Regional identification of specific wetland types in the Wheatbelt region of Western Australia: methodology and outcomes

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Executive Summary

Introduction

This publication describes:

- a methodology for identifying Wheatbelt wetlands at a regional scale; and
- the application of this methodology to develop the *Wetlands of the Wheatbelt and other prioritised areas* dataset.

Table 1. Wetland mapping products in this report

Form of wetland inventory	Methodology	Application
Identification	√	√
Delineation	√	√
Classification		
Evaluation		

Publication details

The development of the methodology and its application to the study area has been undertaken by the Wetlands Section, Department of Environment and Conservation (DEC), Western Australia. This report was written by John Lizamore (DEC) with acknowledgements to Dr Lien Sim (DEC), Adrian Pinder (DEC) and Graeme Behn (DEC)

Copies of this document can be viewed and downloaded from the Department of Environment and Conservation's website at www.dec.wa.gov.au > Management and protection > Wetlands. For further information please refer to the website.

Funding

The development of the methodology and its application to the study area has been funded by the WA Department of Water's Wheatbelt Drainage Evaluation project of the Engineering Evaluation Initiative.

Study area

The project study area is most of the Wheatbelt region of Western Australia, and small areas of the Rangelands to the east and the Darling Scarp to the west, as shown in Appendix A.

Wetland mapping stage

The Western Australian Wetlands Coordinating Committee, with the advice of its Wetland Status Working Group, has determined that the methodology and its application to the study area, as described in this publication, fulfils the requirements of a Stage 1 mapping project. Table 1 outlines the key aspects of a Stage 1 mapping project.

Table 2. The relevant stage of mapping (shaded) from the three stages of wetland mapping outlined by DEC (2007).

Stage	Purpose/ objective	Scale	Approach	Mapping	Mapped classification	Evaluation	Outcome
1	Broad wetland distribution	Regional	Reconnaissance Desktop 'Drive by'	Satellite imagery, aerial photographs, topography Map 'centroid' or approximate boundary 1:250,000 to 1: 100,000 scale	Wetland vs. dryland	Existing data only No further evaluations	Quantify wetland resource
2	Asset evaluation, priority setting	Group of wetlands	Field sampling of sub-set and extrapolation of information	Aerial photograph. Precise or approximate boundaries 1:50,000 to 1:10,000 scale	Geomorphic wetland type	Preliminary indication of conservation value	Preliminary evaluation and prioritisation for future detailed assessment
3	Protection, management, environmental impact assessment	Individual	Individual wetland assessment in field	Aerial photographs (stereoscopic analysis). Precise boundaries 1:25,000 to 1:5,000 scale	Geomorphic wetland type	Detailed assessment of conservation value	Identification of values of individual wetlands as basis for protection, management and/or nomination.

Scale

Wetland identification using remote sensing has been undertaken at a scale of 1:100,000 to 1:250,000. Orthophotograph verification of remote sensed data was then undertaken. Due to time constraints, the accuracy and detail of data capture varies across the study area. Identification and delineation of basin wetlands were identified as a priority by the funding body. Appendix A provides an indication of areas:

- in which all applicable wetland types have been identified and approximate wetland boundaries delineated for use at a scale of 1:100,000 (labelled 'complete'),
- in which only basin wetland types have been identified and approximate wetland boundaries delineated for use at a scale of 1:100,000 (labelled 'basins only') and
- in which only basin wetlands have been identified and approximate wetland boundaries delineated for use at a scale of 1:250,000 (labelled 'remote sensed').

Information regarding the accuracy and detail of data capture for individual wetlands is available from the *Wetlands of the Wheatbelt and other prioritised areas* dataset attribution field entitled 'Mapping method'.

All granite outcrops have been identified as wetlands on the assumption that all outcrops have the capacity to hold water in the form of one or multiple pools. For more information, see section 3.3 of this report.

Relevant wetland types

The methodology is applicable to the full range of inland wetland types, as identified in Table 2. However, in applying the methodology to the study area, the identification and approximate boundary delineation of basin wetland types greater than 1 hectare has been prioritised in accordance with the priorities of the funding body. Where time allowed, other wetlands have also been captured.

Table 3. The wetland types which may be identified using the methodology (shaded), from the geomorphic wetland types identified by Semeniuk & Semeniuk (1995)

Hydroperiod	Landform				
	Basin	**Channel**	**Flat**	**Slope**	**Highland**
Permanent inundation	Lake	River	-	-	-
Seasonal inundation	Sumpland	Creek	Floodplain	-	-
Intermittent inundation	Playa	Wadi	Barlkarra	-	-
Seasonal waterlogging	Dampland	Trough	Palusplain	Paluslope	Palusmont

Limitations
Wetlands can only be identified up to Landform scale with this methodology (as indicated in Table 3). The methodology cannot be applied with great accuracy to identify the presence of wetlands located on slopes and/or highlands.

Wetland evaluation
Wetland evaluation was not undertaken as part of this project.

Associated datasets
The wetland identification and approximate boundary delineation methodology has been applied to the study area by DEC (John Lizamore, Danielle Halliday and Anna Leung) and a dataset produced entitled *Wetlands of the Wheatbelt and other prioritised areas*. For information on the dataset, including metadata and data modification processes, refer to www.dec.wa.gov.au > Management and protection > Wetlands.

Select data collected during this process has been used by DEC to evaluate wetlands. For more information, refer to the associated evaluation methodology: *Evaluating the conservation significance of basin and granite outcrop wetlands within the Avon Natural Resource Management region: Stage One Assessment Method* (Jones et al. 2008).

Endorsement
Regional identification of specific wetland types in the Wheatbelt region of Western Australia: methodology and outcomes and the *Wetlands of the Wheatbelt and other prioritised areas* dataset have been endorsed by the:

- Department of Environment and Conservation
- Department of Water
- Wetland Status Working Group
- Western Australian Wetlands Coordinating Committee

Recommended reference
The recommended reference for this publication is: Lizamore J.M. for the Department of Environment and Conservation 2008, *Regional identification of specific wetland types in the Wheatbelt region of Western Australia: methodology and outcomes*, Department of Environment and Conservation, Perth.

Index:

1 Introduction:

This methodology applies to most of the Wheatbelt region of south-west Western Australia, as well as in a small area of the Rangelands to the east and the Darling Scarp to the west (See Appendix A for a map of the study area).

The primary purpose of the methodology is to identify and delineate approximate boundaries of basin wetlands. This priority was established to meet the requirements of the Department of Water's Wheatbelt Drainage Evaluation project of the Engineering Evaluation Initiative. Where possible, other wetland types are accounted for, and in applying the methodology, other wetland types have been identified and approximate boundaries identified in some catchments.

