Attachment 1 to
Item 10.3.2.

Hawkesbury Floodplain Drainage Review

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Time: 6:30pm

MOLINO STEWART

ENVIRONMENT & NATURAL HAZARDS

a WATER TECHNOLOGY company

Hawkesbury City Council

Hawkesbury Floodplain Drainage

Review

Draft

Hawkesbury Floodplain Drainage

Review

Final

Client: Hawkesbury City Council

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Executive Summary

Molino Stewart was engaged by Hawkesbury City Council to undertake a review of the drainage network across the Hawkesbury River floodplains, within the Hawkesbury Local Government Area boundary. The study area stretches from Yarramundi bridge in the west down to Pitt Town in the east.

The purpose of the study was to identify locations where drainage was inhibited and provide recommendations on site specific solutions for each drainage channel. Additionally, the environmental constraints for the proposed works as well as responsibilities and approval pathways were investigated.

The area was divided into investigation areas and drainage channels were identified using a Digital Elevation Model and satellite imagery. Each of these drainage channels were surveyed separately.

A desktop assessment of the existing environment throughout the project extent was undertaken using existing online mapping and databases. The environmental constraints for each drainage channel were identified, including land contamination, acid sulphate soil potential, Aboriginal and non-Aboriginal heritage, waterway classifications, wetlands, flood and bushfire risk, threatened species records, mapped vegetation communities, biodiversity values, and key fish habitat.

Approximately 70 km of the drainage channels were inspected on foot over several days in May, June and July 2022. Observations were made of where drainage was currently inhibited or may have been inhibited on the recession of the flood March 2022 and July 2022 floods. Attention was also paid to the presence of environmental constraints along the drainage channels.

The information gathered for each drainage channel was collated in this report, providing a brief summary of the field observations with photos, probable cause of drainage inhibition, possible solutions for drainage improvement, and a constraints analysis with constraints mapping for each drainage channel.

The broader conclusion is that the condition of the drainage channels has deteriorated over time, resulting in poor drainage and giving rise to further damage to the area in flood events. The deterioration is partly due to failure by landowners or Council to maintain flood mitigation and drainage infrastructure, and partly due to farm works or practices which have changed the topography of the area. Many of these actions or inactions have taken decades to incrementally create the current situation. The absence of major flooding between August 1990 and March 2020 has meant that the consequences of these changes have not been detected until the series of four floods from March 2020 to July 2022 has repeatedly revealed their impacts.

A total of 23 solutions for drainage improvement were identified across the study area (Table 11, Figure 157). Some of the recommended solutions include works in multiple locations or along a section of the drainage channel (e.g. bank stabilisation). Some sections of the drainage channels were still flooded during the inspections and further investigations would be required to identify solutions for these areas after other drainage solutions have been implemented.

Some issues, such as blocked pipes, would be relatively easy to fix, while others, such as slumped banks or paddock erosion, require significantly more work. It is possible that some of the changes to the landscape cannot practically be reversed or mitigated and so the impacts that have been sustained following the recent floods will continue after every flood. However, even in these areas changes in agricultural practices may be possible to ensure drainage problems don't get worse in the future.

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1 | Introduction

1.1 Background

The Hawkesbury Floodplain, within the Hawkesbury Local Government Area (LGA), includes large areas of agricultural land on the floodplains between Agnes Banks and Wilberforce. For many decades these were dominated by orchards and market gardens but now turf farming is the predominant agricultural activity interspersed with horse studs, cattle grazing and some remaining market gardens and orchards. These floodplains drain into the Hawkesbury River via a combination of natural creek lines and constructed drainage schemes. The hydraulics of these drainage networks have been heavily impacted by the construction of a range of drains, levees and floodgates and indirectly by agricultural activities.

Previous investigations, conducted by Molino Stewart, at Pitt Town Lagoon and Bushells Lagoon suggest that the hydraulics of the drainage networks on the Hawkesbury Floodplain is not well understood and there is little documentation on how constructed systems were meant to operate. There is also evidence that their hydraulic performance may have changed over time due to lack of maintenance, deliberate changes to infrastructure and inadvertent blockage of flows.

Molino Stewart has previously been engaged by Hawkesbury City Council (Council) to investigate the drainage system between Bushells Lagoon and the Hawkesbury River. The intention of the investigation was to identify what work could be undertaken to improve performance of the drainage system and what environmental approvals would be required for such works. This facilitated works which reportedly improved drainage during the February/March 2022 flooding in the Hawkesbury.

Council re-engaged Molino Stewart following the 2022 floods to investigate the drainage networks for the remainder of the Hawkesbury Floodplain, within the Hawkesbury LGA, and provide advice to facilitate the improvement of their performance. The extent of area covered by this report is shown in Figure 1 along with mapped hydrographical features and elevation data. It was generally defined as the areas below 15m AHD with constructed drainage infrastructure but excluded those parts of the Pitt Town Lagoon and Bushells Lagoon networks which had already been investigated.

A draft interim report was prepared in July 2022 to address the issues in what was perceived to be the worst affected area between Ridges Lane and Edwards Road in the Richmond Lowlands. This report covers the whole of the study area and incorporates the findings of the draft interim report.

The focus of the report is on locations where there was clearly impacts caused by drainage being inhibited long after the flood peak had dropped. Many environmental problems along the drainage lines were observed, some of which had been exacerbated by the flood. This included weed infestations, bank slumping, erosion and sedimentation, and large and small items of litter and flood debris. While the location and extent of these are reported, unless they were observed to be having an impact on drainage, no recommendations have been made on dealing with them.

1.2 Report Structure

Chapter 2 of this report sets out the methodologies used for desktop and field investigations. Chapter provides an overview of the environmental constraints which are known in the floodplain and the relevant legislation which applies to their management.

For the purposes of the investigation, the floodplain was divided into investigation areas. Chapters 4 to 15 address drainage issues in each investigation area. Each chapter provides a description of the of the drains and creeks based on field observations and supported by photographs, noting any observed drainage problems and condition generally. This is followed by a description of the possible causes of the observed drainage issues and the presentation of possible options for improving drainage. The remainder of each chapter discusses the environmental constraints in the investigation area with a particular focus on those which apply to the areas where drainage remediation measures are recommended.

Chapter 16 provides an overview of planning approval pathways for the various suggested mitigation options.

Chapter 17 presents conclusions and recommendations.

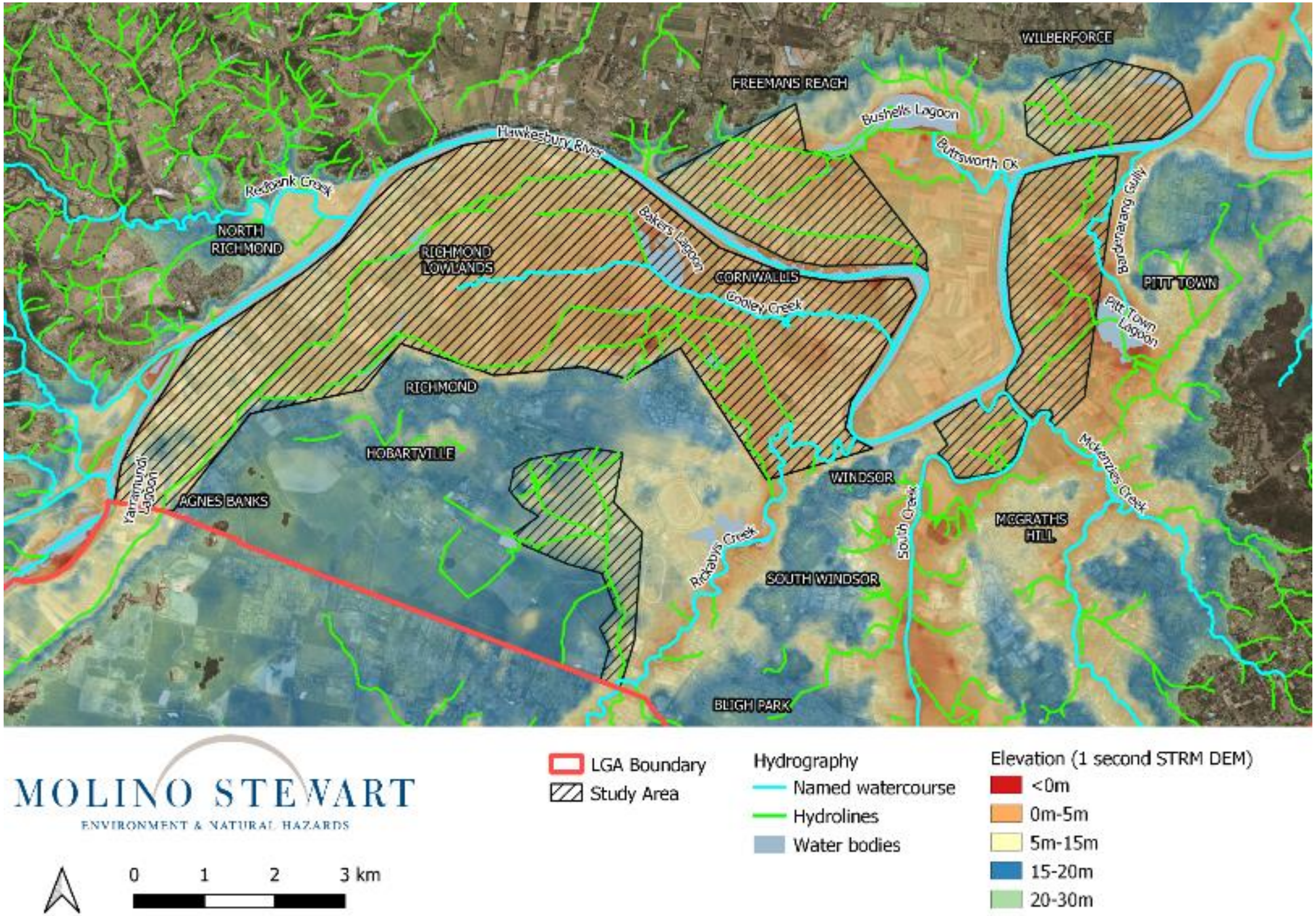

Figure 1: Extent of study area along with topography and hydrological features of the Hawkesbury Floodplain

2 | Methodology

2.1 Desktop Investigations

The extent of the Hawkesbury Floodplain was determined and mapped using a Shuttle Radar Topography Mission (SRTM) derived 1-second Digital Elevation Model (DEM) (Gallant et al., 2011). The hydrological features of the floodplain, including the drainage network, were mapped using the NSW Hydrography dataset (Spatial Services, 2018a) and satellite imagery (Spatial Services, 2018b). This mapping guided on-foot field inspections which examined the entirety of the drainage networks across the floodplain below an elevation of 15m Australian Height Datum (AHD). This level was chosen because no floods since 1867 have exceeded this level.

The total extent of area investigated was divided into 6 Investigation Areas (IAs) (Figure 2), each containing a discrete drainage network. Some of the areas surrounding Bushells Lagoon and Pitt Town Lagoon were excluded as they had previously been investigated by Molino Stewart. During the field inspections any potential issues affecting the flow of water into and through the drainage channels were identified and assessed.

IA1, which was by far the largest investigation area was further broken up into the northern drainage route, the southern drainage route and the Cooleys Creek (central) drainage route. The northern drainage route and the southern drainage route were further broken down into eastern, central and western sections as appropriate. Similar divisions of drainage routes were made in some of the other investigation areas. The naming conventions used throughout this report are:

- IA1NW – Investigation Area 1, northern drainage route, western extent
- IA1NE – Investigation Area 1, northern drainage route, eastern extent
- IA1SW – Investigation Area 1, southern drainage route, western extent
- IA1SC – Investigation Area 1, southern drainage route, central extent
- IA1SE – Investigation Area 1, southern drainage route, eastern extent
- IA1CW – Investigation Area 1, central drainage route, western extent
- IA1CE – Investigation Area 1, central drainage route, eastern extent
- IA2 – Investigation Area 2 drainage route
- IA3N – Investigation Area 3, northern drainage route
- IA3S – Investigation Area 3, southern drainage route
- IA4 – Investigation Area 4 drainage route
- IA5N – Investigation Area 5, northern drainage route
- IA5S – Investigation Area 5, southern drainage route
- IA6 – Investigation Area 6 drainage route

Design drawings and documentation for Council owned drainage infrastructure was requested from Council but it was not able to produce any.

Prior to entering the field, a desktop assessment of the existing environment throughout the project extent was undertaken using State Government and Hawkesbury City Council maps and databases.

The findings of the desktop assessment are presented in Chapter 3. It reviewed various environmental constraints which will need to be considered when planning any construction works for the improvement of the drainage networks. This includes land contamination, acid sulphate soil potential, Aboriginal and non-Aboriginal heritage, waterway classifications, flood and bushfire risk, threatened species records, mapped vegetation communities, biodiversity values, and key fish habitat. Information pertaining to these environmental constraints was sourced from the following publicly available data resources:

- The Department of Planning and Environment's (DPE) Environmental Planning Instrument (EPI) – Land Zoning (DPE, 2022b)
- The Environment Protection Authority's (EPA) contaminated lands record of notices for the Hawkesbury LGA (EPA, 2022b) and listed notified sites (EPA, 2022a)
- DPE's EPI – Acid Sulphate Soils (DPE, 2022a)
- DPE's EPI – Heritage (DPE, 2018b)
- Aboriginal Heritage Information Management System (AHIMS)
- DPE's EPI – Wetlands (DPE, 2014)
- DPE's Remnant Vegetation of the Western Cumberland Subregion (DPE, 2018c)
- Hawkesbury City Council's LEP Terrestrial Biodiversity spatial data (contained in the shapefiles 'conservation_significance' and 'connectivity_significant_veg')
- DPE's Biodiversity Values Map (DPE, 2018a)
- NSW BioNet Species Sightings Data Collection (DPE, 2010)
- Department of Primary Industries' (DPI) Key Fish Habitat - Hawkesbury-Nepean (DPI, 2020)

2.2 Fieldwork

Field inspections were conducted over several days between 26 May and 14 June 2022 by Steven Molino and Brendan Ford and approximately 70 km of drainage channels and creeks were inspected. This was at least 11 weeks after the March 2022 flood which peaked at 13.7 m at Windsor on 9th March. However, the area had been subject to wet weather intermittently for months following the March floods and then further heavy rain and flooding in July 2022.

Site inspections involved walking the drainage lines within the project area to collect all direct and indirect observations required to assess where drainage was currently inhibited or may have been inhibited on the recession of the flood. This required walking more than 120km. It also included observing environmental conditions to the extent necessary to determine whether mapped environmental constraints were accurate and to what extent environmental conditions may have a bearing on improvement options and approval pathways. Particular attention was paid to recording of vegetation types and condition and, where appropriate, searches were made for threatened species.

They spoke to landowners and managers along the way as well as those who rang the Molino Stewart offices, to collect their observations of the water behaviour as the flood rose and receded. Where road access was available, key locations were again inspected by Steven Molino on 12 July, nine days after the peak of the July 2022 flood.

2.3 Qualifications

Steven Molino is a civil and environmental engineer with more than 35 years' experience and was responsible for the identification and assessment of the drainage network's hydrological features, including any potential issues. Steven has worked on a wide variety of floodplain management projects, including in the Hawkesbury, where he has been working since 1991. This includes leading investigations into the drainage networks in the Bushells Lagoon and Pitt Town Lagoon catchments. Steven also has significant experience in environmental impact assessment and management of major public infrastructure projects, particularly in water cycle management including drainage schemes, dams, weirs, pipelines and treatment plants.

Brendan Ford is an experienced ecologist and was responsible for identifying any ecological and environmental constraints which may affect the approval process for drainage channel repair and maintenance works.

Dean Judd is a civil engineer and fluvial geomorphologist with over 30 years of experience across the public and private sectors managing and undertaking consultancy projects. As a specialist Dean is experienced in the investigation of hydraulic and geomorphic processes and their impact on river systems and the environment. Dean provided advice on options for rectifying blockages caused by geomorphic processes and peer reviewed parts of the report.

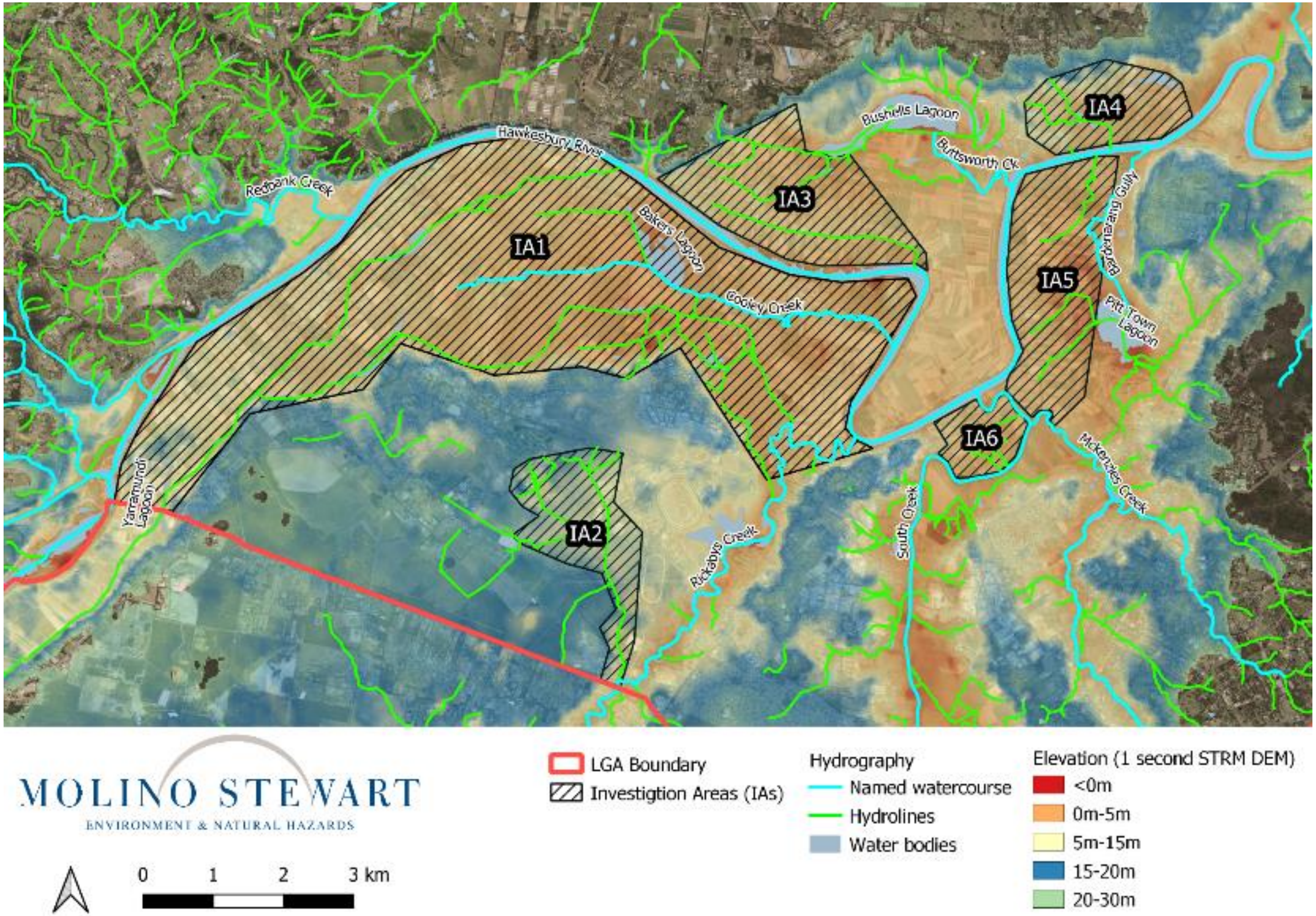

Figure 2: Investigation areas (IAs)

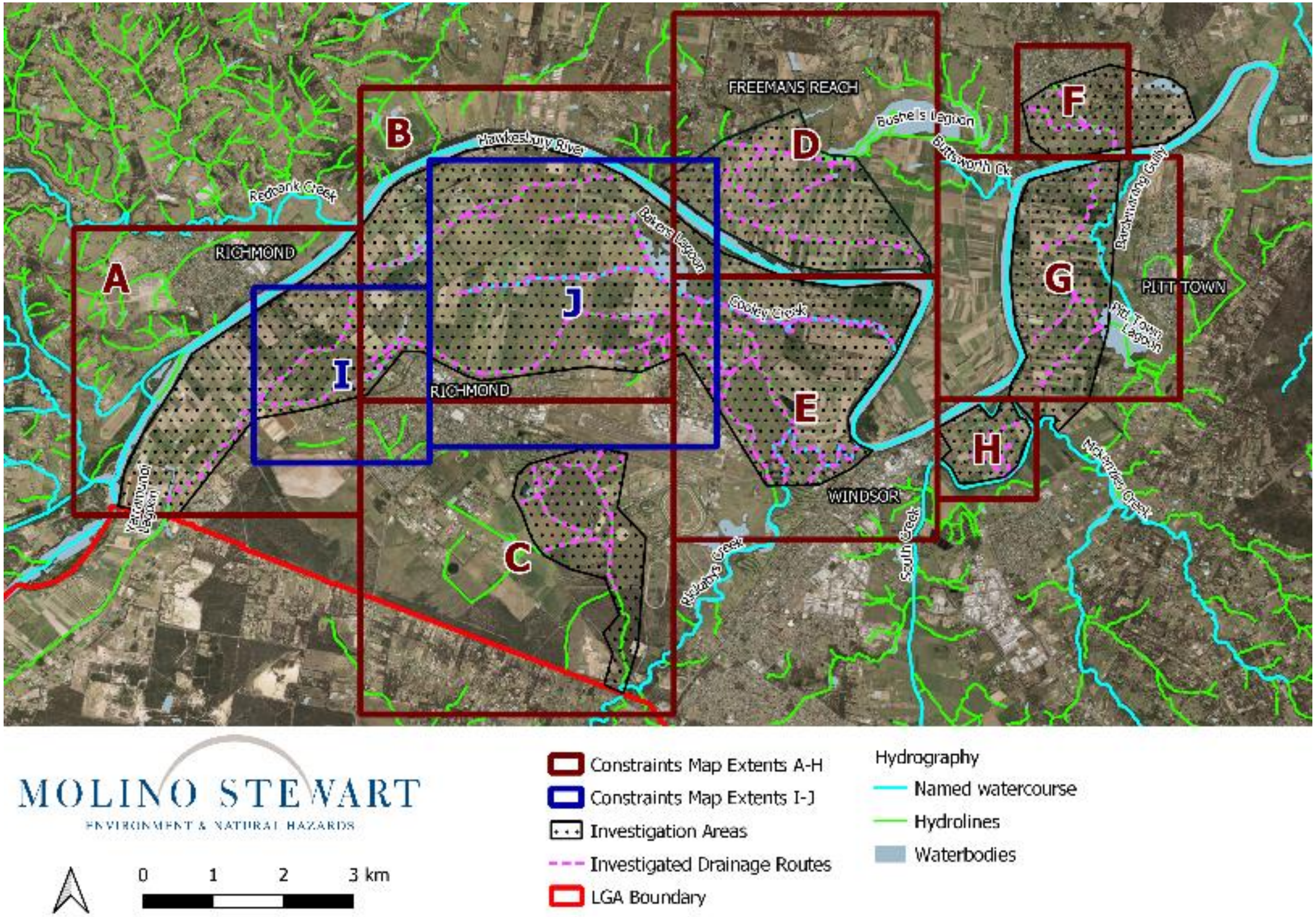

Figure 3: Environmental Constraints Map Extents

3 | Environmental Constraints Overview

This chapter provides an overview of the environmental and planning constraints across the floodplain as identified through the desktop analysis. For each constraint, its legislative context is introduced and its effect and extent over the Hawkesbury Floodplain is discussed generally. In later chapters, where possible, options for dealing with drainage problems at specific locations are discussed along with the actual environmental constraints and planning considerations in that location.

3.1 Zoning

The land within the Hawkesbury Floodplain is divided into different land use zones. For each zone a range of land uses are designated as either permitted, with or without consent of the consent authority, or prohibited in accordance with the objectives of the zone. When carrying out works to repair or improve the drainage network, the specific zoning of the lands on which the works are to be carried out will impact the approval process for those works.

Part 2 of the Hawkesbury Local Environment Plan (HLEP) details the different land zones for the Hawkesbury LGA along with the different types of works that are permitted, with or without consent, for those zones.

Land use zones which surround the Hawkesbury Floodplain Drainage Network are:

- RU2 – Rural Landscape;
- RU4 – Primary Production Small Lots;
- R2 – Low Density Residential;
- SP1 – Special Activities;
- SP2 – Infrastructure;
- RE1 – Public Recreation; and
- C2 – Environmental Conservation.

'Flood mitigation works' are works that are undertaken with the sole purpose of mitigating flood impacts. This includes excavation, construction and enlargement of fill, wall, or levees to alter the level, location, speed or timing of flood waters. 'Drainage' on the other hand includes activities that intentionally alter the hydrological regime of an area by facilitating the removal of surface or ground water. This includes construction, deepening, extending, opening, installing or laying canals, drains or pipes.

Given the objectives of this report, and of any resulting drainage network improvement or repair works, it seems reasonable to classify these works as 'flood mitigation works'. Flood mitigation works are permitted with consent for the zones RU2, RU4, R2, RE1 and C2. For land zoned as SP1 and SP2 all flood mitigation works are prohibited under the HLEP 2012.

Maintenance work on existing drainage channels (clearing, cleaning etc.) on land zoned RU2, RU4, R2, RE1, C2, SP1 and SP2 are considered ancillary to existing flood mitigation works and do not require approval. However, where drainage lines are being reinstated or rectified due to modification over the years and where new drainage lines are installed for flood mitigation, development consent is required on land zoned RU2, RU4, R2, RE1 and C2. On land zoned SP1 and SP2 reinstatement or rectification of existing drainage channels is prohibited unless it can be demonstrated that it is ancillary to the land use, in which case development consent is required. If the flood mitigation works on SP1 and SP2 zoned land are carried out on behalf of a public authority, the works are permitted without consent under State Environment Planning Policy (Transport and Infrastructure) 2021, Division 7 Flood Mitigation Works.

The predominant agricultural landuses on the floodplain were turf farming, irrigated market gardens and orchards, and livestock grazing. Turf farming and the irrigated crops fit the definition of intensive plant agriculture within the LEP while livestock grazing is within the definition of extensive agriculture. Extensive agriculture is permissible without consent in both of the rural zones. Intensive plant agriculture is permissible with consent in the RU4 zone but prohibited in the RU2 zone.

It would be reasonable to argue that the removal of debris such as pallets, silage bales, irrigation pipes, chemical containers and other miscellaneous agricultural debris which has been deposited in drainage infrastructure from the farms, and may or may not be inhibiting drainage, would be part of extensive and intensive agriculture. It is simply the retrieval of agricultural assets which were shifted by the flood.

Similarly, the removal of weeds from the creek banks, which can improve drainage, could also be considered to be part and parcel of the existing agricultural practices and would not require consent under Part 4 of the EP&A Act.

That is not to say that these works might not require approvals under other environmental legislation. This is discussed in more detail in Chapter 16.

Regrading access tracks and paddocks, on the other hand, might not be considered a necessary part of agricultural practice. In the case of the intensive plant agriculture, in particular, development consent may be required for these works.

This report outlines the zoning and permissibility for the solutions suggested within the report. The permissibility of any flood mitigation works additional to the suggested solutions would be assessed based on whether the works are classified as maintenance or reinstatement/rectification, and based on which land zone the works are undertaken on.

3.2 Contamination

3.2.1 Notified Sites

The NSW Environment Protection Authority (EPA) publishes a list of contaminated land notified under section 60 of the *Contaminated Land Management Act 1997* (CLM Act); this list is updated monthly. The list of notified sites contains land that has been notified to the EPA as being potentially contaminated and contains sites which have been assessed and those which are currently under assessment. The list only contains contaminated sites that EPA is aware of. If a site is not on the list, it does not necessarily mean the site is not contaminated. The EPA can manage notified contaminated sites under the CLM Act, the *Protection of the Environment Operations Act 1997* (POEO Act), or both. If land is declared as 'significantly contaminated', it is regulated under the CLM Act and will receive notices relating to the management of this contamination. These notices are published on the record of notices.

The record of notices for the Hawkesbury LGA is shown in Table 1 (EPA, 2022b) and the listed notified sites in the vicinity of the Hawkesbury Floodplain are shown in Figure 4 (EPA, 2022a).

