OBSTRUCTIONS TO FISH PASSAGE IN NEW SOUTH WALES SOUTH COAST STREAMS

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1. SUMMARY

Native freshwater fish populations are affected by obstructions to fish passage because their natural movements throughout river systems are compromised. Artificial barriers such as dams, weirs, causeways and culverts obstruct the free passage of native fish by preventing or impeding their movement from one part of a stream to another. All freshwater fish need to move between habitat areas at some stage in their life cycle to spawn or seek food and shelter, with many having definite migration requirements. Therefore, obstructions which impede the free passage of fish often result in declining populations or local extinction.

A survey was made to identify and document fish passage obstructions in the coastal rivers of south-eastern New South Wales. The area studied ranged from the Wollongong Coast south of Sydney to the Victorian border, also including the Snowy River. This area comprised a total of nine of the Australian Water Resources Council Drainage Basins, including the Wollongong Coast (No. 214), Shoalhaven River (No. 215), Clyde River-Jervis Bay (No. 216), Moruya River (No. 217), Tuross River (No. 218), Bega River (No. 219), Towamba River (No. 220), East Gippsland (No. 221) and Snowy River (No. 222).

A total of 254 obstructions were documented, comprising high dams, farm dams, fixed crest-weirs, rock weirs, stream-gauging weirs, culverts, causeways, bridges and tidal floodgates. Overall, causeways and culverts were the most common structures found to obstruct fish passage. The largest number of obstructions occurred in the Shoalhaven River Basin, where a total of 90 artificial barriers were present. A total of 47 obstructions occurred in the Wollongong Coast Basin, 25 in the Clyde River-Jervis Bay Basin, 24 in the Snowy River Basin, 24 in the Bega River Basin, 18 in the Tuross River Basin, 17 in the Towamba River Basin, 6 in the Gippsland River Basin, and 3 in the Moruya River Basin.

A "fishway priority scheme" was developed to provide a quantative, objective basis to rank the priority of a fish-passage restoration project for any obstruction, either by building a fishway or removing the obstruction. Eleven criteria were used, including details of the size of the river system, location of the obstruction, presence of threatened species, severity of the obstruction and other relevant features.

The Fisheries Management Act (1994) has various provisions for maintaining fish passage in streams, these are summarised in the publication: "Policy and Guidelines. Aquatic Habitat Management and Conservation 1998." The current survey has shown that there are numerous obstructions to fish passage which impede migration and threaten biodiversity in many south coast streams. Fish passage needs to be restored as a major step in restoring healthy rivers.

2. INTRODUCTION

2.1 Migration of freshwater fishes in south coast streams of New South Wales

All Australian freshwater fish have a need to move between habitat areas in streams (Thorncraft and Harris 1996; Smith and Pollard 1998). Most of the freshwater species of south-eastern Australia are known to migrate at some stage of their life cycles (Mallen-Cooper 1994). The coastal rivers of southern New South Wales provide habitat for 48 species of freshwater fishes, of which 35 are native to this region (Harris 1995). These include two species of eels, two hardyhead species, freshwater herring, several species of gudgeons, and a number of species of galaxiids, gobies, mullets, cods and basses. The popular angling fish, Australian bass *(Macquaria novemaculeata),* is one migratory species that has been adversely affected by barriers to fish passage throughout its range (Harris 1988). The list also includes three threatened species, Macquarie perch *(Macquaria australasica)*, Australian grayling *(Prototroctes maraena),* and non-parasitic lamprey *(Mordacia praecox).*

The migration patterns of freshwater fishes have been classified into four different categories, which are described in Harris (1984a). 'Diadromous' fishes migrate between the sea and freshwater for the purpose of breeding. and thus may be either 'anadromous', 'catadromous' or 'amphidromous'. Anadromous fishes usually live in the sea and migrate to fresh water to breed, while catadromous fishes live most of their lives in fresh water and move to estuarine or marine waters to spawn. The catadromous cycle is the most common migration pattern of fishes found in coastal streams in south-eastern Australia (Mallen-Cooper 1994). Australian bass and striped mullet *(Mugil cephalus)* are two species which follow this pattern, which usually involves an autumn-winter migration to the estuaries or the sea, followed by a return to fresh water in early spring. Juveniles move back upstream in late spring to early summer (Mallen-Cooper 1994). Amphidromous fishes migrate between the sea and fresh water, not for breeding purposes, but to feed and to avoid predators. Common amphidromous species include the climbing galaxias and flat-tail mullet (Mallen-Cooper 1994). 'Potamodromous' fishes, such as the Macquarie perch, are those non-diadromous species which migrate within rivers without entering the sea.

Table 2.1 lists the fishes living in the freshwater reaches of coastal rivers of southern New South Wales, together with their known migratory patterns. A number of freshwater fishes have been introduced from countries outside Australia, some of which are regarded as pests (Harris 1995). These alien species are also listed in this table. The silver perch *(Bidyanus bidyanus)* is native to Australia, but has been translocated to coastal freshwater systems from western drainages, and in this context is referred to as an 'introduced' species (Harris 1995).