Data was captured from 1990 and 2000 satellite images at a scale of 1:100 000 with 25m pixel resolution. Please refer to *Wetlands Mapping* (Behn 1990) for more information.

Three levels of data-capturing occurred and were:

- All wetlands that could be identified at a scale of 1:10 000, with the focus on basin type wetlands.
- Basin type wetlands only, as identified at a scale of 1:10 000.
- Basin type wetlands only, as remote-sensed as an indication of the presence of surface water and verified at a scale of 1:24 000.

The base wetland layer derived from satellite imagery was clipped to 1:100 000 topographic map grids. Orthophotograph verification of the data was then undertaken at a scale of 1:10 000 by several operators. As part of this process, data capturing of all wetland polygons within the study area was undertaken. The data were then cross-verified against the 1:250 000 *GEODATA Waterbodies* dataset (GeoScience Australia, 2004).

Each operator (data capturer) was assigned a set of 1:100 000 topographic map grids to capture. To prevent duplication and the possibility that the same data might be captured twice, each data capturer was responsible for a catchment, as a further denominator. Although two capturers could work on the same 1:100 000 topographic map grid, each person was working on a distinct drainage area or catchment.

The operators interpreted aerial photographs to verify whether remote sensed areas of water inundation are in fact wetlands, determine approximate boundaries, add additional areas not indicated to contain surface water and to capture other visual information such as extent of vegetation, impacts, etc. Although this phase is very subjective, aerial photograph interpretation is an acceptable form of land survey which is discussed extensively in literature (Gunn *et al* 1988).

The boundary between wetland and dryland vegetation (as could be detected at a broad scale) formed the primary indicator of the approximate wetland boundaries. However as wetland boundary conditions change from one area to the next and are dependant on climate, topography and vegetation types, other features were also analysed where possible to ensure the approximate boundaries are robust. As such, a hierarchy of decisions was used to determine approximate wetland boundaries. This hierarchy order was not fixed and differed as conditions varied, but generally comprised:

1. Presence of water inundation, as remote sensed by DEC (see Behn 1990).

2. Presence of wetland vegetation or a discernable vegetation change indicating vegetation zones around the wetland (e.g. riparian vegetation, samphire communities, etc). In cases where land has been cleared, any remnant vegetation might be identified as wetland when the original/actual wetland boundary may be much wider. In other cases, the rising groundwater table will have resulted in new wetlands that have developed and are most likely dominated by samphire communities.
3. Topographic contours; indicating slopes, flow direction and potential areas of pooling.
4. Presence of any other data that indicates the area is a wetland e.g. actual sampling sites, historic wetland boundaries or previously identified wetlands.
5. Presence of any surface indicator of possible wetlands, e.g. if there is a drain situated in a certain area, groundwater may be present - the presence of groundwater may be discernable in vegetation changes, topographic contours and/or natural drainage lines.

The specific attributes captured are explained in greater detail in Section 3: *Details of attributes considered,* whilst the metadata is available in the document *Wetlands of the Wheatbelt and other prioritised areas: metadata statement.*

2. Details of attributes considered

A range of attributes were analysed in order to identify wetlands and determine the approximate wetland boundaries. Data upon these attributes is recorded in the *Wetlands of the Wheatbelt and other prioritised areas* dataset. The data captured and use of the data for decision making is described in greater detail in the sections 3.1 – 3.21 below.

- Wetland classification: 1:250 000 topographic map classification
- Wetland classification: Semeniuk broad classes
- Wetland classification: additional information
- Hydrological wetland names
- Extent of vegetation cover
- Dominant vegetation cover type
- Wetland chains and suites
- Flow direction
- Hydrologic placement in the catchment
- Wetland connectivity in the landscape
- Natural vegetation extent around the wetland
- Impacts on wetlands
- Severity of impacts on wetlands
- Spatial accuracy of remote sensing layer
- Confidence rating of the accuracy of the data layer
- Is any survey information available for the wetland?
- Important wetland status
- Ramsar wetland status
- Gazetted name for wetlands
- Field verification
- Hydro-geomorphic classification

In addition, other, specific attribute data was recorded in the *Wetlands of the Wheatbelt and other prioritised areas* dataset for the purpose of informing the evaluation of wetlands as described in *Evaluating the conservation significance of basin and granite outcrop wetlands within the Avon Natural Resource Management region: Stage One Assessment Method* (Jones *et al* 2008a). This includes:

- Area of wetland polygons
- Coordinates of the wetland polygons
- Details of the data capturer
- 1:100 000 topographic map grid
- Catchment
- Sub-Catchment
- Mapping method
- Linking other survey information to the wetland layer
- Data-layer Source
- Duplicate polygons
- Editing comments

More detail on how this data was captured can be found in the document *Wetlands of the Wheatbelt and other prioritised areas: metadata statement* (Lizamore 2008).

2.1. Wetland classification: 1:250 000 topographic map classification:

This field records the wetland class as identified in the existing dataset, *GEODATA Waterbodies* (GeoScience Australia, 2004). A record of these classes is retained, both as a verification technique (to allow cross-referencing between old and new data) and to assist in the revised wetland mapping classification. These classes are not dependent on the interpretation of the data-capturer, but directly reflect the classes that already exist and are therefore not checked for accuracy or correctness.

The following classes are recognised, as already captured by Geoscience Australia:

a) Lake

b) Reservoir

c) Settling pond

d) Subject to inundation

e) Swamp

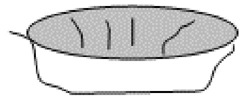
f) Watercourse

g) Not defined (where no value existed in the *GEODATA Waterbodies* dataset or the wetland was not captured previously).

2.2. Wetland classification: Topographic broad classes

This field is based upon the topographic classification of wetlands, as outlined by Semeniuk and Semeniuk (1995:108), but does not include all aspects and classes that reflect landform and water regime characteristics (Table 2). Six landform classes are recognised here. If a system is an artificial storage system, such as a dam or reservoir, this will also be indicated. The six recommended classes are:

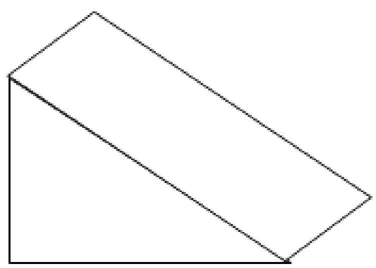
a) Basin



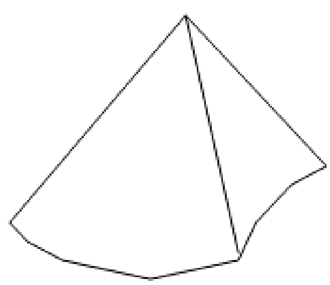
b) Channel

c) Flat

d) Slope



e) **Highlands/Hills**



f) **Reservoir:** for artificial storage structures (no diagram).

