Building the Capacity to Access Spatial Information about the Extent of Riparian Vegetation in New South Wales, Australia

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SUMMARY

Riparian vegetation has an important influence on water quality and habitat (Day, 2001). Government agencies and other organisations require better information to plan and manage riparian conservation and restoration works along rivers. Previously, riparian vegetation had been mapped by different government agencies at different places, for a range of purposes at various scales. However, no single project had mapped the extent of riparian vegetation covering the whole State. This report describes the development of a spatial dataset based on the use of remote sensing and GIS (geographic information system) techniques to assess the extent of riparian vegetation in New South Wales (NSW) for monitoring, evaluation and reporting purposes.

The dataset brings together several datasets to create the first complete coverage of the 11 most eastern catchment management authority (CMA) areas (from a total of 13 CMA areas within NSW). The primary objective of this project was to extract data for the extent of riparian vegetation within 30-metre riparian buffer zones around water courses with higher stream orders (Strahler orders three and above). Additional stream order data were generated for six CMA areas, and to fill gaps in the coverage for coastal catchments using the existing drainage layer. The NSW Interim Native Vegetation Extent (INVE) dataset (DECC, 2008) was used as a primary dataset, as this data provided the best available state-wide coverage of the extent of native vegetation.

The primary product is the Riparian Vegetation Extent (RVE) dataset which includes “woody” and “non-woody” vegetation classes. The secondary product is the Hybrid Riparian Native Vegetation Extent (HRNVE) dataset, which consists of 10 different vegetation classes. Both datasets are binary vegetation extent grids (25 m). Detailed statistics about the extent of the riparian vegetation were generated, based on the boundaries of CMA areas and individual catchments.

We are assessing the quality and reliability of “woody” and “non-woody” classifications, and the accuracy of the estimation of riparian buffer zones. One quarter of the 1:100,000 scale topographic maps covered by our RVE dataset have been assessed using random sampling methodology. Accuracy reports add immense value to both the INVE and RVE datasets.

We recommend investigation of whether high resolution data for vegetation can be utilised to produce significantly more accurate riparian land-cover classifications.

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1. INTRODUCTION

Riparian vegetation provides important benefits for the health of river ecosystems. Vegetated riparian buffer zones adjacent to streams, rivers or other water bodies greatly influence water quality and provide valuable habitat. Riparian buffer zones with dense vegetation also reduce the sediment load carried into streams and water bodies, and protect shorelines and stream banks from erosion. Properly established and maintained riparian buffer zones can help to reduce the severity and recurrence of flooding (Day, 2001). Government agencies—such as Commonwealth and State departments, CMAs, and local government—and other organisations require better information to plan and manage riparian conservation and restoration works along rivers.

Previously, riparian vegetation had been mapped by different government agencies at different places, for a range of purposes at various scales. For instance, for the Yass River and the Bega River, the extent of riparian vegetation was mapped by the former NSW Department of Natural Resources (DNR), riparian condition was assessed by Eurobodalla Shire Council, and the Murray–Darling Basin Authority had assessed riparian vegetation within some areas of the basin. However, no single project had mapped the extent of riparian vegetation covering the whole State.

The State-wide Landcover and Trees Study (SLATS) methodology from Queensland was used in NSW to report on vegetation clearing by the former NSW Department of Environment and Climate Change (DECC). As part of the SLATS process an FPC was generated with subsequent generation of a state-wide dataset for the extent of vegetation. FPC refers to the horizontal percentage of cover (measured from 0 to 100%) of photosynthetic foliage (including under- or over-storey strata), and provides a measure of the photosynthetic activity in low density, Australian vegetation (Specht, 1999). A threshold of about 12% (equating to 20% canopy cover [SLATS, 2003]) was identified on the Landsat derived FPC layers to discriminate between forest and non-forest (Lucas, *et al.*, 2006). This data provided the best available state-wide native vegetation extent dataset, for use in our NSW Riparian Vegetation Extent for Monitoring, Evaluation and Reporting Purposes Project.

Vegetation extent was classified into either “woody” or “non-woody” by applying a single uniform threshold to the state-wide FPC values, which are continuous data indicating the percentage of FPC. The “woody” and “non-woody” classes were further sub-divided into the confidence classes “likely” and “most likely” to document uncertainty in assigning the “woody/non-woody” threshold (DECC, 2008). Despite its limitations, this dataset provided the best available coverage of the state-wide extent of native vegetation. The data provide an estimate of vegetation extent in 2006, based on interim FPC data derived from Landsat data.