Table 1: Environment Protection Authority contaminated lands record of notices for the Hawkesbury LGA

Suburb	Address	Site Name	Notices related to this site
KURMOND	501 Bells Line of ROAD	BP Service Station	1 former
MCGRATHS HILL	31 Groves AVENUE	Asbestos Contamination	3 former
PITT TOWN	Lot 24 Pitt Town Bottoms ROAD	Chemical Waste Disposal Site	3 former

PITT TOWN	1 Canning PLACE	Whites Water Service	2 current
WILBERFORCE	12-14 Box AVENUE	Former Drum Reconditioners	2 former
WILBERFORCE	13 Box AVENUE	Former Solvent Recycling Site	1 current

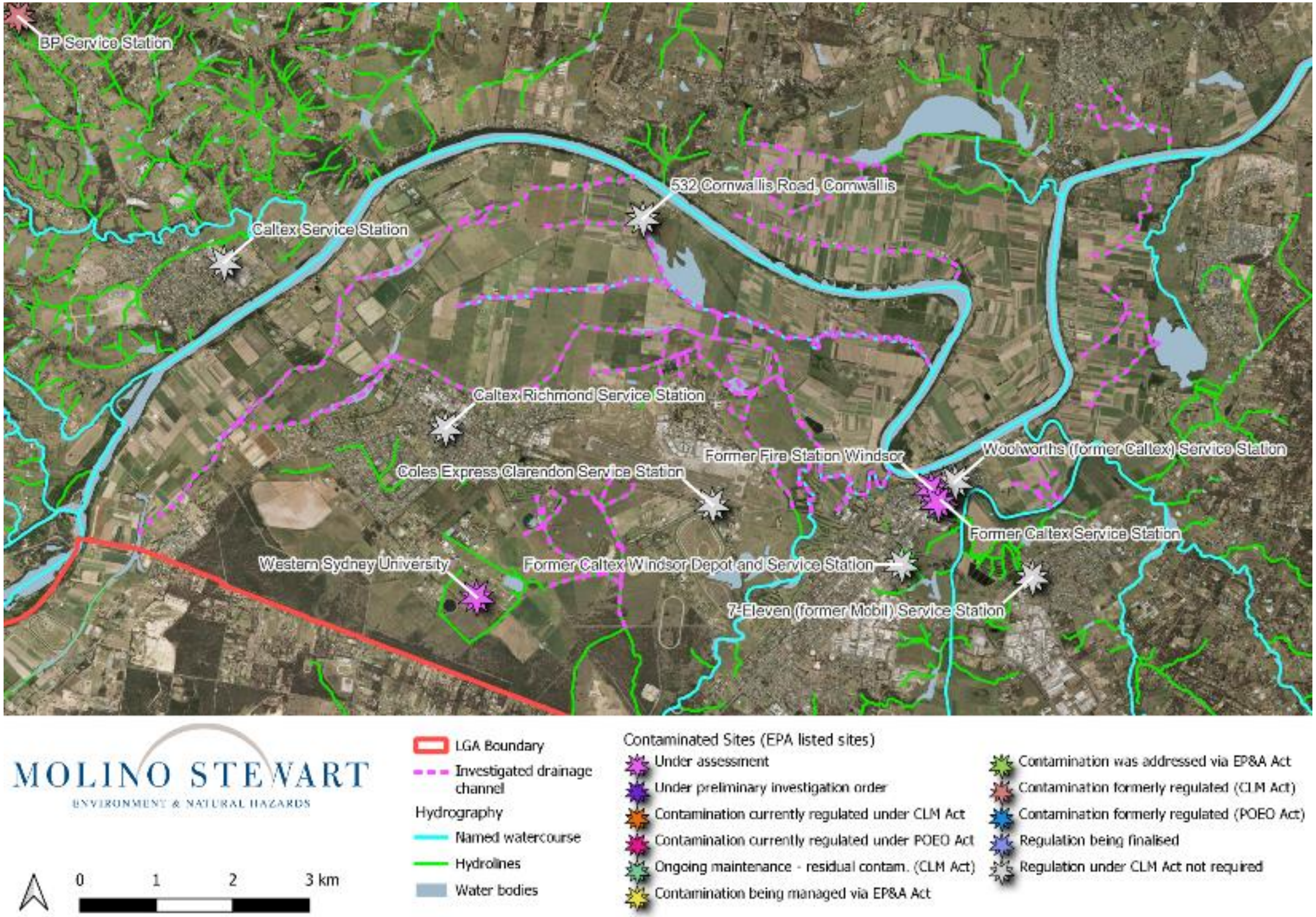

Figure 4: Environment Protection Authority notified contaminated sites

3.2.2 Richmond RAAF base

Per- and polyfluoroalkyl substances (PFAS) are a group of chemicals that are widely used due to their fire retardant, waterproofing and stain resistant qualities. The chemicals are present in a number of products including food packaging, non-stick cookware, fabric, and furniture and carpet stain protection applications. It is also commonly found in some types of fire-fighting foams. PFAS are very stable chemicals that do not easily break down and can persist in the environment.

Historically, fire-fighting foams containing PFAS have been used at the Richmond RAAF base, along with other Department of Defence bases, for training purposes. In 2018 the Department of Defence undertook detailed investigations into the spread of PFAS into the local area, showing that PFAS are present in high levels in the sediment and groundwater on the RAAF base, and that it is leaking into the surrounding environment mainly through surface water flows from the site, but also through groundwater. The possible extent of PFAS spread in groundwater is shown in Figure 5.

Due to their persistent nature and potential for bioaccumulation in living organisms the PFAS can have a severe detrimental impact on the health of both humans and the ecosystems. A Human Health Risk Assessment from 2018 (AECOM, 2018a) shows that humans may be impacted through consuming crops grown in contaminated soils or through use of contaminated ground and surface water. To reduce exposure risks to humans a Precautionary Dietary Advice was issued for specific properties in the area. Ecological risk assessments also show that there may be unacceptable risk to both aquatic and terrestrial ecological receptors both on and offsite from PFAS leakage (AECOM, 2018b). Fish from the Hawkesbury was also sampled and tested for PFAS levels, concluding the levels of PFAS in the fish were within acceptable limits to consumers. The impact from PFAS on the fish themselves was not tested.

The Richmond RAAF base is not within the study area of this report, however, the Department of Defence owns the land east of the base which is part of this review (IA1SE). The management areas for the PFAS also extend into the southeastern parts of IA1 including Bakers Lagoon, Cooley Creek and Rickabys Creek.

The two main management actions for minimising the impacts of PFAS are:

- Preventing and minimising the spread of PFAS from its source, and
- Minimising the community's exposure to PFAS while the sources of PFAS are managed.

The PFAS sources are on the RAAF base itself, however some of the source areas are close to the boundary, causing a higher level of PFAS leakage in these areas (see dark red dots in Figure 5).

Consultation with Department of Defence should be undertaken prior to any work being carried out in the areas of the drainage channels that are within PFAS management areas. This includes work that is located both within the on-site and off-site management areas as well as Bakers Lagoon. The constraint analysis for each investigation area further details the implications for any proposed works.

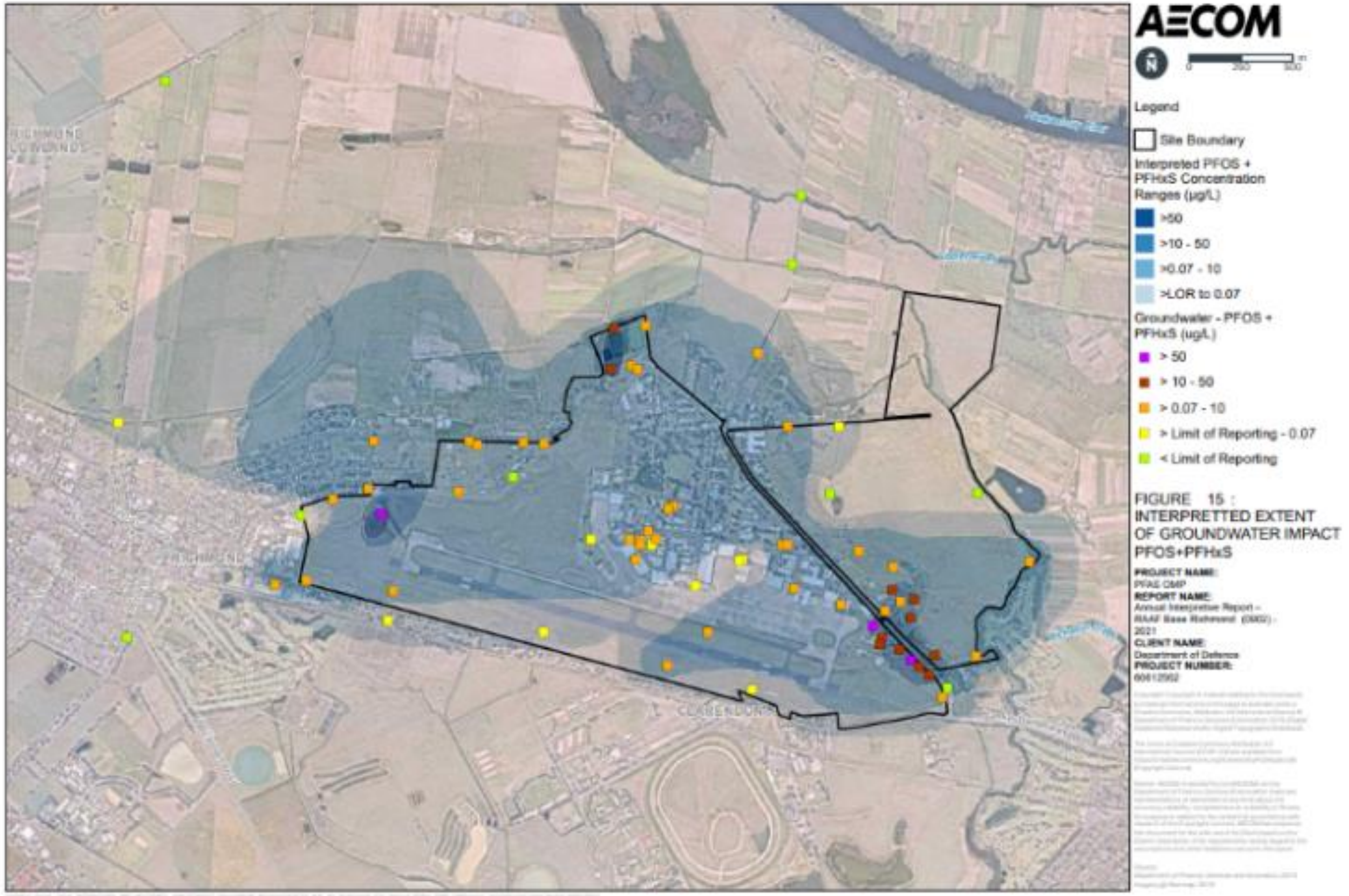

Figure 5: Potential spread of PFAS (PFOS and PFHxS) in the area surrounding the Richmond RAAF base. Figure from the Annual Interpretive Report for PFAS OMP at the Richmond RAAF base (AECOM, 2021).

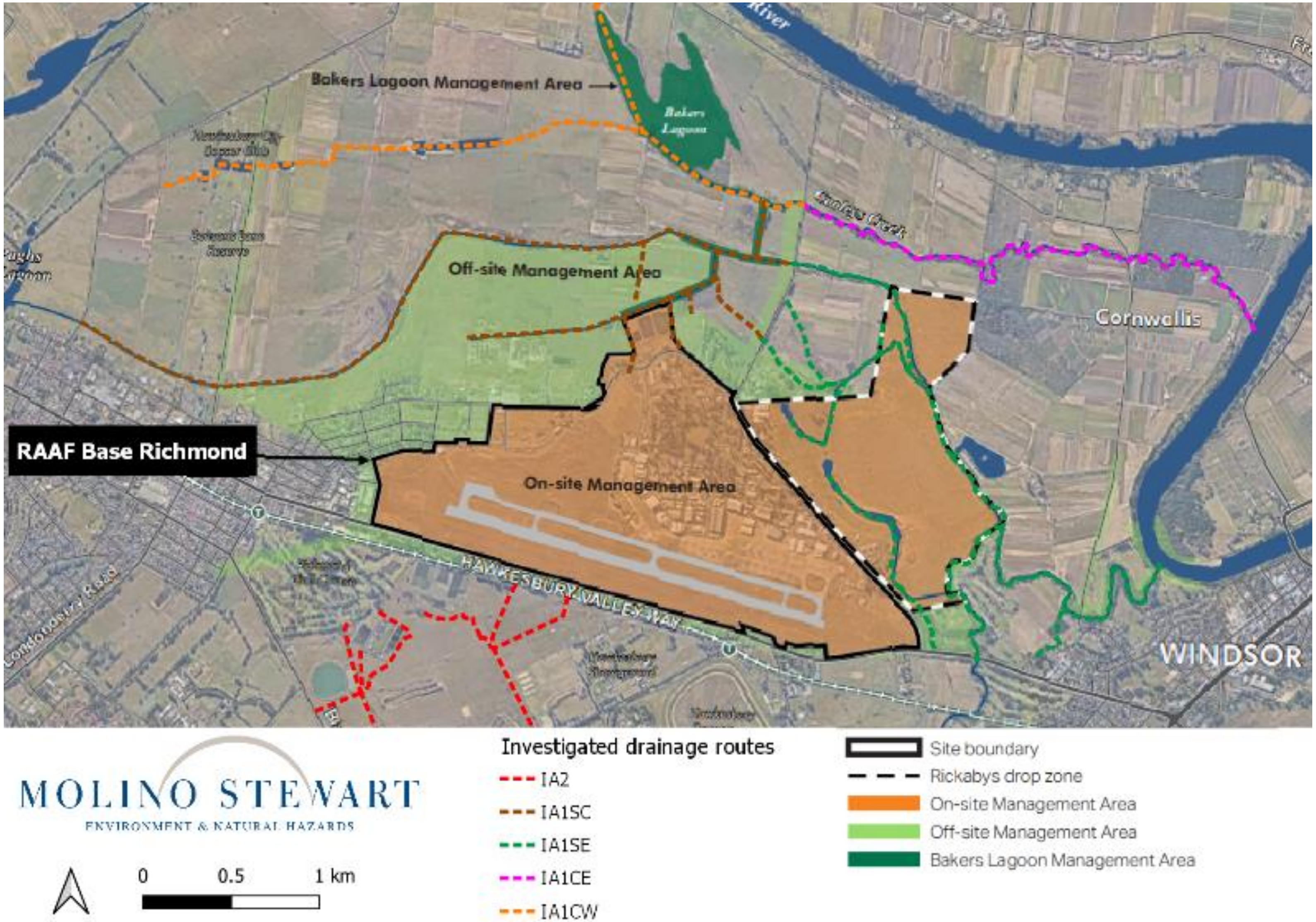

Figure 6: PFAS management areas in relation to investigated drainage routes.

3.3 Acid Sulphate Soils

Part 6.1 of the HLEP sets out provisions pertaining to land shown as Class 1 to 5 on the HLEP Acid Sulphate Soils Map. The objective of these provisions is to ensure that development does not disturb, expose or drain acid sulphate soils and cause environmental damage.

Depending on the class of the land, as per the HLEP Acid Sulphate Soils Map, there are different triggers requiring development consent to be granted for works on the land and which cannot be granted without an acid sulphate soils management plan, prepared in accordance with the Acid Sulphate Soils Manual. For all classes of land, development consent is not required if:

- a preliminary assessment of the proposed works prepared in accordance with the Acid Sulphate Soils Manual indicates that an acid sulphate soils management plan is not required for the works, and the preliminary assessment has been provided to the consent authority and the consent authority has confirmed the assessment by notice in writing to the person proposing to carry out the works (*HLEP 2012* Part 6.1.4);
- the works are conducted by a public authority and are emergency work, routine maintenance work, or minor work (as described in *HLEP 2012* Part 6.1.5);
- the works involve the disturbance of less than 1 tonne of soil (*HLEP 2012* Part 6.1.6a); or
- the works are not likely to lower the water table (*HLEP 2012* Part 6.1.6b).

For all other works, Part 6.1.2 of the HLEP sets out the triggers requiring consent and the preparation of an acid sulphate soils management plan. These are as follows:

- Class 1: Any works;
- Class 2: Works below the natural ground surface, or works by which the watertable is likely to be lowered;
- Class 3: Works more than 1 metre below the natural ground surface, or works by which the watertable is likely to be lowered more than 1 metre below the natural ground surface.
- Class 4: Works more than 2 metres below the natural ground surface, or works by which the watertable is likely to be lowered more than 2 metres below the natural ground surface.
- Class 5: Works within 500 metres of adjacent Class 1, 2, 3 or 4 land that is below 5 metres Australian Height Datum and by which the watertable is likely to be lowered below 1 metre Australian Height Datum on adjacent Class 1, 2, 3 or 4 land.

3.4 Heritage

3.4.1 HLEP Heritage

Part 5.10 of the HLEP sets out provisions pertaining to works which may affect heritage items listed and described in Schedule 5 of the HLEP and shown on the HLEP Heritage Map. The objectives of these provisions are to conserve the environmental heritage of the Hawkesbury, the heritage significance of heritage items and heritage conservations areas, archaeological sites, and Aboriginal objects and Aboriginal places of heritage significance. The provisions of the HLEP Part 5.10 detail: when works do and do not require consent (Parts 5.10.2 and 5.10.3, respectively); the responsibilities of the consent authority before granting consent, which pertain to the effect of proposed works on heritage significance (5.10.4), works on archaeological sites (5.10.7), works affecting Aboriginal places of heritage significance (5.10.8), and the demolition of nominated state heritage items (5.10.9); the mechanisms by which the consent authority can fulfill these responsibilities, including requiring a heritage assessment (5.10.5) and heritage conservation management plan (5.10.6) for the proposed works; and the ability of the consent authority to grant consent in situations where it would otherwise be prohibited, if the criteria presented in the HLEP Part 5.10.10 have been satisfied.

The HLEP heritage items are categorised as either 'General Heritage Items', 'Archaeological Heritage Items', 'Conservation Areas', or 'Aboriginal Places of Heritage Significance'. Each item is either of 'State' or 'Local' significance, that is of State Heritage Register provenance or HLEP provenance, respectively.

Many General Heritage Items are crossed by, or in the vicinity of the investigated drainage channels, however no other categories of heritage items were in the study area. Conservation areas are present in Windsor and Pitt Town, although none are closer than 400 m to the investigated drainage channels and would not be affected by any drainage channel repair or improvement works.

3.4.2 Aboriginal Heritage Information Management System

In NSW, Aboriginal heritage sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act). The Aboriginal Heritage Information Management System (AHIMS) stores information for registered sites of Aboriginal culture and heritage significance across NSW. It is managed by the Office of Environment and Heritage (OEH) as per Section 90Q of the *National Parks and Wildlife Act 1974* (NPW Act). AHIMS is not, however, a complete record of all sites, as only sites known to the OEH are recorded, and the recorded location of sites it does contain are not always accurate. AHIMS also does not generally record the cultural sensitivity of a site, or cultural values of the broader landscape around a location.

AHIMS offers two search features of their database, Basic Searches and Extensive Searches. A Basic Search identifies any Aboriginal Sites recorded in the search area. These sites may be an Aboriginal object (as defined under the NPW Act); a group (i.e. a collection, scattering, deposit etc) of Aboriginal objects; an area of land containing Aboriginal objects; a potential archaeological deposit which is an area where, based on previous investigation, Aboriginal objects are likely to be present; a declared Aboriginal place (as defined under the NPW Act), which may or may not contain Aboriginal objects; or an Aboriginal site that has been partially or completely destroyed under the conditions of a past consent. If a Basic Search indicates that there is an Aboriginal site in the area of proposed works, an Extensive Search is required to determine the precise nature of the Aboriginal site.

An AHIMS Basic Search of and near the study area returned 63 Aboriginal sites, some of which appear to be in close proximity to the investigated drainage channels. However, the results of a Basic Search only serve as a rough guide, and prior to any works being conducted, another Basic Search should be conducted for the works extent. Should such a Basic Search return any Aboriginal sites, an extensive search would be required. Further information is contained in the Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales (DCCEEW, 2010).

3.5 Wetlands

Part 6.5 of the HLEP sets out provisions pertaining to land which is identified as 'Wetlands' on the HLEP Wetlands Map. The objective of these provisions is to ensure that wetlands are preserved and protected from the impacts of development. These provisions are quoted below.

3) *Before determining a development application for development on land to which this clause applies* [i.e. land identified as 'Wetlands' on the HLEP Wetlands Map]*, the consent authority must consider—*

a. *whether or not the development is likely to have any significant adverse impact on the following—*
   i. *the condition and significance of the existing native fauna and flora on the land,*
   ii. *the provision and quality of habitats on the land for indigenous and migratory species,*
   iii. *the surface and groundwater characteristics of the land, including water quality, natural water flows and salinity,*
   iv. *the growth and survival of native fauna and flora,*
   v. *any wetlands in the vicinity of the development, and*
b. *any appropriate measures proposed to avoid, minimise or mitigate the impacts of the development.*

4) *Development consent must not be granted to development on land to which this clause applies* [i.e. land identified as 'Wetlands' on the HLEP Wetlands Map] *unless the consent authority is satisfied that—*
   a. *the development is designed, sited and will be managed to avoid any significant adverse environmental impact, or*
   b. *if that impact cannot be reasonably avoided—the development is designed, sited and will be managed to minimise that impact, or*
   c. *if that impact cannot be minimised—the development will be managed to mitigate that impact.*

3.6 Coastal Management

Being a tidal estuary, the Hawkesbury is subject to the *Coastal Management Act 2016* (CM Act) up to the highest tidal reach at Yarramundi Bridge (Figure 7). The CM Act defines the coastal zone and four coastal management areas:

- Coastal wetlands and littoral rainforests area;
- Coastal vulnerability area;
- Coastal environment area; and
- Coastal use area.

The CM Act establishes management objectives specific to each of these management areas, reflecting their different values to coastal communities. The management objectives are described under the State Environmental Planning Policy (Resilience and Hazards) 2021 (R&H SEPP 2021).

There are multiple coastal wetlands in the study area as displayed in Figure 7. Additionally, the coastal environment area covers all areas within a minimum of 100 m from the riverbank, and the coastal use area covers areas up to 500 m from the riverbank. These areas are subject to development restrictions. The mapping for the coastal vulnerability area in the Hawkesbury estuary is not yet finalised and is thus not included in the constraints analysis of this report.

As per the R&H SEPP 2021, impacts on the following coastal aspects must be avoided, minimised and managed for developments within the coastal environment area:

- The integrity and resilience of the biophysical, hydrological and ecological environment;
- Coastal environmental values and natural coastal processes;
- The water quality of the marine estate, particularly cumulative impacts on sensitive coastal lakes;
- Marine vegetation, native vegetation and fauna and their habitats, undeveloped headlands and rock platforms;

- Existing public open space and safe access for members of the public to and along the foreshore, beach, headland or rock platform, including people with a disability; and
- Aboriginal cultural heritage, practices and places.

Development proposals in the coastal use area must address the following coastal aspects and avoid, mitigate and manage impacts on them:

- Existing safe access to and along a foreshore, beach, headland or rock platform, including access for people with a disability;
- Overshadowing, wind funnelling and loss of views from public places to foreshores;
- The visual amenity and scenic nature of the coast, including headlands;
- Aboriginal cultural heritage, practices and places; and
- Cultural and built environment heritage.

All development within a mapped coastal wetland area requires consent, including harming or removing native or marine vegetation, draining the land, constructing a levee, environmental protection works and so forth. Development within a coastal wetland is generally classified as designated development, meaning that an environmental impact statement must be prepared to support any development application. Exempt and complying developments are not permitted within coastal wetland areas. Additionally, any development within 100 m of coastal wetlands, known as the coastal wetland proximity area, cannot be approved unless shown that it will not significantly impact on the biophysical, hydrological or ecological integrity of, or the quantity and quality of surface and ground water flows to and from the adjacent coastal wetland.

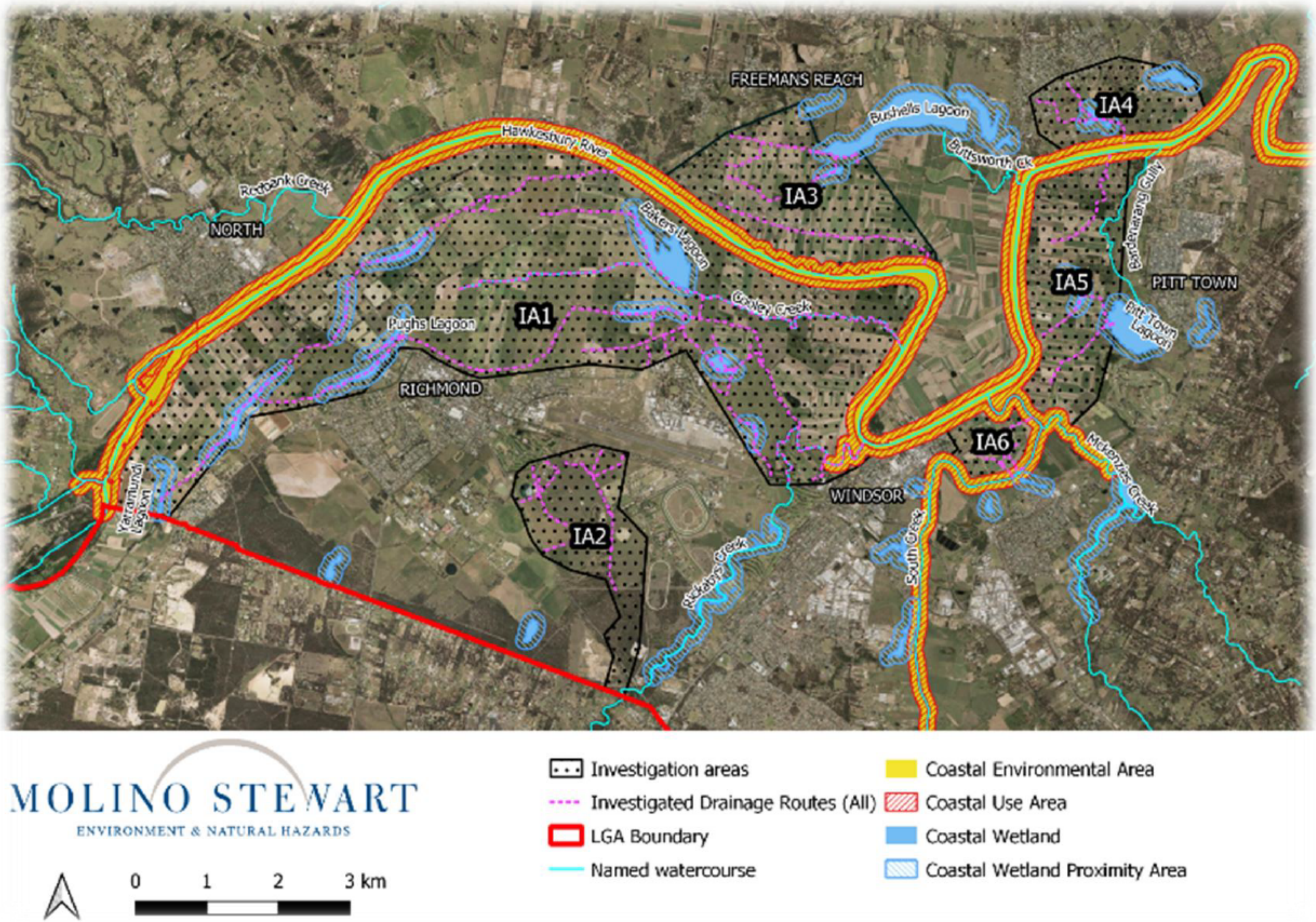

Figure 7: Coastal management areas within the study area.

3.7 Ecology

3.7.1 Plant Community Type mapping

Plant Community Types (PCTs) are the finest level in the NSW vegetation classification hierarchy and are widely used to support biodiversity assessment, conservation planning and land management activities. They identify and describe recurring patterns of native plant species assemblages in relation to environmental conditions, such as soil, temperature, moisture and other factors. The floristic composition of PCTs is characterised by frequently co-occurring species, including combinations of trees, shrubs and/or ground cover plants. PCTs are defined and mapped across NSW and PCT data are managed as part of the Integrated BioNet Vegetation Data program. Some PCTs are referrable to Threatened Ecological Communities (TECs) listed under the BC Act and EPBC Act.

The following PCTs are mapped along or near the study area:

- **PCT 781 – Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion**. This PCT is referrable to TECs under the BC Act as equivalent to the endangered 'Freshwater Wetlands on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions' and 'Sydney Freshwater Wetlands in the Sydney Basin Bioregion'.
- **PCT 835 – Forest Red Gum / Rough-barked Apple Grassy Woodland on Alluvial Flats of the Cumberland Plain, Sydney Basin**. This PCT is referrable to TECs under both the BC Act and EPBC Act as equivalent to the endangered 'River-Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner Bioregions' and the critically endangered 'River-flat eucalypt forest on coastal floodplains of southern NSW and eastern Victoria' (respectively).
- **PCT 849 – Grey Box / Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion.** This PCT is referrable to TECs under both the BC Act and EPBC Act as equivalent to the critically endangered 'Cumberland Plain Woodland in the Sydney Basin Bioregion' and 'Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest' (respectively).
- **PCT 877 – Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion.** This PCT is referrable to TECs under both the BC Act and EPBC Act as equivalent to the endangered 'Western Sydney Dry Rainforest in the Sydney Basin Bioregion' and the critically endangered 'Western Sydney Dry Rainforest and Moist Woodland on Shale' (respectively).
- **PCT 1395 – Narrow-leaved Ironbark / Broad-leaved Ironbark / Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion.** This PCT is referrable to TECs under the BC Act and the EPBC Act as equivalent to the critically endangered 'Shale Sandstone Transition Forest in the Sydney Basin Bioregion' and 'Shale Sandstone Transition Forest of the Sydney Basin Bioregion' (respectively).

The only way to accurately determine whether any of the above mentioned PCTs actually occur within the subject site is for an ecologist to undertake an extensive site survey.

3.7.2 Terrestrial Biodiversity

Part 6.4 of the HLEP sets out provisions pertaining to land which is identified as either 'Significant vegetation' or 'Connectivity between significant vegetation' on the HLEP Terrestrial Biodiversity Map. The objective of these provisions is to maintain terrestrial biodiversity by protecting native fauna and flora, protecting the ecological processes necessary for their continued existence, and encouraging the conservation and recovery of native fauna and flora and their habitats. These provisions are quoted below.

3) *Before determining a development application for development on land to which this clause applies* [i.e. land identified as either 'Significant vegetation' or 'Connectivity between significant vegetation' on the HLEP Terrestrial Biodiversity Map]*, the consent authority must consider—*
   a. *whether the development—*
      i. *is likely to have any adverse impact on the condition, ecological value and significance of the fauna and flora on the land, and*
      ii. *is likely to have any adverse impact on the importance of the vegetation on the land to the habitat and survival of native fauna, and*
      iii. *has any potential to fragment, disturb or diminish the biodiversity structure, function and composition of the land, and*
      iv. *is likely to have any adverse impact on the habitat elements providing connectivity on the land.*
   b. *any appropriate measures proposed to avoid, minimise or mitigate the impacts of the development.*
4) *Development consent must not be granted to development on land to which this clause applies* [i.e. land identified as either 'Significant vegetation' or 'Connectivity between significant vegetation' on the HLEP Terrestrial Biodiversity Map] *unless the consent authority is satisfied that—*
   a. *the development is designed, sited and will be managed to avoid any significant adverse environmental impact, or*
   b. *if that impact cannot be reasonably avoided by adopting feasible alternatives—the development is designed, sited and will be managed to minimise that impact, or*
   c. *if that impact cannot be minimised—the development will be managed to mitigate that impact.*

A site inspection should occur prior to any works being undertaken to assess the potential environmental impact of the development on any areas of significant vegetation or areas of connectivity between significant vegetation as per the HLEP 2012

3.7.3 Biodiversity Values

The Biodiversity Offsets Scheme (BOS) was established under the *Biodiversity Conservation Act 2016* (BC Act) and aims to provide a framework for transparent, consistent and scientifically based biodiversity assessment and offsetting for development which is likely to have a significant impact on biodiversity. Works conducted under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and which trigger the BOS must provide more rigorous biodiversity assessment reporting and potentially biodiversity offsetting, however, this is optional for works conducted under Part 5 of the EP&A Act.

The Biodiversity Values (BV) Map, prepared by the NSW Department of Planning and Environment (DPE) under Part 7 of the BC Act, identifies land with high biodiversity value that is particularly sensitive to impacts from development and clearing. The map forms part of the BOS threshold, which is one of the factors for determining whether the BOS applies to a clearing or development proposal. If works are to be conducted in an area identified as BV on the BV Map and involve the clearing native vegetation or an impact prescribed under clause 6.1 of the Biodiversity Conservation Regulation, the BOS applies. These prescribed impacts are far reaching, and therefore works conducted in BV identified land are very likely to trigger the BOS.

