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# High Quality Streamflow Reference Stations - Stakeholder Consultation Report

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# 1 Introduction

## 1.1 Purpose of report

The long term and seasonal prediction units of the Extended Hydrological Prediction (EHP) section aim to develop prediction services to enhance knowledge of water availability and aid the development of sustainable water resource management decisions. In 2010 EHP commissioned Sinclair Knights Merz (SKM) to develop guidelines for the selection of high quality streamflow reference stations (HQSRS) across Australia (SKM, 2010). The objective of developing and applying the guidelines is to identify streamflow reference stations that can be used in the long term and seasonal prediction of water availability. The set of streamflow gauging stations will also be useful in identifying decadal variability and trends. In 2011 the guidelines have been adapted and applied to streamflow stations in all catchment across Australia (Turner 2011, Turner *et al.* 2011). Essentially, the application of the guidelines is broken into five categories:

1. Identifying unregulated catchments,
2. Identifying catchment with minimal land use change,
3. Identifying streamflow gauging stations with high quality streamflow series
4. Ensuring the distribution of streamflow reference stations is spatially representative of all hydro-climate regions
5. Consult with relevant agencies in each jurisdiction to review the application of the guidelines.

The stakeholder consultation process was designed to improve the rigour of the site selection process. We acknowledged that a desktop study identifying stations across Australia could not encapsulate the intricacies of land use and water resource development that impact on streamflow availability within each river system. Particularly, how those impacts differs across multiple systems and how that will affect the quality of stations selected and quality of long-term and seasonal forecasting outputs.

This report outlines the stakeholder consultation process and outcomes that help to derive a list of high quality streamflow reference stations.

## 1.2 Overview of guidelines

The guidelines developed by SKM (2010) can be broken into five key categories as mentioned above. The criteria in each category are outlined in Table 6. A preliminary list of HQSRS was compiled based initially on three criteria of the guidelines:

1. A long-term series (minimum period of 1975 onwards),
2. Remove station clearly identifiable as a weir, drain, outfall, non-river site,
3. No dams, weirs or irrigation infrastructure upstream.

Previous benchmarking studies including Stewart *et al.* (1991), Peel *et al.* (2000) and Viney (2010) were considered to identify regions where appropriate streamflow stations may be

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present. The distribution of the gauging networks and data availability were also instrumental in streamflow station selection. This selection process provided a total of 246 streamflow stations in the preliminary list of high quality reference stations to take forward into stakeholder consultation.

The criteria discussed with stakeholders in each state and territory is shown in Table 1. Criteria in the high quality streamflow series category were discussed in the context of hydrological stability and completeness of streamflow series.

**Table 6: Guidelines and criteria to select high quality streamflow reference stations.**

Category	Criterion	Discussed in stakeholder consultation
<b>High quality streamflow series</b> (data reporting phase of guidelines)	Minimal missing data (<5% in each climate phase)	√
	A long-term series (minimum period of 1975 onwards)	√
	A minimum of 15 years of continuous data	√
	High quality rating curve that is sensitive to all facets of the flow regime	√
	Minimal data outside the gauging limits	√
	Minimal uncertainty associated with streamflow series	√
	Check for data anomalies and unusual flow patterns	√
Located in an <b>unregulated catchment with minimal land use upstream</b>	Remove station clearly identifiable as a weir, drain, outfall, non-river site	√
	No dams, weirs or irrigation infrastructure upstream	√
	Minimal diversions upstream (< 10% of Mean Annual Flow MAF)	√
	No point source discharges upstream from upstream catchment	√
	Minimal farm dams in upstream catchment	√
	Calculate the change in area of land use upstream including urbanisation, farms dams, forestry and agricultural practice	√
Assessment of the <b>spatial and temporal representativeness</b> of stations within hydro-climate regions	Tag each site with a Köppen Climate region classification	
	Assess the spatial distribution of high quality streamflow reference stations across each hydro-climate region	
<b>Consultation</b> with Regional Hydrology Managers and state agencies	Identify any important stations (water supply or ecological) that have been missed that should be included	√
	Discuss past or potential impacts on stations within the upstream catchment	√
	Inform the aim, scope and proposed outcome of the project	√

## 2 Stakeholder Consultation

Stakeholder consultation consisted of two parts. The aims of part one were:

1. To inform the aim, objective, and proposed outcome of the high quality streamflow reference station project,
2. To identify any sites that have not been considered in the preliminary list of high quality streamflow reference stations, and
3. To identify any impacts within the upstream catchment of the identified streamflow reference stations that could compromise the quality of monitored streamflow.

The aim of part 2 was to confirm if our interpretation of feedback on station quality was correct and if we had addressed any issues or concerns raised in part 1 appropriately. The two part stakeholder consultation process improved the rigour of the streamflow station selection process and the identification and ranking of high quality streamflow reference stations. The two-part stakeholder consultation process is outlined in this section.

### 2.1 Part 1 - Assessment of the preliminary list of high quality streamflow reference stations

#### Regional Hydrology Managers

The preliminary list was discussed with Regional Hydrology Managers (RHMs) of the Bureau of Meteorology to identify whether each station was appropriate for further investigation as a high quality streamflow reference station. Discussions also focussed on issues of hydrological quality and impacts in the surrounding catchment of each reference station. The preliminary list of HQSRS was amended as required following the RHM consultation.

#### Federal, state and territory agencies

Following consultation with Regional Hydrology Managers the preliminary list of HQSRS was sent to managers of water resource planning, environmental health, gauging networks and water information from agencies in each state and territory. It was also sent to federal agencies for comment on stations in the Murray-Darling Basin. The number of participants and each agency consulted is shown in Table 7.

To achieve aim number two and three outlined above stakeholder consultation with key state, territory and federal agencies was to provide additional information on the following criterion:

1. No Diversions channels or irrigation structures upstream
2. No point source discharges upstream from the gauging stations
3. Identify the impact of diversions upstream, if any
4. Discuss past land use impacts within the upstream catchment. This includes the impact of farm dams, land use (clearing, forestry, urbanisation), fire and water resource development.

Also to achieve aim number three above, stakeholder consultation was to identify issues that would affect the quality of streamflow reference stations and the compilation of the list as a whole. Stakeholders were asked to:

1. Identify future potential impacts on the high quality reference stations
2. Identify any important stations (water supply or ecological) that have been missed that should be included
3. Identify any issues of the measuring and recording of streamflow data that may impact on the data quality from the streamflow reference station (This is to aid the data reporting phase of the project).
4. Discuss the purpose for which the streamflow reference stations may be utilised, i.e. for seasonal forecasting, long-term forecasting or both.