The unclassified areas, created by gaps in the land use data coverage, were completed using the FPC derived vegetation extent data. Gaps in the former NSW Department of Environment and Climate Change's (DECC's) INVE dataset were filled using Keith and Simpson's (K&S) native vegetation extent data (version 002, 2006) to attribute FPC derived vegetation extent as "native" or "non-native". This data was 250-metre pixel resolution, so it was resampled to 25-metre pixel size, consistent with the other datasets (Keith and Simpson, 2006; cited in DECC 2008).

The NSW Office of Water's RVE and HRNVE datasets were primarily based on DECC's INVE dataset, to extract riparian vegetation extent within 30-metre riparian buffer zones. This provides important baseline information on the status of riparian vegetation that government agencies require for monitoring and reporting on the status and condition of natural resources. It is important to monitor the condition of riparian areas to ascertain the extent of damage or alteration to these areas that is caused by human activities. Thus this project supports the Monitoring, Evaluation and Reporting Strategy and the State-wide Resource Condition Targets of the NSW State Plan for 2006 to 2009. It also provides spatial boundaries to all themes requiring riparian vegetation information, supporting the State-wide Vegetation Mapping Strategy.

The project delivered data for the riparian vegetation extent with accuracy assessments, and generation of riparian statistics related to the boundaries of CMA areas and catchments (Table 4). Data for individual catchments were also included, when requested.

2. OBJECTIVES

The objectives of the NSW Office of Water's NSW Riparian Vegetation Extent for Monitoring, Evaluation and Reporting Purposes Project were to:

- generate a database, including the NSW Office of Water's RVE and HRNVE datasets, extracted from DECC's INVE dataset (DECC 2008).
- assess the accuracy of the NSW Office of Water's RVE dataset by using high resolution imagery (SPOT5 satellite imagery and/or [ADS40] digital aerial photographs) and random sampling techniques
- develop and build ArcGIS® models to incorporate updated versions of the DECC INVE dataset
- generate stream order classifications for the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee and Murray CMA areas using the existing former Department of Lands (DoL) Topo-Hydroline data, and fill in the gaps in stream order data for the coast of NSW
- generate statistics from the NSW Office of Water's RVE and HRNVE datasets relative to CMA areas and catchment boundaries.

3. METHODOLOGY

GIS and remote sensing techniques were implemented to create a digital spatial database of the extent of riparian vegetation. ESRI® ArcGIS 9.3 with various extensions and RivEX® software was mainly used for preparation, manipulation and spatial analysis of the data. Figure 1 provides a detailed flow chart of the workflow for the project.

3.1 Primary data

The spatial datasets for this project were acquired from various sources.

3.1.1 DECC INVE data

This data provided the best available state-wide native vegetation extent for the NSW Office of Water's NSW Riparian Vegetation Extent for Monitoring, Evaluation and Reporting Purposes Project. It estimated vegetation extent based on interim FPC data derived from Landsat data (DECC, 2008). Vegetation extent was classified as either "woody" or "non-woody" by applying a single uniform threshold to the state-wide FPC values. These are continuous data indicating percentage FPC.

3.1.2 CRA stream order layer

The primary objective of this project was to extract riparian vegetation extent data for streams that are third order and higher. The streams must be either perennial or recurring (have water in their channel for at least part of the year). Comprehensive Regional Assessment (CRA) Stream Order Data were originally created by Forests NSW within the former NSW Department of Primary Industries as a part of its CRA commitment. The dataset covers most of the coastal catchments' area, with few gaps in the data. There were no stream order data for the Central and Western NSW regions. The attribution of the stream orders was reasonably accurate. Forests NSW used a random checking process, especially over state forests, and identified no major data errors (Wayne Mackey, Manager GIS, Forests NSW, DPI, 2008 pers. comm.).

3.1.3 Index maps (1:100,000 and 1:250,000 scale)

To keep spatial datasets at manageable sizes, the coverage was divided into 1:100,000 and 1:250,000 scale topographical map units for the entire work flow.

3.1.4 DoL Topo-Hydroline dataset

The former NSW Department of Lands Topo-Hydroline dataset provided the best available drainage layer for us to generate stream order data for the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee and Murray CMA areas, and to fill in the gaps in the CRA stream order data for the coast.

