THE ASSESSMENT AND MANAGEMENT OF FLOODGATES ON THE NSW SOUTH COAST

REPORT TO THE NATURAL HERITAGE TRUST

Natural Heritage Trust

Helping Communities Helping Australia

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Cover photo: Hinged flap floodgate structure (MANN043F) located on Croakers Creek in the Lower North Coast subregion of the Hunter/Central Rivers CMA.

EXECUTIVE SUMMARY

Stream connectivity and habitat diversity are critical components of healthy rivers. Many fish have evolved to be reliant on a variety of different habitat types throughout their life cycle. The free passage of fish within rivers and streams and between estuarine and freshwater environments is a critical aspect of aquatic ecology in coastal NSW.

The presence of instream structures can affect the health of aquatic habitat and fish populations. Floodgates, traditionally one-way hinged flap structures used to prevent flood and tidal waters from inundating low-lying land, can prevent fish passage by creating a physical blockage, a hydrological barrier, or by forming artificial conditions that act as behavioural barriers to fish. The presence of floodgates can also lead to the fragmentation and degradation of upstream aquatic habitat, as well as a reduction in water quality and the potential exposure of acid sulfate soils (ASS). The exposure of ASS affects water quality by lowering dissolved oxygen and pH levels, having detrimental impacts on the surrounding environment and aquatic biota.

Although current policy within NSW legislates the incorporation of fish passage into the design of all new instream structures, a legacy of poorly designed and passively managed floodgate structures exists that detrimentally affects fish migration. As a result, the NSW Department of Primary Industries (NSW DPI) commenced a comprehensive investigation funded by the Natural Heritage Trust to specifically address the impact of floodgates upon fish passage and stream connectivity in coastal catchments.

Detailed field assessments were conducted along the NSW South Coast, which for this project was defined as the area from the Manning catchment in the Hunter/Central Rivers CMA region, to the Victorian border. Primary findings from this assessment include:

- A total of 521 floodgates assessed in the NSW South Coast region.
- Of the assessed floodgates, 383 were identified as obstructions to fish passage and recommended for remediation.
- The greatest number of obstructions to fish passage were identified in the Hunter/Central Rivers CMA (322 sites) and Southern Rivers CMA (50 sites) regions.
- The traditional hinged flap design accounted for 76% of the structures recommended for remediation, with winch modifications representing 20% of recommended sites.

Floodgates that were recommended for remediation were then divided into their respective CMA region and prioritised in terms of their impact on aquatic biodiversity. This process classified structures as either ‘high’, ‘medium’ or ‘low’ priority sites, with 73 high priority structures identified overall. Some of the major regional findings include:

- Hunter/Central Rivers CMA area
  - 52 structures were classified as high priority, with 56% of these sites located in the Hunter subregion and 44% found in the Lower North Coast subregion.
- Hawkesbury-Nepean CMA area
  - Ten sites were recommended for remediation, with two of these sites classified as high priority.
- Sydney Metropolitan CMA area
  - Only one structure was recommended for remediation, with the structure being a winch design floodgate that was classified as a high priority site.
- Southern Rivers CMA area
  - 50 sites were recommended for remediation, with 18 sites classified as high priority. Floodgate barriers identified in the SRCMA region were located in the Shoalhaven-Wollongong (98%) and the Bega-Eden (2%) subregions.

The top priority sites within each CMA region were identified to provide an initial understanding of the management actions required within each CMA area and highlight the potential benefits that would be achieved from remediation. In the Hunter/Central Rivers CMA area this benefit would include improved access to over 350 km of aquatic habitat, including in excess of 3,500 Ha of wetland habitat, if the top ten priority sites were remediated. Similarly, if the top ten sites were remediated in the Southern Rivers CMA region over 300 km of aquatic habitat, including over 2,100 Ha of wetland area would be reinstated. In the Hawkesbury-Nepean CMA region approximately 11 km of habitat would be reinstated if the top two priority sites were remediated, whilst in the Sydney Metropolitan CMA area, aquatic biota would have improved access to 3 km of aquatic habitat from remediation of the top priority site.

Overall, a range of remediation options were suggested for priority sites including:

- Removal – recommended for redundant structures.
- Basic management/maintenance – suggested for sites that had been adequately modified for fish passage to ensure continued active management at the structure;
- Modification of current active management – recommended for priority sites that had previously been modified but the design and/or management of the modification was inadequate for fish passage, and;
- Active floodgate management – recommended for sites that had no current management modification in place, with further detailed investigations required to determine detailed designs for active management.

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The NSW DPI Fisheries (Conservation and Aquaculture) Aquatic Habitat Rehabilitation Program team managed the project including research, fieldwork and report preparation. Valuable assistance was also provided from regional NSW DPI Fisheries conservation staff and compliance officers. Personnel involved in data collection, data analysis and report writing were: Anthony Townsend, Simon Walsh, Dr Matthew Gordos, Scott Nichols and Cameron Lay. Maps were produced by Ben Maddox.

The four coastal Catchment Management Authorities within the study area provided helpful advice towards the project, whilst the Department of Natural Resources (Hunter Region), local Councils, landholders and farmers provided valuable advice and assistance in locating and accessing structures during the project.

CONTENTS

1. Introduction

The following document outlines results of a project entitled '*The Assessment and Management of Floodgates on the NSW South Coast*'. The project was carried out by the NSW Department of Primary Industries (Fisheries, Conservation and Aquaculture) on behalf of the Southern Rivers CMA, with funding provided by the Natural Heritage Trust Program as part of the 'Bringing Back the Fish' project (Contract No. 2006-03). This document is a report for the NSW South Coast, encompassing the Hunter/Central Rivers, Hawkesbury-Nepean, Sydney Metropolitan, and Southern Rivers Catchment Management Authority (CMA) regions.

1.1 Project aims and objectives

This project was developed to identify and prioritise floodgate structures for remediation in all coastal-draining catchments of southern NSW, completing a comprehensive database of floodgates on the NSW coast with the northern catchments of the state audited during an earlier NSW DPI project. This document outlines the findings of the study relevant to the south coast region, which for this project has been defined as the area from the Manning catchment in the Hunter/Central Rivers CMA area down to the Victorian border.

The primary objectives and outcomes of the project were to:

- Identify and assess the impacts of floodgates on aquatic habitat and fish passage along the south coast of NSW;
- Complete a field inventory of floodgate structures and identify other environmental impacts on aquatic habitat associated with floodgates;
- Develop an aquatic habitat management database and establish environmental auditing protocols for assessing floodgates;
- Demonstrate options for remediation and improved management of floodgates;
- Encourage remediation of priority sites with structure owners, and promote 'fish-friendly' principles for application in future instream works; and
- Increase awareness of the importance of fish passage and aquatic habitat management for floodgate management authorities and the broader community.

2. Background

2.1 Fish passage in NSW

Stream connectivity and habitat diversity are critical components of healthy rivers. Many fish have evolved to be reliant on a variety of different habitat types throughout their life cycle. The free passage of fish within rivers and streams and between estuarine and freshwater environments is a critical aspect of aquatic ecology in coastal NSW.

Approximately 70 percent of the coastal fish species in south-eastern Australia migrate as part of their lifecycles (Fairfull and Witheridge, 2003). These include key species such as Australian bass, sea mullet, short-finned and long-finned eels, freshwater mullet and freshwater herring. Recent NSW DPI research in the Murray-Darling basin has indicated that a much higher percentage of native fish undertake some form of migration than previously thought (Baumgartner, 2006.). In the coastal catchments of NSW, this trend is also likely to apply as our knowledge of coastal fish biology and behaviour develops through ongoing research and monitoring.

Impeding fish passage through the construction of dams, weirs, floodgates and waterway crossings can negatively impact native fish by:

- Interrupting spawning or seasonal migrations;
- Restricting access to preferred habitat and available food resources;
- Reducing genetic flow between populations;

- Increasing susceptibility to predation and disease through accumulations below barriers;
- Fragmenting previously continuous communities; and
- Disrupting downstream movement of adults and impeding larval drift through the creation of still water (lentic) environments.

For fish that have large-scale migrations in their life cycles, preventing fish passage can cause local extinctions above barriers and reduce population numbers downstream (Thorncraft and Harris, 2000).

The importance of free fish passage for native fish is recognised under the *Fisheries Management Act* 1994 (FM Act), which has provisions specifically dealing with the blocking of fish passage. In addition, the installation and operation of instream structures, and the alteration of natural flow regimes, have been recognised as *Key Threatening Processes* under the FM Act and the *Threatened Species Conservation Act* 1995.

These legislative tools, and associated NSW Government policies on fish passage, act to regulate the construction of structures that may be barriers to fish passage. In addition, reinstating connectivity between upstream and downstream habitats and adjacent riparian and floodplain habitats has become an essential part of aquatic habitat management and rehabilitation programs in NSW.

2.2 Impacts of floodgates on the aquatic environment

Floodgates are one-way hinged flap structures that seal against a vertical face, and are commonly found on coastal floodplain drainage systems. They play a significant role in preventing saline tidal water from inundating low-lying agricultural land, as well as preventing river rises from backflooding urban and rural areas (Johnston *et al*., 2003). However, the installation of these structures along the coastal waters of NSW has resulted in numerous negative impacts on the aquatic habitat and biodiversity of the region. This includes the restriction of fish passage, the fragmentation and degradation of aquatic habitat, the reduction of water quality, and the potential exposure of acid sulfate soils (ASS).

The passive design of the majority of floodgate structures presents an obvious physical barrier that directly impacts fish passage between estuaries and tidal tributaries, especially when the hinged flap is in the closed position. This can have a significant impact on the population of estuarine fish species, principally those that are either anadromous[7], catadromous[8], or amphidromous[9], by restricting their passage to important estuarine nursery and feeding grounds (Johnston *et al*., 2003). Impacts include a reduction in juvenile fish recruitment and the depletion of key freshwater and estuarine stocks such as Australian bass (*Macquaria novemaculeata*), long- and short-finned eels (*Anguilla reinhardtii* and *A. australis*), yellowfin bream (*Acanthopagrus australis*), and sea mullet (*Mugil cephalus*). The impact of floodgates on fish passage also reduces species diversity in a waterway, creating two distinct fish assemblages above and below floodgate structures, with freshwater species dominating the waters above and estuarine-marine species dominating below the floodgate (Pollard and Hannan, 1994; Gibbs *et al*., 1999).

The presence of floodgates in a system also results in the fragmentation, alienation and loss of aquatic habitat; with the clearing of land and modification of channels above floodgate structures for agricultural purposes contributing to the degradation of aquatic habitat (Johnston *et al*., 2003). Fragmenting waterways and reducing tidal exchange directly affects aquatic habitat by creating homogenous conditions unfavourable for the recruitment of important estuarine vegetation such as mangroves and seagrasses, with the prevailing environment favouring the introduction of weed species. The clearing of riparian vegetation also favours the prevalence of weed species, as well as indirectly affecting the aquatic biota

[7] Fish that spend most of their life in the sea and migrate to fresh water to breed
[8] Fish that spend most of their life in fresh water and migrate to the sea to breed
[9] Fish that migrate between sea and fresh water, but not for the purpose of breeding

of the waterway by decreasing the supply of food and habitat, and decreasing water quality through nutrient and sediment runoff.

Water quality is also directly impacted by the presence of floodgate structures, predominantly by blocking water exchange. The stagnant water that is often found behind floodgates encourages the accumulation of organic matter, promoting high nutrient levels and episodic algal blooms, as well as reducing water quality through low dissolved oxygen levels and low pH levels in the drain water (Johnston *et al*., 2003).

Deoxygenation and acidification are also associated with ASS, which occur when natural sulfidic sediments that are close to the ground surface are exposed to air and oxidised (Wilson *et al*., 1999). The creation of sulfuric acid also mobilises iron and aluminium ions that are stripped from the surrounding soils (Gibbs *et al*., 1999). When these sediments enter the waterway, either through groundwater seepage or surface run-off, acidic and toxic waters are created, resulting in detrimental effects to the environment and associated biota.

The lowering of pH, and the subsequent creation of iron and aluminium flocs that binds to clay particles, may have the following impacts on the aquatic environment and biota:

- Mortality of fish and invertebrates from acid kills, toxicity kills, suffocation from flocs, and lack of dissolved oxygen;
- Increased susceptibility to disease, especially epizootic ulcerative syndrome (EUS) or ‘redspot’ disease;
- Physiological effects related to reduced growth, visual and olfactory impairment, and bone disorders; and
- Avoidance responses during the movement of aquatic biota (Gibbs *et al*., 1999; Johnston *et al*., 2003).

Acidic and toxic waters can also have a significant impact on the surrounding terrestrial environment, including poor agricultural production in acidified parts of floodplains, corrosion of pipes and cement in associated infrastructure, the acidification of natural aquifers, and potential human health problems from groundwater consumption (Gibbs *et al*., 1999).

The environmental, social and economical impacts that are associated with the installation and operation of floodgate structures have been widely recognised by industry, the public and environmental organisations for several decades (NSW Fisheries, 2002). This recognition has led to the implementation of research and management programs that aim to understand and minimize the potential impacts of floodgates.

2.3 Floodgate management and designs

There are two main forms of floodgate management that have been used in conjunction with the operation of floodgate structures: passive floodgate management and active floodgate management, with both forms having respective advantages and disadvantages.

Passive floodgate management is the traditional method used during the operation of floodgates, which are treated as passive one-way devices. In this approach the structure serves the purpose of draining upstream water from agricultural land and excluding tidal ingress of seawater from downstream. Passive management is predominantly governed by environmental conditions with limited interference from structure owners, and the opening and closing of floodgates is simply controlled by the water level of a drainage system. When the water upstream of a floodgate is higher than that of the downstream side the gates open and water is discharged (NSW Fisheries, 2002). The opposite of this results in the closing of gates, with downstream water that is equal to or higher than the upstream side sealing the floodgate shut (NSW Fisheries, 2002). This style of floodgate management, whilst serving the original purpose of draining and preventing the inundation of low-lying agricultural land, has been attributed with causing many of the impacts described in Section 2.2. These impacts have resulted in the need to adopt a more active management approach during floodgate operation.

Active floodgate management involves the controlled opening of floodgates during non-flood periods to allow tidal water exchange in the drainage system. This form of management usually requires the modification of floodgate structures to allow efficient opening and closing of gates, whilst still allowing for the normal drainage of low-lying land and the control of water levels. The main types of modifications used to actively manage floodgates on coastal floodplains include auto tidal floodgates (Plate 1a), the 'Smart Gate' design (Plate 1b), sluice gates (Plate 1c), and various forms of winch gates (Plate 1d).

<u>Plate 1</u>: Examples of floodgate modification designs including a) tidal floodgate, b) 'Smart Gate', c) sluice gates, and d) winch gates.

Auto tidal designs use a float system to open an aperture within the floodgate, allowing for the tidal exchange of water between systems (Plate 1a). These modifications have the advantage of being automatic in operation and allow for excellent water level control, with the float able to be adjusted to close at preferred water levels (Johnston *et al*., 2003). The 'Smart Gate' design is also automatically operated, with a motor driven winch opening and closing an aperture based on specific water quality parameters (Johnston *et al*., 2003). This modification is a more complex design that doesn't necessarily improve fish passage due to the fluctuations of water quality variables at a structure, which can result in the aperture opening and closing numerous times in a short period or remaining closed over a longer duration.

Sluice gate modifications consist of a sliding plate cover that can be opened and closed either vertically or horizontally over an aperture within the floodgate (Plate 1c). This design provides excellent water level control during non-flood periods, with a variable aperture size making them adaptable to most systems. However, sluice gates require manual operation to open and close the aperture, which can impact on the effectiveness of active management. Manual operation is also needed when actively managing winch modifications (Plate 1d), which consist of a winch and cable system that can open a floodgate either vertically or horizontally (Johnston *et al*., 2003). Although these designs provide excellent fish passage, as the whole floodgate is opened, active management at the site requires intensive manual labour, which can hinder the implementation of management actions.

The benefits associated with active floodgate management are largely related to the frequency and duration of gate opening, and predominantly include:

- Improved fish passage and connectivity between estuarine and drainage habitats;
- Improved habitat condition, including the control of aquatic weeds;
- Enhanced water quality through the controlled exchange of water, which reduces acidity, iron and aluminium flocs, increases stable dissolved oxygen levels, and decreases nutrients and algal blooms: and
- Enhanced wetland habitats upstream (Johnston *et al*., 2003).

When planning to actively manage floodgates and implement a modification or opening program, it is important to consult with local and state authorities, as well as adjacent landholders that may be affected, to gain the relevant approvals and avoid the potential risks associated with opening floodgates. The risks can include flooding, which can result from operator or mechanical failure, and increased salt levels from overtopping of saline water or lateral salt seepage, both of which can impact agricultural productivity and are affected by the hydrology of the surrounding environment (Johnston *et al*., 2003). These potential risks however, can be avoided by undertaking a detailed assessment of the hydrological and hydraulic conditions of the drainage area prior to active management and then commencing a regular maintenance and inspection routine during management actions.

2.4 Waterways of the NSW South Coast

The NSW south coast region defined during this project covers a combined approximate area of 88,900 square kilometres (sqkm). It is bounded in the west by the Great Dividing Range, with the encompassed CMA areas extending seaward to three nautical miles in the east. The extensive region supports a population in excess of five million residents, creating pressure on natural resources through direct use, pollution activities, and tourism.

The south coast area extends from the Manning River at Taree, south to the Victorian border (Figure 1). For reporting purposes the region has been divided into the four recognised CMA areas, highlighting regional and catchment priorities. These include the:

- Hunter/Central Rivers CMA area;
- Hawkesbury-Nepean CMA area;
- Sydney Metropolitan CMA area, and;
- Southern Rivers CMA area.

Hunter/Central Rivers CMA area

The Hunter/Central Rivers CMA (HCRCMA) region covers an area of approximately 36,000 sqkm, extending from just north of Taree to Woy Woy and Brisbane Waters in the south, and supports a population of nearly one million people (NSW DPI, 2006a). This area can be further divided into three subregions; the Lower North Coast subregion, which extends from just north of Taree to just south of the township of Salt Ash and covers an area of 12,700 sqkm; the Hunter subregion, which encompasses all the Hunter River and its tributaries and has a total area of approximately 22,000sqkm; and the Central Coast subregion, which covers an area of 1,600 sqkm from the southern outskirts of Newcastle in the north to Brisbane Water in the south (NSW DPI, 2006a).

The regional centres in the area, which include Taree, Newcastle, Gosford, and Wyong, provide services to the large number of residents and tourists, with the infrastructure concentrated along the coastline. This pressure has resulted in modification of the catchment, causing environmental problems such as a reduction in water quality and the loss of riparian vegetation and aquatic habitat. Intensive landuse practices, such as grazing, dairy, horticulture, mining, and power generation are dependent on waterways of the catchment, whilst recreational and commercial fishing practices that exist in the catchment place extensive pressure on the resources of these waterways (NSW DPI, 2006a).

