Department of National Parks, Recreation, Sport and Racing

Guidelines for conducting an inventory of instream structures in coastal Queensland

Great state. Great opportunity.
And a plan for the future.

Queensland Government

Prepared by: Queensland Parks and Wildlife Service, Marine Resource Management, Department of National Parks, Recreation, Sport and Racing

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Fisheries guidelines for conducting an inventory of instream structures in coastal Queensland, Department of Primary Industries and Fisheries, Fish Habitat Guideline FHG 007, 72p.

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Contents

Overview

The guidelines provide a standardised and consistent approach to identify and prioritise instream structures (artificial) within waterways of coastal Queensland. Instream structures include road crossings, causeways, floodgates, jetties, revetments, pontoons, boat ramps and moorings. The guidelines have been developed following a pilot project within declared Fish Habitat Areas (FHAs) and provide step-by-step instructions on how to undertake an instream structure inventory (ISI) project, from project area selection through to identifying priority structures for management responses. In addressing some of the ecological, logistical and technical issues that surround inventory work, the guidelines are to assist regional Natural Resource Management (NRM) groups and other stakeholders in gaining a better understanding of the processes involved and reduce the need for external input in order to complete such work. Other stakeholders may include a range of government (e.g. councils) and non-government agencies (e.g. on-ground natural resource and catchment management teams such as Landcare).

Queensland's coastal waterways support important wetland habitats. As such, inventory data is added to the Queensland Wetlands Program wetland information base to help document the status and minimise the degradation and loss of important wetland habitats throughout Queensland. Data can inform decisions to address problem structures that continue to have a negative impact on fish habitats or fish passage, particularly in declared FHAs and support the ongoing and future management of the declared FHA network.

The guidelines are the result of integrating and modifying existing protocols associated with freshwater fish barrier remediation (Stockwell et al. 2008; Marsden et al. 2006; Stewart & Marsden 2006; Industry & Investment NSW 2006a) to extend to other 'non-barrier' structures and a shift in the focus to audit and prioritise structures within tidal habitats in declared FHAs. They were originally developed as part of a pilot project in 2008/09,"Targeted collection of inventory data for wetlands fish barriers in the Great Barrier Reef catchment" undertaken by the then Department of Primary Industries and Fisheries (DPI&F) within DEEDI in the Trinity Inlet and Hinchinbrook declared FHAs of North Queensland. A second project (2009/10),"Inventory of instream structures impacting on Ramsar wetlands", implemented the guidelines to conduct ISI projects in Bowling Green Bay (Townsville) and Shoalwater and Corio Bays (north of Yeppoon) and led to some modification of the inventory protocol.

The first and second projects were funded by the Department of Environment, Water, Heritage and the Arts (DEWHA), through the Australian Government's Natural Heritage Trust and the Queensland Wetlands Program, respectively. Machinery of Government changes in 2012 resulted in the transfer of responsibility for declared Fish Habitat Area management from the Department of Agriculture, Fisheries and Forestry (DAFF; previously DEEDI) to the Department of National Parks, Recreation, Sport and Racing (NPRSR). Accordingly, this document replaces the original DEEDI 2009 publication - Fisheries guidelines for conducting an inventory of instream structures in coastal Queensland: FHG 007.

The framework and guidelines enable identification and prioritisation of instream structures and facilitate the delivery of enhanced management outcomes to remediate problem structures, leading to improved quality and access to habitats for fish.

The guidelines, available on the NPRSR website (www.nprsr.qld.gov.au), are divided into two user-friendly parts:

Part 1: The inventory protocol describes how to physically conduct a structure inventory including identification of instream structures and their impacts.

Part 2: The response protocol outlines a decision support system to prioritise structures based on fish habitat and/or fish passage impacts in order to deliver enhanced management responses.

Background

Fish depend on access to a wide range of habitats for their survival. Habitats provide fish with food, shelter, protection from predation and are also important as breeding and nursery areas. A number of fish species rely upon access to different fish habitats at various times of their lives in order to breed and complete their life cycles.

To meet the demands of expanding residential, industrial and agricultural development in coastal Queensland as the number of people living in these areas continues to grow, a range of instream structures have been developed throughout freshwater, estuarine and marine fish habitats. Instream structures include floodgates, levee banks, jetties, pontoons, boat ramps, moorings and road crossings. The diversity of instream and crossing structures and their locations within catchments impact on fish habitat values and functions locally, upstream and downstream of each structure.

By forming complete or partial barriers, some instream structures prevent or severely limit important migrations and movements of fish and other aquatic species. The impacts of barriers on fish passage are now widely recognised as a threat to the health of fish populations and fisheries productivity in Australia. A number of projects have been undertaken in Queensland to identify instream structures that obstruct fish passage and remediate fish passage at priority barriers (Marsden et al. 2006; Marsden & Moore 2008; Stockwell et al. 2008). Projects to date have primarily been in coastal freshwater and riverine waterways. Guidelines have been developed to help NRM groups deal with problem structures and rehabilitate freshwater fish habitats (see Reef coast freshwater fish habitat rehabilitation strategy, June 2006 by R Stewart and T Marsden).

However, there are a range of other instream structure types that occur within tidal fish habitats as a result of increasing development pressure in Queensland’s coastal zone. Jetties, pontoons, revetments and moorings have numerous impacts on natural tidal and subtidal ecosystems important to sustain healthy fish populations and support fisheries productivity. These structures can impact fish habitats by modifying flow regimes and cause permanent physical disturbances that result in direct habitat loss. Negative and cumulative impacts of instream structures may lead to population declines, reduced distributions of species and degraded fish habitats that are critical for supporting Queensland’s commercial, recreational and traditional fisheries.

Queensland’s fishing sectors contribute significantly to local, state and national economies. In 2009/10, Queensland’s commercial fisheries produced approximately 33,000 tonnes of fish, worth approximately $324 million and representing 14.8 per cent of the total gross value of production of the Australian commercial fishing industry (ABARES, 2010). The GVP for Queensland's fisheries in 2013-14 was forecast to be $424 million (DAFF, 2013). In 2010, recreational fishers took home around 13,500 tonnes of fish, crayfish and prawns (Taylor et al, 2012). An estimated recreational fishing value of $73 million was forecast for 2013-14 (DAFF, 2013).

Traditional fishing activities are practised widely by Indigenous people across the state, particularly in northern Queensland coastal communities. Failure to regulate and manage development impacts throughout Queensland’s fish habitats can have detrimental effects on the sustainability of the state’s commercial, recreational and Indigenous fisheries.

Queensland's declared Fish Habitat Area management

NPRSR is responsible for the management of Queensland's declared FHA network. The network was first established by the Department of Primary Industries in the late 1960s in response to development pressures in the coastal zone. The purpose of the declared FHA network is to protect from development key estuarine and inshore areas of fish habitats that sustain fish on which commercial, recreational and traditional fisheries rely. While protecting natural fish habitats (e.g. vegetation, sand bars, rocky headlands) from alteration and degradation from development impacts, declared FHAs allow for natural processes and community use, including community access; boating; and commercial, recreational and traditional fishing. The declared FHA network primarily includes tidal fish habitats, although the boundaries of some declared FHAs extend into freshwater habitats to a small extent.

Declared FHAs are protected from development under the *Fisheries Act 1994*. There are two levels of management for declared FHAs, each of which may be applied to an entire declared FHA or to sections within a declared FHA. Management A areas contain fish habitats that are critical for fisheries productivity and sustainable fishing to maintain the ecological character and integrity of undisturbed fish habitats. Development related disturbances are severely restricted in management A areas.

Management B areas contain fish habitats that are important for fisheries productivity and sustainable fishing to maintain the ecological character and integrity of undisturbed fish habitats. Management B areas are declared in locations where existing or planned uses require a more flexible management approach (refer to FHMOP 002 Management of declared Fish Habitat Areas: departmental policy position).

Despite the legislative and policy framework in place to support declared FHA management, the legality of some structures within declared FHA boundaries is uncertain and the impacts of these structures can be detrimental to the health and value of key fish habitats within the FHA network.

Unauthorised structures include:

- structures that were constructed or installed unlawfully before FHA declaration
- structures that were constructed in such a way that breaches the conditions of a development approval
- structures that were installed since FHA declaration without an approval.

Conducting an ISI project in declared FHAs will identify unauthorised and other structures that are impacting on fish habitats or fish passage. This data informs NPRSR's Assessment and Reporting framework for declared FHAs, which documents the status of the declared FHA network and makes recommendations for management (Batton et al 2012). The aim of this process is to improve the quality of, and enhance access to, key habitats for fish that are critical for supporting and sustaining Queensland's fisheries.

NPRSR manages a five-year program to inventory instream structures in selected declared FHAs in coastal Queensland. This program is part of the declared FHA Network Strategy (2009–14) that consists of three broad initiatives to achieve the vision for the declared FHA network and direct planning for the future. These initiatives include consolidating the declared FHA network, reinforcing declared FHA management and strengthening declared FHA policy. The inventory program aligns with the second strategy initiative to reinforce declared FHA management. The program specifically meets the initiative to 'actively manage and respond to unlawful activities to prevent the degradation of individual declared FHAs and the declared FHA network'.

Impacts of instream structures in declared Fish Habitat Areas

A range of instream structures with a number of different purposes occur throughout the declared FHA network. Public infrastructure such as jetties, pontoons, boardwalks, boat ramps and moorings provide access to waterways, facilitate fishing and contribute significantly to the enjoyment of Queensland's aquatic environments. Pipe and drain outlets support activities associated with agriculture, aquaculture, industry, sewerage treatment and water treatment. Structures such as revetments, groynes and gabions are constructed to protect eroding shorelines and river banks.

Boat ramps, wharves and other structures that are directly installed on the substrate cause direct loss of fish habitats through permanent covering and hardening of bottom substrates (Russell et al. 2003). Incorrect placement of boat ramps on erosive river bends can also lead to bank erosion upstream or downstream of the structure.

Jetties, pontoons, boardwalks, viewing decks and other pile-supported structures can cause shading of marine plants and substrate, which may inhibit marine plant growth within the shaded area (Adams 2002). These structures can also disrupt natural flow conditions (Burns 2001).

Revetments, groynes and gabions are designed to protect the structural integrity of beaches, foreshores, banks and other margins at the land–water interface. Stabilisation structures usually replace natural habitats and alter tidal regimes and the extent of tidal inundation at the site. They may have impacts on adjacent shorelines and fish habitats through physical processes such as scouring.

Pipe intakes/outlets and drain outlets may cause bank and outfall erosion and scouring that results in a loss of access to edge habitats for fish and may cause sedimentation of waterways.

Traditional moorings typically consist of a permanent fixture on or in the substrate, a floating buoy on the surface and a line connecting the fixture to the buoy and moored vessel. Scouring of bottom habitats often occurs from the chain or rope that attaches the fixture to the float and vessel. This is of particular consequence when moorings are located in seagrass habitats as the growth of seagrass in the disturbance path is inhibited.

Derelict vessels and dumped materials disturb bottom substrates and disrupt natural flows. Given that the majority of these structures will be unauthorised, they may pose a greater impact on fish habitats through directly conflicting with declared FHA management.

If designed correctly, instream structures can have a number of positive impacts on fish habitats. Fish-friendly structures are those that cause minimal disturbance to the existing environment and incorporate design features that provide an enhanced habitat in which fish can live. Structures, by providing 'hard' surfaces in largely 'soft' natural habitats, can increase habitat diversity (United States Army Corps of Engineers 1993) and may help to partially mitigate the loss of natural habitats due to the impacts of development. Instream structures can also provide fish with protection from predators, shelter from currents and extra settlement habitat for recruitment. For example, rock revetments have been known to provide refuge habitat for mangrove jack juveniles (Russell et al. 2003).

Although they occur to a relatively minor extent, a number of fish barriers including stream crossings, floodgates and levee banks are within declared FHA boundaries. Fish barriers reduce migration opportunities of Australian fish and restrict access to different fish habitats, which is likely to have negative impacts on the long-term viability of fish populations.

Stream crossings are generally the most common type of barrier within declared FHAs. A stream crossing is a structure on a waterway that provides access for traffic across waterways and includes bridges and culverts as well as low-level crossings such as fords and causeways. Poorly designed stream crossings can have major impacts on fish passage.

Bridges are the preferred type of stream crossing given that their impact on fish passage is either relatively minimal or non-existent. Culverts and low-level crossings commonly restrict the channel width of the waterway, increasing the velocity of water flowing through the structure. Culvert crossings, either consisting of box or arch culverts or pipes, typically have smooth sides that further increase water velocities and they often exceed the swimming ability of many fish. Consequently, fish are prevented from moving upstream and may be washed further downstream.

Causeways are low-level crossings designed so that water flows across the structure. The drop that can occur on the downstream side of a culvert or causeway crossing can present a physical barrier for Australian fish, as many species cannot jump obstacles. Fish that do try to jump may make several attempts at passing a crossing, which can severely deplete their energy reserves, delay spawning fish and decrease general condition. Migrating adult, juvenile and larval fish delayed or trapped below crossings can suffer heavy mortality from recreational fishers and predators.

Fords are relatively low-impact crossings given that they are built at bed level; however, they can also cause impacts when shallow water depths flow across the structure and restrict fish passage. Additionally, water velocities can be increased over the structure since the crossing is usually concreted or consists of relatively smooth material in comparison to a natural stream bed.

While few floodgates occur within declared FHAs, they are often located adjacent to FHA boundaries. Floodgates are traditionally one-way structures that prevent tidal and flood waters from inundating low-lying land that is often used for agricultural activities. The presence of floodgates creates a physical barrier for fish moving onto floodplain and upstream areas and leads to fragmentation of habitats. In reducing or eliminating tidal flushing, water quality around floodgate structures is often degraded and acid sulphate soils may be exposed. This can lead to a reduction in dissolved oxygen and pH levels in the water, which may result in fish kills.

Levee banks or bund walls can be constructed on tidal land to form a barrier across a wetland area or formed through the action of natural processes (e.g. build-up of sand across a creek mouth). These structures are often built on the boundaries of farming properties to protect crops and farming land from tidal inundation. Levees/bunds are also used to develop ponded pastures for grazing. Often the levee bank or bund is also an access road to various parts of properties and may incorporate pipes or floodgates. Levee banks and bund walls create barriers to fish and prevent movement of fish onto floodplain and wetland areas.

Weirs and dams are typically constructed to supply water for irrigation or human consumption or to provide flood mitigation. While weirs are generally smaller structures built across river channels, rather than entire river valleys, both structures form significant physical barriers to fish movement.

The impact that a dam or weir has on fish passage is influenced by the frequency, timing and duration of drown-out. Drown-out occurs when there is sufficient water flow across the structure to drown it out. Fish movement is optimised during drown-out when the water levels above and below the barrier are equal and there is sufficient water depth across the barrier for fish to swim through. Some weirs and dams may drown-out completely and continuously, while others do not drown-out at all (preventing all upstream fish passage and disrupting life cycles).

How will inventory data be used?

Improving the wetland information base and minimising degradation of wetlands

The Queensland Wetlands Program (QWP) was established in 2003 to support projects or activities that result in long-term benefits to the sustainable management, use and protection of wetlands in Queensland, particularly the Great Barrier Reef catchments. It is a joint initiative of the Australian and Queensland Governments to manage and protect wetlands across Queensland. The QWP is managed by the Department of Environment and Heritage Protection (EHP).

Instream structure inventory data may contribute to such QWP projects as the Wetland Information Capture (WIC) project and the Wetland Mapping and Classification project. Information on the location and impacts of instream structures that may alter or disturb local hydrology and threaten wetland condition is integral to the wetlands mapping base, and is used to inform management decisions about the protection and care of wetlands. Project data complements existing QWP activities to map the distribution of Queensland’s wetlands and collate other information relating to the classification and degree of wetland disturbance.

Addressing ‘problem’ structures that impact on fish habitats

Inventory data collected in the identification of structures and assessment of structure impacts can be used to prioritise structures for management responses. The data will help NRM and key stakeholder groups prioritise structures that continue to have a negative impact on fish habitats or fish passage for modification or removal. NRM groups and other key stakeholders can use inventory data to support project proposals or funding applications for carrying out on-ground works that remediate the impacts of problem structures in their region. Given that management responses will be based on information collected through a comprehensive inventory and subject to a standard prioritisation process, external funding bodies will be able to have greater confidence in project outcomes targeting problem structures.

Managing and protecting the values of the declared Fish Habitat Area network

Project data informs NPRSR's declared FHA Assessment and Reporting framework and enables remediation of the impacts of problem structures that exist within declared FHAs to help maintain and enhance the habitat values currently protected by the declared FHA network. In supporting the removal or modification of problem structures within declared FHAs, inventory data will contribute to protection and maintenance of Queensland's highly valuable and productive fish habitats.

Inventory data informs future decisions for managing the declared FHA network. Documentation of the number and location of existing instream structures in a declared FHA provides a measure of current development pressures in the area and temporal changes in these pressures since FHA declaration. This information can be used to assess the effectiveness of current FHA management arrangements and identify implications for the future declaration and management of FHAs.

Part 1: Inventory protocol

Introduction

The inventory protocol provides step-by-step instructions on how to conduct an ISI project. The protocol provides assistance in all aspects of conducting an ISI project, from project area selection through to analysing and summarising collected inventory data.

The inventory protocol is based on the use of geographic information system (GIS) technology to collect, store and manipulate recorded spatial, quantitative and qualitative data pertaining to instream structures. Data is collected in the field using a hand-held personal digital assistant (PDA) uploaded with ArcPad and the FishBarriers version Queensland (VQ) menu system, originally developed by NSW Department of Primary Industries. A basic level of GIS knowledge is recommended in application of the inventory protocol. QPWS can be contacted in order to access the FishBarriers VQ menu system before embarking on an inventory project.

The FishBarriers VQ menu system is an ArcPad application that was used to collect and store information relating to a range of data attributes for each structure. Marking a GPS point in ArcPad activates the FishBarriers VQ menu system. The menu system consists of a series of digital data entry forms (or pages) that prompt the assessor for information on a range of data attributes. The menu system allows data attributes for each GPS point (representing individual structures) to be captured on location and recorded into the same data layer, so that attribute information is directly tied to spatial data for each structure. The created database provides a spatial record of all structures assessed and allows for additional structures to be incorporated into the database as these are identified.