3.1.5 SPOT5 satellite imagery and (ADS40) digital imagery

SPOT5 satellite imagery (at 2.5 m ground resolution) and (ADS40) digital aerial photographs (0.5 m ground resolution) were used as a backdrop for accuracy checks to verify “woody” and “non-woody” classifications.

Figure 1 The work flow used for the NSW Office of Water (NOW) Riparian Vegetation Extent for Monitoring, Evaluation and Reporting Project

3.2 Data issues

3.2.1 Coverage

Figure 2 Coverage of the initial CRA stream order data for NSW

Stream order coverage is indicated by green polylines on the map above.

For NSW, the CRA stream order data cover only seven CMA areas; and amongst those, six CMA areas are only partially covered. Some additional stream order data were generated by DNR for the Murray and Murrumbidgee catchments, but these data were unsuitable because of errors in the stream orders. As a part of this riparian project commitment, additional stream order data were generated and the results, i.e. the areas covered are listed in Table 4, and Figure 8.

3.2.2 Stream network geometry issues

Figure 3 Geometric variations in stream network for CRA and Hydro-Line data

In this image, the actual position of a stream is shown overlaid by blue lines representing the stream's position according to Hydro-Line geometry, and red lines indicating the corresponding CRA geometry. The Hydro-Line geometry matches the actual position of the stream more accurately. Areas where data errors occurred can be seen in the middle of the image.

The CRA stream order data and Hydro-Line data were overlaid onto the SPOT5 imagery and the geometry of the drainage was verified at random sites. It was observed that there were differences in the geometry of the river network. Hydro-Line geometry was more accurate than the CRA stream order data (Figure 3). Hydro-Line data were used to generate Strahler stream orders to extend and complete the data for the Border Rivers – Gwydir, Namoi, Central-West, Lachlan, Murray, and Murrumbidgee CMA areas and to fill gaps in the CRA data for the coastal CMA areas.

CRA stream order data were used to generate data for riparian buffers. As a result, some geometric errors showed distinctly between the actual drainage lines and riparian buffer zones compared to the geometry of the datasets (Figure 4).

Figure 4 Distortions in river network, riparian buffers and vegetation extraction

Upper: a SPOT5 image showing the actual location of a stream (dark blue), overlaid with CRA geometry representing the outer edges of the drainage lines (green lines) and the riparian buffer zone (pink lines). Lower: the same image overlaid with the NSW Office of Water's RVE data representing non-woody vegetation (yellow pixels) and woody vegetation (green pixels). In some areas errors can be seen where the overlaid geometry does not match the actual position of the stream.

Apart from the geometry issues, CRA stream order data also cause connectivity issues at the farm dams, lakes, and other structures (Figure 5) shown in images. The higher stream orders appear to cross over some water bodies because the boundaries of those water bodies were not captured or updated within the CRA dataset. Since the CRA data were compiled, many farm dams have been built and are clearly visible in the latest imagery like SPOT5 or (ADS40). At those places the actual riparian buffers are omitted, and this has caused some minor inaccuracies in the riparian vegetation extent data.

Figure 5 Inaccuracies in the CRA stream order data

In this image, some bodies of water (dark blue areas) formed after the CRA stream order dataset was compiled. As a result, data for riparian vegetation (e.g. yellow to grey pixels) generated inaccurately over these areas.

3.3 Geoprocessing

The first stage of the geoprocessing mainly involved selection and extraction of data for the required drainage layers. After the data for higher stream orders and 30-metre buffer zones were generated, the layers for the NSW Office of Water's RVE and HRNVE datasets were masked out on a 1:250,000 or a 1:100,000 topographic map scale, depending upon the density of the drainage lines.