The infrastructure required to support landuse and aquatic practices, including diversion channels, dams and weirs, has impacted directly on the health and connectivity of river systems, with over 450 of these structures recorded in the catchment and producing major instream barriers to fish passage (NSW DPI, 2006a). Accompanying this infrastructure is the construction of transport networks, which can also impact on the condition of the aquatic environment. Over 420 waterway crossings such as culverts, causeways, and fords have been recorded in the HCRCMA area, with each one having the potential to elevate surface run-off and approximately 360 identified as fish passage barriers (NSW DPI, 2006a).

These anthropogenic impacts affect all waterways within the catchment, especially the major tributaries that include the Manning River in the north, the Hunter River in the centre of the catchment, and the Wyong River in the south. These waterways and their associated tributaries are afforded some protection from the impact of urban and agricultural development by the presence of reserves and protective legislation.

In the north this includes the Myall Lakes National Park and Wallis Island Nature Reserve, as well as the aquatic areas of the Myall Lakes Ramsar Wetland and Port Stephens/Great Lakes Marine Park (NSW DPI, 2006a). In the southern area of the catchment the waterways are protected by the presence of State Forests and National Parks, including Wollemi, Yengo, and Watagans National Parks, as well as the Ramsar listed Hunter Estuary Wetlands and parts of the Greater Blue Mountains World Heritage Area (NSW DPI, 2006a).

Hawkesbury-Nepean CMA area

The Hawkesbury-Nepean CMA (HNCMA) region covers an area of approximately 22,000 sqkm, extending from the headwaters of the Macdonald River above Putty in the north down to Lake George in the south, and bounded by the Great Dividing Range in the west and draining into Broken Bay in the east. The area can be further divided into two distinct subregions; the Lower Hawkesbury-Nepean subregion, which covers an area of approximately 12,000 sqkm that extends from the outskirts of Gosford in the north to Camden and Picton in the south; and the Upper Hawkesbury-Nepean subregion, which extends from the town of Wallerawang in the north to Lake George in the south and covers an area of approximately 10,030 sqkm (NSW DPI, 2006b).

The area contains over 800,000 residents and includes the major centres of western Sydney including Penrith, Camden and Richmond, as well as southern centres such as Goulburn and Lithgow (NSW DPI, 2006b).

These centres provide services to the large number of residents in the area, as well as the nearby Sydney region, with the infrastructure required for the services placing pressure on the catchment and aquatic habitat. Intensive landuse practices, such as grazing, dairy, poultry, horticulture, mining, and power generation are dependent on waterways of the catchment, whilst recreational and commercial fishing, aggregate extraction, and provision of drinking water from the catchment place extensive pressure on the aquatic habitat and resources of these waterways (NSW DPI, 2006b).

Infrastructure such as diversion channels, dams and weirs that are required to support these practices have impacted directly on the health and connectivity of river systems in the catchment, with over 150 dams, weirs and tidal barriers recorded in the Hawkesbury-Nepean CMA area (Thorncraft and Harris, 2000).

In addition to this infrastructure, urban development has also modified the catchment, with the construction of both public and private transport networks impacting on the condition of the aquatic environment. Over 480 waterway crossings such as culverts, causeways, and fords have been identified in the Hawkesbury-Nepean CMA area, with 99 of these acting as barriers to fish passage and reducing the condition of aquatic habitat (NSW DPI, 2006b).

The major tributaries that are affected by these impacts include the Hawkesbury River in the north, the Wollondilly River, which drains into Lake Burragorang in the centre of the catchment, and the Nepean, Avon, Cataract and Cordeaux Rivers in the south.

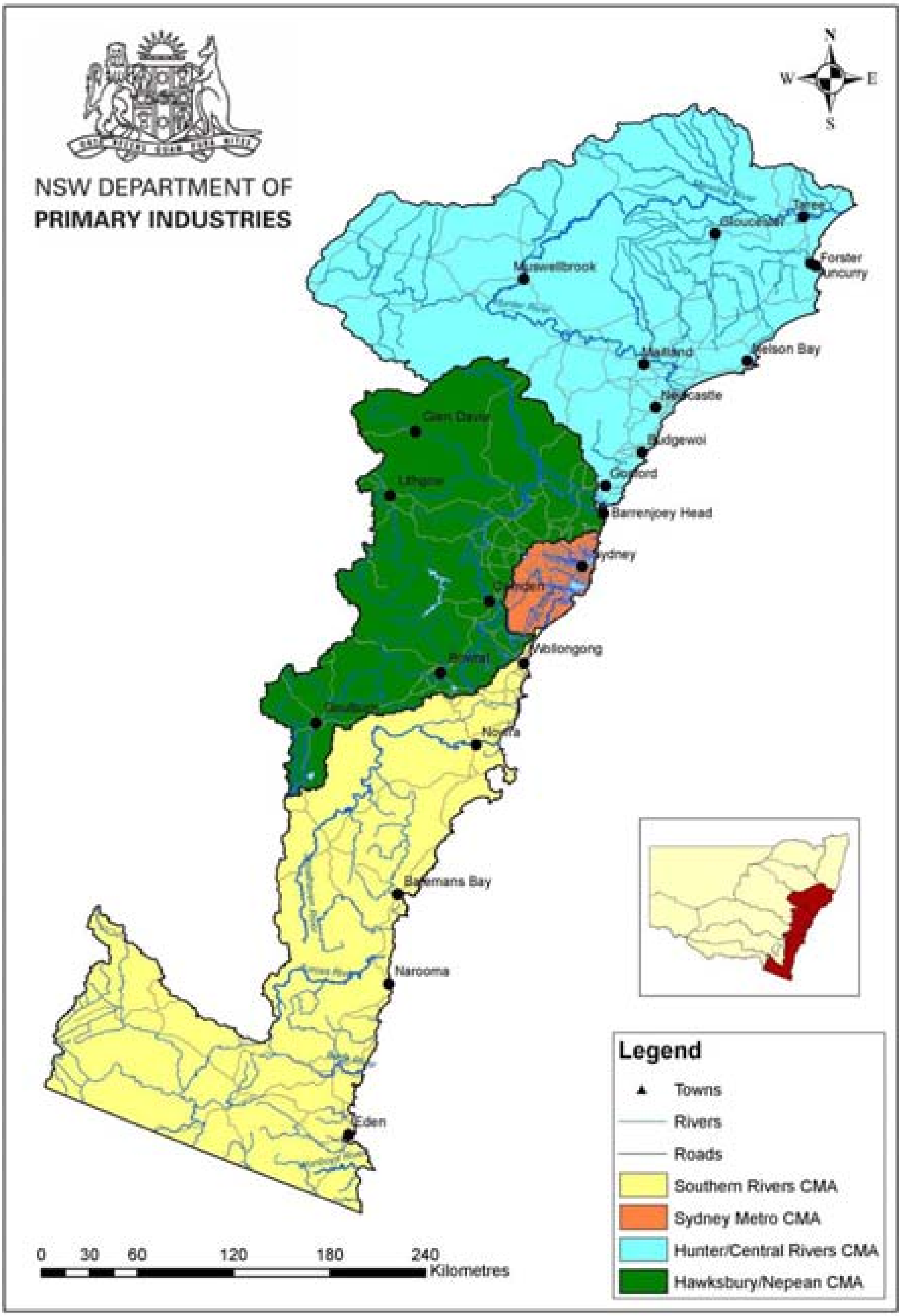

Figure 1: The south coast of NSW, as defined for the project, from the Manning River at Taree down to the Victorian border, highlighting the four CMA areas.

The Hawkesbury River, which is the state's largest estuary, is afforded some protection from the aggregate extractive industries and fishing practices by the presence of National Parks, including Marramarra and Ku-ring-gai Chase, as well as the Barrenjoey Head Aquatic Reserve, which is located at the junction of the Hawkesbury River and the ocean (NSW DPI, 2006b). The catchment areas surrounding Lake Burragorang and the Nepean, Avon, Cataract and Cordeaux Rivers have been designated Water Supply Special Areas due to the fact that these waterways supply approximately 97% of Sydney's drinking water (NSW DPI, 2006b). This classification conserves the condition of the aquatic environment and minimises the potential impact of the surrounding urban and agricultural practices.

Sydney Metropolitan CMA area

The Sydney Metropolitan CMA (SMCMA) region covers an area of approximately 1,900 sqkm and includes all coastal draining waterways that flow to Sydney Harbour and Botany Bay between Narrabeen in the north down to Stanwell Park in the south, and west to Blacktown (Nichols and McGirr, 2005). The Sydney Metropolitan area is the most urbanised and densely populated region in Australia, possessing over 1.5 million permanent residents, in addition to the large amount of tourists who visit the area annually (Nichols and McGirr, 2005).

The extensive urbanisation of the catchment has significantly impacted the aquatic habitat, modifying it through the clearing of aquatic and riparian vegetation, and the creation of impermeable surfaces to provide services to the large number of residents in the area.

Infrastructure such as diversion channels, stormwater drains and flood mitigation systems have resulted in many waterways becoming channelised or piped underground, as well as increased surface run-off, reduced water quality and minimised riparian and aquatic habitat.

Accompanying this development is the construction of extensive transport networks, which impact on the condition of the aquatic environment reducing riparian vegetation and forming instream barriers to fish passage. In the Sydney Metropolitan CMA area over 350 instream structures such as culverts, causeways, weirs and fords have been identified, with 161 waterway crossings requiring remediation to improve the surrounding aquatic habitat and connectivity of waterways (Nichols and McGirr, 2005).

The major tributaries that have been affected by the urbanisation of the Sydney Metropolitan catchment include the Middle Harbour, Lane Cove and Parramatta Rivers in the north, the Georges, Woronora and Cooks Rivers in the centre of the catchment, and the Hacking River in the south of the catchment. All of these waterways and their associated tributaries have been affected by anthropogenic impacts, with only an estimated 3-5% of the Sydney Metropolitan catchment protected by formal reserves (Nichols and McGirr, 2005).

Middle Harbour, Lane Cove and Parramatta Rivers drain into Port Jackson, with the first two waterways afforded some protection from the Lane Cove and Ku-ring-gai Chase National Parks, whilst the Parramatta River catchment has been extensively developed and is drained by highly modified channels (Nichols and McGirr, 2005). Many other waterways in the north shore area have been affected by extensive clearing and development practices (Nichols and McGirr, 2005). Georges River, and the associated Woronora and Cooks Rivers, drain directly into Botany Bay, which is an extensive estuary embayment that has been significantly developed for urban and industrial practices. As a result these waterways have been heavily impacted, with only minimal areas protected by reserve areas such as the Holsworthy Military Reserve in the lower Georges River system. The Hacking River, which feeds into the Port Hacking estuary in the south, is afforded some protection by the presence of the Royal National Park (Nichols and McGirr, 2005).

Southern Rivers CMA area

The Southern Rivers CMA (SRCMA) region covers an area of approximately 29,000 sqkm, extending from Stanwell Park north of Wollongong down to the Victorian border, and is bounded by the Great Dividing Range in the west. For the purpose of this report this area can be further divided into three subregions which include: the Shoalhaven-Wollongong subregion that extends from Stanwell Park in the north to North Durras in the south and covers an approximate area of 7,425 sqkm; the Eurobodalla subregion, which has a total area of 7,060 sqkm that extends from the southern shores of Jervis Bay in the north to Tilba Tilba in the south; and the Bega-Eden subregion, which extends from Wallaga Lake in the north to the Victorian border, covering an area of 6,200 sqkm (NSW DPI, 2005).

The area supports a population of over half a million people, and includes the major regional centres of Wollongong, Kiama, Batemans Bay, Bega and Eden (NSW DPI, 2005). The area is also very popular with tourists, with regional centres swelling during peak periods.

These regional centres provide services to the large number of residents and tourists, with the associated urban and agricultural infrastructure concentrated along the coastline. The pressure resulting from this development has modified the catchment, causing environmental problems such as a reduction in water quality and the loss of riparian vegetation and aquatic habitat. Intensive landuse practices, such as major dairy production, grazing, horticulture, and forestry place pressure on waterways of the catchment, whilst recreational and commercial fishing practices that exist in the catchment, including estuarine fishing, prawn and oyster industries, place additional pressure on aquatic resources (NSW DPI, 2005).

The infrastructure required to support landuse and aquatic practices, including dams, weirs, and tidal barriers, has impacted directly on the health and connectivity of river systems, with over 350 of these structures recorded in the catchment and producing major instream barriers to fish passage (NSW DPI, 2005).

In addition, infrastructure associated with the urban centres of the region, such as transport networks have also impacted on the condition of the aquatic environment. Over 1,600 waterway crossings such as culverts, causeways, and fords have been identified in the Southern Rivers CMA, with approximately 570 of these recorded as barriers to fish passage, significantly affecting the connectivity of the region’s waterways (NSW DPI, 2005).

These modifications to the catchment affect all waterways within the region, especially the major tributaries of the Shoalhaven River in the north, the Clyde and Deua-Moruya Rivers in the centre of the catchment, and the Bega and Nadgee Rivers in the south. Associated with these waterways are numerous estuarine lake and ICOLL systems, including Illawarra Lake, Durras Lake, Tuross Lake, and Wallaga Lake, which are fed by the smaller freshwater floodplain streams (NSW DPI, 2005).

These waterways and their associated tributaries are somewhat protected from the impact of urban and agricultural development by the presence of reserves and protective legislation. In the north this includes the Morton National Park, as well as the Jervis Bay Marine Park, which spans over 100 km of coastline (NSW DPI, 2005). In the central area of the catchment the waterways are protected by the presence of State Forests and National Parks, with the amount of protection provided by these areas making the Clyde River system one of the least-polluted large rivers in eastern Australia (NSW DPI, 2005). This includes the presence of the Deua National Park, as well as the Batemans Marine Park, which conserves marine diversity and habitats in an area that covers 850 sqkm. The southern area of the catchment is also protected by the large presence of reserve areas, with protection along Nadgee River making Nadgee Lake one of the few remaining pristine lakes in NSW (NSW DPI, 2005). The area also includes several SEPP 14 wetlands, with the Bega estuary also declared a Recreational-only Fishing Haven to protect the aquatic resources and habitat.

2.5 Aquatic habitat and biodiversity of the NSW South Coast

The south coast region of NSW as defined for this project encompasses four CMA regions, all of which comprise freshwater, estuarine and marine environments that contain an extensive range of aquatic habitats. These include montane streams, lowland floodplain wetlands and coastal lagoons. Within these broad habitat types, niche habitats such as pools and riffles, gravel beds, snags, aquatic vegetation and riparian vegetation are present, diversifying the habitat available to aquatic species along the NSW south coast.

There is a variety of aquatic and riparian vegetation present within the south coast region. Estuaries within the Hunter/Central Rivers CMA area are characterized by the presence of mangrove and saltmarsh communities, with swamp oak (*Casuarina glauca*) and paperbark (*Melaleuca quinquenervia*) stands dominating freshwater margins and often separated from saltmarsh communities by common reed (*Phragmites australis*) (DEC, 2004). This trend continues down along the coast, with similar sequences evident in the Hawkesbury-Nepean and Sydney Metro CMA regions. However, in the Southern Rivers CMA area estuary vegetation is reduced and supports only small areas of stunted mangrove and salt marsh stands fringed with swamp oak (DEC, 2004). Riparian vegetation in this region is dominated by stands of river oak (*C. cunninghamiana*), which occur all along the NSW south coast, with water gum (*Tristania laurina*) and river red gum (*Eucalyptus camaldulensis*) also present along the river and creek banks of the wetter and more protected areas (DEC, 2004). In addition, the Southern Rivers area also possesses small patches of temperate rainforests with sassafras (*Doryphora sassafras*) occurring along major waterways in protected locations (DEC, 2004).

This extensive range of aquatic and riparian habitat supports a diverse assemblage of species, including over 70 species of finfish (see Appendix A). These native fish populations consist of potamodromous species that undertake migration wholly within freshwater systems, catadromous species, anadromous species, and amphidromous species (Harris *et al*, 1994). This has resulted in the potential widespread distribution of native fish throughout the entire south coast. Twelve of these finfish species are introduced, competing with the native fish species found along the south coast. The pressures from introduced species, as well as other factors such as reduced water quality, increased fishing pressure, and habitat degradation, have resulted in a decline in the population densities of native fish within the waterways of NSW, including those on the south coast.

Of the native fish species, seven are listed as threatened in NSW waters. Important indigenous freshwater species including Macquarie perch[10] (*Macquaria australasica*) and the Australian grayling[4] (*Prototroctes maraena*) have been recorded in the southern areas of the region, with pressures such as habitat degradation, competition, and predation from introduced fish species affecting their populations. The threatened silver perch[4] (*Bidyanus bidyanus*), trout cod[5] (*Maccullochella macquariensis*), and Murray cod[4] (*Maccullochella peelii peelii*) are also present in the NSW south coast waterways as a result of native fish stocking efforts in the area. Waterways of the south coast region also include key threatened and protected estuarine species, such as the black cod[4] (*Epinephelus daemelii*) and the green sawfish[11] (*Pristis zijsron*). These species have been affected by commercial and recreational fishing impacts, as well as the degradation of critical habitats.

The region also supports an array of aquatic macroinvertebrate communities, the majority of which are moderately to significantly impacted due to the pressures associated with river regulation, water extraction and agricultural landuse (Bishop *et al*, 2002). Both the threatened Adams emerald dragonfly[4] (*Archaeophya adamsi*) and Sydney hawk dragonfly[12] (*Austrocordulia leonardi*) have an expected distribution within the aquatic habitats of the south coast region. These rare dragonflies have only been recorded on limited occasions, with activities such as habitat degradation and water pollution affecting their populations.

Over 60 species of frogs are also found along the south coast region including several threatened species such as the Giant burrowing frog, the Green and golden bell frog, the Giant barred frog, the Red-crowned toadlet, the Stuttering frog, Littlejohn's tree frog and the Booroolong frog. Many reptiles are also found in wetlands within the region including skinks, snakes, water dragons and one freshwater turtle, the Eastern long-necked turtle (*Chelodina longicollis*). In addition to this, platypus (*Ornithorhynchus anatinus*) and water rats (*Hydromys chrysogaster*), which are both mammals specialised for freshwater aquatic habitats, can be found in many creeks within the south coast area.

[10] Listed as 'Vulnerable' under the *EPBC Act* and protected under the FM Act.
[4] Listed as 'Vulnerable' under the *EPBC Act* and protected under the FM Act.
[11] Listed as 'Endangered' under the NSW *Threatened Species Conservation Act* 1995.
[12] Listed as 'Vulnerable' under the FM Act.

All these species are dependent on healthy waterways and access to a range of diverse aquatic habitats for their survival. In recognition of this, numerous river and floodplain communities of the catchment areas in the south coast have been listed as an Endangered Ecological Community (EEC), including freshwater wetlands on coastal floodplains, montane peatlands and swamps, Swamp oak floodplain forest, Swamp Sclerophyll forest on coastal floodplains, river flat Eucalypt forest on coastal floodplains, and coastal saltmarsh. This listing includes all native fish and aquatic invertebrates, as well as other aquatic and terrestrial biota that are associated with these communities, recognising the rarity, vulnerability, and ecological importance in the region (DEC, 2006a).