The implications of triggering the BOS are further detailed in section 16.4 of this report.

3.7.4 Threatened Species

A search of the NSW DPE BioNet Atlas was conducted on 3 August 2022 and returned all threatened fauna and flora species records within an approximate 5 km buffer of the study area and which were recorded in the last 10 years (DPE, 2010). A total of 7,751 records were returned for a total of 75 threatened species, comprising 20 plant species, 35 birds, 15 mammals, 3 frogs, and 2 snails (Table 2).

The most frequently recorded species, i.e. all for which there were over 50 records each, are: *Dillwynia tenuifolia* (n = 2707); Nodding Geebung (*Persoonia nutans*; n = 1564); Juniper-leaved Grevillea (*Grevillea juniperina subsp. juniperina*; n = 1171); *Micromyrtus minutiflora* (n = 492); *Pultenaea parviflora* (n = 339); Koala (*Phascolarctos cinereus*; n = 178); Grey-headed Flying-fox (*Pteropus poliocephalus*; n = 146); Bynoe's Wattle (*Acacia bynoeana*; n = 92); Large Bent-winged Bat (*Miniopterus orianae oceanensis*; n = 82); Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*; n = 79); Cumberland Plain Land Snail (*Meridolum corneovirens*; n = 71); *Allocasuarina glareicola* (n = 68); Southern Myotis (*Myotis macropus*; n = 67); and Greater Broad-nosed Bat (*Scoteanax rueppellii*; n = 59).

The species records in the vicinity of the study area were mapped and this mapping is presented in the following chapters. Overall, few records were present along the investigated drainage channels, however this may be due to reduced sampling effort in these areas. No threatened species were observed during the field investigations. It is possible that cryptic plant species were persisting in the study area and that fauna were present but not observed or may use the drainage channels and surrounding habitat temporally.

A site inspection should occur prior to any works being undertaken to assess the likely presence of threatened species and their potential habitat at the site of the works. The presence of any threatened species needs to be considered in the detailed impact assessment for any proposed drainage channel repair or improvement works.

Table 2: Threatened Species Recorded within 5km of the study area

Group	Scientific Name	Common Name	Species Code	NSW status	Comm. status	Records
Plants	*Dillwynia tenuifolia*		2853	V		2707
	Persoonia nutans	Nodding Geebung	5467	E1,P	E	1564
	Grevillea juniperina juniperina	Juniper-leaved Grevillea	10917	V		1171
	Micromyrtus minutiflora		4274	E1	V	492
	Pultenaea parviflora		3007	E1	V	339
	Acacia bynoeana	Bynoe's Wattle	3728	E1	V	92
	Allocasuarina glareicola		8320	E1	E	68
	Acacia pubescens	Downy Wattle	3860	V	V	26
	Pimelea curviflora curviflora		6965	V	V	18
	Rhodamnia rubescens	Scrub Turpentine	4283	E4A	CE	9

Group	Scientific Name	Common Name	Species Code	NSW status	Comm. status	Records
	Syzygium paniculatum	Magenta Lilly Pilly	4293	E1	V	3
	Pimelea spicata	Spiked Rice-flower	6190	E1	E	3
	Cynanchum elegans	White-flowered Wax Plant	1226	E1	E	1
	Marsdenia viridiflora viridiflora		10896	E2		1
	Hibbertia puberula		11422	E1		1
	Tetratheca glandulosa		6205	V		1
	Epacris sparsa	Sparse Heath	7129	V	V	1
	Acacia meiantha		8973	E1	E	1
	Pterostylis saxicola	Sydney Plains Greenhood	9615	E1,P,2	E	1
	Macadamia integrifolia	Macadamia Nut	9680		V	1
Birds	*Calidris acuminata*	Sharp-tailed Sandpiper	0163	P	C,J,K	48
	Daphoenositta chrysoptera	Varied Sittella	0549	V,P		42
	Artamus cyanopterus cyanopterus	Dusky Woodswallow	8519	V,P		40
	Haliaeetus leucogaster	White-bellied Sea-Eagle	0226	V,P		34
	Ninox strenua	Powerful Owl	0248	V,P,3		24
	Lathamus discolor	Swift Parrot	0309	E1,P,3	CE	23
	Glossopsitta pusilla	Little Lorikeet	0260	V,P		21
	Lophoictinia isura	Square-tailed Kite	0230	V,P,3		16
	Gallinago hardwickii	Latham's Snipe	0168	P	J,K	12
	Hieraaetus morphnoides	Little Eagle	0225	V,P		11
	Calidris melanotos	Pectoral Sandpiper	0978	P	J,K	10
	Calidris ruficollis	Red-necked Stint	0162	P	C,J,K	10
	Pluvialis fulva	Pacific Golden Plover	8006	P	C,J,K	8
	Circus assimilis	Spotted Harrier	0218	V,P		7
	Callocephalon fimbriatum	Gang-gang Cockatoo	0268	V,P,3	E	7
	Calyptorhynchus lathami	Glossy Black-Cockatoo	0265	V,P,2		7
	Tringa glareola	Wood Sandpiper	0154	P	C,J,K	6
	Apus pacificus	Fork-tailed Swift	0335	P	C,J,K	5
	Rostratula australis	Australian Painted Snipe	0170	E1,P	E	5
	Chthonicola sagittata	Speckled Warbler	0504	V,P		5
	Calidris ferruginea	Curlew Sandpiper	0161	E1,P	CE,C,J,K	4

Group	Scientific Name	Common Name	Species Code	NSW status	Comm. status	Records
	Tyto novaehollandiae	Masked Owl	0250	V,P,3		4
	Falco subniger	Black Falcon	0238	V,P		3
	Tringa stagnatilis	Marsh Sandpiper	0159	P	C,J,K	3
	Neophema pulchella	Turquoise Parrot	0302	V,P,3		2
	Anthochaera phrygia	Regent Honeyeater	0603	E4A,P	CE	2
	Melithreptus gularis gularis	Black-chinned Honeyeater	8303	V,P		2
	Stictonetta naevosa	Freckled Duck	0214	V,P		1
	Hirundapus caudacutus	White-throated Needletail	0334	P	V,C,J,K	1
	Ixobrychus flavicollis	Black Bittern	0196	V,P		1
	Pluvialis squatarola	Grey Plover	0136	P	C,J,K	1
	Tringa nebularia	Common Greenshank	0158	P	C,J,K	1
	Ninox connivens	Barking Owl	0246	V,P,3		1
	Tyto tenebricosa	Sooty Owl	9924	V,P,3		1
	Petroica phoenicea	Flame Robin	0382	V,P		1
Mammals	*Phascolarctos cinereus*	Koala	1162	E1,P	E	178
	Pteropus poliocephalus	Grey-headed Flying-fox	1280	V,P	V	146
	Miniopterus orianae oceanensis	Large Bent-winged Bat	3330	V,P		82
	Micronomus norfolkensis	Eastern Coastal Free-tailed Bat	1329	V,P		79
	Myotis macropus	Southern Myotis	1357	V,P		67
	Scoteanax rueppellii	Greater Broad-nosed Bat	1361	V,P		59
	Petaurus australis	Yellow-bellied Glider	1136	V,P	V	46
	Falsistrellus tasmaniensis	Eastern False Pipistrelle	1372	V,P		27
	Miniopterus australis	Little Bent-winged Bat	1346	V,P		27
	Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	1321	V,P		16
	Chalinolobus dwyeri	Large-eared Pied Bat	1353	V,P	V	15
	Vespadelus troughtoni	Eastern Cave Bat	1025	V,P		8
	Dasyurus maculatus	Spotted-tailed Quoll	1008	V,P	E	3
	Petaurus norfolcensis	Squirrel Glider	1137	V,P		2
	Pseudomys novaehollandiae	New Holland Mouse	1455	P	V	1
Snails	*Meridolum corneovirens*	Cumberland Plain Land Snail	I006	E1		71

Group	Scientific Name	Common Name	Species Code	NSW status	Comm. status	Records
	Pommerhelix duralensis	Dural Land Snail	I130	E1	E	47
Frogs	*Pseudophryne australis*	Red-crowned Toadlet	3116	V,P		4
	Litoria aurea	Green and Golden Bell Frog	3166	E1,P	V	3
	Heleioporus australiacus	Giant Burrowing Frog	3042	V,P	V	1

3.7.5 Key Fish Habitat

The primary Act governing the management of fish and their habitat in NSW is the *Fisheries Management Act 1994* (FM Act). One of the objectives of the FM Act is to 'conserve key fish habitats', where 'fish' is defined as 'marine, estuarine or freshwater fish or other aquatic animal life at any stage of their life history (whether alive or dead)'. To achieve this objective the NSW Department of Primary Industries (DPI) has identified and mapped Key Fish Habitat (KFH), that is, aquatic habitats that are important to the sustainability of the recreational and commercial fishing industries, the maintenance of fish populations generally, and the survival and recovery of threatened aquatic species.

To facilitate the mapping of KFH, KFH was defined to include all marine and estuarine habitats up to highest astronomical tide level (i.e. that reached by 'king' tides) and most permanent and semipermanent freshwater habitats including rivers, creeks, lakes, lagoons, billabongs, weir pools and impoundments up to the top of the bank. Small headwater creeks and gullies (known as first and second order streams), that only flow for a short period after rain are generally excluded, as are farm dams constructed on such systems. Wholly artificial waterbodies such as irrigation channels, urban drains and ponds, salt and evaporation ponds are also excluded except where they are known to support populations of threatened fish or invertebrates.

As per the definition of KFH, majority of the drainage networks investigated as part of this report are not identified as KFH. Notable exceptions and other KFH in the vicinity of the drainage networks include the Hawkesbury River, Cooley Creek at and downstream of Bakers Lagoon, Rickabys Creek, the drainage channel connecting Cooley Creek to Rickabys Creek, South Creek, the downstream section of Buttsworth Creek, and McKenzies Creek.

Any works within an area mapped as KFH will require an approval under the FM Act.

4| IA1 Northern Drainage Route West

As explained in Section 2.1, IA1 was broken up into a northern, central and southern drainage route and the northern and southern routes were further broken down into a western and eastern section. This chapter deals with the western section of the northern drainage route IA1NW which starts at Springwood Road and continues to where the drain crosses to the southern side of Ridges Lane (Figure 8). Although IA1NW starts at Springwood Road for the purposes of this report, this is because this is the southern boundary of Hawkesbury LGA. The drainage line probably starts about 5km further south between the Nepean River and Castlereagh Road.

Springwood Road crosses Yarramundi Lagoon which is a natural lagoon which forms part of the main drainage line of IA1NW. Yarramundi Lagoon stretches about 700m south of Springwood Road and about 800m to its north. The lagoon overflows on its eastern side into the drainage line about 650m north of Springwood Road (Photo 1). The locations of each photograph referred to in the text can be found in Figure 9.

4.1 Drainage Issues

4.1.1 Field observations

On the day of the May inspection, the level in the lagoon was such that it was flooding a corner of the turf paddock on western side of the lagoon and north of Springwood Road (Photo 2) and much of the grass in this paddock had been killed (Photo 3) from the water level having been elevated for prolonged periods well after the flood had receded. The property owner advised that even though the initial flooding was caused by the floodwaters covering the floodplain, every time there was significant rain in the local catchment the lagoon would rise and flood the paddock and then slowly recede.

This farm was visited again on 12th July and the water level was higher than it had been in May (Photo 4). The property owner advised that the water had dropped to this level about four or five days after the flood peak but had not dropped noticeably since. As seen in (Photo 1), the water level in the lagoon's outlet was the same as in the lagoon itself in May, so the outflow from the lagoon is being controlled further downstream.

There were a couple of bridges over the outlet channel (Photo 5) but these did not appear to be obstructing flow at this water level. However, further downstream there is an embankment constructed across the drain (Photo 6). Although no pipe through the embankment was discernible on the day of the inspection (Photo 7), it is likely that there is one because the water level was the same on both sides of the embankment. Regardless of the size of the pipe or pipes and how blocked they are, if at all, the maximum flow rate through the pipes will be less than the capacity of the channel and so this will be a choke point in the drainage of the lagoon.

Nevertheless, because the water was the same level on both sides of the crossing and there was no discernible flow in the channel, at the observed water level there must be a choke point further downstream. This was found to be at a location just upstream of another road crossing. There was a collapsed concrete bridge followed by reeds growing in sediment within the channel (Photo 8). There was a change in water level here as the water flowed between the reeds but then it only fell a few hundred millimetres before reaching ponded water which was at the same level as water ponded downstream of the crossing (Photo 9).

Water was ponded at this level as far as the pipe under Crowleys Lane (Photo 10) where minimal flow was detected. The Crowleys Lane crossing was visited again on 12 July and the water level was a few hundred millimetres higher and slow flow through the pipe was able to be detected (Photo 11).

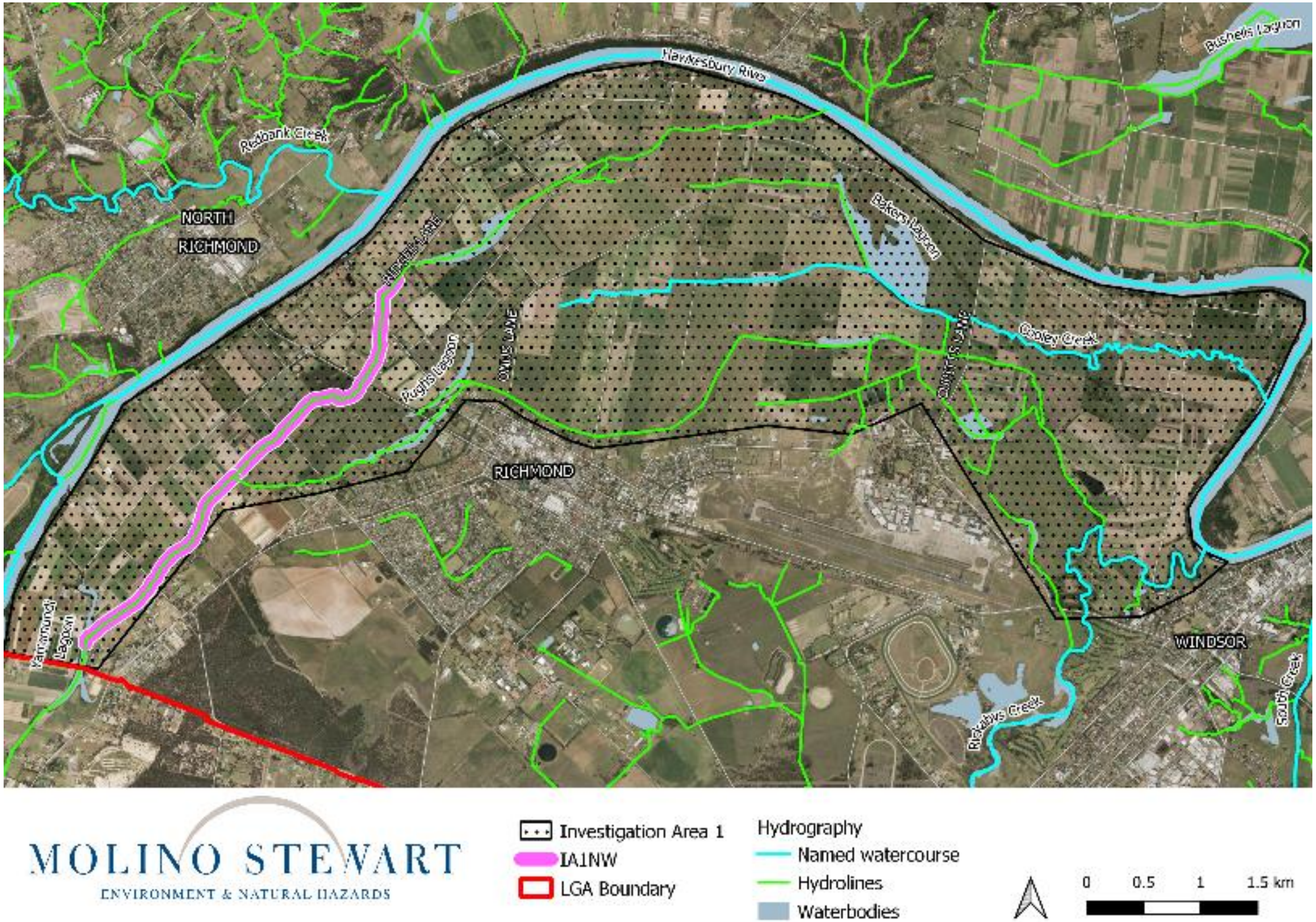

Figure 8: Investigation Area 1 Northern Drainage Route West (IA1NW)

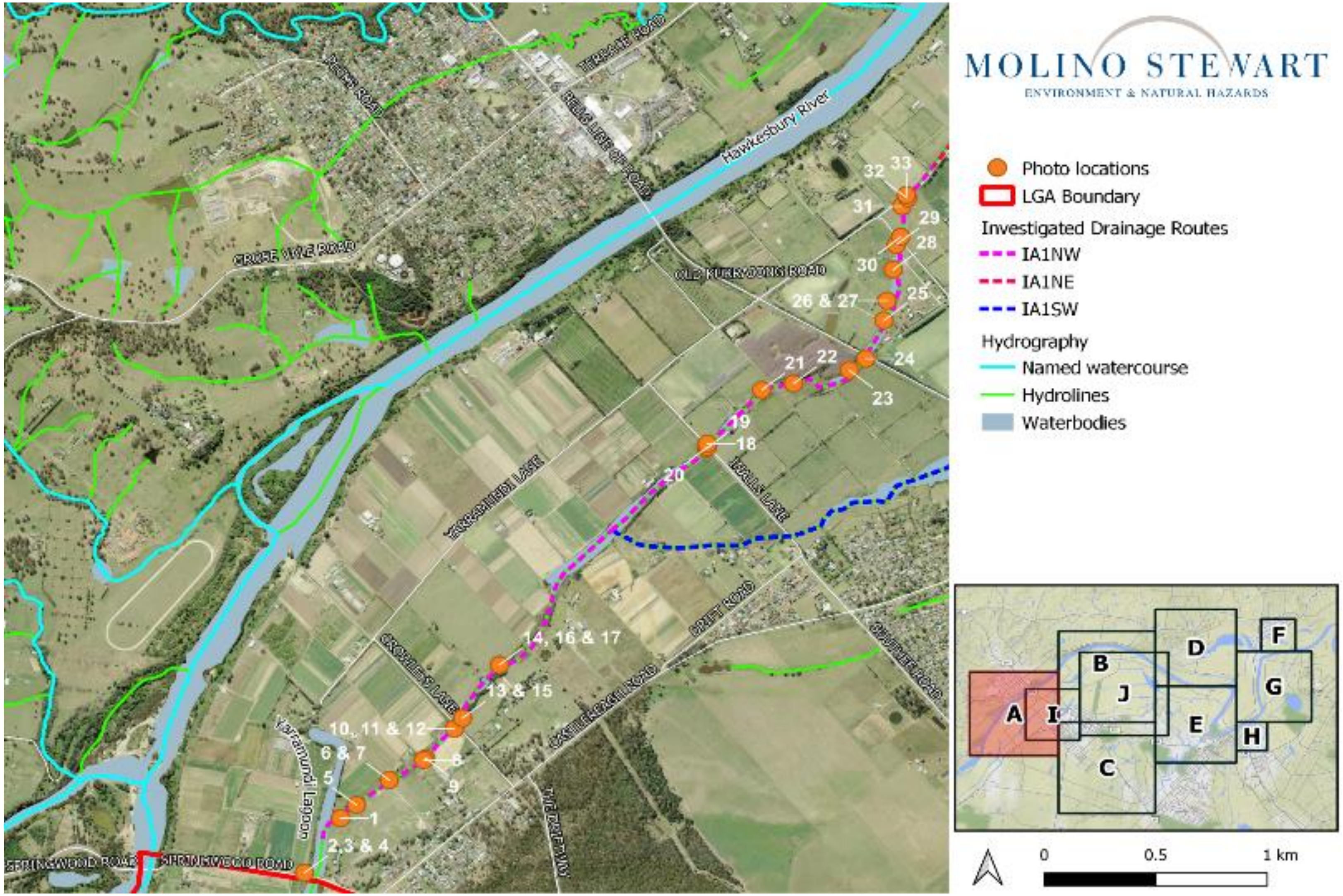

Figure 9: Photo locations for IA1NW

Photo 1

[redacted]

Photo 3

Photo 5

Photo 6

Photo 7

Photo 8

Photo 9

Photo 10

Photo 11

Downstream of Crowleys Lane the channel flows through a stand of native vegetation which is dominated by casuarinas, paperbarks and eucalypts (Photo 12). In places the casuarinas are growing within the channel and are blocking the flow (Photo 13). This is evidenced not only by the sound of running water between the roots of the trees but by the fact that water has been diverted into the neighbouring paddock (Photo 14) before flowing back into the creek at a lower level further downstream (Photo 15). There may be a fall of about 500mm between the upstream overflow point and the downstream return point. The extent of the diversion was only slightly more extensive in July (Photo 16).

A tenant on the property upstream of Crowleys Lane advised on 12th July that the floodwaters did not drop below the crest of Crowleys Lane until the Friday morning following the July 5th flood peak. This is consistent with the report from the turf farmer upstream about the rate of initial fall in the flood level.

Downstream of here the channel was open and quite wide in places before passing under and access road through two pipes with a noticeable flow, suggesting that these pipes are also a flow constriction. There is a line of trees along the northern “bank” of the channel (Photo 17) although at this point the channel becomes a reed bed and the water and reeds extended to the north of the trees.

The water flows out of the reed beds via a 100m section of channel and under an access road and into an unnamed lagoon. This lagoon discharges along a channel (Photo 18) and through two pipes under Inalls Lane (Photo 19) and into another lagoon (Photo 20) which was at the same water level.

There is a pipe under an access track with the water level the same on both sides (Photo 21). This flows into an extensive reed bed (Photo 22) before becoming open water again (Photo 23) and then passing under Kurrajong Road through a culvert (Photo 24).

Downstream of Kurrajong Road there was another lagoon covered in water hyacinth which terminated at a crossing through which two pipes discharged the water into another lagoon at a lower level (Photo 25).

This next water body splits in two around a raised strip running down its centre (Photo 26). There is an access across the lagoon and on one side the water passes under the access and at the observed water level the water passed over the access on the other side (Photo 27 and Photo 28). The ponded water discharges through a pipe under an internal access track before the passing under Old Kurrajong Road through a culvert with three large pipes (Photo 29). There is a fence immediately upstream of the culverts which has caught a lot of debris during the flood. There is ponded water downstream of the culverts which is at the same level as the water upstream (Photo 30). There is an access track across the pond with no pipe discernible but the water is the same level on both sides (Photo 31).

There is a noticeable outflow from this pond via a culvert under Ridges Lane (Photo 32). An open channel flows along the northern side of Ridges Lane and there was a noticeable flow on the day of the inspection in May (Photo 33). It continues in this roadside channel until it crosses back under Ridges Lane which marks the end of IA1NW.

[redacted]

Photo 13

Photo 14

Photo 15

Photo 16

Photo 17

Photo 18

Photo 19

Photo 21

Photo 22

Photo 23

Photo 24

Photo 25

Photo 26

Photo 27

Photo 28

Photo 30

Photo 31

Photo 32

Photo 33

4.1.2 Probable causes

While each of the pipes under roads are likely to inhibit drainage to some extent, throughout most of this investigation area there was no evidence of that having been of such duration that it had caused losses to agricultural production or damage to property in addition to that caused by the initial inundation of the floodplain.

The exception was at the top of the investigation area around Yarramundi Lagoon. The prolonged flooding of the turf farm on Springwood Road and the subsequent loss of production has clearly been caused by blockages in the outlet to the lagoon. The inspection only observed the damage to this one property in Hawkesbury LGA but similar damage is likely to be occurring to properties around the perimeter of the lagoon in both Hawkesbury and Penrith LGAs.

The prolonged inundation around the lagoon perimeter does not only follow immediately after a river flood that spills onto this part of the floodplain but also after heavy rain in the lagoon's local catchment which extends another 5km further south.

The water level in the lagoon which was observed on both the May and July inspections was caused by the accumulation of sediment and reeds within the channel at the location of photo 8.

4.1.3 Possible solutions

Clearing of the channel at the location of photo 8 is the only way of reducing the water level in Yarramundi lagoon. Although this may only reduce the water level by a few hundred millimetres, the flatness of the terrain around the lagoon means that a small reduction in level will result in inundation relief to a relatively large area. The opportunity should be taken to remove the collapsed bridge from the channel at the same time.

A further reduction in the level of the lagoon could only be achieved by removing the casuarinas from the channel downstream of Crowleys Lane. Such a measure may reduce the level in the lagoon by more than 1m which may be environmentally undesirable. Furthermore, the casuarinas are part of an endemic plant habitat which has mostly been removed from the floodplain and this would have a further detrimental environmental impact. Therefore, this is not recommended.

While the removal of the sediment from the channel will permanently lower the water level to a preferable level, the rate at which the lagoon level falls is likely to be controlled by the pipe through the crossing of the channel upstream of the sediment blockage (Photo 6 and Photo 7). Removal of the embankment crossing would ensure that flow through the crossing does not unnecessarily inhibit the rate of drainage of the lagoon. If a crossing of the channel is still needed at this location or somewhere else along this stretch of channel, it should be achieved by construction of a clear span bridge or some other design which does not create any blockage within the channel.

Possible solutions are displayed in Figure 10.

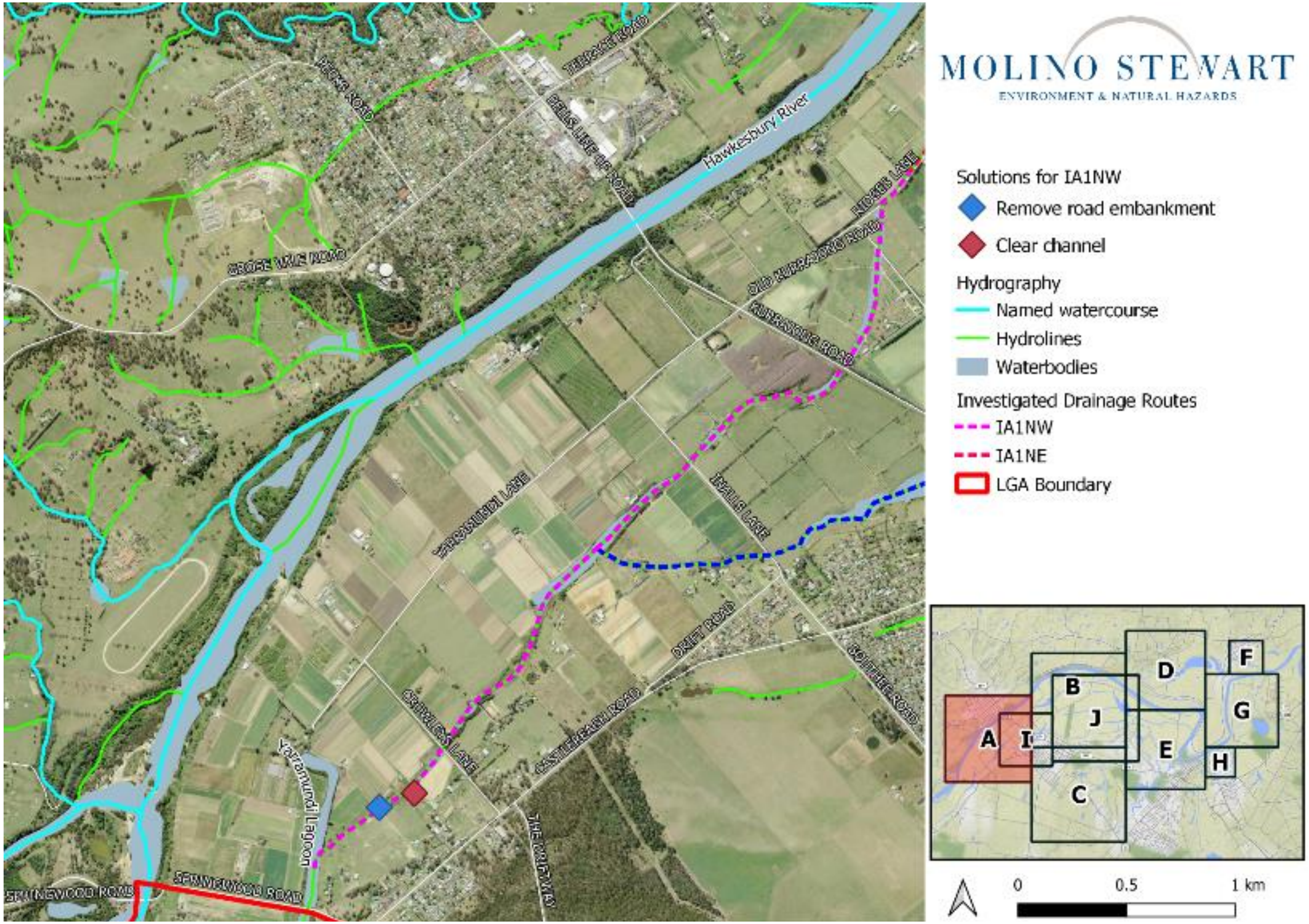

Figure 10: Solutions for IA1NW

4.2 Environmental Constraints

a) Zoning

Section A of the Northern Drainage Route predominantly traverses land zoned as RU2 – Rural Landscape with small segments crossing into the zones C2 – Environmental Conservation, RU4 – Primary Production Small Lots, and SP2 - Infrastructure (Figure 11). Yarramundi Lagoon, which lies at the upstream end of the Northern Drainage Route, is zoned as C2, between Crowleys Lane and Inalls Lane the drainage channel borders land zoned as RU4, and the Kurrajong Road Reserve, through which the channel crosses, is zoned as SP2.

b) Maintenance of existing drainage channels, including clearing of the channel, is permitted without consent for zones RU2, C2, RU4 and SP2, while reinstating or rectifying drainage lines requires development consent. For land zoned as SP2 reinstatement/rectification works are prohibited, unless carried out by or on behalf of a public authority in which case they are permissible without consent. Therefore, clearing the existing drainage channels is permissible without consent, while removing the road embankment is subject to development approval. Contamination

Environment Protection Authority (EPA) contaminated land records of notices for the Hawkesbury LGA are shown in Table 1. Notified contaminated sites on or near the Hawkesbury Floodplain are shown in Figure 4.