During geoprocessing, we performed seven main steps:

1. Reproject the CRA stream order data. All the vector datasets were reprojected to the Lambert Projection for NSW that is based on the GDA94 datum. Its geographic co-ordinates were used so that the angular units were automatically converted to metres.
2. Select, by attributes, streams with third or higher order from CRA stream order data. From the main CRA stream order coverage a selection of higher stream orders greater than or equal to three was queried using simple Structured Query Language (SQL). After selecting the required data it was exported to a new layer which was used for our project.
3. Clip to the extent of 1:100,000 or 1:250,000 topographic map tiles. The stream datasets were clipped to 1:250,000 scale to make the data more manageable.
4. Set the riparian buffer width to 30 m and dissolve the stream order data. A 30-metre width for riparian buffer zones was applied consistently to all the selected third and higher stream orders throughout NSW. The 30-metre width was recommended by riparian ecologists within the NSW Office of Water.
5. Extract by mask using the Spatial Analyst Tool in ArcGIS®. The DECC INVE and Hybrid Native Vegetation Extent (HNVE) layers were masked out separately using the 30-metre dissolved buffers. The masking process was repetitive, so batch processing was used to automate it.
6. Check accuracy by comparing the NSW Office of Water's RVE dataset with high resolution imagery. The RVE dataset was verified on-screen using SPOT5 and/or airborne digital sensor (ADS)-40 images to identify any discrepancies, for example in geometry issues of riparian buffer extents (RBEs), vegetation classes, pixel shifts or missing data.
7. Mosaic and attribute the NSW Office of Water's RVE layer. The derived riparian extent datasets at 1:100,000 and/or 250,000 topographic map scales were mosaiced. After the final mosaic was completed, the relevant classes were attributed by joining the tables from the original INVE dataset (DECC, 2008).

4. ACCURACY ASSESSMENT

The NSW Office of Water's RVE dataset's "woody" and "non-woody" classifications were compared with SPOT5 imagery by applying image interpretation techniques. An accuracy assessment report was generated to determine the quality of the "woody" and "non-woody" classifications. This was done by developing contingency tables (matrix) to calculate the producer's, user's and overall accuracies together with the values for errors of commission and omission.

The random sampling technique was applied to select sample sites. A total of 400 random sample points were generated within 30-metre riparian buffer zones for each 1:100,000 map.

The number of random samples that were used varied for maps of the coastal areas because sampling sites were deleted if they were generated for areas covered by ocean. A separate geodatabase was generated for selected 1:100,000 topographic scale maps to build an error matrix (Story and Congalton, 1986).

Therefore, all accuracy estimates were restricted to the individual 1:100,000 maps only and were not necessarily valid for larger areas. The accuracy assessment was performed on a backdrop of SPOT5 satellite imagery and/or ADS40 aerial photograph imagery. The images were assumed to be accurate and represented ground-truthing information. However, there may have been a small number of errors of interpretation because there is a likelihood of misinterpreting the difference between “woody” and “non-woody” vegetation classes due to their similar density and texture.

The steps in accuracy assessment were:

— Generate random points. For each 1:100,000 topographic map, 400 random sample points were generated and were saved as separate shape files.

— Create a 25 m vector grid for sampling. A 25 x 25 m grid (fishnet) was generated to match the pixel size of the NSW Office of Water’s RVE dataset. This assisted the accurate location of sample sites and their interpretation.

— Compare the randomly sampled “woody” and “non-woody” pixels with the ADS40 and/or SPOT5 imagery, and classify the vegetation at the sample site as “woody” or “non-woody”, including the riparian buffer extents.

Figure 6 Random sampling over the extracted riparian data and overlay of fishnet

A SPOT5 image overlaid with NSW Office of Water’s RVE data, and showing randomly sampled points indicated by red crosses.

Error matrices or contingency tables were used to compare the relationship between SPOT5 and ADS40 imagery with the corresponding results from the NSW Office of Water’s RVE data. The comparison was made on the basis of “woody” and “non-woody” classifications. The matrices were square, with the number of rows and columns equal to the number of categories whose classification accuracy was being assessed (Lillesand, 1994).

Table 1 shows the standard format of error matrix that was applied to this process of accuracy assessment. The relationship between the NSW Office of Water’s RVE dataset and the imagery from SPOT5 and/or ADS40 was usually summarised in an error matrix.

Table 1 Error matrix table

NSW Office of Water's RVE data set	SPOT5 and/or ADS40 imagery Classes:	Woody	Non-woody	Row totals
Woody		a	b	c
Non-woody		d	e	f
Column totals		g	h	*n*

n = total number of random samples (pixels)

Values in the horizontal rows normally correspond to the "woody" and "non-woody" classes of the NSW Office of Water's RVE layer. The vertical columns show the referenced backdrop of SPOT5 imagery interpretation. Values in the cells in the matrix are a count of pixels, which is based on information derived from the class assignments of pixels in both the classified data and the reference SPOT5 imagery.