Because of specific project objectives, data-capturing of basins was prioritised, but in some catchments, other wetland types were also recorded when identified.

The geomorphic classification system requires the identification of a wetland's hydroperiod in order to classify the wetland into one of 13 possible types (as shown in Table 2 above), but it is not possible to determine hydroperiod/wetness characteristics at this mapping scale. If substantial hydrological data exists over long periods and for all seasons, it may be possible to extrapolate some of the information by adapting the method described by Behn (1990) for multiple configurations and time-scales. This was not undertaken during the development of the *Wetlands of the Wheatbelt and other prioritised areas* dataset.

It is also not possible to identify a 'slope' or 'highlands/hills' with any great accuracy as there is little or no surface water present that can be identified using the method described by Behn (1990). It is possible to apply infrared filters to indicate soil moisture, but this will need careful calibration and timing (with regard to seasonal hydroperiod) and is not recommended for remote capture over large geographical areas. This was not undertaken during the development of the *Wetlands of the Wheatbelt and other prioritised areas* dataset.

2.3. Wetland classification: additional information:

This field provides supplementary information to the attributes in Section 3.2: *Wetland classification: Semeniuk broad classes*. Specific aspects that needed further description were:

- Highlands/Hills - indicate if it is a 'granite outcrop'. Rocky outcrops (devoid of vegetation) are included, but no distinction can be made between different geological rock types, such as limestone, granite or quartzite without field verification. Granite outcrops are mapped rather than individual pools on or associated with the outcrops.

This clarification is included since granite outcrops can be important sites for numerous small wetlands (gnamma holes) with high biodiversity values, but these are too small to detect through the mapping process.

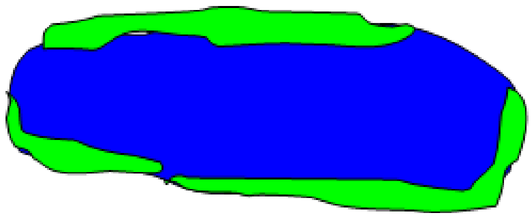
2.4. Hydrological wetland names:

This field assigns a wetland name according to the wetland's hydrological position in a catchment. The full process is described in more detail in the document *Wetlands of the Wheatbelt and other prioritised areas: metadata statement* (Lizamore 2008). The catchment name and/or wetland suite name (as described in Section 3.7) is included as part of the hydrological wetland name for easy reference.

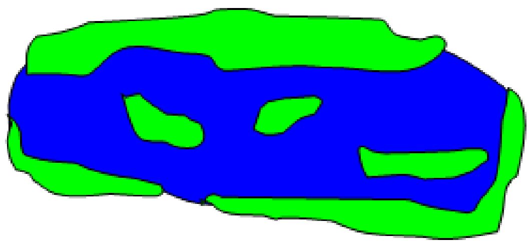
2.5. Extent of vegetation cover

This field identifies the extent of wetland vegetation cover, providing an indication of ecological type, e.g. Yate swamp, etc. It is based upon the Semeniuk (1990) wetland vegetation classification system, a simplified version of the Semeniuk vegetation classes, using three broad classes, is applied. For simplicity, no provision is made for internal organisation of vegetation used in the full wetland vegetation classification system as it can not be done accurately without field verification. The classification is for individual wetlands and not wetland chains or suites. The 3 classes are:

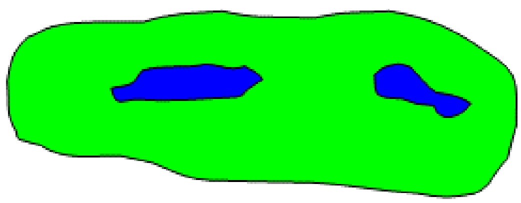
a) Peripheral



b) Mosaic



c) Complete



2.6. Dominant vegetation cover type

This field provides a further descriptor to 'Extent of vegetation cover' described in Section 4.5. Vegetation plays an important role in distinguishing wetland areas from terrestrial areas in orthophotograph interpretation. Although no specific vegetation type is discernable, broad scale vegetation changes can be observed. Three broad classes of dominant wetland vegetation cover type are used:

a) **Open water**. All wetlands classified as 'Peripheral' were also classified as 'Open water'.
b) **Tree/shrub** dominated
c) **Sedge** dominated

It is also possible to identify potential wetlands where distinctly different vegetation occurs, but no surface water is present. This aspect is easier to identify and classify in areas where land has been cleared as opposed to uncleared, natural areas (areas beyond the clearing line will be less accurate than inside the clearing line).

2.7. Wetland chains and suites

This field identifies whether a wetland is part of a hydrological chain or suite. In this context, the term 'suite' refers to a group of wetlands that are hydrologically linked. It does not refer to consanguineous suites of wetlands as described by Semeniuk (1988; 1996). It should be noted that while wetlands in a suite are linked hydrologically, they are not necessarily geographically linked.

Wetland chains should be identified and mapped where different wetlands function together within a system and are influenced by upstream, downstream and neighbouring wetland units. Suites should be mapped as larger systems and not at an individual wetland scale. Wetlands that are hydrologically isolated and are not part of a suite or chain are also identified as such.

Data capturers can rely on visual evidence of aerial photographs to determine this. In some cases, topographic contours suggest that water will overflow from one wetland into another (possibly only during extreme flooding events), but no flow paths, channels or vegetation buffers can be seen on the aerial photographs - in these cases the wetlands should not be identified as part of the same suite.

Vegetation indicators can be used in absence of channels and waterways as indicators of wetland flats. In most cases, the vegetation is likely to be discernibly different from the surrounding area.

2.8. Flow direction

Surface flow direction through the wetland chain/suite over a sub-catchment scale is recorded as it provides valuable insights when field verifying or visiting wetlands. It is determined by interpreting the topographic contour data. It is often extremely difficult to determine the surface flow direction in a wetland if it is not overflowing. Sub-surface flow is disregarded.

2.9. Hydrologic placement in the catchment

By establishing the hydrological position of the wetland in the wetland chain in the sub-catchment (from a surface flow perspective), it can be determined whether a wetland will be the receiver, source or both receiver and source for downstream impacts. Sub-surface flow is disregarded. The following four classes are used:

a) **Headwater** - At the top of the wetland chain where water originates. These systems do not receive water from other wetlands, but only runoff from surrounding land, groundwater seepage, stream channels and rainfall.

b) **Throughflow** – These wetlands lie between headwater wetlands and terminal wetlands (or the sea) in the middle of the wetland chain. They receive water from headwater units and supply water to downstream wetland units. Sub-surface flow is disregarded.

c) **Terminal** - Terminal wetlands are generally at the bottom of the wetland chain. They receive water from other systems but water cannot exit them other than through evaporation or seepage into the ground (or occasional flooding overflow in large events).