Essentially, the inventory data collection process will produce two key data outputs:

- a spatial map layer with GIS coverage of locations of all identified instream structures
- an information database (linked to the GIS layer) that displays an entry for each GPS location and structure recorded, containing quantitative or qualitative information on a range of data attributes pertaining to individual structures

The above outputs feed into the next stage in the inventory process, which is to prioritise identified structures in terms of their impact on fish habitat or fish passage. The response protocol explains how to use the information contained within the above data outputs to prioritise structures in order to assist decisions regarding the appropriate management responses. Additionally, the information will contribute to wetlands management via projects of the QWP. An illustration of the flow of data is shown in Figure 1.

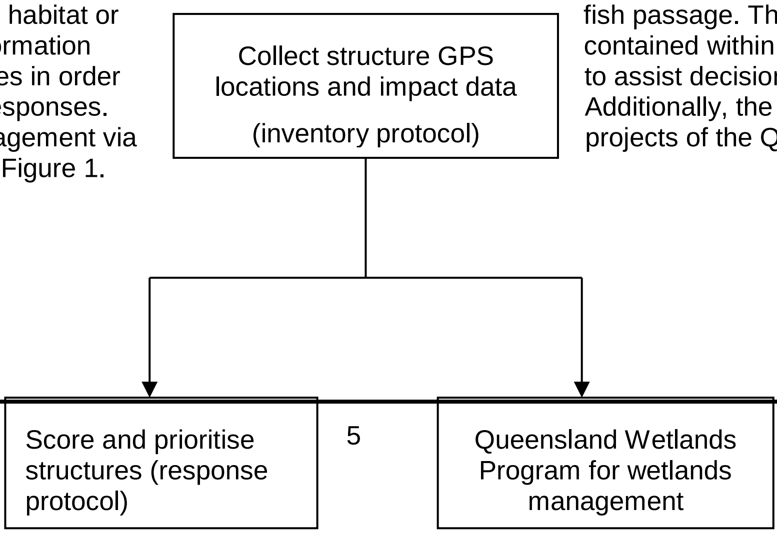


Figure 1. Flow chart showing links between the inventory protocol, response protocol and the QWP

Selecting a project area

A number of factors contribute to the selection of a project area, including the source of project funding, budget and the amount of resources available and current NRM or local government priorities. When selecting an area for an ISI project, some other considerations include declared FHA location, size and management level and the current extent of inventory projects in the region. After selecting a project area it is important to contact local stakeholders. Figure 2 provides an overview of the considerations involved in project area selection.

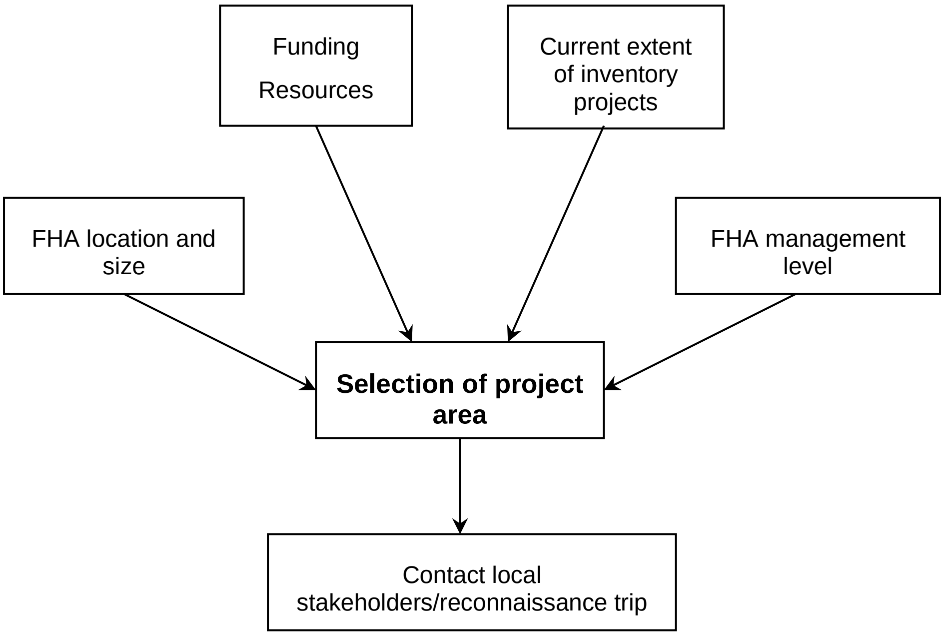


Figure 2. Overview of the considerations involved in project area selection

Declared Fish Habitat Area management levels, locations and size

There are currently 70 declared FHAs spread along the Queensland coast, including within the Gulf of Carpentaria. An overview map of Queensland showing the location of all the FHAs as well as plans of individual FHAs can be obtained from the NPRSR website (www.nprsr.qld.gov.au).

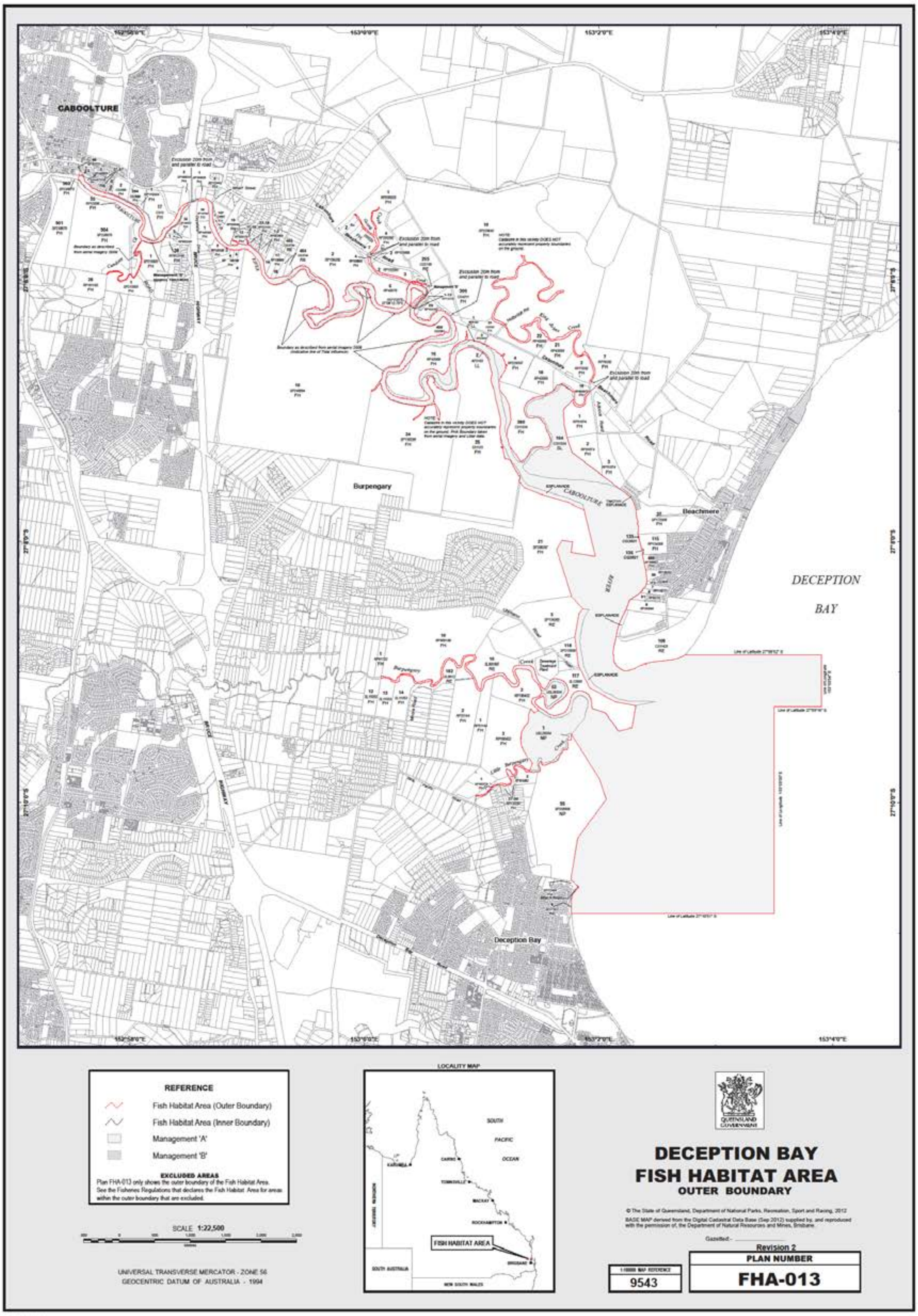


Figure 3. NPRSR plan indicating the boundaries of the Deception Bay declared FHA (South-East Queensland)

Individual plans show the outer boundaries of the declared FHA (Figure 3) and the existing management level. The two levels of declared FHA management offer different levels of protection to declared FHAs that reflect the different nature and value of fish habitats within the network. Management B areas protect important habitat for fisheries productivity and management A areas protect critical habitat for fisheries productivity. Management B areas are also used as a buffer to adjoining management A areas, providing enhanced protection for these key habitats.

Excluded areas (e.g. individual lots) may also be shown on the declared FHA plan. Consult the Fisheries Regulation 2008 (Schedule 3) for more details on the area included within the boundary of a declared FHA and its level of management. Declared FHAs currently range in size from approximately 9–170,000 hectares. The size of the declared FHA targeted for an ISI project may be considered in relation to project resources and budget. Note that the amount of resources and time spent undertaking an ISI project does not always increase in proportion to the size of the declared FHA, eg. a large, relatively undeveloped declared FHA could require less time and resources to complete an inventory compared with a small but relatively highly developed declared FHA.

Current extent of structure inventory projects in Queensland

An important step in selecting a project area is to investigate the extent of other ISI or similar projects in the area by contacting NPRSR's Marine Resource Management unit (Queensland Parks and Wildlife Service). Regional NRM groups are also a valuable contact for finding out about existing and completed inventory work.

Inventory projects may be undertaken in reference to a standard 1:2500 or 1:5000 map grid, allowing the progress of individual inventory projects across the state to be monitored. Use of a standard grid provides a common reference to track completed inventory projects and indicate where work is yet to be done. Figure 4 shows the standard 1:5000 grid applied to Queensland. Having a record of the completion of specific grids in a declared FHA is particularly important in cases where an FHA has been only partially inventoried, as it will provide a clear reference of the areas within the FHA that are yet to be inventoried.

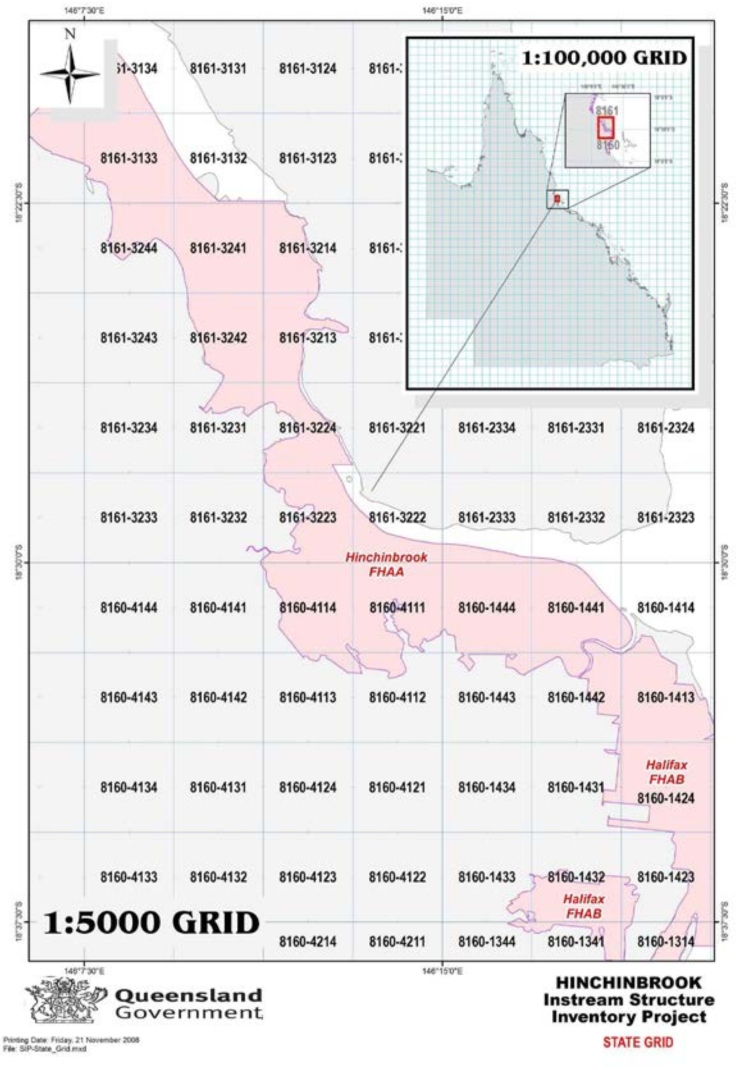


Figure 4. Illustration of standard map grid

Contact local stakeholders

At this point it is essential to contact local stakeholders that have either a responsibility or interest in the project area. Accessing local knowledge will be of great benefit to any ISI project. Local stakeholders have important and additional information on the history of structures and impacts in the area, the practical issues associated with the project area (including other approvals), and general information about the project area. There may be structures of particular interest to local stakeholders that could be included in the inventory process.

Key stakeholders include the local council, other government agencies including NPRSR, EHP, Great Barrier Reef Marine Park Authority (GBRMPA), Department of Transport and Main Roads (DTMR), regional NRM groups or on-ground catchment groups, Traditional Owners and communication and other service providers. It is particularly important to consult Traditional Owners in relation to any Native Title determination areas or Indigenous Protected Areas (IPAs) in the project area, as this may have implications for fieldwork in these areas and future management relating to priority structures.

A reconnaissance visit to the project area can assist with fieldwork planning and preparation. Such a visit may involve a half-day or full-day trip by boat, aircraft or car to the project area to inspect the range of structures in the project and surrounding areas. This is a great opportunity to obtain an overview of the history and nature of structures in the area and to discuss project area considerations and logistics with local stakeholders. The knowledge gained from such a visit will be of great assistance when planning inventory fieldwork. A reconnaissance trip may be carried out before, during or after preparation of project area maps.

Structure identification

Once the project area has been selected, a combination of desktop assessment (Stage 1) and field assessment (Stage 2) are used to identify instream structures. Stage 1 includes compilation of GIS layers and creating project area maps, while Stage 2 involves collection of inventory data using the FishBarriers VQ menu system.

Stage 1. Desktop assessment

Compilation of layers into a Geographic Information System

Compiling a comprehensive range of relevant layers, for example in ArcGIS, will provide a good understanding of the natural and artificial environment of the region. Base layers may include the latest digital cadastral database (DCDB), topographic, declared FHA and wetlands mapping layers and imagery. An example of the declared FHA layer overlaid on topographic mapping is shown in Figure 5 and overlaid on wetlands mapping in Figure 6. Together with topographic mapping, the DCDB indicates basic features of the project area, such as land parcel boundaries and transport corridors and easements (including main roads and railways), in addition to natural features such as main rivers and creeks. A standard 1:250 000 topographic map layer be used. Additional layers may include vegetation, infrastructure, foreshores, watercourses, waterholes and bores mapping (Geosciences Australia).

High resolution imagery (e.g. Spot 5, Landsat, Ikonis) for the project area will allow for the identification of a range of instream structures and areas of interest to be targeted as part of the field assessment in Stage 2.

At this stage GPS coordinates may be added as a layer on project area maps to be ground-truthed. Information on existing approvals for instream structures is held by local governments and a number of state government agencies, including DAFF (development approvals), Department of State Development, Infrastructure and Planning (DSDIP) (development approvals - MyDAS), DTMR (boat ramps) and EHP (prescribed tidal works approvals and Section 86 approvals) and can assist fieldwork planning.