This contingency (error) matrix table could be further evaluated to generate the following values:

- overall accuracy
- user's accuracy
- producer's accuracy
- errors of commission and omission.

Overall accuracy. The overall accuracy is calculated by summing the number of pixels classified correctly, and dividing the sum by the total number of pixels. The pixels classified correctly are found along the diagonal within the confusion (error) matrix table which lists the number of pixels that were classified into the correct ground truth class. The matrix cell values on the diagonal (a, e) represent a pixel count of correctly classified pixels. The sum of the diagonal cells in the matrix (a + e) represents the total number of correctly classified pixels. The value of "n" is the total number of random samples.

User's accuracy. These values are calculated by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total). The values for user's accuracy would be "a/c" and "e/f" for the "woody" and "non-woody" classes respectively (Lillesand, 1994).

Producer's accuracy. This is a measure of how much of the area in each category has been classified accurately, so the total number of diagonal cells of the error matrix divided by the value for the column total would give the producer's accuracy ("a/g" and "e/h" for the respective classes).

Errors of commission and errors of omission. Finally, from the error matrix table, errors of commission (errors of inclusion) and omission (errors of exclusion) were generated. Commission errors occur when an area is included into a category when it does not belong to that category. Omission errors occur when an area is excluded from a category when it truly does belong to that category (Congalton and Green 1999). Thus errors of commission can be calculated by “b/g” and “d/h” for the respective classes. Errors of omission can be calculated by “d/g” and “b/h”.

4.1 Riparian buffer extent (RBE)

The 30-metre riparian buffer widths were also checked against SPOT5 imagery for each sampling point. They are classified into three categories, “exact”, “over” and “under”, to verify the reliability of the defined riparian buffer extents.

Table 2 The accuracy table for riparian buffer extent

CateRB goryE	**RB E perc enta ge (%)**	ExacE t	E/*n*	OverO	O/*n*	Und U er	U/*n*

n = total number of random samples (pixels).

4.2 Stream order classification

Researchers, environmental scientists and many agencies like water management authorities use stream order values to describe the size of particular waterways for many purposes. The stream order value is an important piece of information to know about water courses because it allows classification of drainage based on size.

Figure 7 Representation of the Strahler classification of stream orders

Figure 7 shows the Strahler classification of stream orders that was used for this project. It provides a hierarchical classification of waterways based on the size of their channels and their position within a drainage basin. In the Strahler classification, second order streams combine with other second order streams to form third order streams. Third order streams combine to form fourth order streams, and so on. This method of classifying stream size is important as it gives the idea of the size and strength of specific waterways within stream networks, which is an important component of water management. In addition, classifying stream order facilitates study of the amount of sediment in an area, to support more effective use of waterways as natural resources, especially where riparian vegetation influences the health of waterways. Thus stream order is an effective measure for classifying waterways. Classification of stream orders is a crucial step in understanding and managing the riparian vegetation between various streams of different sizes, and can be used to prioritise streams for restoration purposes.

An additional stream order classification was undertaken to provide stream order data for the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee and Murray CMA areas and to fill the gaps in the CRA stream order data for the coastal catchments. This work was done according to the catchment boundaries, rather than the CMA boundaries because the catchment boundaries more accurately match the natural watershed. Also, the Rivex software has size limitations, and could be used more accurately on the basis of the smaller catchment areas, compared to CMA areas.

Topo-Hydroline drainage data from the Department of Lands was used to provide the additional stream order classification. This data contained many topological errors which required editing and correction before it could be used for stream order classification. Topology was used primarily for quality assurance of the data, and to allow the geodatabase to represent geographic features (ESRI, 2007).

After the topological editing was completed the required Hydro-Line layer could be used as an input for stream order classification. Strahler attribution was the final stage of the process in RivEX, followed by manual checks for quality assurance (QA).

During the quality assurance process, a list of errors was identified and generated for the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee and Murray CMA areas. The errors resulted from inaccuracies in the Hydroline dataset.

Table 3 Errors generated from Hydroline data for the Murray and Murrumbidgee catchments

Errors	**Count**	Disconnected polylines	955	Self intersecting polylines	1721	Sources within network	1682

The more powerful algorithms of RivEX tools were able to generate this list of data errors, which were undetected by ArcGIS, illustrating the limitations of the topological edit tools in ArcGIS. RivEX implements a fast recursive algorithm to calculate Strahler stream order. The excluded river bank information should be merged with manual editing, because of software limitations (Gleyzer *et al*, 2004).

