, inflexible and allow no scope for inclusion of metadata at all. Newer code types are available, and some are strongly recommended for immediate introduction by WMO, yet the Bureau has been slow in adopting them.

Some codes used at present (e.g., MDF, Metar, Synop), while robust and well-established within the Bureau and/or the international meteorological community, are not commonly employed by external agencies, making difficult the transfer and exchange of data between the Bureau and those external agencies or users. With a growing need for the Bureau to depend more on the data from observing systems either shared with or entirely owned and run by external agencies (to be discussed later), and a growing emphasis on providing raw data as well as products to users, to better inform their decision making processes, these incompatability issues will become more accentuated.

Recommendation 42: That a project development plan to address current and future needs for modernising meteorological codes used to transmit data, both domestically and internationally, be developed. (ADO, ADC)

The current SitesDb system offers some metadata recording capability, but is already beyond its original design capacity. The Next Generation SitesDb concept provides considerable scope for, amongst other things, improving the amount and availability of accurate and up-to-date metadata for a large part of the BCOS.

Recommendation 43: That the development and implementation of a Next Generation SitesDb system, that can accommodate current and anticipated future requirements for all relevant Bureau metadata, be pursued. (ADO))

There is also a growing call for the capacity to provide most service areas with higher frequency data (such as 1 minute data) under some circumstances. Further, with the central processing model proposed for the Next Generation AWS comes the opportunity for more extensive quality assurance to be performed on all AWS data 'at source', rather than downstream once the data have reached NCC, so that not just the climate service but all users benefit from the higher quality data. For this quality assurance process to be optimally effective, it will require transmission from AWS units of high frequency data, and the preliminary real-time processing and qualification of incoming data in a database environment before its use by downstream service applications. All of these influences together suggest the need for the priority development, in parallel with the accelerated development of the Next Generation AWS and SitesDb systems, of an Incoming Observations Data Processing (IODP) environment. Note that such development must proceed hand-in-hand with modernisation of meteorological codes (Recommendation 42), without which adequate metadata cannot reach the IODP.

Recommendation 44: That development and implementation be pursued, in parallel with the Next Generation SitesDb system and revision of meteorological codes, of the Incoming Observations Data Processing (IODP) environment. (ADO)

10.5 Effective and Sustainable Operation of the BCOS

BOSS05 has highlighted a number of important data management system support and future-proofing issues which are critical to the effective and sustainable operation of the BCOS. These are considered next.

10.5.1 Staff Resources

Staff numbers at Bureau field stations determine the quantity and quality of observations that can be provided from those key locations. This impacts particularly on upper air flights and manual input to surface observations of value to aviation weather services and the climate program. Staff numbers can be reduced in a manner that minimises the impact on observations outputs but this requires time for planning and implementation.

Over the past two to three years the Observations Program has been called upon to operate with a reduction of the order of 50 observers without forewarning in the Bureau's stated strategic directions. Many of these "empty chairs" are moving around the network semi-randomly while planning and implementation of permanent network reductions catch up.

Recommendation 45: That the Observations Program clearly reflect within its longer term strategic plans the impact of significant staff reductions in the program, so that planning and implementation of adjusted program deliverables may be effected in a timely fashion. (ADO)

10.5.2 Quality Management

The current approach to quality management in the BCOS is inadequate and urgently needs addressing in the short term.

Both formal and informal quality control (i.e. 'before the fact') processes are well-established and well-managed, and reflect the considerable effort that has been made historically, both within the Bureau and internationally through, e.g., WMO's CIMO, to ensure the selection, implementation and operation of appropriate observing systems and techniques.

On the other hand, a formal approach to quality assurance ('after the fact') is lacking altogether in the Bureau and the numerous informal approaches employed are of varying effectiveness. The Bureau's matrix structure hampers critical information feedbacks from user to provider, and also hampers involved individuals' understanding of the end-to-end process of data delivery, and of the overall importance of quality management for the reliable delivery of data of requisite quality. There is inadequate documentation of end-to-end processes, leading to too much reliance on the knowledge of a few people, a critical weakness in today's Bureau, where those with the knowledge are rapidly retiring, staff mobility is high, and the increasing use of informal email communications has led to a decrease in effectiveness of the formal paper-based filing system.

There is likely to be a rapidly increasing requirement for the Bureau's data and services to be more accountable and to abide by formal Service Level Agreements in future. Without prompt adoption of a more formal approach to quality management in the Bureau that suits the Bureau's and its users' needs, it seems doubtful that we will be able to deliver on such agreements.

Recommendation 46: That a working group be established, under the leadership of the Observations Program, to further consider the draft recommendations of the BOSS05 Task Team on Quality Management, and specifically to develop a project to identify and implement a formal quality management system that suits the Bureau's needs and those of its users. (ADO)

With the current pressure on BCOS resources likely to lead to partial replacement of manual observing techniques with more sophisticated, automated techniques, the Bureau's climate record faces grave risk of corruption and degradation unless particular attention is paid to maintenance of data traceability. To ensure this traceability it is imperative that adequate periods of overlapping measurements are provided for in the change-over process for any observing system component.

Recommendation 47: Ensure that, wherever operational observing techniques are modified in any way, provision is made for suitable periods of parallel operation of old and new techniques, so that the overlapping measurements can be used to provide adequate data traceability from one measurement system to the next. (ADO)

10.5.3 Equipment Lifecycle Management

The current trend away from manual observing systems towards more automated systems is leading to an overall increase in total observing system asset value, and maintenance loads. Thus it is becoming increasingly important to ensure more rigorous and transparent links between designated depreciation lifetimes for accrual purposes, equipment lifecycle maintenance costs for planning purposes, and funds allocated for asset replacement and goods and services for this equipment.

With the expected increase in automated observing equipment in future, and a consequent increase in equipment maintenance requirements, it will become increasingly important to ensure that Engineering Service areas, whose staffing resources are already stretched, remain adequately resourced. Of course, with a likely increased capability for remote diagnostics, remote software upgrades, simplified AWS field equipment, possible adoption of a redundant sensor model, and the potential for some equipment calibration and corrective actions to be performed remotely, it is possible that overall equipment maintenance loads will in fact decrease on a per unit basis and/or that the service delivery models and structures may change.

Recommendation 48: Ensure that equipment purchase and design takes into account the need to minimise maintenance requirements while maximising data quality and continuity, using appropriate technology, and that these factors in addition to more accurate and transparently linked equipment lifetime depreciation, lifecycle maintenance costs and funds allocation be properly accounted for within the Asset Replacement Program and the routine operational budget. (ADO)

Recommendation 49: That engineering maintenance requirements for new automated equipment are fully ascertained prior to installation and that the implied human resource expenses are factored into implementation plans.(ADO)

This study notes the recent trend towards specifying and standardising service level requirements for equipment outages, noting that this enables more effective management of engineering service resources, enables engineering services staff to better prioritise requirements, and provides important input to external service level agreements.

Recommendation 50: That the trend towards standardising service level requirements for outages of all equipment is continued. (ADO)

10.5.4 Communications

There is significant scope in the short term for reducing the cost of AWS communications without reducing data volumes, by capitalising on the recent availability of new and cheaper technologies such as GPRS, ERTS, ADSL, etc. Experimental trials are currently underway within the Observations Program, in collaboration with CCSB, to test the feasibility of such technologies for the reliable delivery of AWS data. In the event that these trials are successful, there may be scope for broad-scale implementation of this technology before the arrival of Next Generation AWS.

Recommendation 51: That implementation of new generation communications technology in the existing AWS network, to achieve greater economy of communications in the short term, is pursued. (ADO)

10.5.5 Spectrum Management

The Bureau's use of the radiofrequency spectrum is coming under increasing pressure from other spectrum users, particularly commercial operators, with an increasing requirement for the Bureau to defend its current and future use of the spectrum.

The ACMA is currently discussing whether sections of the spectrum could be successfully managed by private operators, under which arrangement the Bureau would be required to negotiate on a commercial basis with private "Band Managers" to utilise the spectrum it currently uses. At the World Radiocommunications Conference 2003 (WRC-03), the feasibility was discussed of including Radio Local Area Networks (RLANs, or WiFi) in the frequency band where the Bureau currently operates meteorological C-band radars, potentially jeopardizing our future use of this band. Most recently, the advent of UWB devices (such as automotive collision avoidance radars) have emerged as a significant threat to current spectrum usage. All this points to a need for the Bureau to be more vigilant and proactive than in the past, if we are to protect and preserve our spectrum usage.

Recommendation 52: That the Bureau take a greater lead in national spectrum management for and through WMO, ACMA, the APT and ITU-R to minimise the risk of future loss of spectrum. (ADO)

10.5.6 Use of Shared and/or Third Party Data and Systems

As well as the entirely Bureau-owned and Bureau-operated components of the current BCOS, there are numerous systems operated either through Bureau partnerships with external organisations, or entirely owned and run by external organisations. Obtaining data in these ways is economically appealing, but it introduces risks associated with our inability to strongly influence system maintenance and replacement processes, and/or data quality management processes for these systems and their data, or to guarantee that provision of the data will continue in the longer term. Nonetheless, with suitable arrangements in place to deal with these potential problems, the data can provide a very useful supplement to the Bureau's own data sources, especially in areas of common interest with other external agencies. The flood warning service in particular has exploited this market effectively.

Further opportunities exist for the Bureau to capture external data, and there are meteorological applications networks held by third parties that it may be advantageous for the Bureau to tap into in order to establish a foothold for the longer term development of Earth Simulation Models and the Bureau-CSIRO collaboration on the ACCESS project. Networks containing data such as air pollution information, streamflow, greenhouse emissions, soil characteristics and even economic and demographic data will likely prove valuable into the future.

With the Bureau's internal resource constraints expected to tighten further in the future, and noting the existence of large quantities of as yet untapped third party data and increasing opportunities for use of third party data and collaborations, this study tentatively concludes that the Bureau should adopt a more proactive approach to obtaining and utilising these data. This study also notes that a more organised and regulated approach would be required in future than has in some cases been taken in the past, to make maximum economical use of these data.

Overall, this study sees considerable potential in extending our use of these external or shared data in future, and notes that collaborative approaches to data collection are currently viewed favourably by most government organisations, at each tier of government. However BOSS05 has been unable to fully investigate the issue, and suggests it requires, and is worthy of, more complete examination under a separate study.

That study will need to include:

- Deeper consideration of the merits of seeking further involvement in external or shared data and/or systems; and if so
- Development of a bureau-wide policy on this issue which:
  - Includes guidance on how external requests for establishment of observing sites or equipment should be treated if considered inessential to the bureau, and
  - Clearly states the circumstances under which third party data will be either accepted or not accepted by the bureau;

- Establishment of a register of all non-bureau networks which includes information on the robustness and quality of the data from each system; and
- Consideration of issues related to working with local manufacturers and suppliers to encourage development of robust cost effective systems that meet the specific meteorological requirements of small client groups as well as our own.

Many third party data providers provide their data for the Bureau's internal use only, and not for further dissemination. Yet the Bureau does not have a simple system for "quarantining" such data in its databases. Subject to a decision to seek further involvement in these data streams, it will be necessary to develop an efficient method for quarantining particular datasets if the Bureau is to be effective in gaining maximal benefit from all of the potentially valuable third party data sources available.

Recommendation 53: That high priority be given to exploring more fully the merits of involvement in shared and/or third party data or systems, and that policy for Bureau involvement in these systems be developed to reflect the current situation and possible future initiatives. (ADO, ADN, ADS)

10.5.7 Tiered Networks

The Bureau has historically adopted the 'one-shoe-fits-all' model for observing system design, despite an essentially bi-modal distribution in data requirements, by endeavouring to satisfy all requirements together.

The primary requirement of weather service areas tends to be for high data volumes (high resolution and coverage in space and time) delivered in real-time, whereas issues of data quality, permanent archival and length of record come second. On the other hand, the primary data requirement in the climate services area is for high quality, long record length and permanent data storage, with somewhat less concern for timeliness or density of coverage, depending upon the application at hand (with an increasing number of applications also requiring high spatial and temporal density).

The current approach is a robust but expensive solution. It is increasingly difficulty to maintain current network operations in the tight economic environment, while fulfilling all the equipment maintenance and calibration requirements imposed by insisting all data are of highest quality. There may be merit in the adoption of a tiered approach to data sets and networks in future, in which specific networks (e.g. severe weather, climate) are singled out for priority treatment in terms of equipment quality, and inspection and maintenance schedules, while others are viewed as lower priority, perhaps utilising cheaper equipment which is maintained, repaired, recalibrated etc. at a lower frequency, or only if and when resources are available.

Adoption of such a model would provide a partial solution for the data quality issues surrounding third party and shared data, and should help to address some of the issues associated with the highly variable state of quality management from one data stream to the next. It would also enable a simpler means of setting overall priorities for equipment purchase, inspection, maintenance and calibration, easing current concerns in those areas, and likely reduce the overall load on our engineering services resources. Less pressure on immediate reporting of all data should also increase the flexibility in selecting communications strategies and provide increased scope for savings in communications and data handling costs.

This study has been unable to fully assess the merits of implementing a tiered network model, or to ascertain the details of the model to be adopted should the Bureau ultimately choose to follow this path, but suggests it to be another issue for full investigation under a separate study.

Recommendation 54: That high priority be given to exploring more fully the merits of adopting a tiered network model for the BCOS. (ADO, ADN)

10.5.8 Redundant Sensor Model

The redundant sensor model is an option that might be implemented to deliver a more robust system with opportunities for improving performance management. In addition, if done well, it can ease the load on engineering services and field staff. In this model, three temperature or pressure sensors, for example, would be installed in each AWS unit rather than just one as at present, to enable internal monitoring of sensor state, the introduction of a more economical corrective, rather than preventative, maintenance regime, and to both avoid data loss and ease the requirement for rapid engineering response in the case of sensor failure. The drawback is a requirement for increased funding for purchase of sensors, but high quality sensor costs are quite modest these days, so the overall savings in inspections, calibration and maintenance are expected to far outweigh the cost increase. However, the model, only conceptual at this stage requires thorough testing and assessment prior to operational implementation.

Recommendation 55: That a trial of the redundant sensor model for some basic quantities measured by AWS, be initiated to assess suitability of the model for operational implementation. (ADO)

10.5.9 BCOS Planning

Strategic studies of the Bureau’s observing system, such as this, have been carried out from time to time for many years. Conducting such studies in this periodic fashion leads to a degree of policy stagnation in the years between studies, despite the relatively dynamic state of the technological, economic and social environment. Adoption of a ‘rolling’ BCOS planning model would smooth out these periodic peaks in human resource requirements for planning, enable a more dynamic and flexible approach to BCOS planning, and enable more rapid response to changes in system environment.

Recommendation 56: That a ‘rolling’ BOSS model for observing system planning be adopted. (ADO)

It is important for BCOS assessment and planning that we monitor the impact of observing system upgrades on performance of services as measured against the Government’s expected outputs and outcomes targets, and against the perceptions of users. This helps to demonstrate the value of past investments, and assists in demonstrating the potential value of proposed future investments.

The Bureau currently maintains numerous performance metrics on output products, such as the temporal evolution of NWP skill scores, forecast error statistics, and the reliability and timeliness of product delivery, and this enables some assessment of the overall effectiveness of the Bureau in delivering its service outputs. Yet the current simplicity of the performance indicators employed often prohibits detailed attribution of performance to different processes in the services delivery chain. The adoption of performance indicators better tailored to measuring the effectiveness of specific processes would lead to improved performance measurement against outputs.

Most of the existing performance indicators employed by the Bureau are output-related. There is an increasingly urgent need for the Bureau to assess its performance against outcomes, rather than outputs. For example, demonstrating that average or extreme forecast errors have decreased over time provides good evidence of improved outputs, but fails to address the social and/or economic value of those outputs to the Australian community. Although a difficult problem to address, there is a clear need for more effective evaluation of the Bureau’s economic value to the Australian community if we are to convince government of the value in investing further in the Bureau.

As well as a need to better assess performance against agreed government outputs and outcomes by the use of objective indicators, there is a need to do more to continuously monitor social impact and perception. Public perception is a very useful performance indicator. The implementation of web-based radar imagery has had a clear and positive impact on public perception of the Bureau. It is important that we continue to measure and collate information on public perceptions, particularly changes in response to new initiatives. Where positive perceptions are identified, this can serve as powerful evidence in support of future bids for service and system upgrades. Where negative perceptions are identified, this serves as a pointer to areas of operation or policy that may need to be addressed.

Recommendation 57: That improved measurement and routine monitoring of the impact of observing system upgrades on outcomes, including data quality and performance of services, be pursued. (ADO, ADS, ADN)

10.6 Underpinning the BCOS

10.6.1 Data Accessibility and Storage

At the commencement of the present study, the boundary of the BCOS was somewhat arbitrarily drawn at the point at which a data stream first splits into multiple paths on its way to data users. This point was chosen for good reasons, but the choice made has incidentally placed the data storage process for most data streams beyond that boundary, i.e. outside the BCOS. Whether or not this should be the case is open to debate, but what has become transparently clear during BOSS05 is the importance to the BCOS, and all downstream areas, of having in place a more adequate, comprehensive and integrated system for data storage than is currently available.

The term 'data storage' is used here to mean all forms of data storage: both temporary storage and long-term archival. Much of the data used by, e.g., the Bureau's weather forecasters, can have a limited shelf-life (today's 'news', tomorrow's 'fish wrapper') so there may not be a strong need for its long-term storage. On the other hand, the data required by climate services, in particular, is required for future generations of Australians, so must be permanently preserved in an archive. Here, the single term 'data storage' is used to refer to all data storage, irrespective of timescale.

Data storage in the Bureau is presently carried out, if at all, in a piecemeal and somewhat ad hoc manner for many data streams. There is a perception that the climate database is the primary database for storing all Bureau data, however there is some tension between this database's perceived roles as the climate record and as a universal Bureau archive. The Observations Program maintains a number of separate data bases itself (e.g., profiler, GPATS, and AMDAR data) because the data required by it for observing system performance monitoring and assessment are either not available elsewhere, not easily accessible where they are stored, or are not stored with essential metadata associated with those data. Similarly the Regions also hold their own, disparate databases for some observation types.

This current disorganised approach to data storage in the Bureau results in not all useful data being stored, stored data being difficult to locate and/or access, stored data seldom being located alongside other similar data forms, lack of a coherent approach to metadata, and much duplication of effort. Together this has the effect of discouraging the use of historical data, which in turn limits potential for further quality assurance being carried out on those data, limits potential for system performance analysis (unless carried out in real-time), and provides little opportunity for analysing, inter-comparing or merely displaying together similar data types from different sources.

It is acknowledged that there are questions about the need to store all data, given that some is of unknown quality and unaccompanied by quality assurance information. However, past experience has shown that some data, previously only believed to have been of immediate operational interest eg. high resolution AWS data, has developed into a highly valued resource.

There are also questions about the length of time data should be stored. Obviously climate data must be stored indefinitely, but perhaps some data sets of lower quality that are of little interest to anyone once they have served, e.g., their weather watch purpose, should be disposed of after a short period.

A single, Bureau-wide data inventory for all Bureau data requiring storage would address this issue. Whether this must involve physical storage of all data in the one physical place, or merely a virtual store, with different data types physically located in different places, has not been determined by this study. Whichever model is adopted, the data store must contain all data types, provide for simple access to all Bureau users, include quality assurance information for all data, and provide options to extract output data in a range of suitable formats, including GIS-compatible formats.

It is suggested that one group be assigned the task of data management and archival of all observational data and output metadata, in a single, coherent data management structure that allows extraction and cross referencing of all data and metadata types available, to all potential users. Apart from paving the way for better integration of observations in operational systems and consequent service improvements, it would also be an improved research facility, facilitate a better and more comprehensive system for data quality management and performance assessment, and allow provision of a more comprehensive climate service.

Recommendation 58: Conduct a detailed study into its needs for data storage and retrieval, and implement an appropriate system which enables ready access to all data types by all data users. (ADC)

10.6.2 Data Display Systems

The Bureau's capabilities for displaying composite data are limited. Although display systems are in place to enable the display of most data types, many of these provide for display of data from only a single source or a few sources. This limits our ability to routinely intercompare similar data types from different sources or to view composited data for forecasting purposes, which in turn influences user dependence on different data types. The influence that this inadequacy is perceived to have had on our under-utilisation of satellite-derived temperature profiles, hence over-dependence on, e.g., radiosonde profiles, was discussed in section 3.3. above.