There are no known contaminated sites within northern drainage route IA1NW.

c) Acid Sulphate Soils (ASS)

Northern drainage route IA1NW is surrounded by Class 4 and 5 land on the HLEP ASS Map (Figure 12). To the west of Crowleys Lane the drainage channel is surrounded solely by Class 5 land and to the east of Crowleys Lane, extending to Ridges Lane, the channel is surrounded by Class 4 land.

According to the HLEP 2012 Part 6.1, development consent in Class 4 land is required for works more than 2m below the natural ground surface or are likely to lower the watertable by more than 2m below the natural ground surface. For Class 5 land development consent is required for works within 500 m of adjacent Class 1, 2, 3 or 4 land that is below 5 m Australian Height Datum and by which the watertable is likely to be lowered below 1 m Australian Height Datum on adjacent Class 1, 2, 3 or 4 land. Development consent cannot be granted unless an ASS management plan has been prepared for the proposed works in accordance with the ASS Manual.

However, development consent is not required if the works involve the disturbance of less than 1 tonne of soil or are not likely to lower the water table (*HLEP 2012* Part 6.1 (6)); if a preliminary assessment (prepared in accordance with the ASS Manual) indicates that an ASS management plan is not required (*HLEP 2012* Part 6.1.4); or if works are conducted by a public authority and are either emergency work or routine maintenance work as described in the HLEP Part 6.1 (5).

The recommended works of removing the obstructions from the channel and bridging the channel are not likely to exceed any of the above thresholds with regard to ASS disturbance.

d) Heritage

i) HLEP Heritage Items

IA1NW traverses three General Heritage Items; items I444 and I82 between Crowleys Lane and Inalls Lane, and I00035 between Inalls Lane and Kurrajong Road (Figure 13). The details of these heritage items are shown in Table 3 (*HLEP 2012* Schedule 5). The location of the recommended works are outside of these areas. Vegetation clearing within item 1444 would improve drainage, but these works required further assessment due to ecological values in the area.

Table 3: HLEP Heritage Items (IA1NW)

Item Number	Item Name	Address	Significance
1444	"Bronte"	248 Castlereagh Road, Agnes Banks	Local
182	"McMahon Homestead"	26 Drift Road, Richmond	Local
I00035	"Hobartville"	36-86 Inalls Lane, Richmond	State

ii) AHIMS Heritage Items

An AHIMS Basic Search of constraints extent A returned 14 Aboriginal Sites, some of which appear to be near IA1NW (Figure 14). However, the exact location and nature of these sites is not known from a Basic Search. Therefore, for any works on IA1NW, a Basic Search of the specific works extent should be conducted to confirm whether any Aboriginal Sites are nearby. If an initial basic search returns any Aboriginal Sites, an AHIMS Extensive Search is required.

However, given that the recommended works are mostly within the channel through an area highly modified by agricultural activity, there is a low probability that any items of Aboriginal heritage value will be disturbed.

e) Wetlands and Coastal Areas

There are three wetlands identified along IA1NW, of which all are mapped on the HLEP Wetlands map and as Coastal Wetlands in the R&H SEPP. These are Yarramundi Lagoon which is at the upstream end of the drainage route, the segment of the route between Crowleys Lane and Inalls Lane, and the segment between Kurrajong Road and Ridges Lane (Figure 15).

Before development consent can be granted for any works conducted within the extent of these wetlands the provisions set out in Part 6.5 (3) and (4) of the HLEP must be satisfied. These provisions are quoted in Section 3.5 of this report.

The location of the recommended works are outside of Yarramundi Lagoon and none of the works would be in mapped coastal management areas. However, the works will impact on the permanent water level in Yarramundi lagoon and that needs to be carefully assessed before they are undertaken.

f) Ecology

i) PCT Mapping

There are two PCTs mapped along segments IA1NW; these are PCT 781 and PCT 835 (Figure 16). PCT 781 is mapped along Yarramundi Lagoon, surrounding the drainage channel outlet and continuing to the south along the eastern bank; along the majority of the drainage channel between Crowleys Lane and Inalls Lane; and along majority of the drainage channel between Kurrajong Road and Old Kurrajong Road. PCT 835 is mapped along Yarramundi Lagoon, immediately to the north of the drainage channel outlet and continuing to the north; and along the drainage channel either side of Kurrajong Road and extending southwest approximately 200 m.

Plant species observed during field inspections were consistent with the PCTs mapped along IA1NW. However, the 300 m segment immediately east of Crowleys Lane, which is not mapped as a PCT, was densely vegetated with native flora and relatively free of invasive species. Conversely, the plant communities mapped either side of Kurrajong Road were heavily degraded.

The location of the recommended works are not within areas mapped as a PCT.

ii) Terrestrial Biodiversity

Majority of IA1NW is within land identified as either 'Significant vegetation' or 'Connectivity between significant vegetation' on the HLEP Terrestrial Biodiversity Map (Figure 17). This includes the following segments:

- Yarramundi Lagoon to Crowleys Lane: 'Connectivity between significant vegetation';

- Crowleys Lane to Inalls Lane: ‘Significant vegetation’;
- Inalls Lane to Kurrajong Road: ‘Connectivity between significant vegetation’ either side of an approximate 200 m segment which is not identified on the HLEP Terrestrial Biodiversity Map; and
- Kurrajong Road to Ridges Lane: ‘Significant vegetation’.

While the recommended works are within an area mapped as ‘Connectivity between significant vegetation’, the type of works will not disturb any vegetation other than some reeds growing in the channel. They are therefore unlikely to have a significant impact on connectivity values.

iii) BVs

Three segments of IA1NW are mapped as ‘Biodiversity Value’ on the DPE Biodiversity Values Map. These are Yarramundi Lagoon, Crowleys Lane to Inalls Lane, and Kurrajong Road to Ridges Lane (Figure 18).

The recommended works are not within any of these segments and therefore would not have any impact on biodiversity values.

iv) Threatened Species

A range of threatened species have been recorded in close proximity to IA1NW including 6 bird species, 9 bat species, 3 plant species and the Cumberland Plain Land Snail (Figure 19). Suitable habitat for many of these species is present along IA1NW, particularly for the segment between Crowleys Lane and Inalls Lane where the riparian zone is densely vegetated. It is likely that threatened species utilize this habitat, at least temporally.

However, there have been no threatened species recorded in the vicinity of the recommended works and none were observed during the inspection. Threatened species are therefore not likely to be a constraint to the works.

v) Key Fish Habitat

There is no KFH along this drainage line (Figure 20) so this is not a constraint to the recommended works.

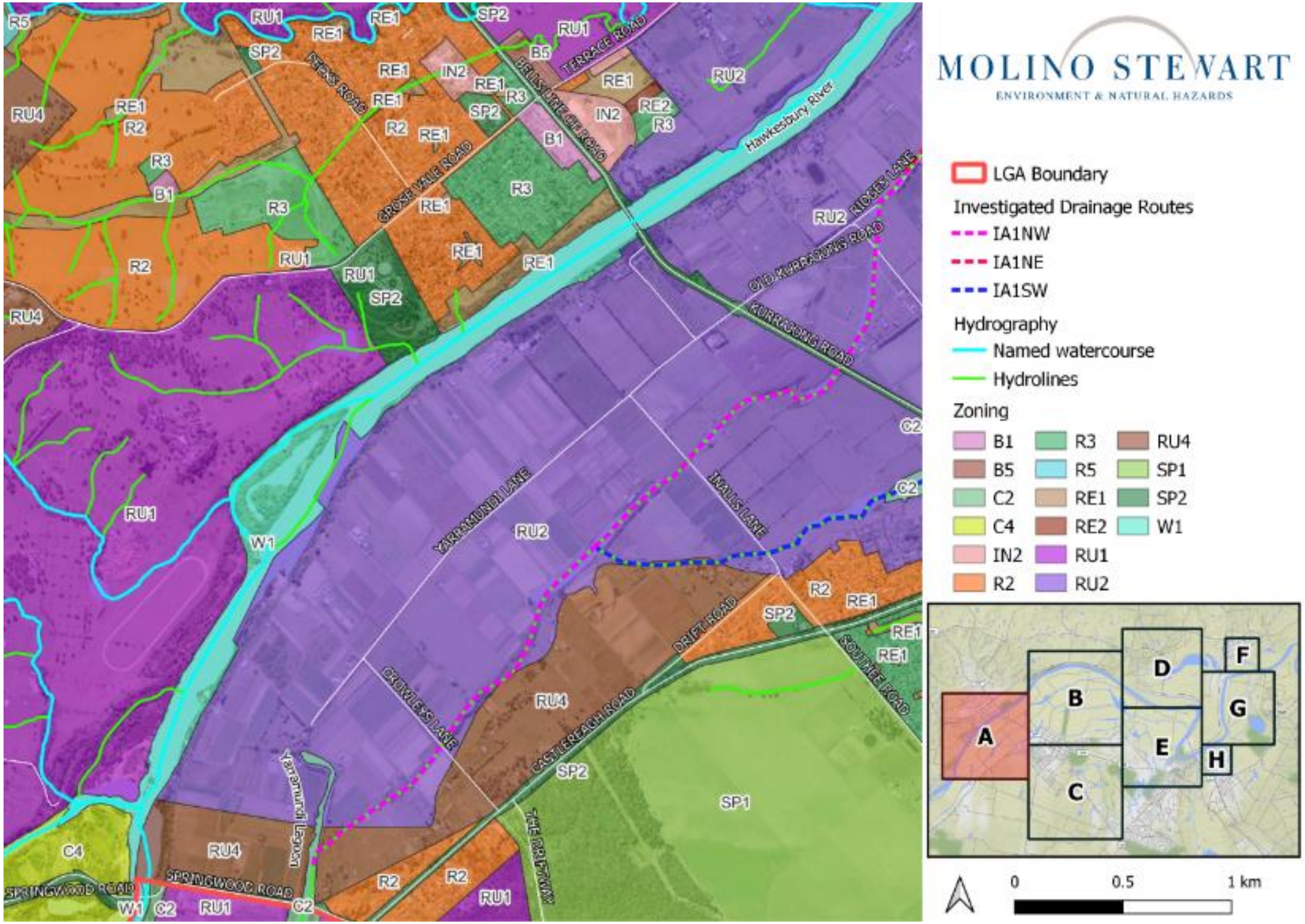

Figure 11: Land Zoning (Extent A)

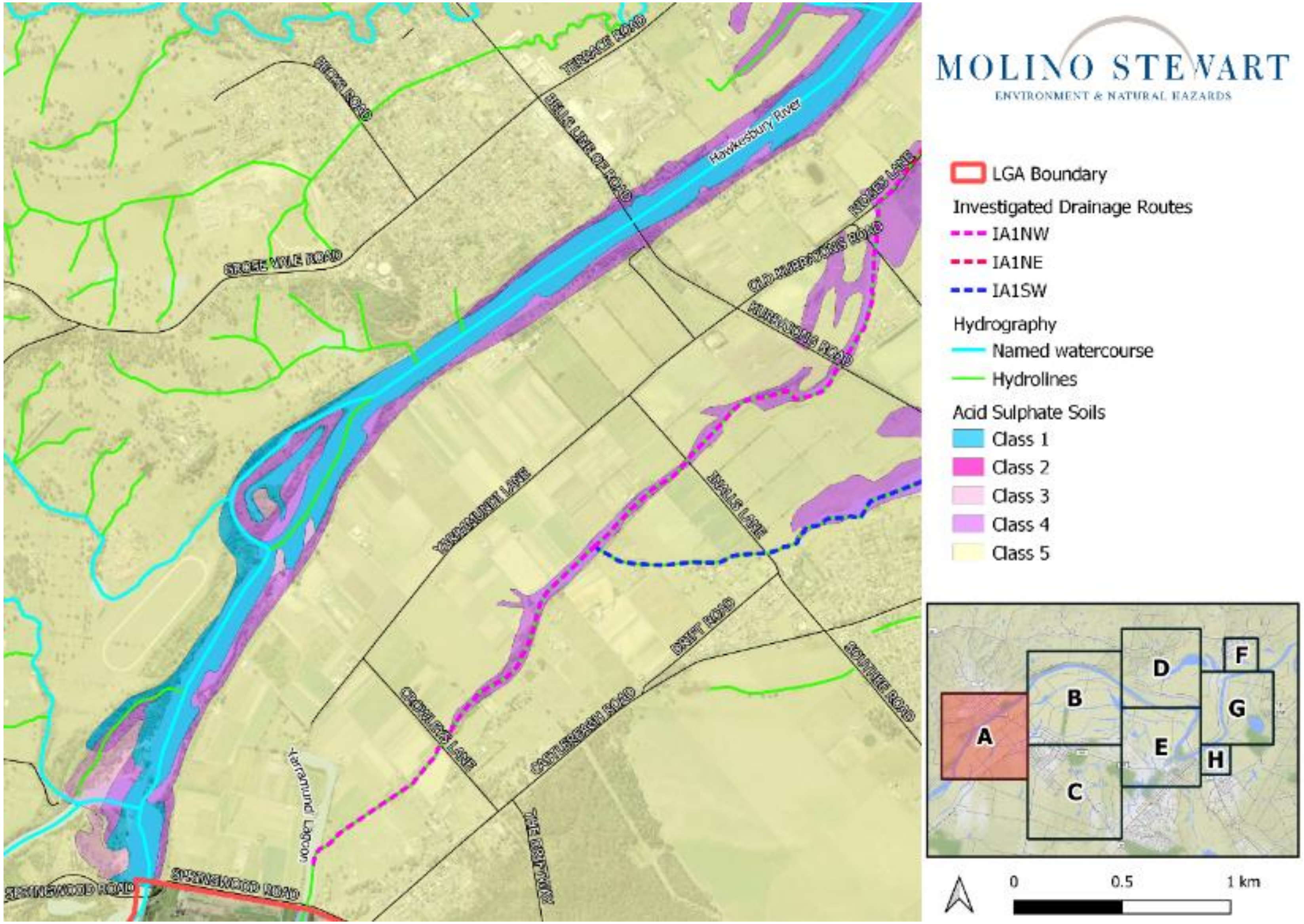

Figure 12: Acid Sulphate Soils (Extent A)

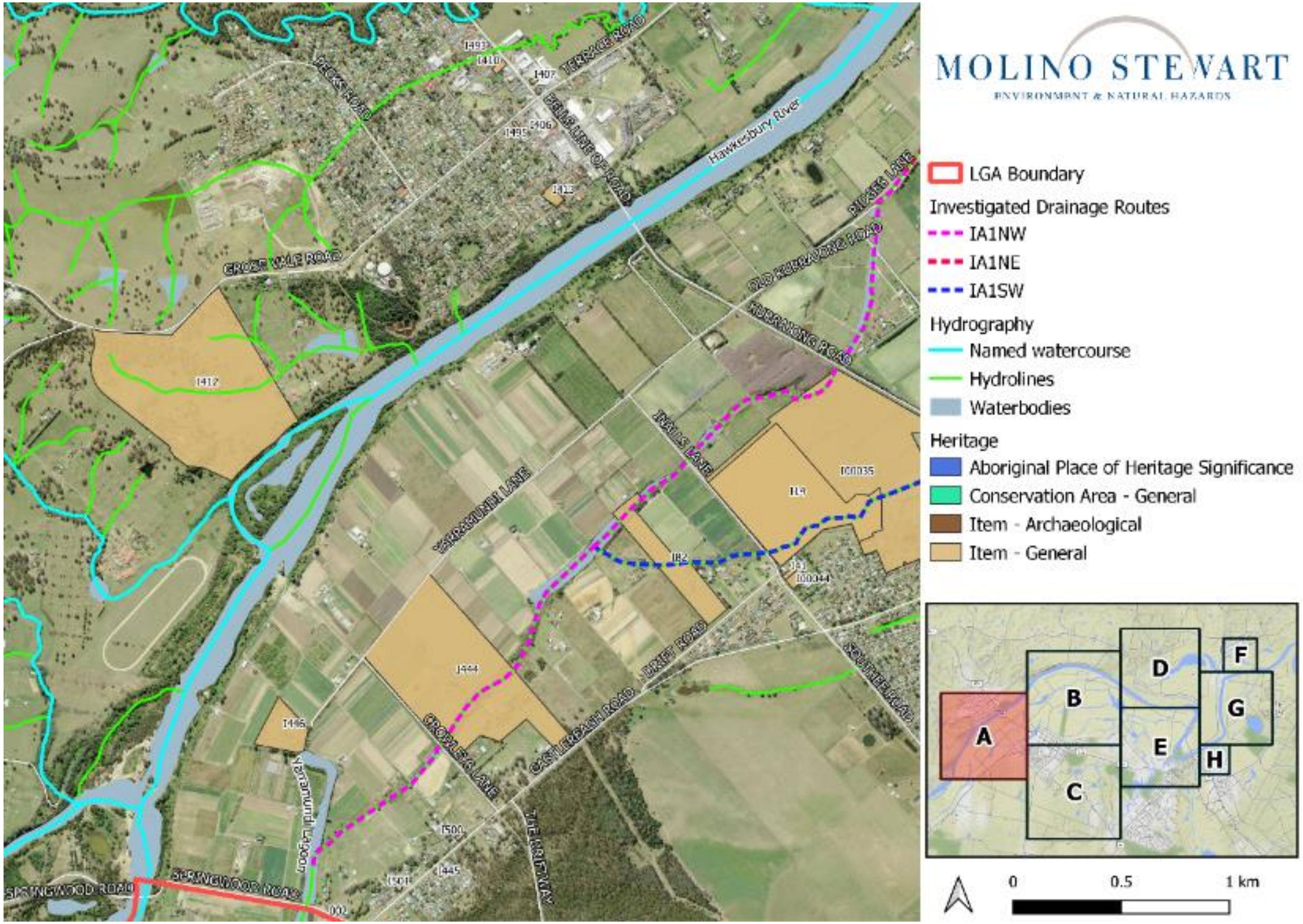

Figure 13: HLEP Heritage Places, Areas and Items (Extent A)

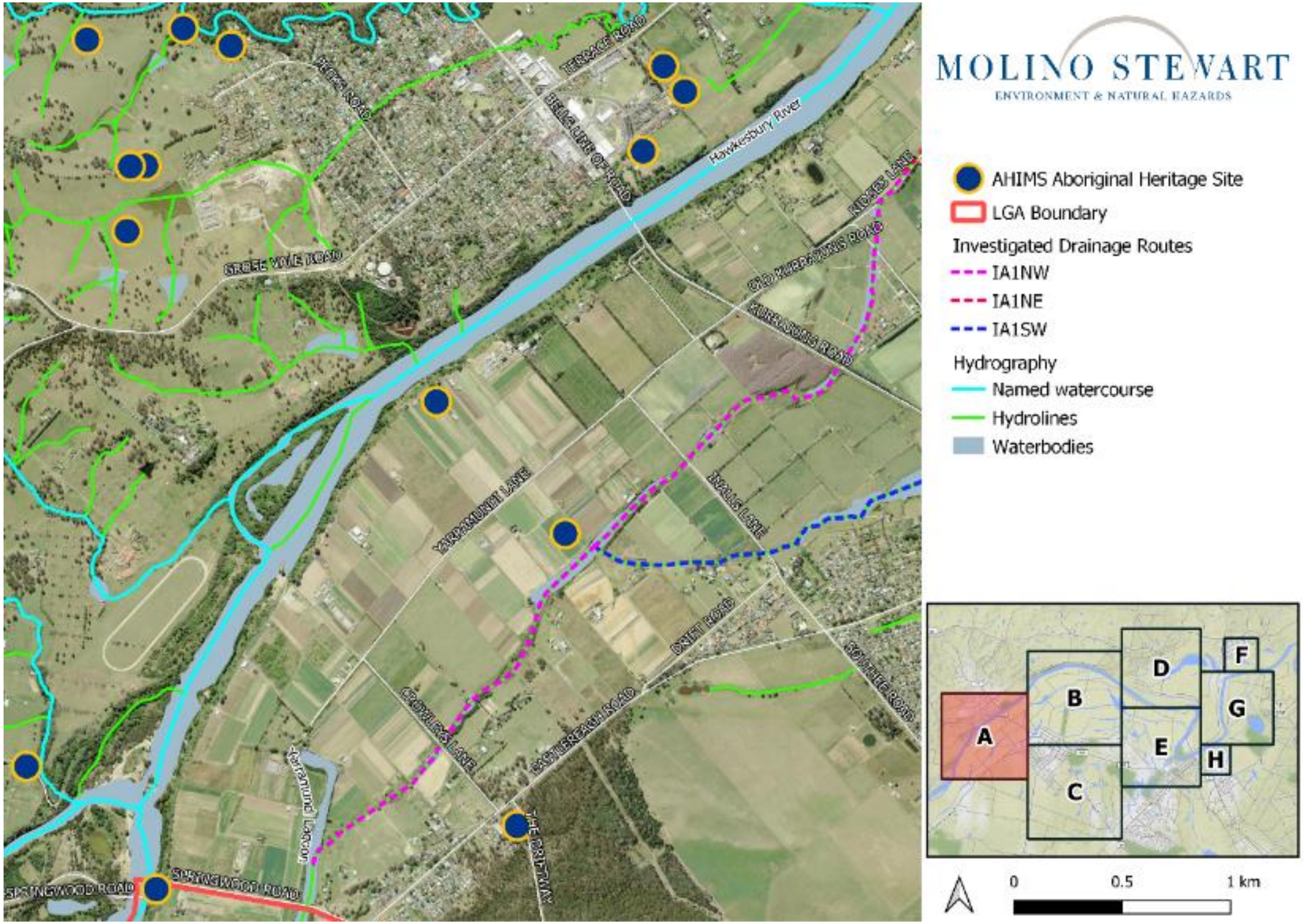

Figure 14: AHIMS Aboriginal Sites (Extent A)

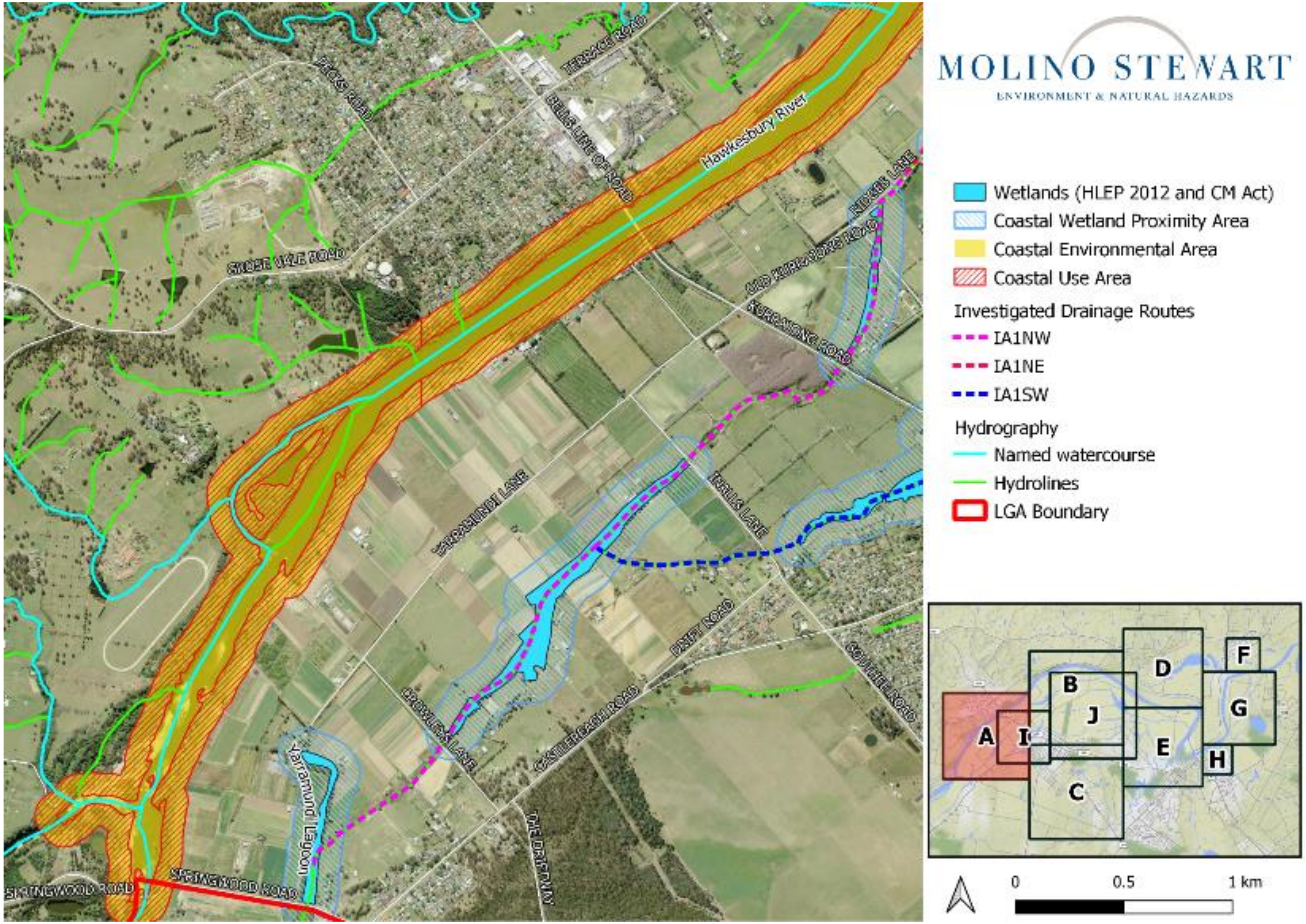

Figure 15: Wetlands and Coastal Management Areas (Extent A)

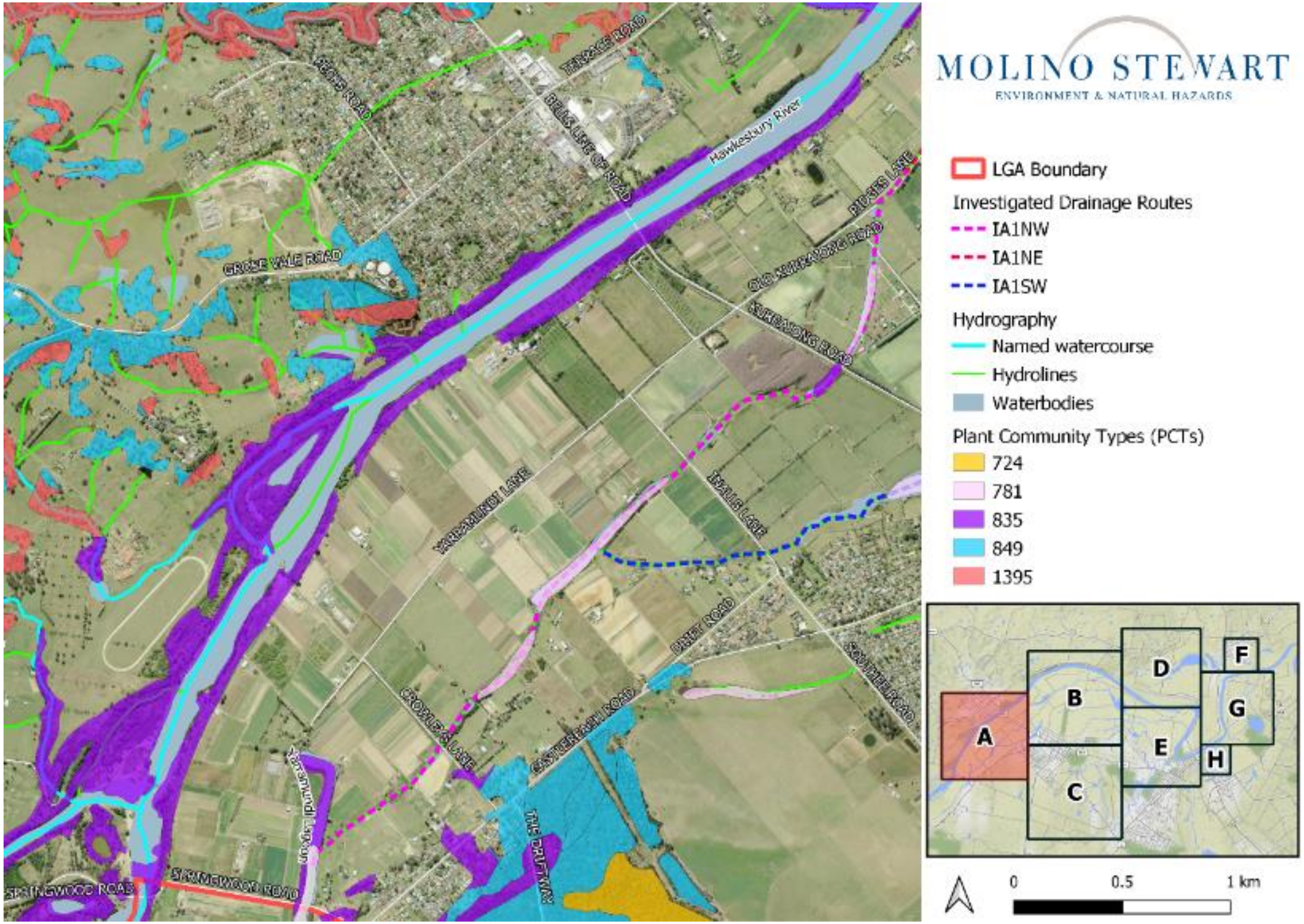

Figure 16: Plant Community Types (Extent A)