**Table 7: List stakeholders in different Jurisdictions**

<b>Jurisdiction</b>	<b>Organisation</b>	<b>Number of Participants</b>
New South Wales	New South Wales Office of Water (NOW)	3
	Sydney Catchment Authority (SCA)	5
ACT	Actew AGL	1
Victoria	Department of Sustainability and Environment (DSE)	6
	Melbourne Water	7
Queensland	Department of Environment, Resources and Management (DERM)	15
South Australia	South Australia Department for Water	6
Northern Territory	Northern Territory Natural Resources, Environment, the Arts and Sport (NRETAS)	1
Western Australia	Department of Water	2
	Water Corporation	1
Tasmania	Department of Primary Industries, Parks, Water and Environment	4
Murray-Darling Basin	Murray-Darling Basin Authority	5
	Commonwealth Environmental Water Holder	1
	Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC).	10
<b>Total</b>		<b>67</b>
*Additional consultation was also carried out with Regional Hydrology Managers within the Bureau of Meteorology		

Feedback on impacts of land use and water resource development in each catchment is discussed in Section 3. As well as feedback on the streamflow stations themselves, part 1 of the stakeholder consultation also raised a number of questions regarding the station selection process. A number of these questions, our response and or solution to the issues raised are summarised in Table 8.

**Table 8: Issues discussed during part 1 of the stakeholder consultation process**

<b>Issue</b>	<b>Action/response to address issue</b>
Does this project involve supplying more data to the Bureau?	No. The stakeholder consultation required input on the quality on the streamflow reference stations and how adequately the reference station met the guidelines.
Streamflow stations with unstable controls will not provide an accurate assessment of long-term trends in streamflow availability.	Discussions with agencies included an assessment of stability of the gauging control. One jurisdiction provided a list of stations that included only those with stable controls for assessment of the guidelines.
How do we maintain data truth when having data available in the web portal?	Streamflow data will be updated on the web portal at regular intervals.
A streamflow station is in a good location with minimal land use impacts. However, the station is going to be closed as it is not required for water resource planning. Could this station be utilised?	The streamflow station was noted for its high quality and the fact it will be closing. It could be used in future for model calibration or an assessment of trends up until the point of closure.
A streamflow station is located downstream of a junction above which one tributary is dammed and provides 5% of streamflow, the other tributary is unregulated provides 95%. The quality of the streamflow station is high. Does this meet the criteria?	The high quality of the streamflow station will be noted. It will be investigated if it meets the requirements for seasonal streamflow forecasting.
There are a number of streamflow stations in the same segment of a catchment. How will it be decided which will be considered in the next step of analysis?	In the first instance, the sites will be ranked based on the degree of impacts identified by stakeholders. Second, the degree of land use change and impacts of water resource developments in the upstream catchment will be analysed where data is available.
There are a number of streamflow stations across multiple catchments in the same region.	All streamflow gauges that meet criterion outlined in section 2.1 were included. The site will then be short listed: - if it is unique to the region – i.e. flow direction, extent of land use change - if there is only one gauge within a catchment region - if the impacted within the upstream catchments are less than other gauging stations.
Most of the upstream catchment has been cleared for agricultural purposes, is it a suitable site?	If the upstream catchment has been cleared long time ago, for example pre-1975, then it should be ok.
Is catchment area considered in the selection process?	Initially the catchment area was not used as a selection criterion to compile the preliminary list of high quality streamflow reference stations. The catchment area will be considered in refining the spatial distribution of streamflow stations.
A streamflow station meets all criteria in terms of land use impacts and hydrological quality however it has a short series.	The quality of the streamflow station will be noted for future forecasting work.
How is the impact of fire considered within the selection process?	Spatial layers of fire coverage will be used, where available, to assess the catchment area impacted by fire. In these areas and other areas where no spatial coverage is available feedback from stakeholders commented on the impact of

Issue	Action/response to address issue
	fire on streamflow availability within a catchment.

The key issues raised during stakeholder consultation regarding the distribution of stations in each jurisdiction are:

### ***Murray Darling Basin***

There is a good coverage of stations in the mid and lower regions of the basin. More stations in the basins of southern Queensland and northern NSW would improve information in key water supply regions. Expanding the network in the Murrumbidgee would also be beneficial. The expansion of sites in the basin will be discussed in the QLD and NSW sections.

### ***Northern Territory***

Most streamflow stations in the Northern Territory region were considered appropriate for inclusion as a high quality streamflow reference stations. Ten additional stations were added for further investigation (Figure 11). Five streamflow stations were in unimpacted regions but are being closed. These were noted for possible use in future work that does not require sites with active streamflow gauging.

### ***Western Australia***

An additional six streamflow stations were added in Western Australia (Figure 12). Feedback incorporated information from a previous benchmarking study to guide information on the quality of Stations and 1982 hydrological review of gauges in Western Australia (The Hydrological Network for Western Australia 1982).

### ***Queensland***

There were two key issues raised that will improve the distribution of sites in Queensland.

1. As mentioned previously sites were added for further investigation in South Queensland. This included the Warrego, Condamine, Moonee and Paroo Catchments.
2. A large number of streamflow stations on the Queensland preliminary list were considered unsuitable due to unstable controls.

During part 2 of the consultation period a list of streamflow stations was provided by the Department of Environment, Resources and Management (DERM) that were considered to have stable bedrock controls. The selection of stations as outlined in section 1.2 was carried out again. The comparison of streamflow stations selected in the preliminary list and the list provided by DERM is shown in Figure 13.

### ***New South Wales***

Most streamflow stations were considered appropriate for further investigation. Distribution of high quality streamflow stations in semi-arid/arid regions of New South Wales need to be improved. Minimal gauges are present in western New South Wales and along the main trunk of the Darling River. This gap is attributable to the unregulated criteria of the station selection process. Streamflow stations were investigated further in the Paroo and Warrego catchments. While the Paroo catchment is subject to diversions and has a number of small weirs the Paroo River is closest to an unregulated streamflow regime in this region. Other regions where distribution was noted to be improved included:

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- Kowmung, Nepean and Grose River - improved information surrounding Sydney's water supply catchment
- Tarcutta Creek region –improved distribution in Murrumbidgee River Catchment
- Streamflow stations in the Castlereagh system

An additional nine streamflow gauges were added. The distribution of high quality streamflow reference stations in New South Wales after part 1 of the stakeholder consultation is shown in Figure 15. It is also important to note that a secondary list of streamflow stations was also provided by the New South Wales Office of Water for further investigation. This investigation will be integrated into the next phase of the analysis.