Another example of the downstream influence of our inability to adequately display composited data may be in the attitude held by our services areas to the adequacy of lightning data provision. GPATS data, lightning/thunderstorm related synoptic observations, and other lightning data sets such as surface-based data from the World Wide Lightning Locator network and space-based data from the Lightning Imaging Sensor on TRMM, are all currently maintained on independent platforms, with no integrated display available to show all of these data in one presentation, or to display the data alongside or overlayed with other data, model output, radar or satellite imagery, and so on. To gain the maximum benefit from all of our data it must be readily presentable in an integrated fashion with other spatial information held by the organisation.

Recommendation 59: Urgently address current significant limitations in our ability to simultaneously display data from a wide range of different sources. (ADC)

10.6.3 Data Impact Assessments

There is currently no group within the Bureau that has as its primary role assessment of the impact of BCOS changes on the scientific adequacy of resultant information for purposes ranging from climate and climate change analyses, to NWP performance, forecast performance and quality of output services. Without such a group these impacts cannot be quantified systematically and objectively.

Data impact studies are required for a broad range of purposes, including:

- Generation of defensible, scientifically based responses to questions such as "what is the optimal network given a particular resource scenario", or "what will be the impact on forecasts if we remove the radiosonde program from a given station", or "if we had to eliminate a station, which would have least impact", or "what would be the impact of placing a new observation site at location X";
- Assessments of the suitability of the spatial and temporal distribution of surface networks, by:
  - Analysis of the overall efficiency and effectiveness of current BCOS design;
  - Analysis of the most effective network design given a set number of observing stations;
  - Separate analyses of the required network design for supporting climate monitoring and change activities, and activities other than those related to climate;
  - Analysis of the costs versus benefits of particular network expansion or observing technique change scenarios, such as the introduction of multi-tiered networks;
  - Assessment of network design required to meet the particular needs of the emerging GFE forecast paradigm; and
  - Analysis of the viability of tiered networks;
- Development of objective tools to routinely assist
  - Forecasters to make decisions on when and where to utilise adaptive radiosondes; and
  - Analysis of the impacts of proposed changes in BCOS design;

- Quantification of the links between NWP accuracy and service delivery standards in order to objectively measure the impact of different components of the BCOS on forecast accuracy;
- Assessment of the impacts on outcomes of previously-implemented changes to the BCOS; and
- Monitoring and verification of forecasts for unobserved locations. The move towards the Graphical Forecast Editor (GFE) as the basis for forecasts over a distributed domain will exacerbate this issue.

In view of the growing need to support proposed BCOS changes with objective evidence of benefit, there is a clear need for a dedicated group to work on assessing data impacts. This group would need to be on-going in order to develop a core of expertise, would require several staff, should be located within or be strongly linked to BMRC to capitalise on the modelling and data assimilation expertise there, and should have priorities set and performance overseen by a steering committee including representation from Observations and Engineering, Services, National Operations and Research program areas.

Recommendation 60: That a dedicated group be established to strengthen efforts in assessment of data impacts. (CSR)

10.7 Organisational Requirements

10.7.1 Field Office Replacement

Increasing implementation of automation and alternative technologies at field stations, particularly for obtaining upper air data, will provide opportunities for significant savings in the costs of construction and maintenance of Field Station Offices. The Field Office replacement project has recently been accelerated with the injection of one-off funding. This adds urgency to the testing and implementation of new technologies and observing techniques, and to ascertaining the impact, before implementation, that these changes will have on BCOS performance.

10.7.2 Limited Opportunities for Increased Cross-Program Collaboration

In recent years, labour-sharing arrangements have been informally but successfully implemented in some regions between regional observations and engineering staff to meet more efficiently the resource requirements for some field inspection and maintenance tasks. This study finds that there may be further scope for such arrangements to be implemented, by more general and formal adoption of the model across all regions, and by inclusion of regional hydrological staff in these arrangements. Broadening the application of this model will impact on skill sets required by each staff category, so in turn will impact on training requirements. These should be fully assessed and provided for prior to any implementation.

Recommendation 61: That the Observations, Engineering, Hydrological Services and Training Programs perform a detailed assessment of the potential operational benefits and training implications of cross-program collaboration for field equipment maintenance and inspection, and implement more formal and widespread arrangements as appropriate. (ADO, ADN, ADE)

Bureau Hydrological Services depend on data from many of the networks that make up the BCOS, especially those networks managed from within the Hydrological Services Program as well as many third party networks, but also much of the surface and other networks managed by the Observations Program. For a range of reasons different practices with regard to network management and operation have developed within each program in order to meet particular program objectives. Hydrology are seen as having a more end-to-end approach to this task and have achieved significant efficiencies by working more cooperatively with other agencies. A further difference is that Hydrology field staff are not just confined to the normal range of equipment-related field activities but are also heavily involved in service delivery and development. Nevertheless there is merit in exploring whether the total resource for network management and operation available within both programs could be better applied to achieve more effective and efficient outcomes for the Bureau taking the full scope of needs into account.

Recommendation 62: That the Observations, Engineering and Hydrological Services Program examine the potential for utilising the combined resources available for network management and operation more effectively and efficiently in achieving desired Bureau outcomes. (ADO, ADN)

10.7.3 Changing Bureau Culture

BOSS05 has highlighted the importance of a cross-program approach to the design, delivery and end-to-end operation of an effective BCOS. The move from the historical equipment-driven approach to a more services-driven paradigm recognises the need to ensure a close linkage between what the Bureau delivers to the community and how well that meets their needs. This process of internal Bureau consultation, planning and assessment must continue and it behoves each program to ensure that all other programs have a sound understanding of what their respective responsibilities are and what questions they need answered, if they are to perform and interact effectively. This approach needs to be part of the day-to-day culture of the Bureau, not just part of a periodic planning process.

11 Recommended Strategy for the BCOS

11.1 Introduction

The BCOS has served the Bureau and the Australian community well for most of the last century. In particular, the last few decades have witnessed enormous gains in BCOS efficiency so that today it represents world’s best practice in many respects. Most of these gains have resulted from the implementation of advanced observing technology, and from the computing and communications revolution.

Yet the BCOS is under critical and increasing pressure. There is a rapidly increasing demand for expansion of Bureau services in the face of an economic climate of contraction. Although there are numerous potential opportunities for achieving further BCOS efficiencies in the medium and longer term, most of the immediately available initiatives have already been implemented. Together, these factors suggest the coming decade will be a particularly challenging period for the Bureau.

11.2 Realistic Options within the Projected Resource Envelope

This study sees little prospect for a ten year strategy for the BCOS that is realistically achievable within the Bureau’s existing budget envelope, yet acceptable to BCOS stakeholders. To remain within its currently-projected resource envelope, two choices are apparent.

The first choice is to continue the BCOS in its present form (‘business as usual’). Despite some opportunities for incremental efficiency gains in the short term, and these will be discussed later, this strategy would be expected to lead to an ongoing and long-term decline in the BCOS. This, in turn, would lead to a corresponding decrease in service outcomes (based on the evidence available) and, in particular, cause a long-term, negative impact on the national climate record.

The second choice is for the Bureau to divert current operational BCOS resources to fund rapid development, testing and operational trialing of a range of emerging, alternative observing technologies that promise long-term operational efficiency gains. Internal provision of the additional resources required for this would necessitate immediate reductions to operational program (over and above those recently implemented), and continuing until the proposed replacement technologies, if successfully trialed, were implemented in the medium term. At best, this would seriously jeopardise the provision of many Bureau services in the short to medium term, and have a longer-term negative impact on the quality of the national climate record. At worst, should the proposed alternative technologies ultimately fail to deliver on their promise, this would result in an even more marked deterioration in service outcomes than the relatively ‘slow death’ of the ‘business as usual’ strategy.

The only circumstance in which such a degradation in BCOS performance could sensibly be permitted would be the prompt production of strong evidence demonstrating only a weak connection between BCOS performance levels and service outcomes. All the evidence available to date indicates that this is not the case, so neither of the above strategies is recommended if the Bureau is to remain a first class provider of weather and related services.

11.3 The Recommended Strategy

This study instead proposes a strategy requiring a significant short to medium term boost in financial and human resources for the BCOS, to enable development and implementation of new technology, while ensuring in the interim that the BCOS achieves acceptable operational performance levels. Subject to the successful trialing of such potential alternative technologies, there should then be scope for operational implementation of a more automated BCOS in the longer term, which both maintains effectiveness in the face of expected increases in service demand, and also achieves further efficiency gains, in particular with regard to the human resource levels required to maintain the system and deliver its outputs successfully. So the short term significant increases in resource allocation required to test, and where successful, implement more efficient solutions, should ultimately be partially compensated through overall reductions in required staffing and infrastructure in the field, and by the accumulation of modest ongoing savings available once the BCOS stabilizes in its new equilibrium state. However, the required short to medium term investment is expected to be too large to be sourced internally without seriously impacting on other program areas: this study suggests that there is no viable alternative to submission of one or more business cases to Government to acquire the additional resources required.

This recommended strategy for the evolution of the BCOS over the next ten years comprises 4 overlapping stages:

- Stage 1: (Years 1 to 4): Consolidation of the existing BCOS;
- Stage 2: (Years 1 to 4): Implementation of overarching and underpinning initiatives;
- Stage 3: (Years 1 to 7): Development and testing of new technology; and
- Stage 4: (Years 1 to 9): Migration to a new and sustainable configuration for the BCOS.

The details of each of these stages are summarized below and tabulated in more detail in Attachment 13. Each table in the latter lists a series of individual initiatives required over and above existing program. Each table entry includes:

- An estimate of the perceived importance/priority of the work;
- The anticipated area in the bureau to be primarily responsible for the work;
- An approximate timeframe for the work;
- Crude estimates of the cost of the work in terms of incremental asset, goods and services, and staffing resources required; and
- The recommendation number(s) from section 10 which the particular initiative addresses.

11.3.1 Stage 1: Consolidation

This stage comprises a number of immediately practicable initiatives which address significant shortcomings in some key areas without making significant changes to the techniques and technology employed within the BCOS.

Indicative (only) 10 year costs for incremental Asset, G&S and Staffing expenditure associated with each of these initiatives are shown in Table (a) of Attachment 13, and the overall year-to-year incremental costing envelope for each expenditure type is shown in Figure (a) of Attachment 14. For the purposes of BOSS05, incremental costs are those over and above the baseline described by the Bureau's draft 2005-10 Asset Replacement Program.

Overall, implementation of all initiatives in Stage I would incur the following (very) approximate incremental expenses:

- +$7M Asset (years 1 to 4), including:
  - $5.5M for Atmosphere Watch (CGBAPS, S&T network), and

    - $1.2M for adjusting the distribution of surface observations;

- +$1.3M (approximately) G&S per annum, mainly to cover the cost of additional radiosonde consumables; and
- +10 ASL, mainly to boost field staff numbers for the radiosonde program restoration.

Note that progressive small reductions in radiosonde consumable expenses and progressive significant reductions in required field staff numbers, expected to become available once the rollout of new technology (Stage 4) is underway, are included as a separate item under Stage 4, since the availability of these compensating savings is strongly dependent on the successful implementation of most of the new technology initiatives.

11.3.2 Stage 2: Overarching and Underpinning Initiatives

This stage involves those initiatives, many of which fall beyond the BCOS per se, which are aimed either directly or indirectly at future-proofing the BCOS from further degradation (e.g. by improving performance measurement, hence accountability and defensibility), and at ensuring that the BCOS and its data can in future be optimally utilised by the Bureau's service programs (e.g. improved data storage, access and display, modernization of meteorological codes, data utilization in NWP and climate activities).

Table (b) of Attachment 13 and Figure (b) of Attachment 14 show the overall and year-to-year incremental expenditure, respectively, required for these initiatives. In summary, they comprise:

- +$1.4M Asset (years 1 to 4), involving:
    - $200K for performance measurement tools;
    - $800K for NWP assimilation of satellite data; and
    - $400K for development of data display software;
- +$1.2M down to +$130K per annum G&S, including:
    - $400K one-off for quality management; and
    - $700K over two years for value assessment;
- +8.5 ASL for ongoing support of these initiatives.

11.3.3 Stage 3: Development and Testing of New Technology

This stage involves the accelerated development and/or testing of new technologies and techniques, such as satellite applications, AMDAR WVSS2 sensors, radar wind profilers, dual polarization radars, cheap lightning sensors. It also includes the detailed investigation of alternative system component models, such as the use of shared and third party data, tiered networks, and alternative administrative models.

Table (c) of Attachment 13 and Figure (c) of Attachment 14 show the indicative incremental costings and the proposed expenditure schedule for this group of initiatives..

Overall, the estimated incremental expenditure for the ten year period for Stage 3 comprises:

- +$1.4M Asset;
- +$400K down to $200K G&S per annum over the first 3 years; and
- +2 ASL.

11.3.4 Stage 4: Implementation of New Technology – BCOS Migration

This stage involves the progressive operational implementation of new technology/techniques/models that offer efficiency savings, especially in staff resources (e.g., wind profilers, AMDAR, Next Generation AWS, automated visual element data) and the implementation of a number of new initiatives, over and above current program, which address some perceived shortcomings in the existing BCOS (e.g. radar network upgrade, implement GPS water vapour network).

It will to fund the purchase of new instrumentation for the weather watch radar network expansion and upgrade initiative, so this is considered on its own in the accompanying ,

Table (d) of Attachment 13 provides estimates of the overall incremental Asset, G&S and Staff expenditure expected to be required for each of these initiatives.

If all the proposed new technology initiatives are implemented successfully, these rollouts will enable an orderly, progressive and substantial reduction in field staff numbers at Bureau staffed stations, and will also enable partially compensating decreases in asset expenses due to the reduced need for field office accommodation, field staff housing, and other existing infrastructure in the field. These effective savings are shown as a separate initiative towards the bottom of Table (d) in Attachment 13.

Regarding the weather watch radar network upgrade and expansion initiative (the last entry in Table (d) of Attachment 13), although the detailed requirements (e.g. number of new radars, etc) for this initiative are yet to be determined, it is anticipated to require a significant capital injection that is larger than all the other BCOS initiatives combined. So as not to cloud the picture of the expenditure implications of all the other Stage 4 initiatives, the expected year-to-year expenditure associated with the radar initiative has been excluded from consideration with the other Stage 4 initiatives. Accordingly, Figure (d) of Attachment 14 shows the year-to-year incremental expenditure profile for all Stage 4 initiatives, excluding the radar initiative, while the corresponding data for the radar initiative are shown on their own in Figure (e) of Attachment 14.

It should also be noted in regard to the Stage 4 costing estimates in general, that the precise requirements for many of these initiatives are also uncertain, and await the determination of detailed requirements which are beyond the scope of this study. Hence the expenditure data for this group of initiatives are merely 'best guesses', and should be considered with caution.

Overall, the incremental expenditure for the ten year period for all Stage 4 initiatives, excluding the radar network initiative and the anticipated compensating savings that should become available subject to successful implementation of Stage 4, is estimated as:

- +$23M Asset, including:
  - $6M for ST profiler purchase;
  - $4M for BL profiler purchase;
  - $8M for provision of comprehensive visual element data from AWS;
  - $1.5M for implementation of cheap lightning sensors on AWS;
  - $2M for expansion of the AMDAR program, including provision of water vapour data; and
  - $2M for agro-meteorological sensors;
- From +$140K G&S for the first year, increasing to $1.9M per annum ongoing G&S from Year 10;
- 0 ASL in Year 1 increasing to a peak of +12 in years 4 to 6 then reducing to an ongoing +8 ASL by Year 10.

These incremental costs should be offset by the aforementioned compensating savings of:

- $29M Asset, comprising:
  - $4M from sale of staff housing;
  - $20M from reduced requirements for field offices;
  - $2M from reduced need for balloon filling facilities;
  - $1M from reduced need for radiosonde ground receivers; and
  - $2M from reduced need for radar equipped with wind-find function;
- G&S increasing to $200K per annum by year 10, in radiosonde savings; and
- Zero ASL in Year 1, increasing to 70 ASL ongoing by Year 9.

The year-by-year total expenditure envelope for all Stage 4 initiatives, excluding the weather radar initiative, but including the anticipated compensating savings discussed above, are shown in Figure (d) of Attachment 14.

The estimated cost of the radar network initiative is estimated at $60M Asset over 7 years, G&S expenses rising to $3M per annum by Year 10, and +7ASL by Year 10. The Asset expenses comprise:

- 10 new conventional radars ($20M Asset);
- 4 new high resolution Doppler radars (16M Asset);
- Digitization of all radar in the network ($3M Asset);
- Dual polarization capability on all high resolution Doppler radars ($5M Asset); and
- $16M for service infrastructure and software development.

The estimated year-by-year expenditure envelope for this weather radar initiative is shown in Figure (e) of Attachment 14.

11.4 Overall Funding Implications

Implementation of the BCOS strategy described in Section 11.3 above is unlikely to be viable within existing resource levels, as discussed. To illustrate the overall resource implications, Figure (f) of Attachment 14 shows the year-by-year envelope of total expenditure for all Stages of the proposed strategy. Its main features, excluding consideration of the radar network initiative (the brown bars in the Figure), are:

- The need for an additional injection of approximately $35M over the first five years, $34M of which is required in the first 4 years;
- Significantly reducing costs from years 4 to 6, as compensating savings begin to kick in;
- Reduced net operating costs relative to current expenditure, from year 6 to 10 inclusive, due to further compensating savings (primarily in staffing and assets) achieved by the progressive migration of the BCOS to a more automated state, which should enable a payback of $12M over the five year period; and
- An ongoing steady state achieved by year 10 which provides an overall reduction of approximately $1.3M per annum in G&S and staff costs compared to present levels, potentially enabling a full refund of the remainder of the incremental expenditure incurred by approximately 2035.

Overall, the above costings comprise best guess estimates for implementing all of the initiatives listed in the tables of Attachment 13. One issue not considered or costed in this study (or in the tables of Attachment 13) is the requirements for implementing the redundant sensor model for the Bureau’s surface observations network. Insufficient information was available to this study to provide a worthwhile estimate for this initiative, though the Next Generation AWS Options Study suggests incremental costs of +$5.5M Asset, -$220K G&S per annum, and a net staff saving of 6.5ASL.

Attachment 1

DIR, DDS, DDC, CSR File Ref: 45/525
cc ADE, ADS, ADN, ADC

Conduct of the Basic Observing System Study 2005

Purpose

1. To advise you of plans for the conduct of the Basic Observing System Study 2005 (BOSS05) and seek your endorsement of the scope and draft Terms of Reference for the study.

Background

2. The Bureau has an ongoing need to ensure that it delivers an efficient and effective basic observing system that meets the requirements for meteorological and related data in support of the Bureau's Basic System and enables the Bureau to deliver its agreed outputs to Government. In order to ensure that the Bureau, and in particular the Observations and Engineering Programs, are well positioned to capitalise to an optimum level on available scientific advances and improved monitoring technologies, that we provide the most efficient and effective system within a continually shrinking resource envelope, and that we have the most coherent and up-to-date basis for decisions in relation to the delivery of the Programs, it is proposed to conduct a Basic Observing System Study 2005.

BOSS05 Proposal

3. The aim, scope, participation and draft terms of reference for the BOSS05 are outlined in the Concept Paper at Attachment A. ADS, ADN, ADC and CSR have agreed to join me on the Steering Committee for the study and have agreed to the conduct of the study as outlined in Attachment A, recognising that the terms of reference will be refined as a result of the Scoping Phase and subject to their approval. At this stage the draft terms of reference, while focussing on the specification and delivery of elements of the Observations and Engineering Programs, are undeniably ambitious and reflect the need for the study to be firmly interfaced to all other Programs that the basic observing system serves and/or depends on. The study will seek wide participation from representatives of relevant Programs, Branches and Regions.