To conserve some of these stressed communities, several areas along the NSW south coast have been placed within reserves or provided with protective legislation. Twelve Aquatic Reserves are located on the south coast, ranging from Fly Point at Port Stephens in the north to Bushrangers Bay at Shell Harbour in the south. These permanent reserves cover a combined area in excess of 2,000 hectares and protect important habitat and nursery grounds, as well as their associated aquatic biota, by restricting damaging practices. In addition to this, the south coast area contains three wetlands of international importance as listed under the Ramsar Convention on Wetlands. These include the Myall Lakes system and Kooragang Nature Reserve in the Hunter/Central Rivers catchment, as well as the Towra Point Nature Reserve in the Sydney Metro CMA area. The protection of these wetlands has been established in recognition of their importance to migratory birds, their uniqueness and their diversity in vegetation and habitat (DEC, 2006b).

As with rivers and lakes, these wetland, saltmarsh, and swamp communities are subject to pressures such as fragmentation, flood mitigation, draining and infilling, and modification of freshwater and tidal flows due to installation of artificial structures (e.g. floodgates and weirs). Therefore, aquatic habitat rehabilitation, in particular reinstating stream connectivity, is essential for maintaining aquatic biodiversity and protecting the integrity of these habitats along the NSW south coast. This particular project was designed to identify locations where the greatest environmental gains could be made when undertaking such remediation works and management actions.

3. Project Methods

3.1 Previous investigations

The initial phase of the project involved the collection of data for inclusion in the *NSW Coastal Floodgate Inventory*, a database of floodgate sites that have been identified as requiring remediation (from a fish passage and/or aquatic habitat perspective).

Fish passage and instream structure reviews have previously been undertaken in coastal NSW by Williams and Watford (1996), Pethebridge *et al*. (1998), Thorncraft and Harris (2000) and NSW Fisheries (2002). These projects investigated the presence and impact of instream structures such as weirs and road crossings, as well as floodgates. The initial assessment conducted by Williams and Watford in 1996 identified 276 floodgates in the tidal zone of the NSW south coast, as defined in the current project (Williams and Watford, 1996). In the subsequent four years this number had grown, as evident in an assessment conducted by Thorncraft and Harris (2000), which identified over 350 floodgate structures along the south coast of NSW (Thorncraft and Harris, 2000). This number was also expected to have increased during the prevailing seven year period.

The North Coast Floodgate Project conducted by NSW Fisheries (now incorporated into NSW DPI), identified 1,004 floodgate structures in the coastal waterways between the Manning River at Taree and the Tweed River on the Queensland border (NSW Fisheries, 2002). Of these sites, 220 structures underwent further field assessments to prioritise structures and recommend management actions (NSW Fisheries, 2002).

The current project used these previous studies as baseline data and updated their findings for the NSW south coast. The methods employed during the north coast project were used as a template for the identification, assessment and prioritisation of south coast floodgates.

3.2 Desktop and field assessment

Fieldwork in this study included on-ground assessment of floodgate sites identified through the following desktop assessments:

a) Assessment of 1:25,000 topographic maps for the NSW south coast region for floodgate sites that may act as potential barriers;

b) Data from structure owners provided additional sites for review. Councils, State Departments and landholders were asked to provide information on known floodgate sites across the region, particularly sites in need of future maintenance/remediation works; and

c) Floodgate structures identified in previous studies, including Williams *et al*. (1996), Pethebridge *et al*. (1998) and Thorncraft and Harris (2000) reports.

Approximately 576 sites were identified for assessment in the south coast region, with information collected on these structures from the desktop analysis used to focus field assessment on priority sites (see Section 3.3). From this, 521 sites were identified as requiring detailed field assessments to investigate the potential impact on fish passage and aquatic habitat, as well as explore management options.

Fieldwork in the NSW south coast region was conducted from July 2006 to January 2007. An assessment sheet was developed prior to fieldwork commencing, ensuring consistency in data collection (Appendix B). This assessment sheet was converted into a digital format, allowing data to be collected and stored on a handheld PDA ("Personal Digital Assistant") device in the field. In the field, floodgates were identified and mapped as data layers using GPS software. Information collected for each site was linked to the mapped point and stored in an underlying database. All information collected could then be retrieved or updated at a later date (in the field or office) by clicking on the mapped point, and accessing the underlying database. Locating sites was facilitated through the use of data layers indicating waterways, roads, and towns.

Data collected for each structure included: structure type and description; ancillary uses of the structure (e.g. bed control); whether the structure was a barrier to fish passage, and if so what type (headloss, slope, debris, flow depth, light, or velocity); aquatic and riparian habitat condition; channel morphology (e.g. width and depth); and surrounding land use. Location information (e.g. section of the catchment), structural details (e.g. ownership, downstream distance to major waterway, available upstream habitat), and further environmental considerations (availability and area of wetland habitat upstream, acid sulfate soil potential) were also determined.

Location details (GPS readings or map grid references) were recorded and digital photographs taken for each site. All data recorded in the floodgate audit was downloaded into the NSW Department of Primary Industries Fish Habitat Database prior to comparative analysis to determine regional remediation priorities.

3.3 Prioritising fish passage obstructions

A prioritisation scheme was developed to assist in ranking floodgate structures within each CMA that required active management (Appendix C). The scheme was developed to determine regional fish passage barrier priorities based on habitat value, with additional factors related to the modification of the structure also acknowledged during the process.

All data within the habitat value criteria (data listed in Appendix D-G) were weighted according to their relative value (e.g. sites that had a greater distance of aquatic habitat available upstream received a greater weighting than those that had a minimal distance; sites that had a larger area of wetland habitat upstream received a greater value than those that had a smaller area, which were weighted greater than those that had none; and sites that possessed intact riparian and aquatic habitat that was in a good condition were seen to have a greater value than those in a degraded condition). The final value for each criterion was determined by Habitat Class (Appendix C), with structures on Class 1 habitat receiving a greater weighting than an equivalent structure on lesser valued habitat.

Data within the habitat value criteria determined the quality and amount of habitat available to fish and gave an initial indication of how impacted the catchment was. This criterion indicated the potential effect of the structure on fish movement and the likelihood of the structure being a site where fish passage was required. This score was therefore used for the initial prioritisation of structures to determine immediate priorities, with the final prioritisation based on the willingness of the landholder/structure owner to remediate. Secondary factors related to the use and condition of the structure, and the potential for ASS were not used during the prioritisation process but should be considered when investigating high priority structures.

Final scores and priority levels for each site were determined by calculating the sum of all the criteria, with sites where there was a reluctance to remediate from the owner receiving a lower priority level. The prioritisation process was applied to all floodgate structures that were identified as fish passage obstructions within each CMA area of the south coast region.

Results are presented in Section 4 illustrating overall south coast results, as well as the results and priorities for the CMA regions.

Recommendations were made on how priority sites could be managed to allow for effective fish passage (Section 4.5 and Section 6). It is expected that data collected from this project, and the recommendations made within it, will guide local and state government expenditure and allow management actions to be incorporated into future work programs.

3.4 Floodgate management plans

To ensure the effective management of floodgates identified as fish passage barriers, floodgate management plans must be incorporated into any proposed actions. These plans provide details on the operation of individual floodgates and formalise the responsibility of all stakeholders in the management of the structures, whilst also providing an insurance avenue for floodgate operators (NSW Fisheries, 2002). More specifically these plans outline:

- Details of the floodgate structure;
- The reasons for actively managing the floodgate and the desired outcomes;
- Details of the management actions, including when the floodgate will be opened/closed, who will open/close the structure, any contingency plans, and closure triggers;
- The responsibilities of each stakeholder party;
- Any modifications needed to make the active management actions safe, simple and effective;
- Training, monitoring, reporting and revision requirements; and
- Insurance arrangements and legal liability.

During this process it is essential that a clear set of aims and objectives for the active management of the structure are determined to ensure that appropriate actions are established. The aims of a floodgate management plan can include increasing fish passage, flushing the drainage channel, controlling aquatic weeds, improving aquatic and riparian habitat, and controlling potential acid sulfate soils (NSW Fisheries, 2002). It is important that the final management plan developed for a site reflects the mutual desires of all stakeholders involved, including councils and landholders, with the final outcome achieving positive environmental benefits for the drainage system.

The principles and aims of floodgate management plans were used during the current project to appropriately prioritise structures and make remediation and management recommendations. The incorporation of formal management plans should be used during the implementation of active management recommendations for priority structures.

4. Assessment results

4.1 Overall project assessment results

A complete data set from this study is available in the accompanying CD (*NSW South Coast Floodgate Inventory 2006/2007*) and includes data on floodgate location, environmental data, recommended remediation action, and a photo library. The discussion below focuses on trends within the data and the top priority sites for remediation.

Overall, 576 floodgate structures were identified in the NSW south coast region, with a total of 521 structures undergoing field assessment. Of these, 383 were identified as obstructions to fish passage and recommended for remediation (refer to Appendix H: Map 1).

Several types of floodgates were assessed during the study including hinged flap, winch, auto tidal, 'Smart Gate', and sluice designs. Structures were also recorded that possessed a combination of these designs. For example, structures with multiple gates possessed both hinged flap cells and an auto tidal modification. For the purpose of this study, where the modification provided adequate active management the structure was classified under the modification design, but where the modification was an inadequate management solution for fish passage the floodgate was classified as a 'Combination' structure. A number of sites were also classified as 'Other', which were commonly structures in a state of disrepair.

Figure 2 displays the total number of floodgates assessed for each type of structure during the study on the NSW south coast, as well as the number of these floodgates that were recommended for remediation.

Within the NSW south coast region, the most common floodgate structure identified was the hinged flap design (78% of all structures identified), with winch (15%), auto tidal (1%) and 'Smart Gates' (1%) being the next most common structure types (Figure 2). This trend reflects the traditional use and installation of floodgates, which were implemented as passively managed structures to prevent the inundation of low-lying land from tidal and flood waters. The hinged flap design was very effective and efficient in achieving this, resulting in its use on the majority of drainages. The idea of modifying these structures for active management is more of a recent development, as evident by the comparatively low numbers of these types of floodgates, with the relatively easier and cheaper winch design representing the greater number of these modified structures.

This trend was also evident in the number of floodgate structures recommended for fish passage remediation, with the hinged flap design accounting for 291 of the 383 structures, whilst the remaining floodgates were composed of 78 winch, six auto tidal and five 'Smart Gate' designs (Figure 2). The hinged flap design is more likely to act as a fish passage barrier than other structure types due to its passive management that results in the floodgate remaining in the 'closed' position for the majority of the time. However, it is important to note that only 71% of the hinged flap structures were recommended for remediation, reflecting the use of these structures on smaller drainage systems that possessed minimal aquatic habitat.

Of the floodgates that had been modified, the winch design again represented the greater number of sites recommended for remediation, however it is important to note that all of the auto tidal and 'Smart Gate' designs that had been assessed were recommended for remediation. This was primarily because, although these structures had already undergone some form of modification, the design provided an inadequate management solution for fish passage at the site or the structures were recommended to ensure the continued active management and maintenance of the modification.

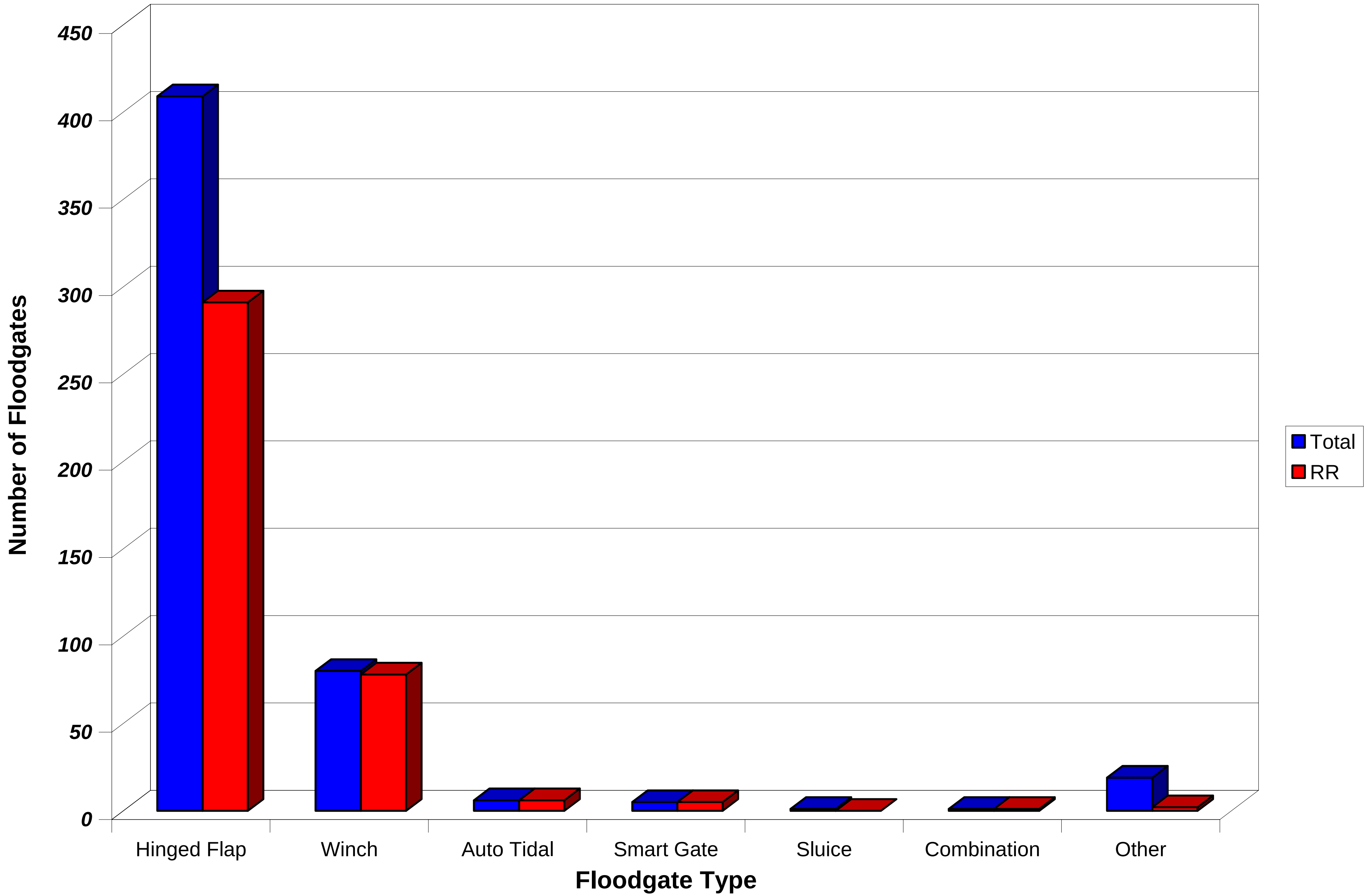

Figure 2: Floodgate structure types assessed during the project in the NSW south coast region, where RR represents 'Recommended for Remediation'.

4.2 Summary of floodgate results by CMA area

In this study, a considerable number of floodgate structures were assessed in the field but not recommended for remediation due either to the site being located in minimal fish habitat (naturally marginal habitat rarely utilised by fish, such as ephemeral waterways), or the site appearing in a heavily degraded or highly modified waterway where other factors play a larger role in dictating river health (e.g. concrete stormwater channels and piped waterways with little or no habitat value).

The number of floodgates assessed, as well as the number of sites that were recommended for remediation, varied considerably between the four coastal CMA areas assessed during this project (Table 1). This variation was predominantly due to the difference in size of the CMA regions within the project area, as well as the different forms of landuse that dominated each CMA region.

Table 1: Summary of structures assessed and recommended for remediation in each CMA region.

Floodgate Type	CMA Region								TOTAL	
	HCRCMA		HNCMA		SMCMA		SRCMA			
	Tot	RR	Tot	RR	Tot	RR	Tot	RR	Tot	RR
Hinged Flap	340	238	14	9	1	0	54	44	**409**	**291**
Winch	78	76	1	1	1	1	0	0	**80**	**78**
Auto Tidal	5	5	0	0	0	0	1	1	**6**	**6**
'Smart Gate'	0	0	0	0	0	0	5	5	**5**	**5**
Sluice	0	0	0	0	1	0	0	0	**1**	**0**
Combination	1	1	0	0	0	0	0	0	**1**	**1**
Other	15	2	0	0	0	0	4	0	**19**	**2**
TOTAL	**439**	**322**	**15**	**10**	**3**	**1**	**64**	**50**	**521**	**383**

Tot – Total number of floodgates assessed during the study.
RR – Total number of floodgates identified as fish passage barriers and recommended for remediation.

Table 1 demonstrates that the HCRCMA region possessed the greatest number of floodgates assessed (84%), as well as the greatest number that were recommended for remediation (84%), with the SRCMA area having the next highest number of floodgates (12%) and those recommended for remediation (13%). The SMCMA region possessed the least amount of floodgates, with only three structures assessed, of which only one was recommended for remediation (Table 1).

This result reflects the area and dominant landuse represented by each of the CMA regions. The HCRCMA and SRCMA areas, which contain large areas of intensive landuse practices on low-lying land, accounted for 40% and 33% of the project area respectively. In contrast, the heavily urbanised area of the SMCMA region only accounted for approximately 2% of the NSW south coast as defined for the project.

Within the four CMA regions the type of floodgate structure also showed significant variation. The hinged flap design, however dominated the structure type within each of the regions, again reflecting the traditional use and installation of floodgates (Table1). The HCRCMA area contained the greatest number of winch (98% of those assessed) and auto tidal (83% of those assessed) designs, reflecting the increasing use of active management in the area. This result benefits from having a single body responsible for the majority of floodgates, with a State government agency, the Department of Natural Resources (DNR), managing over 52% of the structures assessed in the HCRCMA region. The SRCMA region is the only area that possesses 'Smart Gate' modifications, showing the additional problems associated with floodgates experienced in the area and the need for unique management solutions.

4.3 Overall floodgate priority sites

Setting goals and targets for aquatic habitat rehabilitation requires a clear understanding of the extent of aquatic habitat degradation and where the best outcomes can be achieved. The method of prioritising floodgates in the CMA areas of the NSW south coast (Appendix C) is an adapted model that focuses on specific aquatic habitat and biodiversity features to determine the impact of the structures on fish passage and the surrounding environment.

All 383 instream structures that were recommended for remediation were divided into their respective CMA regions and categorised as either ‘high’, ‘medium’ or ‘low’ priority sites, as determined by an objective prioritisation process (refer to Appendix H: Maps 2-8). Overall, this process resulted in 73 sites being recognised as high priority and 113 sites as medium priority throughout the four CMA regions (Figure 3). All other sites (197) were regarded as having a lower importance with regard to fish passage in the CMA areas of the NSW south coast region. Sites that were regarded as a lesser priority should still be considered for remediation, although the urgency for fish passage remediation is not as great. These sites should be included on the owner’s maintenance schedules and remediated when possible.

Figure 3 displays the total number of floodgates recommended for remediation, highlighting the number of each structure type categorised into the three priority levels.