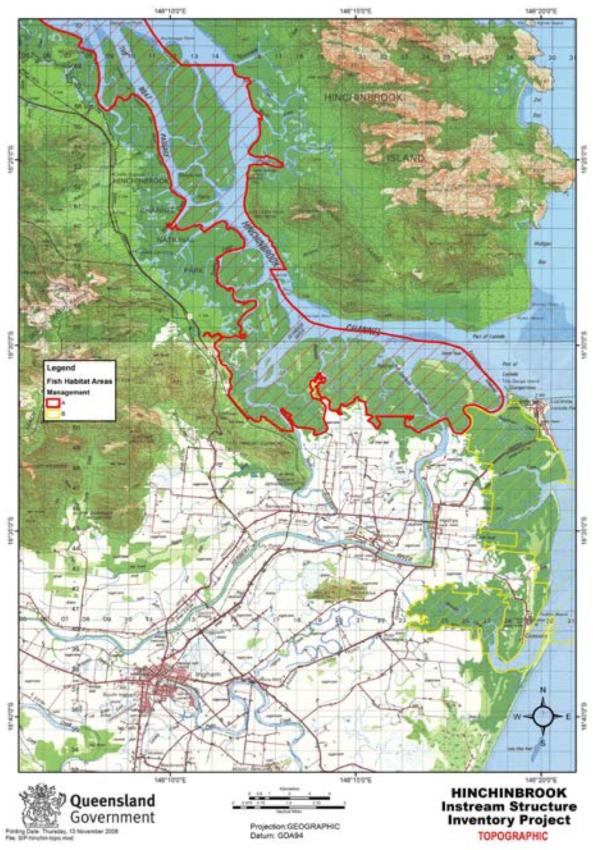


Figure 5. Example of declared FHA mapping overlaid on a topographic map layer

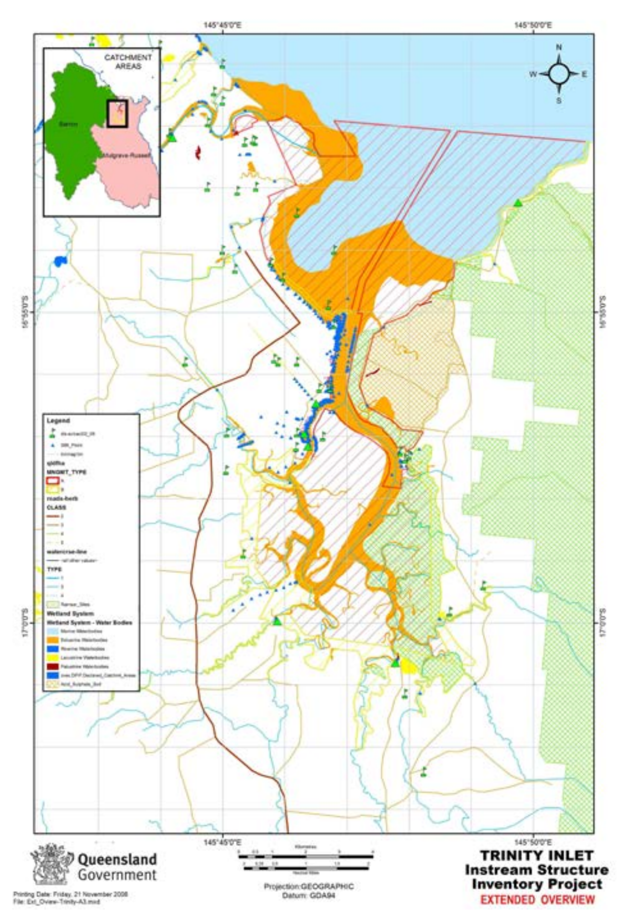


Figure 6. Example of declared FHA mapping and 1:5000 map grid layer overlaid on wetlands mapping layer

Incorporating a map grid layer into ArcGIS will allow the boundaries of the project area to be clearly identified. A 1:2500 and/or 1:5000 map grid may be used (Figure 6). The area of the map grid to be targeted by the project is used to generate a project area grid layer, an important feature of the project area key map and map sheets.

Development of project area key map and map sheets

Equipment and software requirements:

- laptop or desktop computer
- colour printer
- ArcMap desktop/ArcView (ArcGIS)
- access to relevant datasets
- Nomad® PDA with on-board GPS (or similar) and Windows Mobile Operating System.

This section refers to the use of a PDA for data collection and field assessment of structures however the FishBarriers VQ menu system can be uploaded to any type of portable electronic data collection device that is compatible with ArcPad.

Once the project area has been defined from the 1:2500 or 1:5000 map grid, the project area grid layer can be created in ArcGIS. Combined with aerial imagery, or other mapping layers (e.g. DCDB, topography, wetlands, vegetation), the project area grid layer is used to create a key map for the project area (Figure 7). The key map provides a key to individual map sheets and forms the base layer that is the main display viewable on the PDA. Map grids can be numbered using a combination of standard mapping numbers (e.g. 8359-4343, 8359-4334, etc.) and consecutive numbers (Figure 7).

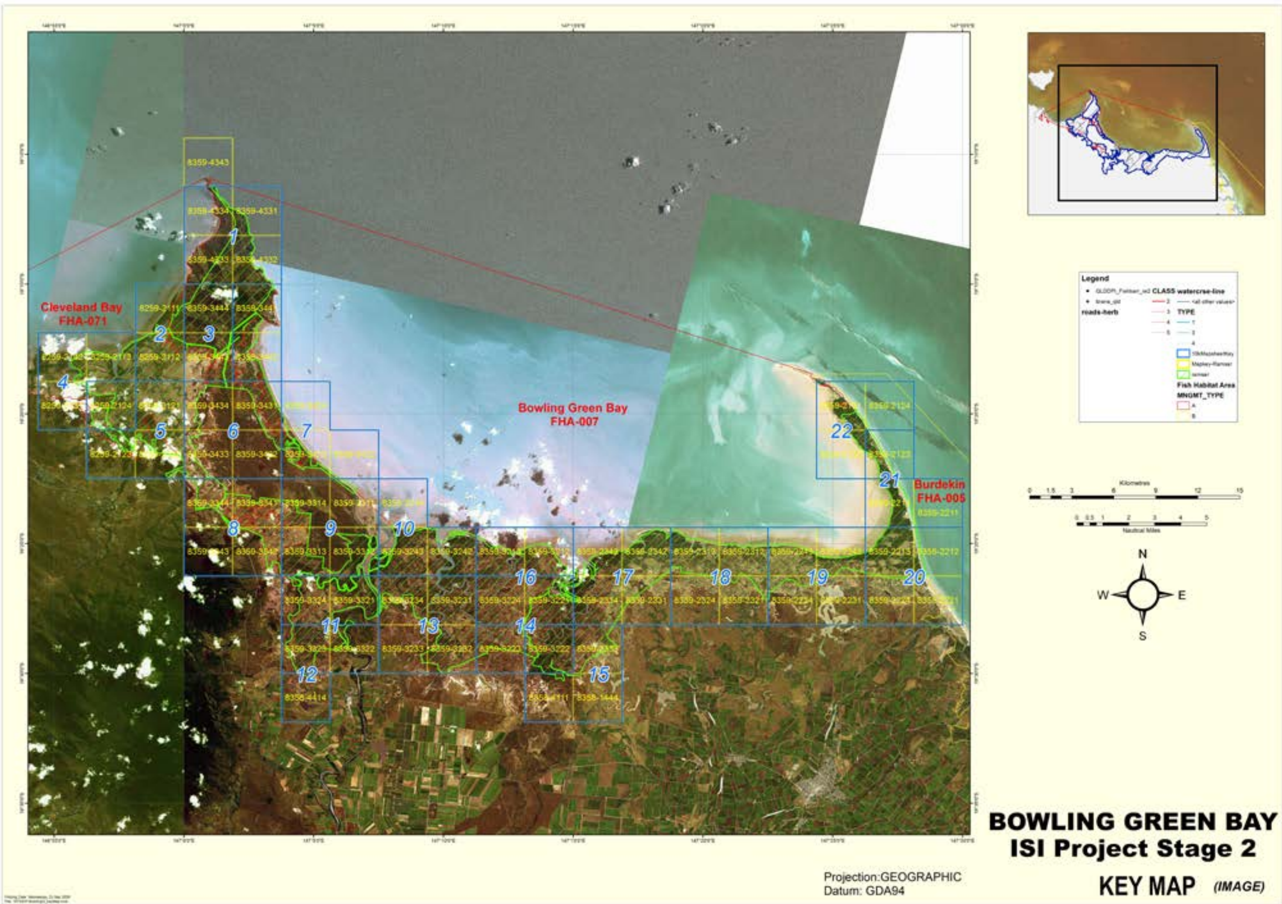


Figure 7. Key map example for the Bowling Green Bay project area with a labelled 1:5000 project area grid (in yellow) overlaid on aerial imagery

Using ArcMap, the project area grid layer can be manipulated to graphically represent fieldwork status. For example, grid squares that have been completely inventoried can be shaded in a different colour from areas that are yet to be inventoried or areas where inventory work is currently in progress. An example of using the project area grid layer to monitor fieldwork progress is shown in Figure 8.

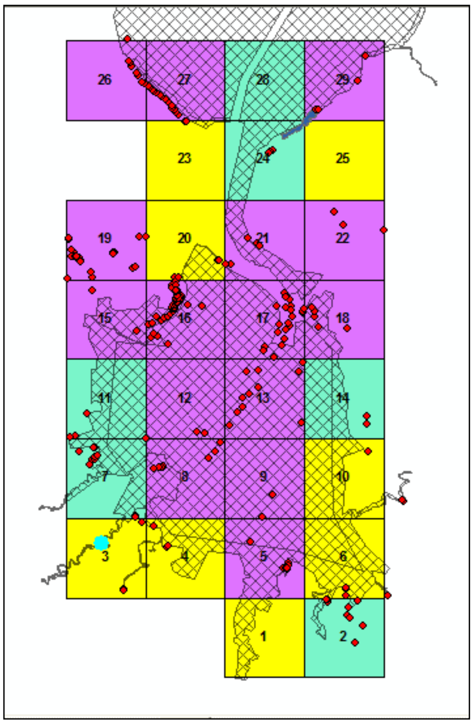


Figure 8. Grid system used to track inventory progress in the Trinity Inlet declared FHA (hatched). Completed grids are highlighted in purple, green indicates grids currently in progress and yellow highlights grids where inventory work is yet to be done.

Individual map sheets are created in ArcGIS and consist of imagery and layers corresponding to individual project area grid squares. Map sheets can be exported as JPEGs or PDFs, from which hard copies (e.g. A4 size) can be produced for field navigation. An individual map sheet is shown in Figure 9. Hard copy map sheets are important for field navigation, given that the PDA screen is relatively small and reflects glare. Map sheets can be created to display various layers as desired.

Knowledge of different land tenures is particularly useful information to have on hand while in the field. An example of a map sheet showing land tenure is displayed in Figure 10. Once project area maps are developed, shapefiles and imagery for the project area are extracted to the PDA (or similar) in preparation for structure identification (Stage 2).

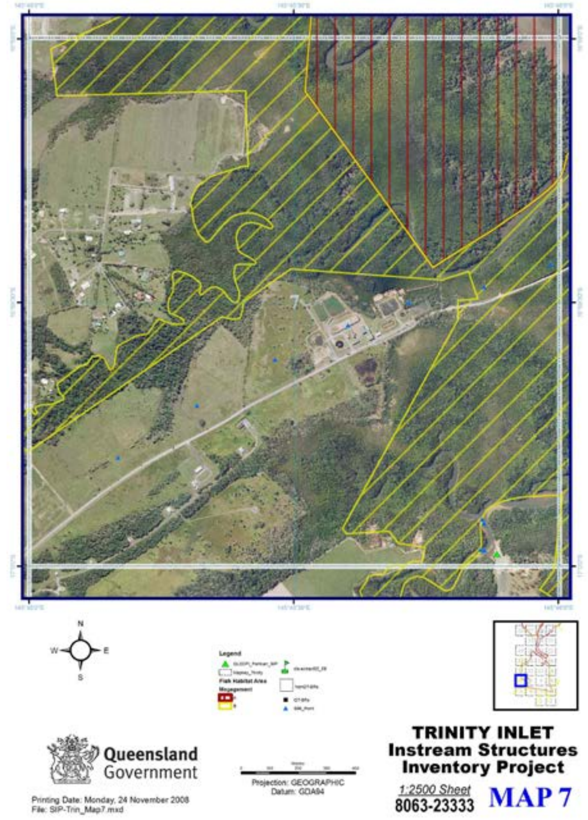


Figure 9. Individual map of aerial imagery to assist with field navigation

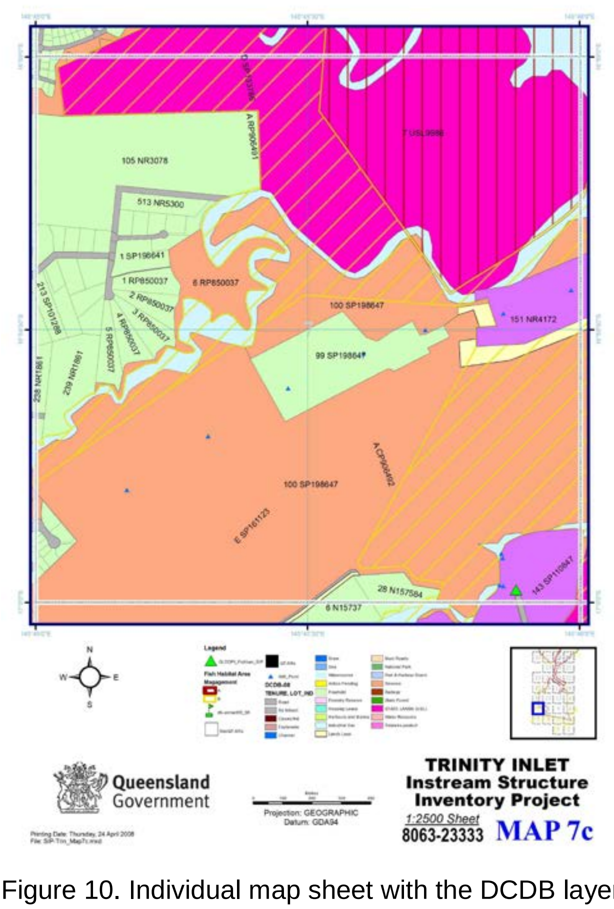


Figure 10. Individual map sheet with the DCDB layer showing land tenure is useful when accessing structures in the field

In addition to shapefiles and imagery, database files are uploaded to the PDA in order for the FishBarriers VQ menu system to operate. These files consist of editable look-up tables (e.g. list of FHAs, catchment areas, vegetation types, weed species, etc.) that form the basis for the drop-down lists that appear within the pages of the menu system. An overview of information uploaded to the PDA for field assessment is shown in Figure 11.

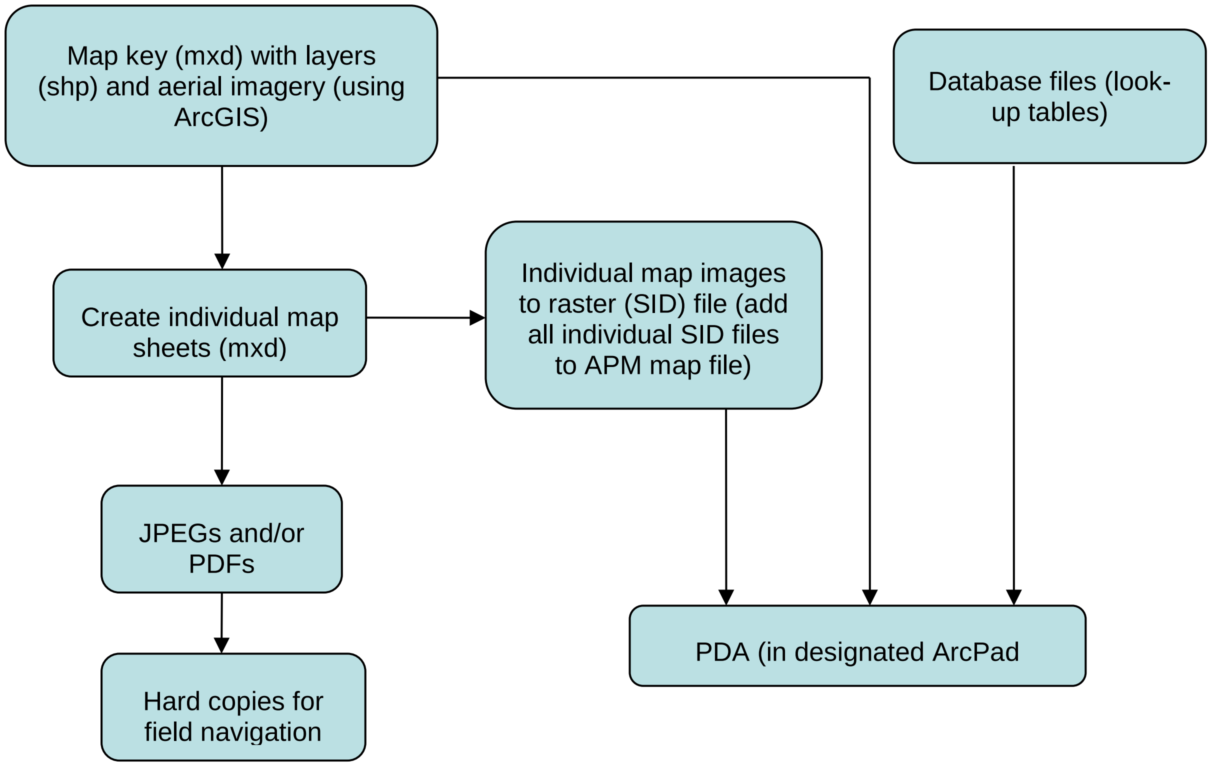


Figure 11. Overview of files uploaded to PDA for field assessment

Stage 2. Field assessment

Collection of inventory data using the FishBarriers VQ menu system

The main objectives of data collection are to:

- confirm the nature and spatial location of known structures
- identify the nature and spatial location of additional instream structures
- record an adequate physical description of each structure
- assess any observable impacts on fish habitats associated with the structure
- record general fish habitat condition/value at the site of the structure
- record information relating to wetland environment and vegetation at the site of the structure.

Requirements:

- hardware – portable digital data collection device (e.g. Nomad® PDA with on-board GPS and in-built camera), digital camera, PC or laptop
- software – ArcMap desktop/ArcView, ArcPad extension tools, FishBarriers VQ menu system.

This section of the inventory protocol outlines data collection methods, based on the use of GIS technology to collect and store inventory data. It describes the use of FishBarriers VQ, a GIS-based structure assessment menu system that can be uploaded onto a hand-held PDA to collect data.

The TDS Nomad® PDA was used in the inventory trials that formed the basis for these guidelines. However, there are a range of PDAs and other portable data collection devices on the market (e.g. Toughbook™ computers) that may be suitable for inventory fieldwork. In preparation for fieldwork, the chosen device should be uploaded with both the ArcPad FishBarriers VQ menu system and all maps and layers relevant to the project, including the key map and individual map sheets.

Menu system structure and data entry

This section provides detailed instructions on how to use the FishBarriers VQ menu system for ArcPad on a hand-held TDS Nomad® PDA. The FishBarriers VQ menu system, originally developed by NSW DPI (now Industry & Investment NSW), is an ArcPad application that relates to a menu of pages that contain a number of data fields pertaining to a range of data attributes. Upon marking the GPS location of a structure in ArcPad, the point is captured directly into an editable data shapefile in ArcPad and the FishBarriers VQ menu appears on the screen. The menu is separated into a number of pages that appear as digital data entry forms, with each page relating to a different broad grouping of data attributes and consisting of a number of data entry fields.

Data entry includes taking photos of structures using the in-built camera on the PDA which will be directly linked to the GPS point relating to the structure along with other recorded data attributes. The TDS Nomad® PDA produces raster images of up to two mega-pixels. It is also recommended that photos are taken using a digital camera to supplement images recorded by the PDA.