4. I propose to appoint Dr Roger Atkinson (EL2, Program Operations and Standards Group, OEB) as the Study Leader. He will work off-line (reporting to ADO) for the period of the study, commencing immediately on the Scoping Phase. As well as mapping out the overall approach to the study, this phase will provide a reality check on what is achievable within the assigned timeframe, aiming at completion by end April 2005 (with possible extension to end June, 2005, depending on the outcome of the Scoping Phase). The intent is for the overall study to build on the wealth of material already available, updating prior studies as required and commissioning new investigations, such as exploring new technologies and conducting science-based sensitivity studies, as required. At the completion of the Scoping Phase, Dr Atkinson will present a Scoping Report to the Steering Committee and seek their support for the approach to the overall study and the nomination of additional members of the study team from a wide cross-section of areas across the Bureau, on either a part-time or full-time basis.

5. It is hoped that the final study report will provide a practical and strategic framework for the Bureau's basic observing system for the next 5 to 10 years, and hopefully further into the future, and that it will serve as a basis for related developments and decisions across the Bureau. While the study will focus on delivery of a basic observing system within existing resource constraints, any outcomes of the study that have short or longer term resource implications or that have an impact beyond the routine conduct of the Observations and Engineering Program will be brought to the Executive for consideration in due course.

Recommendation

6. That the Executive note the plan to conduct the Basic Observing System Study 2005 and that they endorse the overall approach, the scope and draft terms of reference as outlined in the attached Concept Paper.

Sue Barrell
Assistant Director (Observations and Engineering)

24 November 2004

ATTACHMENT A (to Attachment 1)

45/525

Basic Observing System Study 2005: Strategies to improve the delivery of Australia's Basic (Meteorological and related) Observing System

Aim

Set within the context of the next five to ten years, the Basic Observing System Study 2005 (BOSS05) aims:

- to identify the essential basic observing system necessary to deliver efficiently and effectively on the Bureau's agreed outputs to government;
- to develop end-to-end strategies for delivering the elements of that system efficiently and effectively; and
- to recommend strategies (logistical and resource-based) for migrating, as required, from existing to specified systems.

Scope

1. The focus of this study is on the basic observing system required to meet current and near future (ie next 5-10 years) demands, capitalising on the best available scientific and technical know-how and operational and administrative practices, while bearing in mind longer-term future demands and future scientific and technical potential. The study will identify strategies for meeting public good requirements for systematic (meteorological and related) observations to support short to long term monitoring requirements, research, climate, forecasting and warning requirements, and other public (and private, where applicable) good services applications, and international commitments – including support for operational numerical weather prediction. Requirements relating to more specialised service and data applications, such as aviation and defence, will also be addressed to ensure synergy (where appropriate) with public weather service requirements.

2. In doing so, the study will draw on and update, as appropriate, previous Bureau studies and reports involving user requirements for, and design of, the basic observing system; internal and external reviews and assessments; case studies and research reports; documented WMO/WWW and GCOS recommendations; and other relevant published material (including in relation to identifying needs of other stakeholders eg other areas of government natural resource management, natural hazard reduction, etc); and will benchmark where possible against other NMHSs, and utilise analytical techniques such as sensitivity studies as appropriate.

3. It is not intended that the study reinvent work that has already been completed, but that it utilises already completed work as far as possible, updates and builds on this work where necessary and, where possible, adds insight into future directions. The study will be conducted within a closed resource envelope; that is, it will aim to deliver a basic observing system for no more resources than are currently available to support the existing system. However, if genuine additional resource requirements are identified, especially in areas where up-front investment in development will be repaid through future efficiencies, then these will be identified within the specific implementation strategies.

4. It is important that the BOSS05 has broad Bureau participation and ownership and that it is visibly not system-driven; rather that it is clearly driven by the requirements of the Bureau's output programs and user communities. To ensure that the study covers all relevant elements and applications of the basic observing system, and that recommended strategies are consistent and integrated, where appropriate, with those of other Programs, the study will require the participation of officers across all relevant disciplines, Programs, Branches and Regions. If done well, the Study will provide a reference framework for related planning activities across all Bureau programs.

Steering Committee and Study Team

5. A Steering Committee comprising ADO (chair), ADS, ADN, ADC and CSR will provide oversight and direction to the study. STNM will provide the secretariat to the Steering Committee.

6. A Study Team, reporting periodically to the Steering Committee, will be established to undertake the study in accordance with agreed terms of reference.

7. The leader of the Study Team will be appointed on a full time basis, for a period of 4 months (potentially extendable to a maximum of six months). The remaining team members will comprise senior representatives from, as appropriate, Services (Weather, Climate, Hydrology, Ocean, NMOC), Research, International, Monitoring (Observations, Engineering, Communications, Computing), Regional Office (forecasting, observations) and Meteorological Office (field station OIC), and will embrace system development and support elements. The Study Team members could participate on a part-time or full-time basis, as agreed by their respective Branch Heads.

Terms of Reference

8. The Study Team will conduct a study on strategies for the efficient, effective and sustainable delivery of a basic observing system in support of the Bureau's Basic System, and report on its findings and recommendations in accordance with the following terms of reference:

a. Draw together a comprehensive, strategic-level understanding of the needs that underpin definition of the Australia's basic observing system;

b. Specify the basic observation requirements for Australia and its territories necessary to support delivery of the Bureau's climate, weather, ocean and hydrological services, research and international outputs, including addressing (at a level sufficient to specify key elements rather than detailed operation):

- the type of data and systems;
- provision of appropriate spatial and temporal coverage;
- precision and accuracy;
- quality monitoring and control systems;
- reporting, communications and data handling aspects;
- organisational, structural and management aspects.

c. Identify relative priorities for key system components and attributes, based on the extent to which common and/or essential requirements can be achieved.

d. Investigate the capacity of current and potential observing system solutions and procedures, including those achievable through data processing and NWP assimilation systems, for delivering on the requirements specified in (b) to (d). In doing so, also take account of the particular aspects outlined in (f) to (h) below.

e. Identify, where relevant, opportunities for cost-effective application of automated and/or remotely sensed system components, while recognising the need for a balanced and sustainable mix of in situ and remotely sensed technologies. In doing so, assess the effectiveness of the Bureau's uptake of automated technologies and the extent to which automation has delivered real improvements in productivity within the Observations and Engineering Programs, and other programs as appropriate.

f. Identify issues relevant to developing cost-effective communications and computing systems necessary to underpin the efficient and effective operation of the basic observing system. These aspects may benefit from further specific study in collaboration with ADC and CCSB staff.

g. Advise on achievable down-time and mean-time-between-failures for key system components, as a basis for planning appropriate maintenance and repair frameworks, and to schedule replacement of critical and/or unreliable system components. Investigate tolerable down-times, taking into account the requirements of weather, ocean, climate and hydrology services programs.

h. Assess the Bureau's existing and currently under-development observing systems, networks, staffing arrangements, operational procedures, quality and data handling systems, reporting arrangements and underpinning structures against the specification developed on the basis of (b) to (h), and recommend:

- specific actions, including where relevant changes to systems, networks, distribution of stations and staff, procedures and delivered observing program, required to align these elements with the specification; and
- working as far as possible within the existing Observations and Engineering Programs resource envelopes, a realistic range of resource scenarios over the coming decade, including savings options and resource proposals, to underpin delivery and sustainability of the basic observing system.

i. Within or as an adjunct to (i), assess the extent to which the Bureau can work in partnership with other government agencies, the private sector, academic institutions or others to deliver the basic observing system in a sustainable and cost-effective manner.

j. Within or as an adjunct to (i), assess the potential for use of non-Bureau networks and/or third-party funded observing infrastructure.

k. Assess the extent to which Bureau users of observational data are effectively incorporating new (current and planned) observing systems, data types and associated products into their operational work practices (eg the forecast process) and achieving projected productivity benefits – already or through strategies that are under development.

Deliverables

9. Scoping Report by 17 December 2004. Progress reports as agreed and final report by (tentatively) end April 2005, with the final report date to be flexible until better informed by the report of the Scoping Project.

Phase 1: Scoping project

10. Initial scoping project, aiming to:

- indicate the feasibility, effort, time, participants, and level of engagement required to deliver the above;
- propose revisions to the terms of reference in accordance with the feasibility;
- determine the extent to which existing resource material can expedite the study and additional investigations or enquiries will be required;
- identify any resource requirements essential to undertake the study, such as travel and videoconferencing costs for regional contributors; and
- propose an overarching approach to the study and a detailed plan and timeline for its implementation.

11. The Scoping Project will be conducted on a full time basis by the Study Leader, reporting to ADO on a routine basis and with a Scoping Report to be considered by the Steering Committee.

12. The Scoping Project is estimated to take 3-4 weeks.

Phase 2: BOSS2005

13. After the Steering Committee has considered the Scoping Report and agreed to the conduct of the main study, they will assist in compiling the full study team by identifying appropriate representatives from the relevant areas of the Bureau, in consultation with the relevant managers. While

it is expected that most members will contribute to the Study on a part-time basis, it would be beneficial if at least one other member could be made available on a full time basis for a substantial part of the Study.

14. The full Study Team, or a subset thereof, will need to meet face to face on occasion, but it is expected that much of the communication could be done by email.

15. Resources: A small amount of travel funds (TBD, depending on the Scoping Report but likely up to $5-10K) will be provided by ADO to assist the conduct of the Study.

Attachment 2

55/938

DIR, DDC, DDS, CSR
All Assistant Directors, MSSU, Dr Zillman
All Regional Directors
All Head Office Section Heads

MINUTES OF EXECUTIVE MEETING 2004/20 – 9-10 DECEMBER 2004

1. A meeting of the Bureau Executive was held from 4.00pm till 6.00pm on Thursday 9 December 2004 in DIR's office and was attended by DIR, DDC, DDS, CSR and ADE. The meeting reconvened on Friday 10 December 2004 at 3.00pm with DIR, DDC, DDS and ADE in attendance.

Agenda Item 1 700 Collins St: Update

2. DDC provided the Executive with an update on progress with the fit-out of Stage 2 (main office areas) and Stage 3 (wintergardens) and indicated that progress was broadly on track against the updated completion plan. It remained likely that the wintergardens on 6 West and 9 West would be largely completed by 23 December and that the remaining wintergardens on 6 East and 9 East would be completed by the end of March 2005.

Agenda Item 2 Basic Observing System Study

3. ADO's paper of 24 November 2004 on the proposed Basic Observing System Study 2005 was considered by the Executive. The Executive:

(a) welcomed the paper and agreed it was important that the Bureau revalidate its future vision for the basic observing system in the light of the overall resource situation;
(b) agreed that the definition of "basic" was fundamentally important and asked DDS to discuss this aspect with ADO;
(c) encouraged the study to take a positive approach to the Bureau's future capabilities to meet national needs; and
(d) considered that the outcome of the study would be critical to the Bureau's future strategic directions. (Action: DDS, ADO)

Agenda Item 3 Visit by the Parliamentary Secretary

4. The Executive considered a draft program prepared by ADE for the planned visit by the Parliamentary Secretary, the Hon Greg Hunt, on 16 December and agreed the broad outline. The main emphases are expected to be a general introduction to the Bureau, then a more detailed analysis of issues requiring early, Ministerial level, decision.

Agenda Item 4 Payroll and HR Services

5. The Executive considered ADM's paper of 1 December 2004 on the *Continuation of Bureau Payroll Services Beyond June 2005* and:

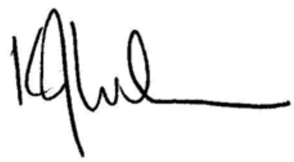
(a) recognised the need to have new arrangements in place to ensure continuity of the Bureau's payroll function prior to the mid 2005 withdrawal of the current supplier;
(b) noted that any solution adopted would need to balance the short term payroll imperative against the Bureau's overall HR information and systems needs on strategic timescales;
(c) noted the recommendations of the Human Resource Information System (HRIS) Steering Committee set out in the paper;
(d) was of the view that it was worth examining a hybrid solution that would combine aspects of the two options preferred by the Steering Committee; and
(e) agreed that, before any decision was taken, DDC should follow-up with the Steering Committee on the scope for a solution that ensured coverage of the payroll function in the short term and the benefits of integration with existing management systems in the longer term. (Action: DDC)

6. The meeting broke at 6.00pm on 9 December 2004 to allow for the necessary follow-up with the HRIS Steering Committee and was reconvened at 3.00pm on 10 December.

7. At the reconvened meeting, the Executive:

(a) agreed in principle to the implementation of a SAP-based Human Resource Management System (HRMS), including payroll; and, in relation to that decision,
(b) requested a revised project costing as soon as possible to allow an assessment of its resource implications; and
(c) requested an assessment of the feasibility of implementing the key elements, including the payroll function, by June 2005 given the internal and external resources expected to be available. (Action: DDC)

8. The meeting closed at 3.30pm.



K J Wilson
ADE

24 December 2004

Attachment 3

Conduct of the Study

The Bureau Executive endorsed ADO's original proposal to carry out BOSS05 at its meeting 2004/20 of 09-10 December 2004 and Dr. Roger Atkinson (OEB) was taken off line from regular duties and requested to scope the study in more detail, and to report back to a Steering Committee comprising ADO (Chair), ADS, ADN, ADC, CSR and STNM (secretariat) by the end of December 2004.

The detailed Scoping Report was submitted to ADO on 28 December 2004 and endorsed by the BOSS05 Steering Committee at its meeting of 14 January 2005. The report proposed a series of relatively self-contained tasks to be performed over a six month period commencing in early February 2005, with each task to be performed by a largely independent team drawn from key areas from across the Bureau, and each led by a senior representative from within the respective sub-discipline area. (see BOSS05 website at http://aifswiki-ho.bom.gov.au/twiki/bin/viewauth/OEB/BasicObservingSystemDevelopment)

To select Task Teams and fine-tune the study plan, a half day workshop, sponsored by ADO and involving approximately 30 representatives from both services and systems areas of the Bureau, was held at Head Office on 3 February 2005. The Task Teams selected at the workshop are listed at Appendix A to this attachment.

Each Task Leader was invited to join a BOSS05 Management Team, which met approximately weekly for the duration of the study. (The composition of the Management Team, minutes of all meetings, and all other detailed information and meeting reports for BOSS05 are available on the BOSS05 website.) The Study Leader, as Chair of the Management Team, in turn provided regular progress reports to the Steering Committee, which met approximately fortnightly.

A second ADO-sponsored workshop, primarily involving about 30 specialists from the Bureau's Services Division, was conducted at Head Office on 10 March 2005 to enable presentation and discussion of the information provided by the specialist areas in specifying the Bureau's service requirements for observational data.

A final one-day BOSS05 workshop, involving all study participants, was conducted at Head Office on 10 May 2005, for preliminary presentation of the work being completed under each of the information-gathering tasks, to identify the key strategic issues for the BCOS identified during the study so far, and to begin to explore potential future pathways for the BCOS.

Attachment 4

Previous Studies Related to the Basic Observing System

'The Year 2000 Basic System: An Infrastructure Specification', Coleman et al, 1990 (BS90).

BS90 was performed by a team from the Basic Systems Program Office of the (then) Services Policy Branch during the 1980s. It was motivated by the need to develop a Bureau Charging Policy, so was primarily concerned with differentiating between that 'basic' part of the Bureau's services which were seen as 'public good' and should therefore be funded by the tax payer, as opposed to those more specialised services which were deemed to fall beyond the Bureau's basic functions and should therefore be funded by the users of the respective services. It tended to be idealistic rather than pragmatic, was very restricted in scope, and is now rather dated.

'Defining the Basic Observing System', Sharp et al, 1995 (BOS95)

BOS95 was the first part of a two part examination of the observing system carried out in OEB during 1995. It took a more pragmatic approach than BS90. It was driven by the perceived need to define the 'essential' BOS: that minimum observing system which must be supported were the Bureau to avoid significant degradation in the quality of its basic service outputs, i.e., that for which the Bureau would 'be willing to die in the trenches'. BOS95 was motivated by a marked deterioration in our observing networks which had occurred in the 80s and early 90s due to aging observing system infrastructure coupled with the tight economic climate of the time. Based on limited input from the respective services programs, BOS95 categorized each station or platform in the Bureau's observing program according to the service output(s) to which it directly contributed and, dependent on the number of service functions supported, ruled each observing site in or out of the BOS accordingly. The BOS so obtained was then compared with those of overseas NMHSs and internationally-specified (WMO, UNEP) requirements for NWP and climate network requirements, showing the existing BOS to be deficient in several respects, and mapping out potential resource scenarios to restore it to a more satisfactory state.

BOS95 served as key input to the Slatyer enquiry ('Review of the Operation of the Bureau of Meteorology', R. Slatyer, 1996), assisting the Bureau to secure additional funding in the late 1990s to restore its observing networks to their requisite standard. BOS95 contains ideas and information of direct relevance to the present study. For example, comparing the Bureau's observing system with those of other countries to assess adequacy is a tool employed here, as is measuring the adequacy by reference to international specifications.

'Report to ADO on the 2001 Observing System Study for Staffed Observing Offices of the Bureau of Meteorology', Stickland et al, 1996 (OSS96)

OSS96 was a study commissioned by ADO in 1996 and examined future configuration options for the Bureau's observing system, focused primarily on its staffed observing offices. It was motivated by the need to maintain the minimum observing system required to deliver basic service requirements, in an environment of progressively tightening government fiscal constraint, coupled with the rapidly ageing profile of both the Bureau's observing staff and infrastructure. The study was specifically targeted at achieving greater economy by better use of automation and by rationalization of existing observing programs. In this sense it is particularly relevant to BOSS05, and provides useful guidance for the present study.

'The Basic Observing System', Sharp et al, 1995- (BOS2)

Commenced at the conclusion of BOS95 and continuing until 2001, was the second part of that study, BOS2, carried out in OEB in consultation with key staff in the various service programs. Whereas BOS95 was primarily concerned with describing the existing BOS and comparing it with overseas practice and WMO requirements to highlight its shortcomings, BOS2 was aimed at specifying the requisite BOS based on (primarily a subset of weather) service requirements. Although never completed due to staff turnover, BOS2 laid down a (today rather restricted) definition of the BOS, specified those responsible for defining, planning and managing its various component networks, and the (then) data delivery requirements for those networks. It went on to specify, as far as possible, the individual observing sites comprising each network. Although never completed, BOS2 is highly relevant to BOSS05 and provides a wealth of information upon which BOSS05 will build.