As shown in Figure 3, the high priority structures were dominated by the hinged flap (66%) and winch (29%) designs, with the remaining high priority sites composed of auto tidal (3%), ‘Smart Gate’ (1%), and combination structures (1%). This result reinforces the impact that passively managed floodgates can have on fish passage when they are used on waterways with significant aquatic habitat potential. The high number of winch gate designs also supports this result, with the majority of these floodgate designs usually remaining in the ‘closed’ position due to the manual labour required to actively manage them.

The medium priority sites were also dominated by the hinged flap (74%) and winch designs (19%), however it is important to note the majority of auto tidal (four out of six) and ‘Smart Gate’ (three out of five) structures recommended for remediation were also classified in this priority level (Figure 3). This result demonstrates the benefit of modifying floodgates for active management; however it also shows the importance of selecting an appropriate management design and maintaining this modification over time.

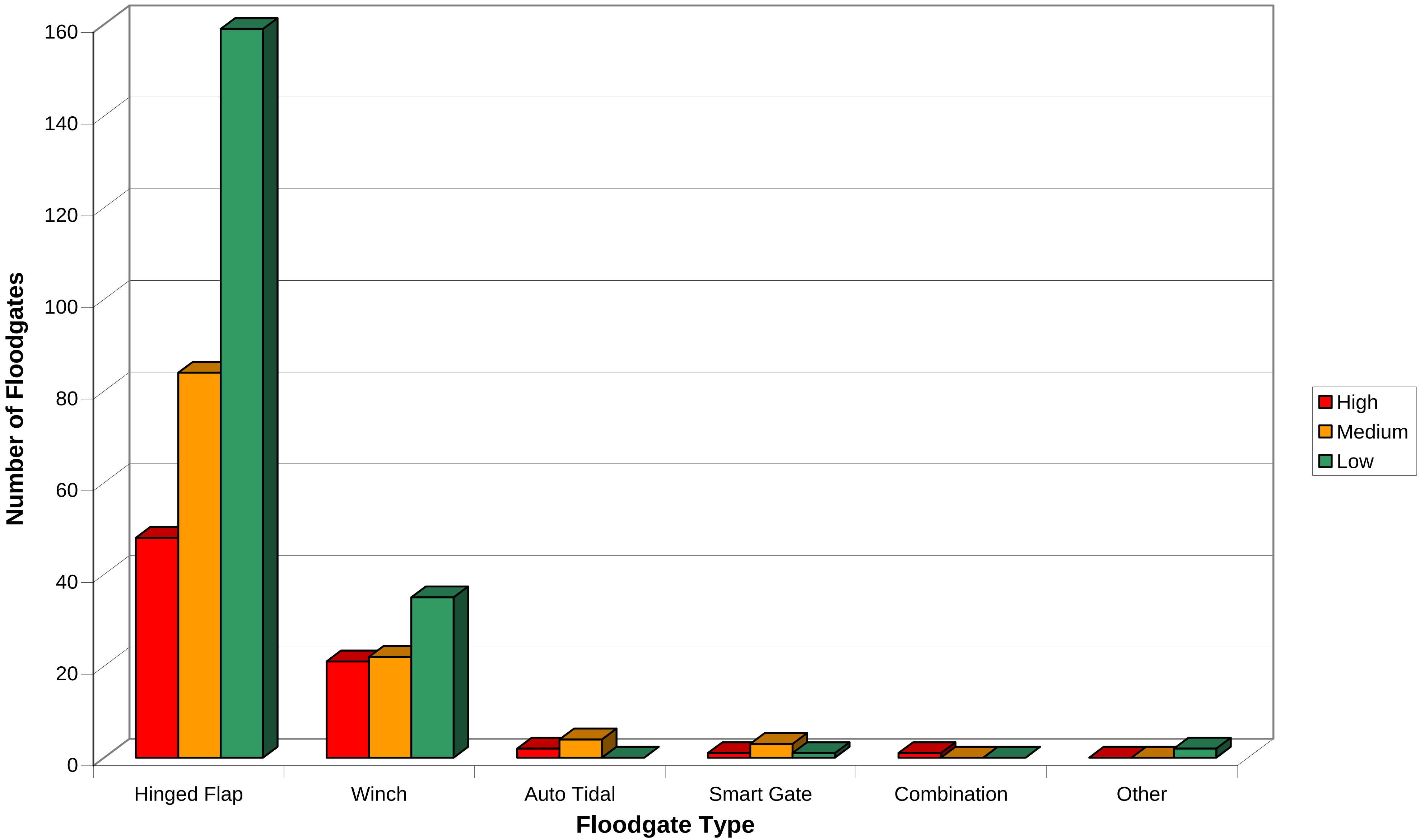

Figure 3: Priority levels of the floodgate structure types that were recommended for remediation in the NSW south coast region.

4.4 Regional summary of priority floodgate sites

Prioritised data was examined at the catchment management authority scale, highlighting the number of ‘high’, ‘medium’ and ‘low’ priority sites found within each of the four coastal CMAs. Where applicable, further analysis was conducted on the subregions within each management area showing the spread of priority structures within the respective region. This further analysis involved the HCRCMA (Table 2), HNCMA (Table 3) and SRCMA (Table 4) regions. Data in the SMCMA area was unable to be further divided due to the low number of floodgates recommended for remediation in this region.

HCRCMA regional summary of priority floodgate sites

Overall, 322 of the 439 floodgates assessed were prioritised within the Hunter/Central Rivers CMA region (Appendix D). The large number of structures across this area allowed the priority floodgates to be further divided into the three subregions of the HCRCMA, highlighting the geographical distribution of priority sites (refer to Appendix H: Maps 2-4). Subregions of the HCRCMA area include the Lower North Coast (Manning and Karuah catchments), the Hunter subregion, and the Central Coast (Macquarie and Tuggerah Lakes systems).

Table 2 displays the total number of floodgates recommended for remediation in the HCRCMA region, highlighting the number of ‘high’, ‘medium’ and ‘low’ priority structures across the three subregions.

Table 2: Summary of prioritised sites in the HCRCMA area, showing the difference between subregions.

Priority Level	HCRCMA Subregion			TOTAL
	Lower North Coast	Hunter	Central Coast	
High Priority	23	29	0	**52**
Medium Priority	63	30	1	**94**
Low Priority	90	86	0	**176**
TOTAL	**176**	**145**	**1**	**322**

The large number of floodgates recommended for remediation in the HCRCMA area highlights the use and placement of floodgates on waterways with significant aquatic habitat across the region. The use of these structures on higher class waterways with aquatic and riparian habitat in good condition has resulted in more structures identified as barriers to fish passage and requiring the need for active floodgate management.

The Lower North Coast and Hunter subregions possessed the greatest number of sites recommended for remediation, contributing 54% and 45% respectively, whilst the Central Coast subregion only possessed one prioritised site (Table 2). This result reflects both the difference in area and landuse represented by each subregion, with the Lower North Coast (35%) and the Hunter (61%) subregions being dominated by low-lying grazing and dairy practices. Contrary to this trend, the Central Coast subregion only represents approximately 4% of the Hunter/Central Rivers management area, with the low-lying landuse dominated by urban developments.

A similar trend is also evident in the distribution of high priority structures, with the Hunter subregion possessing 29 of the 52 sites and the Lower North Coast subregion containing the remaining 23 high priority sites (Table 2). This trend again reflects the size and landuse of these two subregions; however the greater number of high priority sites in the Hunter subregion further reflects the use of floodgates on higher class waterways within this area. The Hunter subregion contained 16 structures on waterways with Class 1 or Class 2 habitat, whilst the Lower North Coast contained nine. This finding increased the impact that floodgates in the Hunter subregion have on fish passage and augments the need for active management in the area (Appendix D).

HNCMA regional summary of priority floodgates

Of the 15 structures assessed in the Hawkesbury-Nepean region, ten were recommended for remediation and categorised as either 'high', 'medium' or 'low' priority as part of the prioritisation process (Appendix E). All structures were located in the Lower Hawkesbury-Nepean subregion (refer to Appendix H: Map 5). The Lower Hawkesbury-Nepean subregion is dominated by the MacDonald River and Colo River catchments (NSW DPI, 2006b).

Table 3 displays the total number of floodgates prioritised in the HNCMA region.

Table 3: Summary of prioritised sites in the two subregions of the HNCMA area.

Priority Level	HNCMA Subregion	TOTAL
	Lower Hawkesbury-Nepean	
High Priority	2	**2**
Medium Priority	4	**4**
Low Priority	4	**4**
TOTAL	**10**	**10**

There were a relatively low number of structures assessed in the HNCMA, however a high proportion of these were recommended for remediation (Table 3). This trend reflects landuse within the HNCMA region, with a large portion of land in the lower part of the catchment either located in National Parks, where they are afforded some protection from anthropological impacts, or in urbanised areas. In the areas where floodgates were required, predominantly on low-lying land used for agricultural purposes, the structures were located on waterways with aquatic habitat potential that would benefit from floodgate management.

Table 3 shows that the Lower Hawkesbury-Nepean subregion possessed all of the sites prioritised in the HNCMA, with the Upper Hawkesbury-Nepean subregion having no sites recommended for remediation (Table 3). This result demonstrates both the difference in size and, more importantly, the difference in location between the two areas. The Lower Hawkesbury-Nepean subregion represents approximately 55% of the total HNCMA area, with the majority of this land located lower in the catchment near waterways that are still under tidal influence. In contrast, land in the Upper Hawkesbury-Nepean occurs higher in the catchment and is surrounded by inland waterways that are serviced by smaller tributaries, negating the need for floodgates.

SMCMA summary of priority floodgate sites

Only one of the three floodgates assessed in the SMCMA area was recommended for remediation (Appendix F). The low number of sites assessed and prioritised in the area can be attributed to the highly modified nature of the Sydney Metro CMA region, which has significantly impacted local waterways due to intensive urban and industrial development. This modification has resulted in some streams being piped or channelised, with such changes negating the need for floodgates.

The structure that was recommended for remediation was classified as a high priority site, predominantly as a result of the significant impact it was having on potential fish movement. The floodgate is located in the Lower Georges River subcatchment of the SMCMA region (refer to Appendix H: Map 6) and occurs on a Class 2 waterway that possesses aquatic and riparian habitat in fair condition, increasing its impact on fish passage and strengthening the need for active management at the site.

SRCMA regional summary of priority floodgate sites

A total of 50 structures from the 64 assessed in the SRCMA region were recommended for remediation and prioritised into the three priority levels (Appendix G). During this process, floodgates in the SRCMA region were divided into the three coastal subregions to examine the distribution of sites across the Southern Rivers area (refer to Appendix H: Maps 7-8).

These areas included the Shoalhaven-Wollongong subregion; the Eurobodalla subregion, which contains the Clyde River, Moruya River and Tuross River catchments; and the Bega-Eden subregion (Bega and Towamba River catchments).

Table 4 presents the total number of prioritised floodgates in the SRCMA region, outlining the number of 'high', 'medium' and 'low' priority structures across the three subregions.

Table 4: Summary of prioritised sites in the three subregions of the SRCMA area.

Priority Level	SRCMA Subregion			TOTAL
	Shoalhaven-Wollongong	Eurobodalla	Bega-Eden	
High Priority	18	0	0	**18**
Medium Priority	15	0	1	**16**
Low Priority	16	0	0	**16**
TOTAL	**49**	**0**	**1**	**50**

The relatively large number and proportion of floodgates recommended for remediation in the SRCMA area highlights the use and placement of these structures on waterways that possess significant aquatic habitat. The presence of these structures on higher class waterways has resulted in more structures identified as barriers to fish passage and requiring the need for active management.

Table 4 shows that the Shoalhaven-Wollongong subregion contained the majority of prioritised sites in the SRCMA area, possessing 49 of the 50 structures recommended for remediation (Table 4). The remaining floodgate that was prioritised in the SRCMA area was assessed in the Bega-Eden subregion, with no floodgates recommended for remediation in the Eurobodalla subregion (Table 4). This trend is also evident in the distribution of high priority structures, with the Shoalhaven-Wollongong subregion accounting for all of the high priority sites in the SRCMA area (Table 4).

These results complement the findings of an earlier study by Williams *et al* (1996), which found that the majority of floodgates in the Southern Rivers management area were located in the Shoalhaven-Wollongong area (42 floodgates), with only one floodgate located outside this region (Williams *et al*, 1996). The trends observed in both studies reflect not only the difference in size between the subregions, with the Shoalhaven-Wollongong area representing 25% of the SRCMA region, but also the difference in catchment size between each subregion. The largest catchment in the Shoalhaven-Wollongong subregion, the Shoalhaven River system, covers an approximate area of 7,000 sqkm that is predominantly on low-lying coastal land. In the Eurobodalla and Bega-Eden subregions the largest catchments cover an approximate area of 2,900 sqkm and 2,800 sqkm respectively (NSW DPI, 2005). The greater size of low-lying catchment area, and the use of this land for agricultural and urban development, has resulted in the increased use of floodgates in the Shoalhaven-Wollongong subregion.

4.5 Top priority sites and active management issues

Regional priorities for fish passage remediation in each of the four CMA areas are outlined in the following section. A recommendation category has also been included; with management actions divided into 'active management', 'modify current active management', 'maintenance', and 'removal'. These categories provide an initial understanding of the direction that management actions need to take within each CMA area, with further investigations required on a site-specific basis to determine detailed designs for the active management of these priority floodgates.

HCRCMA regional summary of top priority sites and management issues

Of the 322 floodgates recommended for remediation, 52 were grouped as high priority structures, highlighting the significant impact that these structures have on the surrounding aquatic environment and the need for active management at these sites.

Table 5 outlines the top ten priority structures within the HCRCMA region, displaying location and ownership information for each structure, as well as the recommended management category and the potential benefit from this action.

Table 5: Summary of the top ten priority sites in the HCRCMA region.

Rank	Structure ID	Waterway	Subregion	Ownership	Recommendation	Benefit from Active Management
1*	HUNT001F	Ironbark Creek	Hunter	State	Modify active management	Fish passage access to over 70 km of habitat including 1,520 Ha of wetland
2	HUNT004F	off Dunns Creek	Hunter	State	Active management	Access to over 35 km of habitat including 400 Ha of wetland
3	HUNT002F	off Hunter River	Hunter	State	Active management	Access to over 35 km of upstream habitat including 400 Ha of wetland
4	MYAL014F	Tilligerry Creek	Lower North Coast	State	Active management	Access to over 100 km of habitat
5	MYAL001F	off Wallis Creek	Lower North Coast	Drainage Union	Active management	Fish passage access to over 30 km of habitat including 62 Ha of wetland
6	MANN043F	Croakers Creek	Lower North Coast	Drainage Union	Active management	Fish passage access to over 14 km of upstream habitat
7^	HUNT070F	Greenways Creek	Hunter	State	Modify active management	Fish passage access to over 11 km of habitat including 225 Ha of wetland
8^	HUNT182F	Barties Creek	Hunter	State	Modify active management	Access to 18 km of habitat including 900 Ha of wetland
9^	HUNT033F	Wallis Creek	Hunter	State	Modify active management	Access to 25 km of habitat
10	MANN082F	Millers Creek	Lower North Coast	Drainage Union	Active management	Fish passage access to over 14 km of habitat including 25 Ha of wetland

Note: * Planned active floodgate management
^ Current floodgate management

The top ten priority structures in the HCRCMA area prevent passage to a combined total in excess of 350 km of upstream aquatic habitat (Table 5). Adequate remediation and active management of these structures, as a whole or as individual sites, would significantly improve the quality and quantity of habitat available to aquatic biota, with a large proportion of sites containing a significant area of wetland habitat (Table 5).

It should be noted that the top priority structure, HUNT001F, has been targeted for future active management. This floodgate has been included in a HCRCMA project that aims to rehabilitate Hexham Swamp and restore the aquatic and riparian habitat associated with this estuarine wetland. The project will primarily involve the staged opening of cells within the structure to allow for the tidal exchange of waters, significantly enhancing fish passage at this site. The classification as a high priority floodgate from this study justifies the proposed modification and further highlights the need for active management at this structure.

Table 5 also shows that three of the top ten priority structures (HUNT033F, HUNT070F and HUNT182F) have already undergone some form of modification. However, the current management of these modifications is inadequate for fish passage, with their inclusion as high priority sites showing how important active management is at these sites. All three structures posses winch modifications, with HUNT033F also containing an auto tidal modification on one of the six cells. The large size of each structure and their location on major waterways has warranted that the management of the sites be modified to provide for fish passage. At the time of inspection, management involved all hinged flap cells being closed at two of the floodgates (HUNT033F and HUNT182F), with only one hinged flap cell out of ten opened at HUNT070F.

HNCMA regional summary of top priority sites and management issues

Two of the ten structures recommended for remediation in the HNCMA region were classified as high priority structures, with Table 6 outlining the benefit that actively managing these two sites would have in the region. The table also displays the recommended management action for the sites, as well as location and ownership information.

Table 6: Summary of the top priority sites in the HNCMA region.

Rank	Structure ID	Waterway	Subregion	Ownership	Recommendation	Benefit from Active Management
1*	HAWL015F	off Cahill Creek	Lower Hawkesbury-Nepean	Private	Active management	Access to over 3 km of habitat
2	HAWL008F	Buttsworth Creek	Lower Hawkesbury-Nepean	Local Government	Active management	Access to over 8 km of habitat
Note: * Interest in active floodgate management						

The two top priority structures in the Hawkesbury-Nepean CMA area were found in two different aquatic environments, with HAWL015F located in a predominantly estuarine habitat surrounded by urban development and HAWL008F located on a major creek system that drains into the Hawkesbury River, which is surrounded by agricultural landuse. However, both of these locations provided potentially substantial upstream aquatic habitat, with over 10 km of this habitat blocked to fish passage by the presence of the two floodgates (Table 5).

It should be noted that there is interest in actively managing the top priority structure in the Hawkesbury-Nepean region (HAWL015F) from both the structure owner and the local council. The structure is located in the Pittwater Council LGA area who, in consultation with the structure owner Bayview Golf Club, has expressed interest in examining the operation and management of the floodgates. This action will focus on improving water quality and aquatic habitat in the waterways associated with the golf course and the surrounding estuary. The classification as a high priority floodgate from this study further highlights the need for active management at this structure.

SMCMA region top priority site and management issues

Table 7 outlines the details of the only priority structure in the SMCMA region, displaying location and ownership information, as well as the recommended management action and its potential benefit.

Table 7: Summary of the top priority site in the SMCMA region.

Rank	Structure ID	Waterway	LGA	Ownership	Recommendation	Benefit from Active Management
1	SYDN001F	Kelso Creek	Bankstown City Council	Local Government	Modify active management	Access to approximately 3 km of habitat

The top priority floodgate is located on a moderate creek system that drains directly into the Georges River. The impact of this structure has been recognised in previous studies, with Nichols and McGirr (2005) highlighting this site as a priority fish passage barrier in the Lower Georges River subcatchment during their assessment of instream structures and their impact on fish passage in Sydney catchments. The recommended remediation action from this study reflects the proposed actions from the current study, suggesting that management of the structure should be improved (Nichols and McGirr, 2005). Modification to the management of this site would allow fish passage to approximately 3 km of upstream aquatic habitat (Table 7).