Table 2.1 Fishes found in the coastal rivers of southern NSW

Family	Species	Common name	Migratory Requirements	Distribution (Basin Nos)
Anguillidae	*Anguilla australis*	short-finned eel	catadromous	214-222
	A. reinhardtii	long-finned eel	catadromous	214-222
Atherinidae	*Atherinosoma microstoma*	small-mouthed hardyhead		214-221
	Pseudomugil signifer	Pacific blue-eye		214218
Bovichtidae	*Pseudaphritis urvilii*	tupong (congolli)	amphidromous	220-222
Clupeidae	*Potamalosa richmondia*	freshwater herring	catadromous	214-221
Cobitidae	*Misgurnus*	oriental weatherloach		222
Cyprinidae	*Carassius auratus**	goldfish		214-222
	*Cyprinus carpio**	common carp		215
Eleotridae	*Gobiomorphus australis*	striped gudgeon	amphidromous	214-221
	G. coxii	Cox's gudgeon	potamodromous	214-221
	Hypseleotris compressa	empire gudgeon		214-220
	H. galii	firetail gudgeon		214-220
	Philypnodon grandiceps	big-headed gudgeon		214-222
	Philypnodon sp. 1.	dwarf flathead gudgeon		214-222
Galaxiidae	*Galaxias brevipinnis*	climbing galaxias	amphidromous	214-222
	G. maculatus	common galaxias	catadromous	214-221
	G. olidus	mountain galaxias		214-222
Gobiidae	*Arenigobius bifrenatus*	bridled goby		214-221
	Pseudogobius olorum	Swan River goby	amphidromous	
	Redigobius macrostoma	large-mouthed goby		214-221
Mordaciidae	*Mordacia mordax*	short-headed lamprey	anadromous	214-222
	M. praecox	non-parasitic lamprey	anadromous	217-218
Mugilidae	*Aldrichetta forsteri*	yellow-eye mullet	amphidromous	214-221
	Mugil cephalus	striped mullet	catadromous	214-221
	M. petardi	freshwater mullet	catadromous	
Percichthyidae	*Macquaria australasica*	Macquarie perch	potamodromous	215
	M. colonorum	estuary perch		214-221
	M. novemaculeata	Australian bass	catadromous	214-221
Percidae	*Perca fluviatilis**	redfin perch		215, 222
Plotosidae	*Tandanus tandanus*	freshwater catfish		214
Poeciliidae	*Gambusia holbrooki**	gambusia		214-222
Prototroctidae	*Prototroctes maraena*	Australian grayling	anadromous	214-222
Retropinnidae	*Retropinna semoni*	Australian smelt	amphidromous	214-222
Salmonidae	*Oncorhynchus mykiss**	rainbow trout		222
	*Salmo salar**	Atlantic salmon		222
	*S. trutta**	brown trout		222
	*Salvelinus fontinalus**	brook trout		222
Scorpaenidae	*Notesthes robusta*	bullrout	catadromous	214-216
Terapontidae	*Bidyanus bidyanus#*	silver perch	potamodromous	

* Alien species, # Introduced species

The fish species mentioned above cover a range of sizes and swimming abilities. The migratory stage may be the adults and/or the juveniles of both large or small species. Many of the adult catadromous and amphidromous species may weigh less than 2 kilograms (Mallen-Cooper 1994), while Australian bass may grow to 3.8 kilograms (McDowall 1996). A single fish of some species may swim 1000 kilometres or more during a spring and summer (Mallen-Cooper 1994), while others may need to travel for only short distances.

2.2 Consequences of obstructions to fish passage

Since the arrival of European civilisation in Australia, there has been a marked decline in the range and abundance of freshwater fishes (Harris and Mallen-Cooper 1994, Mallen-Cooper 1994). A number of factors have led to this decline of Australian freshwater fish and fisheries, including habitat degradation, introduction of alien fish species, overfishing and obstruction of fish passage by obstructions such as dams, weirs, culverts and causeways (Mallen-Cooper 1988; Harris and Mallen-Cooper 1994; Smith and Pollard 1998). The decline of the Australian grayling to 'potentially threatened' status has been a result of such obstructions (Wager and Jackson 1993). Timms (1995) summarised the effects of obstructions to fish passage as shown in Figure 2.1

Obstructions to fish passage occur throughout the Australian continent, the driest in the world. Numerous dams and weirs have been built along river systems since the 1800s in order to provide reservoirs for water supply for Australia's growing population (Harris 1984a; Mallen-Cooper 1994). Numerous weirs have also been built in order to gauge the flow of rivers and streams. In addition to dams and weirs, causeways and culverts have been built across streams to provide access for vehicles. All of these structures form unnatural obstacles which impede or modify stream flow and the movement of fish from one part of the river to another. These obstacles prevent fish passage in periods of low flow, but many may allow the movement of fish in times of flood when inundation eventually provides free passage and the obstacle is said to be 'drowned-out'. Some obstacles prevent fish passage at all times, constituting a complete barrier which leads to local extinction of migratory species upstream, and possibly downstream also (Harris 1984a; Harris and Mallen-Cooper 1994; Marsden *et al.* 1997).