Attachment 5

Summary of Service Requirements for Data

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Surface Observations	MSL Pressure	3 hourly and SPECI absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Each model grid point e.g. 50 to 3km. Ideally <150 nm apart to ensure detection of cyclones at a 75 nautical mile range for cyclone forecasting	Real time	0.3 to 0.5hPa		Aviation, Climate, Defence, Hydrology, NWP, Marine, Ocean, Tropical	1 minute data for real time data delivery to control towers and AWIB. 3 hourly for all other uses Note robust comms essential and reliability of equipment governed by SLA
Surface Observations	MSL Pressure	3 hourly and SPECI absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Each model grid point e.g. 50 to 3km.	Real time	1hPa		Fire	Only need for gradient winds. Values taken from the Aeronautical Service Handbook
Surface Observations	MSL Pressure	3 hourly and SPECI absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Each model grid point e.g. 50 to 3km.	1 hour	0.3hPa		NWP, Hydrology	Basic surface observations are primarily an input for NWP models. Hydrology dependent on NWP outputs. Values for NWP taken from CIMO and EU-METSAT documents

Observation Type	Element	Frequency	Density	Timeliness	Info. Quality	Product Quality	User	Comment
Surface Observations	MSL Pressure	hourly to half hourly	WMO GOS specs	Real time	0.5 hPa		Fire, External, Marine, Public	Density - Priority for observations at all locations where a forecast is provided. As they are required to verify forecasts. It is also important to ensure that all agricultural centres have representative observations.
Surface Observations	MSL Pressure	10 to 1 minutes	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas for severe weather. Surface observations are required to be collected at all airports. Ideally <150 nm apart to ensure detection of cyclones at a 75 nautical mile range for cyclone forecasting	Real time	0.3 to 0.5hPa		Aviation, Defence, Fire, Ocean, Severe, Tropical	1 minute data for real time data delivery to control towers and AWIB. 3 hourly for all other uses Note robust comms essential and reliability of equipment governed by SLA. Values taken from the Aeronautical Service Handbook
Surface Observations	Air Temperature	1 mins to 3 hourly	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas for severe weather. Surface observations are required to be collected at all airports. Ideally <150 nm apart to ensure detection of	Real time or within 15 mins	0.3 to 0.5 °C		Climate, External, Fire, Ocean, Severe, Tropical	Density - Priority for observations at all locations where a forecast is provided. As they are required to verify forecasts. It is also important to ensure that all agricultural centres have representative observations. Climate - Need a blend of manual and automated observations to ensure quality and reliability of

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
			cyclones at a 75 nautical mile range for cyclone forecasting.					data. As many as possible, especially in areas with high rainfall gradients to define the climatology well. Some areas like SW Tasmania grossly under-sampled. Also need to cover broad 'holes' through inland and particularly central area. Not possible to be specific – daily down to 10-minute. Hourly and ½ hourly is becoming more used and 10-mins will cover most applications. Public and Severe - The hourly and SPECI requirement is for forecasting and warning; while the daily totals are need for agriculture
Surface Observations	Air Temperature	3 hourly	WMO GOS specs. Each model grid point e.g. 50 to 3km	1 hour	0.1°C		NWP, Hydrology	Basic surface observations are primarily an input for NWP models. Hydrology dependent on NWP outputs. Values for NWP taken from CIMO and EU-METSAT documents
Surface Observations	Air Temperature	1 mins to 3 hourly	WMO GOS standards Surface observations are required to be collected at all airports	Real time	1°C	10°C	Aviation, Defence	1 minute data for real time data delivery to control towers and AWIB. 3 hourly for all other uses Note robust comms essential and reliability of equipment governed by SLA

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Surface Observations	Dew point	3 hourly and SPECI absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Each model grid point e.g. 50 to 3km. Ideally <150 nm apart to ensure detection of cyclones at a 75 nautical mile range for cyclone forecasting	Real time	<0.3°C		Aviation, Climate, Defence, Hydrology, NWP, Marine, Ocean, Tropical	This is of a lower priority for real time cyclone forecasting. 1 minute data for real time data delivery to control towers and AWIB. 3 hourly for all other uses Note robust comms essential and reliability of equipment governed by SLA. Values for NWP taken from CIMO and EU-METSAT documents
Surface Observations	Dew point	3 hourly and SPECI absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Each model grid point e.g. 50 to 3km.	Real time	<1°C		Aviation, Defence	1 minute data for real time data delivery to control towers and AWIB. 3 hourly for all other uses Note robust comms essential and reliability of equipment governed by SLA. Values taken from the Aeronautical Service Handbook
Surface Observations	Dew point	3 hourly and SPECI absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Each model grid point e.g. 50 to 3km.	1 hour	0.1°C		NWP, Hydrology	Basic surface observations are primarily an input for NWP models. Hydrology dependent on NWP outputs. Values for NWP taken from CIMO and EU-METSAT documents

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Surface Observations	Dew point	hourly to half hourly	WMO GOS specs	Real time	<0.3°C		Fire, External, Marine, Public	Density - Priority for observations at all locations where a forecast is provided. As they are required to verify forecasts. It is also important to ensure that all agricultural centres have representative observations.
Surface Observations	Dew point	10 to 1 minutes	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas for severe weather. Surface observations are required to be collected at all airports. Ideally <150 nm apart to ensure detection of cyclones at a 75 nautical mile range for cyclone forecasting.	Real time	<0.3°C		Aviation, Defence, Fire, Ocean, Severe, Tropical	1 minute data for real time data delivery to control towers and AWIB. 3 hourly for all other uses Note robust comms essential and reliability of equipment governed by SLA. Values taken from the Aeronautical Service Handbook
Surface observations	Wind direction	3 hourly	WMO GOS Specs. Each model grid point e.g. 50 to 3km are required to be collected at all airports	1 hour, Real time for Aviation and	10 deg		Aviation, Defence, Hydrology, NWP, Ocean	Basic surface observations are primarily an input for NWP models. Hydrology and Oceanography dependent on NWP outputs. Values for NWP taken from CIMO and EU-METSAT documents

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Surface observations	Wind direction	6 to 1 mins	WMO GOS Specs. Strategic bays and ports i.e. 1 site per 1000km of mainland coastline and Surface observations are required to be collected at all airports	Real time or within 15 mins	10 deg		Aviation, Defence, Ocean	
Surface Observations	Wind Direction	3 hourly, hourly and SPECI as minimum, prefer 10 min.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas for severe weather. Surface observations are required to be collected at all airports. Ideally <150 nm apart to ensure detection of cyclones at a 75 nautical mile range for cyclone forecasting..	Real time or within 15 mins	22.5 deg		Public, Severe, Tropical	Wind gust information is critical to Tropical cyclone and Severe weather forecasting
Surface Observations	Wind Direction	hourly to 10 min.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas, <1500km i.e. 1 site per 1000km of mainland coastline.	Real time or within 15 mins	10 deg	20 deg	External, Fire, Marine	Marine prefer 30min reports

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Surface Observations	Wind Direction	3 hourly to 10 mins, absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas good general coverage of continent	Real time or within 15 mins, however can tolerate longer for some stations	5 deg		Climate	Density - Priority for observations at all locations where a forecast is provided. As they are required to verify forecasts. It is also important to ensure that all agricultural centres have representative observations. Climate - Need a blend of manual and automated observations to ensure quality and reliability of data. As many as possible, especially in areas with high rainfall gradients to define the climatology well. Some areas like SW Tasmania grossly under-sampled. Also need to cover broad 'holes' through inland and particularly central area. Not possible to be specific – daily down to 10-minute. Hourly and ½ hourly is becoming more used and 10-mins will cover most applications. Public and Severe - The hourly and SPECI requirement is for forecasting and warning; while the daily totals are need for agriculture

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Surface observations	Wind speed	3 hourly	WMO GOS Specs. Each model grid point e.g. 50 to 3km are required to be collected at all airports	1 hour, Real time for Aviation and	1m/s		Aviation, Defence, Hydrology, NWP, Ocean	Basic surface observations are primarily an input for NWP models. Hydrology and Oceanography dependent on NWP outputs. Values for NWP taken from CIMO and EU-METSAT documents
Surface observations	Wind speed	6 to 1 mins	WMO GOS Specs. Strategic bays and ports i.e. 1 site per 1000km of mainland coastline and Surface observations are required to be collected at all airports	Real time or within 15 mins		2.5 m/s or 5kt	Aviation, Defence, Ocean	
Surface Observations	Wind speed	3 hourly, hourly and SPECI as minimum, prefer 10 min.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas for severe weather. Surface observations are required to be collected at all airports. Ideally <150 nm apart to ensure detection of cyclones at a 75 nautical mile range for cyclone forecasting. At each Airport.	Real time or within 15 mins	2.5 m/s or 5 knots		Public, Severe, Tropical	Wind gust information is critical to Tropical cyclone and Severe weather forecasting

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Surface Observations	Wind speed	hourly to 10 min.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas, <1500km i.e. 1 site per 1000km of mainland coastline.	Real time or within 15 mins	0.5 m/s or 1 knots	1 m/s or 5 km/h	Fire, Marine	Marine prefer 30min reports
Surface Observations	Wind speed	4 hourly to 10 mins, absolute minimum of 2 per day at 9 am and 3 pm.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas good general coverage of continent	Real time or within 15 mins, however can tolerate longer for some stations	1 m/s below 10 m/s and 10% above 10 m/s		Climate, External	Density - Priority for observations at all locations where a forecast is provided. As they are required to verify forecasts. It is also important to ensure that all agricultural centres have representative observations. Climate - Need a blend of manual and automated observations to ensure quality and reliability of data. As many as possible, especially in areas with high rainfall gradients to define the climatology well. Some areas like SW Tasmania grossly under-sampled. Also need to cover broad 'holes' through inland and particularly central area. Not possible to be specific – daily down to 10-minute. Hourly and ½ hourly is becoming more used and 10-mins will cover most applications. Public and Severe - The hourly and SPECI requirement is for forecasting and warning; while the daily totals

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
								are need for agriculture
Surface Observations	Rainfall	3 hourly to 1 min. Some Hydrology uses require event monitoring.	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas for severe weather. Surface observations are required to be collected at all airports. 1 per catchments. Each model grid point e.g. 50 to 3km	Real time or within 15 mins	3% to 5%, NWP would like 1 to 0.1 mm/h		Climate, Hydrology, NWP, Public Weather, Severe, Tropical	As above Values for NWP taken from CIMO and EU-METSAT documents
Surface Observations	Rainfall	3 hourly	WMO GOS	Within 1 month		1mm	Tropical	For post Cyclone analysis
Surface Observations	Rainfall	1 mins to 3 hourly	WMO GOS standards Surface observations are required to be collected at all airports	Real time	Qualitative		Aviation, Defence	Occurrence / non- occurrence
Surface Observations	Rainfall intensity	Event to 5min	4 sites per catchments	Real time to 1 hour	3% to 10%		Hydrology	The temporal resolution is driven but the usage and nature of the event.
Surface	River Height	hourly to daily	1 per forecast point plus	1 hour	0.1m		Hydrology	Data come from external

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Observations			one up stream					providers
Surface Observations	Stream flow	Weekly	Min one per major river basin	Monthly	??		Hydrology	Data come from external providers
Surface Observations	Solar Radiation Exposure	½ hourly Integrals (from minute averages)	16 Stations	Real time			AW, Climate	Climate - There is a huge demand for solar radiation data. Need to expand the ground based network to at least all BOM observing Offices, and also city areas and selected rural areas to gain spatial resolution. Solar sites include mainland (13), Tasmanian(1), Indian Ocean(1) and NZ(1) sites.
Surface Observations	Terrestrial Irradiance	½ hourly Integrals (from minute averages)	16 Stations	Real time			AW	Terrestrial sites include mainland (13), Tasmanian(1), Indian Ocean(1) and NZ(1) sites.
Surface Observations	UVB Irradiance	~25 per day	3 Stations	Real time			AW, BMRC	Averaged up to daily values
Surface Observations	Aerosol Extinction	1 minute	16 Stations				Atmosphere Watch	Climate data on a 1 minute frequency with modeling data averaged for daily and monthly values. Aerosol Extinction sites include mainland (13), Tasmanian(1), Indian Ocean(1) and NZ(1) sites.

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Visual Observations	Present Weather - WMO 0-99 e.g. fog, Snow, Thunderstorms etc	10 min, 3 hourly and SPECI	WMO GOS Spec. All airports	Real time or within 15 mins of obs	Qualitative. Values referenced as for Surface obs handbook and ASH		Aviation, Defence	All weather elements need to be identified. Values taken from the Aeronautical Service Handbook
Visual Observations	Present Weather - WMO 0-99 e.g. fog, Snow, Thunderstorms etc	3 hourly and SPECI	WMO GOS specs. Spatially correlated with surface obs including all population centres, <1500km i.e. 1 site per 1000km of mainland coastline.	Real time or within 15 mins of obs	Qualitative. Values referenced as for Surface obs handbook		Climate, Fire, Hydrology, Marine, Ocean, Public, Severe	
Visual Observations	Cloud type	3 hourly and SPECI	WMO GOS	Real time or within 15 mins of obs.	Qualitative		Climate, Severe	The current network is unsatisfactory for visual observations for a climate perspective. We can offer advice on likely cloud cover and visibility at very few locations - there is significant demand for this information. Need synop sites scattered about to get the (climatologically
Visual Observations	Cloud amount	3 hourly and SPECI	WMO GOS	Real time or within 15 mins of obs.	1 octa		Climate, Severe	As Above

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Visual Observations	Cloud amount	30 minute to continuous or I min.	All aerodromes	Real time	1 octa		Aviation, Defence	
Visual Observations	Cloud amount	3 hourly	Each model grid point e.g. 50 to 3km	1 hour	5%		NWP	Values for NWP taken from CIMO and EU-METSAT documents
Visual Observations	Cloud height	30 minute to continuous or I min.	All aerodromes	Real time	±10m to 100m height, ±10% from 100m	±30m to 120m 30% from ±120m to 3000m	Aviation, Defence	Values taken from the Aeronautical Service Handbook
Visual Observations	Cloud height	3 hourly	Each model grid point e.g. 50 to 3km	Within 1 hour to 30 min of obs	500m	1000 ft below 6500 ft	Climate, Fire, Severe, Tropical	Lower priority for tropical cyclone forecasting
Visual Observations	Visibility	10 minute to continuous	All aerodromes	Real time	±50m to 600m ±10% from 600m to 1500m ±20% above 1500m	±200m to 700m ±30% from 700m to 10km	Aviation, Defence, External, Public	Values taken from the Aeronautical Service Handbook
Visual Observations	Visibility	3 hourly and SPECI	WMO GOS specs. Denser coverage in populated & topo-graphically rich areas	Real time or within 15 mins of obs		500m up to 5km or 1000m up to 10km	Fire, Severe, Tropical	This is desirable but not essential for severe or tropical cyclone weather. Higher spec for fire weather

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Visual Observations	Storm spotting	On commencement and ending of event	WMO GOS specs. Spatially correlated with surface obs including all population centres.	Real time	Qualitative		Public, Severe, Tropical	Not specifically a requirement for Tropical Cyclones. More Important for server weather. For storm spotting tends to be regionally defined.
Visual Observations	Lightning data	On commencement and ending of event	Spatially correlated with surface obs. With a radius of 10 km. Including all airport	Real time	Qualitative. Count desirable but not essential.		Aviation, Defence, Ocean, Public, Severe, Tropical	The two key criteria for lightning are the observations can be matched in space with other surface and visual obs, and that the start and end of the event are well defined. Required for warning airport staff and to identify the presence of thunderstorms.
Visual Observations	Lightning data	Need at least hourly summaries of flash densities.	Resolution of 25km over populated areas. Required for insurance industry. Needs to correlate with surface observations. Higher resolution needed by some researchers e.g. 10km	Real time or within 15 mins of obs	Quantitative, but not specified. Typically % efficiency.		Climate, Fire, External	High demand for flash count. Particularly in Queensland and NSW, approx 1000 and 600 enquires per month.
Agricultural Observations	Evaporation	Daily	WMO GOS Coverage over agricultural areas of 1 site per 250 km2	1 month		1 mm	Climate, Public	Climatic averages
Agricultural Observations	Evaporation	Daily	WMO GOS Coverage over agricultural areas of 1 site per 250 km2	Day	1mm		Hydrology	Used in estimating evap-transporation modeling

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Agricultural Observations	Soil Temperature	Daily	WMO GOS	23 hours	1°C		Hydrology	
Agricultural Observations	Soil temperatures	6 hourly	Each model grid point e.g.50 to 1km	24 hours	1°C		NWP	Values for NWP taken from CIMO and EU-METSAT documents
Agricultural Observations	Soil temperatures	Daily	WMO GOS	24 hours	0.5°C		Public	
Agricultural Observations	Soil temperatures	3-hourly		1 month	0.5°C		Climate	Increase AWS capabilities at rural sites and long-term city sites (with previous soil data). Useful input to our clients in agricultural community. Most or all stations representative of agriculturally significant area should have this capability.
Agricultural Observations	Soil Moisture	Daily, ideally 2 per day.	WMO GOS specs	Day	20g/kg		Climate, Hydrology, Public	Not an existing measurement. Need to increase AWS capabilities at rural sites and long-term city sites (with previous soil data). Useful input to our clients in agricultural community. Most or all stations representative of agriculturally significant area should have this capability.
Agricultural Observations	Soil Moisture	Daily	Each model grid point e.g. 50 to 1km	Day			NWP, Hydrology	Values for NWP taken from CIMO and EU-METSAT documents

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Marine and Ocean Observations	Sea Level e.g. Tide gauge	1 min	Strategic bays and ports	Real time		5cm	Marine, Ocean	
Marine and Ocean Observations	Sea Level e.g. Tide gauge	hourly	WMO GOS Specs. 150 nm along the coast.	Real time, <30 mins after obs	Unknown		Defence, Tropical	Not critical to Tropical Cyclone forecasting
Marine and Ocean Observations	Sea state	6 hourly	Variable	Real time	Qualitative		External, Marine	Currently these observations are collected via volunteer ships.
Marine and Ocean Observations	Sig wave direction observations	hourly	<1500km i.e. 1 site per 1000km of mainland coastline	Real time	+-22.5 deg		External, Marine, Ocean	Typically from manual observers. Reduced frequency of observation for climate. However they would like obs every 100 – 200km and located off coastal sectors with variant orientation from neighboring sectors. e.g. In Victoria, Shipwreck coast, Bass Coast, Phillip Island Coast and the Gippsland Coast. Particularly need platform: central Van Diemen Gulf and off north NT coast.
Marine and Ocean Observations	Sig wave height observations	hourly	<1500km i.e. 1 site per 1000km of mainland coastline	Real time	+- 0.5m for <5m waves +- 10% for waves >5m	1m	Climate, External, Marine, Oceanograp hy	Typically from manual observers. Reduced frequency of observation for climate
Marine and Ocean	Wind	6 hourly Crucial to have	WMO GOS specs. Variable along shipping	Real time, <30 mins	+-22.5 deg		Climate, Defence,	Currently these observations are collected via volunteer ships and

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Observations	direction	9am and 3pm obs.	lanes and drogue paths. Tropical cyclone - 150 nm along the coast and off shore to a distance of 200 – 300 nm.	after obs			Marine, Public, Ocean, Tropical	drogue buoys. Don't necessarily need more buoy data just strategic placement. Buoy data are used to ground truth satellite data. Oceanography claims to want twice this accuracy on the measurement, however it is primarily for NWP input.
Marine and Ocean Observations	Wind speed	4 hourly Crucial to have 9am and 3pm obs.	WMO GOS specs. Variable along shipping lanes and drogue paths. Tropical cyclone - 150 nm along the coast and off shore to a distance of 200 – 300 nm.	Real time, <30 mins after obs	+-5 knots		Climate, Defence, Marine, Public, Ocean, Tropical	As Above.
Marine Observations	Air Temperature	6 hourly. Crucial to have 9am and 3pm obs. 3 hourly would be desirable for Defence.	WMO GOS Specs.	Real time, within 15 mins of obs	0.5°C	1°C	Climate, Defence, Marine, Public	Currently these observations are collected via volunteer ships and drogue buoys. Don't necessarily need more buoy data just strategic placement. Buoy data are used to ground truth satellite data.
Marine Observations	Air Temperature	30 mins or less, see above	WMO GOS Specs. Plus 150 nm along the coast and off shore to a distance of 200 – 300 nm for Tropical Cyclones.	Real time, within 15 mins of obs	0.5°C	1°C	Tropical	As Above

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Marine and Ocean Observations	Sea Surface Temperature	Daily	WMO GOS specs. Variable along shipping lanes Desire every 100km.	Daily	<0.5°C	1°C	Aviation, Climate, Defence, Fire, Public	Oceanography Coverage of 80E to 180E, +10 to –70 100km spatial density. For tropical Cyclones 150 nm along the coast and off shore to a distance of 200 – 300 nm.
Marine and Ocean Observations	Sea Surface Temperature	6 to 3 hourly	WMO GOS specs. Variable along shipping lanes Desire every 100km.	Real Time <15 mins of obs	<0.5°C	1°C	Marine, Ocean, Tropical	As Above
Marine and Ocean Observations	Temperature profiles	Daily	Coverage of 80E to 180E, +10 to –70 500km spatial density?	24 hours to 1 month	0.5°C		Climate, Ocean	Vital for monitoring El Nino, etc. BMRC oceanographers should be consulted on this one. And for models.
Marine and Ocean Observations	Temperature profiles	Daily	NWP	Real time, <30 mins after obs	0.5°C		NWP	Vital for monitoring El Nino, etc. BMRC oceanographers should be consulted on this one. And for models. Values for NWP taken from CIMO and EU-METSAT documents
Marine and Ocean Observations	O2 profiles	Daily	NWP	Real time, <30 mins after obs	Unknown		Atmosphere Watch	
Atmospheric Chemistry	Ozone Total Column	2 to 4 times per day	Current remote-sensing probably OK. Need to retain surface stations.	Daily			Climate	24 hour average used for modeling