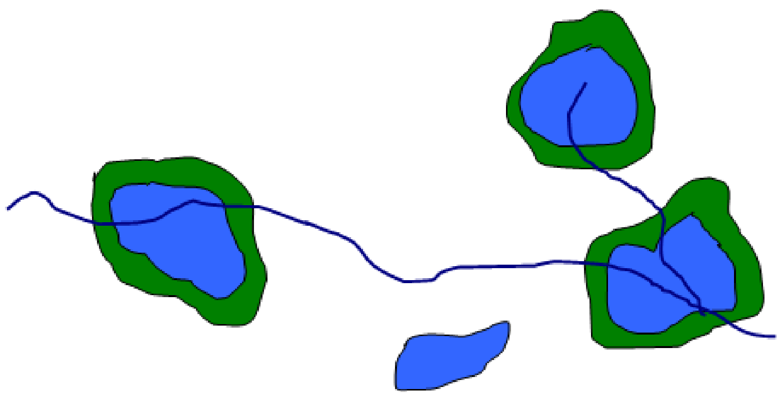
d) **Isolated** - Not linked to other wetlands (endoreic or internally-drained). Water will enter into the wetland from surrounding land and groundwater seepage, but not from other wetlands. Water can only exit the wetland through evaporation or seepage into the ground (or occasional flooding overflow in large events).

Although some wetlands can be classed as 'terminal', they may still have inflow and outflow during high rainfall events.

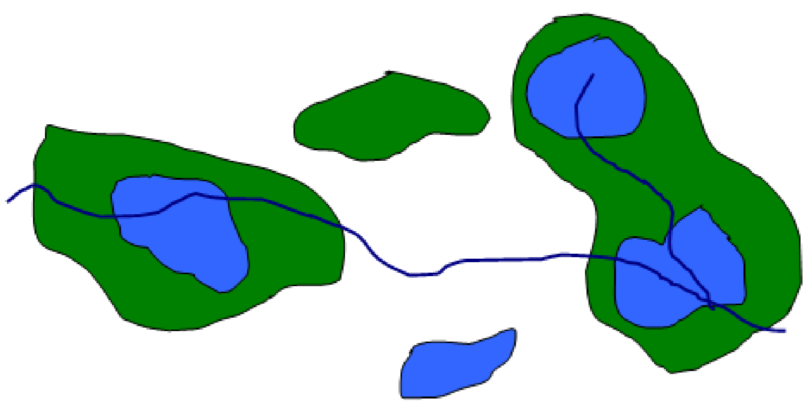
2.10. Wetland connectivity in the landscape

This field describes the level of connectivity of the wetland to other natural areas in the landscape. It has been adapted from Kotze *et al.* (2005). It includes connectivity of remnant vegetation as well as hydrological connectivity and provides an indication of whether species (aquatic and terrestrial) will be able to migrate between different wetland units. The following classes are recommended:

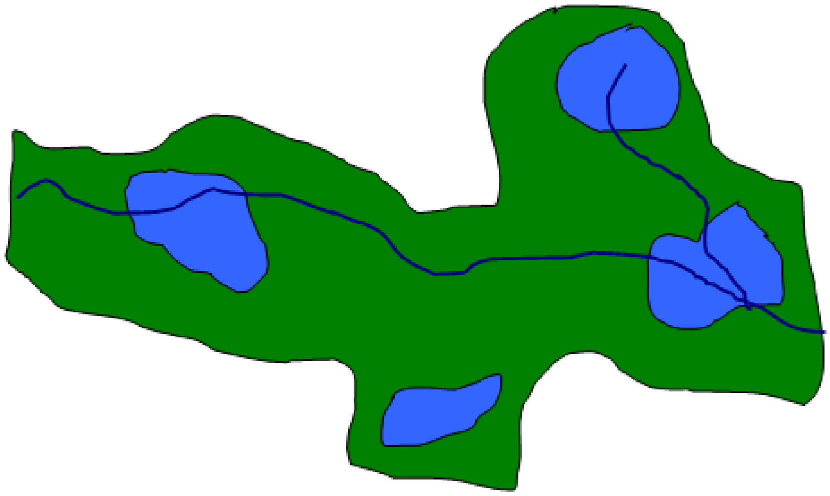
a) Low



b) Intermediate



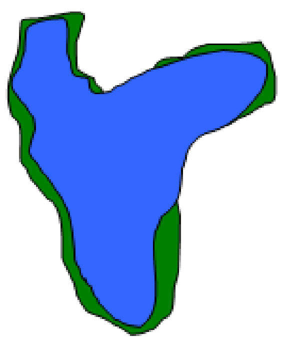
c) High



2.11. Natural vegetation extent around the wetland

This field identifies the intactness of remnant vegetation and other natural areas such as wetlands, that can act as a natural corridor for faunal migration, absorb impacts of surrounding land uses, such as pollution, and also provide some indication of the probability of occurrence of wetland dependant species requiring foraging areas outside of wetlands. The methodology has been adapted from Kotze et al. (2005). The following classes are used:

a) Low (below 50m)



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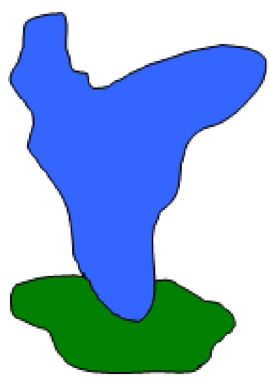
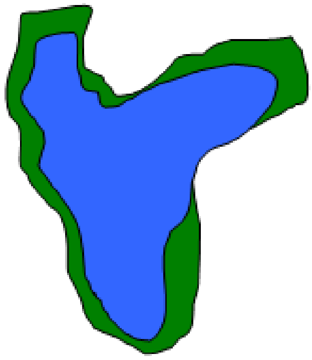
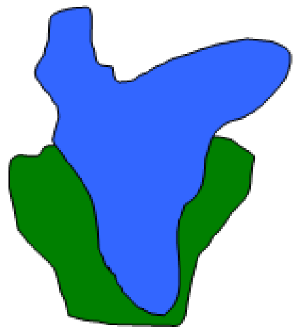


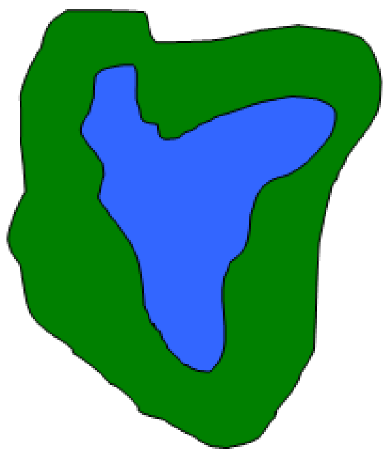
b) Intermediate



or



c) High



2.12. Impacts on wetlands

Many wetlands may have impacts that are discernable on orthophotographs. The type of impacts in and around a wetland may affect its function and integrity. Although a very subjective assessment without field verification for accuracy, it could act as a guide to determine future priorities for field verification and further study. It is possible to list more than one disturbance activity.