SRCMA regional summary of top priority sites and management issues

A total of 18 out of the 50 floodgates recommended for remediation were classified as high priority structures in the SRCMA region. Table 8 outlines the top ten of these priority structures, highlighting location and ownership information for each structure, as well as the recommended management action and its potential benefit.

Table 8: Summary of the top ten priority sites in the SRCMA region.

Rank	Structure ID	Waterway	Subregion	Ownership	Recommendation	Benefit from Active Management
1	SHOA046F	Crookhaven River	Shoalhaven-Wollongong	Local Government	Active management	Access to 28 km of upstream habitat including 300 Ha of wetland
2	SHOA017F	Horseshoe Creek	Shoalhaven-Wollongong	Local Government	Active management	Fish passage access to 59 km of habitat including 600 Ha of wetland
3	SHOA058F	off Ryans Creek	Shoalhaven-Wollongong	Local Government	Active management	Access to over 50 km of habitat including 200 Ha of wetland
4	SHOA059F	off Shoalhaven River	Shoalhaven-Wollongong	Local Government	Active management	Fish passage access to over 50 km of habitat including 350 Ha of wetland
5	SHOA024F	Snake Island Creek	Shoalhaven-Wollongong	Local Government	Active management	Access to over 30 km of upstream habitat including 150 Ha of wetland
6	SHOA001F	Blue Angle Creek	Shoalhaven-Wollongong	Private	Active management	Access to over 12 km of upstream habitat including 200 Ha of wetland
7	SHOA057F	Saltpan Creek	Shoalhaven-Wollongong	Local Government	Active management	Access to over 50 km of habitat including 60 Ha of wetland
8	SHOA015F	off Shoalhaven River	Shoalhaven-Wollongong	Local Government	Active management	Access to 23 km of upstream habitat including 150 Ha of wetland
9	SHOA054F	off Crookhaven River	Shoalhaven-Wollongong	Local Government	Active management	Access to over 10 km of habitat including 150 Ha of wetland
10	SHOA004F	off Shoalhaven River	Shoalhaven-Wollongong	Local Government	Active management	Fish passage access to over 14 km of habitat including 30 Ha of wetland

The top ten priority structures in the SRCMA area prevent passage to a combined total of over 320 km of upstream aquatic habitat, which includes in excess of 2,190 Ha of wetland area (Table 8). Adequate remediation and active management of these structures, as a whole or as individual sites, would significantly improve the quality and quantity of habitat available to aquatic biota, with all of the top ten sites containing a significant area of wetland habitat, as well as riparian and aquatic habitat in reasonable condition (Table 8).

5. Steps in stream rehabilitation projects

This study provides baseline data for the rehabilitation of waterway connectivity in the NSW south coast region. The following section illustrates how this report can inform and lead to on-ground stream rehabilitation works and floodgate management. For this purpose, a *12 Step Stream Rehabilitation Process*, taken from the Manual for Rehabilitating Australian Streams (Rutherfurd *et al*, 2001), has been adopted here to outline the main stages of undertaking on-ground fish passage projects.

The Rutherfurd stream rehabilitation process includes the following steps:	
1. Visions and goals	7. Setting measurable objectives
2. Gain support	8. Feasibility
3. Assess stream condition	9. Detailed design
4. Identify problems and assets	10. Evaluation
5. Priorities	11. Implementation
6. Strategies	12. Maintenance and evaluation

Steps 1 – 5 Visions and goals, gaining support, assessing stream condition, identify problems and assets, priorities:

This report has provided information to successfully complete steps 1 to 5 in the process of rehabilitating fish passage barriers by achieving the following:

- Establishing a vision for reinstating stream connectivity and improving fish passage in coastal waterways of NSW;
- Providing a source document for stakeholders outlining major findings and providing management recommendations for regional groups and local government; promotion of the report findings will offer an opportunity to gain broad regional and local support for future initiatives;
- Identifying specific floodgate structures that are obstructions to fish passage across the NSW south coast region; and
- Establishing and implementing a method of prioritising fish passage obstructions at the regional and catchment scale.

Steps 6 to 12 in the stream rehabilitation process need to be undertaken by relevant stakeholders (private landholders, Councils, state government and the CMA) with the aim of achieving on-ground outcomes. The following is a summary of how those steps can be achieved for floodgate remediation and active management in coastal NSW.

Step 6 – 8 Strategies, setting measurable objectives, and feasibility:

Strategies for rehabilitation, in this instance options for actively managing floodgates, need to be set out within an overall floodgate management plan that involves outlining specific project objectives. In this investigation, rapid assessments were conducted for floodgate structures to provide a ‘snap shot’ view of environmental conditions at a site. Due to the number of structures along the NSW south coast, detailed assessments of each structure were not feasible. For the purposes of informing future planning, the application of a rapid assessment technique (the fieldwork methodology and desktop prioritisation outlined above) was a simple and effective way of highlighting the extent of the problem and determining broad regional priorities. Many environmental, social, cultural and economic considerations need to be reviewed before undertaking on-ground management works recommended within this report. Additional pertinent considerations include:

- Location and severity of other instream structures (e.g. weirs, dams and road crossings) and natural barriers within the waterway;
- Existence of sensitive habitats in the vicinity of proposed works;
- Impact of structure removal/modification on channel bed and bank stability;
- Presence of acid sulfate soils;
- Impacts of mobilising sediment stored behind the floodgate;
- Impacts on water quality (e.g. from contaminated sediments) and water chemistry (e.g. at tidal barriers) upon upstream and downstream habitats;
- Benefactors and stakeholders – identifying support and opposition; and
- Estimated costs of various remediation and management options.

The above factors must be considered well before detailed designs for remediating a fish passage barrier can be considered.

Step 9 – Detailed design:

Design guidelines in relation to actively managing floodgate structures can be found in:

- *Restoring the Balance: Guidelines for managing floodgates and drainage systems on coastal floodplains* (Johnston *et al*., 2003)

Johnston *et al*. (2003) provide a comprehensive overview of the best way to prepare, design and implement active management actions for floodgates, outlining the reasons for floodgate management, as well as benefits and risks involved. Floodgate modification devices that may be implemented during rehabilitation works are also described, with information about the advantages and disadvantages of each option provided. The document was developed with input from national experts in the fields of coastal floodplain and floodgate management.

Table 9 is adapted from Johnston *et al*. (2003) and provides a summary of the modification devices that can be used to actively manage floodgates, outlining the attributes, advantages and disadvantages of each option.

Table 9: Floodgate modification devices used for active management.

Modification Device	Attributes	Advantages	Disadvantages
Tidal floodgate	Uses a float system to open the aperture and allow water exchange, opening on the low tide and closing with the rising tide	Excellent water level control, with float able to be adjusted; Automatic operation; Low OH&S costs; Self-cleaning and flood secure	High costs associated with large floodgates; Can require a new gate in some cases
Sluice gates	Consists of a sliding plate cover over the aperture that can be opened vertically, horizontally or rotationally	Excellent water level control during non-flood periods; Simple design; Variable aperture size; Minimal maintenance; Low OH&S costs	Requires manual operation and manual closure in event of flooding
Winch gates	Consists of either a winch and cable system that opens the floodgate horizontally or vertically, or a worm drive mechanism that opens the floodgate vertically	Vertical gates have good water level control; Can allow large, rapid inflow of water; Can be fully raised	Horizontal gates have limited water level control; Intensive manual operation; Greater risk of overtopping; Closing difficulties due to friction; High OH&S costs
'Smart Gate'	Uses motor-driven winch lifting gates to open and close the aperture based on water quality indicators that are scanned by upstream and downstream dataloggers	Excellent water level control; Opening/closing adjusted to suit site specific water quality issues; Automatic operation; Can be controlled by off-site technology	High costs; Complex design; Doesn't necessarily address fish passage issues; Greater maintenance

Step 10 – 12: **Evaluation, implementation, monitoring and maintenance:**

Steps 10 to 12 are common steps in any project management process and include establishing an evaluation procedure, implementing the plan and assessing the success of the project. These stages include developing a timeline, allocating responsibilities, finalising funding, conducting on-ground works and organising an evaluation schedule.

For floodgate remediation and management works, establishing a floodgate management advisory committee (comprising representatives from local landholders, as well as relevant government agencies and other associated parties) to ratify remediation works and management plans is an effective way of ensuring that the plan meets project objectives.

The financing of on-ground rehabilitation works can be achieved through several avenues of cost-sharing between stakeholders and value-adding to existing programs/projects. Funding opportunities include State and Federal environmental grants for aquatic habitat rehabilitation projects. The NSW Department of Primary Industries (Fisheries, Conservation and Aquaculture) can assist councils, structure owners and community groups interested in applying for funding related to stream connectivity and fish passage projects in NSW.

6. Recommendations

This study contributes to the management of aquatic habitats along the south coast region of NSW by achieving the following outcomes:

- Development of a floodgate inventory;
- On-ground application of a floodgate assessment method;
- Identification of remediation options and management plans for floodgate sites;
- Application of a prioritisation method to rank floodgate structures; and
- Promotion of the findings from the report.

A complete data set from this study is available in the accompanying CD (*NSW South Coast Floodgate Inventory 2006/2007*) and includes data on floodgate location information, environmental data and recommended remediation and management actions. The recommendations in relation to floodgate management options for each site have been provided as a basic indication of the scale and extent of remediation required (e.g. active management, modifying current management, maintenance, and structure removal).

This report recommends that:

- The respective catchment management authority, local governments, and other structure owners, along with NSW DPI, investigate the feasibility of remediating high priority sites identified in this report. Detailed assessments of each individual site will be required prior to significant monetary investment at these sites;
- Sites that are obsolete have the potential to be remediated in the near future, with these structures able to be remediated with minimal financial outlay and stakeholder negotiation;
- Active floodgate management and remediation should be given preference to structures located lower in the system or on waterways with few other barriers, as opposed to structures on waterways that have a large number of barriers associated with them; and
- Active floodgate management and remediation should be given preference to sites where rare or threatened species are present within the catchment as opposed to sites outside of these species distribution.

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8. Appendices

Appendix A: Freshwater and Estuarine Finfish of the NSW South Coast Region

Scientific Name	Common Names	Status	Migration[7] and habitat
Acanthopagrus australis	Yellowfin bream Silver bream	Common	Amphidromous; coastal marine; estuaries & inshore reefs
Afurcagobius tamarensis	Tamar River goby	Common	Estuaries, coastal lakes & lower freshwater river reaches
Aldrichetta forsteri	Yellow-eye mullet	Common	Marine & estuarine; brackish coastal lakes & lower freshwater reaches
Ambassis marianus	Estuary perchlet Glass perchlet	Common	Local migration; brackish mangrove estuaries & tidal creeks
Acanthogobius flavimanus	Yellowfin goby	**EXOTIC**	Freshwater reaches of streams just above tidal influence
Amniataba percoides	Banded grunter	**EXOTIC; NSW NOXIOUS LISTING**	Freshwater habitats – in Clarence River, has potential to spread to the Southern Rivers region
Amoya bifrenatus	Bridled goby	Common	Estuarine & marine waters
Anguilla australis	Short-finned eel	Common	Catadromous; coastal rivers & wetlands
Anguilla reinhardtii	Long-finned eel	Common	Catadromous; coastal rivers
Arius graeffei	Freshwater fork-tailed catfish	Common	Can complete life cycle in freshwater, estuarine and marine populations are anadromous
Arrhamphus sclerolepis	Snub-nosed garfish	Common	Coastal bays & brackish estuaries
Atherinosoma microstoma	Smallmouthed hardyhead	Common	Unknown migration pattern; coastal estuarine & fresh waters
Bidyanus bidyanus	Silver Perch	**NSW THREATENED SPECIES (*VULNERABLE*)**	Large scale migration; Habitat is predominantly in lowland and slope waterways. Present as a result of stocking
Caranx sexfasciatus	Bigeye trevally	Common	Marine; juveniles common in mangrove estuaries, tidal creeks and can enter freshwater
Carassius auratus	Goldfish	**EXOTIC**	Widespread in lowland rivers
Carcharhinus leucas	Bull shark	Common (not abundant)	Estuaries, lower reaches of rivers; coastal waters
Chanos chanos	Milkfish	Common	Amphidromous; Warm water marine & estuarine species, will travel up rivers
Cyprinus carpio	Common carp	**EXOTIC; NSW NOXIOUS LISTING**	Still gentle flowing rivers in inland NSW & some catchments along the coast
Elops hawaiensis	Giant herring	Common	Sheltered embayments and estuaries
Epinephelus daemelii	Black cod	**NSW THREATENED SPECIES (*VULNERABLE*)**	Inshore marine caves & rocky reefs; larger juveniles around rocky shores in estuaries (natural distribution to south of Bega NSW)
Gadopsis marmoratus	River blackfish	Reduced range	Local migration; freshwater streams only
Galaxias brevipinnis	Climbing galaxias	Uncertain; Distribution contracted	Amphidromous; headwaters & forested streams
Galaxias maculatus	Common jollytail	Common	Catadromous; coastal streams, lakes & lagoons – salt & fresh water environs
Galaxias olidus	Mountain galaxias	Common	Local migration; moderate & high elevations in coastal & inland rivers
Gambusia holbrooki	Gambusia, Plague minnow	**EXOTIC; NOXIOUS LISTING**	Widespread in coastal & inland NSW

[7] Migration patterns of freshwater fish include: *Potamodromous* – fish that migrate wholly within fresh water; *Anadromous* – fish that spend most of their life in the sea and migrate to fresh water to breed; *Catadromous* - fish that spend most of their life in fresh water and migrate to the sea to breed; *Amphidromous* - fish that migrate between sea and fresh water, but not for the purpose of breeding.

Scientific Name	Common Names	Status	Migration and habitat
Gerres subfasciatus	Silver biddy	Common	Marine estuaries & bays, brackish coastal rivers & lakes
Gobiomorphus australis	Striped gudgeon	Common	Amphidromous; coastal streams generally at lower elevations
Gobiomorphus coxii	Cox's gudgeon	Common	Potamodromous; freshwater reaches of coastal rivers
Hippichthys penicillus	Steep-nosed pipefish	Common	Mangrove estuaries, lower reaches of freshwater streams
Hypseleotris compressa	Empire gudgeon	Common throughout its range	Unknown migration; lower reaches of coastal rivers
Hypseleotris galii	Firetailed gudgeon	Common	Potamodromous; freshwater reaches of coastal streams
Hypseleotris klunzingeri	Western carp gudgeon	Common	Freshwater; around aquatic vegetation in slow moving rivers, lakes or wetlands
Hypseleotris spp.	Gudgeon	Common	Unknown migration; lower reaches of coastal rivers
Leiopotherapon unicolor	Spangled perch	Common	Amphidromous; freshwater, although wide salinity tolerance; flowing streams, wetlands, lakes, dams, bores
Liza argentea	Flat-tail mullet	Common	Estuaries & sea beaches
Lutjanus argentimaculatus	Mangrove Jack	Common	Estuaries & tidal river reaches
Maccullochella macquariensis	Trout cod	**NSW THREATENED SPECIES (*ENDANGERED*)**	Potamodromous; prefer deep flowing freshwaters with woody debris. Present as a result of stocking
Maccullochella peelii peelii	Murray cod	**FEDERALLY THREATENED SPECIES (*VULNERABLE*)**	Potamodromous; Habitat predominantly in lowland and slope waterways. Present as a result of stocking
Macquaria australisica	Macquarie perch	**NSW THREATENED SPECIES (*VULNERABLE*)**	Potamodromous; freshwater; natural distribution Hawkesbury R, Shoalhaven River & inland NSW
Macquaria colonorum	Estuary perch	Uncertain	Amphidromous; estuarine areas in coastal rivers & lakes
Macquaria novemaculeata	Australian bass	Uncertain	Catadromous; Coastal rivers up to 600m altitude
Megalops cyprinoids	Oxeye herring	Common	Amphidromous; marine & estuarine, juveniles & small adults frequent freshwater reaches of rivers
Melanotaenia duboulayi	Duboulay's rainbowfish	Common	Potamodromous; Still, clear waters east of the Great Dividing Range
Misgurnis anguillicaudatus	Oriental wetherloach	**EXOTIC**	Still and slow-flowing freshwaters with muddy substrate
Monodactylus argenteus	Diamondfish Silver batfish	Common	Bays, mangrove estuaries, tidal creeks & lower reaches of freshwater streams
Mordacia mordax	Shortheaded lamprey	Moderately abundant in some rivers	Anadromous; coastal rivers from Hawkesbury River to southern catchments
Mordacia praecox	Non-parasitic lamprey	Uncertain	Anadromous; has been found in Moruya & Tuross rivers in NSW
Mugil cephalus	Striped mullet Sea mullet	Common	Amphidromous; lower reaches & estuaries of coastal catchments
Mugilogobius platynotus	Flat backed goby	Common	Estuaries, can tolerate freshwater but mainly a marine species
Myxus elongatus	Sand mullet	Common	Amphidromous as juveniles; estuaries & brackish waters in lower river reaches
Myxus pertardi	Freshwater mullet	Common	Catadromous; prefers deep pools of slow flowing rivers, adults spawn in estuaries and sea
Notesthes robusta	Bullrout	Limited abundance but not threatened	Catadromous; tidal estuaries & fresh waters

Scientific Name	Common Names	Status	Migration and habitat
Oncorhynchus mykiss	Rainbow trout	**EXOTIC**	Local migration; montane regions along the Great Dividing Range
Perca fluviatilis	Redfin perch	**EXOTIC**	Still and slow-flowing waters in inland rivers & southern coastal NSW
Philypnodon grandiceps	Flathead gudgeon	Common	Unknown migration; inland & coastal waters especially lakes & dams
Philypnodon sp.	Dwarf flathead gudgeon	Common	Unknown migration; coastal & inland streams
Platycephalus fuscus	Dusky flathead	Common	Amphidromous; marine & estuarine waters
Potamalosa richmondia	Freshwater herring	Not common but not considered under threat	Catadromous; estuaries & coastal fresh water rivers
Pristis zijsron	Green sawfish	**NSW THREATENED SPECIES (*ENDANGERED*)**	Inshore marine & estuaries; last confirmed sighting in 1972 from Clarence River (natural distribution to Jervis Bay NSW)
Prototroctes maraena	Australian grayling	**FEDERALLY THREATENED SPECIES**	Amphidromous; coastal waterways from Hawkesbury River south to Victoria
Pseudaphritis urvillii	Congolli Tupong	Abundant throughout its range	Catadromous; south coast NSW & the Snowy River catchment; freshwater & estuarine
Pseudogobius sp	Blue-spot goby	Common	Sheltered estuaries & coastal lakes
Pseudomugil signifer	Pacific blue-eye	Common	Amphidromous; eastern draining catchments
Redigobius macrostoma	Largemouth goby	Common	Amphidromous; estuaries, coastal rivers & some freshwater streams
Rhabdosargus sarba	Tarwhine	Common	Coastal waters, often entering estuaries
Rhadinocentrus ornatus	Softspined rainbowfish	Common	Potamodromous; Inland and coastal freshwater
Retropinna semoni	Australian smelt	Common	Potamodromous; Inland & coastal freshwater
Salmo salar	Atlantic Salmon	**EXOTIC**	Restricted to cooler waters, including Lake Jindabyne, Snowy River catchment
Salmo trutta	Brown trout	**EXOTIC**	Restricted to cooler waters; montane waterways above 600m elevation
Salvelinus fontinalis	Brook Char	**EXOTIC**	Restricted to cool-cold waters, restocking sustains populations in Tasmania, NSW, SA
Scatophagus argus	Spotted scat	Common	Estuarine and coastal, mangrove creeks, lower reaches of freshwater streams
Selenotoca multifasciata	Banded scat	Common	Estuarine and coastal, mangrove creeks, lower reaches of freshwater streams
Tandanus tandanus	Eel tail catfish	Common (eastern draining form)	Translocated from western species in most of Hunter/Central region; native subspecies in the Manning R and waterways north of this
Tanichthys albonubes	White cloud mountain minnow	**EXOTIC**	Temperate freshwaters
Terapon jarbua	Crescent Perch	Common	Marine, but also penetrating estuaries and lower river reaches
Valamugil georgii	Fantail mullet	Common	Amphidromous; estuarine and marine, young entering freshwater

Sources: McDowall (1996), Thorncraft and Harris (2000), Yearsley *et al* (2001), Allen *et al* (2002) and NSW DPI (2005).