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Atmospheric Chemistry	Ozone Profile	1/Week	4 Stations	1 week	0.5mPa		Atmosphere Watch	Ozone profile stations include Melbourne and Antarctic/MacQuarie Is, Davis funded by AAD. It is desirable to have a station in the tropics to monitor ozone generation as a complementary station to loss in the Antarctic. However currently there is no funding
Atmospheric Chemistry	Precipitation Chemistry / BAPMoN	Daily	1 stations	Bi monthly sample return. Annual analysis			Atmosphere Watch	Climate, These stations include Darwin that samples daily through the wet season and weekly sampling at Wagga Wagga and Coff Habour. Cape Grim operates weekly samples of both baseline and non-baseline rainfall.
Atmospheric Chemistry	CO2	~hourly	1 station	Real time			Atmosphere Watch	Greenhouse Gases (20+ species) Cape Grim
Atmospheric Chemistry	CO	~hourly	1 station	Real time			Atmosphere Watch	Greenhouse Gases (20+ species) Cape Grim
Atmospheric Chemistry	CO2, CO, NOx, SOx, Ozone, CFCs,	~hourly	1 station	Real time			Atmosphere Watch	Climate, Greenhouse Gases (20+ species) Cape Grim
Atmospheric Chemistry	NOx SOx,	~hourly	1 station	Real time			Atmosphere Watch	Greenhouse Gases (20+ species) Cape Grim

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Continuous 2D Field Observations and Products	Rainfall e.g. Rainfields	30 mins	Coverage of areas for which forecasts are produced.	Real time	10%		Fire, hydrology	
Continuous 2D Field Observations and Products	Windfields e.g. Sat Data (winds)	As available Minimum of 2 per day up to 10 mins	5km to 1km	Real time <15 mins from obs		5 knots / 30 deg	Aviation, Defence, NWP, Ocean, Public, Tropical	Potentially very useful for constructing climatologies, need to ensure coverage in high southern latitudes. NWP can tolerate some delay in delivery up to 6 hours. Oceanography - For analysis of wind changes over adjacent ocean areas. Values for NWP taken from CIMO and EU-METSAT documents
Continuous 2D Field Observations and Products	Windfields e.g. Sat Data (winds)	6 hourly to hourly	20 to 50 km	Real time <15 mins from obs	5 knots / 22.5 deg		Fire, Marine	
Continuous 2D Field Observations and Products	Solar Radiation e.g. Satellite	hourly	1 km	<0.5 hour	5mW/m2		Climate, Hydrology, NWP, Public	Climate - Current density OK but need to ensure coverage in high southern latitudes. Values for NWP taken from CIMO and EU-METSAT documents

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Continuous 2D Field Observations and Products	Atmospheric Moisture, e.g. GPS Total precipitable water	As available Minimum of 2 per day up to 10 mins, 3 hourly would be a good compromise	Australian Region, 20 to 1 km	Real time <15 mins from obs	Unknown		Climate, Fire, Ocean, Severe, Tropical	Gradual increase in accuracy of analysis of low level. Less critical than profile moisture. Climate - Current density OK but need to ensure coverage in high southern latitudes
Continuous 2D Field Observations and Products.	Present Weather e.g. Radar data (PPI)	10 mins	Fire weather consider the present network covers most critical areas. However climate see a need for better coverage in some of the inland agricultural/rural areas (e.g., Victorian Wimmera, western NSW).still large tracts of NT (even coastal NT) without radar coverage. Aviation and Defence need cover at all airports.	Real time		Qualitative measure. Low reflectivity needed for the detection for smoke plumes	Aviation, Climate, Defence, External, Marine, Public	To provide an equitable public weather service to the Australian public, complete coverage would be required. Presently there are many areas of Australia with moderate levels of population density or economic value without radar coverage (e.g. Central and western Queensland and NSW, the SW Land Division of WA, the Eyre Peninsula of SA, eastern Tasmania and the Wimmera in Vic), not to mention the remoter areas. A key product for public weather. It is heavily used by the public via web access. Consistent delivery of these data is critical. Quantitative data on a broad scale at high resolution. Typically derived from satellite or radar remote sensing networks. These data are used in the prediction of development of weather.

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Continuous 2D Field Observations and Products.	Present Weather e.g. Radar data (PPI)	5 mins	Coverage of Aust. coastline in tropical zones to 350 – 400 km off shore. i.e. between Perth and Coffs Harbour	Real time			Tropical, Ocean	
Continuous 2D Field Observations and Products	Soil Moisture e.g. Satellite	Daily	1km	1 hour	??		Hydrology	
Continuous 2D Field Observations and Products.	Sea wave height obs e.g. satellite products	hourly	50km	Real time	+-0.5m		Marine	
Continuous 2D Field Observations and Products.	Swell wave height obs e.g. satellite products	hourly	50km	Real time	+-0.5m		Marine	
Continuous 2D Field Observations and Products.	Sea ice coverage e.g. microwave sat data	3-6 hourly.	Current density OK but need to ensure coverage in high southern latitudes	Real time <15 mins from obs			Climate	

Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
Continuous 2D Field Observations and Products.	Fire Fuel estimates e.g. Grassland curing estimates	Daily	25 km	Daily		+/- 1 rating value (10%)	Fire	Indicator of fuel state.
Remote Sensing Imagery	Imagery e.g. Geostationary Satellite images – (IR, Vis, water vapour) or Polar Orbiting Satellite Pictures	hourly or as available approximately 2 per day	Australian region including Southern, Indian and Pacific Oceans	Real time <15 mins from obs	< 1km	0.05 degrees or qualitative	Aviation, Climate, Defence, External, Fire, Hydrology, Oceanography, Public, Severe, Tropical	Broad scale imagery for the monitoring the development of weather events. Currently this is provided via geostationary and polar orbiting satellites and weather watch radar. A key product for public weather. It is heavily used by the public via web access. Consistent delivery of these data is important. Imagery is critical to tracking of cyclones and determination of strength. Monitoring river flows.
Atmospheric Profile & 3D Observations and Products	Upper Temperature e.g. sondes, AMDAR and satellite soundings	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	WMO GOS Specs. NWP would prefer 200 to 3km.	Within 60 min of obs	0.3°C	<1°C	Aviation, Climate, Defence, Hydrology, Marine, NWP, Oceanography, Public, Severe, Tropical	Need to specify some criteria for minimum spatial density. This may require impact studies. Profiles to a height of 30 km during cyclone events. Need to specify some criteria for minimum spatial density. This may require impact studies. Two profiles approximately 12 hours apart to establish a 24 hour climatology. The capacity to have 6 hourly profiles on demand during an event is important.

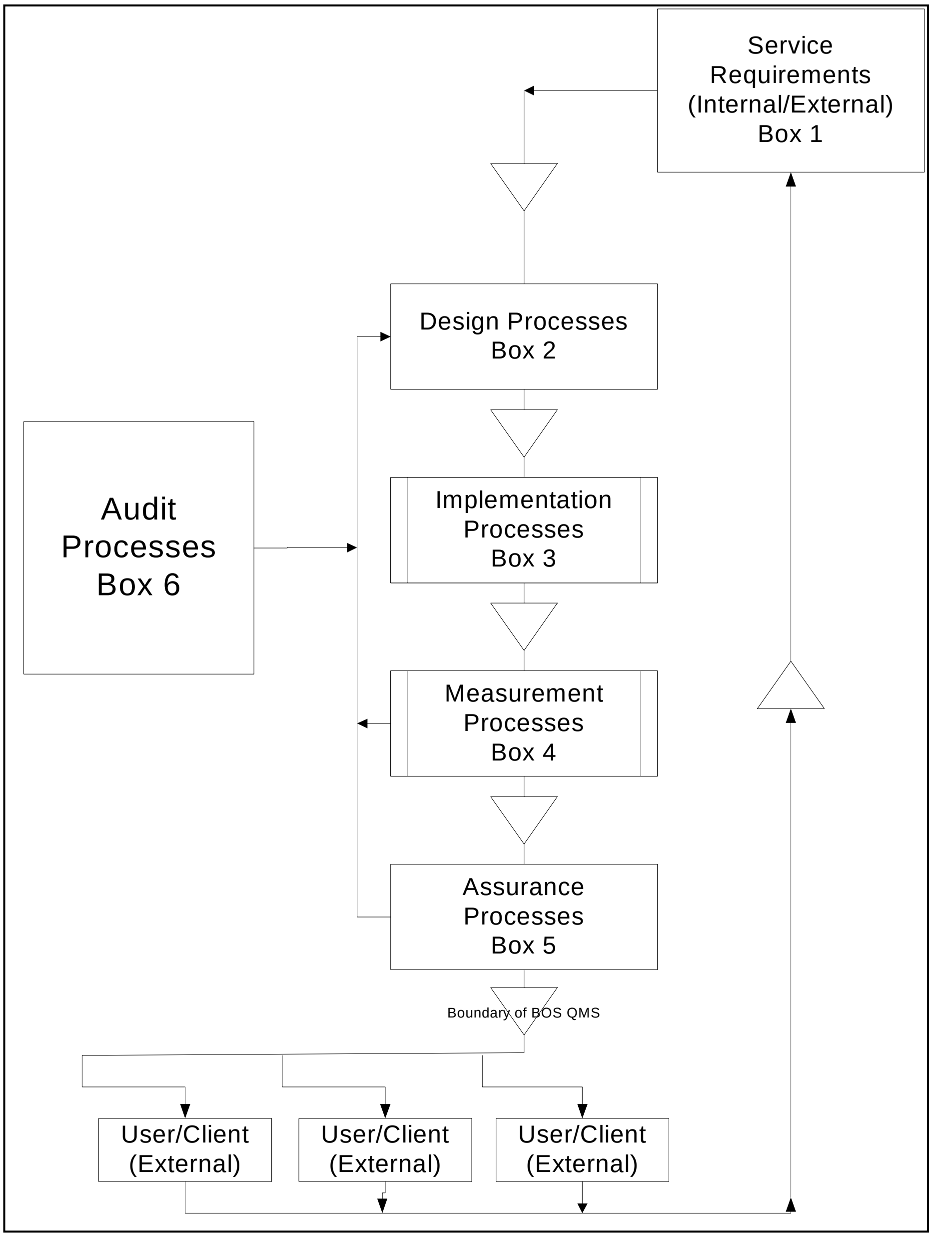
Observation Type	*Element*	*Frequency*	*Density*	*Timeliness*	*Info. Quality*	*Product Quality*	*User*	*Comment*
								Data available more frequently e.g. 30 min from profilers is desirable for severe weather. More frequent observations from e.g. profilers or AMDAR or soundings will allow more accurate prediction of changes for fire weather. Values taken from the Aeronautical Service Handbook, CIMO and EU-METSAT documents
Atmospheric Profile & 3D Observations and Products	Upper Temperature e.g. sondes, AMDAR and satellite soundings	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	High resolution. 50 to 1km	Within 15 min of obs	1°C		Public, Tropical	As for Temperature
Atmospheric Profile and 3D Observation and Products	Upper Moisture e.g. sondes, AMDAR and satellite soundings	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	WMO GOS Specs. NWP would prefer 200 to 3km.	Within 60 min of obs	0.3°C	<1°C	Aviation, Climate, Defence, Hydrology, Marine, NWP, Oceanography, Public, Severe, Tropical	As for Temperature

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Atmospheric Profile and 3D Observation and Products	Upper Moisture e.g. sondes, AMDAR and satellite soundings	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	High resolution. 50 to 1km	Within 15 min of obs	1°C		Public, Tropical	As for Temperature
Atmospheric Profile and 3D Observation and Products	Wind profiles e.g. satellite data	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	WMO GOS Specs. NWP would prefer 200 to 3km.	Within 60 min of obs	1 knots / 10 deg	5knots / 30 deg	Aviation, Climate, Defence, Fire, External, Marine, NWP, Ocean, Tropical	As for Temperature
Atmospheric Profile and 3D Observation and Products	Wind profiles e.g. satellite data	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	WMO GOS Specs. NWP would prefer 200 to 3km.	Within 60 min of obs	5 knots / 22.5 deg		Public, Hydrology, Severe	As for Temperature
Atmospheric Profile and 3D Observation and Products	Wind profiles e.g. satellite data	Minimum of 2 per day - 00Z and 12Z, ideally 6 hourly.	High resolution. 50 to 1km	Within 15 min of obs			Tropical	

Observation Type	***Element***	***Frequency***	***Density***	***Timeliness***	***Info. Quality***	***Product Quality***	***User***	***Comment***
Atmospheric Profile and 3D Observation and Products	3D Wind e.g. Radar (Doppler winds)	5 mins	WMO Specs. Coverage of areas for which warnings are produced. i.e. between Perth and Coffs Harbour	Real time	5 knots / 22.5 deg	10 knots / 45 deg	Tropical Cyclone, Severe	
Atmospheric Profile and 3D Observation and Products	3D Wind e.g. Radar (Doppler winds)	10 mins	WMO Specs. Coverage of areas for which fire forecasts are produced. Within 200nm of capital cities and major population centres. Within 60nm of the coast.	Real time	5knots / 22.5 deg	10 knots / 45 degree	Climate, External, Fire, Oceanographic, Public	
Atmospheric Profile and 3D Observation and Products	3D Wind e.g. Radar (Doppler winds)	10 mins	WMO Specs Within vicinity of international airports and local waters.	Real time	1 knots / 10 deg	5knots / 30 deg	Aviation, Defence, Marine	

Attachment 6

The Six Quality Management Processes



Attachment 7

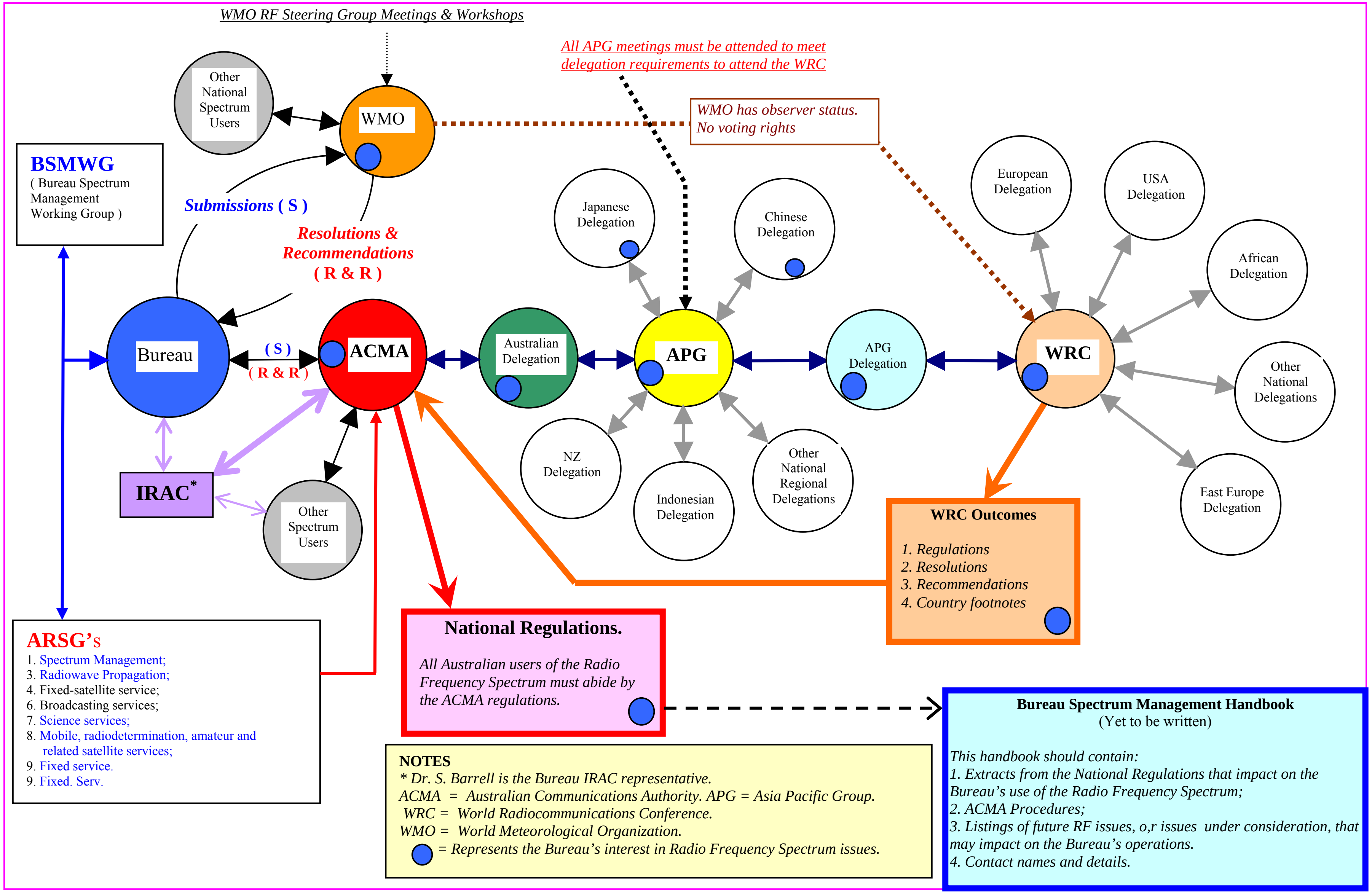
Summary of Communications and Data Handling Systems

System	Basic Description	No. of Stations	Data Flow	Comms Protocol	Reporting Interval	Report Volume	Comments
Radars	RF horizontal scan of atmosphere – moisture and rain	65	Radar – Polling station - ROs		Every 10 minutes, except when in wind find mode	10-15kb per image	
Wind Profilers	RF vertical scan of atmosphere	11					
Radiosondes	Ascending balloon – temp, press, humidity	38	Balloon instruments – Ground receiver – CMSS, AIFS		1-2 balloon flights per day		Diagram available
AWSs	Automatic - Temp, press, humidity, rain, wind speed, wind direction, etc.	555	AWS – AIFS, CMSS AWS – GMS satellite – Japan – CMSS - AIFS	1200bps Xon/Off async to PSTN, Weathernet, Trunk Radio	Local – 1 min Remote – 30 or 60 min	Synop 140 char 10min 300 char MDF 1000 char (72Mb/day for all Regions)	Spec. A2669 Diagram available
EFBs	Manual observer - Temp, press, humidity, rain, wind speed, wind direction, cloud cover, etc.	335	Obs – EFB terminal – AIFS - ADAM	PSTN AAXX message format	3 hourly	80-100 characters per message	
ROCS	Event manual observer – rainfall and river height.	2300	Obs – ROT – ROCS controller - AIFS	ROT – DTMF via PSTN ROCS – FTP of HHZZ message format	1 per day, if raining	~30 character per report	Diagram available
Hydro ALERT	Automatic event report – rainfall and river height	1200	River/Rain gauge – ALERT Radio – Weathernet - Watergate – AIFS	HHRR message format	Bucket tip (0.2, 0.5 or 1mm of rain)		Diagram available
Hydro Data Loggers	Automatic event report – rainfall and river height		River/Rain gauge – Watergate - AIFS	HHRR message format	Floods – 3 hourly No Floods – 12 or 24 hourly		Diagram available
Hydro – External Agencies	Automatic event report – rainfall and			HCS message format			Diagram available

System	Basic Description	No. of Stations	Data Flow	Comms Protocol	Reporting Interval	Report Volume	Comments
	river height						
GPATS	Automatic event report – Lightning	24	Sensor – Controller – ROs – CMSS - GPATS		Approx. 27,000 lightning events per day	5-20Mb per receiver per day	Diagrams available
Satellite Reception	Polar orbit and geostationary satellites - Visible and IR cloud cover radiation	12	Satellite – Ground earth station – processor – HO RTDB and ROs	FTP, socket stream ASDA, McIDAS formats	28 images per day	NOAA 70Mb/i GOES 5.6Gb/i FY2 1Gb/i	Diagram available
Climate Obs	Manual observer - Temp, press, humidity, rain, wind speed, wind direction, cloud cover, etc.	72	Obs – Report form - NCC		1 per month		
AMDAR	Aircraft obs		Aircraft – ground control - CMSS				
Drifting Buoys	Drifting buoys - Temp, pressure, position, wind speed, wind direction	25	Buoy DCP – satellite - ARGOS - CMSS	FGGE, SVP-B	Hourly obs transmitted every 90 seconds	56-64 bits per transmission	Diagram available
Ship Reports (volunteer ships)	Manual and automatic ship observer – Air temp, press, humidity, wind speed/dirn.	11	Ship – Inmarsat satellite – Xantic DNID mailbox – CMSS - ADAM	BBXX message format	- 3 hourly - Spirit of Tasmania II – hourly when moving	56 bytes per message	