The presence of certain landuse activities or impacts may also indicate the possible presence of wetlands, e.g. a drain on a slope may indicate the presence of groundwater and potentially a 'slope' wetland. Similarly, a road traversing a natural drainage line may affect the natural drainage patterns to an extent that a wetland may form upstream of the road as damming occurs.

The following classes are used:

a) **Drain** - Where evidence is visible on the ortho-photos that drain(s) have been constructed into or out of wetlands.

b) **Damming** - Where there is evidence of a damming structure to capture or store water e.g. a bund or levee bank.

c) **Excavation** - Where there is evidence that excavation into the bed of the wetland has been undertaken to store or capture water

d) **Road** - Where there is evidence of access routes into or through wetland units. This includes such aspects as railway lines, but excludes small tracks where no compaction of the road surface is evident.

e) **Building** - Where a structure is visible inside the boundary of the wetland. This includes pump-houses, bird-hides, houses, sheds, etc.

f) **Agriculture** – Where there is agricultural fields bordering on the wetland.

g) **Other** - Any disturbance activity that is evidence that is not qualified above.

The age of orthophotographs used to analyse wetland impacts varied across the study area, ranging from two years old to more than ten years old, and therefore these attributes may be out of date.

2.13. Severity of impacts on wetlands

This field acts as a quantifier for Section 3.12: *Impacts on wetlands*. This is a very subjective assessment and if not field verified for accuracy, should only be used as a guide. Three classes are used:

a) **Minor** - An isolated impact. The activity or impact does not appear to have altered the hydrology or the structure of the wetland.

b) **Moderate** - The impact is more pronounced. The hydrology of the wetland is most likely altered or disturbance of the wetland is more than 10% of the surface area.

c) **Major** - The impact is severe. The hydrology of the wetland is very likely altered and/or more than 30% of the surface of the wetland area is disturbed.

2.14. Spatial accuracy of remote sensing layer

The presence of surface water *per se* cannot be used to determine the presence of wetlands. It is recommended that accuracy of the remote sensed information obtained by using the method prescribed by Behn (1990) is described. Statistically, if the method is over-indicating or under-indicating the presence of surface water, it can be calibrated to display more accurate values by adding additional filters to improve data or by stratifying the mapping area. The field is most useful as a simple statistical value after all data capturing has been completed. The following four classes are used:

a) **Over** - the spatial layer indicates that the wetland boundary is larger than the actual wetland.

b) **Accurate** - the spatial boundary is a true reflection of the wetland boundary.

c) **Under** - the spatial boundary indicates that the wetland boundary is smaller than the actual wetland.

d) **None** - the spatial layer failed to indicate a wetland that does exist.

2.15. Confidence rating of the accuracy of the data layer

As most of wetland delineation by orthophotograph interpretation is subjective, it is useful to record the data capturer’s confidence level regarding the accuracy of the data. It also allows for prioritisation of wetland units that have to be field verified. Three values are used:

a) **Low –** The data capturer is unsure of whether an area is actually a wetland. For example: 1) the area might have surface water present but are in fact ponding areas that are part of watercourses rather than wetlands or 2) the area displays similar vegetation to adjacent wetlands or signs of salinisation, but was, is or might be agricultural land.

b) **Moderate –** The data capturer is confident of the fact that the area is a wetland, but unsure of the exact boundary, the type of wetland or any of the other attributes associated with the polygon.

c) **High –** The data capturer is confident of the accuracy of the wetland boundary as well as the attributes captured.

2.16. Is any survey information available for the wetland?

This field indicates whether there is any additional ecological survey information available for the wetland.

2.17. Important wetland status

This field indicates whether the wetland has been identified as a wetland of national significance in the *Directory of Important Wetlands in Australia* (Environment Australia 2001). Mapping is available from the Australian Wetlands Database on the Australian Department of Environment, Water, Heritage and the Arts website http://www.environment.gov.au > Databases and maps > Australian Wetlands Database.

2.18. Ramsar wetland status

This field indicates whether the wetland is a Ramsar wetland Mapping is available from the Australian Wetlands Database on the Australian Department of Environment, Water, Heritage and the Arts website http://www.environment.gov.au > Databases and maps > Australian Wetlands Database.

Please note the Ramsar site boundaries are not for individual wetlands, but an administrative boundary for the purposes of the Ramsar convention.

2.19. Gazetted name for wetlands

This field records only those wetland names that are published in the Government Gazette or recorded in the *GEODATA Waterbodies* dataset (GeoScience Australia, 2004). Other names are not used because some wetlands are known by more than one name, and some names are used at a number of wetlands.

2.20. Field verification

This field records whether field verification was done at a wetland. Data includes the date, coordinates, a short description of any findings, and whether photographs were taken during the field verification.

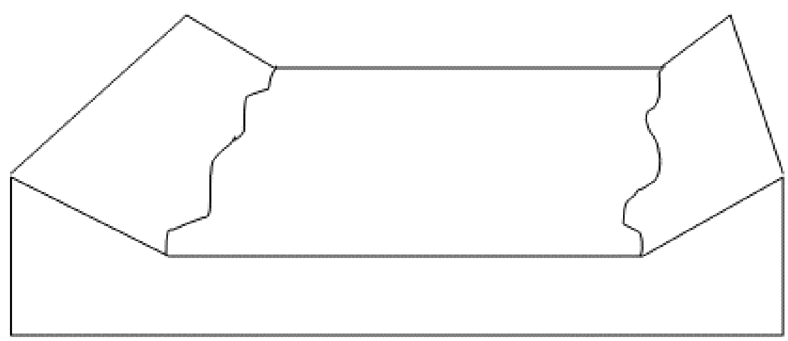
Lizamore (2008) undertook field verification on more than 100 wetlands as part of the boundary calibration process. Wetland boundary verification typically included soil verification and vegetation indicators interpretation. This process indicated a wetland boundary error of less than 1% at the appropriate scales of 1:100 000 and 1:250 000 respectively utilising the methodology. However, Lizamore (2008) indicated that the field-verification did not present a representative sample and can be used as a guide only. As no wetland delineation guideline was available for the wheatbelt of WA, this interpretation is based on the personal experience of the personnel involved, which utilised soil verification (US Army Corps of Engineers, 1987 & Department of Water Affairs and Forestry, 2007) and vegetation indicator interpretation for wetland boundary verification.