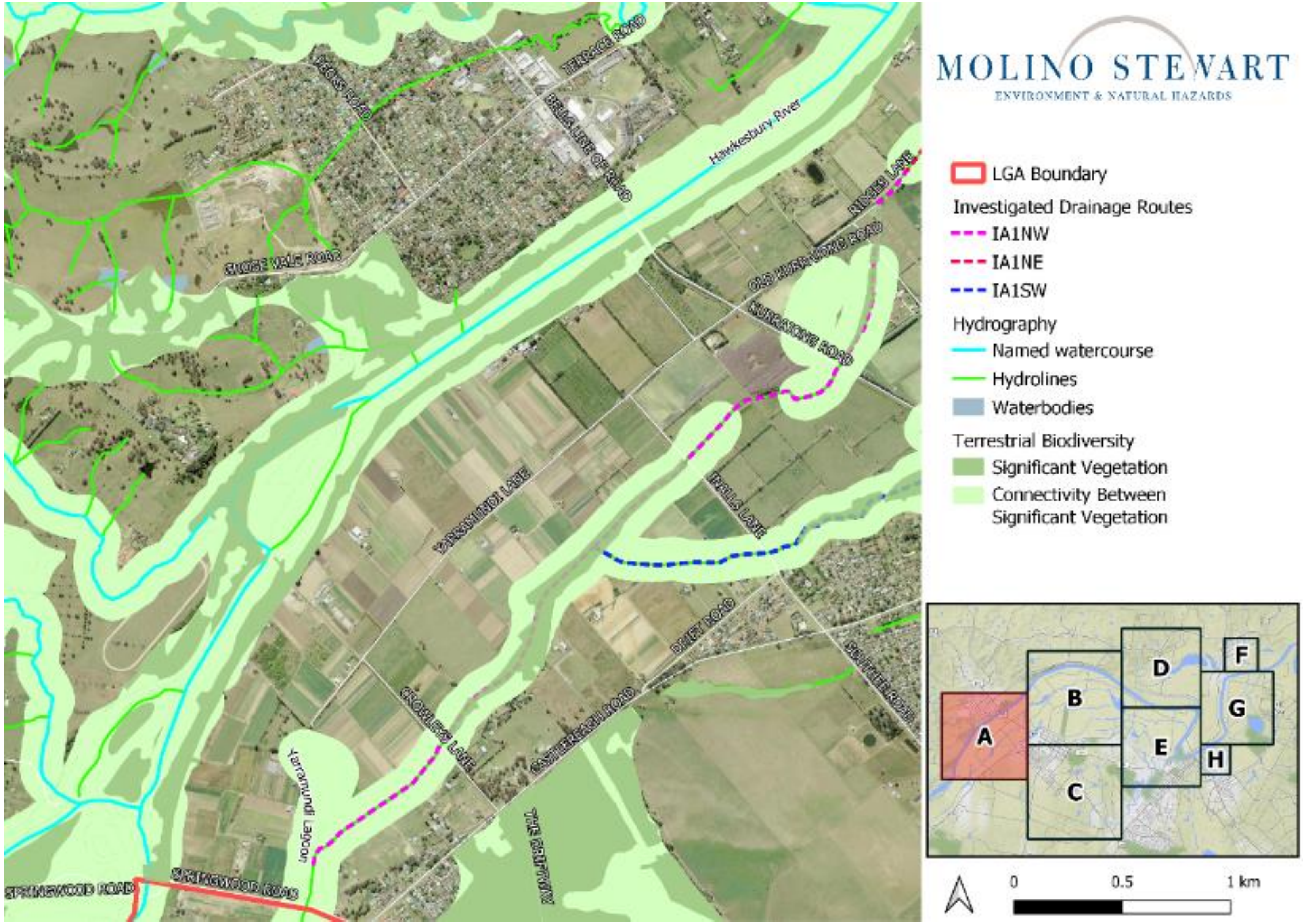

Figure 17: Terrestrial Biodiversity (Extent A)

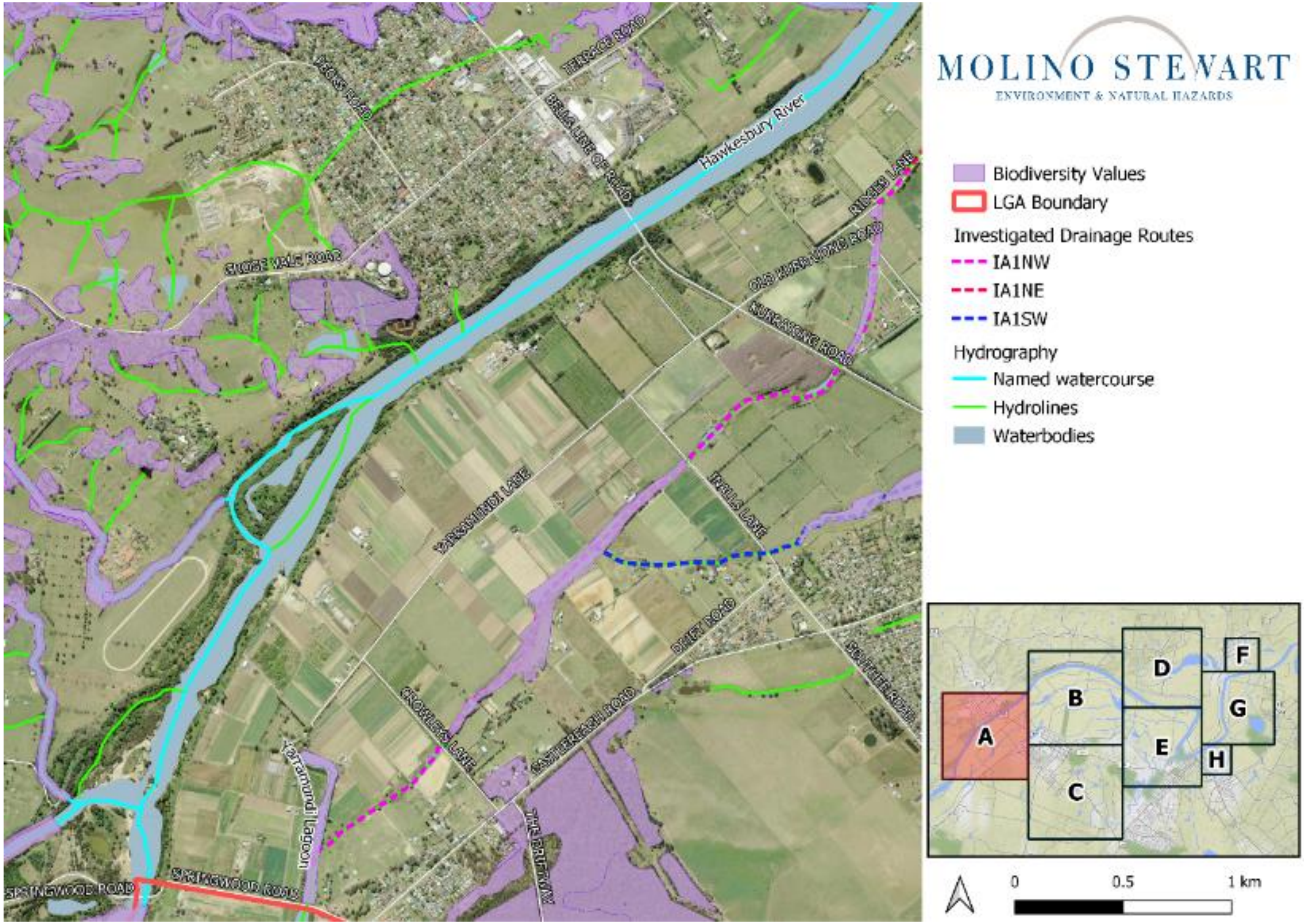

Figure 18: Biodiversity Values (Extent A)

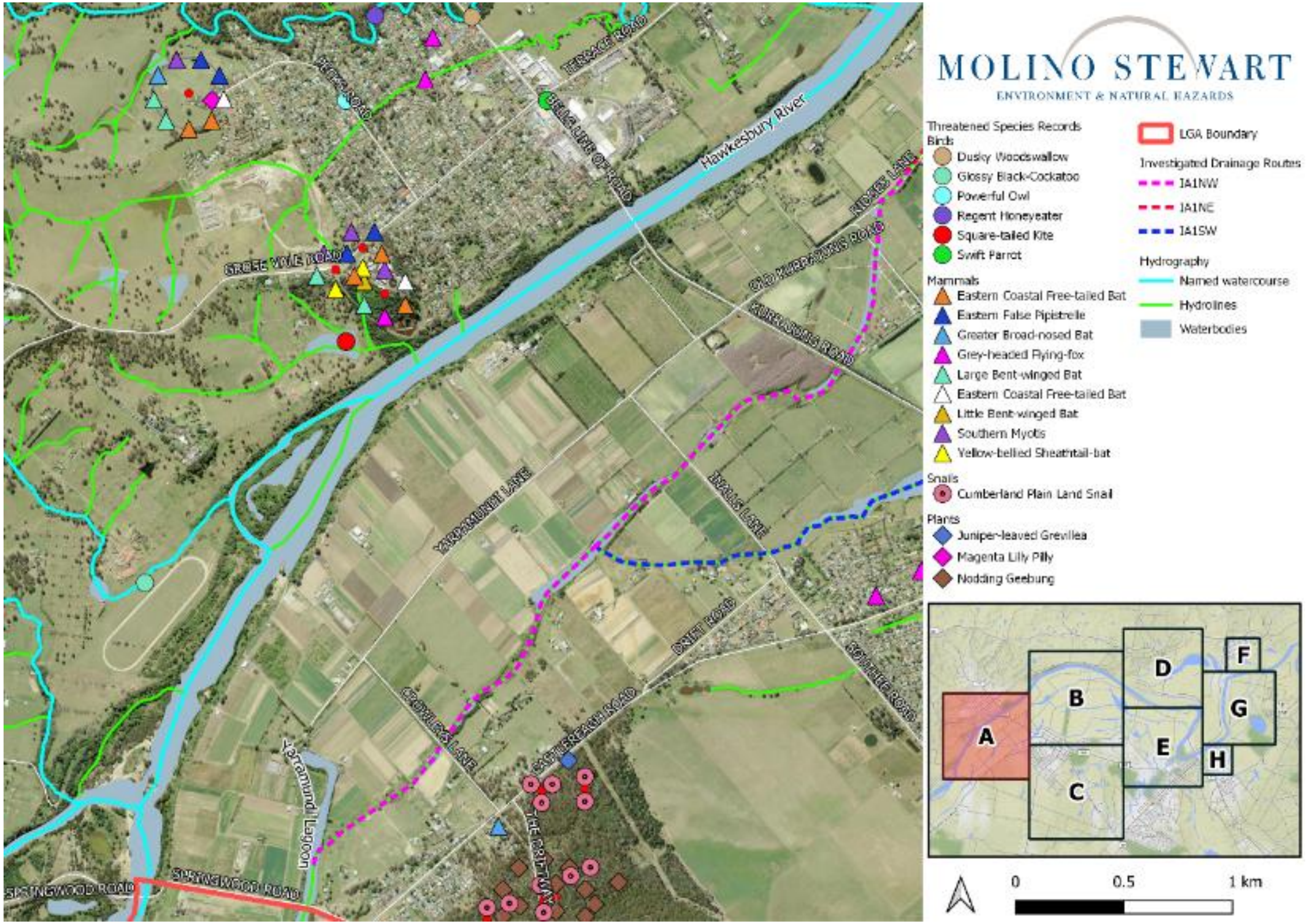

Figure 19: Threatened Species Records (Extent A)

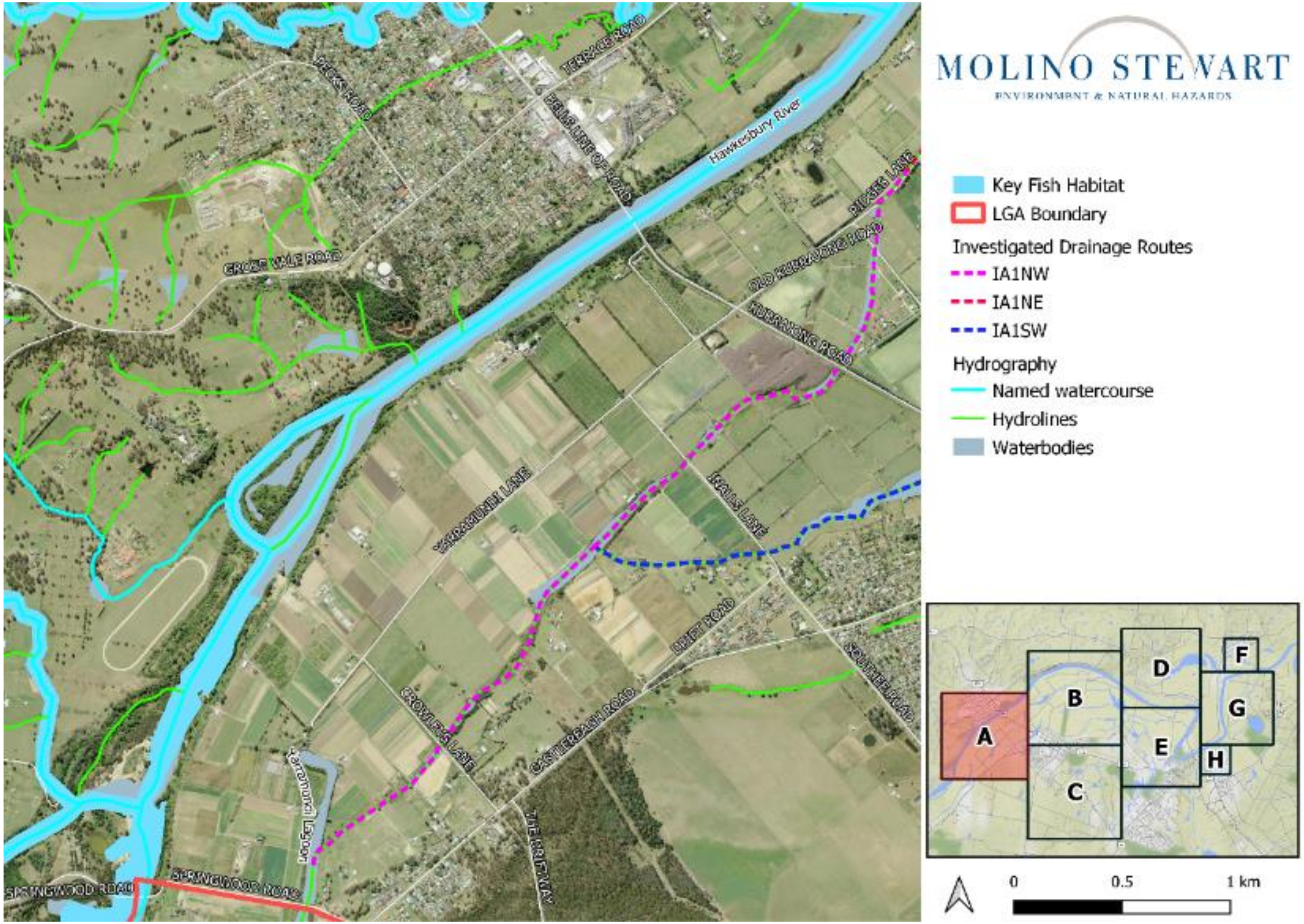

Figure 20: Key Fish Habitat (Extent A)

5| IA1 Northern Drainage Route East

5.1 Drainage Issues

This chapter deals with the eastern section of the northern drainage route IA1NE (Figure 21). This starts at the eastern end of IA1NW where it veers east and crosses under Ridges Lane before flowing north past Sydney Polo Club and eventually crossing Edwards Road and into the Hawkesbury River to the north of Cornwallis Road.

The locations of each photograph referred to in the text can be found in Figure 22.

5.1.1 Field observations

There is a drainage channel along the northern side of Ridges Lane (Photo 34) which was free flowing through a pipe under Ridges Lane (Photo 35) and into a pond on the southern side of the road (Photo 36). At this flow rate there was no apparent constriction to flow along this section of the drainage path.

However, the outlet of the pond (Photo 37) was partially submerged with no discernible flow through the pipe. This indicated that the level in the pond was controlled by the water level downstream of the outlet which itself was ponded.

The expanse of water downstream of the pond outlet and at the same level as the pond water, had formed in a natural depression in the landscape which is mapped as a lagoon on the topographic maps and as a wetland in the Hawkesbury Local Environmental Plan (LEP) 2012. The lines of trees on the northern side of the lagoon suggest what the property owner considers to be the “full” level of the lagoon. These are the trees which can be seen to be standing in water in (Photo 38) on 26 May.

There is an access road which crosses the lagoon towards its downstream end and this has four 900mm diameter pipes under it (Photo 39). The water level was the same upstream and downstream of these pipes and there was no flow observed running through them. This means they do not constrict flow at this water level.

The manager of the property on which this lagoon sits noted that the water level had fluctuated following the March 2022 flood with the water slowly draining immediately after the floods but then rising again from local rainfall events within the catchment.

The outlet to the lagoon passes under Powells Lane through two 1.8m box culverts (Photo 40) through which there was no discernible flow. A few metres downstream of this culvert the drainage line is crossed by a private access track on the farm which is immediately to the east of Powells Lane. There is a smaller culvert under this track (Photo 41) but its size could not be measured because it was fully submerged.

The water level upstream and downstream of the box culverts under Powells Lane and upstream and downstream of the small culvert under the private access road were the same and there was no discernible flow through the culverts. This means that at this flow rate, neither culvert is constricting flow out of the lagoon. It means that there is an obstruction further downstream which is causing water to pond in the lagoon.

When this location was visited following the July flood the water level was a few hundred millimetres higher but there was still no discernible flow through the large culverts (Photo 42) and the private crossing was completely submerged.

While at the observed water levels the small downstream culvert did not appear to be constraining outflow from the lagoon, were water to be flowing downstream of this culvert then it would most certainly control the rate of outflow from the lagoon.

Moving downstream, the drainage line is a broad swale with varying invert levels so that during dry periods it becomes a series of disconnected ponds but was a long continuous pond in May 2022 (Photo 43). It is crossed by a private access road about 400m downstream of Powells Lane and flows through a culvert of a similar size to the one further upstream on the same property (Photo 44). As there was no flow through this culvert it too was not the control of ponding upstream of this point.

Downstream of this access road the drainage line meanders somewhat but becomes increasingly channelised but informally so (Photo 45). About 450m downstream it is traversed by two separate crossings 30m apart (Photo 46). The first of these has a single 1,200mm diameter pipe and the second two 600mm and one 900mm diameter pipes (Photo 47). These crossings are far less formal than those upstream both in the way in which the road has been constructed and the fact that the pipes protruded from each end of the embankment with no headwall.

Nevertheless, there is no measurable flow in the channel at this point and no level change between upstream and downstream of either crossing. Therefore, there is no flow obstruction in this reach of the drain at this water level. That is not to say that at lower water levels there is no obstructions to flow through these pipes or that the pipes themselves do not form a restriction to the flow at higher or lower water levels. This comment equally applies to each culvert along the channel.

About 350m downstream of these crossings the channel becomes formalised (Photo 48) and is about 5m wide by 2m deep. There is another drainage channel which enters at this point after flowing through an embankment with a flood gate (Photo 49). The flood gate looks like it might be faulty as it was neither open nor closed on the day of the inspection.

The formalised channel continues as far as Edwards Road, a distance of about 450m. About midway along this section of channel there is a crossing with a 1500mm pipe (Photo 50). Irrigation pipes cross the channel below the obvert of the pipe immediately upstream and downstream of the crossing (Photo 50 and Photo 51). On the day of inspection on 31 May the water level in the channel was below the pipes, there was no noticeable flow in the channel and the water level was the same at each end of the culvert.

The drain passes under Edwards Road through a 1500mm pipe with no headwall (Photo 52) and there are irrigation pipes passing across the channel below its top immediately upstream and downstream of Edwards Road (Photo 52 and Photo 53). During the 31 May inspection the water level was below the obvert of the culvert and below the inverts of the irrigation pipes although two of the downstream irrigation pipes had broken and fallen into the channel. There was no discernible flow in the channel and no change in water level.

When this location was observed on 12 July, the water level was above the obvert of culvert and there was a fast flow in the channel (Photo 54 and Photo 55). Downstream of Edwards Road the channel continues for another 200m but changes character in that there are large casuarinas scattered along its banks and the terrain rises so the channel becomes more incised (Photo 56). It then passes under a private access road via a 1500mm pipe (Photo 57). Again, there was no noticeable flow at this point.

Downstream from here the banks become progressively more incised and more densely vegetated, mostly with weeds (Photo 58), until it passes under another road through a pipe (Photo 59). There was still no noticeable flow at this point.

As the channel moves from this point toward the river the terrain continues to rise and the channel resembles a deeply incised creek with vegetated banks. Weeds dominate the vegetation with only the occasional Casuarina observed (Photo 60).

As the banks become higher and steeper there is increasing evidence of bank collapse. At a location about 550m downstream of Edwards Road there is a particularly severe bank collapse which has deposited material in the channel (Photo 61, Photo 62, Photo 63 and Figure Photo 64). While some of this material has been reworked by the water, it remains an obstruction to flow. In May this was the first location downstream of Ridges Lane that any flow was able to be observed. This means that this material is causing the water to back up for about 3 km.

A little further downstream there is some more material which has collapsed into the stream (Photo 65) and the channel narrows (Photo 66). These create further obstructions to flow, albeit at lower levels.

This location was also visited on 12 July. The flow rates were discernibly greater but these locations still were showing a drop in the surface level of the water as it passed these obstructions (Photo 67).

Downstream of these constructions the water was flowing freely through the creek and into a large culvert (Photo 68) which is fitted with floodgates which appeared to be stuck open. This was the same situation on 12 July but there was considerably more flow through the culvert.

Downstream of the floodgates there is several metres of fall over a number of small cascades down to the river level. While there has been significant bank collapse in this reach of the creek, the material has been reworked and does not pose an obstruction to flow upstream of the flood gates.

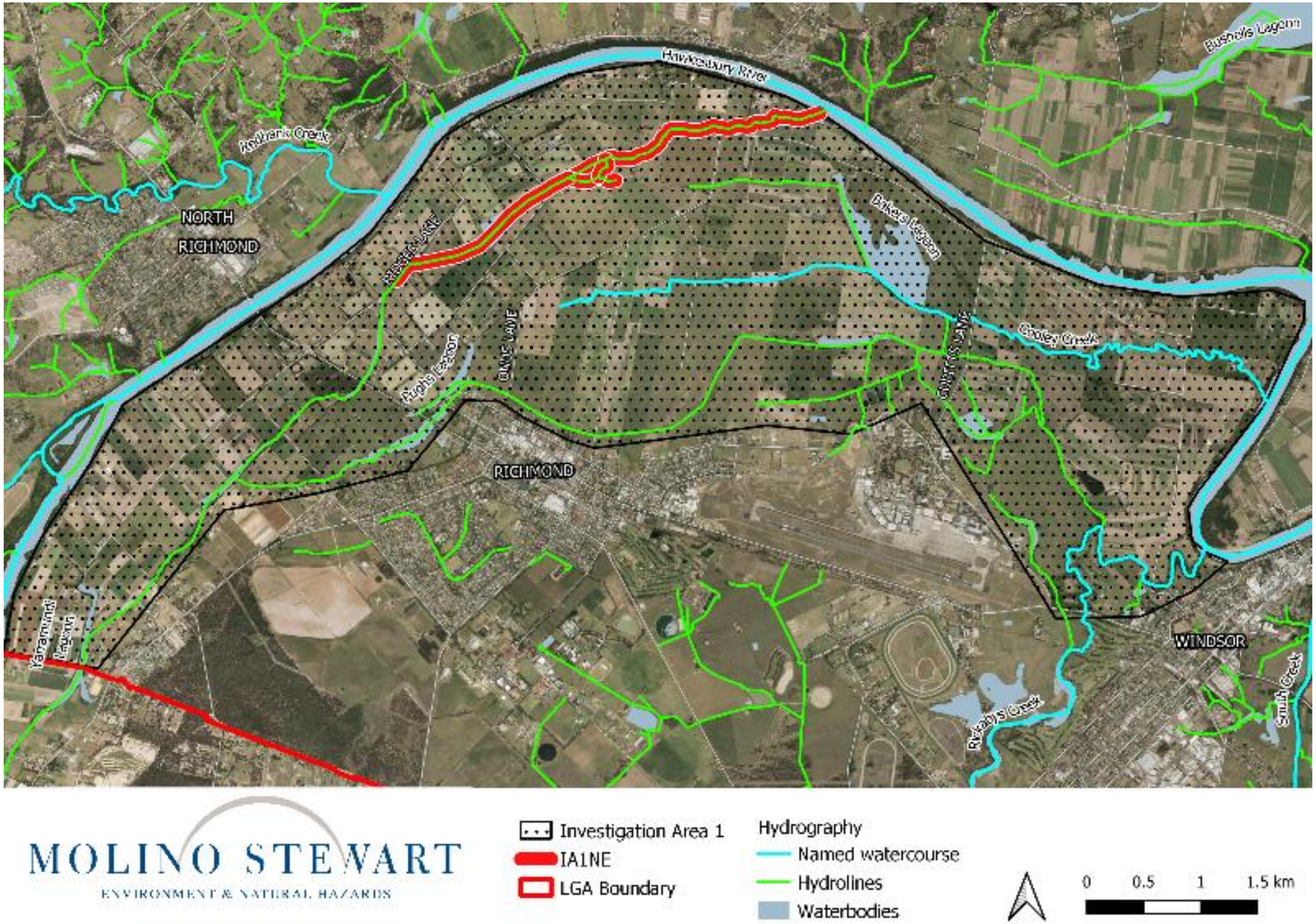

Figure 21: Investigation Area 1 Northern Drainage Route East (IA1NE)

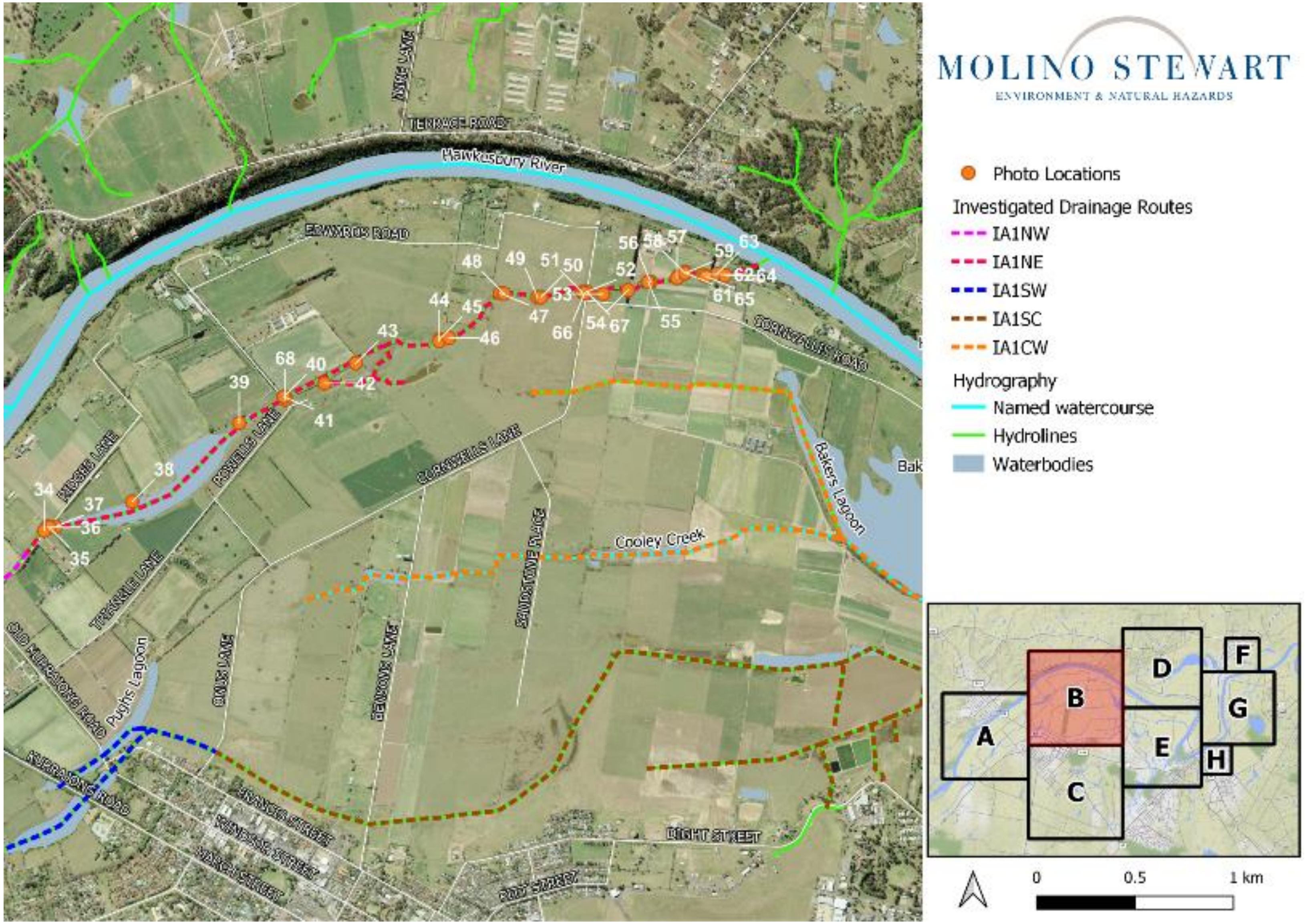

Figure 22: Photo locations for IA1NE

Photo 35

Photo 36

Photo 38

[redacted]

[redacted]

Photo 41

Photo 42 [redacted]

Photo 43 [redacted]

Photo 44

Photo 45

Photo 47

Photo 50

Photo 52

Photo 53

Photo 54

Photo 55

Photo 57

Photo 58

Photo 59

Photo 60

Photo 62

Photo 64


Photo 66


Photo 67


Photo 68

5.1.1 Probable causes

Because no difference in water level or flow rate was observed between Ridges Lane and the bank collapse 3km downstream, it is reasonable to surmise that the ponded water observed between these locations in May was being caused entirely by the material which had blocked the channel due to the bank collapse.

Removal of this material will remove the obstruction at this point and enable the ponded water to drop to a lower level more rapidly. However, as this choke point is 3km downstream of the broadest extent of the ponded water, there is the potential for latent chokepoints to be revealed within this 3km stretch as the water level drops. For example, there may be material deposited in the bed of the creek or the drains upstream of the observed choke point which may simply cause the obstruction to flow to be moved upstream but at a slightly lower level. Alternatively, the many culverts under roads and crossings may have a capacity less than the culverts upstream or downstream of them and therefore the rate of drainage will be controlled by the crossing with the lowest flow capacity. These constraints will only be revealed as the material from the bank collapse is removed from the channel or the levels in the channel drop over time.

Furthermore, as the July 2022 flood has occurred since the original field inspections, it is possible that further outflows may have moved some of the sediment. The water levels were higher during the limited field observations in July, so it was not possible to ascertain this but at the location of major bank collapse the situation did not seem to have improved.

It should also be noted that the detailed observations were made at least seven weeks after the floodplain had been covered by floodwaters from the Hawkesbury River and so obstructions which slow the drainage at higher water levels were not observed. Yet such obstructions must exist because on 12 July there was significant flow through the drain at Edwards Road but at Powells Lane no flow was able to be discerned. This means that there is at least one point between these two roads which is constricting flow at these higher water levels.

While removal of sediment from the drainage channel will provide an immediate solution to the flow constriction caused by the bank collapse, it is important to understand what has caused the bank collapse in the first place when considering long term solutions to the problem.