All data attribute information is recorded directly into the same layer with GPS points, linking attribute information for each structure directly to the corresponding spatial data. The created database provides a spatial record of all structures assessed and allows for additional structures to be incorporated into the database as these are identified. The FishBarriers menu system was originally created by NSW DPI (now Industry & Investment NSW) for the purpose of collecting baseline information required for inventory and prioritisation of fish passage barriers in NSW. This system was modified to develop the FishBarriers VQ menu system. A summary of the pages and an explanation of data attributes included in the FishBarriers VQ menu system is provided below.

FishBarriers VQ menu system pages and data attributes

A full list of FishBarriers VQ menu system pages and data attributes is provided in Appendix B. A large proportion of the list was taken directly from the New South Wales field guide prepared for the FishBarriers menu system in 2006. Some attributes have been adapted directly from the field survey proforma designed for recording on-ground wetland inventory information for the WIC. A copy of the proforma is available on the WetlandInfo website: http://wetlandinfo.ehp.qld.gov.au/wetlands/resources/tools/contribute-data/contribute-data-tools.html

Additionally, some attributes have been modified or added to ensure that the list applies to the range of structures that are likely to be found in Queensland’s declared FHA network. Data attributes currently included in the menu system have been grouped into different pages based on the following broad categories: general, spatial location, site details, non-barrier, barrier type, barrier details, fish passage details, habitat, vegetation, threats, location and ownership. A brief summary of each page is provided below.

General

This page consists of some general information such as the assessor’s name, organisation, time, date, weather and flow/tide stage. The structure type is also recorded on this page. Initially, it is necessary to record the structure type so that you can then choose which structure-specific pages to fill in.

Spatial location

This page refers to location details such as the location ID, location derivation and location precision. This page also provides the capacity to assign a new location to an existing structure if the location originally entered is deemed to be inaccurate.

Site details

Site details refer to details pertaining to the structure location (e.g. system type, catchment section, habitat class, wetlands ID, waterway name), as well as the structure name, nearest road name and road type.

Non-barrier

This page is specific to non-barrier structures and is mainly a physical description of the structure. The non-barrier's physical dimensions (length, breadth, height) are recorded, as well as the construction material used, whether the structure is obsolete and any other comments. The type of non-barrier is also recorded on this page.

Barrier type

The barrier type page specifically applies to barrier structures. This page defines the type of barrier structure, which will determine what barrier details are required on the 'barrier details' page. It is possible to select from floodgate, road crossing and weir/dam. This page also includes information on the structure's construction material and whether the structure is obsolete.

Barrier details

The attributes recorded on this page largely relate to the physical details of the barrier and include details such as length, breadth, height, invert height, number of pipes/cells, cell shape, cell height and cell width.

Fish passage details

The fish passage page incorporates attributes to determine how severely restricted fish passage is at the site. These attributes include head loss, whether there is a fishway on the barrier, if water pools upstream and if light, slope, water velocity or debris are likely to cause problems for fish passage.

Habitat

The habitat page is where details about the habitat surrounding the structure are recorded as well as some physical details about the waterway. For example, bank width, height and low-flow wetted width, dominant substratum, if acid sulphate soils are present and whether the structure is providing habitat for the attachment of epibiota (indicated by epibiota attached to the structure's surface).

Vegetation

Vegetation details are important to the QWP and include details about the dominant land use in the area, dominant vegetation type and genus, presence of weeds, the presence of wetlands and wetlands type.

Threats

The purpose of this field is to note any phenomena that may be adversely impacting the environmental values of the wetland. The threat must be observable rather than inferred (includes the impact of the structure on the environment/wetlands). The threats page relates only to non-barrier structures and records whether the structure is causing any related impacts, such as accretion, dead native flora, erosion, altering the inundation extent, inhibiting marine plant growth, slumping, siltation, scouring, dredging or filling. This is where the footprint of the structure and any additional disturbance area outside the footprint is recorded.

Location

The location page refers to the location of the structure on a wider scale. It includes attributes such as catchment name, declared FHA name, local government area, nearest town, NRM region and topographic map reference.

Ownership

These details refer to the owner of the structure, if there is one. If ownership can be determined, details are recorded such as whether the ownership is private or commercial, the owner's name and contact details and licence ID. It is important to note that ownership information is sensitive and must be kept confidential. The owner of the structure must be contacted before his/her details are released.

Once data collection and checking is complete, ArcGIS can be used to create structure locations maps, in addition to generating queries and producing reports. An example of a structure locations map for the Hinchinbrook project area is shown below in Figure 12. The data collected is used to prioritise structures following the response protocol.

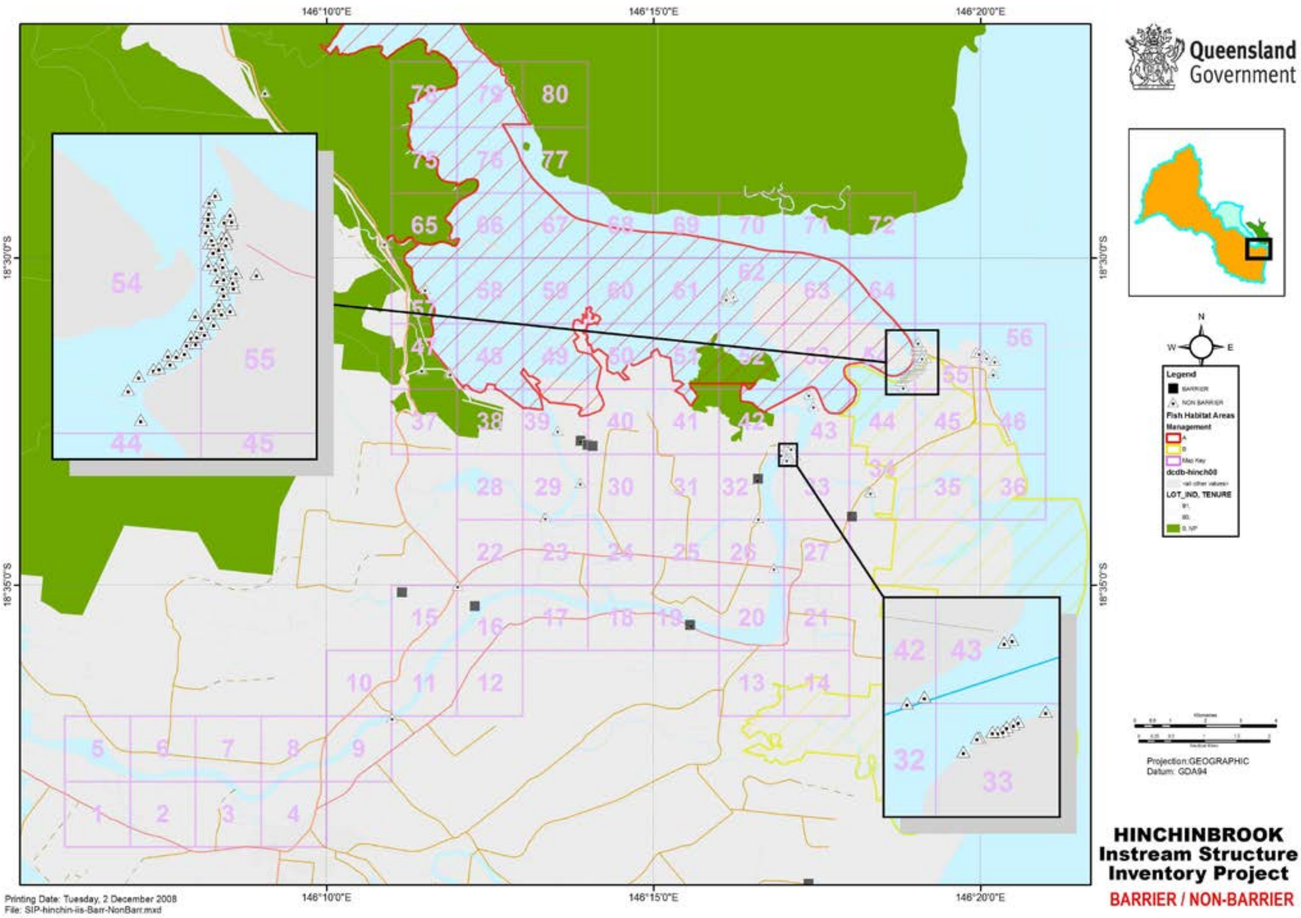


Figure 12. Example of a map that can be created at the end of the inventory protocol, showing the locations of identified structures within the project area

Data management

Data ownership and maintenance

NPRSR is the repository for all information collected as part of ISI projects in Queensland using the FishBarriers VQ menu system and as described in the inventory protocol. On completion of an ISI project, all inventory data should be supplied to NPRSR as data custodian. Essentially, a project will produce two different types of data outputs: a record of structures and data attribute information in the form of an Access database, and a spatial layer that contains the GPS locations of all identified structures (which is linked to inventory data attributes).

Data attribute information is stored in a statewide instream structures database maintained by NPRSR. The database includes the capacity for existing inventory information to be updated and for new information to be added, to reflect any changes in the status of structures. A spatial layer with the statewide distribution of structures linked to data attribute information, maintained and updated by NPRSR as required, is available for download from the Queensland Spatial Catalogue (http://qspatial.information.qld.gov.au).

Data transfer to the Queensland Wetlands Program

An important end point for all inventory data is to be uploaded to QWP databases. These established links allow inventory information to be used across QWP projects such as the WIC and the Queensland Mapping and Classification Project.

Data sharing

Queensland structure inventory data may be requested by NRM groups or other key stakeholders for operational purposes and to supplement management actions in relation to problem structures (actions are discussed in the response protocol). Data collectors will be advised before the release and use of any information by any external parties, including QWP, NRM groups or local councils etc. NPRSR can be contacted regarding access to and use of any inventory data.

Acid sulfate soils (ASS)

Coastal wetlands in a number of Queensland regions are known to contain potential acid sulfate soils (PASS). When soils are exposed to air, often during restricted tidal flows, acid is produced by the oxidation of iron sulfides. Run-off over these exposed soils collects acid and this affects fisheries resources and fish habitats, and may cause fish kills, fish disease (red spot), alteration of marine plant communities and loss of habitat. Any development works in coastal wetland areas has the potential to disturb PASS.

The Atlas of Australian Acid Sulfate Soils, developed by the National Committee for ASS (NatCASS), contains information on the extent and severity of the ASS problem in both coastal and inland environments throughout Australia. Current ASS mapping must be investigated before modifying or removing structures as works in coastal wetland areas may disturb or expose PASS. The ASS atlas can be accessed as a web served GIS at the Australian Soil Resource Information System (ASRIS) website (www.asris.csiro.au).

If removal or modification of a structure will result in alleviation of an existing ASS issue, then the structure may be considered a high priority. Areas affected by acid sulfate soils (i.e. low-lying areas below 5 m Australian Height Datum) can be restored in accordance with the *Queensland acid sulfate soil technical manual*. The manual, originally produced by the Department of Natural Resources and Water, outlines the best practice management of ASS and is available on the Queensland Government website (www.qld.gov.au).

Part 2: Response protocol

Introduction

The response protocol outlines a system for making decisions relating to the management of instream structures in declared FHAs. The inventory protocol described in Part 1 of the guidelines provides instructions on how to conduct a structure inventory, including identifying structures and their location and assessing structure impacts. Following on from the inventory protocol, the response protocol outlines how inventory data is integrated to prioritise structures for delivery of enhanced management responses, particularly with regard to ‘problem’ structures.

The response protocol is essentially a decision support system to help NPRSR, NRM and key stakeholder groups prioritise individual structures and identify management response actions (MRAs) appropriate for those that continue to have a negative impact on fish habitat or fish passage. A number of criteria are used to score structures based on their impact on either fish habitats or fish passage and their location in relation to ecologically high value areas. A prioritisation matrix is applied to identify priority structures for MRAs. A key output of applying the response protocol is a response action plan (RAP) that encapsulates priority structures and recommended MRAs. A RAP forms the basis for on-ground actions to remediate the impacts of priority structures. An overview of the response protocol and how it fits into the decision-making process is shown in Figure 13.

The response protocol includes an overview of some of the management responses that apply generally to particular categories of structures. However, it should be noted that before responding to priority structures that are identified through the response protocol, there are a number of other management considerations that should be taken into account when making decisions related specifically to individual structures.

Specific management considerations related to individual structures include: the purpose of the structure, its location, its proximity to other structures, its ownership, its legality and compliance, its current/ancillary uses, its current condition, logistics of undertaking action, access, capacity of the owner or others to respond, presence of acid sulfate soils (ASS), timeframe, availability of funding, approvals necessary to implement one or more actions, and rehabilitation opportunities, both onsite and adjacent to the site.

There are a number of important considerations regarding barriers to fish passage. These include the number of existing upstream and downstream obstructions and the amount of potential habitat that would become available for fish upon remediating a barrier. Ideally, the most downstream barrier in a stream is to be addressed first; otherwise the benefits of barrier removal may be thwarted by the presence of additional barriers downstream.

While it is not within the scope of this document to detail these specific management considerations, they would be applied in the assessment of individual priority structures before initiating a response to individual structures. This may involve further and more detailed assessment of individual structures and specific circumstances, following prioritisation of structures and consideration of general management issues that apply to structure categories.

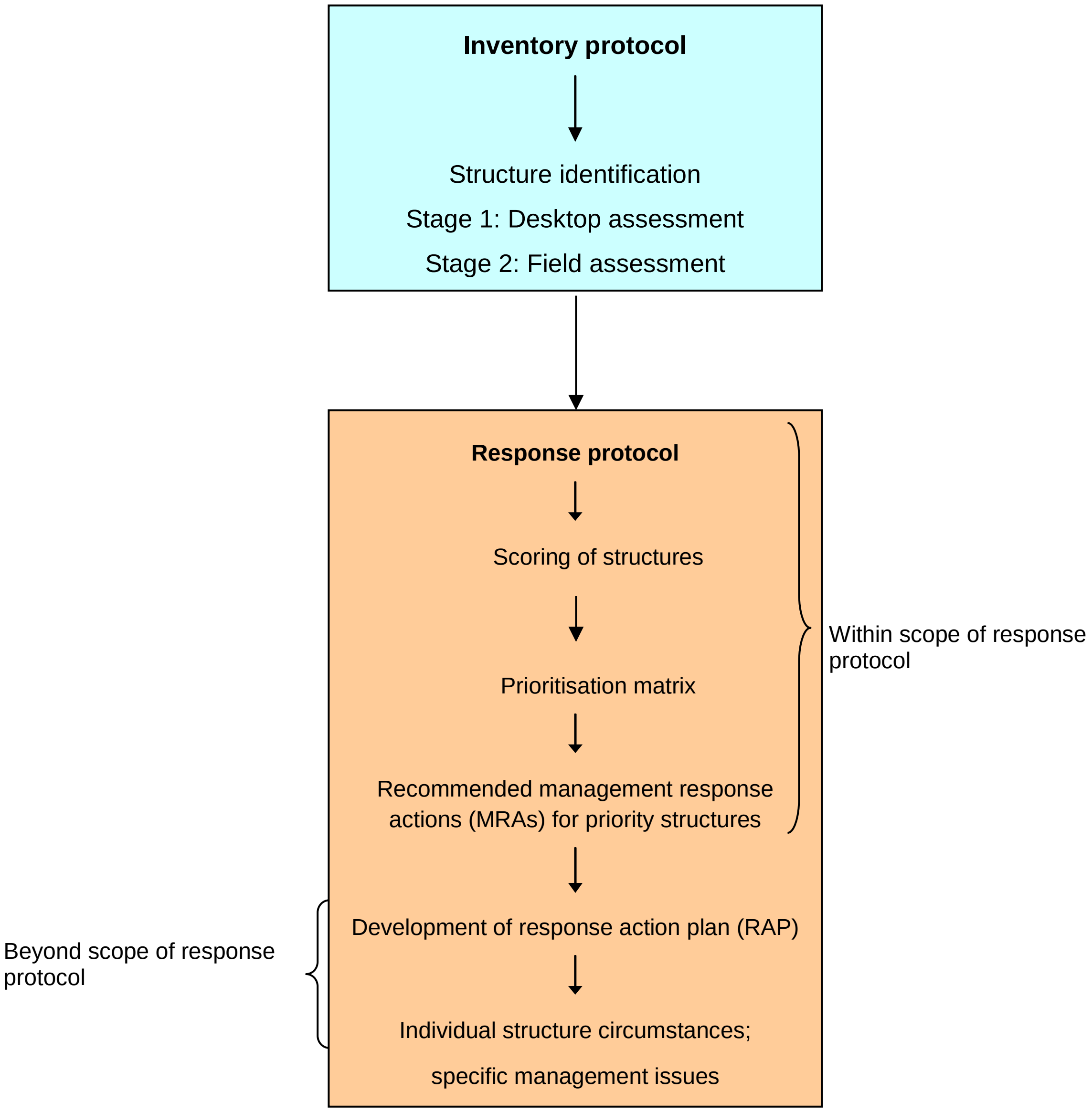


Figure 13. An illustration of how the response protocol fits into the decision-making process

Prioritisation criteria and scoring system

Prioritisation criteria have been developed to score and prioritise individual structures based on their impacts on either fish habitats or fish passage. The criteria are based on those originally formulated by DEEDI as part of a project to prioritise freshwater fish barriers in the Mackay–Whitsunday region (Marsden et al. 2006). These criteria have been modified to extend to non-barrier structures and allow prioritisation of structures within the declared FHA network.

Prioritisation criteria fall into two categories: habitat value criteria and impact criteria. Habitat value criteria provide an indication of the value of habitat that surrounds a particular structure, while the impact criteria give a measure of the severity of a structure's impacts on fish habitats or fish passage. The habitat value criteria apply to both non-barriers and barriers; however, there are differences in the impact criteria between the two structure groups. These differences reflect the nature of impact (fish habitat versus fish passage) of each structure group. Therefore, each of the two structure groups are considered separately when prioritising structures.