2.21. Hydro-geomorphic Classification

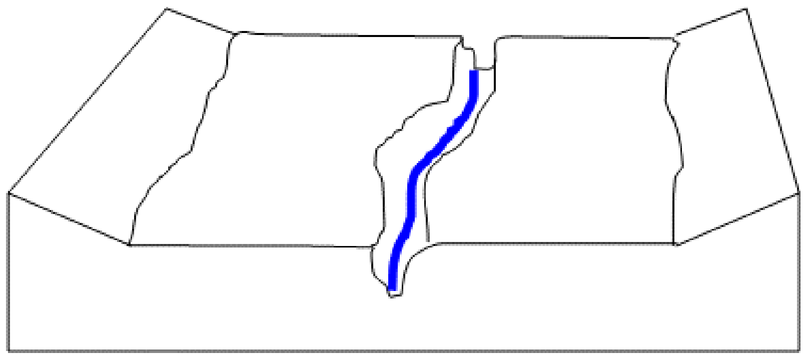
Wetland function and characteristics are often defined by hydrological drivers and the geology of the area around the wetland. This features may be classified using the hydro-geomorphic (HGM) classification system, which indicates how water move through a landscape as determined by the geology of the landscape. This classification differs to the geomorphic classification system as indicated in Table 2 in that certain wetland types, such as basins, may be part of a floodplain system and will then not be classified as basins, but as floodplains.

The following six HGM types are used (as adapted from Kotze *et al* (2005) and Brinson (1993).

a) **Unchannelled valley bottom** – Usually gently sloped. May be characterised by alluvial deposits and accumulation of sediments. Source of the water can be seepage from sides (as a result of a high water table) or from upstream surface and sub-surface sources. Water flow tends to be diffuse and slow over a wide area.

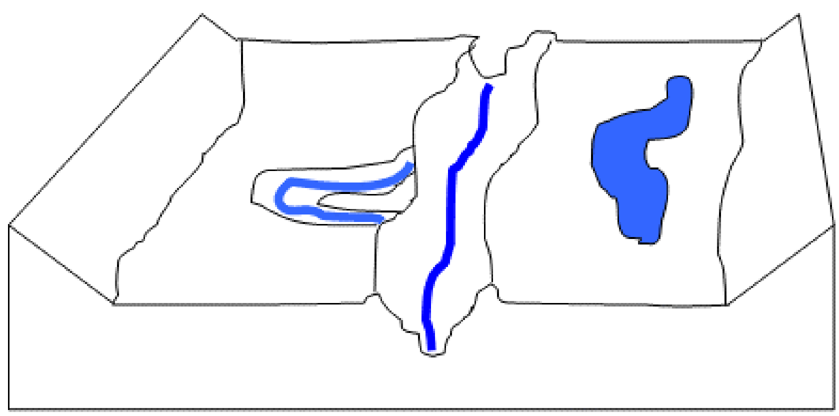


b) **Channelled valley bottom** – Can be gently sloped, but generally steeper, resulting in higher surface-flows and a net-loss of sediments. Usually have a clearly defined eroded/developed channel, but without levees or other characteristic floodplain features. Source of the water can be seepage from sides (as a result of a high water table) or from upstream surface and sub-surface sources. Surface flow tends to be higher and concentrated in the channel. During extreme flow events, the water will spread out of the channel onto surrounding flat and return (flow back) to channel soon after.

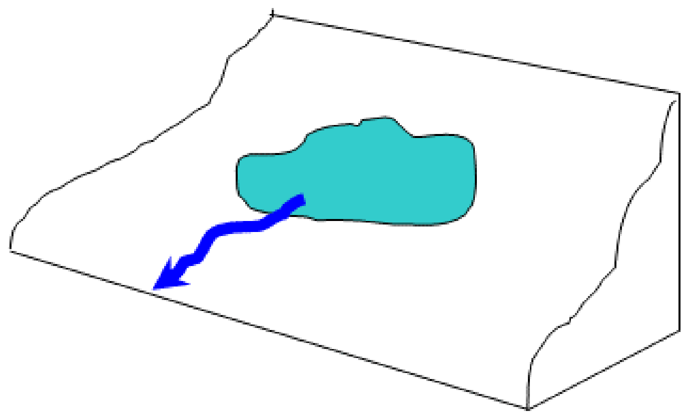


c) **Floodplain** - Can be gently sloped, but generally steeper, resulting in higher surface-flows and a net-loss of sediments. Usually have a clearly defined eroded/developed channel, but with levees and/or depressions outside the main channel. These can include cut-off meandering channels (horseshoes). The flat area outside the channel can also be characterised by alluvial sediment deposits.

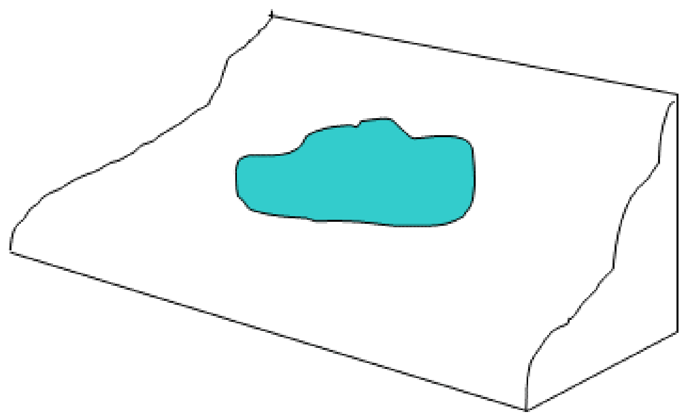
The source of the water can be seepage from sides (as a result of a high water table), but generally from upstream surface and sub-surface sources. Surface flow tends to be higher and concentrated in the channel. During extreme flow events, the water will spread out of the channel over the levees onto surrounding flat. As a result of the levees and inundations, water is unable to return to the main channel and will result in several retention ponds forming, which may hold water for extended periods of time.



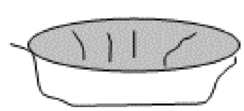
d) **Seep feeding a stream** – Water is mainly from sub-surface sources where the groundwater discharges onto the surface and includes springs. The outflow is usually via a well-defined channel towards a watercourse. The slope can be gentle or severe.



e) **Seep not feeding a stream** – Water is mainly from sub-surface sources where the groundwater discharges onto the surface and includes springs. The seep tends to disappear again as flow dissipated underground and there is no apparent link to any defined watercourses.



f) **Depressions** – A basin shaped area that allows for the accumulation of surface water. It may or may not have an inflow or outflow. Water sources include precipitation, sub-surface water as well as surface flows. Depressions tend to accumulate salts and minerals.