The Richmond Lowlands are composed of alluvial material which has been deposited by millennia of floods. It is a combination of silts, sands and clays and, because it has simply deposited as the water level in the river has dropped, the material is unconsolidated. Furthermore, as water spills from the river channel over the Richmond Lowlands during a flood, the reduction in water velocity causes suspended material to drop out of the water and deposit on the floodplain. This deposition has created a natural levee along the eastern and southern banks of the Hawkesbury River along the reach from Agnes Banks to Cornwallis and this can be seen in the ground elevation data in Figure 23. The material closest to the river has a high proportion of coarser materials such as sands and some silts while further from the river more silts and clays are deposited as the water ponds and slowly drains.

The natural drainage process after a flood is that the build up of water behind the levee would penetrate though weak points in the levee and drain the floodplain to a certain degree but low points would remain filled with water and form wetlands and lagoons. The course of the river, the location of the levee and penetrations which form creeks would have shifted over time depending on the pattern of floods and other flows in the river. Since non-indigenous settlement of the floodplain, efforts have been made to fix the location of the riverbanks, levees and drainage points and to improve the flood protection and the rate of drainage of the lowlands by installing flood gates and constructing drainage channels.

While it is clear that sections of the drainage line which is the subject of this report have been constructed, it is unclear whether that is the case along its whole length. For example, the meandering path of the channel as it approaches the river suggests that this section at least is a natural water course. The earliest air photo we were able to find for the area dates from October 1955 (Figure 24) and the lower reach is meandering, devoid of vegetation other than grasses and appears to have banks less steep than they are today.

The steepness of the banks today is a critical issue. As the floodplain gets covered by water all the soils become saturated. As the water level in the river drops, the ground water level in the soils begins to drop also but at a much slower rate because it has to find its way through the soil particles and out into the open at the river or creek banks. This causes a buildup of water pressure within the soils on the banks reducing the effective stress between soil particles and hence the shear strength of the sediment. If the draining groundwater reduces sediment shear strength to below that required to keep the stream bank stable, the stream bank will collapse. Because the soils are unconsolidated with nothing but the weight of soil above them to compact them, they have very little cohesive strength. Closer to the river the composition of the soils has more sand and silt than clay which gives the soils even less cohesiveness.

The consequences of this are that wherever river and creek banks are steep and composed of unconsolidated and non-cohesive sediments, they are prone to slumping as the water level in the river and creeks drop and there is unequal water pressure between the soil and the air.

In the location of the observed bank collapse the creek is deep because it is penetrating through the natural levee along the river. The banks are steep because it appears that as the land use has moved from grazing to food crop production in the 1970s (Figure 25) and more recently turf farming, efforts have been made to flatten and expand the fields at the expense of flatter creek banks

5.1.2 Possible solutions

Removal of the sediment deposited into the drainage channel as a result of the multiple bank collapses would improve the water flow through the channel, resulting in a decrease in the water level within the channel upstream. A small decrease in this water level would result in a relatively large contraction to water pooling upstream, given that land on which the pooling was observed is particularly flat. It would also accelerate the desaturation of soils beyond the pooled waters. The degree to which these effects would occur, following the sediment removal, is dependent on the presence of latent choke points upstream.

The banks along the final 500m downstream end of the drainage channel are steep, lacking deep rooted vegetation, and formed of unconsolidated alluvium. These are properties consistent with poor bank stability and are likely to lead to future bank collapses, particularly during exceptionally wet seasonal conditions.

Table 4 provides a summary of potential intervention options to deal with blockages caused by the bank instability along the final 500m of the drainage channel. A discussion of each follows.

Possible solutions are displayed in Figure 26.

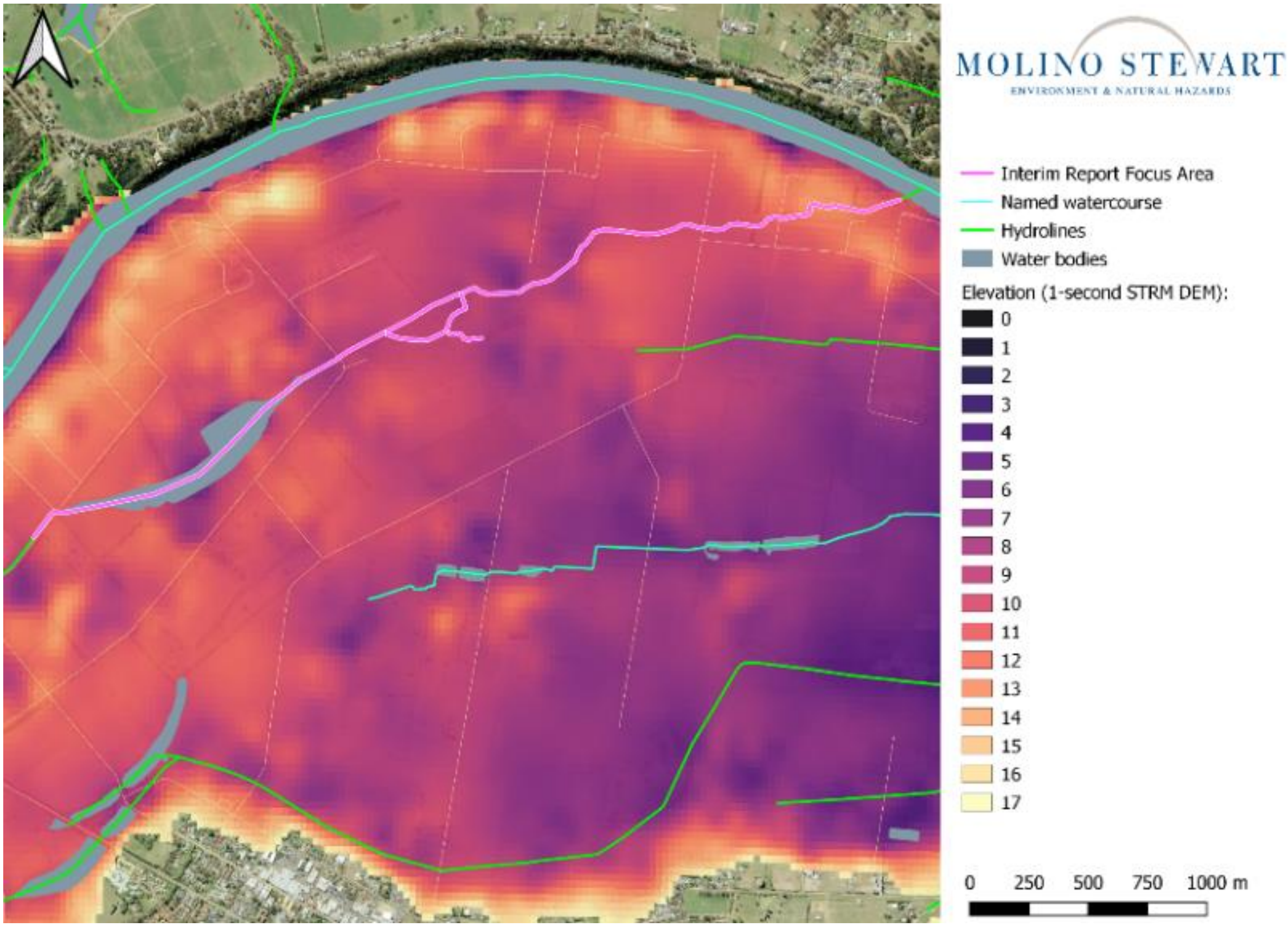

Figure 23: Richmond Lowlands floodplain showing fine scale elevation data

Figure 24: Historical aerial image captured in 1955

Figure 25: Historical aerial image captured in 1970

Table 4: Intervention options for bank stability issues along the final 500m of the drainage channel.

Intervention options	Rationale	Advantages	Disadvantages
Remove sediment that has slumped into the base of the channel.	The current bank failures are occurring during exceptionally wet seasonal conditions. Hence the drain would likely be stable under most other seasonal conditions.	• No capital cost. • Limited impact on adjoining land use.	• Does not improve bank stability. • Reoccurrence of current issues likely during wet seasonal conditions. • Access to clear may be limited immediately following a flood • Maintenance cost of future bank failures.
Bench (terrace) or batter the banks#	Reducing the overall slope between the floodplain and channel invert will reduce the weight (gravitational forces) on the lower bank and thereby the likelihood of bank failure.	• Some assurance regarding efficacy can be provided if based on geotechnical design. • Provides bank conditions amenable to revegetation.	• Cost of design and construction. • Substantial disturbance during construction. • Impact on adjoining land use through reduction in arable land. • A level of geotechnical design required to ensure success.
Install sub-surface drainage#	Install sub-surface drainage at depth to assist groundwater levels to drop with water levels in drain. Thereby reducing the pressure from groundwater in the lower bank and the likelihood of slumping failures.	• Once complete, footprint of works will not impact adjoining land use. • Some assurance regarding efficacy can be provided if based on geotechnical design.	• Cost of design and construction. • Construction footprint. • A level of geotechnical design required to ensure success. • Function of subsurface drains can deteriorate over time. • There will be a local impact on groundwater levels.
Revegetation#	Plant deep rooted vegetation on the banks of the drain, and potentially up to and on top of bank. Such vegetation can augment bank stability.	• Relatively low cost • Has multiple benefits, including ecological. • Low disturbance footprint. • Can complement other intervention options.	• Requires some follow up intervention/ maintenance to ensure vegetation success. • Efficacy relatively low, may not prevent bank slumping. • Difficult to provide design assurance regarding efficacy. • Revegetation on top of bank/ floodplain may impact adjoining land use.

These intervention options include the removal of the sediment that has slumped into the base of the channel

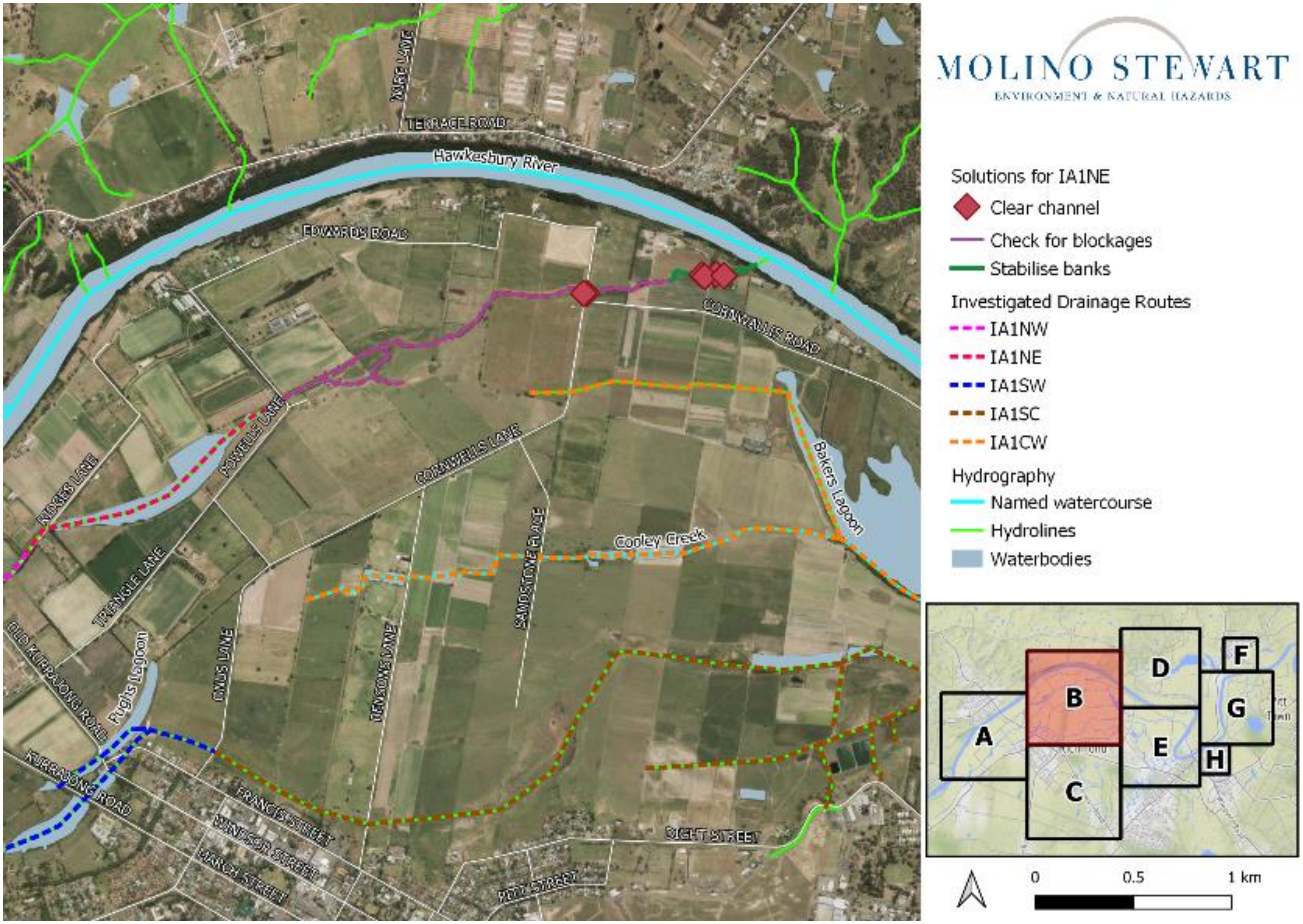

Figure 26: Solution for IA1NE

a) Periodically Clear Blockages

One solution may simply be to remove material from the channel each time a bank collapse occurs or whenever the bank collapse is observed to be blocking drainage. This simply requires targeted works when a problem occurs and would have the lowest immediate cost to implement. Note, the current (July 2022) flooding and drainage of the landscape may partially erode the blockages.

However, since this is most likely to occur immediately after a flood, access may be limited for some time and so the ponding of water will occur until the sediment is removed. The height and steepness of the banks, their unconsolidated nature and their saturation following a flood would make it unsafe to simply park a long-armed excavator at the top of the embankment to reach down and remove material from the creek bed. An access ramp and working platform would most likely be needed for a practical and safe working environment for excavation. This will create some disturbance of the adjoining farmland.

It would be logical that while the earth moving equipment is on site to flatten the bank somewhat and then to revegetate it to prevent erosion in the location where the bank collapse had occurred.

b) Regrade Creek Banks

A longer-term solution to the bank collapses along this section of the drainage channel could involve regrading the banks to a more stable profile. This would benefit from some geotechnical design and could involve either benching the banks or grading them to a more gentle and stable batter, perhaps closer to what was observed in parts of the area from the 1955 photograph. This would have a high upfront financial cost but would have limited ongoing maintenance costs. An indirect cost of this would be the short term disturbance to adjoining farm land and the long term loss of some of that land from agricultural production.

Gentler bank slopes would make them more amenable to revegetation and weed management.

c) Install Subsurface Drainage

An alternative means of dealing with the buildup of water pressure within the banks would be to install subsoil drainage to collect the water and discharge into the creek at numerous points. This would require less ground disturbance than bank regrading but would still have short term disturbance of adjacent farming enterprises along both sides of the creek. It would also not reduce the area of flat land available for agricultural production but may result in a permanent lowering of the water table close to the creek which may reduce the efficiency of irrigation on the margins of the farms.

While it would have less upfront financial cost than regrading the creek banks, its efficiency is likely to deteriorate over time and many need to be redone at some point in the future. It too would benefit from geotechnical engineering design.

d) Revegetate

Vegetation can contribute to bank stability with roots binding soils together. However, vegetation also increases the weight of material being supported by the bank and this may exceed the binding capacity of the roots. Revegetation therefore is best seen as an adjunct to the other options to enhance their benefits. It also delivers ecological benefits if the appropriate species are planted and established. This does add to the financial cost of an option not just in the cost of plantings but the ongoing maintenance which is required to establish the desired plants and suppress weeds in the five or so years that it would take for the plants to fully establish.

e) Check for Upstream Blockages

No matter what interventions are implemented in the last 500m, once the water levels have been lowered by removing sediment from the channel, the whole channel length should be checked upstream to see if there are further choke points which were submerged.

5.2 Environmental Constraints

In addition to the costs, impacts and physical challenges associated with each option discussed in the preceding section, there are environmental constraints and statutory processes which must be considered when selecting a preferred option and its implementation.

a) Zoning

IA1NE predominantly traverses land zoned as RU2 – Rural Landscape, with segments crossing into the zones C2 – Environmental Conservation, SP1 – Special Activities, and RE1 – Public Recreation (Figure 27). Between Ridges Lane and Powells Lane the drainage channel becomes a wetland zoned as C2, immediately upstream of Edwards Road the channel crosses land zoned as SP1, and near the channel's outlet into the Hawkesbury River it crosses land zoned as RE1.

Maintenance of existing drainage channels is permitted without consent for zones RU2, C2, SP1 and RE1. Checking for blockages, clearing the existing drainage channel and stabilising the banks are all considered maintenance of existing drainage channel, therefore the suggested works are permissible without consent.

b) Contamination

Environment Protection Authority (EPA) contaminated land records of notices for the Hawkesbury LGA are shown in Table 1. Notified contaminated sites on or near the Hawkesbury Floodplain are shown in Figure 4.

There are no contaminated sites within the vicinity of IA1NE.

c) Acid Sulphate Soils

IA1NE is surrounded by Class 4 and 5 land on the HLEP Acid Sulphate Soils Map (Figure 28). Majority of the drainage channel is surrounding by Class 4 land with the exception of a continuous tract of Class 5 land which extends from approximately 130m west of Edwards Road to approximately 630m east of Edwards Road.

According to the LEP Development consent in Class 4 land is required where the works are more than 2m below the natural ground surface or the works are likely to lower the watertable by more than 2m below the natural ground surface. The Class 5 land is within 500 m of the adjacent Class 4 land which itself is below 5m AHD. Development consent would therefore be required in this land if the works were likely to lower the water table to below 1m AHD in adjacent Class 4 land.

The options of simply removing the existing material from the creek bed or revegetating would not trigger the requirement for development consent under this provision. Arguably neither would bank regrading. The impacts of subsurface drainage on the surrounding water table would need to be investigated more closely to see whether these provisions trigger the requirement for development consent.

d) Heritage

i) HLEP Heritage Items

IA1NE traverses two General Heritage Items; items I25 and I23 between Powells Lane and Edwards Road (Figure 29). The details of these heritage items are shown in Table 5 (*HLEP 2012* Schedule 5). Any of the options would not occur on, or impact upon, these properties.

Table 5: HLEP Heritage Items (IA1NE)

Item Number	Item Name	Address	Significance
I25	Georgian farmhouse	216 Edwards Road, Richmond Lowlands	Local
I23	Hawkesbury Agricultural College River Farm	173 Cornwells Lane, Richmond Lowlands	Local

ii) AHIMS Heritage Items

An AHIMS Basic Search of mapped area B returned 4 Aboriginal Sites, none of which appear to be near the area requiring works (Figure 30). However, the exact location and nature of these sites is not known from a Basic Search. Therefore, for any works on IA1NE, a Basic Search of the specific works extent should be conducted to confirm whether any Aboriginal Sites are nearby. If an initial Basic Search returns any Aboriginal Sites, an AHIMS Extensive Search is required. The historical photographic imagery shows that the landforms in this area have been highly modified over the past 70 years and so the likelihood of items of Aboriginal heritage value being disturbed by the works is very low.

e) Wetlands and Coastal Areas

There is one wetland along IA1NE, as identified on the HLEP Wetlands Map and in the R&H SEPP, located between Ridges Lane and Powells Lane (Figure 31). The downstream areas of IA1NE where bank stabilisation works and channel clearing is recommended falls partly within the coastal environmental and coastal use areas as per the R&H SEPP.

Works undertaken within the coastal environment area and the coastal use area must follow the provisions set out in sections 2.10 and 2.11 of the R&H SEPP respectively. These provisions are quoted in Section 3.6 of this report.

The location of the area requiring works is 2km downstream of the wetland, however, should works at the critical location reveal the benefit of other works further upstream, then any works within the mapped extent of this wetland would need to be conducted in accordance with Part 6.5 (3) and (4) of the HLEP and sections 2.7 And 2.8 of the R&H SEPP. These provisions are quoted in sections 3.5 and 3.6 of this report.

f) Ecology

i) PCT Mapping

There are two PCTs mapped along segments of IA1NE; these are PCT 781 and PCT 835 (Figure 32). PCT 781 is mapped along the waterbody between Ridges Lane and Powells Lane and PCT 835 is mapped along the drainage channel east of Edwards Road and continuing to the outlet into the Hawkesbury River.

The drainage channel at the site of the bank collapses is mapped as Plant Community Type (PCT) 835 - Forest Red Gum-Rough-barked Apple Grassy Woodland on Alluvial Flats of the Cumberland Plain, Sydney Basin (DPE, 2018). This PCT is referrable to Threatened Ecological Communities (TECs) under both the Biodiversity Conservation Act as equivalent to the endangered River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions, and the Environment Protection Biodiversity Conservation Act as equivalent to the critically endangered River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria.

Field observations suggest that this mapping may not be accurate as there was little native vegetation in this stretch of the creek.

ii) Terrestrial Biodiversity

Roughly two thirds of IA1NE is within land identified as either ‘Significant vegetation’ or ‘Connectivity between significant vegetation’ on the HLEP Terrestrial Biodiversity Map (Figure 33). This includes the following segments:

- Western end of IA1NE to approximately 150 m northeast of Powells Lane: ‘Connectivity between significant vegetation’ with an approximate 900 m segment of ‘Significant vegetation’ starting immediately east of Ridges Lane; and
- Edwards Road to eastern end of IA1NE: ‘Significant vegetation’.

The area of the bank collapse is mapped as 'Significant vegetation' therefore, the following provisions of Part 6.4 Terrestrial Biodiversity of the LEP apply:

3) *Before determining a development application for development on land to which this clause applies, the consent authority must consider—*
    a. *whether the development—*
        i. *is likely to have any adverse impact on the condition, ecological value and significance of the fauna and flora on the land, and*
        ii. *is likely to have any adverse impact on the importance of the vegetation on the land to the habitat and survival of native fauna, and*
        iii. *has any potential to fragment, disturb or diminish the biodiversity structure, function and composition of the land, and*
        iv. *is likely to have any adverse impact on the habitat elements providing connectivity on the land.*
    b. *any appropriate measures proposed to avoid, minimise or mitigate the impacts of the development.*
4) *Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that—*
    a. *the development is designed, sited and will be managed to avoid any significant adverse environmental impact, or*
    b. *if that impact cannot be reasonably avoided by adopting feasible alternatives—the development is designed, sited and will be managed to minimise that impact, or*
    c. *if that impact cannot be minimised—the development will be managed to mitigate that impact.*

However, vegetation communities persisting along the drainage route were observed, generally, to be in a severely degraded state during the field inspections. This was the case along the drainage channel east of Edwards Lane and including the area of the proposed bank collapse repair works, where vegetation communities are dominated by invasive species such as Broad-leaf Privet (*Ligustrum lucidum*), Small-leaf Privet (*Ligustrum sinense*), Honey Locust (*Gleditsia triacanthos*), Green Cestrum (*Cestrum parqui*), Tobacco Bush (*Solanum mauritianum*), Balloon Vine (*Cardiospermum grandiflorum*), Caster Oil Plant (*Ricinus communis*), and introduced herbs and grasses. Native vegetation in this area was limited to an intermittent and sparse canopy of Swamp She-oaks (*Casuarina glauca*) with the occasional mid and ground-storey plant.

A historical satellite image shows little vegetation surrounding the drainage channel in 1955 (Figure 24), suggesting that very little of the native vegetation surrounding the drainage channel could be classified as remnant native vegetation. Rather it seems that majority of the vegetation surrounding the drainage channel has developed since then, whether that be via natural processes or planting.

iii) Biodiversity Values

One segment of IA1NE is mapped as 'Biodiversity Value' on the DPE Biodiversity Values Map. This is an approximate 950 m segment immediately east of Ridges Lane (Figure 34). The proposed drainage channel bank collapse repair works do not occur within the extent of any BV mapped land

iv) Threatened Species

A search of the NSW DPIE BioNet Atlas was conducted for threatened fauna and flora species records within an approximate 5 km radius of the whole investigation area. Records within mapped area B are show in Figure 35. Although no records were returned near the area of the bank collapses and no threatened species were observed in the area, a great diversity of bird species was observed along the drainage route, indicating favourable habitat for bird species generally. This includes the area of the bank collapses where a bird nest was observed in close proximity.

Therefore, assessment of the likely presence of threatened species and potential habitat at the site of the works will need to be considered in the detailed impact assessment because of the PCT and significant vegetation mapping.

v) Key Fish Habitat

The Hawkesbury River is identified as Key Fish Habitat, however, the drainage channel including the site of the proposed bank collapse repair works is not identified as Key Fish Habitat (Figure 36) and thus provisions of the Fisheries Management Act do not apply.

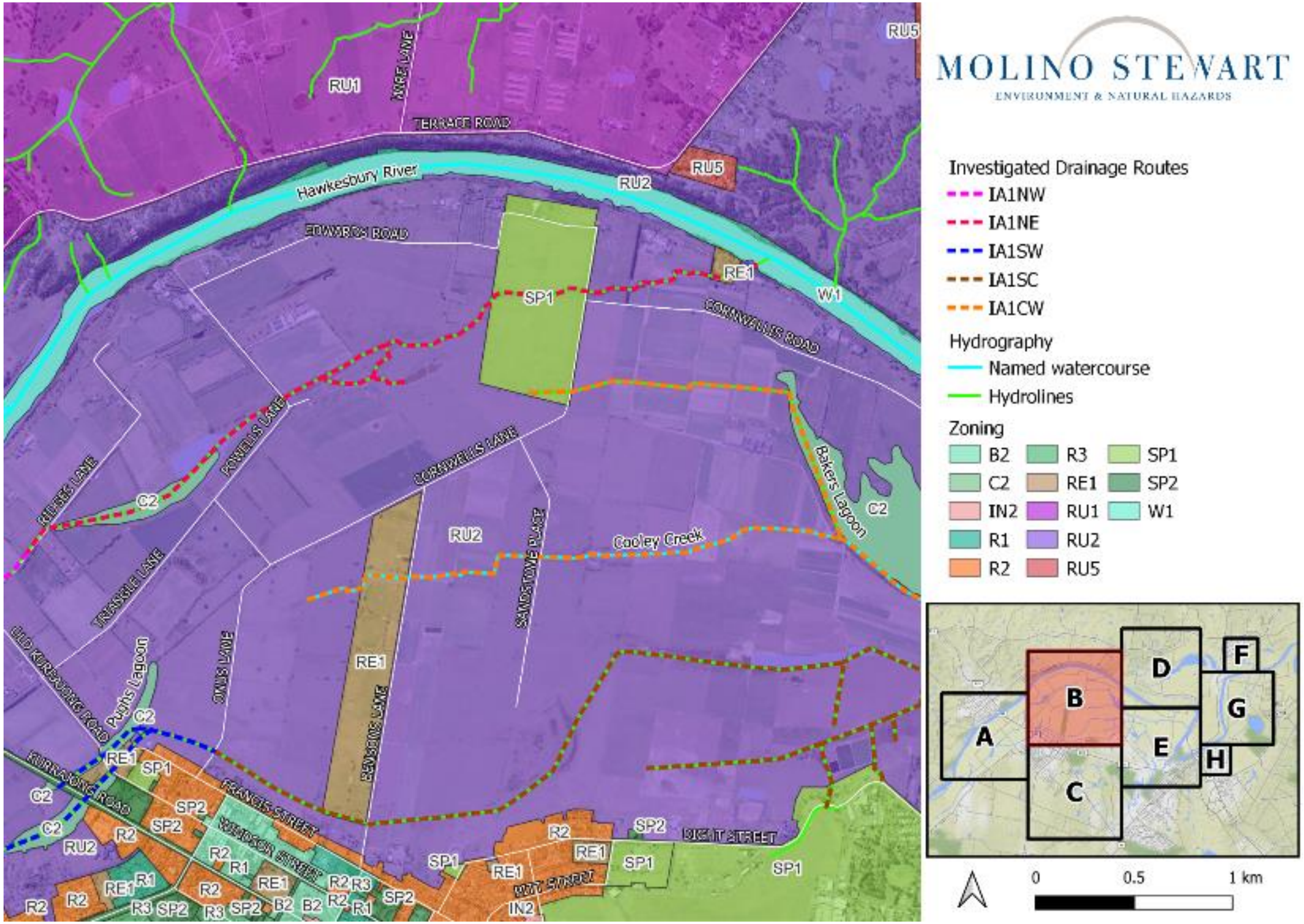

Figure 27: Land Zoning (Extent B)

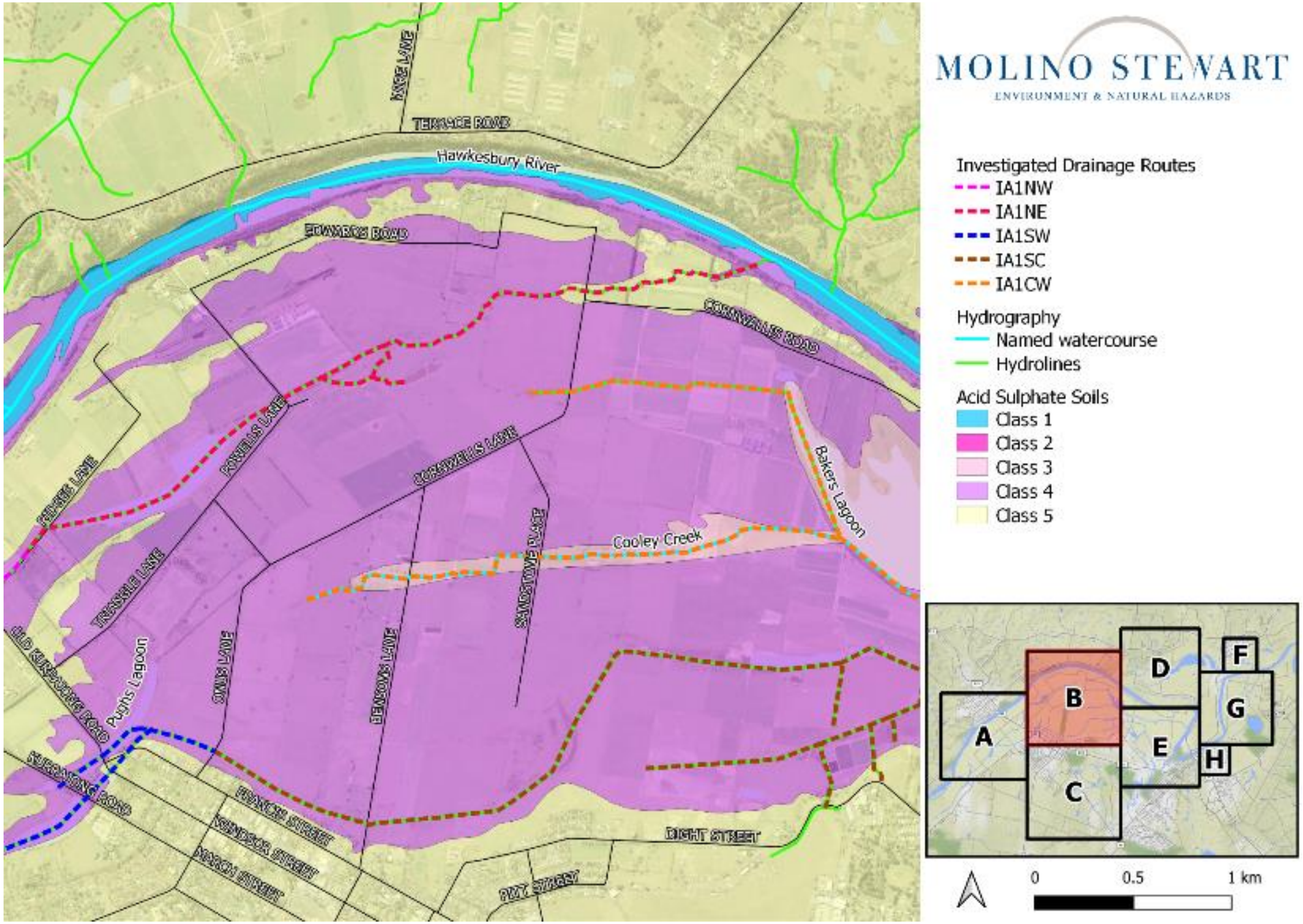

Figure 28: Acid Sulphate Soils (Extent B)