Bureau Spectrum Management Activity Diagram

Attachment 8



Attachment 9

The Ten Climate Monitoring Principles

1. The impact of new systems or changes to existing systems should be assessed prior to implementation

2. A suitable period of overlap for new and old observing systems is required

3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e. metadata) should be documented and treated with the same care as the data themselves

4. The quality and homogeneity of data should be regularly assessed as a part of routine operations

5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as Intergovernmental Panel on Climate Change (IPCC) assessments, should be integrated into national, regional and global observing priorities

6. Operation of historically uninterrupted stations and observing systems should be maintained

7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution

8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation

9. The conversion of research observing systems to long-term operations in a carefully planned manner should be promoted

10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems

Attachment 10

Selected Statistics for Overseas Observing Systems

COUNTRY	**Australia**	**USA**	**Canada**	**UK**	**South Africa**	**South Korea**	**Indonesia**	**New Zealand**
Area (‘000 km2)[1]	7,682	9,159	9,221	2448[8]	1,221	120	1,812	268
Population (million)[1]	19.9	286	31.0	58.8	45.5^	22.4	215	3.8
Pop. Density (people per km^2)	2.6	31.2	3.4	241	37.2	186	119	14.2
Urbanisation[1]	87%	77%	79%	90%	53%	61%	42%	86%
GNI Per capita (US$)[1]	$19,900	$34,280	$21,930	$27,040^	$1,859	$1,000	$690	$13,250
NHMS Cost to Government	AU$163M[6]	US$1,383M[9]	C$261M[3]	£76M4[4∞]	R80.6M[5]	$?	$?	NZ$1.4M2[2∞]
Surface Synoptic								
#: 00, 06, 12, 18	865, 810 530, 543	?	700, 700 700, 700	158, 167 170, 170	?	?	?	78, 77 70, 77
Density: 0000 UTC (per million sq km)	113	?	76	647	?	?	?	291
Upper Air Sonde								
#: 00, 06, 12, 18	49, 35 35, 18	?	40, 0 40, 0	6, 0 6, 0	?	?	?	8, 0 6, 4
Density: 0000 UTC	6.4	?	4.3	24.6	?	?	?	29.8
GCOS Stations[∂] [GSN/GUAN][7]	68/16	82/11	83/5	9/3	14/4	3/1	18/1	10/4
Annual Satellite Costs[β]: Satellites, Launch, Ground Stations & Receivers	$10 Million	$2,000 Million	$200 Million[ϕ]	$200 Million	$?	$200-$400 Million	$2-$5 Million	$1-$3 Million
AMDAR (average per day)	4000	?	18,410	32,000[⊕]	?	?	?	600-700
Rainfall Stations	7531	?	434[*]	3607	?	?	?	1100[∀]
BapMon/Solar Rad Stations	1/17	?	19[λ]/43	?/88	?	?	?	0/94[∀]
Weather Watch Radar[♣] (No. per million km^2)	51 6.6	154 17	31 3.4	9 37	11 9.0	9 7.5	7[π] 3.9	3 11
Marine Buoys/Argo Floats	32/56	990/910	25/77	37/84	11/0	0/54	0/0	9/5
Voluntary Observing Ships Fleet size, (synoptic Obs per annum)	102 52387	?	161 81066	392 71319	?	?	?	48 28396

Notes on the Table:

[∂] Includes Antarctic and Island stations

^ 2002 data
∞ Significant privatisation
♣ Obtained from respective met service websites (except Indonesia)
π Actually 11-12 exist in Indonesia but some are known to be inoperative long-term
β Meteorological and environmental satellites only
ϕ Proportion of EUMETSAT
∀ 711 rainfall stations and 55 solar radiation stations belonging to the National Institute of Water & Atmospheric Research (NZ equivalent to the Australian Bureau's National Climate Centre, but existing as a separate entity.)
* Only 36% reach national archive
⊕ Includes data in support of WWW as well as EUCOS requirements
λ CAPMoN - Canadian Air and Precipitation Monitoring Network
? Data not available

References:

1 Whitaker's Almanac 2005; A&C Black, London [refers to 2001 figures] – *unless noted otherwise*
2 http://www.transport.govt.nz/publications/annual-report/2004/45.php#note-5
3 The Meteorological Service of Canada: Annual Report 2003-04
4 Met Office: Annual Report and Accounts 2003/04 HC578 London: The Stationery Office
5 South African Weather Service: Annual Report 2003/2004
6 Australian Government Bureau of Meteorology: Annual Report 2002-03
7 http://www.wmo.ch/web/gcos/networks.htm
8 The Times Comprehensive Atlas of the World, 2000: Times Books, London.
9 Economic Statistics for NOAA, April 2004: US Department of Commerce National Oceanic & Atmospheric Administration

Attachment 11

Summary Table of Cost-Benefit Ratios for Selected Bureau Services

Meteorological service	Benefit-cost ratio	Remarks
Basic public weather services for householders (forecasts and warnings)	4:1	Excludes the benefits from use of basic public weather services as inputs in the production processes of business firms and organisations.
Cottonfields Weather Service for cotton producers in New South Wales and Queensland	12:1	Benefit-cost ratio is based on the reduction in the unit cost of production of cotton from the use of the service.
Terminal aerodrome forecasts service for international flights to Sydney international airport (for Qantas Airways Limited)	2.7:1	Benefits mainly in terms of fuel savings less the cost of diversions from inaccurate forecasts. The ratio is strictly a financial benefit- cost ratio for Qantas Airways Limited.
Terminal aerodrome forecasts service for international flights to all Australian international airports used by Qantas Airways Limited	1.7 – 2.6:1	Benefits due to fuel savings. The ratio is strictly a financial benefit-cost ratio for Qantas Airways Limited.
Public weather and climate services for mining firms in Queensland	17:1	This ratio is for mining firms in Queensland only.
Tropical cyclone warning service for homeowners in QLD	10 - 66:1	Benefit-cost ratios are preliminary figures.

Attachment 12

New and Emerging Observing Technology

SPACE-BASED OBSERVATIONS

Advanced Satellite Sounders

- High resolution hyperspectral sounders of terrestrial and atmospheric irradiance
- Examples are AIRS (already in orbit), CrIS and IASI (from 2006)
- Benefits:
    - Improved vertical and thermal resolution (for profiles of temperature, moisture, etc.)
    - Improved spatial and temporal resolution
    - Greater array of measurements possible (atmospheric constituents, aerosols)
- Significant impact on NWP expected
- Requires staffing resources for software and applications development and implementation
- Optimal data usage will offer opportunities for some rationalization of surface-based observing program.

Advanced imagers

e.g. MTSAT-1R (Japan), FY-2C, FY-2D (China), COMS (Korea)

- Increased resolution (spatial, temporal) over previous generation platforms
- Promises higher quality value added products (e.g., volcanic ash detection, SST, fog/low cloud, atmospheric motion vectors).

Scatterometers

- Space-based microwave radars.
- Backscattered signal from ocean surface allows derivation of oceanic surface wind speed and direction.
- Data are already used by the Bureau (e.g. QuikSCAT), further opportunities scheduled (Metop, NPOESS).
- Limited coverage for next several years, thereafter a significant increase, with several instruments in orbit continuously.

SURFACE-BASED OBSERVATIONS: SYSTEM MANAGEMENT

Next Generation SitesDB

- Current SitesDB:
    - The Bureau's corporate repository of site-specific metadata
    - Increasingly valuable management tool (used for system and data quality management, asset management, network management, performance monitoring, etc.)
    - Supplements corporate FMS
    - Usage has grown beyond original design capacity (more successful and useful than originally anticipated)
    - Urgently requires re-engineering and future-proofing
- Next Generation SitesDB:
    - Will provide all existing functionality, plus many additional features
    - Planning underway with extensive stakeholder involvement
    - Main features:

- Ease of maintenance, scalability
- Improved and simplified access to information (more efficient, effective and responsive)
- Greatly increased capacity and functionality
- More user friendly
- Will enable overall reduction in overhead costs

Incoming Observations Data Processing (IODP) environment

- Major component of Next Generation AWS and WebConsole system
- Platform to process AWS data in real-time and supply user-friendly Web-based data products via, e.g., WebConsole
- Will be designed to accept a range of input data types and formats (e.g. from Tidal networks)
- Planning underway with extensive stakeholder involvement

LAND-BASED SURFACE OBSERVATIONS

Next Generation AWS and WebConsole

- Simplified field unit and field application software (simpler and more centralized support, simpler expandability, broader range of suppliers)
- Centralised processing (replaces the numerous and various field MetConsole units with a single centrally located and maintained server, enables centralized software and/or configuration upgrades, much improved data Q/A ‘at source’)
- Internet browser access to field units (enables centralized diagnostics, display of output from many AWS from a PC located anywhere, no proprietary field software)
- Next generation communication networks (cheap, high temporal resolution data, more effective Q/A) with lower annual communications costs
- Lower maintenance / field support costs
- Capacity to equip more sensors, with universal sensor connections, and quicker innovation cycles
- Similar capital/installation costs to current AWS (including sensors) for new installation
- Upgrade cost from current AWS: $10-20K
- Implementation probable 2007/08.

AWS: Sky Cameras

- Automated cloud cover observations
- Upward pointing fish eye lens, or downward pointing with hyperbolic mirror
- Solar tracking disk to protect camera lens
- Automated cloud cover reports that represent the whole sky.
- Standard measurement at all sites regardless of wind direction and local effects, which affect the cloud cover estimates currently used.
- Trialling and Development work would be required before considering integrating with our AWS.
- Cleaning requirements for lens or mirrors is an issue.
- Possible implementation after 2010.

AWS: IR Sky Camera Coupled with Ceilometer

- All sky camera, sensing in the atmospheric window only, to provide 24/7 cloud height/amount observations.
- Current IR cameras are broadband (4-100um):
    - ‘Sees’ sky temperature
    - Limited to detection of clouds below height of effective sky temperature
- Band limited cameras
    - Only sense in atmospheric window, so ‘see’ clouds to higher altitude
    - Coupled with ceilometer, surface temperature and humidity data, can provide automated, scaled cloud observations, including cloud amount and height
    - Developing technology, requires extensive testing and costing
- Estimate cost: similar to ceilometer ($30K) by 2010
- Possible implementation: 2010-2015

AWS: Automated Evaporimeter

- Class A evaporimeter with hydraulically-coupled still well and ultra-sonic sensor for level measurement
- Enables provision of high frequency evaporation data (> 1 minute)
- Current trial by OEB at SARO suggests a viable system
- At least monthly maintenance inspections required to clear algae from pan
- Great potential for enabling automation of AgroMet observations
- Requires water/plumbing, rainfall measurement and communications on-site
- Expected lifetime of ultrasonic sensor currently untested
- Expected cost: $7700 plus shipping plus installation
- Possible operational implementation: 2009

AWS: Present Weather Sensor

- Originally developed in the 1990s to discriminate between liquid and frozen precipitation
- Numerous variations available, varying greatly in price and performance
- Vaisala FD12P sensors already employed in a number of AWS in the BCOS
- Only capable of reporting a subset of weather types
- Approximate cost: $25K plus installation and maintenance
- Possible implementation: immediate

AWS: Lightning Sensor

- Currently under development between Bureau and University of Queensland (CGR4)
- Detects radiofrequency emission of a lightning discharge
- Only provides strike counts from within a certain range of sensor (does not provide additional range or bearing information), but can differentiate positively from negatively charged strikes
- Envisaged as a cheap and effective replacement and upgrade for our aged Lightning Flash Counter Network (potential addition to all AWS)
- Expected cost: $2000
- Possible implementation: 2008

AWS: Throw-away Redundant Sensors for Basic Parameters

- A new model for 'basic' sensor life cycle and data quality management.
- Current model:
  - Surface observing sites employ just one sensor for measurement of each of temperature, humidity, and pressure.
  - Prohibits remote detection of subtle calibration shifts in a sensor, so sensors require regular inspection and maintenance, and a fixed replacement schedule.
  - When a sensor fails prematurely, data are lost until the sensor is replaced by a Bureau technician.
  - Places additional pressure on technical staff priorities.
  - High quality sensors used today are quite cheap compared with Bureau expenditure on equipment inspections and maintenance, and on some downstream data quality assurance tasks that might not be required under different circumstances.
- Throw Away/Redundant Sensor Model:
  - Employs three sensors for each basic quantity at each telemetered observing site, either AWS or cooperative.
  - Provides the opportunity to remotely diagnose subtly calibration drift or shifts in an individual sensor, Enables a schedule of less frequent inspection visits, and perhaps replacement on failure.
  - Reduces load on technical staff, and downstream quality assurance needs
  - Expected cost: Unknown, probably double current expenditure on basic sensors, but savings in inspections and maintenance visits and knock-on effects in other programs.
  - As yet unproven: requires extensive testing and detailed cost-benefit analysis.

Long Path Transmissometer for Visibility Observations (e.g., RVR)

- Currently, automated visibility observations are made using vismeters:
- Very local measurement (optical path length approx 1 metre)
- Can be highly unrepresentative in situations where visibility varies greatly on small scales (e.g. smoke, fog patches, etc)
- Impending requirement via ICAO for RVR information in Metar messages
- Technology exists for monitoring long-path (> 1 km) optical transmission either using LIDAR or high powered light sources.
- Expensive technology, but prospects for funding via Aviation Weather Services Program
- Possible implementation: 2007 (subject to certification/characterisation)

Stand Alone Thunderstorm/Lightning Sensors

- Several options commercially available.
- Most detect radiofrequency emissions accompanying lightning discharges, some also detect either magnetic pulse or visible flash, or both.
- Vaisala TSS928 already employed in stand-alone mode at some International or Defence airports in Australia
- TSS928 provides binned information on strike bearing and range
- Lightning current strength can vary greatly, so range uncertainties can be large and detection efficiency is not perfect
- Approximate cost: \$20K without data display software package
- Possible implementation: immediate

Mercury-in-Glass Inspection Thermometer Replacement

- A plan for retiring Mercury-in-Glass (Hg-in-G) thermometers, improving data quality and reducing calibration load on staff
- Current model:
  - Site inspection thermometers (transfer standards) are Hg-in-G type
  - Carried by inspectors in the field for referencing field equipment
  - Field equipment is often a platinum resistance thermometer.
  - Overall uncertainty in reference is 0.2oC
  - Hg-in-G thermometer needs manual RIC calibration every year, time-consuming process, sensor cannot be carried by air, unnecessary use of Hg is increasingly frowned on
  - Thermometer is relatively cheap, but frequent breakages (an OH&S issue) lead to an average life of just a few years
- New model:
  - Inspection thermometers are electronic platinum resistance type
  - Overall uncertainty in reference reduced to 0.08oC
  - Can be quickly, accurately and automatically calibrated by RIC
  - Very stable so only requires RIC calibration every two years
  - Can be operated in the field with, e.g. a laptop, to avoid manual reading or transcription errors
  - Average lifetime of approximately 10 years
  - Can travel by air
  - Overall improvement in temperature data uncertainty
  - Purchase price 5 time that of Hg-in-G, but reduced load on RIC resources.
  - Requires detailed cost-benefit analysis

Mobile Nowcasting Sensors

- A plan for capturing real-time temperature and humidity data from commercial surface traffic (trucks, buses, trains), or Vehicles of Opportunity (VOO), much as we currently obtain AMDAR data from commercial aircraft.
- Modern road vehicles continuously monitor temperature and humidity for optimal performance of onboard air conditioning systems.
- Many of these vehicles also carry GPS units for monitoring location, and GMS mobile phones for communications.
- This plan is to meld these three mature technologies to provide, via SMS, real-time environmental information from vehicles on the move.
- These VOO would provide high density supplementary data for nowcasting purposes in critical weather situations.
- The envisaged intermediate quality data from VOOs would be temporarily stored, but not archived, released to the public or stored in the climate data bank.
- As yet unproven: requires extensive testing and detailed cost-benefit analysis.

Tiered Rainfall Network Sensors

- Current rainfall networks are based on a ‘one-shoe-fits-all’ model, comprising:
  - Manual gauges: no information on time dependency of rainfall, and
  - TBRGs: inadequate temporal and spatial resolution
- Opportunities exist for a more ‘fit-for-purpose’ model:
  - Continue use of manual gauges and TBRGs where appropriate

  - Include strategic placement of mass gauges for high quality rainfall and rain-rate data (at climate reference stations and around Doppler radars)
  - Include strategic placement of disdrometers (which measure drop size distribution, integrated volume, and inferred rainfall rate)
  - Combine use of Doppler radar in key locations, in conjunction with disdrometer and mass gauge data
- Potential for significant overall resource savings via reduction in total number of observing sites
- Reduced need for manual observations at climate stations, improved data quality
- Improved data quality and more effective coverage in key locations
- Current TBRG costs: $1-2K purchase, ~$10k per unit lifetime for maintenance, data verification
- Mass gauge cost: $5-8K purchase, simpler maintenance, less requirement for data checking
- Requires extensive testing and detailed cost-benefit analysis

MARINE OBSERVATIONS

- New generation Ship-based AWS
- Ship-board version (modified for a moving platform) of Next Generation AWS
- Benefits:
  - Enables a Bureau-wide uniform Data Collection Platform
  - Standardisation of maintenance and Data Quality management
  - Ease of installation to allow greater flexibility with ship selection
  - Possible integration with other Ship reporting system, ie XBT
- Requires detailed investigation, development and cost-benefit analysis
- Relies on effective communications systems across Ocean regions (e.g, SatComms)
- Expected cost: $20 - $25K for full installation
- Possible implementation: After 2007/08.

Moored Buoys

- Deep-ocean moored platform with sensors to measure meteorological (temperature, pressure, wind, solar irradiance), chemical (e.g., carbon) and oceanographic (SST, sub-surface temperature, current) quantities.
- Meteorological sensors (pressure, temperature, wind, SST) installed in pairs (provides for redundancy in the event of premature failure).
- Battery powered, supplemented by solar panels
- A variety of atmospheric sensors (radiation, carbon) are available, as well as surface oceanographic sensors (waves) and sub-surface sensors (temperature and current)
- Enables observations from fixed locations, and more complete environmental sampling than existing units.
- Expected cost per platform: $150-300K, dependent on sensor suite
- Possible implementation: 2006 (mature technology).

Devil XBT

- Essential replacement for existing and now obsolete DOS-based XBT data acquisition and reporting system
- Promises higher resolution data, cheaper communications method
- Currently undergoing extensive testing.

- Possible implementation 2006

SURFACE-BASED UPPER AIR OBSERVATIONS

AMDAR: TAMDAR

- Multi sensor suite with built-in satellite communications, for installation on commercial aircraft not equipped with AMDAR-compatible software or communications
- Provides temperature, pressure, wind, icing, turbulence and altitude data
- Currently under trial in USA, Europe
- Aircraft certification yet to be obtained
- Potential partial replacement or supplement for radiosonde program
- Turnkey solution currently offered by the provider – potential data ownership issues
- Data range restricted to areas of aircraft operations
- Expected costs (post certification): $20K plus installation plus communications
- Possible implementation: unlikely before 2009

AMDAR: WVSS2 (Water Vapour)

- Laser diode instrument for installation on commercial aircraft with AMDAR compatability.
- High quality data (3-5% uncertainty in humidity)
- Complements other AMDAR data to comprise potential replacement/supplement for radiosonde data from major airports
- Potential for provision of middle and upper tropospheric water vapour data from data sparse regions (e.g. inland air routes, oceanic air routes)
- Requires cooperation of airlines for installation and maintenance
- Recent operational trials in USA show encouraging results
- Low maintenance requirement expected
- Awaits certification for most aircraft types
- Potential economical source of data
- Expected costs (post certification): $30K purchase and installation
- Possible operational implementation: 2009

Advanced Radiotheodolite

- Passive upper wind system using patch array antenna to track a radiosonde signal
- Enables reduced use of expensive GPS radiosondes (replace with cheaper PTU sonde)
- Economical replacement for wind-find radar (frees up existing radar for 24/7 weather watch)
- Not practical for upper wind only sites (sondes too costly)
- Data uncertainty similar to that of windfind radar
- Low maintenance requirement cf windfind radar
- Expected cost ~$100K
- Possible implementation: 2008

Wind Profiler

- VHF or UHF upward pointing radar, which tracks the passage of atmospheric turbulence patches as they are advected overhead

- Provides high temporal resolution (> 15 minute) limited vertical domain (purportedly 300m to 6km for boundary layer profiler, 1km to 18 km for tropospheric profiler) upper wind information
- Operable in either Doppler mode or Spaced Array (SA) mode
- Recent Bureau experience with SA profilers suggests reduced vertical domain (max reliable altitude 3km), large mean bias and relatively large data uncertainty: requires further investigation, may need to employ Doppler mode for improved performance.
- Low maintenance requirement post installation
- Approximate costs: $250-500K installed for B/L version, $750-1300K for tropospheric, dependent on supplier.
- Possible implementation: available and employed now, but require further characterization prior to further purchases.