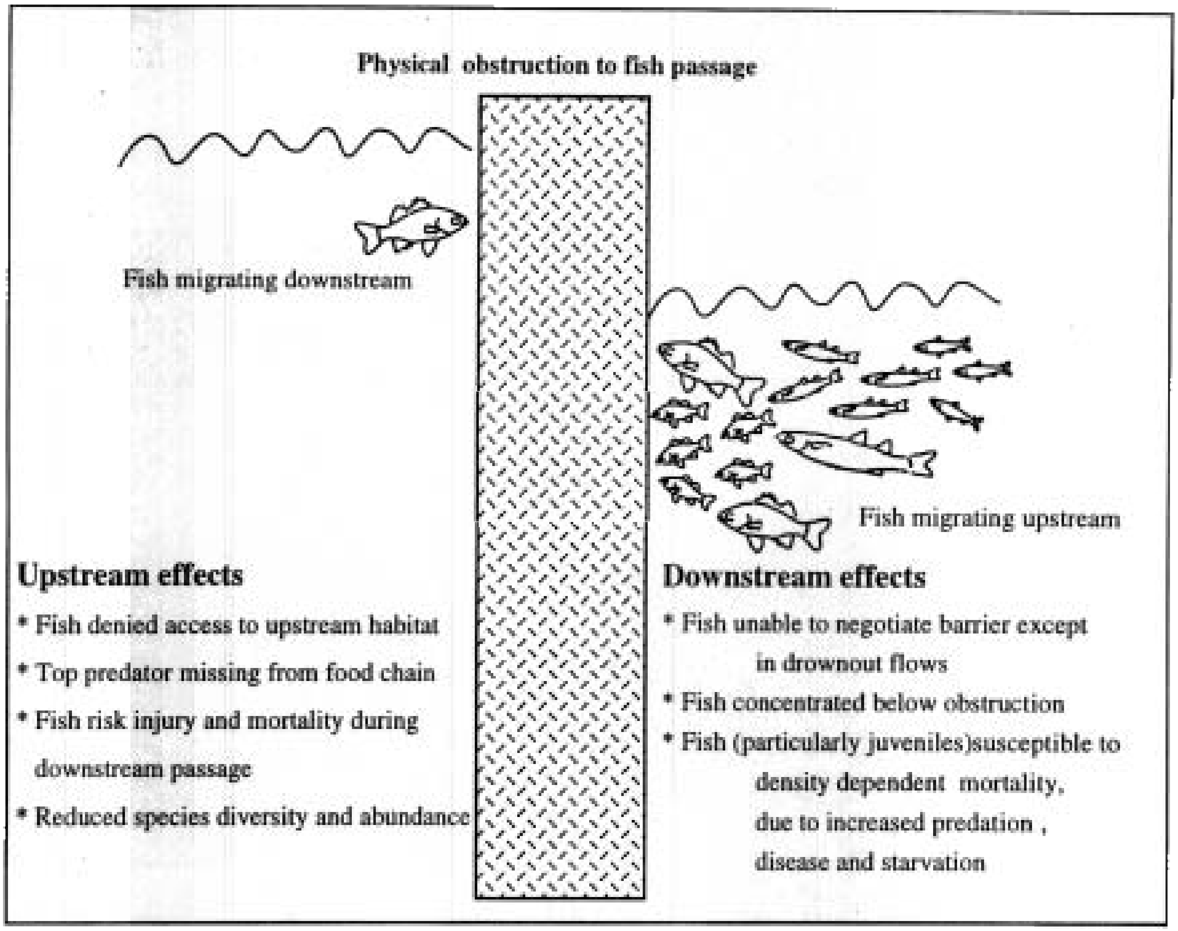

Figure 2. Consequences of obstructions to fish passage (modified from Timms 1995)

Harris (1984a) carried out a study to determine the amount of freshwater fish habitat obstructed by impoundments on the coastal drainages of south-eastern Australia within the geographical range of the Australian bass. This covered coastal drainages from the Mary River in Queensland to Lakes Entrance in eastern Victoria (22 drainage basins). A total of the barriers found, including 111 dams, 30 tidal barriers, 96 weirs and 56 high weirs. Most of these barriers (70%) were found in the more highly developed areas, which included Brisbane, the Gold Coast, Hunter-Hawkesbury, Sydney, Illawarra and Lakes Entrance. The largest number of barriers (80) in a single catchment was found on the Hawkesbury River System near Sydney. The results indicated that artificial barriers have obstructed about half of the total length of streams which are potentially available as fish habitat. These obstructions have contributed to the decline and loss of populations of catadromous fishes, such as the Australian bass.

Another study by Harris (1988) indicated that the spawning behavior of bass is triggered by flooding, with bass recruitment being higher in years of high winter river flows. Therefore, the recruitment of bass is not only affected by the obstruction of rivers by barriers, but also through the effects of dams on the flow regime. There have been very few studies carried out on the biology of other native fishes which inhabit the coastal regions of south-eastern Australia, but it can be assumed that other migratory species having similar life-histories would be affected in a similar way.

Timms (1995) studied obstructions to fish passage in the Shoalhaven catchment below Tallowa Dam for a B.Sc. Honours project through the University of Wollongong. A total of 62 barriers (comprising dams, weirs, floodgates, levees, culverts and causeways) were found in this catchment. These barriers have the potential to alienate 67 km of estuarine and 87 km of freshwater fish habitat below the Tallowa.

It has been documented that obstructions to fish passage may have detrimental effects on all fish species, not just recognised migratory species (Koehn & O'Connor 1990; Harris and Mallen-Cooper 1994; Berghuis *et al.* 1997). Fishes need to move between stream habitat areas not only for spawning or feeding migrations, but also for recolonisation, and habitat selection (Koehn and O'Connor 1990). The result of obstructions can be to concentrate populations into smaller river reaches or pools, thus increasing the potential for disease starvation and predation.

2.3 Aims and objectives of this study

It was noted by Harris (1984a) that only limited information was available about the occurrence and features of physical barriers in Australian streams. Until recently there has also been little control over the construction of these barriers. In the Shoalhaven catchment below Tallowa Dam, only 11 structures were found by Harris (1984). In 1995, however, Timms found 62 barriers for the same area. However, Harris's study was on a broader scale, and only weirs and dams on streams were surveyed. Timms' (1995) study was more comprehensive study of one area, and including smaller-scale physical structures (e.g. low-level weirs, causeways, culverts and floodgates) as well as dams and weirs. These small-scale obstructions may still cause serious problems for fish passage. Because Harris's 1984 study was completed over a decade ago, and did not include small-scale obstructions the need for a more up-to-date inventory of barriers to fish passage on the streams of the south coast of NSW was identified.

The main aims of the project were:

to locate, identify and document the barriers to fish passage which occur on NSW south coast streams,

to estimate the amount of fish habitat being obstructed,

* to prioritise the barriers found in terms of the need to provide for fish passage at these sites, and
* to prepare a strategic plan of future actions to address the problems posed by these barriers.

3. METHODS

A steering committee was set up to plan and oversee the progress of the project. The committee was made up of staff from NSW Fisheries (NSWF) and the Department of Land and Water Conservation (DLWC) (Table 3.1). At the first meeting, in April 1996, the methodology for the study was discussed. It was decided to use NSW Central Mapping Authority (CMA) topographic maps for the identifying fish habitat and the preliminary location of sites.

Table 3. Project Steering Committee

Name	Department
Robyn Pethebridge (Project Officer)	NSWF
John Harris	NSWF
Allan Lugg	NSWF
David Pollard	NSWF
Rob Williams	NSWF
Mark Conlon	DLWC
Tim Entwistle	DLWC

3.1 Study area

The steering committee for the project decided to survey all of the coastal river systems from Lake Illawarra south to the Victorian border, including the Snowy River catchment area. The Australian Water Resources Council Drainage Division No. 2, which includes all of the coastal river basins of NSW, was used to determine catchment boundaries.

The drainage basins south of the Sydney region which were studied, include the Wollongong (No. 214), Shoalhaven River (215), Clyde River-Jervis Bay (216), Moruya River (217), Tuross River (218), Bega River (219), Towamba River (220), East Gippsland (221), and Snowy River (222) Basins (see Figure 3.1). The numbers in brackets indicate the numbers allocated by the Australian Water Resources Council (AWRC) 'Pinneena' maps.