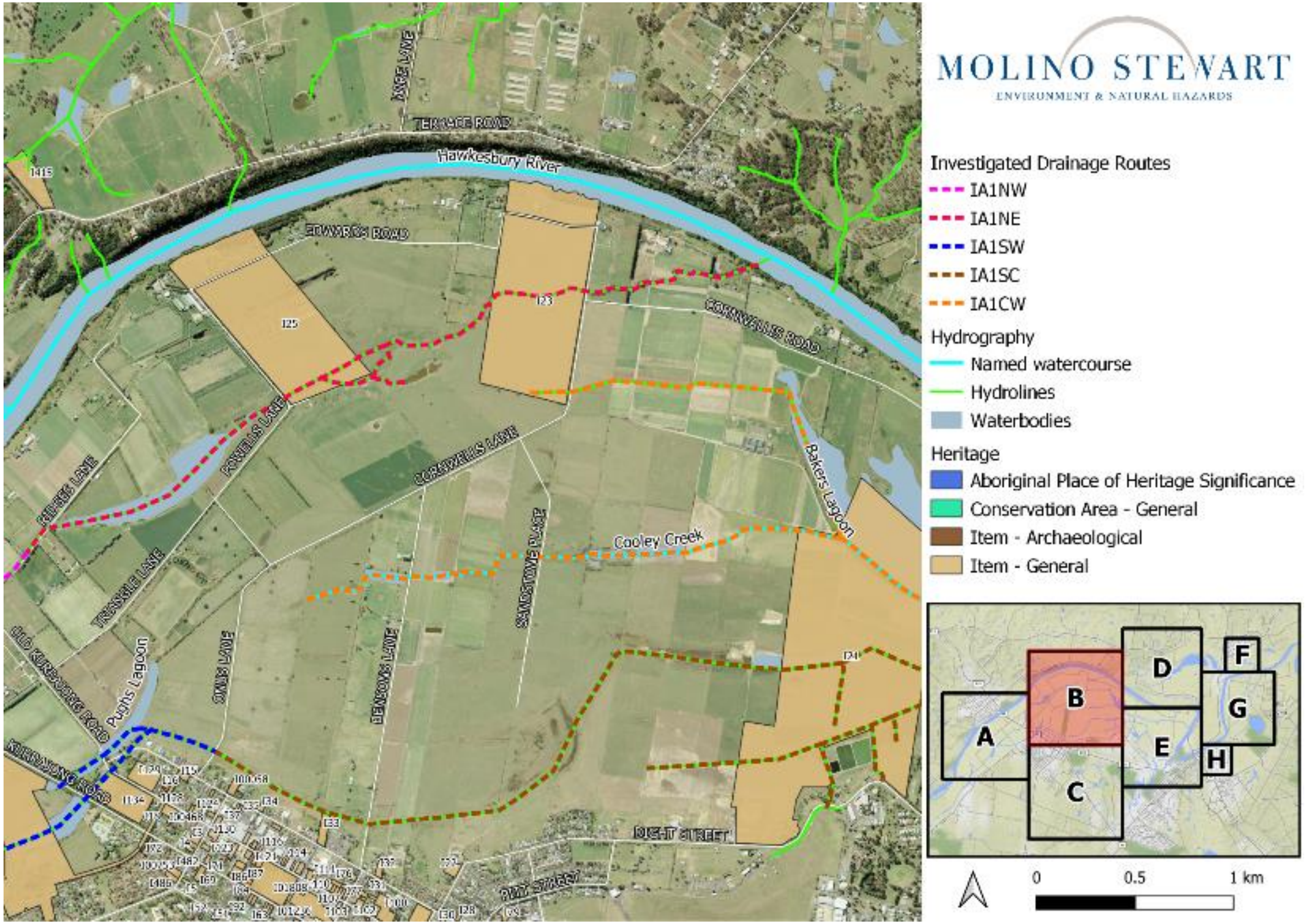

Figure 29: HLEP Heritage Places, Areas and Items (Extent B)

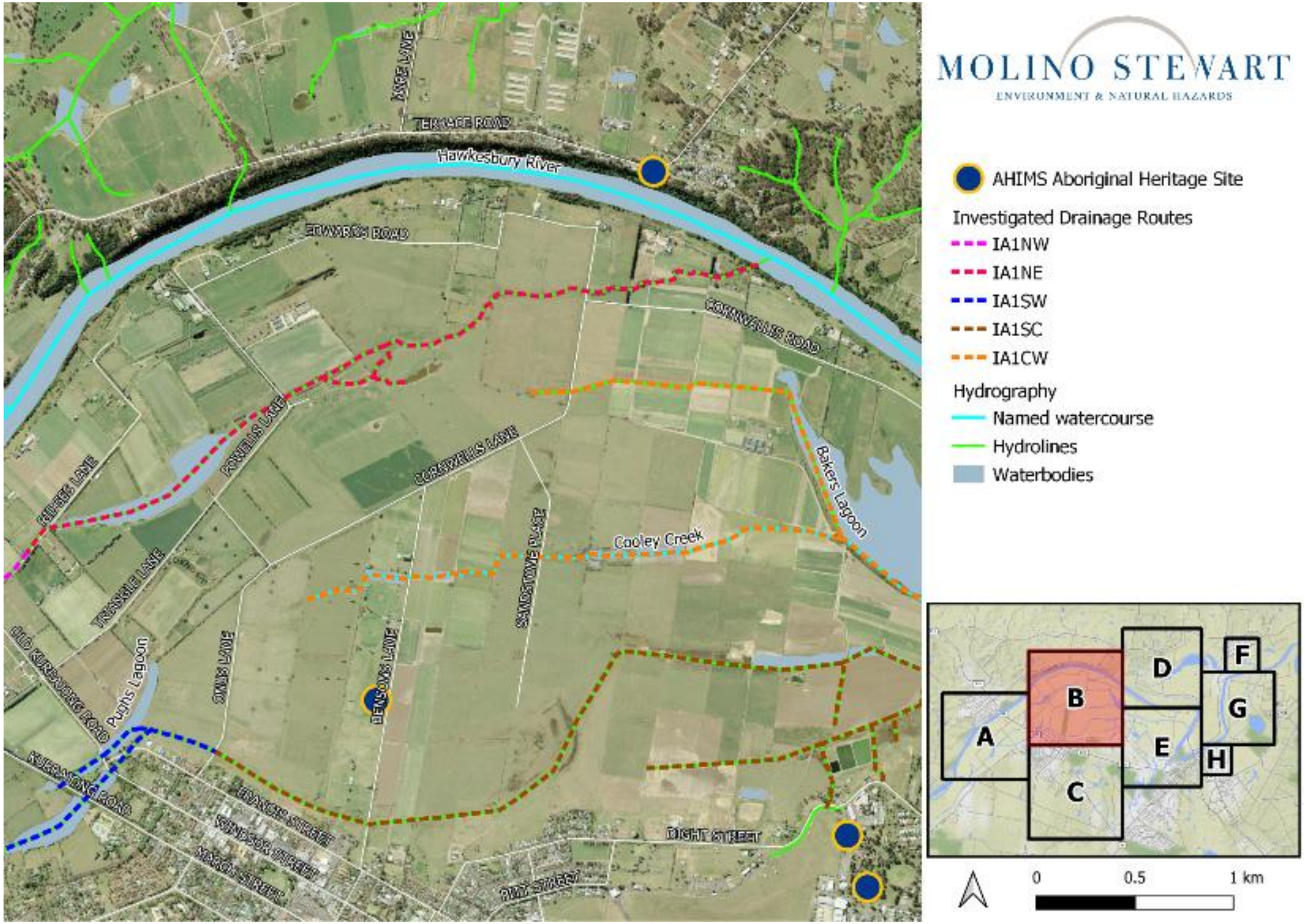

Figure 30: AHIMS Aboriginal Sites (Extent B)

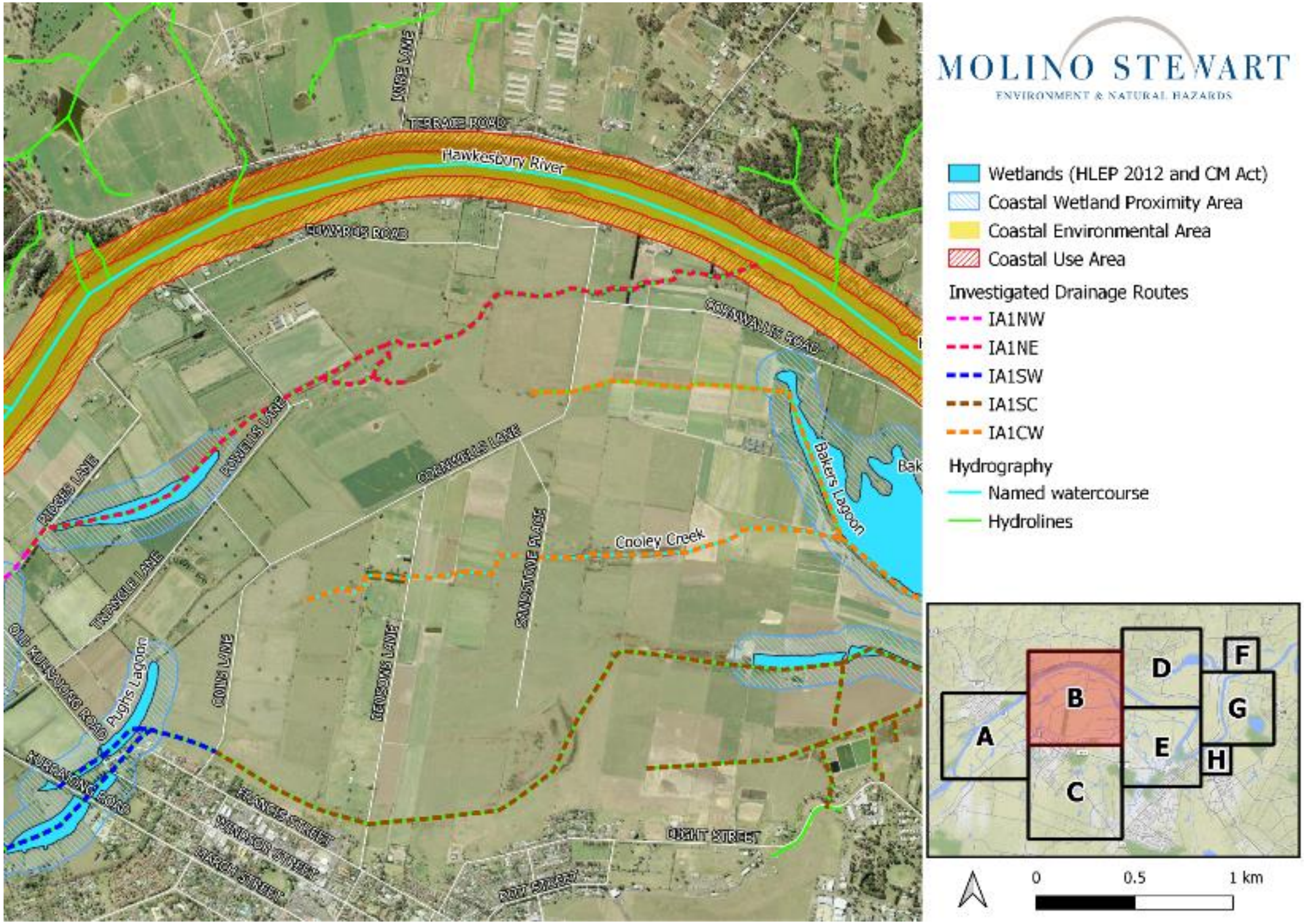

Figure 31: Wetlands and Coastal Management Areas (Extent B)

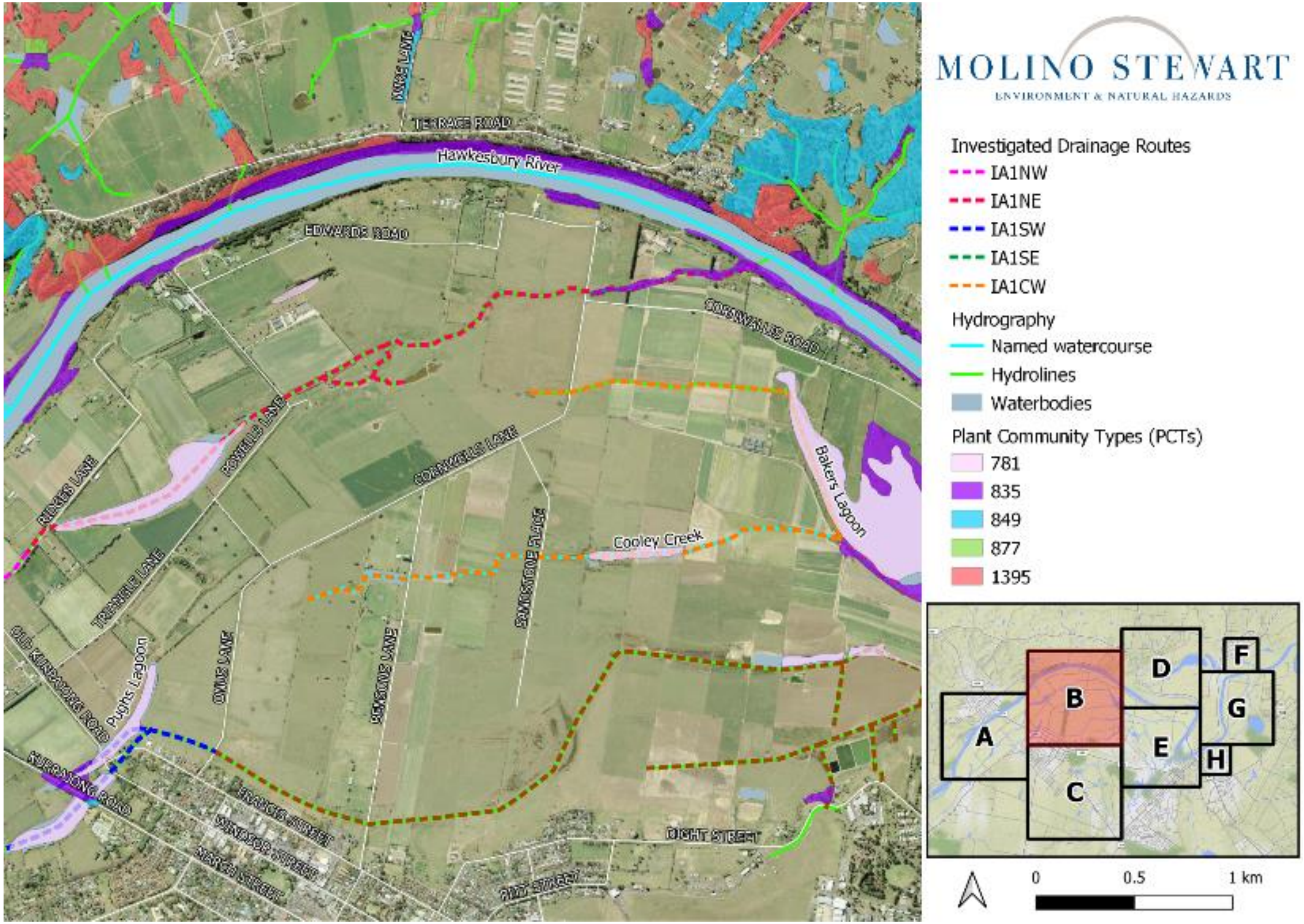

Figure 32: Plant Community Types (Extent B)

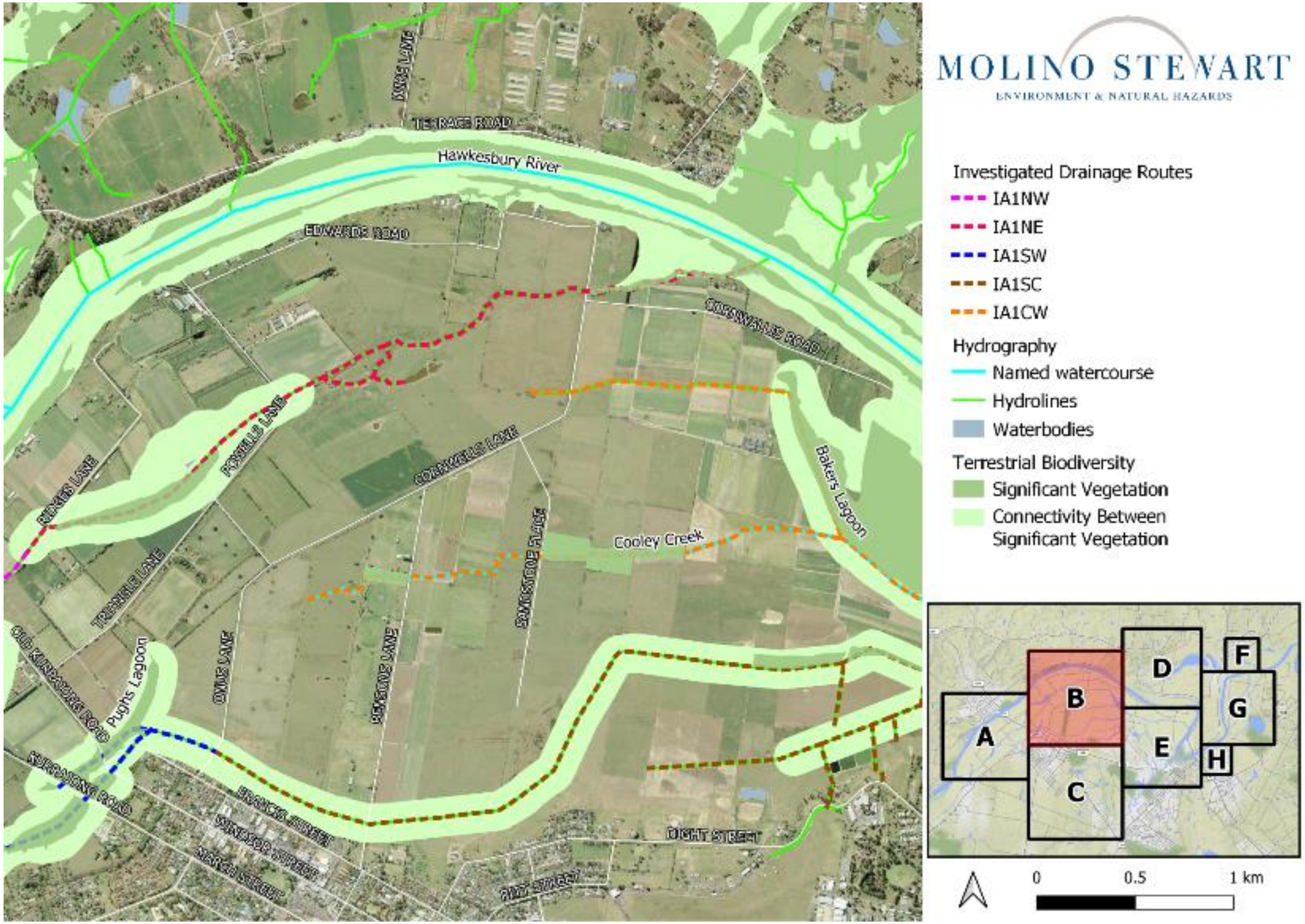

Figure 33: Terrestrial Biodiversity (Extent B)

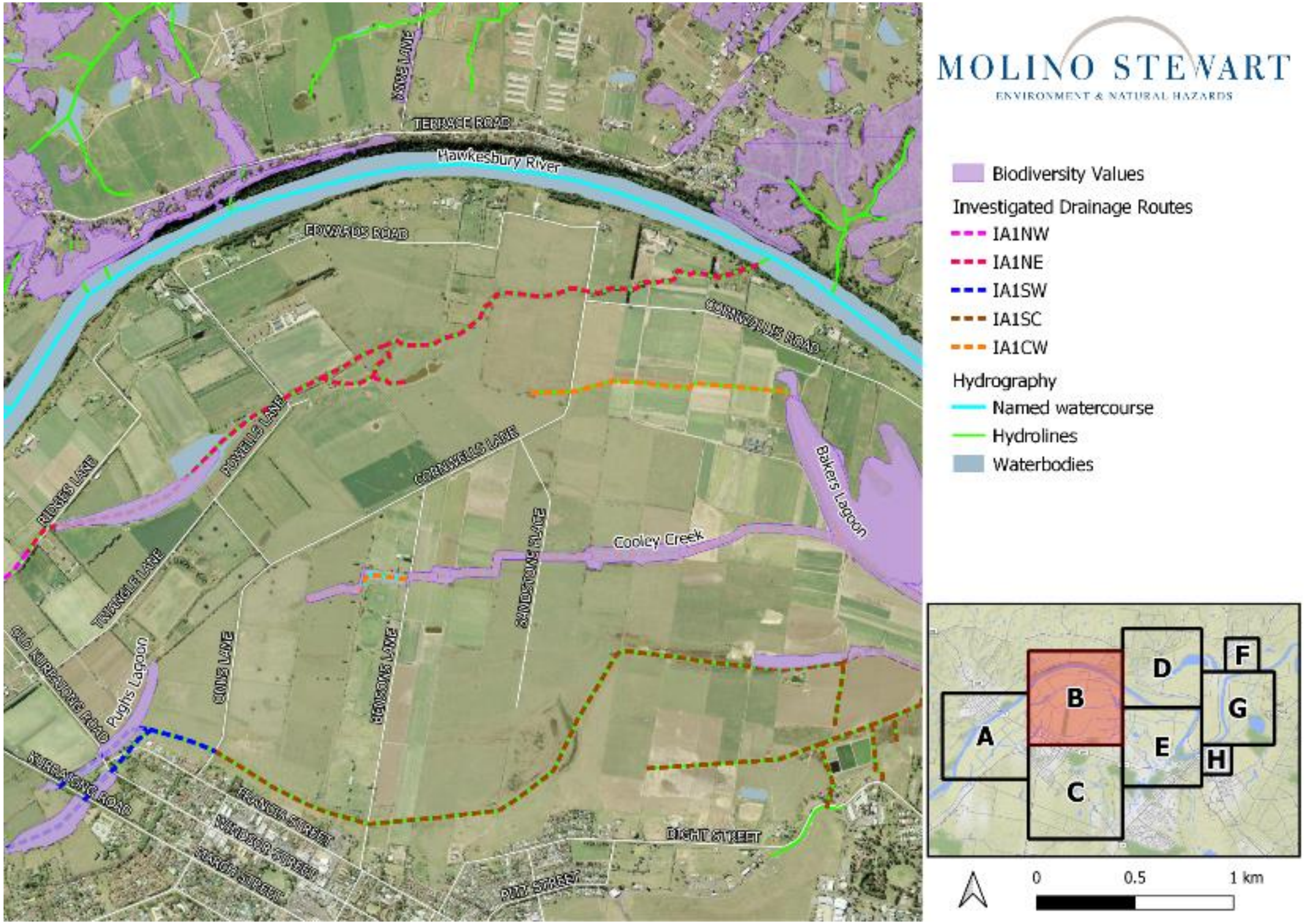

Figure 34: Biodiversity Values (Extent B)

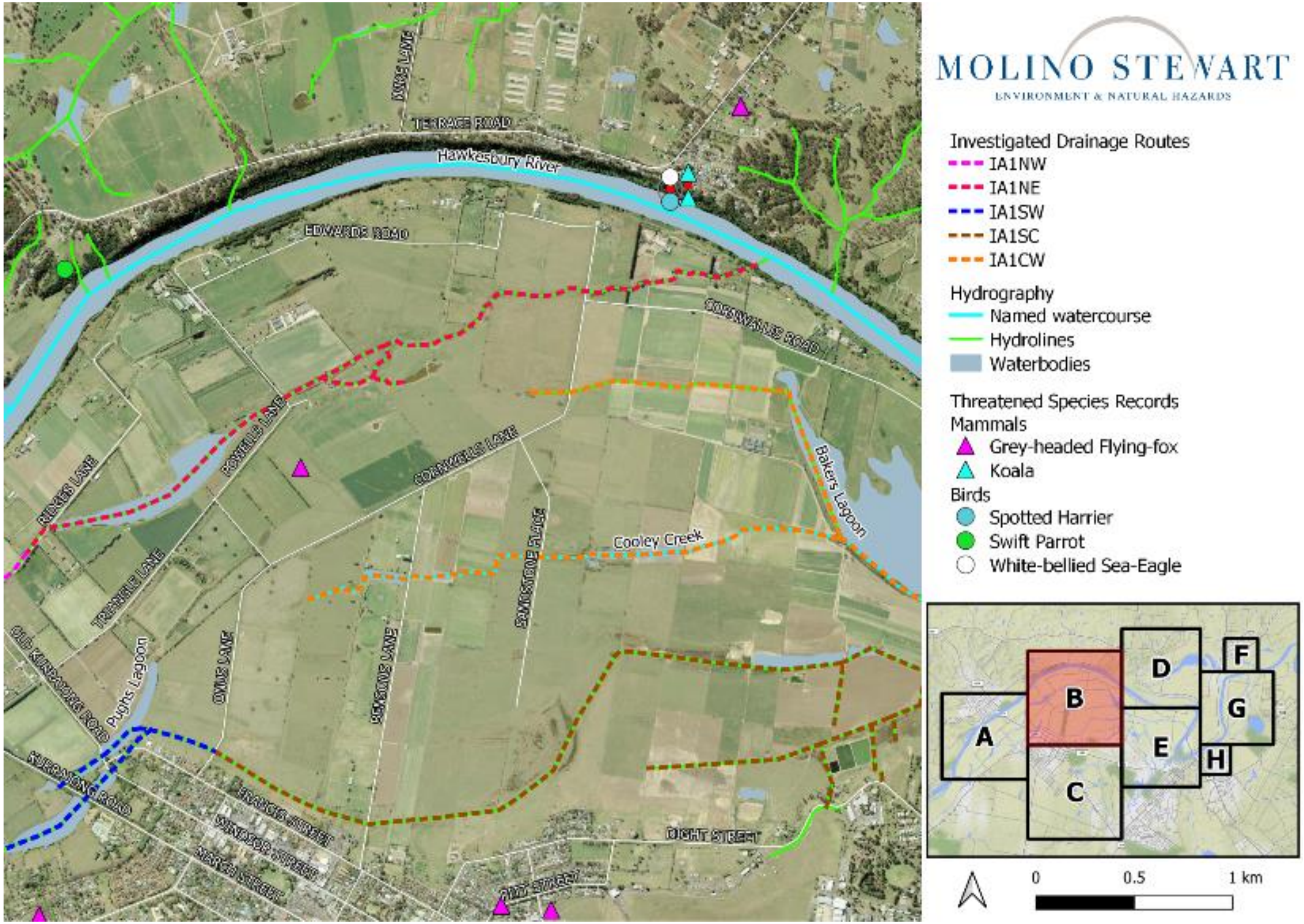

Figure 35: Threatened Species Records (Extent B)

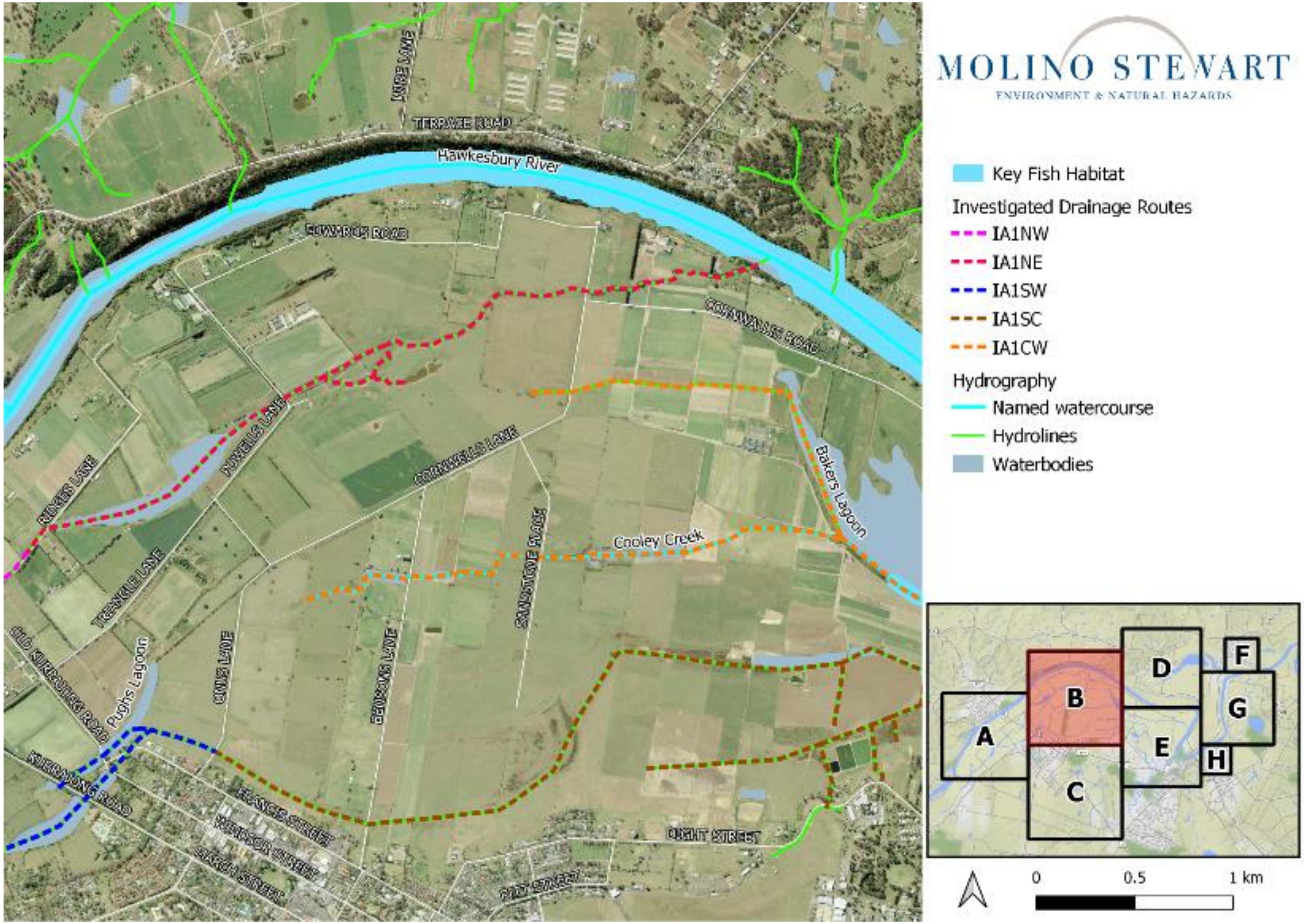

Figure 36: Key Fish Habitat (Extent B)

6| IA1 Southern Drainage Route West

6.1 Drainage Issues

The western extent of the southern drainage route in IA1 (IA1SW) is shown on the topographic maps as starting as an overflow from the southern side of the lagoon which lies west of Inalls Lane. However, in the field, there is no discernible channel until about 250m west of Inalls Lane. For this report IA1SW was defined as running from this point to Onus Lane. The locations of each photograph referred to in the text can be found in Figure 38.