5. RESULTS

5.1 Stream order

For the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee and Murray CMA areas, and for the gaps in data for the NSW coast, stream order classification was achieved using the Topo-Hydroline dataset, as previously described.

Figure 8 Generation of new stream order data for the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee and Murray CMA areas, and data gaps on the coast of NSW

Table 4 and Figure 8 give the areas where additional stream ordering was undertaken.

Table 4 CMAs and catchments for which stream order coverage was completed

CMA	Catchment	Coverage of stream order data
Border Rivers Gwydir	Macintyre, –Gwydir River	complete
Central West	Castlereagh, Macquarie	complete
Hawkesbury–Nepean	Hawkesbury	complete
Hunter Central Rivers	Lake –Macquarie – Tuggerah Lakes	complete
Lachlan	Lachlan	complete
Murray	Murray	complete
Murrumbidgee	[illegible]	[illegible]

5.2 Extent of riparian vegetation

Our project delivered two products:

- NSW Office of Water's RVE dataset
- NSW Office of Water's HRNVE dataset.

These datasets are binary vegetation extent grids (25 m) derived from the INVE dataset (DECC, 2008) which includes "woody" and "non-woody" classes.

Our secondary product, the HRNVE dataset, consists of 10 different classes:

- non-woody—(most likely) native
- non-woody—(most likely) non-native
- non-woody—(likely) native
- non-woody—(likely) non-native
- non-woody—(K&S[1]) native
- woody—(most likely) native
- woody—(most likely) non-native
- woody—(likely) native
- woody—(likely) non-native
- woody—(K&S) native.

This data provides complete coverage for the Border Rivers – Gwydir, Namoi, Central West, Lachlan, Murrumbidgee, Murray and all coastal CMA areas, and the Australian Capital Territory (ACT).

Figure 9 The extent of riparian vegetation for which data were completed by the NSW Office of Water

5.3 Riparian vegetation statistics

The data extracted from the NSW Office of Water's RVE dataset were used for further interpretation by deriving statistics relative to CMA administration boundaries. Table 5 gives the extent of riparian vegetation, and the percentages of "woody" and "non-woody" classes of vegetation for individual CMA areas. Table 9 gives the extent of riparian vegetation and the percentages of "woody" and "non-woody" classes of vegetation for individual catchments. Tables (6 to 8) give the extent of riparian vegetation, and the percentages of the derived HRNVE dataset classes of vegetation relative to individual CMA areas.

[1] "K&S" refers to the Keith and Simpson native vegetation extent data.

Table 5 The extent of classes of riparian vegetation in CMA areas, derived from the NSW Office of Water's RVE dataset

CMA	Riparian (ha)	Woody (ha)	Woody (%)	Non-woody (ha)	Non-woody (%)	Others (ha)	Others (%)	Coverage
[redacted] Border Rivers – Gwydir	1344 03.9	614246.8 4.9		710952.9 6.9		18821.4 .1		Full
[redacted] Central West	1713 89.6	645137.6 0.5		106061.8 02.9		876. 2	0.5	Full
[redacted] Hawkesbury – Nepean	1001 01.8	757975.7 1.6		181218.1 4.2		61866.2 .0		Full
[redacted] Hunter – Central Rivers	1634103 –90.7	43.4						

Table 6 The extent of riparian, native vegetation in the Border Rivers – Gwydir, Namoi, Northern Rivers, and Southern Rivers CMAs, derived from the NSW Office of Water's HRNVE dataset

CMA:	**Border Rivers – Gwydir**	**Namoi**	**Northern Rivers**	**Southern Rivers**	[redacted]	**Class**	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	[redacted]	Non-woody—(most likely) native	380528.35.1	443538.50.4	553823.21.6	217916.05.1	[redacted]	Non-woody—(most likely) non-native	92176.8.4	78246.8.1	34901.5.3	13051.0.4	[redacted]	Non-woody—(likely) native	196514.65.4	142412.44.4	21048.84.4

“K&S” refers to the Keith and Simpson native vegetation extent data.