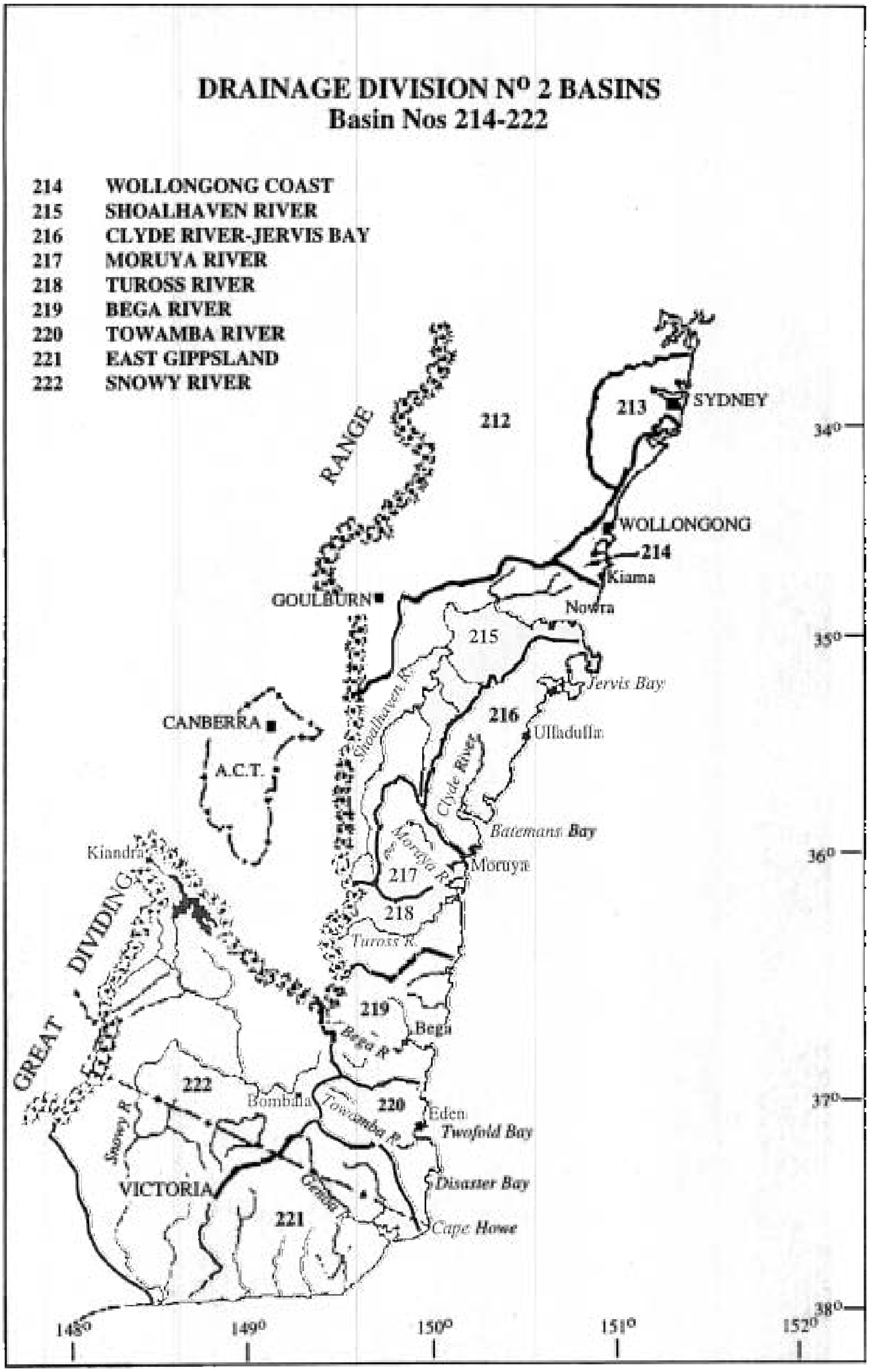

Figure 3.1: Study Areas showing Basin Numbers 214-222 (redrawn from AWRC Pineena Map)

3.2 Trial Survey Project

The project steering committee decided that the Minnamurra River, Macquarie Rivulet and Pambula River catchments would be used in a pilot survey because of their manageable size and fish-passage significance. The Minnamurra River and Macquarie Rivulet catchments are located in the Wollongong Basin (No. 214), while the Pambula River catchment is located in the Towamba River Basin (No. 220). The following methods for identifying and locating obstructions to fish passage were found to be efficient in the pilot survey and were therefore used for all other catchments.

3.3 Site selection

Relevant 1:100 000 topographic maps to be used were selected from the Commonwealth Mapping Authority's (CMA) 1995 catalogue. Each individual catchment boundary within each basin was marked out. From these maps, it was determined which 1:25 000 topographic maps were needed for a study of greater detail in each catchment. For the purpose of the survey, significant fish habitat was defined as perennial streams marked on the 1:25 000 scale maps. Any potential obstructions (e.g. dams, weirs, road and rail crossings etc.) were marked on these maps. Intermittent streams were excluded, generally being headwater streams subject to numerous natural barriers and temporary habitats.

3.4 Information collection

To seek information about the potential obstructions marked on the 1:25 000 CMA maps, and any other obstructions which may not be shown, letters were sent to relevant authorities including local government councils and other State Government authorities (e.g. State Forests, National Parks and Wildlife Service) informing them about the objectives of the survey and asking for information. These authorities were later contacted by telephone to arrange meetings to discuss the project, to study maps and to seek local knowledge to determine which structures may constitute obstructions to fish passage.

The type of information needed about each structure was determined from the report of DLWC's Weir Inventory project, an inventory of licensed structures (DLWC 1996). Information gathered from this survey will be added to the DLWC inventory. A questionnaire (see Figure 3.2) was designed to accommodate this information. It was also used as a guideline for which relevant authorities could provide necessary information.

3.5 Field observations

For each catchment, field inspections took place after meetings with the relevant authorities. Each site was located using the 1:25 000 CMA maps, from which a grid reference was also obtained. Criteria used to determine the fish-passage significance of each site were:

1. Whether the structure altered the stream-bed profile sufficiently to create a vertical discontinuity in the water surface at low flows.
2. Whether the slope of the structure created a flow-velocity barrier in the stream flow
3. Whether a piped structure excessively reduced daylight penetration into the stream.

Obstructions were classified as one of nine different kinds of structure (Figure 3.2), and grouped into dams, weirs, road crossings and erosion control structures.