Each structure is assessed and assigned values under each criterion, resulting in a habitat value score and an impact score for each structure. A high habitat value score indicates a structure is located in an area of high habitat value, while a low score refers to a structure located in relatively poor quality habitat. Similarly, a low impact score refers to a structure that has a relatively low impact on fish habitat or fish passage, while a structure with high impacts on fish habitat or fish passage would result in a relatively high impact score.

Structures that may be encountered within the declared FHA network are listed in Table 1. Note that not all of these structures are currently included in the decision support system. The decision support system has been limited to structures identified as part of the inventory trials that were used to develop these guidelines.

Table 1. Non-barrier and barrier structures that may exist within the declared FHA network

Non-barriers	Barriers
Moorings (traditional and environmentally friendly) Pipe and drain intakes/outlets Pile-supported structures: boardwalks jetties pontoons (fixed and floating) walkways viewing decks Rubbish/wreckage: dumped material derelict vessels Stabilisation structures: revetments groynes gabions breakwaters Fill and slab: boat ramps slipways wharves other non-barriers (e.g. illegal huts)	Stream crossings: bridges culverts causeways fords Floodgates Levee banks/bunds/ponded pastures

In addition to structures approved for a specific purpose, unauthorised and obsolete structures may exist within declared FHA boundaries. The rubbish/wreckage category is likely to contain the majority of unauthorised structures identified as part of the inventory process. Should unauthorised structures be identified, DAFF's Queensland Boating and Fisheries Patrol (QBFP) should be contacted and notified of the structure location and its details.

Habitat value criteria

Habitat value criteria are common to both non-barrier and barrier structures. There are three criteria within the habitat value category (listed in Table 2) that provide an indication of the value of the habitats surrounding structures. The habitat value criteria include waterway class, habitat class and habitat condition. Combined, the criteria give a total habitat value score out of 30 for each structure.

Table 2. Habitat value criteria and scoring system

Criterion	Description	Score
1. Waterway class	Inshore coastal waters/tidal inlet/main stream/lowland lagoon*	10
	Major tributary of main stream direct to sea/small lowland lagoon**	8
	Minor tributary of main stream/large low-order tributary direct to sea***	4
	Minor, low order tributary****	0
2. Habitat class	High fisheries significance plants dominant (mangroves, seagrass, saltmarsh)	10
	Known to previously support high fisheries significance plants	8
	Other tidal fish habitats (naturally bare/unveg dominant)	5
	Low significance fisheries plants (non-tidal, terrestrial plants, trees, grasses) dominant	2
3. Habitat condition	Pristine, 100% natural forest	10
	Low disturbance, <25% of waterway degraded	8
	Moderate disturbance, 25–50% of waterway degraded	6
	High disturbance, 51–75% of waterway degraded	4
	Very high disturbance, >75% of waterway degraded	0
	Total habitat value score	/30

*e.g. Trinity Inlet (Cairns); Bowling Green Bay & Haughton River (Townsville)

**e.g. Redbank Creek (Cairns); Burrambush Creek (Townsville)

*** e.g. Mackey Creek (Cairns); Ratchett Creek (Townsville)

****e.g. Middle Creek (Cairns)

Habitat value criterion 1: Waterway class

The ‘waterway class’ criterion gives a measure of the size of the waterway within which a particular structure is located. This criterion is based on the concept that larger waterways and estuaries at the bottom of the catchment are more important for fisheries productivity and provide greater area and diversity of habitats relative to smaller waterways higher up in the catchment. While it is acknowledged that all habitats within declared FHAs are important for fish for different reasons, and a mosaic of habitats is necessary to support productive fisheries, this criterion distinguishes between habitats within a declared FHA for the purposes of identifying priorities within the declared FHA. Taking this approach means that larger waterways and areas of fish habitat are initially targeted for management responses before focusing on structures and habitats within smaller waterways.

Habitat value criterion 2: Habitat class

All fish habitats are important in providing a diverse habitat mosaic essential for fisheries productivity. However, for the purposes of targeting structures in areas of high value habitat for management responses, the ‘habitat class’ criterion provides a measure of the significance of habitat in the vicinity of a structure to fisheries productivity.

The levels within this criterion reflect DAFF's current management arrangements relating to fish habitats. Mangroves, seagrass and saltmarsh are protected in Queensland and are considered essential for fisheries productivity. Sites of structures that are visibly dominated by these plants are therefore given a higher habitat class score. Sites that are known to have previously supported high fisheries significance plants (but may have been modified or disturbed in some way) are also given a relatively high score. This is to recognise the potential value of disturbed tidal areas as important fish habitats, particularly if there is opportunity for rehabilitation of marine plants at the site.

Other tidal fish habitats include bare or unvegetated areas (e.g. sand and mud flats and sand bars at estuary mouths). These habitats receive a lower habitat class score; however, they are included due to their fish habitat value as recruitment, spawning and feeding areas for fish. The upper tidal zone ‘bare’ areas of clay pans and salt pans provide habitat for transitory fish accessing tidal saltmarsh areas as juveniles and adults or act as feeding areas. ‘Bare’ areas operate as nutrient sinks contributing to adjoining productive fish habitats of saltmarsh and mangrove areas. Of least significance to fisheries productivity are non-tidal and terrestrial plants, which are given the lowest habitat class score.

Habitat value criterion 3: Habitat condition

‘Habitat condition’ is the third habitat value criterion and refers to the health of the surrounding fish habitats based on the amount of riparian clearing and bank degradation. The condition of habitat along the entire waterway (including any part of the waterway that extends outside declared FHA boundaries) in which the structure is located should be considered when assigning a habitat condition score. This may be determined through a combination of assessing aerial photography and imagery and on-ground visual surveys. Pristine aquatic habitats with no clearing of riparian vegetation and no bank degradation have higher habitat values and therefore achieve a higher score than disturbed and degraded areas with no remaining riparian vegetation and excessive bank erosion.

Impact criteria (for prioritising non-barriers)

There are three impact criteria that apply to the prioritisation of non-barrier structures and provide an indication of the level of impact a structure may be having on fish habitats. The scores for each criterion are combined to obtain an overall impact score out of 40 for each structure. The three criteria include: non-barrier type, footprint area and disturbance area outside footprint. Low impact structures that cause a relatively minimal amount of disturbance to the existing environment receive a low score. Those structures that have a high level of impact receive a high score. The scoring system for impact criteria is illustrated in Table 3.

Impact criterion 1: Structure type

The first impact criterion is ‘structure type’, in which structure categories reflect the level of impact a structure has on fish habitats. Design elements, such as size, footprint, materials, location and surface texture, all contribute to the type and level of impact that a structure has on fish habitats (Adams 2002). The structure categories included in this criterion are based on the similarity in design elements among each category.

Each category has been ranked in order of the severity of the category’s impact relative to the other structure categories. A high score is indicative of a structure that belongs to a category that typically has a high impact on fish habitats. On the other hand, a low score is attributed to a structure that belongs to a lower impact category. There are two scoring levels to choose from within each structure category, in order to separate the higher impact structures within the category from lower impact structures.

Fill and slab structures include structures such as boat ramps, wharves and slipways. Structures within this group typically have large footprints that are directly related to the size of the structure and result in the direct loss of fish habitat (Adams 2002). Fill, revetment and slab structures are considered to have the highest (permanent) impact on fish habitats and are therefore given the highest impact score. Boat ramps that have a natural surface (e.g. mud launches) are considered to have a relatively low impact on fish habitats and are considered outside the ‘fill and slab’ category.

Stabilisation structures include revetments, gabions, groynes and breakwaters. They are built to protect developments and adjacent lands from eroding shorelines. These structures are usually associated with a significant footprint and greatly affect tidal regimes. In affecting the extent of tidal inundation, marine plant communities are altered and fish habitats may be completely lost. Depending on the design and construction materials, these structures may enhance fish habitats by adding a level of complexity to the available fish habitats and through providing ‘hard’ surfaces in largely ‘soft’ natural habitats (United States Army Corps of Engineers 1993).

The rubbish/wreckage category of structures refers to dumped material and includes derelict vessels. Although these structures directly impact on fish habitats through covering and smothering of the substrate, they generally have a lower impact than fill, revetment and slab structures as fish can access both the structure and the substrate. These structures can enhance fish habitats by providing fish with protection from predators, shelter from currents and extra settlement habitat for recruitment (Derbyshire 2006). For this reason ship wreckages and sunken vessels are often approved for use as artificial reef habitat to attract fish for recreational fishing and diving.

The impacts of moorings are typically associated with disturbance of the substrate and scouring from movement of the chain or rope that secures the vessel to the mooring block. This is particularly a problem in seagrass habitats. However, environmentally friendly moorings are designed to have no or minimal impacts on the substrate and associated fish habitats. Due to the low impact of environmentally friendly moorings, these structures are given a significantly lower score relative to the traditional block and chain moorings.

In contrast to fill, revetment and slab structures, pile-supported structures have a smaller footprint that is related to the area covered by the base of the pylons—rather than being a direct function of the structure size (Adams 2002). Pile-supported structures include boardwalks, jetties, viewing decks and pontoons.

Shading is the main impact of pile-supported structures on fish habitats, with the amount of light penetration decreasing and the area of shading increasing with the size of the structure (Adams, 2002). Depending on the degree, shading may result in acute inhibition of marine plant growth where the growth of marine plants is completely inhibited (higher impact), or may result in chronic inhibition whereby some plant growth is possible within the shaded area (lower impact) (Adams 2002).

Table 3. Impact criteria and scoring system to prioritise non-barriers

Criterion	Description	Score
1. Structure type	Fill, slab – obvious changes to wave and sand patterns	20
	Fill, slab – possible changes to sand and wave patterns	18
	Stabilisation structures – vertical/concrete face; unlikely habitat	16
	Rubbish/wreckage – no fish/epibiota observed/unlikely habitat	15
	Rubbish/wreckage – fish/epibiota observed/likely habitat	13
	Stabilisation structures – rubble/rock; providing some fish habitat	12
	Moorings – traditional block system	10
	Pile-supported – shading; inhibiting marine plant growth	8
	Pile-supported – adequate light penetration	6
	Mooring posts	6
	Discharge/pipe – no/inadequate scour protection	5
	Formed natural surface ramp	4
	Discharge/pipe – with scour protection	3
	Moorings – environmentally friendly	3
2. Footprint area	>250 m² (provide estimate)	10
(from structure)	101–250 m²	8
	51–100 m²	6
	11–50 m²	4
	0–10 m²	1
3. Disturbance area	>250 m² (provide estimate)	10
(outside footprint)	101–250 m²	8
	51–100 m²	6
	11–50 m²	4
	0–10 m²	1
	Total impact score	/40

Discharge/pipe structures have a relatively low impact on fish habitats compared with the above structures and this is reflected in a relatively low impact score. Impacts are mostly associated with scouring and bank erosion that result from inadequate scour protection or incorrect siting of the outlet (e.g. on an erosive river bend). Structures with adequate scour protection that are not causing any erosion problems are considered to be lower impact than those discharge/pipe structures that are causing erosion/sedimentation problems.

Impact criterion 2: Footprint area (from structure)

The size of a structure's 'footprint area' is the second habitat impact criterion and refers to the actual area that the structure currently occupies. Structures with a larger footprint are considered to have higher impacts on fish habitat and receive a higher impact score. Structures with a smaller footprint (lower impact) receive a lower impact score. Please note that in the case of moorings, it is very difficult to determine the footprint area without an underwater survey of the structure. Therefore, it is recommended that all traditional block and chain moorings are assigned a footprint area of 0–10 m^2.

Impact criterion 3: Disturbance area (outside footprint)

In some cases, there will be no area of disturbance outside the footprint area of a structure. However at other times there are significant additional impacts associated with the structure that fall outside the structural footprint. Capturing these additional impacts is the basis for this criterion. For example, installation of revetments often results in areas of sand accretion upstream of the structure. There may also be disturbance associated with gaining access to structures (e.g. tracks that are constructed to access boat ramps).

Structures with a larger 'disturbance area' (higher impact) receive a higher score than structures with smaller disturbance areas. In the case of moorings, it is very difficult to determine this additional disturbance area without an underwater survey of the structure to observe the interaction of the rope and chain with bottom substrate and habitats. Therefore, it is recommended that all traditional block and chain moorings are assigned disturbance area (outside footprint) of 11–50 m^2. Moorings with no or minimal impact on marine plants and fish habitats should have a combined footprint/disturbance area (outside footprint) of no more than 1 m^2 (DAFF self-assessable code MP06).

Impact criteria (for prioritising barriers)

There are two impact criteria to prioritise barriers: barrier type and barrier impact. These criteria and scoring system are shown in Table 4. Both criteria provide an initial indication of how severely a barrier is restricting fish passage. A detailed technical assessment of potential fish barriers is required to accurately quantify the impacts of the structure on fish passage. The impact criteria within these guidelines provide an initial indication of where fish passage issues may exist and where technical assessments are likely to be required. The barrier type score and barrier impact score are combined to obtain an overall impact score for each structure. Structures that have less impact on fish passage will obtain a lower impact score, while structures with significant impacts on fish passage have a higher impact score.

Impact criterion 1: Barrier type

'Barrier type' has significant effect on fish passage. Design of some structures creates partial barriers to fish passage while other structures form complete barriers that fish are unable to negotiate. In some cases, structures that typically form barriers can be modified or designed to allow fish passage (e.g. a bridge structure that spans the waterway or a dam installed with a fishway). The different barrier types included in this criterion are tidal barrages, floodgates and stream crossings (culverts, causeways, bridges).

A tidal barrage is designed with the aim of completely excluding tidal water from intruding past the barrage. Being the most downstream barrier in a system, a tidal barrage has the potential to cut off access to hundreds of kilometres of fish habitats in the catchment upstream and poses the most severe barrier to fish passage. This barrier type receives an impact score of 20, reflecting the high impact nature of this structure. Tidal barrages are not scored any further and therefore do not obtain a barrier impact score.

Dams and weirs are typically constructed to supply water for industry or domestic consumption or to provide flood mitigation. While weirs are generally smaller structures built across river channels rather than entire river valleys, both structures form significant physical barriers to fish movement. The impact that a dam or weir has on fish passage is greatly influenced by the height of the structure and the frequency, timing and duration of drown-out.

Tidal bund walls or levee banks are constructed on tidal land to form a barrier across a wetland area or formed through natural processes (e.g. build-up of sand across a creek mouth). These structures are often built on the boundaries of farming properties to protect crops and farming land from tidal inundation and to develop ponded pastures for grazing. These structures create significant barriers to fish and prevent their movement onto floodplains and fish habitats.

Floodgates are designed to prevent the overtopping of seawater during king tides. Traditionally, tidal floodgates are passively managed, opening only in response to water level rise on the upstream side of the gates during flood events. Often gates remain closed for extended periods of time, reducing water quality and preventing fish from moving further upstream and onto floodplain areas. During times of flood when gates do open, velocities are often too great to allow fish passage. These structures can therefore prevent fish passage completely in some instances.

Actively managed floodgates have significant benefits for fish passage (NSW Fisheries 2002) and are managed to be open more frequently, allow some tidal flushing and so encourage fish passage. These barrier structures receive a lower impact score (5) than passively managed floodgates (11).

Table 4. Impact criteria and scoring system for barriers

Criterion	Description	Score
1. Structure type	Tidal barrage – no further scoring	20
	Large dam or weir (e.g. across whole river valley >3 m high)	13
	Tidal bund wall or levee	12
	Tidal floodgate passively managed	11
	Medium dam or weir (1.5–3 m high) or culvert <60% of waterway width	11
	Small dam or weir (e.g. across waterway; <1.5 m high)	10
	Culvert crossing >60% of waterway width	8
	Causeway/ford	7
	Tidal floodgates actively managed	5
	Bridge or fish-friendly structure (e.g. incorporates fishway) – no further scoring	2
2. Barrier impact	a) Dams and weirs	
(select one of	Headloss/invert level >100 mm	6
a, b, c, d, e or f)	Headloss/invert level <100 mm	0

b) Tidal bund walls or levee banks	
No evidence of tidal flow through (barrier at most times)	6
Evidence of some tidal flow through (partial barrier)	0
c) Floodgates	
Evidence of tidal flow through	6
No evidence of tidal flow through	0
d) Culvert crossings	
Culvert length >6 m	2
Culverts length <6 m	0
Individual culvert width >600 mm	2
Individual culvert width <600 mm	0
Culverts raised from bed level or evidence of scouring	2
Culverts at bed level	0
e) Causeways	
Drop on downstream side	3
No drop on downstream side	0
Incorporates pipes with length <6 m	3
Doesn't incorporate pipes or incorporates pipes with length >6 m	0
f) Fords	
Evidence of increased water velocities across the structure (e.g. scouring)	6
No evidence of increased water velocities across the structure	0
Total impact score	/20

Culverts concentrate flows into a reduced cross-sectional area of the waterway resulting in increased velocities that cause a hydrological barrier to fish. Once water flow and fish passage is greatly restricted—for example to less than 60% of the width of the waterway—there can be significant reductions in species diversity (Marsden 2008 pers. comm.). Culverts that do this are given a lower fish-friendly score compared with culverts that keep 60% of the waterway width open to flows. Many road crossings are designed with box or pipe culverts, including some causeways. When scoring culverts, the three features of culvert length, individual culvert width and whether the culvert is raised from bed level should be added together to obtain a barrier impact score.

Causeways are low-level crossings designed where water flows occur under or across the structure. These structures are considered the lowest impact form of stream crossing; however, if designed incorrectly they can present a barrier to fish passage, particularly during periods of low flows.

Fords are also relatively low impact crossings, being built at bed level, and therefore receive a low impact score. However, they can restrict fish passage when water depths across the structure are too shallow for fish to swim through or when water velocities are increased over and around the structure.