Surface-based GPS Water Vapour Measurement

- Measures time delay in surface receipt of GPS signals from satellite due to presence of water vapour along path, enabling estimation of total precipitable water
- System components: network of GPS receivers providing realtime data, plus a central processing unit
- Potential for utilizing data from third party GPS receiver networks (e.g. LandVic, GA)
- Potential to greatly improve effective spatial resolution of upper air moisture information over land
- Data are of assimilation quality and have shown positive impact on NWP
- Startup costs: 1ASL for 1 year plus $20K. Minimal recurring costs if only third party data are used.
- Possible implementation: 2007

SURFACE-BASED REMOTE SENSING OBSERVATIONS

Weather Radar: Dual Polarization

- Improved rainfall measurement and hail detection
- Possible implementation after 2007/08 (RNDSUP)
- Requires services/training/display development
- Hardware cost ~$400K per radar (depends on radar)

Weather Radar: Digital Signal Processing

- Improved permanent echo suppression (higher quality data)
- Improved immunity from radiofrequency interference (higher quality data)
- 5db improved sensitivity (higher quality data)
- PC-based (enables remote diagnostics and adjustment, less onsite maintenance required)
- Enables more sophisticated data Q/A on site
- Enables high resolution I&Q video capture (improved algorithm development capabilities)
- Approximate cost for conversion from analogue signal processing: $100K per radar
- Possible implementation: immediate

Networked Thunderstorm/Lightning Sensors

- Several options commercially available

- BCOS currently includes GPATS network, which detects time of arrival at 4 widely spaced sensors of VLF radio emissions associated with lightning discharge and infers strike location by triangulation)
- Network detection efficiency can vary significantly, dependent on sensor spatial resolution and e/m environment.
- Approximate cost: $150K per sensor to purchase. Alternative is to purchase data from third party, but this introduces data ownership issues.

ATMOSPHERE WATCH OBSERVATIONS

Total Ozone

- Current instrument employed is the Dobson spectrophotometer:
    - Purchase cost: ~$250K; 'Installation' costs ~$250K
    - Manual instrument, requires skill to use well
    - Only provides a few observations per day
    - Requires specialist staff for time-consuming calibrations
    - Large, heavy, high-precision instrument: difficult and costly to transport
- Opportunity for use of automated UV spectrometer:
    - Similar to, but cheaper than, existing UVB spectrometers under trial at Darwin and Alice Springs
    - Introduce use of charged-couple-detectors (cheap and effective) to reduce purchase price to ~$20K
    - Also provides for global and direct UVA and UVB solar irradiance data
    - Small and modular, no need for specialist staff to install and maintain
    - Reduced data uncertainties
    - Potential for further adaptation to monitor agriculturally important quantities (e.g., PAR)
    - Requires development, extensive testing and costing
- Estimated price: $20K
- Possible implementation 2010

Fourier Transform Interferometer Radiometers (FTIR)

- For monitoring radiatively active gases
- In common use, forming a major component of the NDSC.
- BMRC has one at Melbourne Airport for use in fog research.
- Mature technology, can be used to derive a number of quantities (e.g., temperature and moisture profiles)
- Can also be used for:
    - Column amounts of various greenhouse gases
    - Direct measurement of the greenhouse effect itself, hence long-term changes in the radiation budget
- Would enhance our contribution to GAW and Montreal Protocol
- Proposed installation at 5 strategic surface sites
- Expected cost: $200K purchase per unit, recurring network costs of $300K
- Requires extensive testing and detailed cost-benefit analysis
- Expected implementation: 2010

Attachment 13

4 Proposed Stages for BCOS Development: 2006-2016: (a) Stage 1 - Consolidation of the Existing BCOS

Topic	Rec No.	Initiative	Priority	Primary Respons-ibility	Timing (Yrs from 2005)	Asset $1000s	G&S $1000s pa	Incr. ASL	Exist. ASL
Satellites	8	Install X-band ground receiving equipment. (incl in ARP)	1	OEB	1-3	0*	0*	0	2
Satellites	9	Upgrade existing ingestion and applications software. (incl in ARP)	1	OEB	1-4	+1200 (incl 3cs x 4 yr)	0	+1 x 4yr (training)	2
Radiosonde	15	Restore the radiosonde program to pre-January 2005 levels.	2	OEB	1-2	0	+1200, down to +700 by yr 7	+10	N/A
Sfc Obs	32 .	Review the distribution of surface observing sites, and make adjustments to improve network effectiveness. (reloc 40 sites)	2	OEB	1-3	+1200	0	0	0
Sfc Obs	34	Review and standardise routine reporting frequencies from surface observing sites across the country.	1	OEB	1-2	0	0	0	0.3
Sfc Obs (AWS)	35,51	Implement new generation communications technology in the existing AWS network (50 sites), subject to favourable cost/benefit.	3	OEB	1	50	-30 pa after rollout	1ASL during roll-out, 0 after	0
Ozone soundings	40	Restore expertise in ozone sondes to pre-January 2005 levels.	2	OEB	2-3	0	0	0	1
Solar and Terrestrial Network	40	Restore 8 stations and add two new stations.	1	OEB	2-4	1500	20	0.5	2
CGBAPS	40	Restore CGBAPS equipment.	1	OEB	1	+1000	0	0	0.3
CGBAPS	40	Refurbish/rebuild CGBAPS building infrastructure as planned in FY08-09.	1	OEB	2-3	+3000 (incl 0.3cs x 1yr)	0		0.4 (x 2yr)
GPATS	27	Work with GPATS to upgrade its network, and realtime performance monitoring system.	1	OEB	1-2	0	0	0	0.3

4 Proposed Stages for BCOS Development: 2006-2016: (b) Stage 2 - Overarching and Underpinning Initiatives

Topic	Rec. No.	Initiative	Priority	Primary Responsibility	Timing (Yrs from 2005)	Asset $1000	G&S $1000s pa	Incr. ASL	Exist. ASL
Performance and Impact Measurement	57	Upgrade BCOS performance measurement tools, with particular emphasis on the effectiveness of the BCOS and its components, and on measuring the impacts of BCOS changes on the delivery of services.	1	OEB/ WOSPB	2-3	+200 (1cs x 2yr)	0	0	2
Quality Management	46	Identify and implement an appropriate, formal quality management system for the BCOS.	1	OEB	1-2	0	+400 (x 1yr)	+1.5	0.5 (x 3yr)
Data Impacts	13,14 60	Establish a dedicated group for assessment of BCOS data impacts on NWP performance, and other service outputs.	1	BMRC/NMOC/WOSPB	1 ongoing	0	+100 (super-computing)	+3	0.5
Value Assessmt.	1,7	Ascertain the overall value (benefits vs costs) of the Bureau, and of its respective components (systems, services), to the Aust. community.	1	EIAB	1-2	0	+350 (x 2yr)	0	0
Spectrum Management	52	Take a greater lead in national radiofrequency spectrum management.	2	OEB	1 ongoing	0	30 (travel)	+1	0.5
Executive	2,3,6	Continue to promote removal of the efficiency dividend, the ongoing free international exchange of data, and specification of realistic international data requirements.	1	EIAB	1 ongoing	0	0	0	0
NWP	10	Upgrade data assimilation systems for the ingestion of satellite data from a wide range of new generation platforms.	1	BMRC	1-4	800 (incl 2cs x 4yr)	100 (x 4 yr)	+1	0.5
Data Display	11,59	Develop and implement, within the AIFS/FSEP/GFE environment, a flexible and universal data display system for the simultaneous display of data from multiple sources, including satellite retrievals.	1	CCSB	1-2	400 (2cs x 2yr)	0	0	0.5
Climate Analysis	12	Pursue the utilization of new generation satellite data for climate monitoring and diagnostic purposes.	2	NOB/BMRC (/CSIRO)	1 ongoing	0	0	+2	1
Message Codes	42	Address current and future needs for modernising meteorological codes used to transmit data, both domestically and	1	OEB/CCSB/ NOB	1-3	0	0	0	1

Topic	Rec. No.	Initiative	Priority	Primary Responsibility	Timing (Yrs from 2005)	Asset $1000	G&S $1000s pa	Incr. ASL	Exist. ASL
		internationally.							
Data Storage & Access	58	Carry out a detailed study into needs for data storage and archival, leading to implementation of an appropriate data storage system which enables ready access to all data types by all data users.	2	CCSB/OEB	1-4	0	+200 (x 3yr)	0	0.5

4 Proposed Stages for BCOS Development: 2006-2016: (c) Stage 3 - Development and Testing of New Technology

Topic	Rec. No.	Initiative	Priority	Primary Respons-ibility	Timing (Yrs from 2005)	Asset $1000	G&S $1000s pa	Incr. ASL	Exist. ASL
Satellites	9	Develop new high priority applications. * incl. in ARP	2	OEB	5-7	0	0	0	1
Satellite	8	Develop hemispherical array antenna design	3	OEB/SSU	1-4	0 (ext. funded)	0	0	0.5
Sfc Obs (AWS)	39	Develop a specification for a Next Generation AWS system, including a replacement for MetConsole.	1	OEB	1	0	+100 (x 1yr)	0	0.5 (x 1yr)
SitesDB	43	Develop and implement a Next Generation SitesDB system.	1	OEB	1-2	+400 (2cs x 2yr)	0	1	1
IODP	35,44	Develop and implement an Incoming Observations Data Processing environment (IODP), subject to agreed need for development in-house.	1	OEB	1-2	+200 (1cs x 2yr)	0	1	1
Autosonde	16,17	Investigate the capability for fully unattended operation at Autosonde stations, by trialing zero staffing arrangements at one suitable site, and working with Vaisala to improve Autosonde system performance.	1	OEB	1-2	50	20 (x2 yr)	-1 (x 2 yr)	0.3
AMDAR	18	Trial the use of WVSS2 sensors on AMDAR-equipped commercial aircraft.	1	OEB	1-3	+80	+60 (x 3 yr)	0	0.25
B/L Profilers	20	Complete the performance assessment of boundary layer wind profilers.	1	OEB	1	0	0	0	0.25
S/T Profilers	22	Assess the performance of a stratosphere/troposphere wind profiler. (profiler gifted by JAXA 03/06)	1	OEB	1-3	50 *	+50 (x 2yr)	0	0.25
WW Radar	26	Evaluate the benefits of dual polarization Doppler weather radars.	3	BMRC	1	0	0	0	0.1
WW Radars	26	Carry out a detailed review of the Bureau's weather radar network.	1	OEB	1-2	0	0	0	0.3x1yr
Lightning	28	Investigate the availability and use of alternative sources of lightning mapping data.	2	OEB	1-3	0	0	0	0.2
Lightning	29	Develop a real-time-reporting replacement for the aged LFC network, with the ability to discriminate between cloud-to-cloud and cloud-	2	OEB	1-2	+30	0	0	0.7

Topic	Rec. No.	Initiative	Priority	Primary Respons-ibility	Timing (Yrs from 2005)	Asset $1000	G&S $1000s pa	Incr. ASL	Exist. ASL
		to-ground strikes.							
AWS Visual Obs	31	Investigate the capability of advanced AWS units for providing comprehensive surface observations, with a particular focus on visual element information.	1	OEB	1-3	+200	+70 (x 3 yr)	0	0.1
Auto Evap	37	Investigate the capability of automated evaporimeters for unattended operation at remote sites.	2	OEB	1-3	+20	+5 (x 3 yr)	0	0.25
Evap	37	Investigate the acceptability to users of increasing reliance on derived evaporation data.	3	OEB	1-3	+300	10	0	0.25
Soil Moisture	38	Investigate potential techniques for effective measurement of soil moisture at selected surface sites.	3	OEB	1-3	+30	+50 (x 3yr)	0	0.5 (x 2yr)
Redundant Sensors	55	Trial the redundant sensor model for basic AWS measurements (pressure, temperature, humidity).	1	OEB	1-3	+20	+40 (x 3yr)	0	0.2 (x 3yr)
Shared / 3rd Party Data	53	Investigate the scope for extending Bureau involvement in shared and/or third party data or systems.	1	OEB	3-5	0	0	0	0.3 (x 3yr)
Multi- Tiered Networks	54	Investigate the feasibility of adopting a tiered network model for the BCOS.	1	OEB	3-4	0	0	0	0.5 (x 2yr)
Organis-ational	61	Investigate scope for increased cross-program collaboration for field equipment maintenance and inspection.	2	OEB	1	0	0	0	0.2 (x 1yr)
Organis-ational	62	Investigate the potential benefits of combining resources for network management and operation (OEB/Hydro)	3	OEB/ NOB	3	0	0	0	0.1 (x 1yr)

4 Proposed Stages for BCOS Development: 2006-2016: (d) Stage 4 - Implementation (Subject to Operational Suitability)

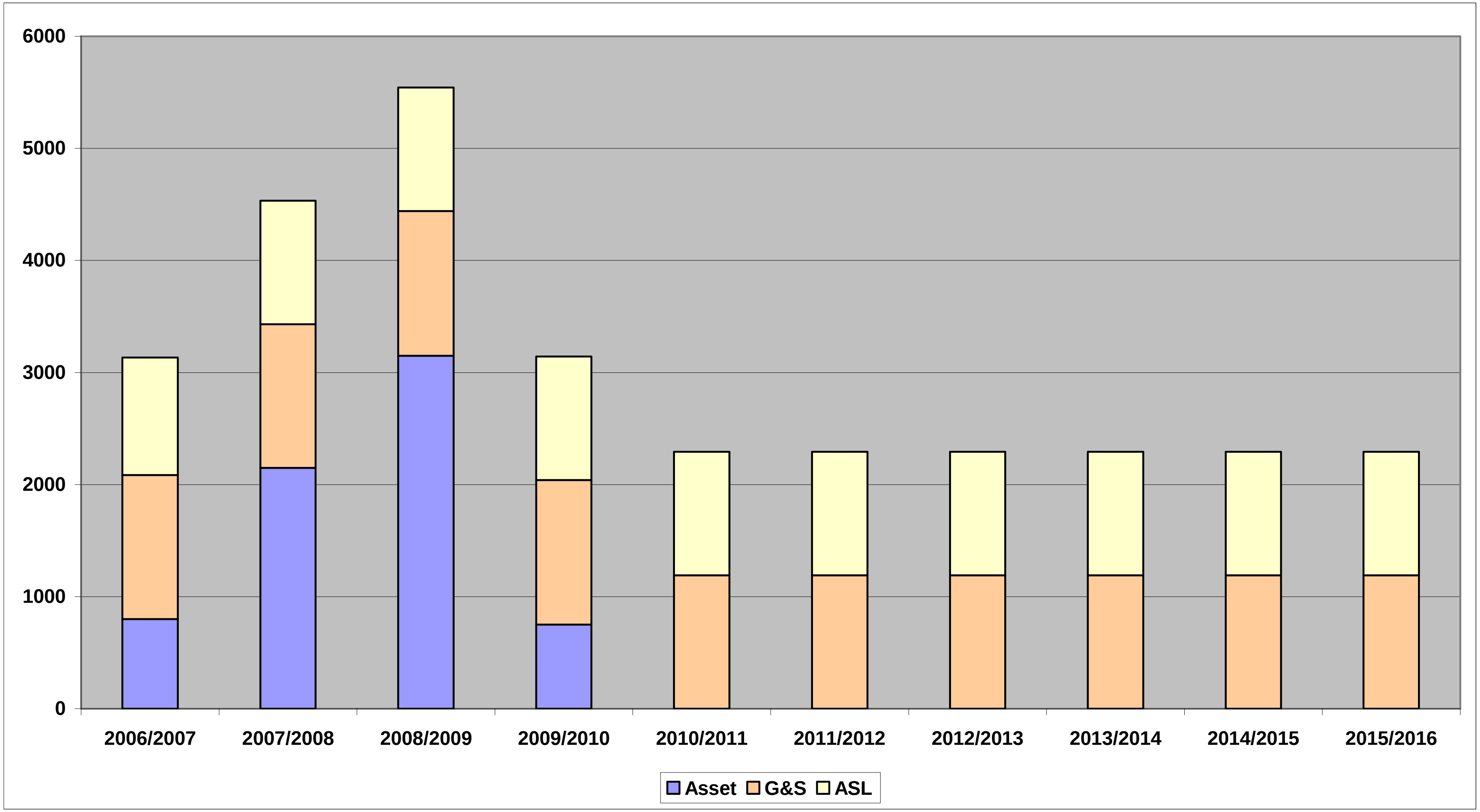
Topic	Rec. No.	Initiative	Priority	Primary Respons-ibility	Timing (Years from 2005)	Asset $1000	G&S $1000 per annum	Incr. ASL	Exist. ASL
WVSS2	16	Acquire and progressively implement WVSS2 sensors on AMDAR-equipped commercial aircraft (assume 50 sensors).	1	OEB	3-10	1500	150	+2	0.25
AMDAR	17	Expand the AMDAR program to include additional airlines, and supply of ADS-B data from commercial aviation. (assume 200 new equipped aircraft, plus ADS-B, plus data redundancy system.)	1	OEB	3-10	500	100	+1	0.5
B/L Profilers	19	Implement boundary layer wind profilers, including RASS equipped units, at some existing upper air sites (assume 12).	1	OEB	2-5	3000	400 (spares, comms)	+1	0.4
S/T Profilers	21	Implement ST profilers at upper wind only sites (assume 5).	1	OEB	3-6	6000	400 (spares, comms)	+1	0.4
GPS H20	23	Establish an operational GPS water vapour program.	1	OEB	1-2	135	20	0	0.4
Lightning	27	Implement a cheap, real-time-reporting replacement for the aged LFC network and manual T/S observations, with the ability to discriminate between cloud-to-cloud and cloud-to-ground strikes, to be installed on most AWS units (assume 500).	1	OEB	3-10	1500	150	+0.5	0.2
Vis Data	28	Upgrade AWS units at selected sites for the provision of comprehensive visual element data (assume 100).	1	OEB	3-10	8000	800	+2	0.2
Portable AWS	30	Provide additional portable AWS units to Regions for emergency deployment in critical weather situations (assume 10).	3	OEB	4-10	200	25	0	0.4
Sfc Obs	32 *	Establish additional AWS sites (10 per year) based on service requirement and availability of external funding.	2	OEB	1-10	0 *	0 *	0 *	0

Sfc Obs (AWS)	39	Implement Next Generation AWS and MetConsole systems.	1	OEB	2-6	0	-350	+4 x 5 yr –4 off base at tend	4
Agromet	33,34	Implement advanced agro-meteorological sensors on AWS units in key agricultural areas (assume 100).	2	OEB	4-10	2000	200	+0.5	0.1
Compensating Savings	Many	Progressively reducing field staff numbers, field office infrastructure (buildings, balloon sheds, HOGEN, Digicora receivers, staff housing, etc)		OEB	4-9	-29000	100K to 200K pa savings	-70	0
WW Radar	24	Expand and upgrade the weather watch radar network. Assume digitization of all radars, coverage from 10 new regional sites, upgrade to high resolution Doppler services at 4 sites, implementation of dual polarization at all high resolution Doppler sites	1	OEB	4-10	60000	5000	+7	0