Figure 3.2. Survey Proforma

SURVEY OF FISH MIGRATION BARRIERS ON THE SOUTH COAST OF NSW

Robyn Pethebridge, NSW Fisheries, PO Box 21, Cronulla NSW 2230
ph: (02) 527 8411, fax: (02) 527 8576

1) Field details

Name of barrier (incl. NSW Fisheries code) ____________________
Name of river/stream ____________________
Name of major river catchment ____________________
Drainage Basin name ____________________
Drainage Basin number ____________________
Date and time of observation ____________________
Photographs of barrier (list negative numbers) ____________________

2) Barrier location

Map (1: 25 000): ____________________
Property: ____________________
Road: ____________________
Nearest cross road: ____________________

Grid reference: Easting /Northing____________________

Lat./long.: ____________________

Nearest town: ____________________

Directions from nearest town (with distances): ____________________

____

Vehicle access (Yes/No) ______ 4WD or 2WD

3) Type of barrier

Dam ❑ High dam ❑ Farm dam ❑ Fabridam

Weir ❑ Fixed crest ❑ Rock weir ❑ Sheet pile ❑ Gated weir

❑ Bypass ❑ Stop log ❑ Stream gauging weir

Road crossing ❑ Bridge ❑ Culvert ❑ Causeway

❑ Tidal Barrage

❑ Natural (e.g. waterfall)

Erosion control structure ❑ rock shute ❑ drop structure

❑ pipe drop ❑ silt trap

4) Structural characteristics

Vertical height (m): ____ Base length (m): ____ Crest length (m): ____ Crest width (m): ______

Head loss (m): ______

Height between tailwater and crest at low flow (m): ______

Diameter of outlet pipe (m): ________

Spillway type: Slope: Gradient: ____ height (m) ___ Width (m)_

Stepped: Height (m):___ Width: (m) ____

Vertical: Height: (m) ___ Width: (m) ____

Length of weir pool (m):

Capacity (ML): ______________

Foundation material: qRock qAlluvium qOther ________

Construction material: q Concrete qGabion qRock

q Steel q Wood/Timber q Earth

qRock fill qPermeable Rock q Other________

5) Other details

Year built: ____

Builder: ____

Proposed action (yes/no): ______________________________

Barrier owner: ____

Owner's address: ____

Contact position and name: ______________________________

License No.: ____

Licensing authority: ____

Barrier status: a) existing __ b) proposed __ c) removed __

Structure in use (yes/no) ______

6) Fishway details

Fishway present (yes/no): _

Gradient: ______________

Type of fishway: q Denil

q Rock ramp

q Vertical slot

q Submerged orifice

q Weir pool

q Fish lock

q Fish pump

q Fish lift

7) Stream/ catchment characteristics

Flow characteristics of the river

q High spring flows with low summer flows
q High summer flows
q Stream dry for a period of each year
q Other ______________

River regulation

distance to the nearest upstream barrier (m) __
distance to the nearest downstream barrier (m)

Barrier drownout (yes/no) ____ Frequency of drownout ______________
Catchment area above barrier (sq km) ______________
Catchment condition upstream of the barrier

q Pristine, undisturbed (100% natural forest)
q Minor forestry and/or agriculture (< 25% of catchment area: > 75% natural forest)
q Moderate forestry and/or agriculture (25-50% of catchment area: 50-75% natural forest)
q Major forest and/or agriculture (51-75% of catchment area: 25-49% natural forest)
q Highly modified; major forestry and/or agriculture (<25% natural forest remaining)

Stream condition upstream of barrier

❑ Pristine, undisturbed (no apparent clearing of riparian vegetation, bank degradation, etc)
❑ Low disturbance (<25% of upstream areas degraded as above)
❑ Moderate disturbance (25-50% of upstream areas degraded as above)
❑ High disturbance (51-75% of upstream areas degraded as above)
❑ Very high disturbance (>75% of upstream areas degraded as above)

8) Environmental study details

Has an environmental study been carried out? (e.g. environmental flow, water quality, flora/fauna survey, etc) (yes/no)
Organisation which conducted study______________
Date of study______________
Other details______________

9) Fish survey details

Has a fish survey been carried out? (yes/no)
Organisation ______________
Date of study ______________
Fish species
upstream of the barrier ______________
____
____
downstream of the barrier ______________
____
____

If the structure did not pose a fish-passage problem (e.g. a road crossing which turned out to be a bridge with no impediment to stream flow or excessive shading), then the structure was marked on the topographic map with a circle. If the structure did pose a problem (e.g. a road crossing which was in the form of a restricting culvert or causeway), then photographs and measurements were taken. The measurements taken for each structure included the vertical height, crest length, base length, crest width and difference in height between tailwater and crest at low flow (see proforma (Figure 3.2). A GPS reading was also recorded for accurate latitude and longitude. Any other available information (e.g. ownership, builder and year built) was recorded.

3.6 Defining obstructions

A total of eight different types of structures were observed as obstructions to fish passage within the nine drainage basins studied. These belonged to three of the categories as described in part 3 of Figure 3.2, and included dams, weirs and road crossings.

Two dam types were recorded, high dams and farm dams. A high dam was defined as a large structure (above 10 m in height) which was used for major water storage for domestic, agricultural or industrial purposes. Farm dams were impoundments of streams and drainage lines, constructed from natural materials, which usually occur on private properties and which are used for domestic or private agricultural purposes.

The three types of weirs observed were the fixed-crest weir, rock weir and stream gauging weir. Fixed-crest weirs were usually built of concrete as fixed structures across stream beds. Rock weirs were also impoundments across streams, but were built from natural rock material. Stream-gauging weirs were usually concrete weirs with a v-notch.

Three types of road crossings were observed, including bridges, culverts and causeways. A bridge was defined as a structure which allowed for the stream to flow underneath, but which may impede flow at medium or high river levels. Culverts were identified as road crossings which traversed streams and which allowed for restricted flow because they contained pipes or other outlets. Causeways were identified as road crossings which impeded stream flow without any outlet pipes. Tidal floodgates were also recorded in the data, but were not observed in the field. Information about tidal floodgates was gathered from Timms (1995).

3.7 Data management

Data collected from field observations or contact with authorities were collated and data sheets were stored in folders, together with photographs for each structure, and sorted by catchment. A database was designed and set up using a Microsoft Access 2.0 software package on an IBM personal computer. This package enables the user to create a database, without programming, to access data in various files and file types, and to generate forms and reports (O'Dwyer Technology Training Pty Ltd 1994). Access was chosen as the database application to be consistent with the Weir Inventory (DLWC 1996).