3. Conclusion:

The wetland identification and delineation methodology described here fulfils the criteria for a Stage 1 wetland delineation, as described in *Framework for mapping, classification and evaluation of wetlands in Western Australia* (DEC 2006).

This wetland delineation methodology was used for the compiling the *Wetlands of the Wheatbelt and other prioritized areas* dataset (Lizamore *et al;* 2008). Lizamore (2008) undertook field-verification on more than 100 wetlands as part of the boundary calibration process. This process indicated a wetland boundary error of less than 1% at the appropriate scales of 1:100 000 and 1:250 000 respectively utilising the methodology. However, Lizamore (2008) indicated that the field-verification did not present a representative sample and can be used as a guide only. As no wetland delineation guideline was available for the wheatbelt of WA, this interpretation is based on the personal experience of the personnel involved, which utilised soil verification (USACE,1987 & DWAF,2007) and vegetation indicator interpretation for wetland boundary verification.

4. More information & feedback:

For further inquiries or feedback on the *Wetlands of the Wheatbelt and other prioritized areas* dataset, please refer to www.dec.wa.gov.au > Management and protection > Wetlands.

5. References:

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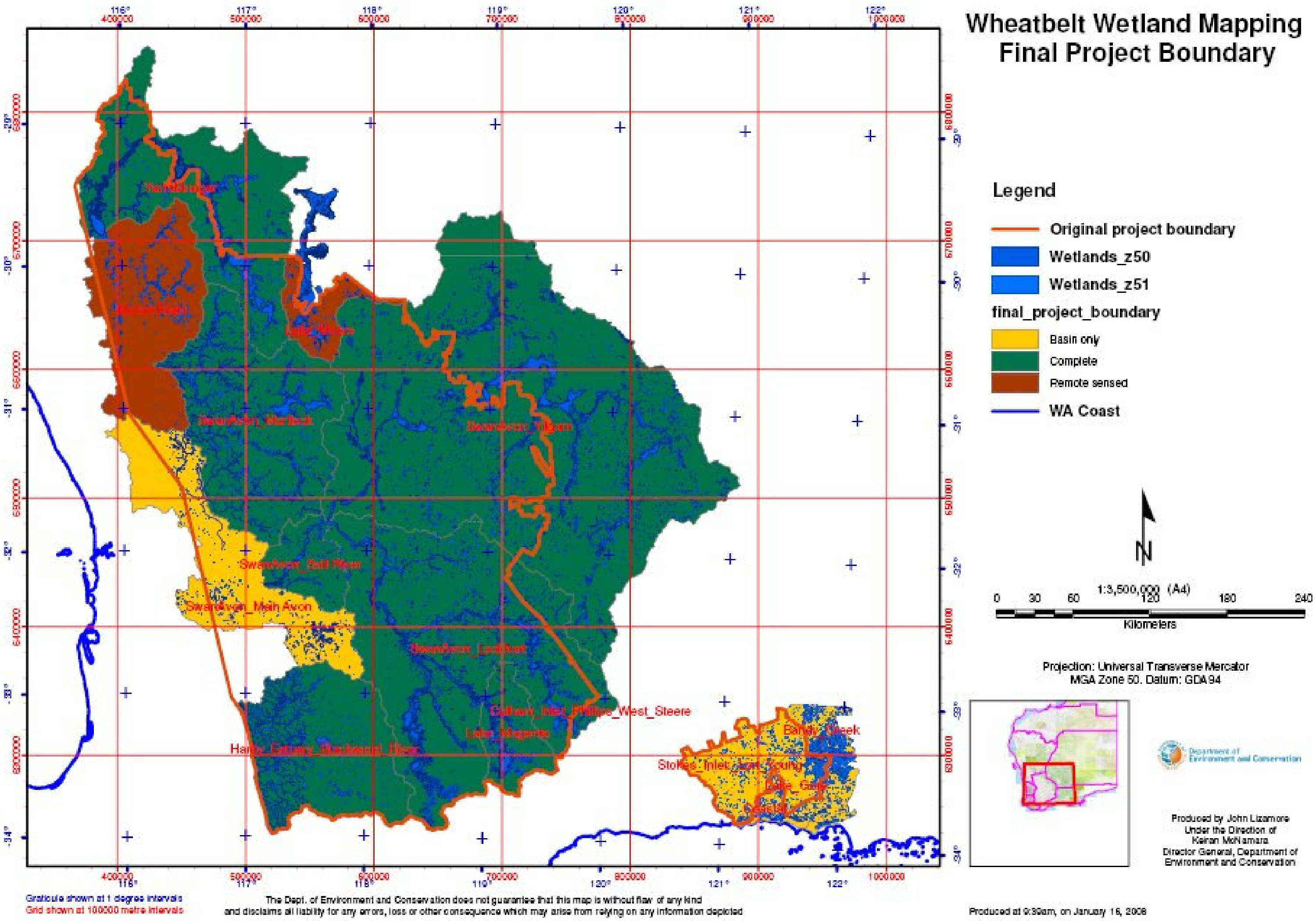
Adrian Pinder; Anna Leung; Catherine Prideaux; Christine Semeniuk; Dani Halliday; Dave Cale; Graeme Behn; Justine Lawn; Lien Sim; Susan Jones.

Appendix A


Wheatbelt Wetland Mapping
Final Project Boundary
Legend
Original project boundary
Wetlands_z50
Wetlands_z51
final_project_boundary
Basin only
Complete
Remote sensed
WA Coast
West_Steere
1:3,500,000 (A4)
0
30
60
120
180
240
Kilometers
Projection: Universal Transverse Mercator
MGA Zone 50. Datum: GDA94
Department of Environment and Conservation
Produced by John Lizamore
Under the Direction of
Keiran McNamara
Director General, Department of
Environment and Conservation
Graticule shown at 1 degree intervals
Grid shown at 100000 metre intervals
The Dept. of Environment and Conservation does not guarantee that this map is without flaw of any kind
and disclaims all liability for any errors, loss or other consequence which may arise from relying on any information depicted
Produced at 9:39am, on January 16, 2008

Appendix B:

B.1. Delineating wetland boundaries by remote methods: Practical mapping tips

The following information is aimed at providing a systematic approach to allow users to map wetland boundaries. The following attributes will assist in delineating wetland boundaries by remote methods:

- Geographic information system (GIS) proficiency and experience
- A clear understanding of:
    - wetland hydrology and functions;
    - cartographic principles and criteria;
    - catchment hydrology principles
    - catchment impacts and their affect on catchment hydrology
- Personal knowledge/experience of the geographic area to be mapped
- Non-impaired colour vision (can't be colour blind)

A clear understanding of the scale and/or objectives is needed before mapping can start. Some aspects can be mapped with great accuracy, but requires high levels of calibration, which makes it impractical for large geographic areas with little or no ground-truthing data. Such an example includes the presence of seeps or wetlands located on hill-side slopes where all water is located below the surface.