Bridges or fish-friendly structures (e.g. that incorporate a fishway) are considered to have no impact or the least impact on fish passage and receive the lowest impact score. Structures in this category have been designed in a way that allows free fish passage. Such structures may include a bridge crossing that spans the waterway, a bridge that includes few or no instream pylons or headwalls, or a stream crossing with an effectively functioning fishway. Due to the relatively low impact nature of bridges, they are not scored against the barrier impact criteria. However, it should be noted if the bridge has been poorly designed (i.e. contains an excessive number of pylons, is creating temporary eddies around pylons that make it difficult for fish to pass by or if it traps debris).

Impact criterion 2: Barrier impact

The second impact criterion refers to ‘barrier impact’ and provides another level of quantifying the impact of a particular barrier on fish passage. The basis for scoring a structure under this criterion will vary depending on whether the structure is a dam or weir, tidal bund wall/levee, floodgate, culvert crossing, causeway or ford.

Dams/weirs

The drop over the wall of a dam or weir to the apron below, or the structure’s ‘headloss’, can provide a significant danger to fish during downstream migration and will often prevent fish from swimming upstream and downstream. The higher the headloss, the more difficult it is for fish to navigate the structure.

Tidal bund walls or levees

Some bund walls and levee banks completely block tidal flow and subsequently prevent all fish passage. These structures are higher impact structures compared to bund walls and levees, which allow for some tidal flows and fish passage (perhaps through gaps or pipes in the levee).

Floodgates

Similar to bund walls and levee banks, floodgate structures that completely prevent the passage of fish are scored higher than those allowing some fish through.

Culverts

There are a number of factors that contribute to the impact of culvert crossings on fish passage and Cotterell (1998) describes these in detail. The length of the culverts is important for fish passage because if culverts are too long these structures form a behavioural barrier to fish. It is known that some fish hesitate at the entrance to long dark culverts. The width of individual culverts is also important and if culverts are not wide enough they will cause a further increase in water velocities as flows are concentrated into a small opening. Culverts that are raised from the stream bed, causing a drop on the downstream side, may present a physical barrier for fish. Culverts at bed level are considered to be more fish-friendly and are awarded a higher score.

Causeways

The drop that can occur on the downstream side of a causeway crossing can present a physical barrier for Australian fish, as many species cannot jump obstacles. Fish that do try to jump may make several attempts at passing a crossing, which can severely deplete their energy reserves, delay spawning fish and decrease general condition. Migrating adult, juvenile and larval fish delayed or trapped below crossings can suffer heavy mortality from recreational fishers and predators. Causeways that incorporate pipes are likely to reduce the impact of a crossing on fish passage, providing pipes are designed correctly.

Fords

Given that ford crossings are usually concreted or consist of relatively smooth material in comparison to a natural stream bed, water velocities can be increased over the structure. Evidence of increased water velocities include scouring of the bed on the downstream side of the crossing or scouring of the bank around the structure.

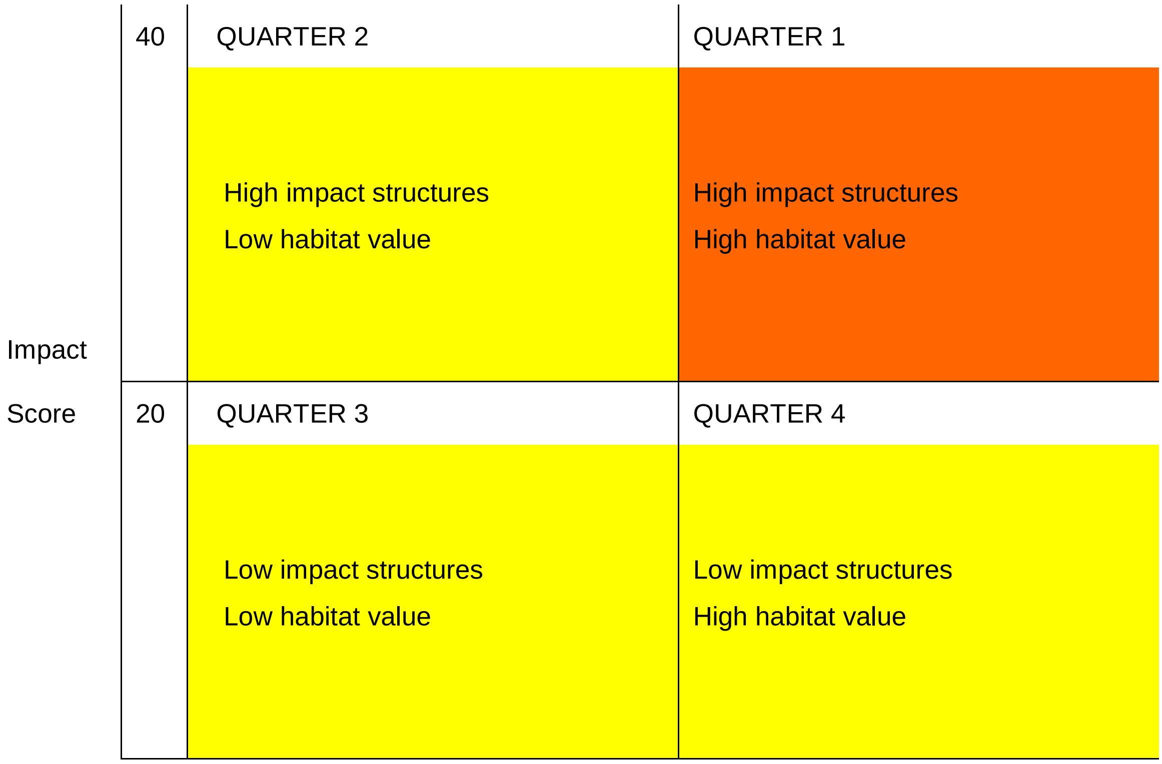
Prioritisation matrix

Scoring of structures gives each structure a habitat value and impact score. The range of possible scores is shown in Table 5.

Table 5. The range of habitat value and impact scores for non-barriers and barriers

	Non-barriers	Barriers
Habitat value score	(Criteria 1 + 2 + 3) 0–30	(Criteria 1 + 2 + 3) 0–30
Impact score	(Criteria 1 + 2 + 3) 0–40	(Criteria 1 + 2) 0–20

Once the habitat value and impact scores have been obtained for each structure, each structure is assigned a position in a prioritisation matrix (see Figure 14).



0 15 30

Habitat value score

Figure 14. Prioritisation matrix concept (non-barriers)

The prioritisation matrix, consisting of a habitat value axis and an impact axis, separates structures into four main quarters: high impact structures in high value habitat (quarter 1), high impact structures in low value habitat (quarter 2), low impact structures in low value habitat (quarter 3) and low impact structures in high value habitat (quarter 4). Structures identified in quarter 1 are considered the highest priority for management response. These structures have relatively high impacts on fish habitats and are located in relatively high value habitat.

Table 6. A sample of priority structures per structure category from quarter 1 (high impact structures in areas of high habitat value) of the Great Sandy Strait non-barrier prioritisation matrix.

Structure category	Structure ID	Non-barrier type	Habitat value score	Impact score
Fill, slab	BURR005MA	Mini marina	20	31
	BURR008AC	Access Channel	26	36
	NOOS212SW	Slipway	22	25
	BURR006JE	Jetty	26	29
	BURR010VD	Viewing deck	26	25
	BURR002BR	Boat ramp	26	27
	BURR003BR	Boat ramp	26	25
	BURR004BR	Boat ramp	23	23
	MISC023BR	Boat ramp	23	23
	NOSS020BR	Boat ramp	26	23
	NOOS069BR	Boat ramp	23	27
	NOOS114BR	Boat ramp	23	25
	NOOS142BR	Boat ramp	23	25
	BURR013BR	Boat ramp	18	23
	NOOS066BR	Boat ramp	23	27
Stabilisation	FRAS031RE	Revetment	28	23
	BURR019RE	Revetment	23	21
	MISC032RE	Revetment	23	23
	NOOS137RE	Revetment	23	21
	NOOS138RE	Revetment	23	21

Rubbish/dumped material	FRAS005DV	Derelict vessel	24	22
	FRAS015DV	Derelict vessel	23	22
	FRAS017DV	Derelict vessel	22	22

Identification of structure position within a specific matrix quarter defines its inclusion in a particular quarter and allows priorities to be developed for the project area. A separate matrix is required for each of the non-barrier and barrier groups. Given that the matrix provides a relative view of structures, it also reveals trends in results that may be important in relation to management decisions (e.g. the matrix might identify a particular category of structures with similar levels of impact that may be best addressed within a single management response). Once priority (quarter 1) structures are defined, RAPs identifying key MRAs for priority structures can be developed. An example list of priority (quarter 1) structures is shown in Table 6.

Developing a response action plan for priority structures

A RAP lists the priority structures from quarter 1 and recommends management response actions (MRAs) to remediate the impacts from those priority structures. The priority structures include all those non-barriers and barriers (quarter 1 of the prioritisation matrix) that were assessed to have relatively high impacts to fish habitats and were also in ecologically high value areas (near pristine habitats). Development of the RAP includes identifying MRAs in consultation with local stakeholders.

Identifying management response actions

The selected MRAs will vary depending on the type of structure and nature of impacts. MRAs are not restricted to but may include:

- further investigation/assessment of impacts and of approval status
- developing strategic approaches to identified management issues
- decommissioning informal/unauthorised structures
- restricting access to informal/unauthorised structures
- raising awareness of ecological values
- removal of structures and rehabilitation of the site
- roles for key stakeholders in implementing the MRAs.

MRAs may include both general and specific recommendations. General recommendations (outlined below) apply across structure categories (within the non-barrier and barrier groupings) and are largely based on management considerations informed by policies, guidelines and legislation.

Specific and practical recommendations depend on a good understanding of the site and local knowledge gained from stakeholder consultation. This includes consideration of the legality of the structure, ownership, logistics of undertaking action, availability of funding, special fisheries features present at the site and the location of the structure in relation to protected areas (e.g. declared FHAs, Ramsar sites, national parks and marine parks) and role of stakeholders. Detailed discussion of these considerations is beyond the scope of this document.

Before implementing MRAs there are some important statutory considerations, which are outlined below.

General management considerations

This section of the response protocol outlines some of the management considerations and recommended MRAs that apply generally to different structure categories. Each structure category (within the non-barrier and barrier structure groupings) is evaluated in terms of the impacts and related management considerations important across the structure category. These evaluations are to provide NRM and key stakeholder groups with an overview of some of the considerations that apply within structure groupings and form a basis for the RAPs recommended MRAs.

Non-barriers

Fill and slab (BR = boat ramp, SW = slipway, WH = wharf, HO = house)

This category includes structures that satisfy a basic requirement of launching and retrieving vessels, and servicing and loading vessels. Many are public structures, while others are owned and operated privately. Illegal housing (or permanent 'squatting') associated with private access structures is an activity that isolates fish habitats and prevents public access to and through tidal waters.

The main impacts are from permanent loss of fish habitats (e.g. with boat ramps, slipways and revetments, and shading and erosion from wharves).

Management of these structures relates to regulating launching/retrieving to designated areas, provision of ancillary facilities for parking (vehicles/trailers) on non-tidal lands, maintenance of revetments, maintenance of boat ramps and slipways, and using appropriate materials/preservatives used for decking on wharves. Within declared FHAs, subject to the management level, public structures can be approved and private structures may be approved.

Potential MRAs include determining the legality of the existing structures and their fate, ensuring public access is regulated, employing fish-friendly design and construction, and best management practices are used on wharf and revetment maintenance. Where removal of structures occurs, rehabilitation may be appropriate for impacted areas (e.g. to re-establish foreshore mangrove corridors).

- Stabilisation structures (RE = revetment)

This category includes structures that armour foreshores against erosion. Many are public structures while others are operated privately.

The main impacts are from permanent loss of fish habitats, alteration of the extent of tidal inundation and changing tidal regimes.

Management of these structures relates to maintenance. Within declared FHAs, subject to the management level, public structures can be approved and private structures may be approved.

Potential MRAs include determining the legality of the existing structures and their fate, employing fish-friendly design and construction, and ensuring best management practices are used on revetment maintenance. Where removal of structures occurs, rehabilitation may be appropriate for impacted areas.

Rubbish/wreckage (DM = dumped material, DV = derelict vessel)

The materials and structures in this category are of concern as their presence is usually from unauthorised activities and their impacts may extend beyond the dump site through leaching.

The main impacts are those of materials covering and smothering intertidal habitats and communities and derelict vessels not having been properly decommissioned (e.g. hydrocarbons drained off, batteries removed, etc.) or scuttled in approved sites.

The management of these materials and structures relates to the physical removal of these materials from fish habitats and restoration of the impacted sites. Within declared FHAs, no approval can be supported for the dumping of materials or the deployment of derelict vessels.

Potential MRAs include determining the persons responsible for the dumping of the materials and the derelict vessels, a coordinated program to remove or neutralise the materials and vessels from within the boundaries of the declared FHAs, and restoration of impacted sites.

Moorings (MO = mooring)

These structures are integral to the safe storage of vessels and may be for private or public purposes. While the mooring block may have relatively minor direct impacts on the substrate and its fish habitat values (in terms of the area occupied generally being less than 1 m2), impacts do occur from the chain or rope attaching the mooring block to the float and the vessel, particularly where the mooring blocks are located on seagrass habitats. Permanent losses of these habitats result from scouring by the attachment line and the vessel. Environmentally friendly moorings are designed to avoid these impacts.

Management of these structures relates to ensuring that moorings are located away from key fish habitats (such as seagrass), only environmentally-friendly moorings are deployed, designated mooring areas are provided and a program for replacing traditional moorings is implemented. Within declared FHAs, subject to the management level, moorings may be approved.

Potential MRAs include determining the legality of the existing structures and their fate, a replacement program to deploy environmentally friendly moorings, and designation of specific mooring areas.

Pile-supported structures (BW = boardwalk, JE = jetty, PF = pontoon floating, PX = pontoon fixed, WW = walkway, VD = viewing deck)

These structures provide access to vessels and fishing platforms or to enable the general public to view key fish habitats up close as part of gaining an awareness of the benefits of such habitats.

The main impacts are those of location relative to intertidal marine plant communities, shading of the substrate and loss of the fauna and flora communities, physical disturbance of habitat through anchoring with chains/wires, and localised scouring/erosion.

Management of these structures relates to the decking that promotes light penetration (40% minimum) to the substrate to ensure communities are maintained and passage is not disrupted; use of materials (e.g. timber with preservatives or metals) that do not leach and pollute the waterways, materials that promote epibiotic growth, treatment of run-off water prior to discharge to ensure higher downstream water quality, and appropriate siting. Within declared FHAs, subject to the management level, these structures are encouraged and supported for public purposes but constraints apply to private structures.

Potential MRAs include determining the legality of the existing structures and their fate, a maintenance program to upgrade decking to meet light penetration targets, raising the height of the structure, and minimisation of scouring/erosion, especially at lower tide levels.

Pipe intake/outlet (PI = pipe intake/outlet, DR = drain intake/outlet)

These structures are fundamental to maintaining run-off from residential, industrial or agricultural lands.

The main impacts are those of inappropriate location of pipe or drain outlet relative to substrate and river bends, discharge of poor water quality and subsequent scouring and erosion, particularly during flood events and from inadequate armouring around the outlets. Deep, narrow drains also impact with higher run-off velocities and often convey acid run-off.

Management of these structures relates to capturing and treating run-off water prior to discharge to ensure higher downstream water quality, appropriate siting and armouring, and replacing deep drains with shallower wider drains. Within declared FHAs, subject to the management level, pipes and drains may be approved.

Potential MRAs include determining the legality of the structures and their fate, a replacement program to upgrade substandard pipes and drains, and armouring appropriate for all outlets.

Barriers

Weir/dam (WD)

Weirs and dams are typically constructed to supply water for industrial and domestic consumption or to provide flood mitigation. While weirs are generally smaller structures built across river channels rather than entire river valleys, both structures form significant physical barriers to fish movement.

The impact that a dam or weir has on fish passage is influenced by the frequency, timing and duration of drown-out. Drown-out occurs when there is sufficient water flow across the structure to drown it out. Fish movement is optimised during drown-out when the water levels above and below the barrier are equal, water velocity is suitable and there is sufficient water depth across the barrier for fish to swim through. Some weirs and dams may drown-out completely and continuously, while others do not drown-out at all, preventing all upstream fish passage and disrupting life cycles.

Recognised as structures for water supply or flood mitigation, management of these structures relates to ensuring that fish passage is adequately provided for at the structure. Due to the major impact that water impoundment structures have on the maintenance of current fish habitat values and functions of the area, the construction of permanent dams and weirs within declared FHAs is not supported.

Potential MRAs include determining the legality of the existing structures and reviewing the current need for their existence. Any obsolete structures should be removed and the adjacent areas rehabilitated. If structures are still in use and are identified as a problem for fish movement the structural design features of the dam or weir should be modified or upgraded to provide for fish passage (e.g. incorporating a fishway).

Levee bank/bund (LB)

By obstructing tidal flows, levee banks/bunds can degrade the health of wetland fish habitats and prevent fish from accessing floodplain and upstream habitats.

Levee banks are recognised as structures designed to protect adjacent lands and developments, often associated with agricultural activities, from tidal inundation. Management of these structures relates to ensuring that fish passage is adequately provided for at the structure.

Potential MRAs include determining the legality of the existing structures and reviewing the current need for their existence. Any obsolete structures should be removed and the adjacent areas rehabilitated. If structures are still in use and are identified as a problem for fish movement, the structural design features of the levee/bank should be modified or upgraded to provide for fish passage (e.g. incorporating floodgates).

Floodgate (FG)

Floodgates remove access to large areas of fish habitat and prevent the movement of native fish upstream, downstream and onto floodplain areas. By preventing the tidal exchange of water, floodgates can decrease water quality above the floodgate, further reducing or eliminating the habitats available to fish. ASS can become an issue if tidal flushing is restricted and soils have the opportunity to dry out and create acidic conditions. In flood events or on the occasion when the tide is able to inundate the area, acid sulfate run-off can create harmful conditions for fish and may result in fish kills.

These impacts are more of an issue when floodgates are passively managed or poorly maintained, as they remain closed for extended periods of time, limiting tidal flushing and fish passage and reducing water quality. Automatic floodgates are designed to allow bi-directional exchange of water while still preventing overtopping of seawater during king tides.