### ***Tasmania***

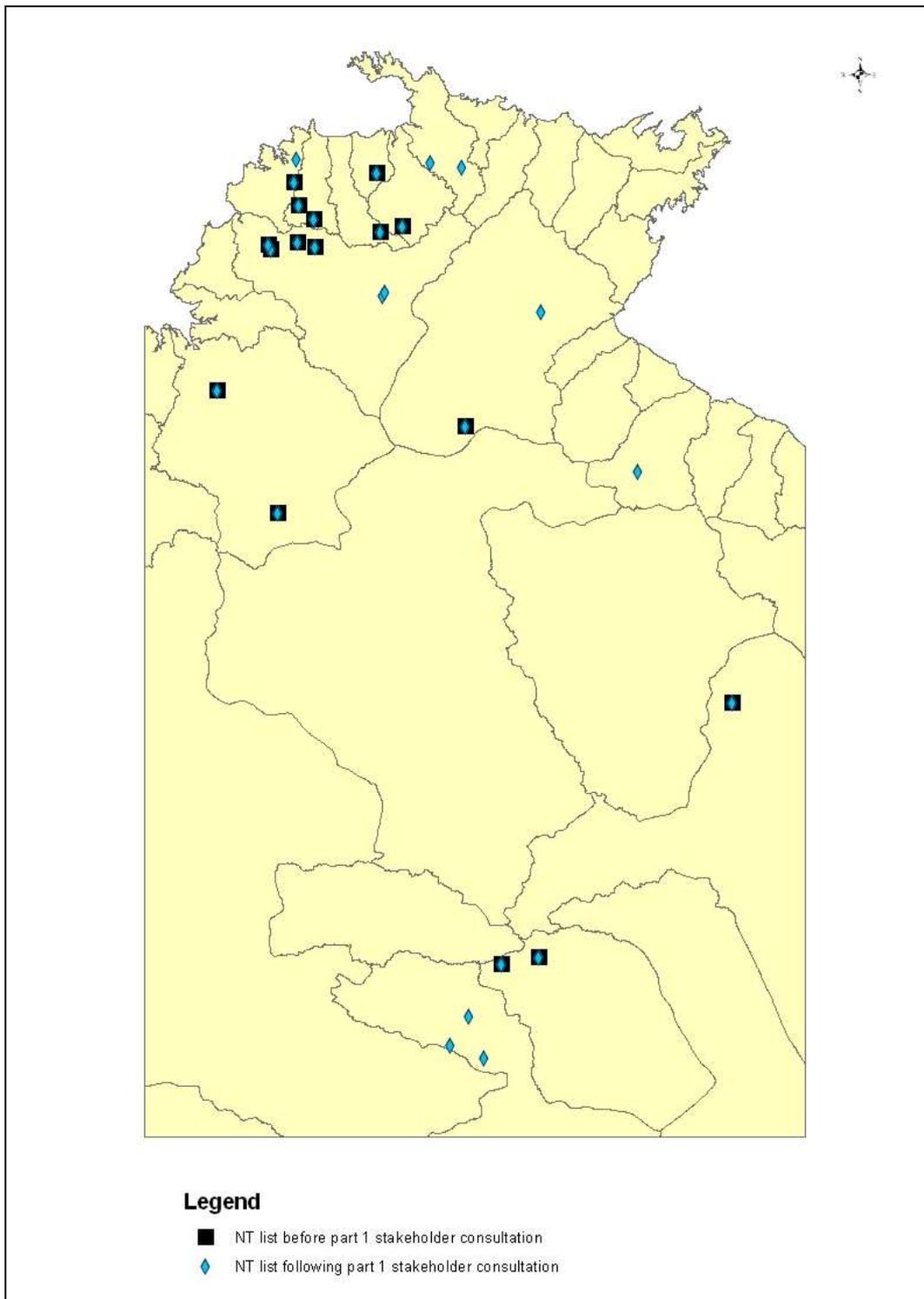
The key issue for the Tasmanian region was the distribution of streamflow reference stations included on the preliminary list. Most sites were located in the mid to west region. An additional eight stations in the eastern regions of Tasmania were added following part 1 of stakeholder consultation (Figure 5).

### ***South Australia***

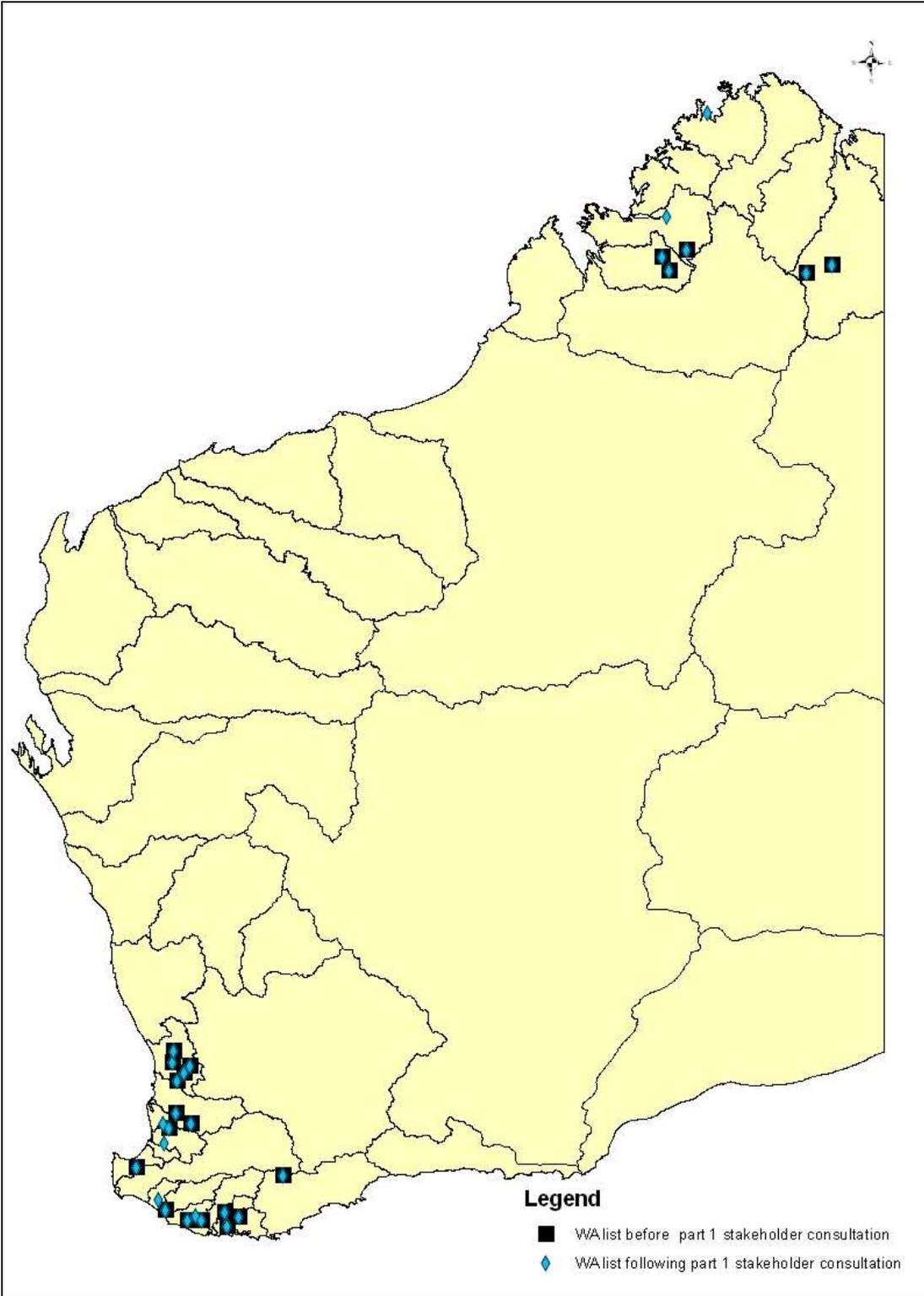
The distribution of streamflow stations included on the preliminary list was poor in South Australia given most of the gauging network is localised in regions impacted by land use change and water resource development. Discussions with the Department for Water were adding 22 potential streamflow stations for further investigation (Figure 16).