Table 7 The extent of riparian, native vegetation in the Sydney Metropolitan, Murray, Murrumbidgee and Hawkesbury – Nepean CMAs, derived from the NSW Office of Water's HRNVE dataset

CMA:	Sydney Metropolitan	Murray	Murrumbidgee	Hawkesbury – Nepean	[redacted]	Class	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	[redacted]	Non-woody—(most likely) native	102.6	1.3	250525.5 9.6	723840.6 8.3	105710.6 2.7	[redacted]	Non-woody—(most likely) non-native	15.3	0.2 .8	60936.2	17099.6 0.4	629.6	0.6	[redacted]	Non-woody—(likely) native	188.8	2.3	176618.0 8.8	271915.2 9.3

“K&S” refers to the Keith and Simpson native vegetation extent data.

Table 8 The extent of riparian, native vegetation in the Hunter – Central Rivers, Central West and Lachlan CMAs, derived from the NSW Office of Water's HRNVE dataset

CMA:	**Hunter –Central Rivers**	**Central West**	**Lachlan**	[redacted]	**Class**	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	**Area (ha)**	**Percentage (%)**	[redacted]	Non-woody—(most likely) native	296918.2 7.0	545931.8 8.6	559642.2 4.5	[redacted]	Non-woody—(most likely) non-native	22101.4 .4	11896.9 1.3	10578.0 5.0	[redacted]	Non-woody—(likely) native	214213.1 6.5	363821.2 6.3	238718.0 9.5	[redacted]	Non-woody—(likely) non-native	11940.7 .2	31611.8 .9	166… .3

“K&S” refers to the Keith and Simpson native vegetation extent data.

5.4 Accuracy estimation

Assessment of the accuracy of our remote-sensing data products is ongoing, with increasing attention to its results because of the immense value that it adds to the data. “A classification is not complete until its accuracy is assessed”, (Lillesand, 1994). One of the most common means of expressing classification accuracy is by preparing a classification error matrix. For our project, error matrices were compared by category basis as “woody” and “non-woody” classes against SPOT5 and/or ADS40 imagery. An accuracy estimation of the extent of riparian buffers was also included, and the results were classified as “over”, “under”, and “exact”.

Accuracy estimation was performed on 25% of the randomly selected 1:100,000 topographic maps. For example, the results of accuracy assessment of 51 topographic maps are listed in Table 9.This accuracy assessment report provides valuable information for the data custodians of the Interim Native Vegetation Extent (INVE) dataset (DECC 2008) for its ongoing refinement.

Table 10 gives the accuracy estimation of the riparian buffer extents from the generated riparian buffers and the extracted riparian vegetation extent. These accuracy reports provide excellent background information about the reliability and quality of our riparian vegetation dataset products, both for users and data custodians.

Table 9 Detailed accuracy assessments of the derived riparian vegetation extent for 1:100,000 topographic maps

1:100,000 topographic maps	Total random samples	Producer's accuracy (%)		User's accuracy (%)		Overall accuracy (%)	Errors of commission (%)		Errors of omission (%)	
[redacted]		Woody	Non-woody	Woody	Non-woody		Woody	Non-woody	Woody	Non-woody
[redacted] Ashford_9139	401	79.8	87.9	78.7	88.6	85.0	21.5 0	11.2	20.1	12.0
[redacted] Ballina_9640	92	60.8	79.7	50.0	85.9	75.0	60.8	13.0	39.1	20.2

Table 10 Accuracy report on riparian buffer extents at 1:100,000 map scale

1:100,000 topographic maps	Exact (%)	Over (%)	Under (%)	1:100,000 topographic maps	Exact (%)	Over (%)	Under (%)	[redacted]	Ashford_09139	95.00	3.50	1.50	Inverell_09138	94.70	5.00	0.30	[redacted]	Ballina_90640	76.0	24.00	nil	Jerilderie_8027	83.0	5.70	11.20	[redacted]	BarePoint_9538	94.50	5

6. RECOMMENDATIONS

We recommend completion of the NSW Riparian Vegetation Extent for Monitoring, Evaluation and Reporting Purposes Project by the NSW Office of Water.