Floodgates are recognised as infrastructure for agricultural activities to protect farming lands and/or developments from flood and saltwater intrusions. Management of these structures relates to ensuring that fish passage is adequately provided for at the structure.

Potential MRAs include determining the legality of the existing structures and reviewing the current need for their existence. Any obsolete structures should be removed and the adjacent areas rehabilitated. In cases where floodgates are necessary, floodgates should be effectively managed to incorporate fish passage considerations. Where possible, floodgates should be modified to be automatic floodgates. This type of floodgate is designed to allow bi-directional water exchange and is only fully closed when the bankfull water level behind the floodgate reaches 80%. This allows fish passage to occur outside of these times.

Stream crossing (SX = stream crossing, includes bridges, culverts, causeways)

Bridges

Bridge crossings that span waterways or include few pylons have relatively minor direct impacts on instream fish habitat values, other than those from pylons, other footings, bank armouring and shading of a section of the waterway. Fish-friendly bridge structures that have no impacts on fish passage are DAFF’s preferred stream crossing type.

Bridge structures may be considered as barriers if incorrect placement of bridge pylons leads to the creation of eddies and increased water velocities around the pylons/footings that remove substrates and delay migrating fish through confused flow signals. This disorientates and prevents fish from moving freely past the structure.

Recognised as crossings for public use, the management of these structures relates to access to allow maintenance, maintenance to ensure the integrity of pylons/footings/armouring and of decking/surface, use of materials (e.g. timber with preservatives) that do not leach and pollute the waterways, and erosion and scouring at pylons/footings and armouring locations.

Other than best management practices during maintenance, no further MRA is proposed. Where crossings are for private use, determination of legality and assessment of impacts are warranted.

Culverts

Culvert crossings typically restrict the channel width, concentrating the stream into a relatively small culvert width and causing increased velocities that pose a hydrological barrier to fish passage. Culverts are usually designed to be hydraulically efficient for the purposes of supporting high flows and removing water quickly in flood conditions. The smooth, symmetrical shape of culverts further increases water velocities, often to speeds that exceed the swimming ability of many fish.

Culvert crossings are often built at a level elevated from the stream bed. This creates a drop (the invert height) on the downstream side of the crossing that presents a physical barrier to fish. If the water depth in the culvert is too low (<0.2 m) and the water velocity over or through the culvert is too high (>0.3 m/s), those fish that do manage to jump into the culvert may be swept back over the edge (Cotterell 1998). Erosion and scouring can form pools on the downstream side of these structures that leads to undercut areas that exacerbate the drop on the downstream side.

The length of the culverts is also important. Where culverts are too long, they form a behavioural barrier to fish. While the reason for this is unclear, some fish hesitate at the entrance to long dark culverts and refuse to travel through.

Causeways

Although causeway crossings are low-level crossings designed to drown-out, the drop that results from the raised crossing can function like a small weir in low flow conditions. These structures often do not incorporate pipes and are a problem particularly during low flows, as the shallow water depth across the structure during these conditions can restrict fish passage. If pipes are present, they are often dark and create high velocities that restrict upstream movement of fish.

Stream crossings are recognised as crossings for public and private use. Bridges and culverts can be commissioned by the state government (e.g. DTMR, Queensland Rail), local governments, statutory authorities (e.g. port authority) and property owners (farmers, developers). Causeways tend to be used on private roads or infrequently used public roads. Within declared FHAs these public structures may be approved to ensure safe crossing of the waterways. Management of these structures relates to ensuring that fish passage is adequately provided for at the structure.

Potential MRAs include undertaking a technical assessment of the impact of structures on fish movement. If structures are identified as a problem for fish movement, the structural design features of the crossing (e.g. culvert design, structure slops, number of pipes, etc.) should be modified or upgraded to incorporate fish-friendly design principles. The first opportunity for this may fall within the maintenance schedule.

It may also be feasible to install a fishway at the crossing site (Contact DAFF for further information on fishways). Where crossings are for private use, determining legality and assessing impacts is warranted. Any obsolete crossing structures with no ancillary uses should be removed, with the substrate restored.

Statutory considerations

There are important statutory considerations when addressing the management of instream structures. Activities that disturb fish habitats, including the development of instream structures, may at least require a development approval under state or Commonwealth legislation.

Within declared FHAs, the development of instream structures requires authorisation under both the *Fisheries Act 1994* and *Planning Act 2009*..'Development' in this case refers to the development of new structures as well as any works to maintain, upgrade, modify or remove existing structures. Other agencies that may be involved in the approval process include EHP and DTMR. Approval is also required from NPRSR if the waterway is within a marine park. Local council also has a role in the approval process, particularly in relation to the removal and relocation or disposal of problem structures. Any works that form part of an MRA may be subject to an offset agreement and Queensland's environmental offsets framework may apply.

For further information on approvals that may be necessary, contact the local council or visit the DSDIP website (www.dsdip.qld.gov.au).

The wetlands planning and legislation toolbox on EHP's WetlandInfo website is designed to help identify relevant legislation, policies and information that applies within a particular basin, NRM region or local government area. WetlandInfo can be accessed via the EHP website (www.wetlandinfo.ehp.qld.gov.au).

Local stakeholder consultation

An inter-agency approach is critical for developing and implementing the RAP and recommended MRAs. It is therefore essential to undertake consultation with NPRSR, local stakeholders (e.g. the regional NRM body, local government, EHP, GBRMPA and the recreational fishing industry). Hosting a workshop provides a good forum for discussing the options for RAPs and finding a way forward. It may be necessary to establish a working group with the specific role of implementing RAPs. Part of this role would include investigating potential funding sources for on-ground works. Once stakeholder support for the RAP has been obtained, it will be easier to implement the recommended MRAs and achieve on-ground outcomes.

Glossary of terms

Acid sulfate soils (ASS)	ASS contain iron sulfides. When exposed to air these sulfides oxidise to produce sulfuric acid, which has negative consequences for animals, plants and humans. ASS are mainly found on coastal lowland areas below 5 m Australian Height Datum (AHD).
AGPS	Averaged position recorded by a global positioning system (GPS) given the time on the point and the accuracy of the GPS unit.
Datum	Reference to the formal GRID system on which the location has been recorded. The GRID system may be local, national or worldwide. The most common datum used in Australia is Geocentric Datum of Australia (GDA) 1994.
Declared Fish Habitat Area (FHA)	Defined in the *Fisheries Act 1994*, section 4, schedule dictionary. See also section 120 and 122 of the Fisheries Act 1994 and part 9, section 94 and schedule 7 of the Fisheries Regulation 2008. Declared FHAs protect fish habitats from alteration and degradation by strictly limiting development within and adjacent to the boundaries of the declared FHA.
Differential GPS (DGPS)	Differential GPS, which is a position recorded by a GPS that has differential correction by reference to ‘FIXED’ locations. The corrected location is received by radio signals emitted from base stations of fixed location.
Digital cadastral database (DCDB) map	A digital cadastral data base of all property boundaries and land parcels in Queensland. The DCDB consists of a spatial component which displays land parcel boundaries and natural features, such as rivers and creeks, and a second component that identifies attributes such as roads, rails etc.
Epibiota	Aquatic organisms living on a substrate. Sometimes referred to as ‘encrusting’ or ‘fouling’ growth.
EST	Position that has been placed by estimating location in reference to current surroundings.
Fish	Defined under the *Fisheries Act 1994*, section 5. Includes finfish, crustaceans, molluscs, echinoderms, sponges and worms.

Fish-friendly structure	A structure that causes minimal disturbance to existing fish habitats and incorporates design features that provide enhanced habitats for fish.
Fish habitat	Defined under the *Fisheries Act 1994*, section 4, schedule dictionary. Includes land, waters and plants associated with the life cycle of fish, and includes land and waters not presently occupied by fisheries resources.
Fisheries productivity	Biomass of fish produced in a given area over a given time.
Fisheries resources	Defined in the *Fisheries Act 1994*, section 4, schedule dictionary. Includes fish and marine plants.
Habitat	The area or environment in which an organism or group of organisms lives, for all or part of its life cycle.
Instream structure	Any artificial structure occurring within a waterway or wetland (these are defined below)
Intertidal	Area of land between the extent of the highest and lowest astronomical tides.
LANDSAT	The longest running program of satellites orbiting the earth recording raster data and multiple frequencies. This data was then used to form 'Landsat imagery'. Landsat 7 data has eight spectral bands with spatial resolutions ranging from 15–60 metres.
Location precision	The uncertainty or error inherent in position due to atmospheric conditions, reflection of signal off buildings, water etc.
MAP	Position that has been placed either from some other source (map/street directory) or visually (site on photo).
Marine plant	Defined under the *Fisheries Act 1994*, section 8: a plant (a 'tidal plant') that usually grows on, or adjacent to, tidal land, whether it is living or dead, standing or fallen the material of a tidal plant, or other plant material on tidal land a plant, or material of a plant, prescribed under a regulation or management plan to be a marine plant. 'Marine plant' does not include a declared plant under the *Rural Lands Protection Act 1985.*

MyDAS	An online system for the preparation and lodgement of development applications to DSDIP, as the single state assessment and referral agency
Polygon	A two-dimensional parcel that encloses a particular area of the earth's surface (as opposed to a 'straight line'—having direction only).
Raster	Refers to digital imagery in pixel data (as opposed to a continuous tone).
Recruitment	The influx of new members into a fish population by reproduction or immigration. Recruitment to a fishery occurs when fish become vulnerable to capture by fishing gear.
Saltmarsh	Intertidal habitats occupied mainly by herbs and dwarf shrubs, characteristically able to tolerate extremes of environmental conditions, notably tidal and seasonal waterlogging and salinity.
Stream crossing	A structure on a waterway that provides access for foot and vehicle traffic across a waterway. Stream crossing structures include bridges, culverts and causeways. A fish-friendly stream crossing is designed to minimise impacts on fish passage.
Substrate	The surface on or in which an organism lives, including the sea bed or bed of a waterway.
Tidal land	Defined in the *Fisheries Act 1994*, section 4, schedule dictionary. Includes reefs, shoals and other land permanently or periodically submerged by waters subject to tidal influence.
Waterway	Defined under the *Fisheries Act 1994*, section 4. Includes a river, creek, stream, watercourse or inlet of the sea.
Wetland*	An area of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres. To be classified as a wetland, the area must have one or more of the following attributes: at least periodically, the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers

	the substratum is not soil and is saturated with water, or covered by water at some time. *This definition (Wetland Mapping and Classification Methodology of the Queensland Wetlands Program, Department of Environment and Resource Management, 2005) differs from the Ramsar wetlands definition, as the latter includes waters >6 metres below the lowest astronomical tide.

Acronyms

ASS	Acid sulfate soil
DAFF	Department of Agriculture, Forestry and Fisheries (previously part of the Department of Employment, Economic Development and Innovation; and Department of Primary Industries & Fisheries)
DCDB	Digital cadastral database
EHP	Department of Environment and Heritage Protection (previously part of the Department of Environment and Resource Management and Department of Natural Resources and Water)
DoE	Department of the Environment (Commonwealth)
DTMR	Department of Transport and Main Roads
FHA	Fish Habitat Area
GBRMPA	Great Barrier Reef Marine Park Authority
GIS	Geographic Information System
ISI	Instream structure inventory
MRA	Management response action
MSQ	Maritime Safety Queensland
NPRSR	Department of National Parks, Recreation, Sport and Racing
NRM	Natural resource management
PDA	Personal digital assistant
QWP	Queensland Wetlands Program
RAP	Response Action Plan
The Act	Queensland Fisheries Act 1994
VQ	Version Queensland

WIC	Wetland Information Capture project

Further information

Groups wishing to undertake an ISI should contact NPRSR's Marine Resource Management Unit on 13QGOV (13 74 68) for further information (e.g. obtaining and using software, current extent of inventory work in Queensland, obtaining spatial layers etc.).

Copies of the project reports: Targeted collection of inventory data for wetlands fish barriers in the Great Barrier Reef catchment—final report, Inventory of instream structures impacting on Ramsar wetlands – final report, are available on the NPRSR website at www.nprsr.qld.gov.au.

For further information on the declared FHA program, FHA plans, declared FHA information and management, refer to the NPRSR internet site: www.nprsr.qld.gov.au or contact NPRSR on 13QGOV (13 74 68)

For further information on the Queensland Wetlands Program, refer to the Australian Government website (www. www.environment.gov.au) or the EHP website (www. wetlandinfo.ehp.qld.gov.au).

For further information on GIS visit www.gis.com

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Appendices

Appendix A: Planning the logistics of fieldwork

The logistical issues associated with undertaking inventory fieldwork are important considerations in the project's planning stages and a lack of planning in this area can lead to a waste of valuable time and resources. This list includes some key considerations in planning the logistics of inventory fieldwork to assist groups in undertaking the appropriate planning before commencing inventory fieldwork. The key considerations, categorised into three broad areas of support, access and safety are listed below:

Support

Enlist staff/helpers to help with inventory fieldwork, especially in remote areas. For safety reasons (and to facilitate a manageable workload), conduct fieldwork in teams of two staff. At least one staff person should remain constant throughout the entire inventory fieldwork, in order to ensure consistency in assessing structures and impacts. Ideally some knowledge of fish habitats is required, and familiarity with GIS mapping and PDA use is advantageous.

Organise transport mode. A range of transport modes, including boat, car or helicopter/aeroplane, can be used to locate and assess structures. Different transport modes to access structures are likely to be more or less appropriate depending on the structure location and the available funding. While there are many benefits to undertaking an aerial survey of the project area (see below), it is not recommended that an entire inventory be undertaken in this way. Besides being very costly compared with other methods of collecting data, information pertaining to specific structures is best collected while observing the structure and surrounding habitats in close proximity and without the time constraints that exist when undertaking an aerial inspection. A combination of vehicles or vessels may be most appropriate. When deciding on the most appropriate method of transport, consideration of the following logistical issues will also be useful.

Access

Undertake aerial reconnaissance. This is of great benefit if funding permits. The advantages of undertaking an aerial survey include: it is easier to obtain an overall perspective of the project area; it assists with on-ground navigation and identifying access; it is an extra way of ensuring that structures are not missed; it saves time due to the ability to cover a large area in a relatively short time. If possible, conduct an aerial reconnaissance at low tide to allow the greatest visibility of structures.

Determine land tenure. Consult mapping to determine the tenure of land at the location of known or potential structures. Tenure should also be determined for any surrounding areas that need to be entered to obtain access to a structure. Ideally, structures adjacent to private property should be viewed from the water or from the air so as not to cause any unnecessary disturbance to landholders. Otherwise freehold landowners will need to be consulted in order to get property access if the area is being accessed by vehicle or on foot. On-ground NRM contacts will be useful here, as they may have had previous contact and established a good rapport with particular landholders.

Investigate tides. Investigate local tide tables before scheduling fieldwork, in particular before scheduling the boat-based component. Visibility of structures is increased at low tide, so those structures that are low on the bank or submerged are best observed around low tide. However, working at high tide is advantageous when conducting fieldwork in upstream areas that may prove difficult to access at low tide.

In addition to knowing the times of low and high tide, it is of key importance to calculate the access 'time', being the period of time before and after high or low tide that can be utilised to undertake fieldwork. This is particularly important when accessing upstream areas, as not only will a high tide be required while assessing structures in upstream areas but it will also be partly necessary for the return trip to the boat ramp/retrieval area. When planning a boat trip it is therefore necessary to include the total time it takes to launch and retrieve the boat, travel to and from structures and assess structures when calculating access time.

It is also essential to consider tide heights as well as tide times, given that in terms of visibility or access issues, a high low tide may prove to be similar to a low high tide. It should be noted that conducting fieldwork at high tide is advantageous for accessing upstream areas difficult to access at low tide, but more structures are visible at low tide. It is therefore a great idea to revisit areas at low tide whenever possible.

Safety

Personal safety. When conducting fieldwork personal safety should be considered in the first instance at all times. Personal safety issues in and around the project area should be investigated prior to any fieldwork being undertaken. These issues may be local and will vary with different project areas. For example, in North Queensland some safety issues to consider before and during fieldwork include the presence of crocodiles and stingers. Appropriate precautions to ensure personal safety should be taken when conducting fieldwork, including working in pairs, notification of whereabouts with an identified contact person, wearing the appropriate fieldwork clothing, following boat safety rules.

Create a timetable for the fieldwork period. Although creating a timetable is an extremely important part of organising inventory fieldwork, it is important to remain flexible since certain aspects of the timetable may need to be altered in response to a change in weather conditions, access issues, unexpected fieldwork delays etc. Support and access issues will need to be included in timetable considerations.

Ensure field equipment is appropriate, organised and ready for use. Be sure to add any other site-specific items you may need. Any vehicles or boats should be refuelled and all electrical equipment should be charged. Boats should be stocked with appropriate safety equipment (e.g. life jackets, emergency position-indicating radio beacons—EPIRBs). Computer access is necessary for the storage of digital photos and to backup inventory data at the end of each day.

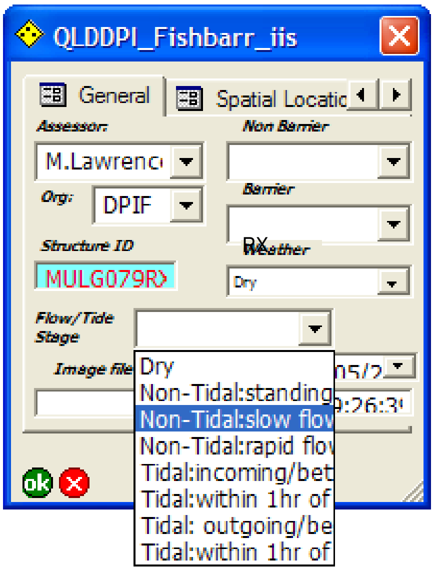
Fieldwork equipment may include:

- A4 copy map key and individual map sheets
- PDA
- digital camera
- measuring tape (to a minimum 50 m)
- field clothing (hat, long-sleeve shirts and trousers, work boots, dive booties/wellington boots)
- fluro safety vests to assist visibility when working near traffic
- first aid kit
- vehicle/boat
- mobile phone
- sunscreen, insect repellent
- EPIRB
- water/snack bars.