### ***Victoria***

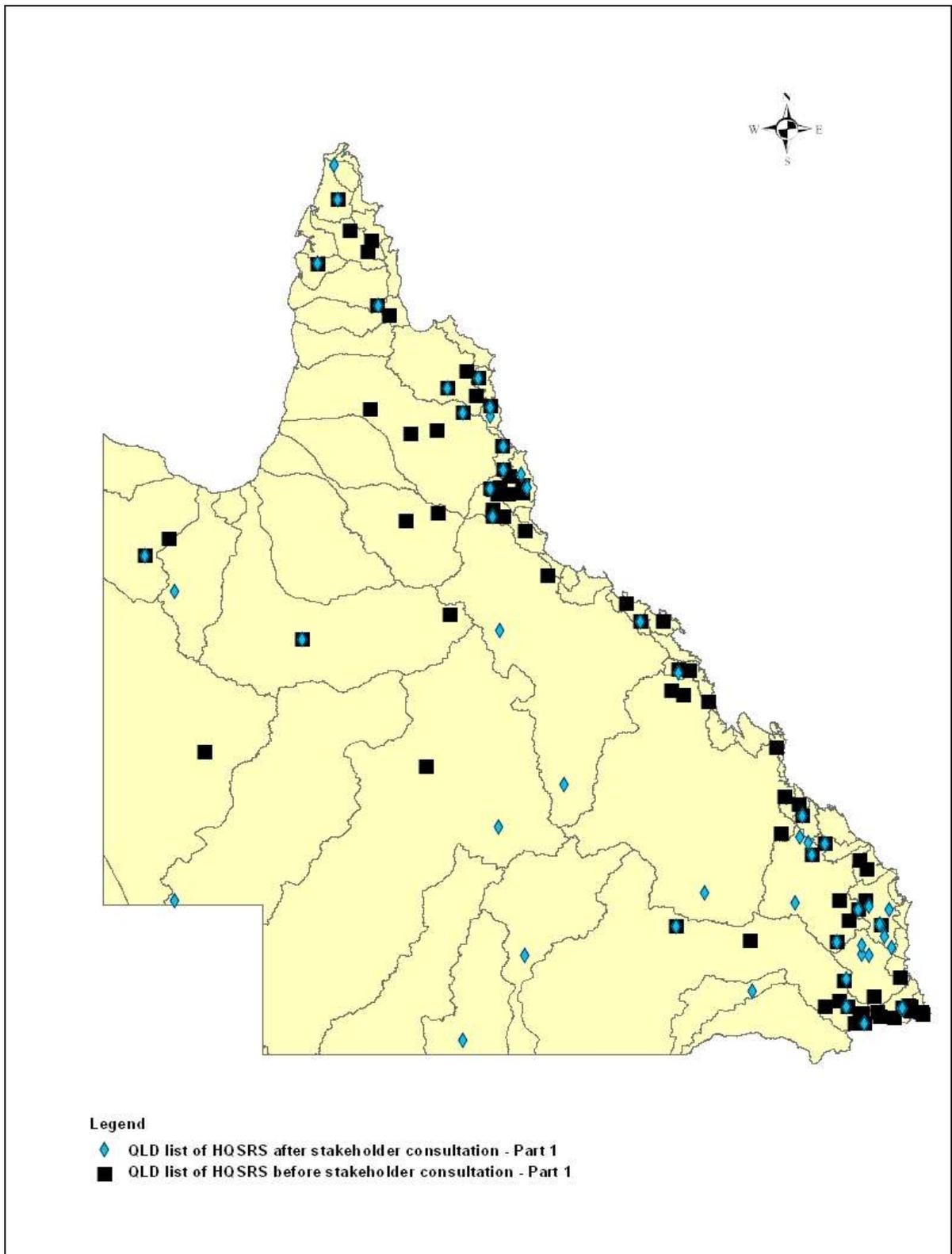
Distribution of streamflow gauges on the preliminary list was widespread. Stakeholder consultation improved the distribution of streamflow stations in the Melbourne Water catchment areas (Figure 17). Additional streamflow stations were also added in the Mitchell and Avoca catchments.