The benefits of the NSW Riparian Vegetation Extent for Monitoring, Evaluation and Reporting Purposes Project are:

- A complete baseline dataset for the extent of riparian vegetation for use in environmental monitoring and evaluation for individual catchments, CMA areas and (if completed) for the whole of NSW.
- A tool for reporting on a regional scale.
- A stream order classification layer covering individual catchments, CMA areas and (if completed) the whole of NSW.
- Statistics on the extent of "woody" and "non-woody" riparian vegetation classes covering individual catchments, CMAs and (if completed) the whole of NSW.
- The capacity to incorporate updated data from the DECC INVE dataset through generation of time-series data, which can also provide land-use land cover and change-detection within the riparian zones.
- Accuracy assessment reports that could be used to update and refine the DECC INVE data. This information could provide substantial savings in time during updating of the INVE dataset.
- Accuracy values that add immensely to the value of both the DECC and NSW Office of Water's datasets.

Together with the NSW Office of Water's RVE and HNRVE datasets, the project has had outcomes including:

- Data have been provided to all the relevant CMAs and some local government councils.
- Additional statistics for stressed sub-catchments have been supplied to the Hunter Catchment Management Authority.
- Data on riparian vegetation extent within 100-metre buffer zones for estuarine areas were generated for the former DECC, and are being used by DECCW to generate statistics.
- Accuracy assessment reports providing in-depth feedback about the classification of "woody" and "non-woody" classes of riparian vegetation. These reports can be used for future refinement of the DECC INVE dataset.
- RBE (riparian buffer extent) results to provide feedback for quality assurance of the geometry of the drainage data.
- Requests from various government agencies for the NSW Office of Water's extended coverage of Strahler stream order data for NSW.

To complete a NSW Office of Water RVE dataset for the whole of NSW, we recommend:

- Investigation of whether high resolution data for vegetation can be used as a basis for a riparian vegetation extent dataset. It may produce significantly more accurate riparian land-cover classifications than the present 25 m INVE data used in our project.
- Preparation of an accurate, state-wide coverage of the drainage layer for NSW. The layer must have stream order classification and its network connectivity and geometry must be

accurate. The layer must also include river-bank information which should accurately align with the centreline of the drainage lines. Better and definite connectivity is needed at various scales between the polylines of the drainage layer to optimise the performance of the available geospatial software and to save time. We recommend topological correction of vector datasets by their custodians.

— Continuation of the work to complete stream order values and stream network coverage for the Western and Lower Murray – Darling CMA areas. This task would be best completed by collecting high resolution digital elevation models (DEMs), preferably extracted from the available LiDAR data.

ABBREVIATIONS

ACT	Australian Capital Territory
[redacted]	
ADS	airborne digital sensor
CMA	catchment management authority
CRA	comprehensive regional assessment data (generated by Forests NSW, within the former NSW Department of Primary Industries)
DECC	the former NSW Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water
DEM	digital elevation model
DNR	the former NSW Department of Natural Resources
DoL	the former NSW Department of Lands
DWE	the former NSW Department of Water and Energy

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BIOGRAPHICAL NOTES

1.Mr.**Narsimha Garlapati** holds an MSc by research degree from Monash University 2009 by submitting a thesis "Lang Lang Catchment canopy cover changes (1947–2004): Exemplifying increased significance of time series air photo archive in catchment management". His previous publications were especially related to land use and land cover changes, time-series mapping of canopy cover changes on Lang Lang catchment, Victoria, Australia. He also holds an MSc in Applied Geosciences from Osmania University in 1999. He has been a young professional member of the SSSI-Australia since 2005. He has gained experience in photogrammetry, image processing to build historical digital spatial databases, hydrological modelling, stream ordering for large scale areas, navigational mapping, LiDAR and also in emerging GPS technologies. Since 2008 he has been working as a spatial analyst in the NSW Office of Water, focussing on natural resource management projects.

2. Mr **Mustak Shaikh** holds a Master of Engineering Science degree from the University of New South Wales and a Master of Science degree from Maharaja Sayajirao University of Baroda. He has 20 years of experience in applying remote sensing for natural resources, in particular for wetlands, environmental flows, vegetation and compliance related issues. He has authored more than 20 publications.

3. Mr **Mick Dwyer** has 35 years experience in natural resource information management and in provision of natural resource products. During that time he was responsible for management of state-wide GIS strategies and programs related to integrated land and vegetation resource planning and assessment, and for management of corporate natural resource databases. Sustainable natural resource management policies, practices, guidelines and recommendations are reliant on the validity and accessibility of this information.

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