When all data were entered and validated, they were summarised in the form of queries and reports according to drainage basin numbers. These summaries were translated into Microsoft Excel tables and thenceinto the Microsoft Word tables provided in the Appendices.

4. RESULTS

4.1 Overall results

A total of 254 obstructions were found in the nine drainage basins of the south coast of New South Wales. These obstructions were made up of high dams, farm dams, fixed-crest weirs, rock weirs, stream gauging weirs, causeways, culverts, bridges, and tidal floodgates. Table 4.1 summarises the results.

Table 4.1. Obstructions found on south-eastern NSW streams.

Type of structure	Number	Proportion
culvert	87	34%
causeway	73	29%
fixed crest weir	35	14%
tidal floodgate	24	9%
high dam	17	7%
stream gauging weir	7	3%
farm dam	5	2%
rock weir	3	1%
bridge	3	1%
Totals	254	100

The highest proportion of obstructions identified was that of culverts at 34%. This proportion was followed closely by causeways (29%). Therefore, it seems that out of 9 different types of obstructions, the most common types of obstruction are these two types of road crossings. Figure 4.1 displays the proportions of the various types of obstructions found.

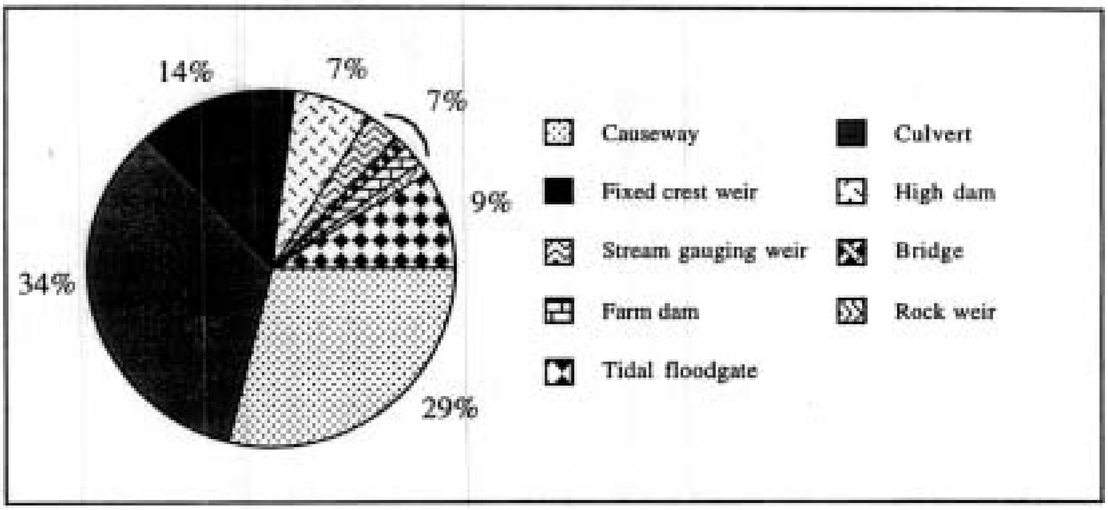

Figure 4.1. Proportions of various types of stream obstructions in south-eastern NSW

Figure 4.2 shows the proportional representation of obstruction types by river drainage basin. Culverts occur in all drainage basins, causeways occur in seven of the nine basins (78%) and bridges in two of the nine basins (22%). High dams occur in five of the nine basins (56%) and farm dams in four of the nine basins (33%). Fixed crest weirs occur in six of the nine basins (67%), rock weirs in two of the nine basins (22%) and stream gauging weirs in three of the nine basins (33%). Tidal floodgates occur only in the Shoalhaven Basin.