Appendix B: Fish Passage Barrier Desktop and Field Assessment Form

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Assesor:_________________Date:_________________Structure ID:_________________

CMA:________________Catchment:________________Barrier Type:________________

Latitude:________________Longitude:________________Elevation:_________________

1a. Location Information - Desktop Assessment

Nearest Town:_______________LGA:_______________Topographic Map:_______________

Catchment Section: Upper Middle Lower Tidal

Road Name:____________Waterway Name:____________Wetland Upstream:___________

1b. Location Information – Field Assessment

Waterway Class: 1 2 3 4

Watercourse Type: Natural Constructed Combination

Landuse: Grazing Cropping Rural Urban
Industrial State/National Park Plantation Forest

2a. Structure Information – Desktop Assessment

Structure Ownership:___________Owner Name:___________Contact Details:____________

Common Name:__________Existing License/Code ID:_________Obsolete Structure:______

2b. Structure Information – Field Assessment

Structure Type
Road Crossing: Bridge Pipe Culvert Box Culvert Causeway Ford Weir Floodgate

Weir: Fixed Crest Adjustable Release

Floodgate: Hinged Flap Winch Sluice Auto Tidal Other

Construction Material: Concrete Steel Timber Rock Gravel
Sand Clay Sheet Piling Gabion Other

Structure Condition: Good Fair Poor Road Type: Sealed Unsealed

Fishway Type: Vertical Slot Denil Submerged Orifice Full Width RR
Partial Width RR Fishlock Bypass

Fishway Working: Yes No Unknown

Structure Details
Length (m):________________Breadth (m):_______________Height (m):_______________

Invert Height:____________Number of Pipes/Cells:____________Cell Width:____________

Cell Shape: Circular Box Other Pooling Upstream: Yes No

Ancillary Use: Flood Mitigation Water Supply Irrigation Regulation
Stock Watering Recreation Bed Control

3a. Environmental Considerations – Desktop Assessment

No. of Downstream Barriers:______Distance Dowsntream:______Upstream Habitat:_______

Invert Level (AHD):__________Lowest Drain Height:___________Tidal Range:___________

Acid Sulfate Soil: High Probability Low Probability Unknown

3b. Environmental Considerations – Field Assessment

Fish Passage
Fish Passage Barrier: Yes No

Headloss (mm):________________Flow Depth:_______________Light:_________________

Blockage:_______________________________Velocity:______________________________

Slope: 1:20-1:10 >1:10 Debris: Partial Barrier Complete Barrier

Habitat
Bank Height (m):___Bank Full Width (m):___LF Wetted Width (m):___Channel Depth(m):___

Riparian Condition: Good Fair Poor

Aquatic Habitat Condition: Good Fair Poor

4. Comments

5. Recommendations

<u>Appendix C</u>: Prioritisation Scheme

Throughout NSW, the NSW Department of Primary Industries Fisheries (Conservation and Aquaculture) applies a basic 'CLASS' system to assign aquatic habitat values to waterways. The table below outlines the characteristics of each waterway class. This criterion was used in the prioritisation scheme as one of the main criteria to determine the habitat value of floodgate structures in the NSW south coast region assessed during the project.

NSW DPI classification of fish habitat in NSW waterways	
Classification	**Characteristics of waterway class**
CLASS 1 Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek); habitat of a threatened fish species or 'critical habitat'.
CLASS 2 Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
CLASS 3 Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.
CLASS 4 Unlikely fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (e.g. dry gullies or shallow floodplain depressions with no permanent aquatic flora present).

Data utilised during the prioritisation process is shown in the table below.

Data employed to determine floodgate priorities	
Primary Factors	**Secondary Factors**
Habitat Class	Acid Sulfate Soil Potential
Habitat Available Upstream (km)	Salinity Potential
Wetland Upstream and Size (Ha)	Structure Condition
Low Flow Channel Width (m)	Is Structure Obsolete?
Aquatic Habitat Condition	Landholder Willingness to Remediate
Riparian Habitat Condition	In-kind Contribution Potential

Data within the primary factor category provided an indication of the quality of habitat for fish and how the remediation of the structure would benefit fish (amount of habitat potentially made available upstream of the site and the presence and size of wetland habitat upstream). This category also described the local habitat condition (channel width, aquatic vegetation and riparian vegetation condition) and thus the local habitat features available for fish. The final score for this data was determined by the Habitat Class associated with each structure, with data occurring on a higher Habitat Class receiving a greater score.

The parameters within the secondary factors were not used during the prioritisation process but were included in the scheme as parameters that need to be taken into account when investigating management actions for priority sites. This data primarily focussed on the potential environmental impacts of any modifications (acid sulfate soils and salinity impacts), as well as the condition of the structure and if it was still required (an obsolete structure being more likely to be remediated through removal than a structure that was still in use), and how willing the landholder/structure owner was to remediate the structure (a very significant factor in determining priority sites targeted for future remediation works, with the cooperation of all landholders potentially affected by the proposed works required before implementation).

The scoring system used to prioritise sites according to the above criteria is presented overleaf.

Primary Factor	Data Breakdown	Habitat Class			
		1	2	3	4
Habitat Available Upstream (km)	>50	60	30	15	0
	25-50	40	20	10	0
	10-25	20	10	5	0
	5-10	8	4	2	0
	0.5-5	4	2	1	0
	<0.5	2	1	0	0
Wetland Upstream (Ha)	>500	60	30	15	0
	100-500	40	20	10	0
	50-100	20	10	5	0
	20-50	8	4	2	0
	<20	4	2	1	0
	None	0	0	0	0
Low Flow Channel Width (m)	>8	60	30	15	0
	4-8	40	20	10	0
	2-4	20	10	5	0
	1-2	8	4	2	0
	0.5-1	4	2	1	0
	<0.5	2	1	0	0
Aquatic Habitat Condition	Good	20	10	5	0
	Fair	10	5	3	0
Riparian Habitat Condition	Good	30	15	8	0
	Fair	15	8	4	0
					TOTAL

Score	TOTAL

Secondary Factor	Data Breakdown
Acid Sulfate Soil Potential	High
	Medium
Salinity Potential	Low
	Medium
Landholder Willingness to Remediate	High
	Medium
	None
Structure Condition	Poor
	Fair
Obsolete Structure	True
	False
In-kind Contribution Potential	High
	Medium

Appendix D: Floodgate Data for High Priority Structures in the HCRCMA Region

Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
1	HUNT001F	Hunter	Newcastle City	Ironbark Creek	-32.854695	151.700913	Hinged Flap	1	72.0	1530	Modify active management
2	HUNT004F	Hunter	Port Stephens	off Dunns Creek	-32.840677	151.766028	Hinged Flap	1	36.0	400	Active management
3	HUNT002F	Hunter	Port Stephens	off Hunter River	-32.842488	151.755318	Hinged Flap	2	36.0	400	Active management
4	MYAL014F	Lower North Coast	Port Stephens	Tilligerry Creek	-32.790262	151.919425	Hinged Flap	2	103.5	0	Active management
5	MYAL001F	Lower North Coast	Port Stephens	off Wallis Creek	-32.763158	152.057753	Hinged Flap	2	31.5	60	Active management
6	MANN043F	Lower North Coast	Greater Taree City	Croaker Creek	-31.934640	152.597858	Hinged Flap	2	14.5	0	Active management
7	HUNT070F	Hunter	Port Stephens	Greenways Creek	-32.788942	151.694400	Winch (auto tidal)	2	11.5	225	Modify active management
8	HUNT182F	Hunter	Port Stephens	Barties Creek off Hunter R	-32.727600	151.692200	Winch	2	18.5	900	Modify active management
9	HUNT033F	Hunter	Maitland City	Wallis Creek	-32.736900	151.574300	Winch	2	25.5	0	Modify active management
10	MANN082F	Lower North Coast	Greater Taree City	off Millers Creek	-31.891125	152.623068	Hinged Flap	2	14.5	25	Active management
11	HUNT061F	Hunter	Port Stephens	Purgatory Creek off Hunter R	-32.817345	151.679633	Hinged Flap	2	30.0	0	Active management
12	HUNT215F	Hunter	Maitland	off Paterson River	-32.680723	151.607313	Winch	2	9.5	25	Active management
13	MANN090F	Lower North Coast	Greater Taree City	off Dickensons Creek	-31.868140	152.539085	Hinged Flap	2	9.5	0	Active management
14	HUNT071F	Hunter	Port Stephens	Scotch Creek	-32.786015	151.700828	Winch	2	29.5	0	Modify active management
15	HUNT186F	Hunter	Port Stephens	off Hunter River	-32.742177	151.667977	Winch	2	44.5	0	Modify active management
16	HUNT217F	Hunter	Maitland	off Paterson River	-32.671167	151.606890	Winch	2	9.5	150	Modify active management
17	HUNT080F	Hunter	Port Stephens	Windeyers Creek	-32.774347	151.728628	Auto Tidal (winch)	2	18.5	0	Maintenance
18	HUNT081F	Hunter	Port Stephens	Nalleys Creek	-32.771623	151.723047	Winch	2	8.5	0	Modify active management
19	HUNT189F	Hunter	Port Stephens	off Hunter River	-32.728405	151.655905	Winch	2	44.5	0	Modify active management
20	HUNT057F	Hunter	Maitland City	Howes Lagoon	-32.737673	151.596628	Winch	2	1.5	0	Modify active management
21	HUNT103F	Hunter	Port Stephens	off Williams River	-32.747260	151.752565	Winch	2	6.0	0	Modify active management
22	HUNT237F	Hunter	Newcastle City	off Hunter River	-32.850048	151.697357	Hinged Flap	3	4.0	1530	Active management
23	MYAL003F	Lower North Coast	Great Lakes	Penenton Creek	-32.185323	152.515783	Hinged Flap	2	2.0	0	Active management
24	MANN128F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.795243	152.678885	Hinged Flap	3	22.5	600	Active management

Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
25	MANN132F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.818487	152.664565	Hinged Flap	3	22.5	600	Active management
26	MANN133F	Lower North Coast	Greater Taree City	off Cattai Creek	-31.821098	152.662367	Hinged Flap	3	22.0	600	Active management
27	HUNT125F	Hunter	Port Stephens	off Williams River	-32.692286	151.750852	Winch	3	19.5	700	Modify active management
28	HUNT003F	Hunter	Port Stephens	off Hunter River	-32.842332	151.755502	Hinged Flap	3	36.0	400	Active management
29	MANN130F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.805930	152.675587	Hinged Flap	3	22.5	600	Active management
30	HUNT138F	Hunter	Port Stephens	off Williams R (Eskdale Swamp)	-32.688610	151.722787	Hinged Flap	3	16.0	700	Active management
31	HUNT233F	Hunter	Port Stephens	off Fullerton Cove	-32.843690	151.809842	Winch	3	103.5	0	Modify active management
32	HUNT234F	Hunter	Port Stephens	off Fullerton Cove	-32.843873	151.809565	Winch	3	110.5	0	Modify active management
33	MANN005F	Lower North Coast	Greater Taree City	off Lansdowne River	-31.829523	152.604448	Hinged Flap	3	9.0	0	Active management
34	HUNT119F	Hunter	Port Stephens	off Williams River	-32.706906	151.748137	Winch	3	19.5	700	Modify active management
35	HUNT120F	Hunter	Port Stephens	off Williams River	-32.706572	151.748738	Winch	3	19.5	700	Modify active management
36	HUNT230F	Hunter	Port Stephens	Saltwater Gully	-32.741152	151.680160	Winch	3	44.5	0	Modify active management
37	MANN127F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.792477	152.679615	Hinged Flap	3	22.5	600	Active management
38	MANN129F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.799747	152.677725	Hinged Flap	3	22.5	600	Active management
39	MANN023F	Lower North Coast	Greater Taree City	off Ghinni Ghinni Creek	-31.849303	152.600755	Hinged Flap	3	28.5	0	Active management
40	MANN032F	Lower North Coast	Greater Taree City	off Lansdowne River	-31.825568	152.581358	Hinged Flap	3	28.5	0	Active management
41	MANN038F	Lower North Coast	Greater Taree City	off Manning River	-31.878271	152.584216	Hinged Flap	3	3.0	16	Active management
42	MANN118F	Lower North Coast	Greater Taree City	off Manning River	-31.907982	152.532630	Hinged Flap	3	8.5	1.5	Active management
43	HUNT059F	Hunter	Port Stephens	off Hunter River	-32.838098	151.732332	Hinged Flap	3	36.0	0	Active management
44	HUNT183F	Hunter	Port Stephens	off Hunter River	-32.726662	151.686103	Winch	3	2.5	900	Modify active management
45	MANN006F	Lower North Coast	Greater Taree City	off Lansdowne River	-31.829646	152.599698	Hinged Flap	3	9.0	0	Active management
46	MANN089F	Lower North Coast	Greater Taree City	off Dickensons Creek	-31.866972	152.533637	Hinged Flap	2	0.5	0	Active management
47	MANN102F	Lower North Coast	Greater Taree City	off Manning River	-31.863292	152.607657	Hinged Flap	3	2.0	0	Active management
48	HUNT127F	Hunter	Port Stephens	off Williams River	-32.692242	151.752454	Winch	3	40.5	500	Modify active management

Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
49	MANN049F	Lower North Coast	Greater Taree City	off Cattai Creek	-31.853177	152.636692	Hinged Flap	3	1.5	1500	Active management
50	MANN123F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.784157	152.682258	Hinged Flap	3	11.0	100	Active management
51	MANN131F	Lower North Coast	Greater Taree City	off Pipeclay Canal	-31.813255	152.669395	Hinged Flap	3	22.5	600	Active management
52	HUNT202F	Hunter	Maitland	off Paterson River	-32.707707	151.647938	Winch	3	18.5	900	Modify active management

<u>Appendix E</u>: Floodgate Data for All Priority Structures in the HNCMA Region

Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
High Priority Structures											
1	HAWL015F	Lower Hawkesbury-Nepean	Pittwater	off Cahill Creek	-33.667207	151.301103	Hinged Flap	2	3.0	0	Active management
2	HAWL008F	Lower Hawkesbury-Nepean	Hawkesbury City	Buttsworth Creek	-33.570228	150.831295	Winch	3	9.0	0	Modify active management
Medium Priority Structures											
3	HAWL011F	Lower Hawkesbury-Nepean	Hawkesbury City	off South Creek	-33.642072	150.824237	Hinged Flap	3	6.0	0	Active management
4	HAWL010F	Lower Hawkesbury-Nepean	Hawkesbury City	off Hawkesbury River	-33.589022	150.791847	Hinged Flap	3	24.5	0	Active management
5	HAWL006F	Lower Hawkesbury-Nepean	Hawkesbury City	off Hawkesbury River	-33.482882	150.894273	Hinged Flap	3	0.1	0	Active management
6	HAWL007F	Lower Hawkesbury-Nepean	Hawkesbury City	off Hawkesbury River	-33.572825	150.850393	Hinged Flap	3	1.0	0	Active management
Low Priority Structures											
7	HAWL001F	Lower Hawkesbury-Nepean	Hawkesbury City	off Hawkesbury River	-33.444967	151.078188	Hinged Flap	4	0.05	0	Active management
8	HAWL004F	Lower Hawkesbury-Nepean	Hawkesbury City	off Douglas Creek	-33.429552	150.958907	Hinged Flap	4	0.5	0	Active management
9	HAWL005F	Lower Hawkesbury-Nepean	Hawkesbury City	off Douglas Creek	-33.429223	150.957510	Hinged Flap	4	0.5	0	Active management
10	HAWL009F	Lower Hawkesbury-Nepean	Hawkesbury City	off Hawkesbury River	-33.574237	150.785443	Hinged Flap	4	0.5	0	Active management