Attachment 14

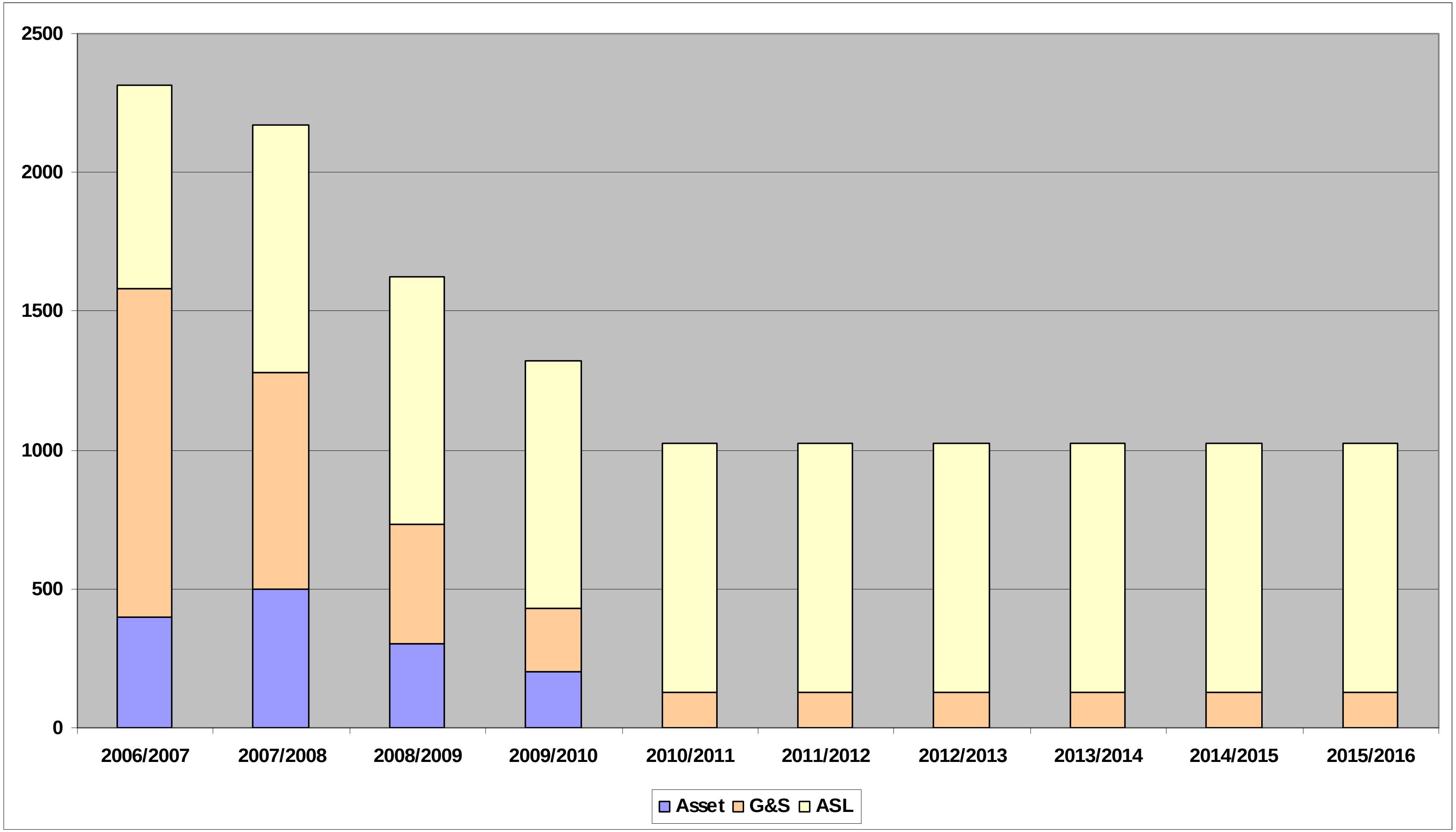
Expenditure Profiles (Cash Flow): INDICATIVE COSTS ONLY

(a) Total Incremental Expenditure Envelope ($1000s) for Stage 1 – BCOS Consolidation



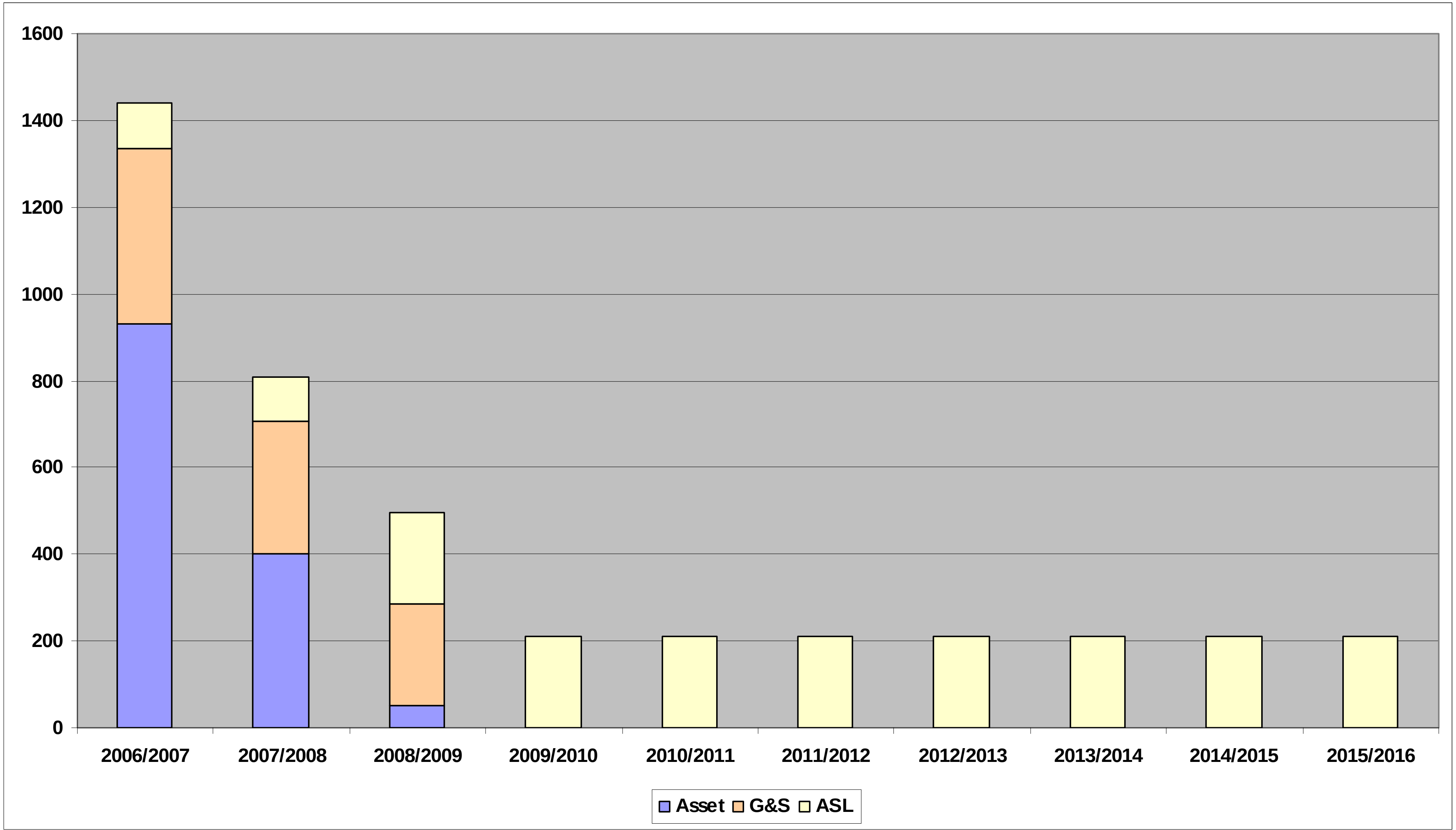
Expenditure Profiles (Cash Flow): INDICATIVE COSTS ONLY

(b) Total Incremental Expenditure Envelope ($1000s) for Stage 2 - Overarching and Underpinning Initiatives



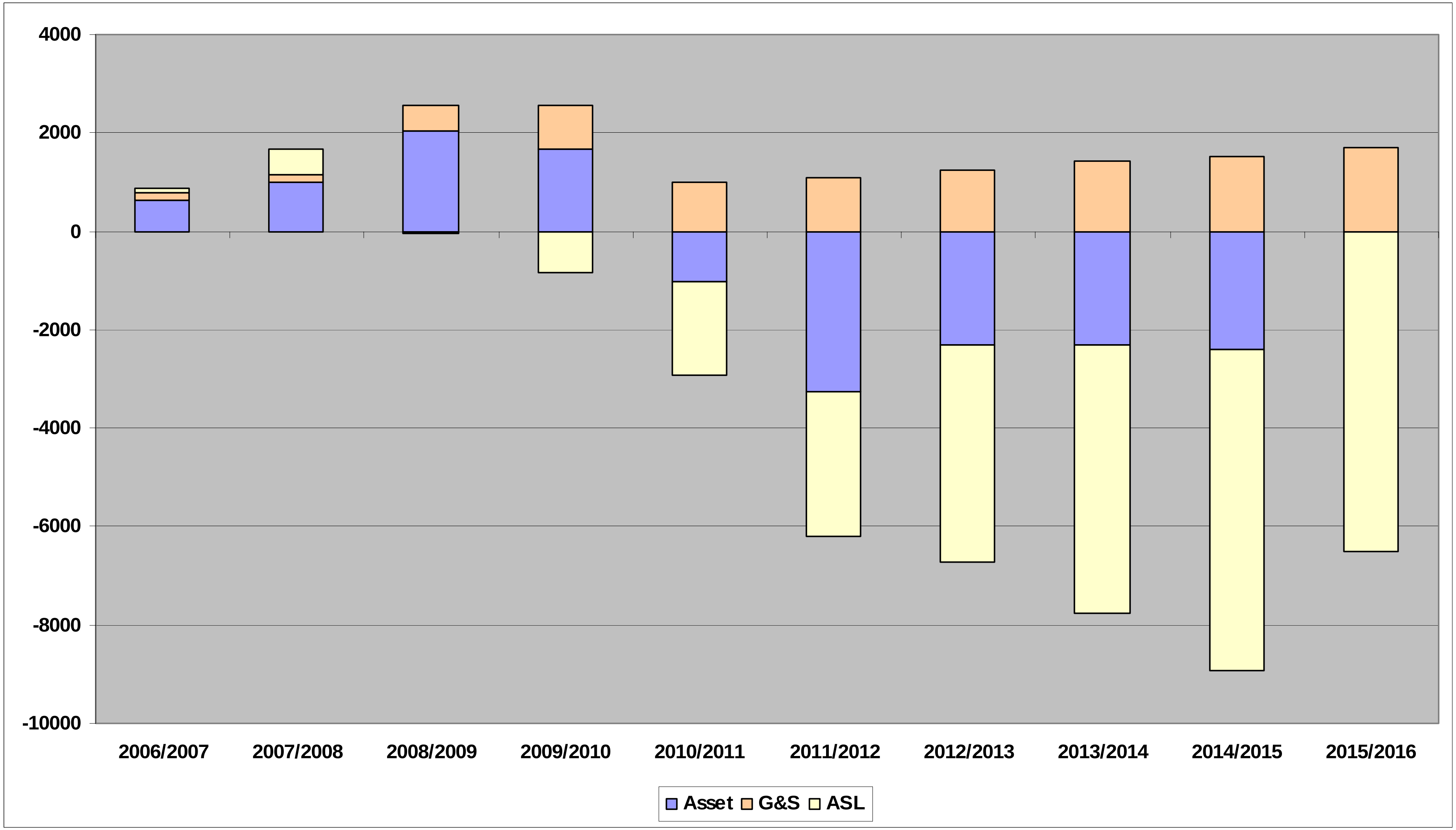
Expenditure Profiles (Cash Flow): INDICATIVE COSTS ONLY

(c) Total Incremental Expenditure Envelope ($1000s) for Stage 3 – Development and Testing



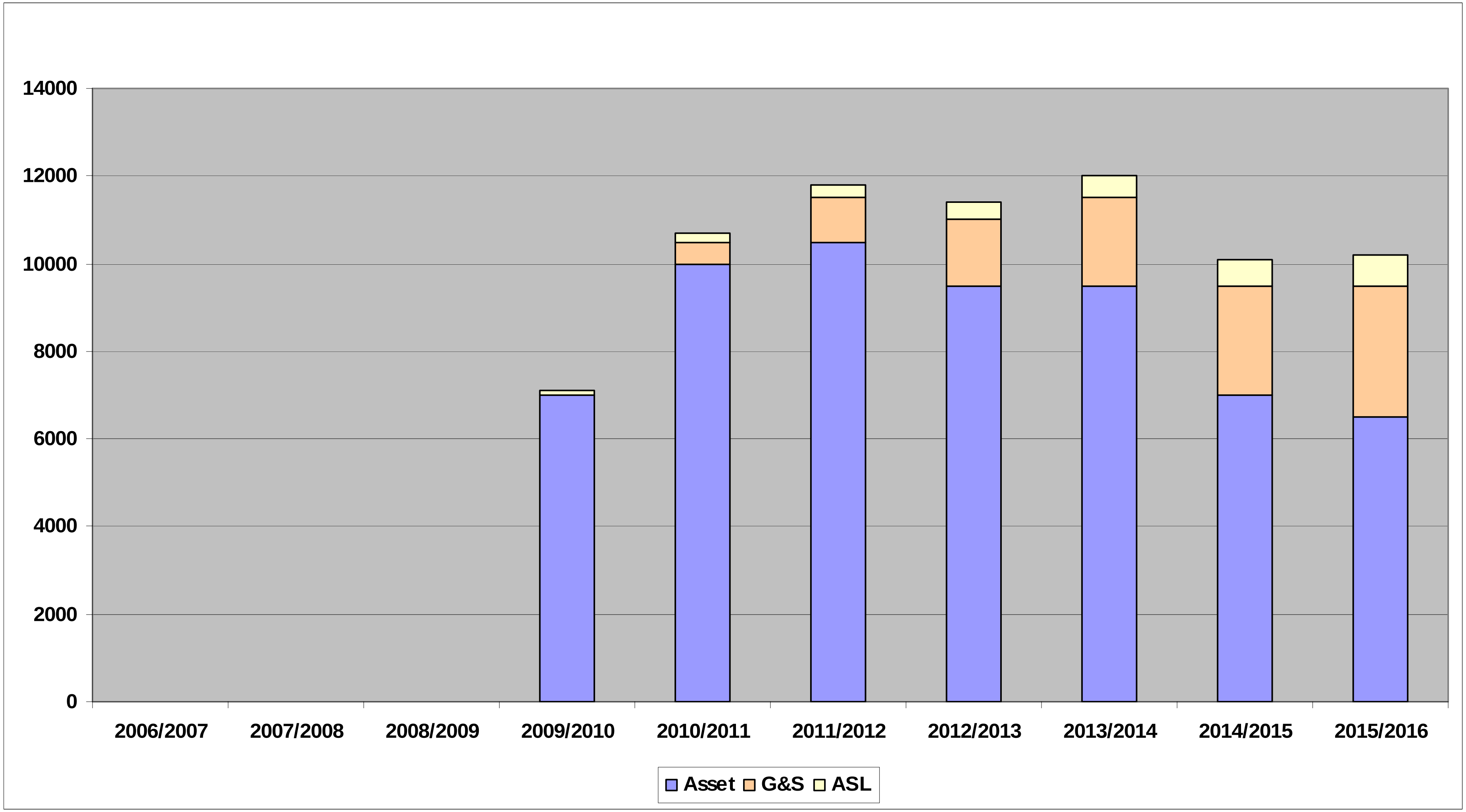
Expenditure Profiles (Cash Flow): INDICATIVE COSTS ONLY

(d) Total Incremental Expenditure Envelope ($1000s) for Stage 4 – Implementation of New Technology (Excluding Radar Network Expansion and Upgrade)



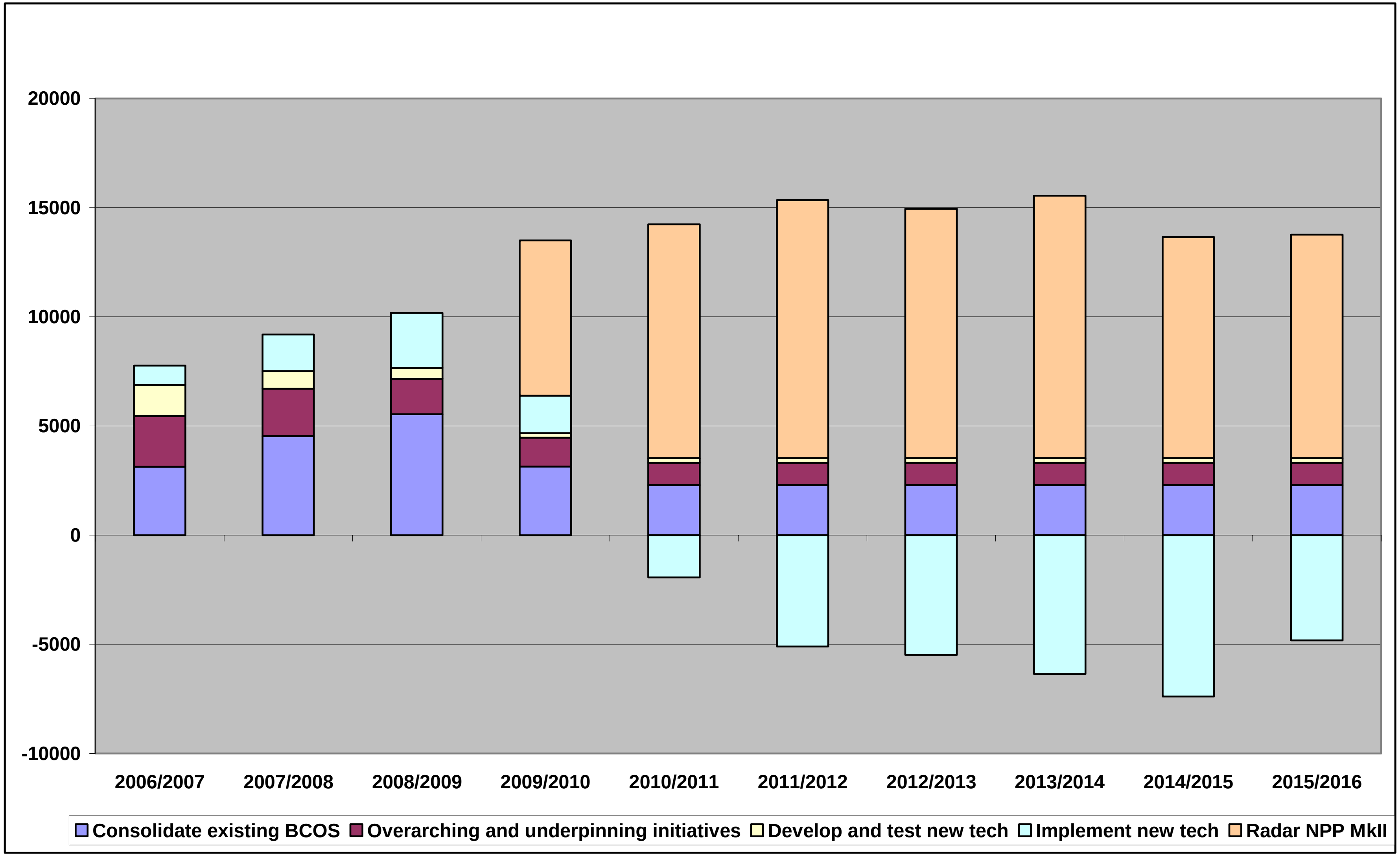
Expenditure Profiles (Cash Flow): INDICATIVE COSTS ONLY

(e) Total Incremental Expenditure Envelope ($1000s) for Stage 4 - Radar Network Expansion and Upgrade Only



Expenditure Profiles (Cash): INDICATIVE COSTS ONLY

(f) Total Incremental Expenditure Envelope ($1000s) for All Initiatives



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