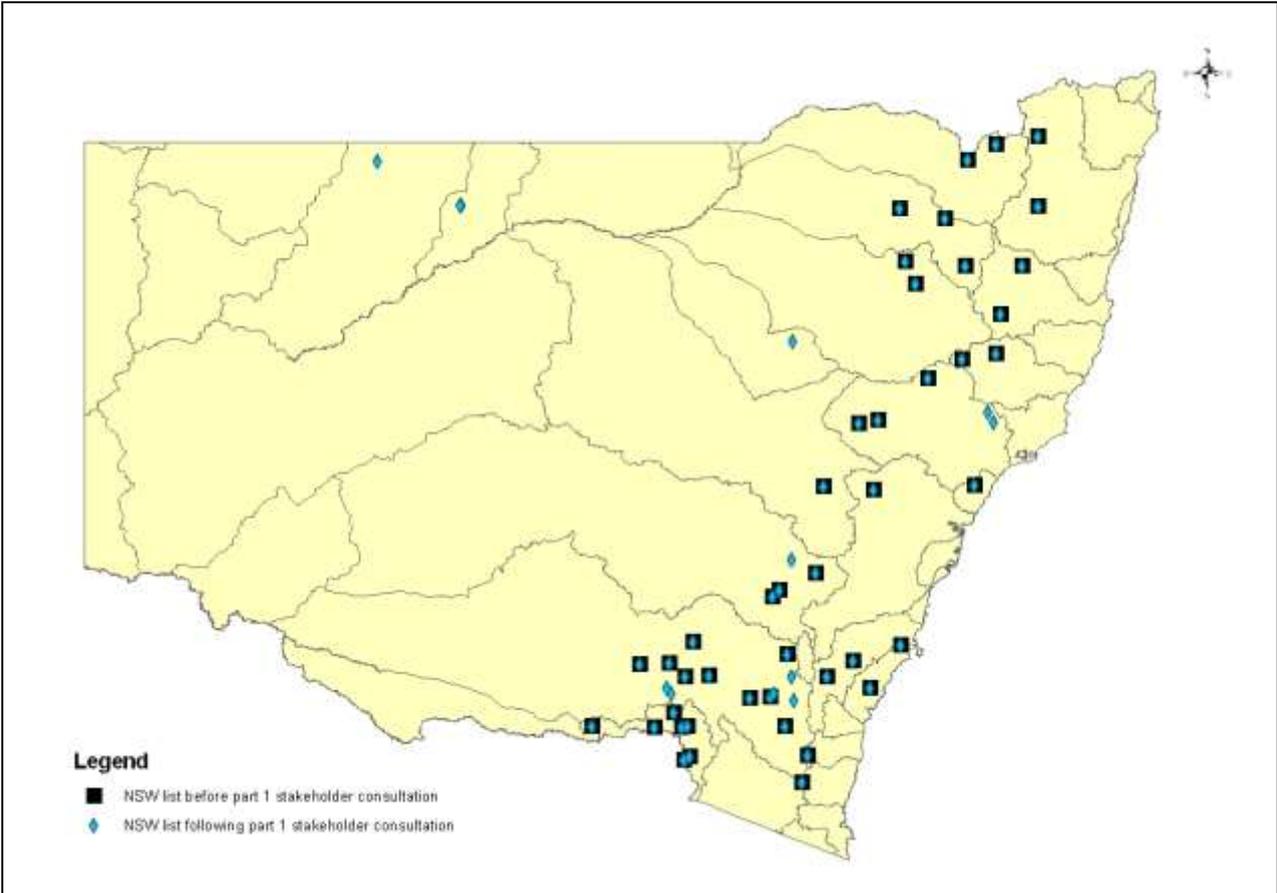
**Figure 11: Distribution of high quality streamflow reference station across the Northern Territory prior to and following part one of stakeholder consultation.**



**Figure 12: Distribution of high quality streamflow stations in Western Australia prior to and following part one of stakeholder consultation.**

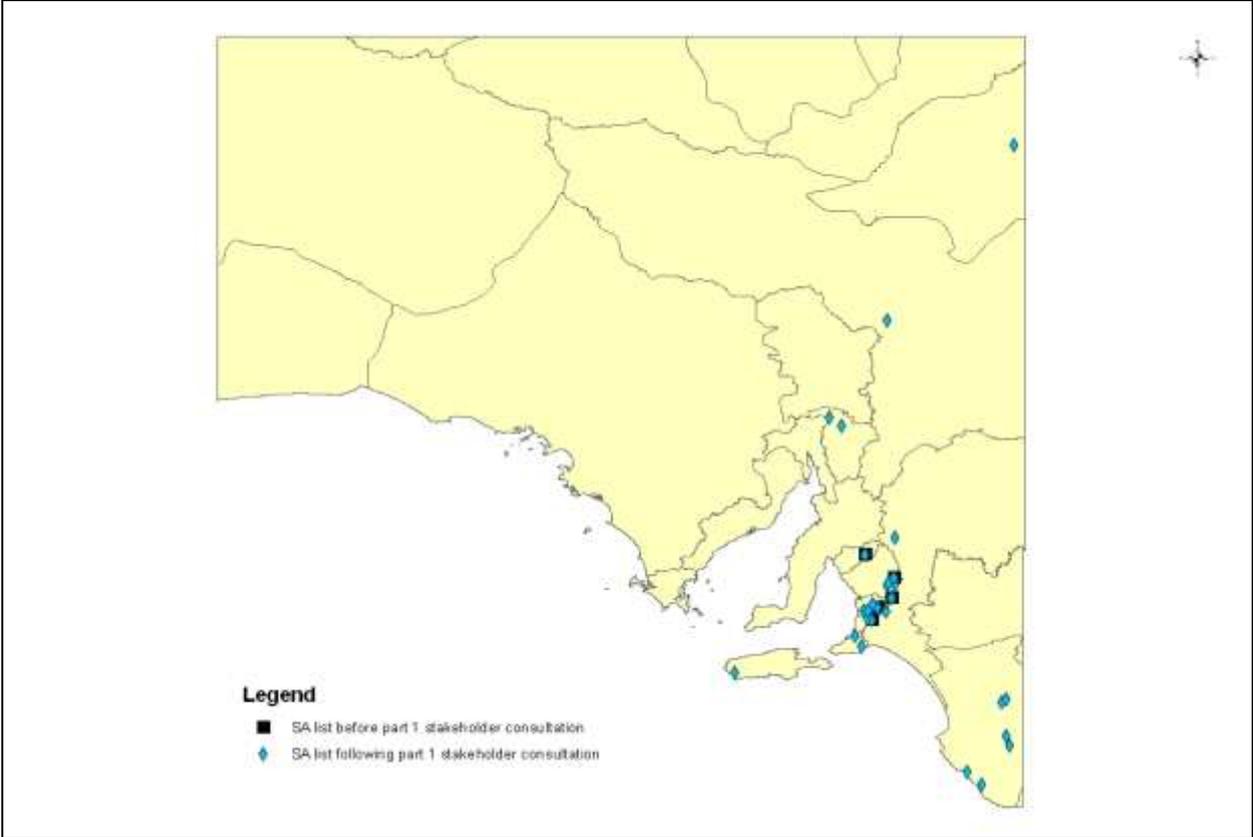


**Figure 13: Distribution of high quality streamflow reference stations across Queensland prior to and following part one of stakeholder consultation**