The methodology and interaction is explained in more detail below.

B.2. Hardware and software requirements:

Any ArcGIS software that will allow polygons to be added and attributed is sufficient. The specific software package will determine the minimum system requirements. In general the following system works well as:

- ArcMap 9 or higher software platform
- Pentium 3+ processor
- 1GB+ RAM
- 512MB+RAM or capable of running 1280x1024 32bit resolution
- 20GB+ Hard drive space
- 15"+ video display (2 x 19" ideal)
- 4096 MB Virtual memory (maximum)

A dual screen PC or extended desktop display is recommended for easier mapping and faster/more productive capturing.

B.3. Required data layers:

The following datasets or layers are recommended to assist in mapping wetlands and verifying data:

1. Topo-clipped remote-sensed wetland layer (Behn 1990)

2. Existing datasets, such as:
    - *GEODATA Waterbodies* (GeoScience Australia, 2004);
    - Ramsar wetlands as identified in the Australian Wetlands Database (refer to http://www.environment.gov.au > Databases and maps > Australian Wetlands Database); and
    - Wetlands identified in the *Directory of Important Wetlands in Australia* (Environment Australia 2001) as identified in the Australian Wetlands Database (refer to http://www.environment.gov.au > Databases and maps > Australian Wetlands Database)
3. *Hydrographic Catchments - subcatchments* (Department of Water, Various dates).
4. Orthophotograph layer (LandSat, Various dates)

The following datasets may be useful to interpret data:

1. *Contours (5-10m)* (Department of Land Information, Various dates)
2. *AUSLIG 250 000 Geo-referenced Mapsheet images* (GeoScience Australia, Various dates)

B.4. Working order:

Capture remote-sensed surface water layer from 1990 and 2000 satellite images at a scale of 1:100 000 with 25m pixel resolution. Please refer to *Wetlands Mapping* (Behn 1990) for more information. Clipping data to 1:100 000 maps allows for smaller datasets that are easier to manipulate and require less computer resources. It also makes it easier to combine datasets into larger units (if required) at a later stage.

Systematically pan across the screen at a relevant scale. In general, a scale factor of 10 is recommended to determine the most appropriate scale to capture data at: i.e. if the intended usage scale is 1:250 000, the data capturing should occur at a scale of no smaller than 1:25 000 OR 1:100 000 usage scale = 1:10 000 capture scale.

As wetland boundary conditions change from one area to the next and are dependant on climate, topography and vegetation types, the capturing has to adapt as far possible to be effective. Local knowledge of the area and "what it looks like" on the orthophotographs greatly assist in calibration. As such, a hierarchy of decisions are recommended to determine the boundary. This hierarchy order is not fixed and may differ as conditions vary, but ideally would be:

1. Presence of water inundation, as remote sensed by DEC (see Behn 1990).
2. Presence of wetland vegetation or a discernable vegetation change indicating vegetation zones around the wetland (e.g. riparian vegetation, samphire communities, etc). In cases where land has been cleared, any remnant vegetation might be classified as wetland when the original/actual wetland boundary may be much wider. In other cases, the rising groundwater table will have resulted in new wetlands that have developed and are most likely dominated by samphire communities.

3. Topographic contours; indicating slopes, flow direction and potential areas of pooling.
4. Presence of any other data that indicates the area as a wetland, e.g. actual sampling sites, historic wetland boundaries or previously identified wetlands.
5. Presence of any surface indicator of possible wetlands, e.g. if there is a drain situated in a certain area, there may well be groundwater present- try and substantiate the presence of groundwater by looking for vegetation changes, contours and/or natural drainage lines.

B.5. Wetland suites:

Wetlands that are hydrologically linked are described as wetland suites. As such, it is possible that one large wetland system can be broken down into smaller units with similar hydrological characteristics. The following criteria may assist in determining which wetlands are in a suite:

When are wetlands a part of a suite? The following wetlands can be linked as a suite:

- If the remote sensing layer (surface water inundation) indicates a singular wetland and there is more than one wetland;
- If the wetland is immediately adjacent or within another wetland (e.g. a basin on an island) and/or the vegetation boundary encompasses both wetlands; or
- If you are unsure, link them.

When are wetlands not a part of a suite?

- When they are not part of the main drainage line and not linked by surrounding vegetation;
- When they are clearly different wetland types and will function hydrologically different without any hydrological link, like a stream corridor, channel, drainage line, etc.
- When water cannot move from wetland to the other.

Catchment name: it is best to reflect the catchment in which the suite is situated for the suite name.

Large wetlands broken into different wetlands: roads, railways and other similar impacts may break large wetlands up into smaller units that function separately. In these cases, although still part of the suite and reliant on the other wetlands, the hydrology driving the system will have changed, and as a result sedimentation patterns as well. Because of this, wetlands are split up into smaller units based on surface hydrology changes.

Watercourses vs. wetlands: It can be confusing when the ponding indicated within remote sensed layers (Behn 1990) is associated with watercourses. Generally, natural drainage lines are not mapped as wetlands, with some exceptions. Some drainage lines that will not be mapped are easy to discern, in that the area appears to have been ploughed or it is part of an agricultural field. But some are not. When unsure, ask for a second opinion. Use disturbance, connectivity and vegetation as a guide. If you are unable to discern any natural vegetation around that system, it may be that it is not a wetland (even though it is a clear natural drainage line). Contours also provide an indication if the unit is located in the valley bottom or on a slope. Getting rid of all the small portions first (noise and clutter from the remote sense layer) and then making a call on the larger remaining sections also help.

B.6. Other practical aspects to consider:

Panning around on the screen: Because the wetlands as sometimes larger than the computer screen when zoomed in at 1:10 000, it is necessary to pan around to view or work on a large polygon. Make a note of the coordinate in the middle of the screen before you start panning, as it will provide a point to return to once you are finished and want to continue. Make notes of where you were before you exit the program or leave for the day (especially where you got to the previous day so as not to redo everything). Again, the coordinate in the centre of the screen can assist. Never delete any selected polygons unless you can see the complete polygon on the screen and are sure that is what you want to do.

Backups: regular backups are needed to prevent data loss. It's not uncommon for the datasets to get corrupted, so ensure daily backups are made or more often if there is substantial progress. Keep backups in a separate directory on the hard-drive and keep copies on the network server. Make hard copy backups weekly that can be kept separate from the computers - fire, electrical power surges and electrical thunder storms can destroy complete computer systems with all data stored. It is best to store hard copies in a fire-proof storage facility like a safe.

Scale: Ensure the relevant scale is specified as on the scale bar (e.g. 1:10 000). Don't map at any other scale to ensure consistency.