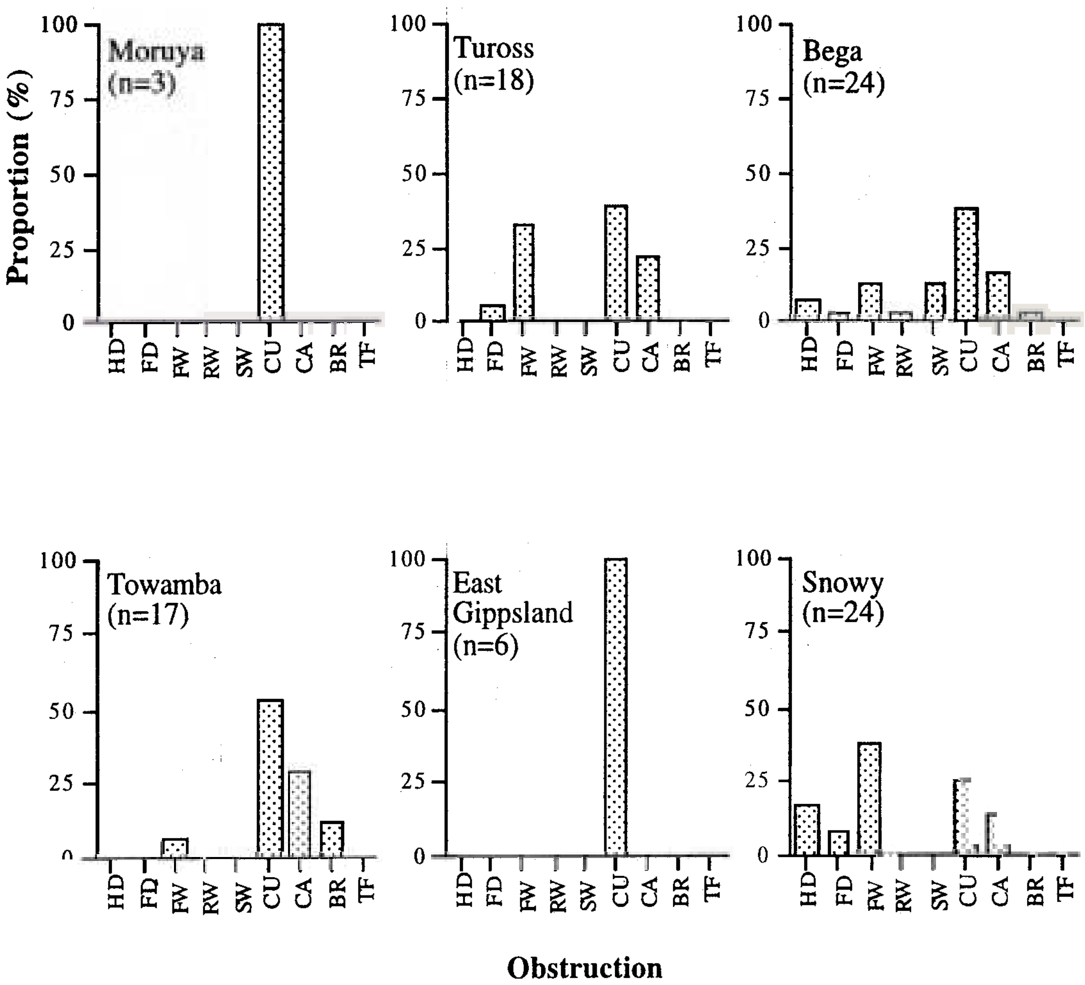

Figure 4.2. Proportional representation of obstruction types by drainage basin. (HD: High dam; FD: Farm dam; FW: Fixed crest weir; RW: Rock weir; SW: Stream gauging weir; CU: Culvert; CA: Causeway; BR: Bridge; TF: Tidal Floodgate n:total numbers of obstructions)

Most of the artificial obstructions found in the Wollongong drainage basin (Figure 4.3) are causeways and culverts, with a small number of high dams, fixed crest weirs and rock weirs. The majority of obstructions found in the Shoalhaven River Basin (Figure 4.4) are culverts, with a substantial proportion of causeways and tidal floodgates, a small proportion of high dams, fixed crest weirs and stream gauging weirs. Obstructions between the Clyde River to Jervis Bay Basin (Figure 4.5) are made up mostly of causeways a smaller proportion of fixed-crest weirs. A substantial number of culverts was also present, with small numbers of stream gauging weirs, high dams and farm dams. Moruya River Basin (Figure 4.6) obstructions included only culverts, and the Tuross River Basin (Figure 4.7) has mainly culverts and causeways, with a small proportion of farm dams and fixed-crest weirs. The Bega River Basin (Figure 4.8) obstructions were mostly culverts, with a substantial proportions of causeways and stream gauging weirs. Some high dams, farm dams, fixed-crest weirs, rock weirs and bridges were also found. The Towamba River Basin (Figure 4.9) obstructions are mostly made up of culverts and causeways and a smaller proportion of bridges. The six obstructions in the East Gippsland Basin (Figure 4.9) were all culverts Obstructions in the Snowy River Basin (Figure 4.10) are mainly made up of culverts and fixed crest weirs, with a substantial proportion of high dams and causeways, and a small proportion of farm dams. These proportions are outlined in further detail in the basin summaries (Section 4.2).

Fishways were present on only seven of the 254 individual obstructions (2.7%) in the nine drainage basins. These are listed in Table 4.2.

Table 4.2 Fishways on obstructions on south-eastern NSW streams.

Basin No.	Structure ID*	Structure name	Stream name	Structure type	Fishway
214	Mac 12	McDonalds Weir	Macquarie Rivulet	Rock weir	Rock-ramp
214	Min 13	Kurraroo Rock Weir	Minnamurra River	Rock weir	Rock-ramp
215	Sho 48	Tapitallee Weir	Tapitallee Creek	Fixed crest weir	Submerged orifice
216	Cly 10	Buckenbowra Weir	Buckenbowra River	Fixed crest weir	Submerged orifice
222	Sno 04	Nimmitabel Weir	McLaughlin River	Fixed crest weir	Weir and pool
222	Sno 08	Dalgety Weir	Snowy River	Fixed crest weir	Vertical slot/ rock ramp
222	Sno 24	Anglers Reach Weir	Long Plain Creek	Fixed crest weir	Weir and pool

* For codes see tables in Appendices A to I.

Typical examples of the various kinds of obstructions recorded in south in south coast streams during field work are illustrated in Figures 4.11 - 4.17. Examples of a typical culvert and causeway are displayed in Figures 4.11 and 4.12. Figures 4.13 and 4.14 show a typical fixed-crest weir and a stream gauging weir. Figures 4.14a and Figure 4.14b are views of a rock weir found in the Wollongong Coast Basin. Figure 4.14a shows the view across this weir, while Figure 4.14b shows a wider view of the both the upstream and downstream pools. Figures 4.15a and 4.15b display views of both the upstream dam wall and the upstream lake of Jindabyne Dam, an example of a high dam in the Snowy River Basin. The downstream views are displayed in Figures 4.15c and 4.15d. Figure 4.16 is an example of a farm dam and Figure 4.17 displays a view of a low bridge. The above figures (4.11a to 4.17) are computer scans of photographs which were taken during field observations.