Appendix B: Data attributes included in the FishBarriers VQ menu system

This appendix may be printed out in hard copy format for use in the field. Please note that the menu system is continually being reviewed and updated. NPRSR should be contacted for further information about the menu system.

General page



Assessor given name/surname: The given name and surname of the person recording data in the field.

Start time: The start time of data collection at a site; this should be set to automatically record when a GPS point is recorded.

Date: Date of data collection; this should be set to automatically record when a GPS point is recorded.

Organisation: The ordinary name of the organisation with which contact should be made to obtain more detailed information about the project. If a private individual collects data they should enter their organisation as ‘individual’.

Present weather: Indicate the current weather conditions, particularly in relation to precipitation. Select from: 1. dry. 2. smog/smoke. 3. fog/mist. 4. frost. 5. intermittent rain/drizzle. 6. intermittent hail. 7. intermittent snow. 8. continuous rain/drizzle. 9. continuous hail. 10. continuous snow. 11. thunderstorm.

Flow/tide stage: A broad categorisation of hydrology at the site. For sites in tidally influenced wetlands (potentially all wetland types), this describes the current state of the tide. For sites in non-tidally influenced wetlands (potentially all wetland types other than estuarine and marine) this describes the degree of flow. Select from 1. Dry. 2. Non-tidal: standing water. 3. Non-tidal: slow flow. 4. Non-tidal: rapid flow. 5. Tidal: incoming/between tide. 6. Tidal: within one hour of high tide. 7. Tidal: outgoing/between tide. 8. Tidal: within one hour of low tide.

Non-barrier type: Select appropriate non-barrier type from scroll down menu: BR = boat ramp, BW = boardwalk, CA

= canal, DM = dumped material, DR = drain intake/outlet, DV = derelict vessel, GR = groyne, JE = jetty, MO = mooring, ON = other non-barrier, PI = pipe intake/outlet, PF = pontoon floating, PX = pontoon fixed, RE = revetment, SW = slipway, VD = viewing deck, WH = wharf, WW = walkway.

Barrier type: Select appropriate non-barrier type from the scroll down menu: FL = floodgate, LB = levee bank/bund, NA = natural, OB = other barrier, SX = stream crossing, WD = weir/dam.

Structure ID: This is a unique identification number assigned to each individual structure (e.g. HERB001SX (Herbert River catchment = HERB; structure ID number that increases incrementally = 001; structure type = stream crossing SX).

Project ID: The ordinary name of the project in full (e.g. targeted collection of inventory data for wetlands fish barriers in the Great Barrier Reef catchment. A maximum of 200 characters is allowed).

Image file numbers: Photos should be taken of the following, using a digital camera: 1. structure front-on (either from river or land). 2. upstream habitat. 3. downstream habitat. At least one photo should be taken of the structure using a PDA, so that the structure can be linked to its corresponding GPS location.

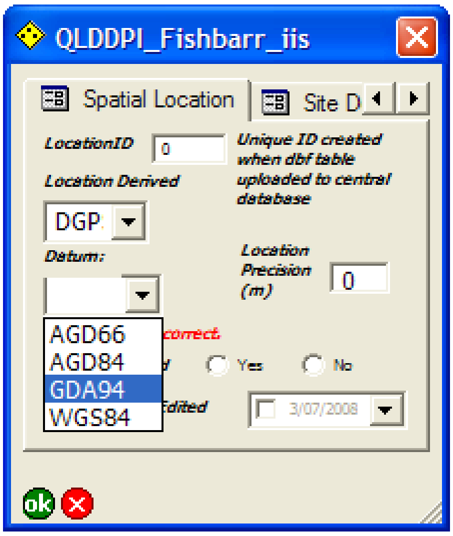
Spatial location page

Location ID: Identification code based on the GPS coordinates of the structure. An attempt should be made to record the location ID at the mid-point of the structure.

Location derived: Select from AGPS, DGPS, EST, MAP.

Datum: The datum (or geographic referencing system) in which the original data was recorded. GDA94 is the preferred datum for project data and all efforts should be made to convert to GDA. In the case where this is not possible, other datum may be used. Select from: 1. (AGD66) Australian Geodetic Datum 1996. 2. (AGD84) Australian Geodetic Datum 1984. 3. (GDA94) Geocentric Datum of Australia 1994. 4. (WGS84) World Geodetic System 1984 (used in Google Earth™).

Location precision (m): The precision of location coordinates in metres.

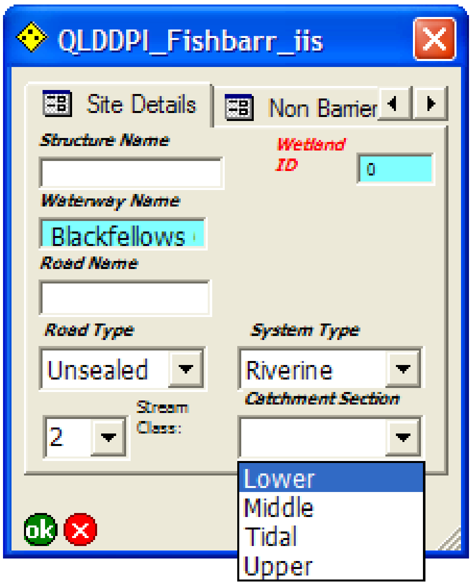


If position is incorrect: The accuracy of the GPS position that has been recorded for a structure. Should a recorded position be found to be incorrect, the GPS point can be edited to reflect the accurate position of the structure.

Feature moved: This refers to whether the GPS location has been edited in order to reflect a more accurate position.

Date position edited: The date on which the GPS point was edited.

Site details page



Wetlands ID: Refer to wetlands layer.

Structure name: Enter the common name(s) for the structure if known, (e.g. College's Crossing).

Waterway name: Enter the name of the waterway if known.

Road name: Enter the name of the road that crosses the watercourse, or the road that is closest in proximity to the structure being assessed. Consult nearby street signs, Queensland state topographic maps, the ArcPad road layer, local/state street directories, council asset registries, or the web. Please note that the name of the road on site may vary from the name appearing on topographic maps or within the roads layer on ArcPad. If the road is an unnamed private driveway, enter 'private road'; if no name or ownership (private versus public) can be discerned, enter 'unnamed road'.

Road type: Sealed or unsealed.

The Wetland Mapping and Classification Methodology of the Queensland Wetlands Program definition of wetlands: Wetlands are areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6 metres. To be classified as a wetland, the area must have one or more of the following attributes:

- at least periodically, the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle
- the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers
- the substratum is not soil and is saturated with water, or covered by water at some time.

(Department of Environment and Heritage Protection, 2014)

This definition differs from the definition of Ramsar wetlands, as the Ramsar definition includes waters greater than 6 metres below the lowest astronomical tide.

System type

Estuarine – wetlands with oceanic water sometimes diluted with freshwater run-off from the land

Lacustrine – large, open, water-dominated systems (e.g. lakes) larger than 8 hectares. This definition also applies to modified systems (e.g. dams), which possess characteristics similar to lacustrine systems (e.g. deep, standing or slow-moving waters)

Marine – the area of ocean from the coastline or estuary, extending to the jurisdictional limits of Queensland waters (three nautical mile limit)

Palustrine – primarily vegetated non-channel environments of less than 8 hectares. They include billabongs, swamps, bogs, springs, soaks, etc. and have more than 30% emergent vegetation

Riverine – all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created; they periodically or continuously contain moving water, or form a connecting link between two bodies.

Habitat class

1. inshore coastal waters or tidal inlet or main stream or river or large lowland lagoon
2. major tributary of main stream or river or major creek direct to sea or small lowland lagoon
3. minor tributary of main stream or river, or large lower-order tributary or minor creek direct to sea
4. minor, low-order tributary.

Non-barrier page

Non-barrier type: Select appropriate non-barrier type from scroll down menu: BR = boat ramp, BW = boardwalk, CA = canal, DM = dumped material, DR = drain intake/outlet, DV = derelict vessel, GR = groyne, HO = house, JE = jetty, MO = mooring, ON = other non-barrier, PI = pipe intake/outlet, PF = pontoon floating, PX = pontoon fixed, RE = revetment, SW = slipway, VD = viewing deck, WH = wharf, WW = walkway.

Construction material: Concrete, cemented rock, debris (artificial), debris (natural), gravel, log, metal/steel, other, polystyrene, rock, rubble, timber.

Length (m): Measure the length of the structure (metres).

Breadth (m): Measure the breadth of the structure (metres).

Height (m): Measure the structural height (metres). For those structures that are supported by pylons, the height of the structure is the measurement from the seabed to decking of the structure. The height of the pylons should also be noted in the ‘pylons’ attribute below.

Comments: Note if there are any ancillary uses of the structure, or note details of any associated structures. If the structure is a pontoon and there is a walkway attached, although a separate GPS point and attribute details will be recorded for the walkway, it should be noted when recording information about the pontoon that there is a walkway attached (and vice versa). For instance, the comments pertaining to the pontoon structure would include, for example, 10 × 2 metal/steel WW (pontoon associated with a 10 m long x 2 m wide metal/steel walkway). Comments included when recording information relating to the GPS point of the walkway might include: 8 × 5 poly PF (walkway associated with an 8 m long x 5 m wide polystyrene floating pontoon). Although the relative location of these structures can be deduced from the spatial layer of structures, it is important to include such comments so that it is clear that the two structures are linked. Details (number, size, construction material) should also be recorded here of any instream pylons that are supporting the structure (e.g. 2 × 0.5 diameter concrete).

Barrier type page

Barrier type: Select appropriate non-barrier type from the scroll down menu: BC = bed control, FL = floodgate, GS = gauging station, LB = levee bank/bund, NA = natural, OB = other barrier, RX = road crossing, WD = weir/dam.

Road crossing: Box culvert, bridge, causeway, ford, pipe culvert.

Weir/dam: Adjustable release, fixed crest.

Floodgate: Auto tidal, hinged flap, other, sluice, winch.

Construction material: Clay, concrete, gabion, gravel, other, timber, rock, sand/fines, sheet piling, steel.

Barrier details page

Length (m): Measure the length of the structure (metres) from bank to bank for full bank flows.

Breadth (m): Measure the breadth of the structure (metres) in the upstream to downstream direction.

Height (m): Measure the structural height (metres) from the downstream toe of the structure to its apex.

Invert height (m): Measure the invert height (metres) from the downstream toe of the structure to the lowest point that flows over/through the structure.

Number pipes/cells: Record the number of pipes or cells beneath the deck of the structure.

Pipe/cell width (m): Record the cross-sectional width (metres) of a cell beneath the deck of the structure or pipe diameter. If variable cell widths or pipe diameters are evident, attempt to record the average width. The range of individual cell or pipe widths can be recorded in the ‘comments’ field.

Cell height (m): Record the cross-sectional height (metres) of a cell beneath the deck of the structure. If variable cell heights are evident, attempt to record the average height.

Cell shape: Identify the cell shape from the following options: arched, box, circular, or other.

Pipe diameter (m): Record the cross-sectional diameter (metres) of a pipe. If variable pipe diameters are evident, attempt to record the average pipe diameter.

Water pools upstream: Indicate whether water pools upstream of the structure.

Comments: If an average has been recorded for any of the structural dimensions such as cell width, cell height, pipe diameter, etc., the range of any average dimensions recorded should be noted here. For example, if the structure has three cells with heights of 1 m, 0.5 m and 2 m respectively, an average cell height of approximately 1.2 m would be recorded above. The comments field should then read: ‘cell height range 0.5 m – 2 m’. Any additional barrier details not already recorded may be included here.

Fish passage page

Fishway type: Record if there is a fishway associated with the structure. Select from: bypass, denil, fishlock, full-width rock ramp (RR), other, partial width rock ramp (RR), submerged orifice, vertical slot, fishlift.

Fishway working: Indicate if the fishway is working—yes, no, unknown.

Head loss (mm): If excessive headloss occurs across the barrier measure the vertical drop in water height (millimetres) occurring from the upstream to downstream side of the barrier.

Slope: Estimate the slope of the barrier as being 1:20–1:10 or >1:10.

Debris: If woody or sediment debris has accumulated at the top of the structure identify whether the accumulated debris acts as a partial or complete barrier to migrating fish.

Velocity: Indicate if excessive water velocities are evident at the structure.

Blockage: Indicate if there is a blockage to water flows through/across the structure.

Flow depth: Select this box if flow depth exceeds 100 mm.

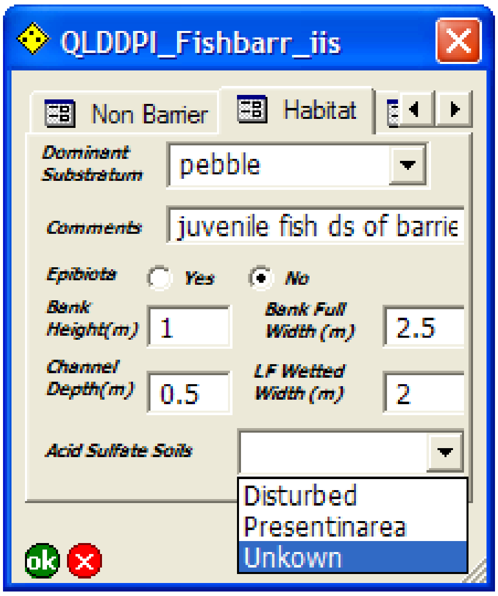
Comment: Record any other information about fish passage at the site.

Habitat page

Dominant substratum: Indicate the dominant substratum at a site. Select from fines (<0.06 mm), sand (0.06–2 mm), gravel (2–16 mm), pebble (16–64 mm), cobble (64–256 mm), boulder (>256 mm), bedrock/reef, unknown.

Acid sulfate soils: Disturbed, present in area, unknown. To deduce the status of acid sulfate soils at the site of the structure, CSIRO mapping and the Australian Soil and Resource Information System (ASRIS) should be consulted, in addition to any other relevant studies.

Bank height (m): Estimate the bank full height (m) as determined from the channel bed just downstream of the structure to average bank apex.



Bank full width (m): Estimate the bankfull width (m) of the waterway just downstream of the structure.

Epibiota: Note if any epibiota is observed on the structure surface (e.g. barnacles).

Habitat condition: Select from 1 (pristine), 2 (low disturbance), 3 (moderate disturbance), 4 (high disturbance) or 5 (very high disturbance).

Comments: For example, dense mangrove forest, heavy weed infestation, productive yabby bank, mangrove seedlings present, mullet observed.

Vegetation page

Dominant vegetation genus: Indicate the dominant vegetation family/group/genus visible at the site and in the vicinity of the structure. Select from: blue bush, bulrush/cumbungi, cane grass, casuarina, common reed (Phragmites), eucalypt, ferbland, ferns, grass, heath, lignum, mangrove, other, paperbarks, rainforest, saltbush, saltcouch, samphire, sedge, spikerush (Eleocharis), water lilies, wattle, wild rice.

Dominant vegetation: Indicate the dominant vegetation growth form visible at the site and in the vicinity of the structure. Select from: emergent, floating, grasses/herbs, not vegetated, shrubs, submerged, trees.

Weeds: Cabomba, hymenachne, lantana, parthenium, rubber vine, water hyacinth, water lettuce.

Land use: Identify the predominant land use upstream of the structure (e.g. agriculture/livestock, urban/residential, industrial, recreation/tourism, state forest, national park).

Modifyer type: 1) dam/weir (on river); 2) levee bank/bund (separating freshwater from salt water); 3) dam/levee (not on river); 4) canal/irrigation channel. These structures cause hydrological modifications to wetlands. Indicate if any are present at the site. This information is important in classifying wetland systems.

Threats page

Threats: Indicate any impacts (by ticking the appropriate box) on wetland ecosystems and processes that are associated with the structure—erosion, dredging, dumped material, filling, footprint only, maintenance, accretion downstream, accretion upstream, siltation, slumping, scouring, dead native flora, altered inundation extent, inhibiting marine plant growth.

Footprint: <10 m^2, 11–50 m^2, >51-100 m^2, 101-250 m^2, >250 m^2 (provide estimate). This relates to non-barrier structures. Estimate the area of the footprint of the structure.

Disturbance area (outside footprint): <10 m^2, 11–50 m^2, >51–100 m^2, 101–250 m^2, >250 m^2 (provide estimate). This relates to non-barrier structures. Estimate the area outside the footprint of the structure that is observed to be directly impacted by the structure.

Noxious fish of Queensland: Note if any noxious fish species are observed at the site of the structure (e.g. carp, chinese weatherloach, gambusia/mosquitofish, tilapia).

Comments: Any notes required to clarify or describe the observed threat mechanisms (e.g. four dead freshwater catfish observed).

Location page

Desktop assessor: The given name and surname of the person entering or editing data via desktop methods.

NRM: Murray–Darling, Burnett Mary, North Queensland Dry Tropics.

Catchment: Record the overarching catchment that the structure is located within rather than the subcatchment.

LGA: Record the local government area that the structure is located within.

Nearest town: Record the town in closest proximity to the structure being assessed.

Topographic map: Record the name of the 1:25 000 or 1:50 000 Queensland topographic map on which the structure is located.

Fish Habitat Area: Select the name of the appropriate declared FHA.

Ownership page

Structure ownership: Determine whether structure ownership is private, local government, government agency or commercial. If the ownership of the structure has been investigated extensively, yet no owner has been identified, label as ‘unknown’.

Owner name: Record the full name(s) of the structural owner(s). If the ownership of the structure has been investigated extensively, yet no owner has been identified, label as ‘unknown’. Entering of personal details should be conducted only with the consent of the structural owner, with full knowledge that their details will be recorded onto a database.

Contact details: Record all known contact details for the structural owner(s) including telephone, fax, email, residential address and mailing address.

Licence/code ID: If the structure is licensed or has a departmental or LGA code, record the relevant reference ID.