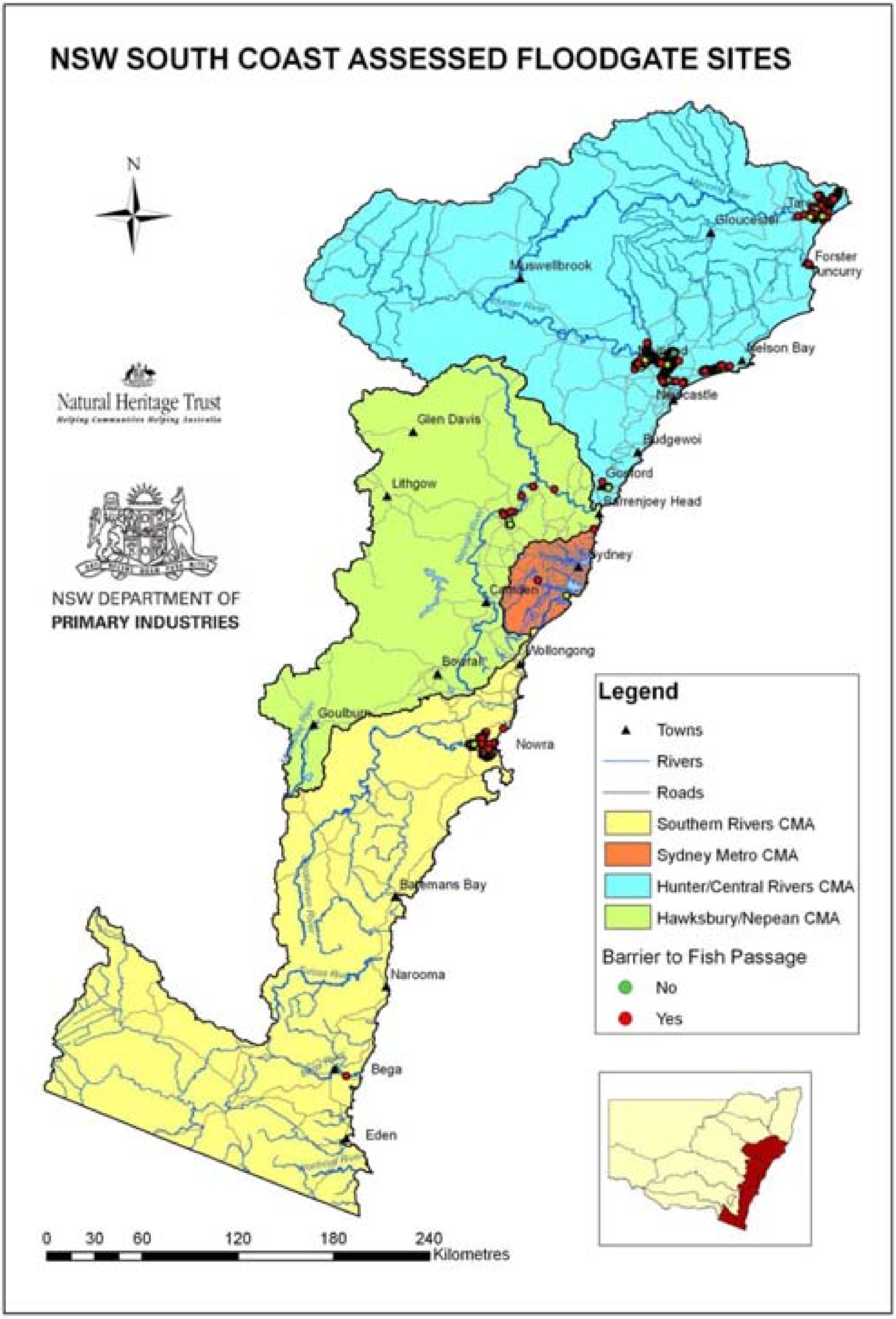
<u>Appendix F</u>: Floodgate Data for All Priority Structures in the SMCMA Region

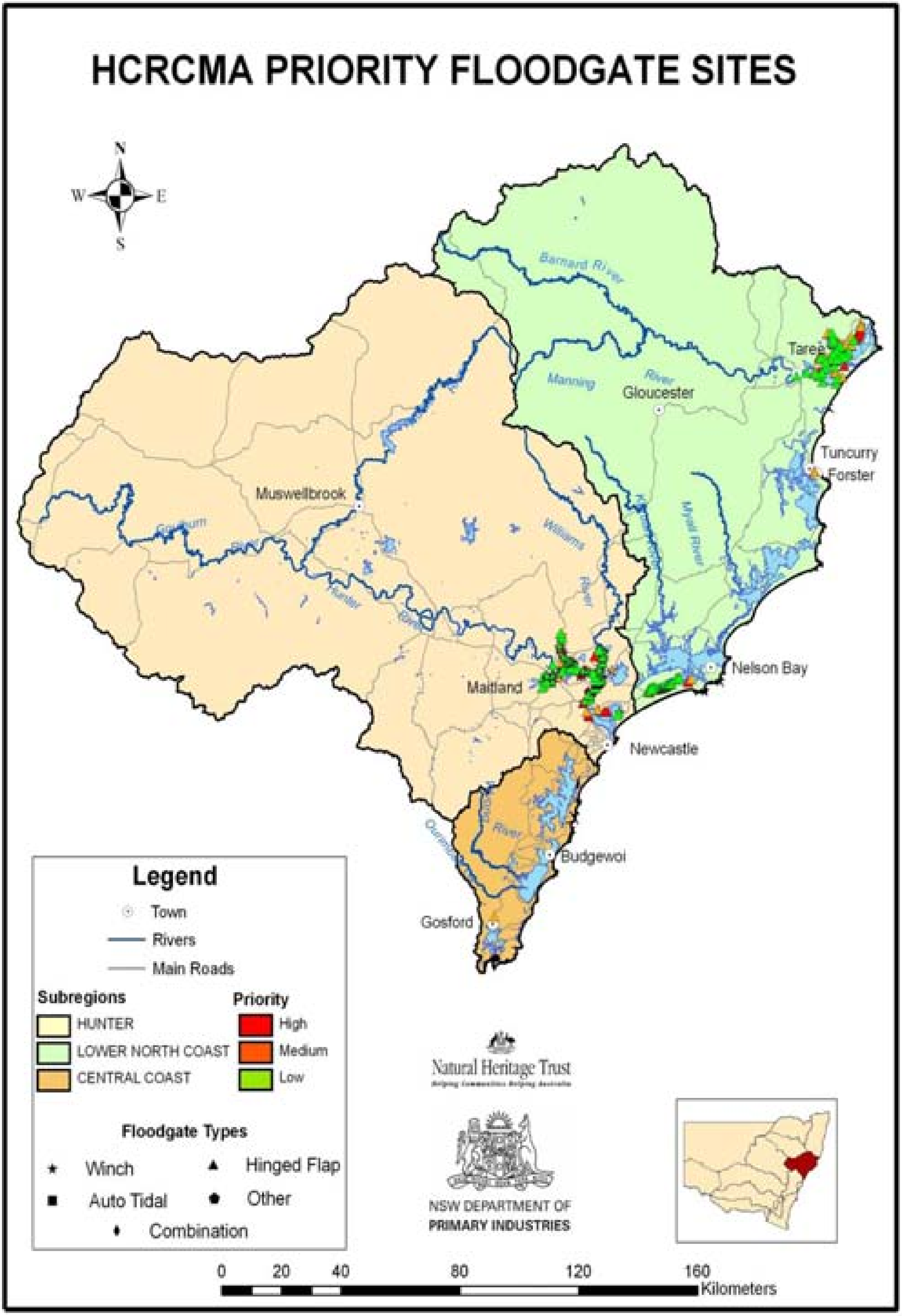
Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
High Priority Structure											
1	SYDN001F	Georges River	Bankstown City	Kelso Creek	-33.954834	150.984500	Winch	2	3.0	0	Modify active management

Appendix G: Floodgate Data for High Priority and Medium Priority Structures in the SRCMA Region

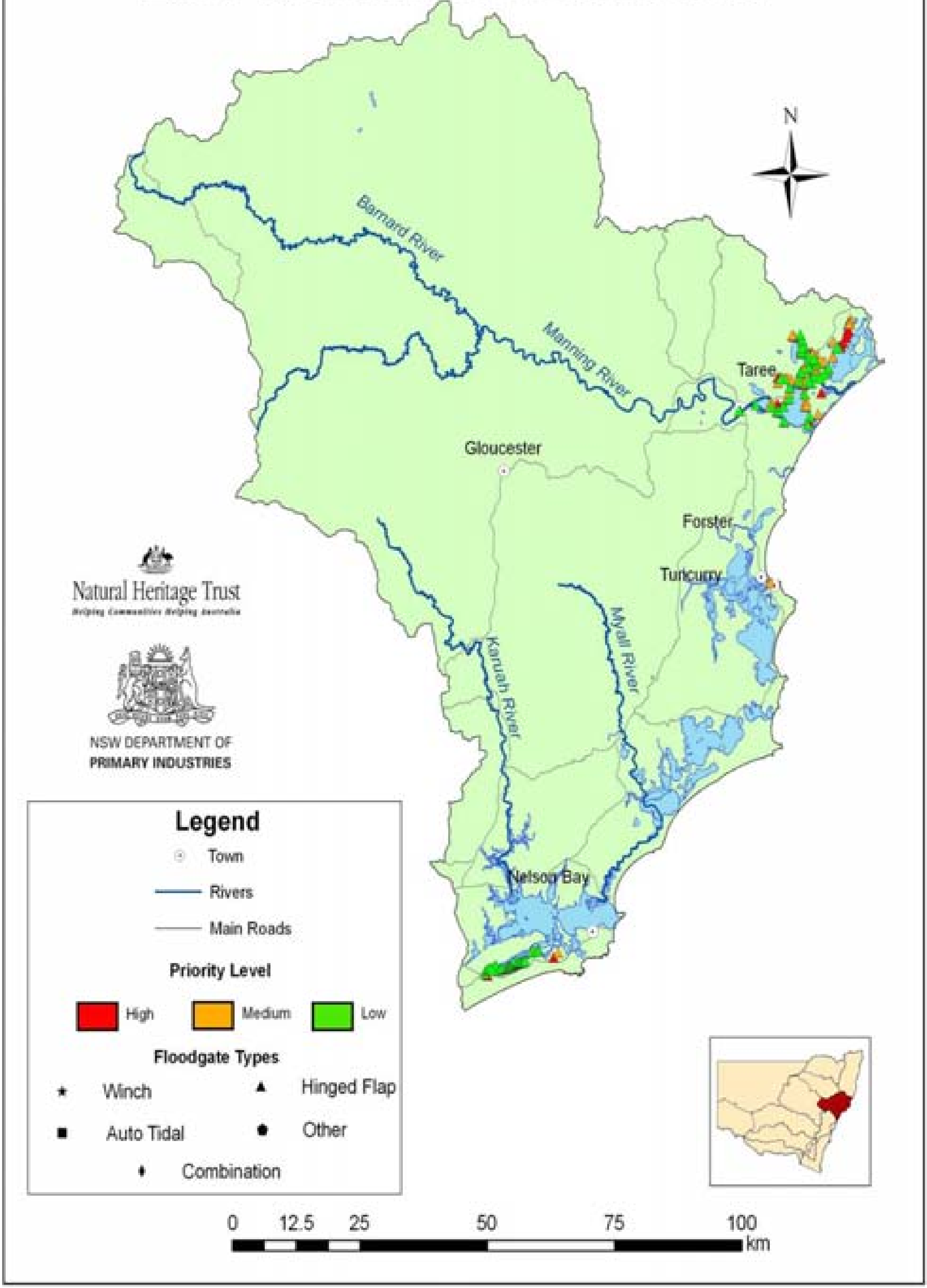
Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
High Priority Structures											
1	SHOA046F	Shoalhaven-Wollongong	Shoalhaven City	Crookhaven River	-34.936923	150.694483	Hinged Flap	1	28.5	300	Active management
2	SHOA017F	Shoalhaven-Wollongong	Shoalhaven City	Horseshoe Creek	-34.826268	150.654385	Hinged Flap	2	59.5	600	Active management
3	SHOA058F	Shoalhaven-Wollongong	Shoalhaven City	Ryans Creek	-34.890512	150.708797	Hinged Flap	2	52.0	200	Active management
4	SHOA059F	Shoalhaven-Wollongong	Shoalhaven City	off Shoalhaven River	-34.863050	150.666572	Hinged Flap	2	52.0	350	Active management
5	SHOA024F	Shoalhaven-Wollongong	Shoalhaven City	Snake Island Creek	-34.827693	150.675788	Hinged Flap	2	33.5	150	Active management
6	SHOA001F	Shoalhaven-Wollongong	Kiama	Blue Angle Creek	-34.775778	150.790815	Hinged Flap	2	12.0	200	Active management
7	SHOA057F	Shoalhaven-Wollongong	Shoalhaven City	Saltpan Creek	-34.899645	150.718633	Hinged Flap	2	52.0	60	Active management
8	SHOA015F	Shoalhaven-Wollongong	Shoalhaven City	off Shoalhaven River	-34.865030	150.617607	Hinged Flap	2	23.5	150	Active management
9	SHOA054F	Shoalhaven-Wollongong	Shoalhaven City	off Crookhaven River	-34.921960	150.722275	Hinged Flap	2	12.5	150	Active management
10	SHOA004F	Shoalhaven-Wollongong	Shoalhaven City	off Shoalhaven River	-34.859090	150.729618	Hinged Flap	2	14.0	30	Active management
11	SHOA042F	Shoalhaven-Wollongong	Shoalhaven City	Eelwine Creek	-34.913578	150.674653	Hinged Flap	2	52.0	0	Active management
12	SHOA045F	Shoalhaven-Wollongong	Shoalhaven City	off Crookhaven Creek	-34.923262	150.671358	Hinged Flap	2	28.5	0	Active management
13	SHOA018F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.823608	150.659390	Auto Tidal (Hinged)	3	59.5	200	Maintenance
14	SHOA038F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.822223	150.675997	Hinged Flap	3	59.5	75	Active management
15	SHOA036F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.815898	150.679332	Smart Gate (Hinged)	3	60.5	150	Modify active management
16	SHOA039F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.830473	150.670023	Hinged Flap	3	59.5	100	Active management
17	SHOA041F	Shoalhaven-Wollongong	Shoalhaven City	off Crookhaven Creek	-34.902135	150.669962	Hinged Flap	3	52.0	0	Active management
18	SHOA052F	Shoalhaven-Wollongong	Shoalhaven City	off Crookhaven River	-34.932122	150.711803	Hinged Flap	3	12.5	170	Active management

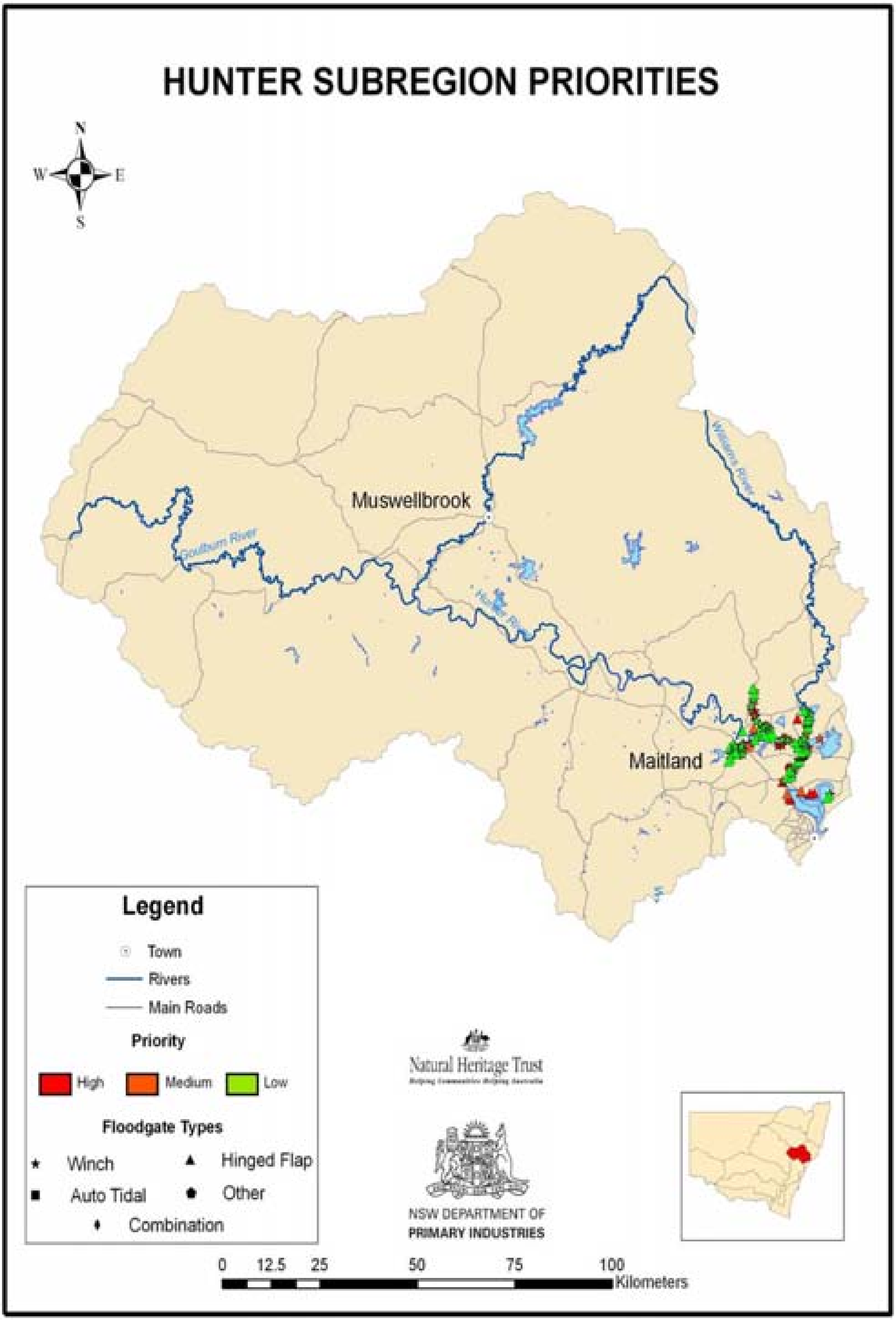
Rank	Structure ID	Subregion	LGA	Waterway	Latitude	Longitude	Structure Type	Stream Class	Habitat u/s (km)	Wetland u/s (Ha)	Recommendation
Medium Priority Structures											
19	SHOA027F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.815865	150.685513	Hinged Flap	3	33.5	70	Active management
20	SHOA040F	Shoalhaven-Wollongong	Shoalhaven City	off Crookhaven Creek	-34.902162	150.669873	Hinged Flap	2	23.5	0	Active management
21	BEGA001F	Bega-Eden	Bega Valley Shire	Jellat Jellat Creek	-36.719325	149.903605	Hinged Flap	3	6.5	200	Active management
22	SHOA006F	Shoalhaven-Wollongong	Shoalhaven City	off Bevan Creek	-34.861203	150.709818	Hinged Flap	3	2.0	10	Active management
23	SHOA026F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.816685	150.680673	Hinged Flap	3	33.5	30	Active management
24	SHOA029F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.806722	150.688610	Smart Gate (Hinged)	3	33.5	30	Modify active management
25	SHOA035F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.795770	150.692225	Smart Gate (Hinged)	3	25.5	100	Modify active management
26	SHOA003F	Shoalhaven-Wollongong	Shoalhaven City	off Bevan Creek	-34.859205	150.727172	Hinged Flap	3	6.0	0	Active management
27	SHOA053F	Shoalhaven-Wollongong	Shoalhaven City	off Crookhaven River	-34.928203	150.718570	Hinged Flap	3	12.5	30	Active management
28	SHOA007F	Shoalhaven-Wollongong	Shoalhaven City	Abernethys Creek	-34.857243	150.613853	Hinged Flap	3	49.5	10	Active management
29	SHOA028F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.805502	150.688627	Hinged Flap	3	33.5	30	Active management
30	SHOA030F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.806947	150.688617	Hinged Flap	3	33.5	30	Active management
31	SHOA023F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.830115	150.673108	Hinged Flap	3	33.5	5	Active management
32	SHOA002F	Shoalhaven-Wollongong	Shoalhaven City	Unnamed drain off Shoalhaven River	-34.854075	150.744335	Hinged Flap	3	0.5	0	Active management
33	SHOA021F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.844267	150.668253	Hinged Flap	3	1.5	50	Active management
34	SHOA033F	Shoalhaven-Wollongong	Shoalhaven City	off Broughton Creek	-34.799745	150.687323	Smart Gate (Hinged)	3	25.5	10	Modify active management