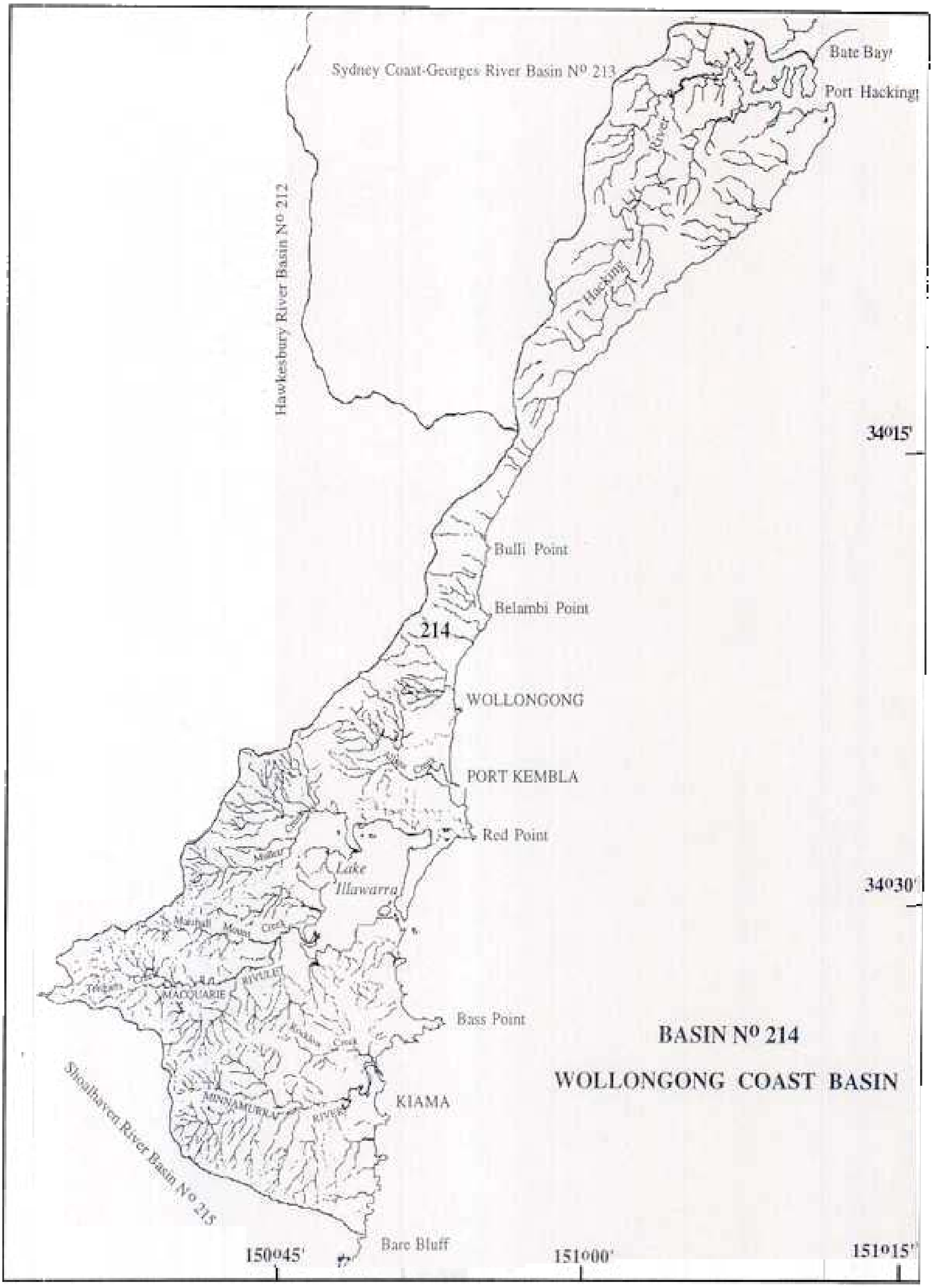

FIGURE 4.3: Wollongong Coast Basin

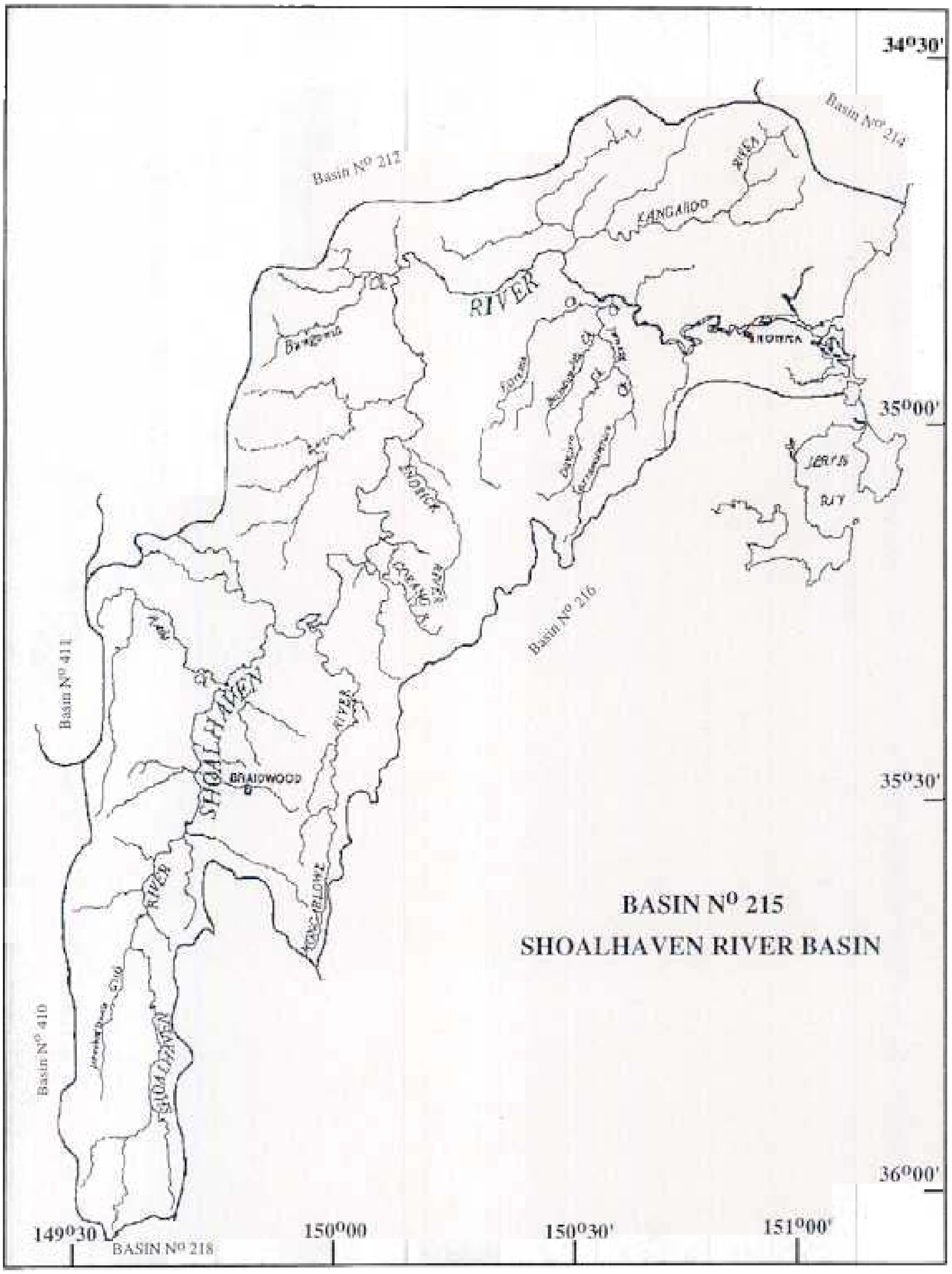

FIGURE 4.4: Shoalhaven River Basin