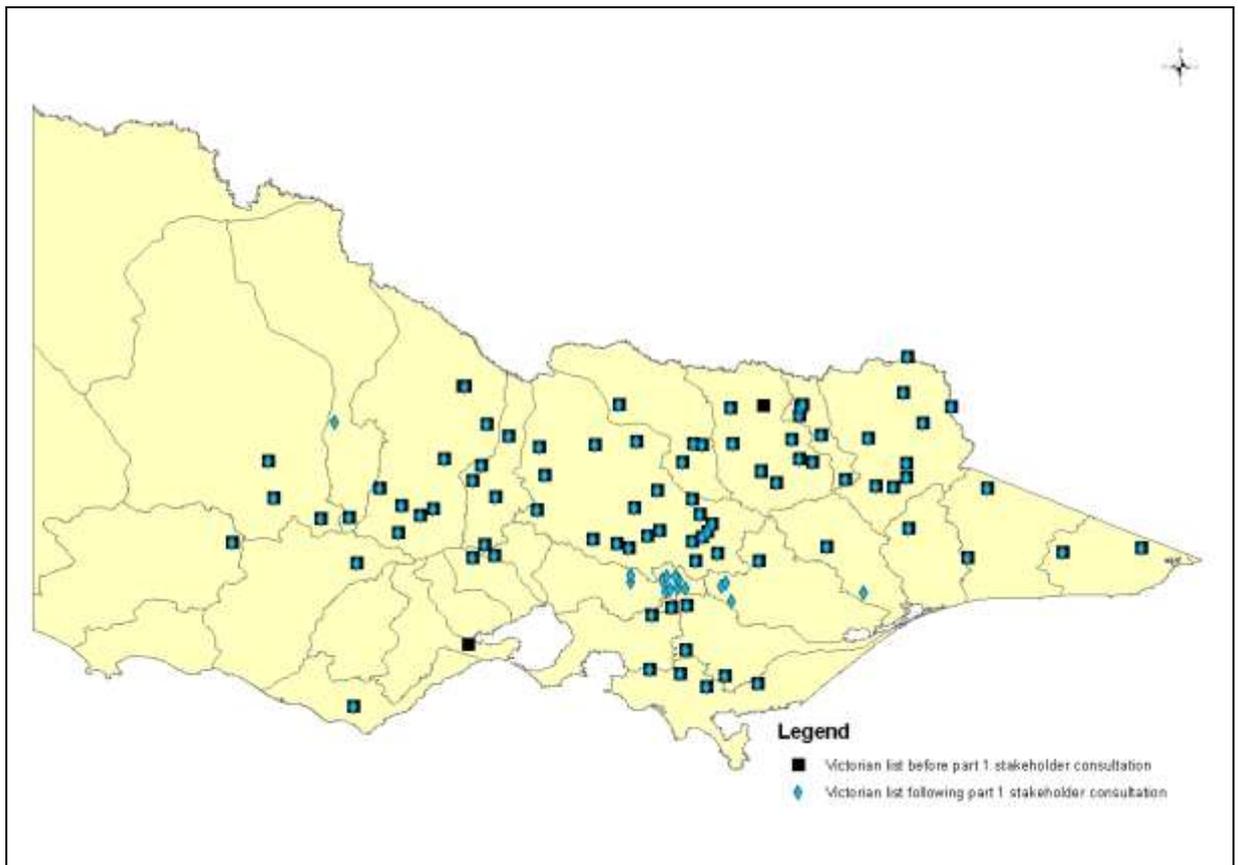


**Figure 14: Distribution of high quality streamflow reference stations across New South Wales prior to and following part one of stakeholder consultation.**





**Figure 16: Distribution of high quality streamflow stations across South Australian prior to and following part one of stakeholder consultation.**



**Figure 17: Distribution of high quality streamflow reference stations across Victoria prior to and following part one of stakeholder consultation.**

## 2.2 Part 2 – Development of streamflow station ranking classification

A classification system was developed following part 1 of stakeholder consultation. The station classification system provided a basis on which to assess and rank stations consistently across jurisdictions. Based on the type of feedback that was provided during the stakeholder consultation the classification system provides a summary of station quality and the next step required in the application of the guidelines (Table 9).

A site classification was assigned to each HQSRS on the preliminary list. The ranking of sites was sent back to each jurisdiction to assess if the interpretation of feedback was correct and to confirm they agreed with the classification of site quality. All but one jurisdiction confirmed a suitable classification had been applied to each station.

**Table 9: Site ranking classification system developed based on stakeholder feedback**

Category	Definition	Action
1. Pristine	A station with an unimpacted catchment upstream.	Do data reporting/time-series check. Land use and farm dam coverage will be checked <sup>1</sup> but not expected to be an issue.
2. Good site	A station with minimal impacts in the upstream catchment.	Do data reporting/time-series check <sup>2</sup> . May be some land use impacts but are considered stable. Land use and farm dams will be checked but not expected to be a problem.
3. Good site	Currently minimal land use impacts. However, there is potential for future impacts in the upstream catchment.	Do data reporting/time-series check.
4. Reasonable site	May be some land use impacts or some issues of hydrological quality.	Need to confirm land use change and farm dams. Do data reporting/time-series check.
5. Suggested by stakeholder	Good site recommended for inclusion by the stakeholder. Minimal land use are impacts expected.	Land use and farm dams coverage will be checked but not expected to be a problem. Do data reporting/time-series check.
6. Suggested by stakeholder	Site recommended by stakeholder. However, possible land use impacts also flagged by stakeholder.	Land use impacts need further investigation. Do data reporting/time-series check.
7. Flag for seasonal use only	Good site is located in a relatively unimpacted region. Unable to use for long-term trend analysis as time-series is too short. But the site could be useful for seasonal streamflow predictions.	
8. Remove (Category A)	Good site but unable to use due to planned closure.	Remove station from list.
9. Remove (Category B)	Site impacted by land use or has a poor rating curve history.	Remove station from list.
10. Remove (Category C)	One of multiple sites in a region of similar condition.	Remove station from list.
<p><i>1. Land use and farm dam coverage will be checked</i> – spatial analysis of land use change from 1972 to 2005 will be combined with a landuse history (where required) to confirm land use history in the upstream catchment.</p> <p><i>2. Do data reporting/time-series check</i> – this refers to criterion in the data reporting category of the guidelines. This step will be carried out prior to trend analysis at each HQSRS</p>		

A total of 362 streamflow stations were classified based on feedback from stakeholder consultation. A summary of feedback received on streamflow stations within each jurisdiction is shown in Table 10. The distribution of streamflow stations across Australia is shown in Figure 18.

A total of 259 streamflow stations remain after the removal of those ranked 8, 9 and 10 (Figure 19). Forty-nine percent of streamflow stations were classified as 1, 2, 3, or 5. This means the streamflow stations are either pristine or are considered to have minimal water resource of land use impacts in the upstream catchments. These streamflow stations are identified for use in the next phase of the project that includes the application of the data reporting portion of the guidelines and further land use analysis (Figure 20). The data reporting and land use change analysis will identify a shortlist of sites at which to investigate the long-term trends in streamflow availability in 2012.

The remaining streamflow stations (ranked 4, 6 and 7) require further investigation of land use and water resource development in the region. For example, many streamflow stations in Victoria have been given classification 4. This is a result of supplementary data needing further investigation to ascertain how the density of farm dams, area of fire coverage and the area of forestry upstream of each station compares between catchments.