NSW SOUTH COAST ASSESSED FLOODGATE SITES
N
Natural Heritage Trust
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
Muswellbrook
Gloucester
Forster
Nelson Bay
Newcastle
Glen Davis
Lithgow
Budgewoi
Gosford
Barrenjoey Head
Sydney
Camden
Wollongong
Bowral
Goulburn
Nowra
Batemans Bay
Narooma
Bega
Eden
Legend
Towns
Rivers
Roads
Southern Rivers CMA
Sydney Metro CMA
Hunter/Central Rivers CMA
Hawksbury/Nepean CMA
Barrier to Fish Passage
No
Yes
0 30 60 120 180 240
Kilometres

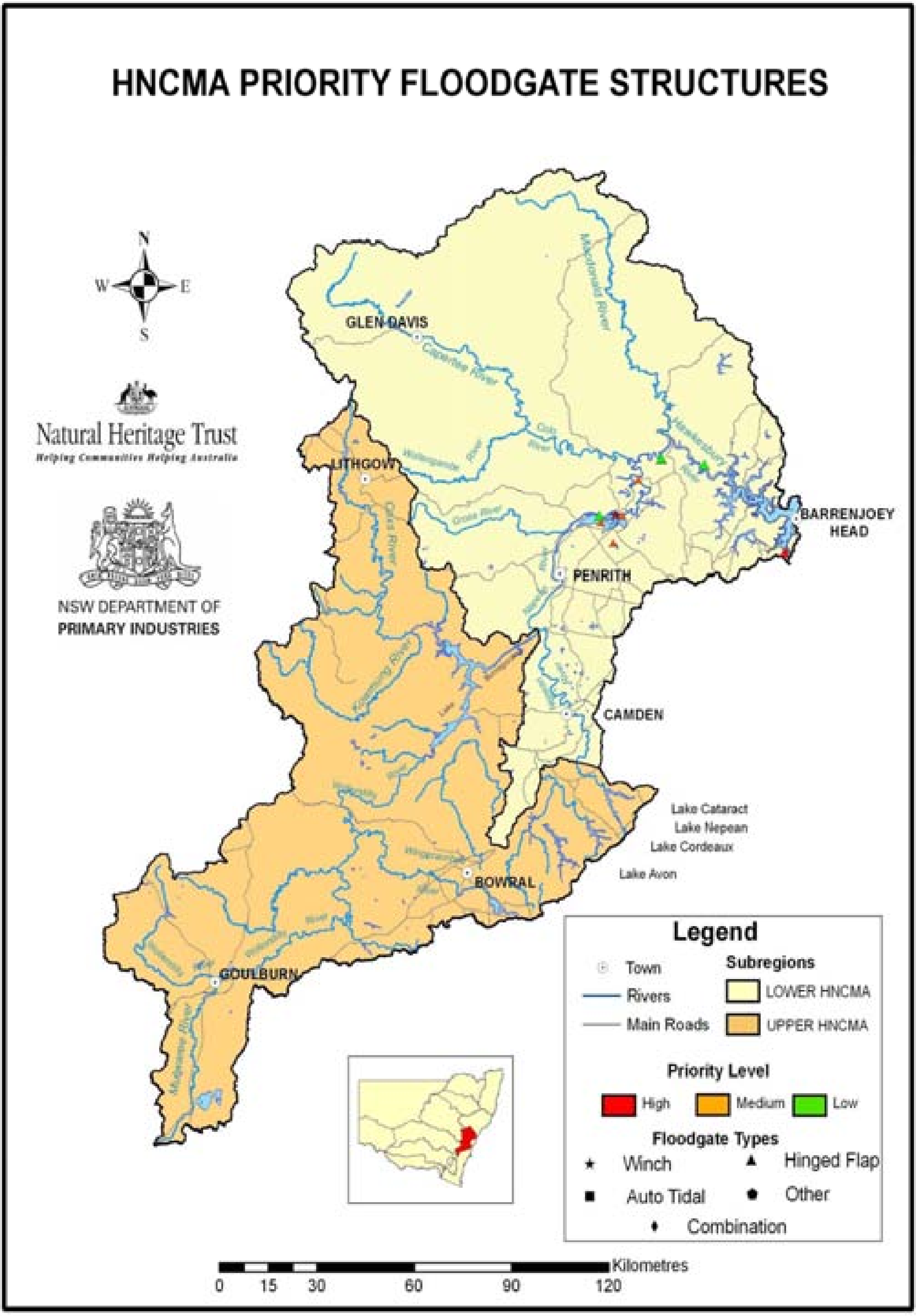

HCRCMA PRIORITY FLOODGATE SITES
N
W
E
S
Barnard River
Manning
River
Gloucester
Taree
Tuncurry
Forster
Muswellbrook
Williams
River
Myall River
Hunter
River
Maitland
Nelson Bay
Newcastle
River
Budgewoi
Gosford
Legend
Town
Rivers
Main Roads
Subregions
HUNTER
LOWER NORTH COAST
CENTRAL COAST
Priority
High
Medium
Low
Floodgate Types
Winch
Hinged Flap
Auto Tidal
Other
Combination
Natural Heritage Trust
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
0
20
40
80
120
160
Kilometers

LNC PRIORITY FLOODGATE SITES

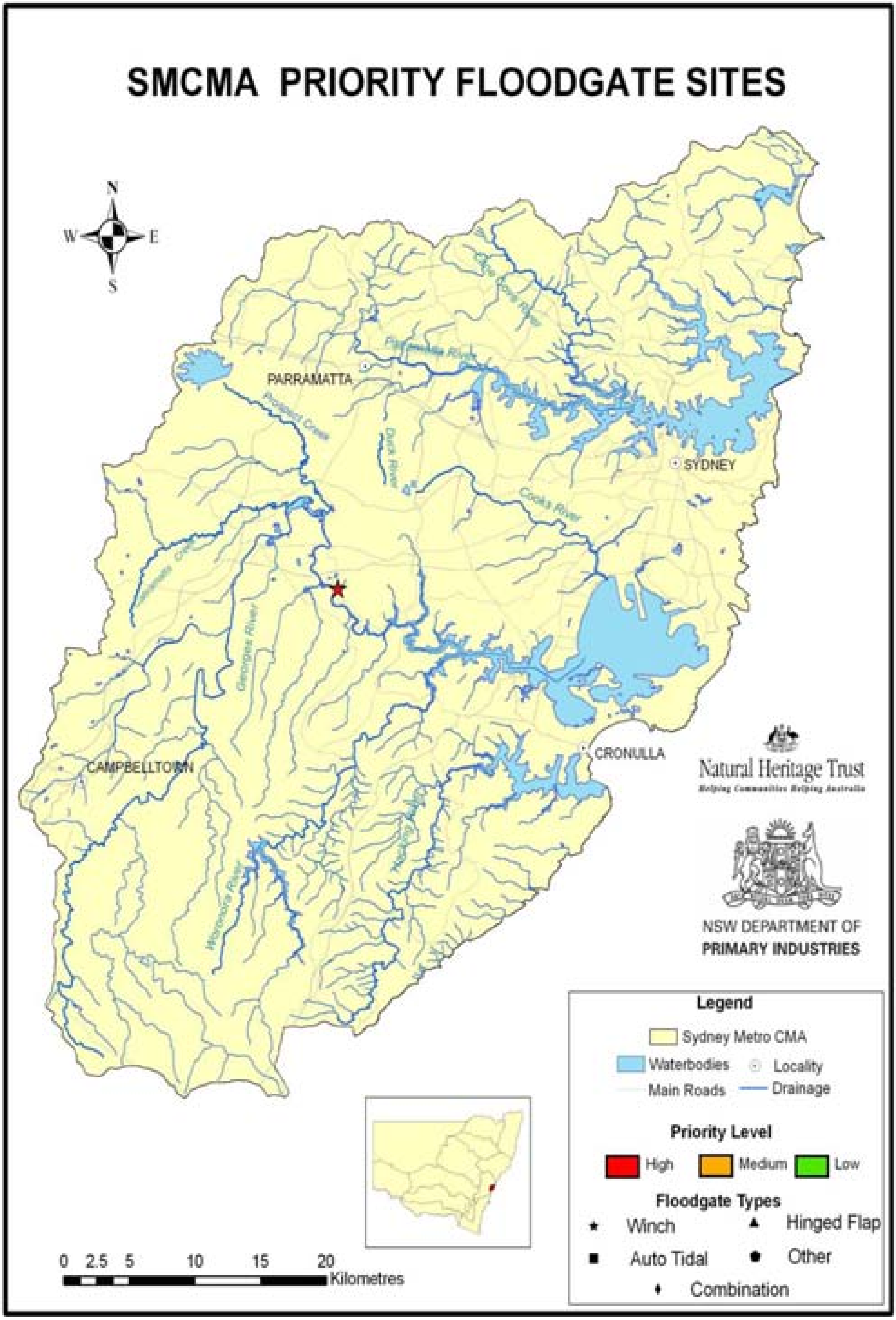


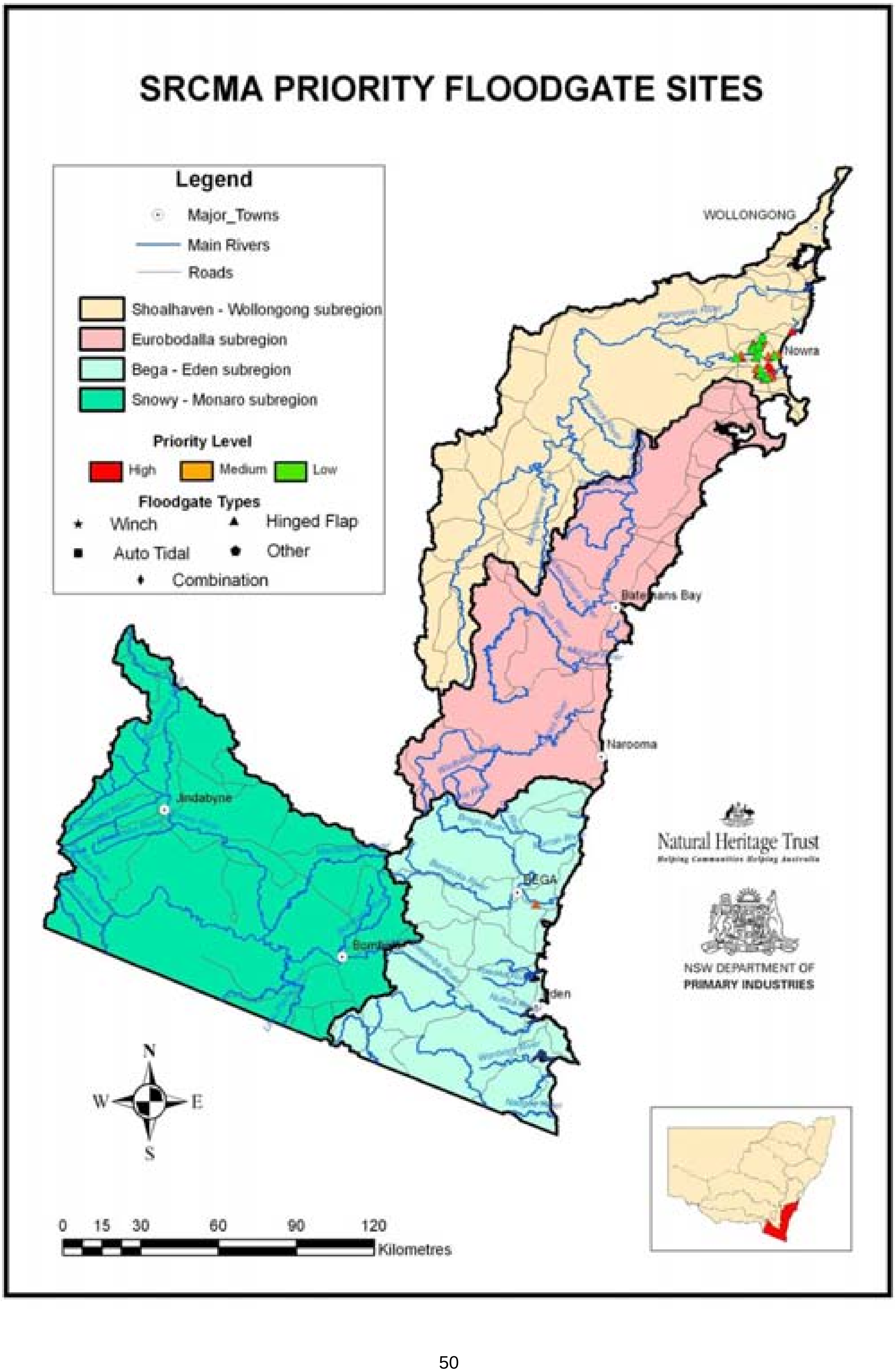


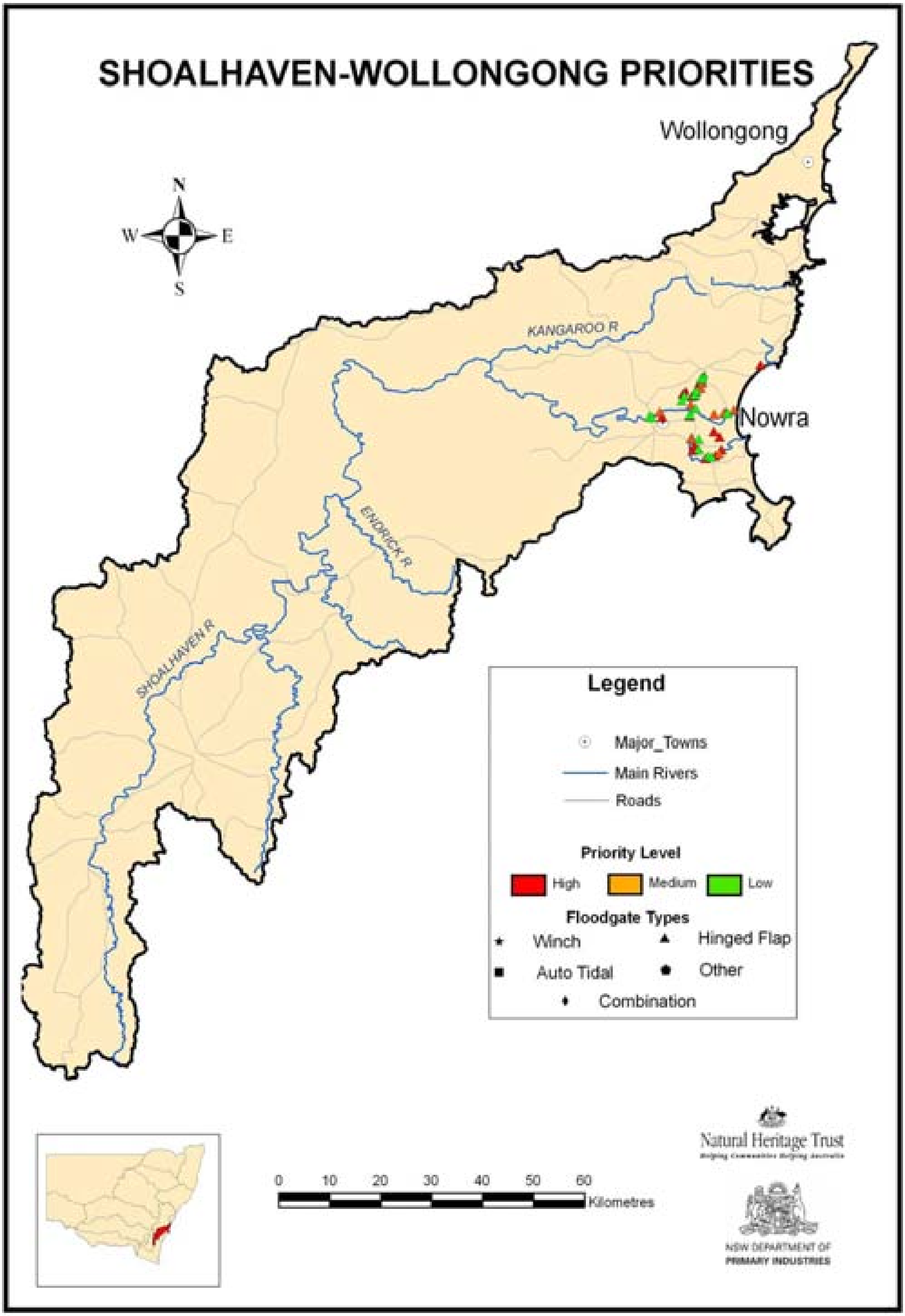
HUNTER SUBREGION PRIORITIES
N
W
E
S
Muswellbrook
Goulburn River
Hunter River
Williams River
Maitland
Legend
Town
Rivers
Main Roads
Priority
High
Medium
Low
Floodgate Types
Winch
Hinged Flap
Auto Tidal
Other
Combination
Natural Heritage Trust
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
0
12.5
25
50
75
100
Kilometers



HNCMA PRIORITY FLOODGATE STRUCTURES
N
W
E
S
Natural Heritage Trust
Helping Communities Helping Australia
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
GLEN DAVIS
LITHGOW
PENRITH
CAMDEN
BOWRAL
GOULBURN
BARRENJOEY HEAD
Lake Cataract
Lake Nepean
Lake Cordeaux
Lake Avon
Legend
Town
Rivers
Main Roads
Subregions
LOWER HNCMA
UPPER HNCMA
Priority Level
High
Medium
Low
Floodgate Types
Winch
Hinged Flap
Auto Tidal
Other
Combination
Kilometres
0
15
30
60
90
120


SMCMA PRIORITY FLOODGATE SITES
N
S
E
W
PARRAMATTA
SYDNEY
CRONULLA
CAMPBELLTOWN
Duck River
Cooks River
Georges River
Woronora River
Natural Heritage Trust
Helping Communities Helping Australia
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
Legend
Sydney Metro CMA
Waterbodies
Locality
Main Roads
Drainage
Priority Level
High
Medium
Low
Floodgate Types
Winch
Hinged Flap
Auto Tidal
Other
Combination
0 2.5 5 10 15 20
Kilometres


SRCMA PRIORITY FLOODGATE SITES
Legend
Major_Towns
Main Rivers
Roads
Shoalhaven - Wollongong subregion
Eurobodalla subregion
Bega - Eden subregion
Snowy - Monaro subregion
Priority Level
High
Medium
Low
Floodgate Types
Winch
Hinged Flap
Auto Tidal
Other
Combination
WOLLONGONG
Nowra
Batemans Bay
Narooma
Jindabyne
BEGA
Bombala
Eden
Natural Heritage Trust
NSW DEPARTMENT OF
PRIMARY INDUSTRIES
N
W
E
S
0 15 30 60 90 120
Kilometres


SHOALHAVEN-WOLLONGONG PRIORITIES
Wollongong
Nowra
N
S
E
W
KANGAROO R
ENDRICK R
SHOALHAVEN R
Legend
Major_Towns
Main Rivers
Roads
Priority Level
High
Medium
Low
Floodgate Types
Winch
Hinged Flap
Auto Tidal
Other
Combination
0
10
20
30
40
50
60
Kilometres
Natural Heritage Trust
NSW DEPARTMENT OF
PRIMARY INDUSTRIES

aquatic habitat
rehabilitation

making more fish **...naturally**