**Table 10: Classification of streamflow stations in each jurisdiction**

Classification	Tas	NSW	VIC	NT	QLD	SA	WA	ACT	MDB <sup>1</sup>	Total
1	2	3	0	1	1	0	1	2	3	<b>10</b>
2	4	13	16	2	30	0	5	0	16	<b>70</b>
3	0	5	0	4	9	0	4	0	6	<b>22</b>
4	2	6	59	1	15	2	7	0	48	<b>92</b>
5	2	9	0	5	2	7	0	1	6	<b>26</b>
6	1	0	3	1	19	5	0	0	6	<b>29</b>
7	3	3	1	1	1	2	0	0	3	<b>11</b>
8	0	0	0	6	0	0	0	0	0	<b>6</b>
9	4	16	18	5	27	13	10	0	24	<b>93</b>
10	0	0	3	0	1	0	0	0	3	<b>3</b>
<b>Subtotal (1-7)</b>	<b>14</b>	<b>39</b>	<b>79</b>	<b>15</b>	<b>77</b>	<b>15</b>	<b>17</b>	<b>3</b>		<b>259</b>
<b>Total</b>	<b>18</b>	<b>55</b>	<b>100</b>	<b>26</b>	<b>105</b>	<b>28</b>	<b>27</b>	<b>3</b>		<b>362</b>

1. Not double counted in total

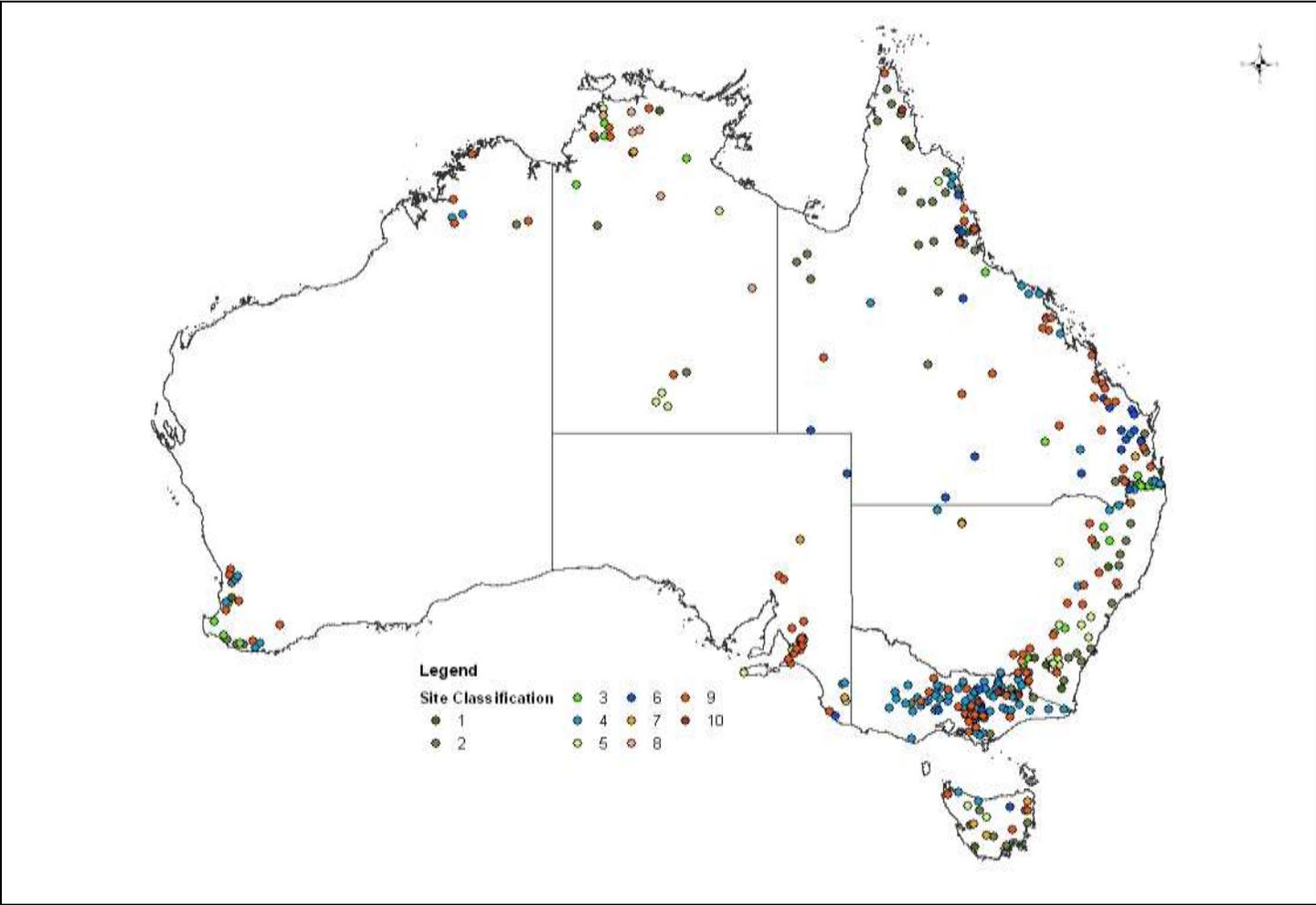
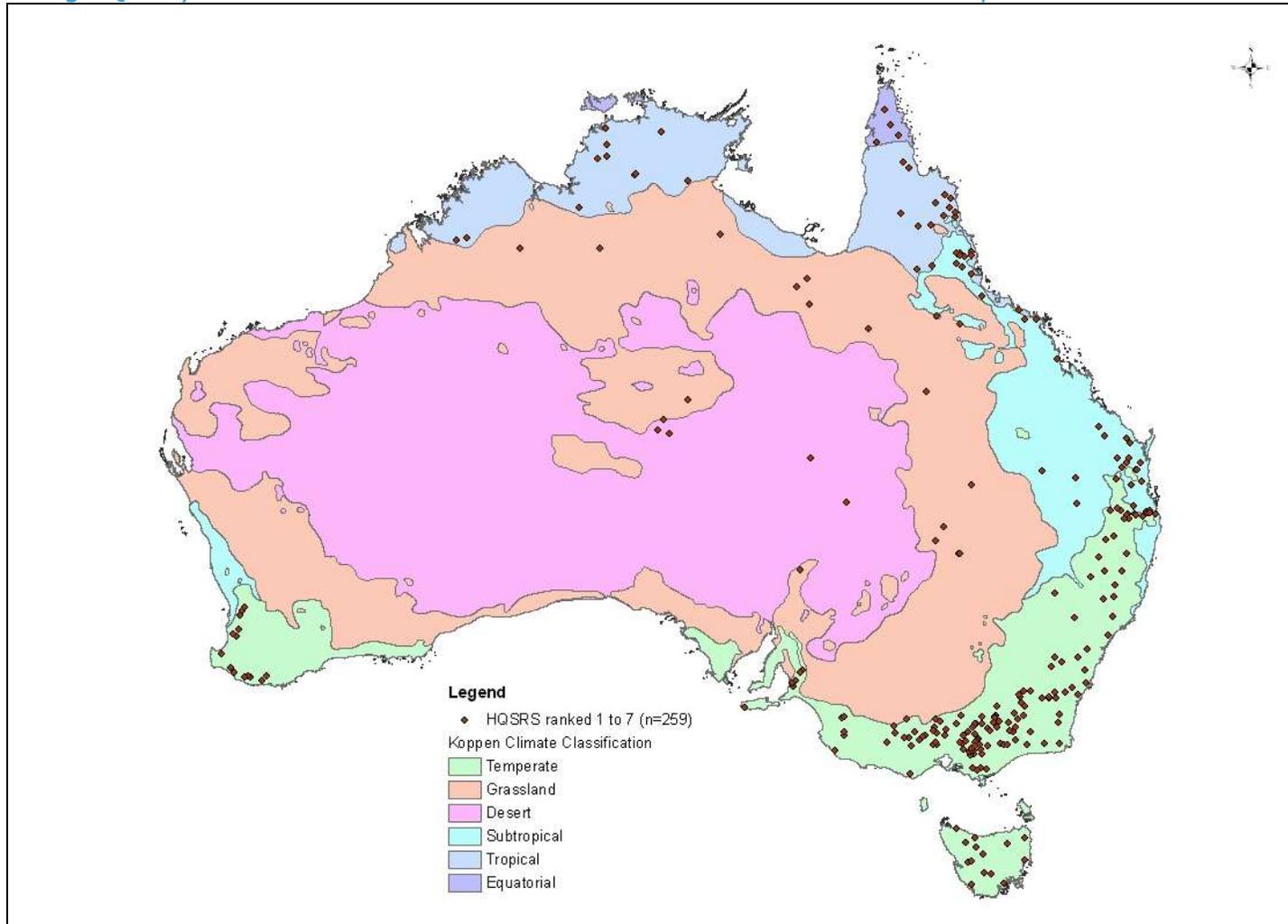


Figure 18: Classification of all streamflow stations following part 2 of stakeholder consultation (n=362)

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**Figure 19: Distribution of high quality streamflow reference station following the removal of unsuitable sites**

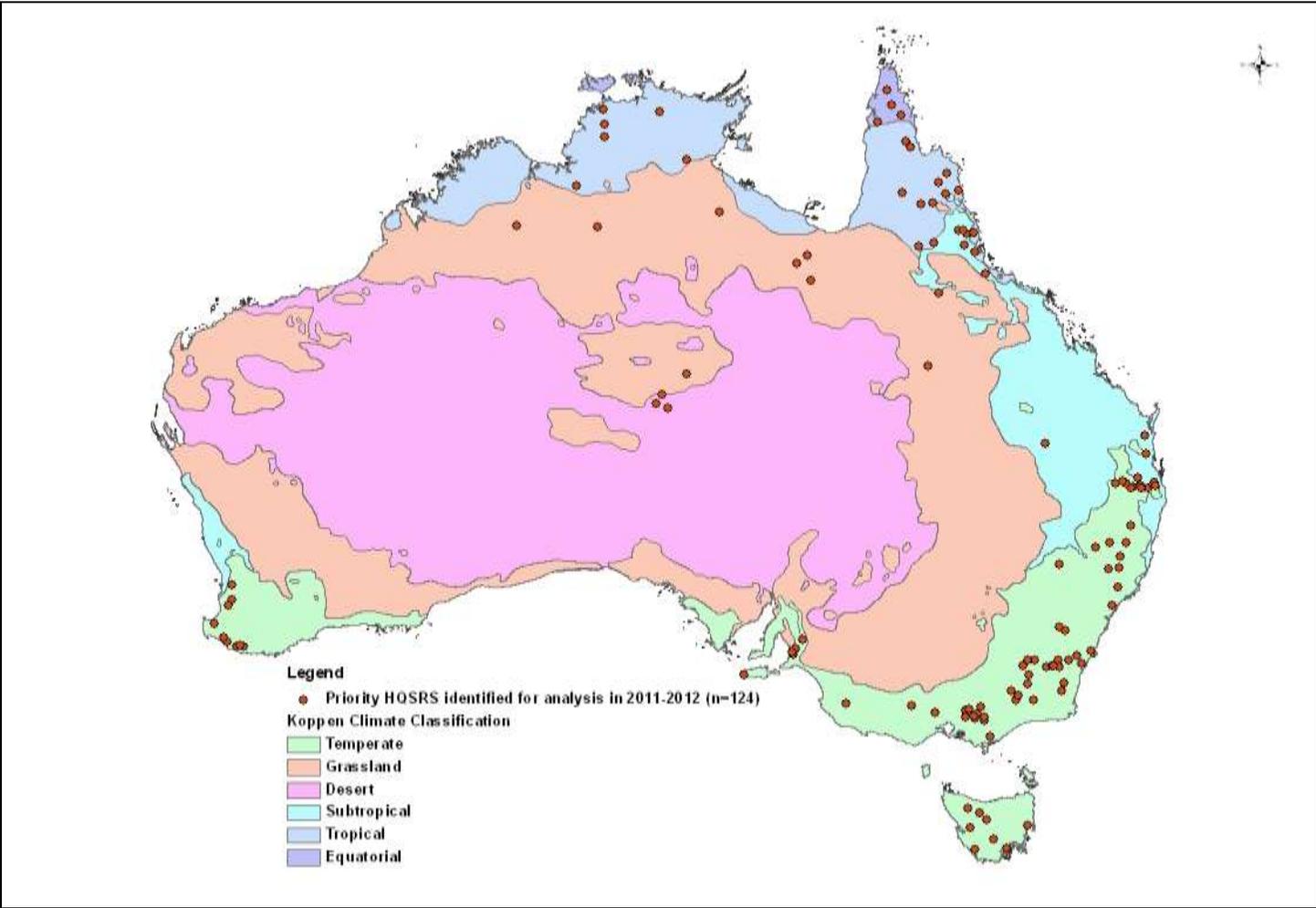


Figure 20: Distribution of priority HQSRS identified for further investigation in 2011-2012



### 3 Summary

Stakeholder consultation was carried out in all state and territory jurisdictions as well as with key federal agencies. In total 14 organisations and 67 officers participated in the consultation process. All agencies commented on the quality of streamflow stations in part 1 of the consultation process. Suggestions were also made on additional streamflow stations to add as well as those to remove. A total of 259 streamflow stations are considered to be potential high quality streamflow reference stations. These stations will be taken further into the next step of data report and land use analysis.

A station classification system was developed to rank the feedback in part 1 of stakeholder consultation process. Part 2 of the stakeholder consultation confirmed a suitable classification had been applied to each streamflow station. The classification system identified 124 sites that were considered to have minimal impacts in the upstream catchments. Data quality and land use change will be confirmed at these sites prior to the analysis of streamflow trend and data quality in 2012.

The stakeholder consultation process improved the rigour of the streamflow station selection and the application of the guidelines developed SKM (2010). The high quality streamflow stations identified will be useful for understanding streamflow variability and trends. Some of these stations will also be useful for both the long-term and seasonal forecasting undertaken by the Extended Hydrological Prediction section.

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