6.1.1 Field observations

West of Inalls Lane there is a shallow channel full of reeds (Photo 69). Drainage under Inalls Lane is via a piped culvert. East of the road the drain is a weed filled ditch (Photo 70) which discharges into a lagoon (Photo 71 and Photo 72). The lagoon discharges under a farm access road into another lagoon which has a lower water level (Photo 73).

This lagoon is crossed by Kurrajong Road and is divided by a spit of land at Pughs Lagoon Reserve. This lagoon overflows via a pipe under Old Kurrajong Road into Pughs Lagoon which sits at a lower water level (Photo 74). On the day of the inspection in May the water level in the upstream lagoon was so high that there was water over the road (Photo 75) and low discharge through the connecting pipe (Photo 76). However, during the July inspection there was a greater flow through the pipe (Photo 77) and the upstream water level was lower (Photo 78) which suggests that in May the pipe was blocked upstream.

Pughs Lagoon overflows through a drain which passes under a farm access road through two large pipes (Photo 79) and under another farm access road through similar pipes about 150m downstream (Photo 80). There was a noticeable drop in water level and flow from one end of these pipes to the other (Photo 81). This open channel continues through to Onus Lane under which it passes through two large pipes (Photo 82).

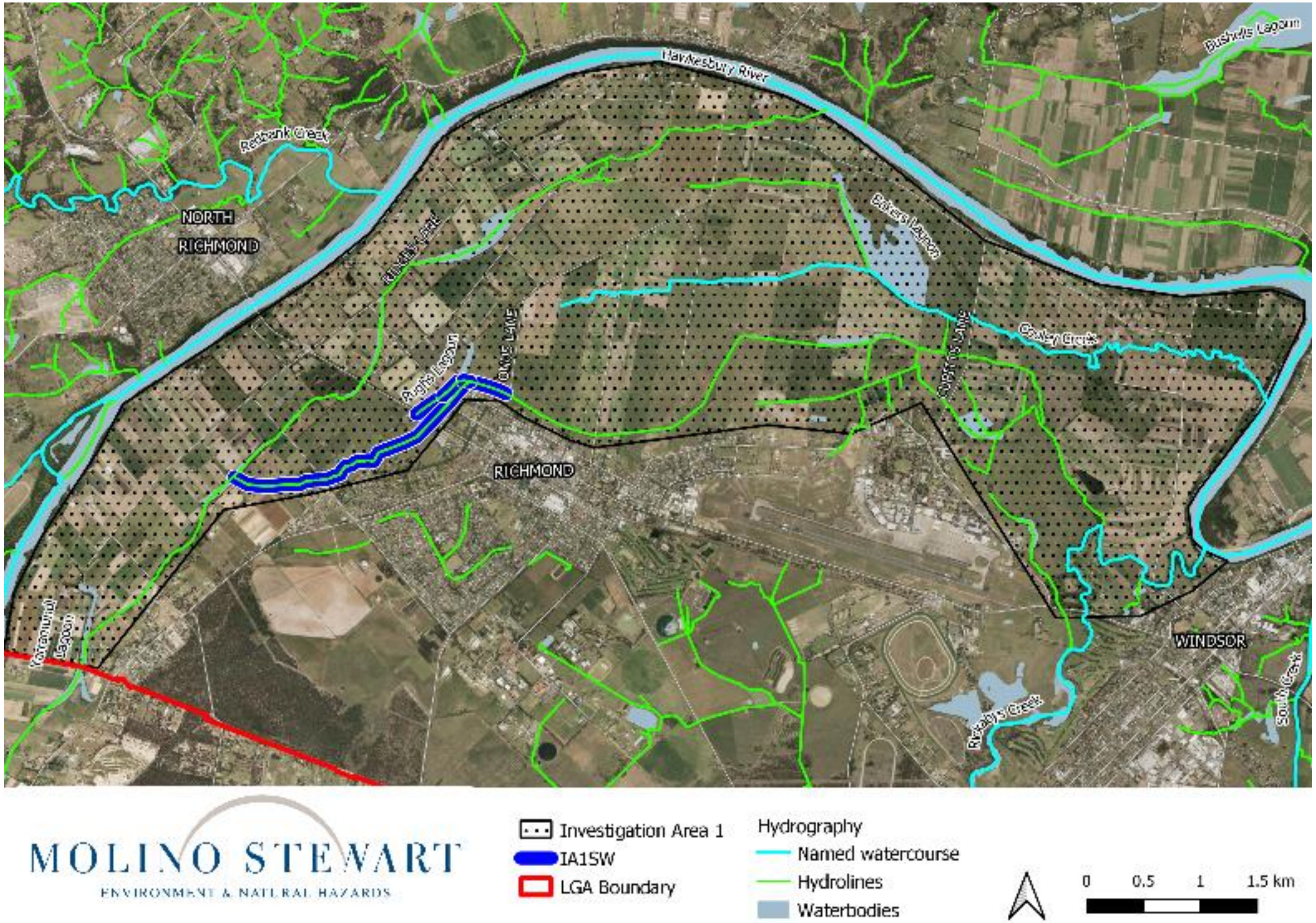

Figure 37: Investigation Area 1 Southern Drainage Route West (IA1SW)

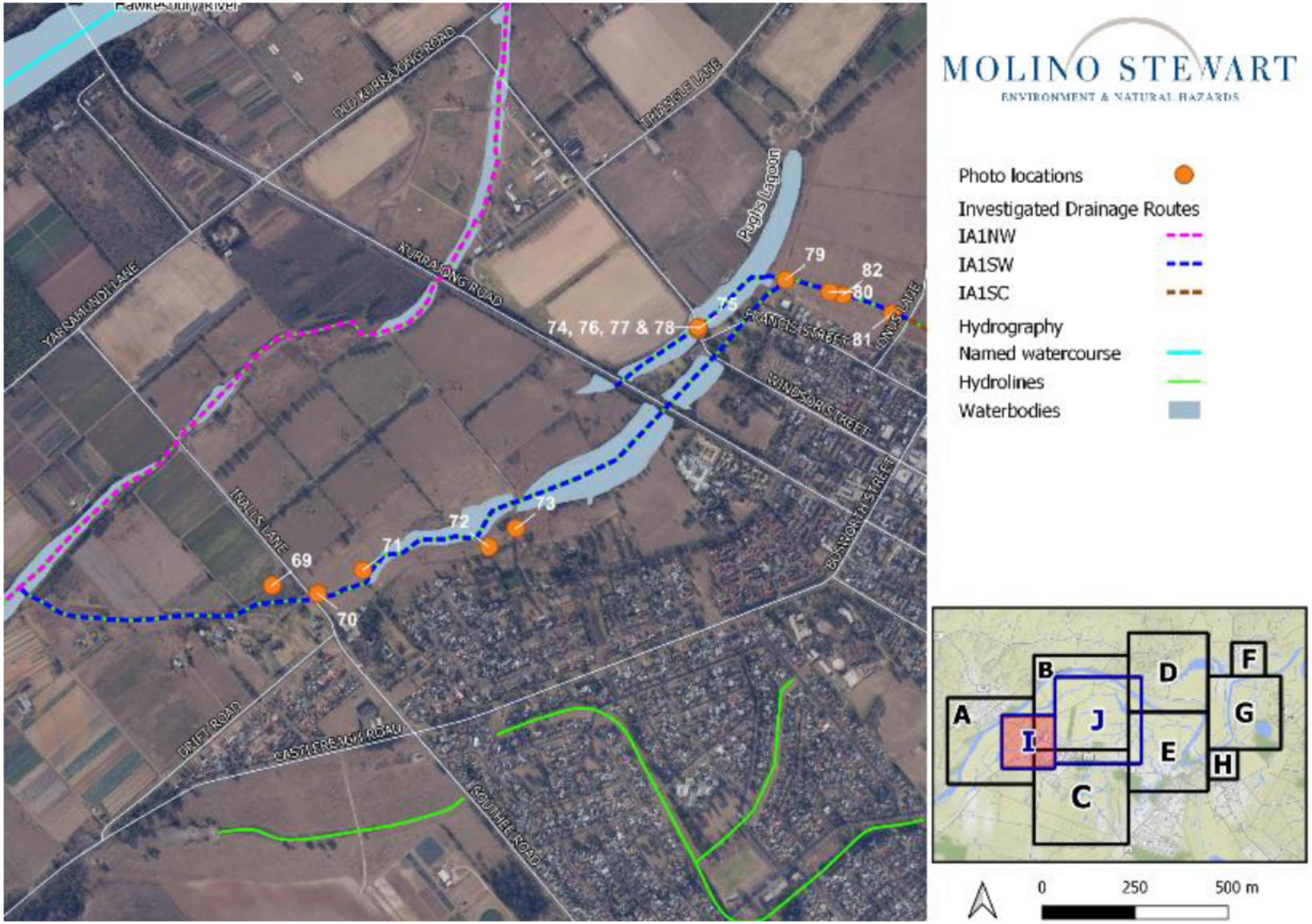

Figure 38: Photo locations for IA1SW

Photo 72

Photo 74

Photo 75

Photo 77

Photo 78

Photo 79

Photo 80

Photo 81

Photo 82

6.1.2 Probable causes

Two areas with drainage problems were noted in IA1SW.

The first was not observed during the field inspections but reported by a property owner by telephone. She advised that she had lived on, then owned, a property on the northern side of Drift Road since 1960 and had seen it flood numerous times. Her opinion was that in the past her paddocks had drained much more quickly but following recent floods the paddocks had remained boggy and untrafficable by farm vehicles for months.

It has been observed that there was no discernible drainage channel through this area yet it was shown as a water course on the topographic maps. One possibility may have been that at some time since 1960, and possibly since 1990, a former drainage line had been filled in. To investigate this, historical airphotos were searched and Figure 40 to Figure 43 show the period from 1955 to 2018. At the scale of the imagery there does not appear to be any discernible changes to any drainage lines or channels.

However, in the 1980 image (Figure 41) houses and outbuildings can be seen on the properties at 14 and 22 Drift Road. The buildings have been built on substantial fill platforms which have extended into the floodplain. One possibility is that these are inhibiting drainage from the west but a detailed ground level survey through the area would be needed to determine whether this is the case or not.

The second location where there was an obvious problem was where water was flowing over Old Kurrajong Road at Pughs Lagoon Reserve. Judging by the difference in flows between May and July and the difference that made to the water levels upstream, this appears to be a simple case of pipe blockage.

6.1.3 Possible solutions

If the building fill platforms in Drift Road are causing drainage to be blocked, and that is yet to be determined, then the options are limited. The fill is at least 5m high and supports substantial structures and their removal may not be practical.

It may be possible to construct retaining walls to support the fill which would reduce the footprint of the fill on the floodplain and leave more water for drainage. Alternatively, the construction of a formal drain through this area may relieve the problem.

With regard to the pipe blockage at Old Kurrajong Road, that could dealt with by either:

- Council staff checking and cleaning the pipe inlet as floodwater receded
- installing some form of structure upstream of the pipe to reduce the risk of blockage
- installing larger pipes which are less prone to blockage.

Possible solutions are displayed in Figure 39.

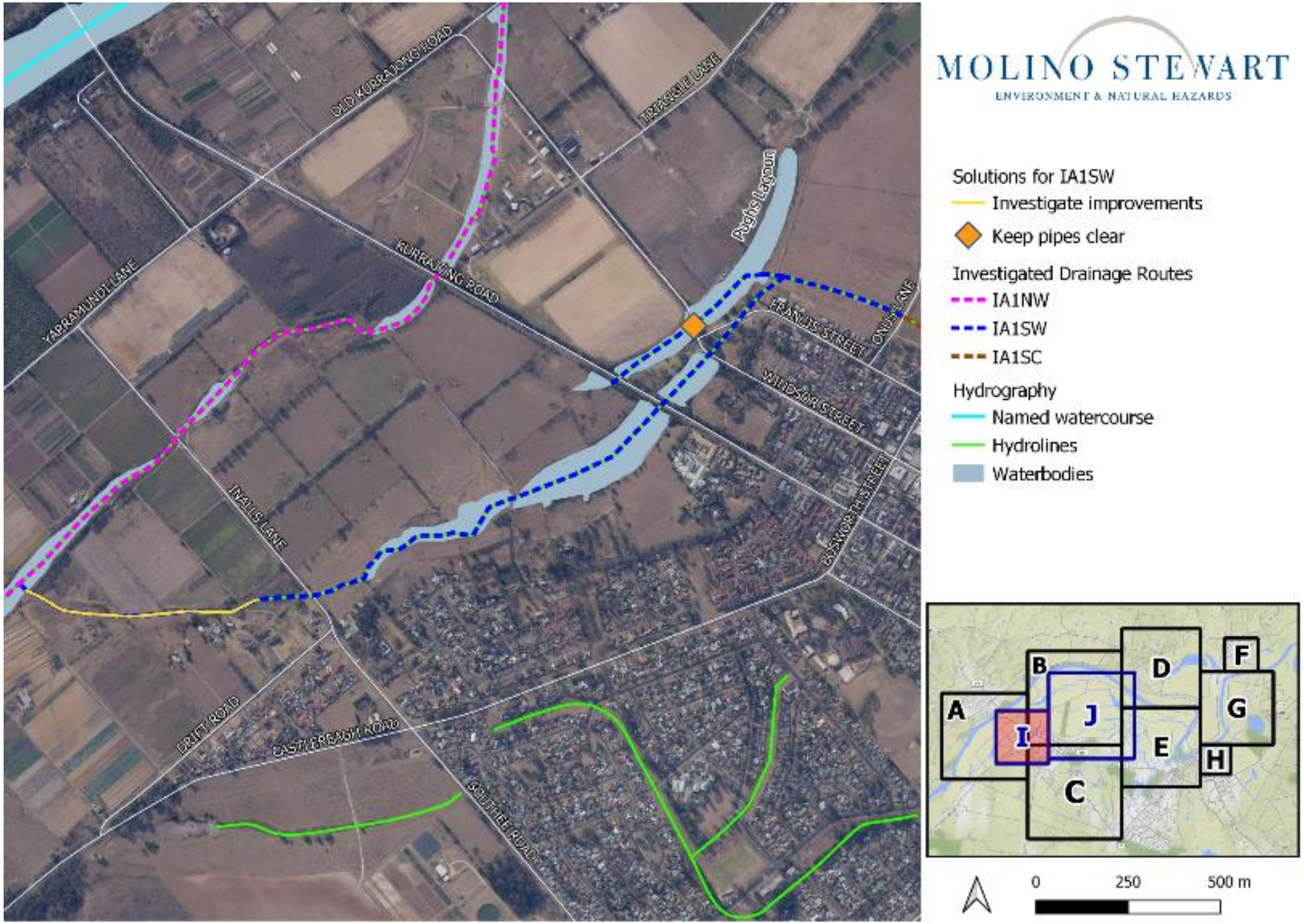

Figure 39: Solutions for IA1SW

Figure 40: West of Inalls Lane and North of Drift Road 1955

Figure 41: West of Inalls Lane and North of Drift Road 1980

Figure 42: West of Inalls Lane and North of Drift Road 2002

Figure 43: West of Inalls Lane and North of Drift Road 2018

6.2 Environmental Constraints

a) Zoning

IA1SW predominantly traverses land zoned as RU2 – Rural Landscape, with segments crossing into the zones RU4 – Primary Production Small Lots, C2 – Environmental Conservation, SP2 – Infrastructure, and RE1 – Public Recreation (Figure 44). To the west of Inalls Lane the drainage channel crosses land zoned as RU4. Between Inalls Lane and Onus Lane the channel enters and exits water bodies zoned as C2, including Pughs Lagoon, and crosses the Kurrajong Road reserve which is zoned as SP2 and Smith Park and Pughs Lagoon Reserve which are zoned as RE1.

Maintenance of existing drainage channels, including clearing of pipes, is permitted without consent for zones RU2, RU4, C2, SP2 and RE1. Therefore, clearing pipes in the existing drainage channel is permissible without consent.

Any further drainage improvement solutions from further investigations would be in either the RU2 or RU4 zones. As these would be for the purposes of flood mitigation they would be classed as flood mitigation works and would be permissible with consent if carried out by the property owner but would be permissible without consent if undertaken by or on behalf of Council.

b) Contamination

Environment Protection Authority (EPA) contaminated land records of notices for the Hawkesbury LGA are shown in Table 1. Notified contaminated sites on or near the Hawkesbury Floodplain are shown in Figure 4.

There are no known contaminated sites within the vicinity of IA1SW.

c) Acid Sulphate Soils

IA1SW is surrounded by Class 4 and 5 land on the Acid Sulphate Soils Map (Figure 45). Majority of the drainage channel is surrounding by Class 4 land with the exception of a continuous tract of Class 5 land which extends from the start of IA1SW, west of Inalls Lane, to approximately 130m east of Inalls Lane.

According to the LEP Development consent in Class 4 land is required where the works are more than 2m below the natural ground surface or the works are likely to lower the watertable by more than 2m below the natural ground surface. The Class 5 land is within 500 m of the adjacent Class 4 land which itself is below 5m AHD. Development consent would therefore be required in this land if the works were likely to lower the water table to below 1m AHD in adjacent Class 4 land.

The standing water bodies in this area are above 1m AHD so the water table cannot be lowered below this level. Constructing a drain is the only one of the options discussed which might locally lower the water table but given the flatness of the terrain it would be physically impossible to lower it by more than 2m below the ground surface.

d) Heritage

i) HLEP Heritage Items

IA1SW traverses four General Heritage Items. These are items I82 west of Inalls Lane, I14 and I00035 between Inalls Lane and Kurrajong Road, I134 between Kurrajong Road and Old Kurrajong Road (Figure 46). The details of these heritage items are shown in Table 6 (*HLEP 2012* Schedule 5).

Table 6: HLEP Heritage Items (IA1SW)

Item Number	Item Name	Address	Significance
I82	McMahon Homestead	26 Drift Road, Richmond	Local

I14	Grounds and landscaping surrounding "Hobartville"	36-86 Inalls Lane, Richmond	Local
I00035	"Hobartville" (including outbuildings)	36-86 Inalls Lane, Richmond	State
I134	St Peter's Anglican Church	384 Windsor Street, Richmond	Local

While construction of a drain might go through the property covered by I82, it would not directly affect the homestead and is unlikely to impact on its curtilage. Nevertheless, if such an option were pursued it impacts on the site's heritage values would need to be considered.

ii) AHIMS Heritage Items

An AHIMS Basic Search of constraints extent I found no Aboriginal Sites (Figure 47). This does not mean that there are no sites in the area. Therefore, for any works which are likely to result in ground disturbance on IA1SW (such as the excavation of a drain), a Basic Search of the specific works extent should be conducted to confirm whether any Aboriginal Sites are nearby. If an initial basic search returns any Aboriginal Sites, an AHIMS Extensive Search is required.

e) Wetlands and Coastal Areas

There are two wetlands along IA1SW as per the HLEP Wetland Map and the R&H SEPP mapping (Figure 48). The first one starts on the drainage line east of Inalls Lane and extends through to Windsor Street. This wetland is unnamed on maps and is crossed by a private access road and Kurrajong Road which effectively cuts it into three separate but hydraulically connected wetlands.

The other wetland is Pughs Lagoon which is also divided in three but in this case by Kurrajong Road and Old Kurrajong Road.

However, this drainage line commences at its upstream end in the coastal wetland proximity area of Mareh Mareh Lagoon.

IA1SW does not intersect any coastal environmental areas or coastal use areas.

Before development consent can be granted for any works conducted within the extent of these wetlands the provisions set out in Part 6.5 (3) and (4) of the HLEP and in Section 2.7 and 2.8 of the R&H SEPP must be satisfied. Furthermore, if any works are proposed within the coastal wetland proximity area of Mareh Mareh Lagoon then the provisions of Section 2.8 of the R&H SEPP apply. These provisions are quoted in sections 3.5 and 3.6 of this report.

f) Ecology

i) Plant Community Type Mapping

There are three PCTs mapped along segments of IA1SW; these are PCT 781, PCT 835, and PCT 849 (Figure 49). PCT 781 is mapped for the waterbodies either side of Kurrajong Road, including Pughs Lagoon. PCT 835 is mapped along the drainage channel either side of Kurrajong Road. A very small section of PCT 849 is mapped immediately east of the drainage channel as it crosses Kurrajong Road.

There are no PCTs mapped in the area reported to have drainage issues west of Inalls Lane.

ii) Terrestrial Biodiversity

The whole of the length of IA1SW is within a zone mapped as Connectivity Between Significant Vegetation (Figure 50). Those areas along the mapped wetlands are mapped as Significant Vegetation. Any works would need to take this into consideration.

iii) Biodiversity Values

All of the wetlands in IA1SW are mapped as 'Biodiversity Value' on the DPE Biodiversity Values Map (Figure 51). This places controls on the removal of vegetation in these areas. The area west of Inalls lane with the reported drainage problems is not mapped as having biodiversity values.

iv) Threatened Species Records

The grey headed flying fox is the only threatened species which has been seen within map extent I which covers IA1SW and these have been sighted in the urban areas south of the drainage line (Figure 52).

v) Key Fish Habitat

There is not key fish habitat along IA1SW (Figure 53)

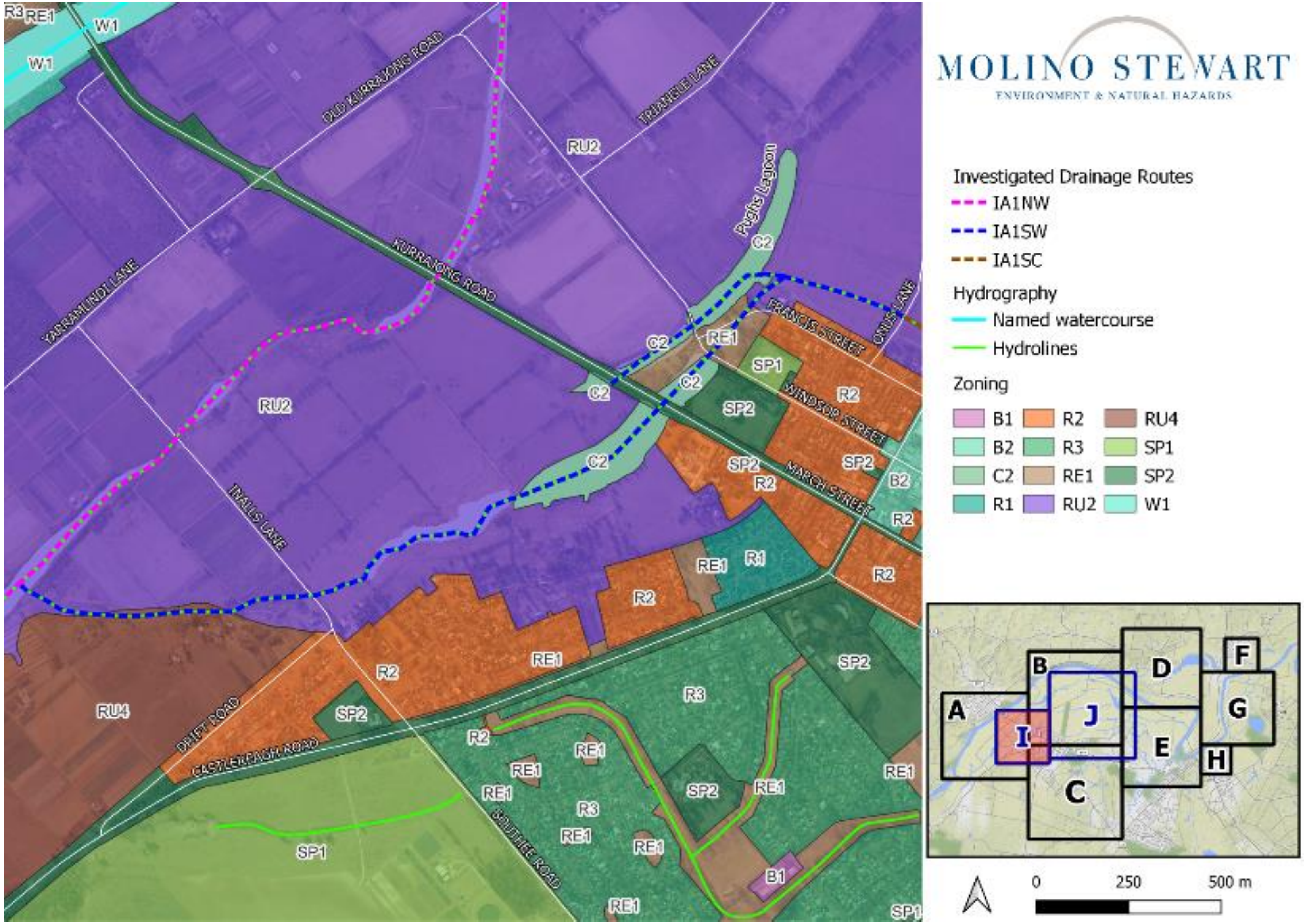

Figure 44: Land Zoning (Extent I)

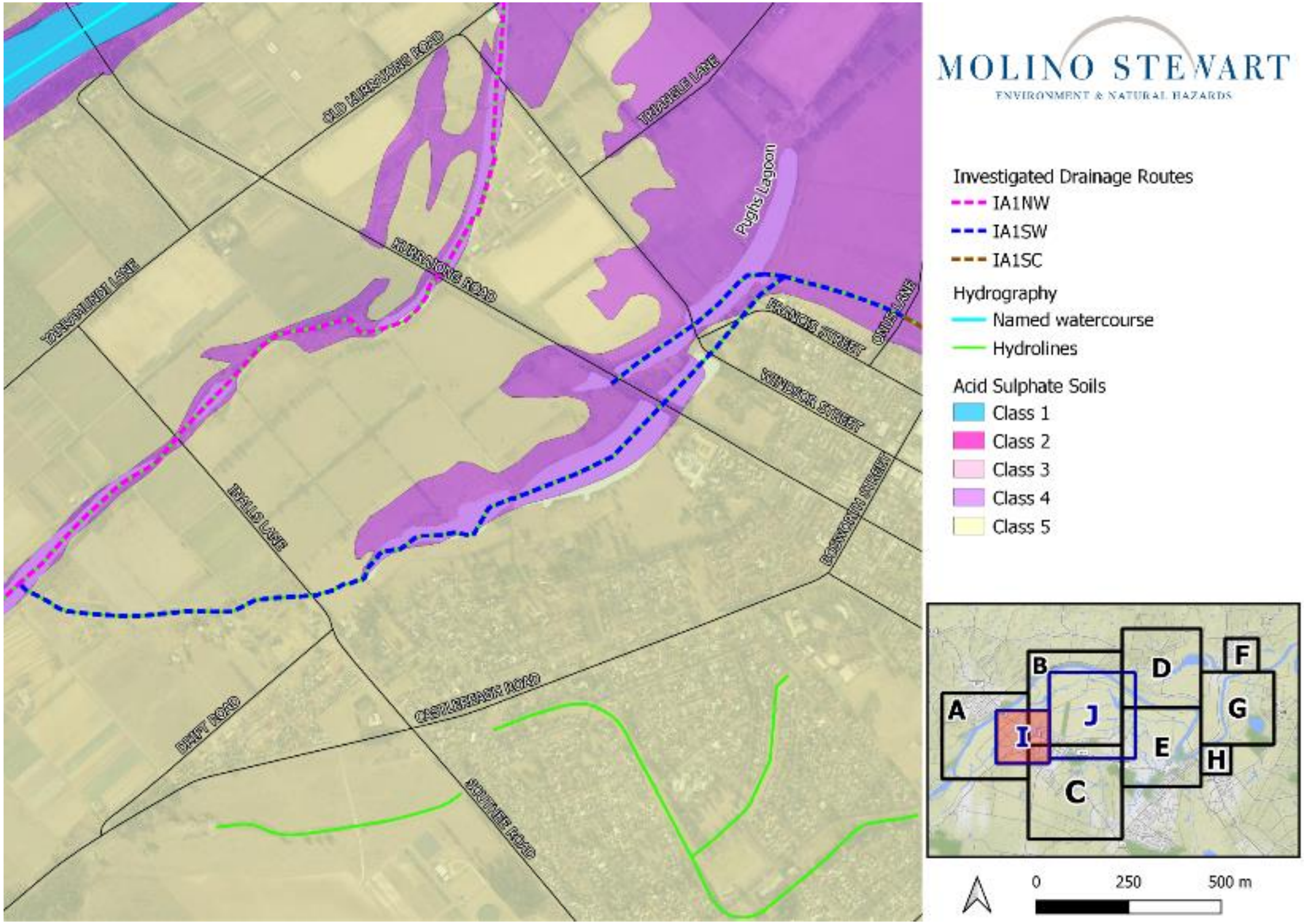

Figure 45: Acid Sulphate Soils (Extent I)

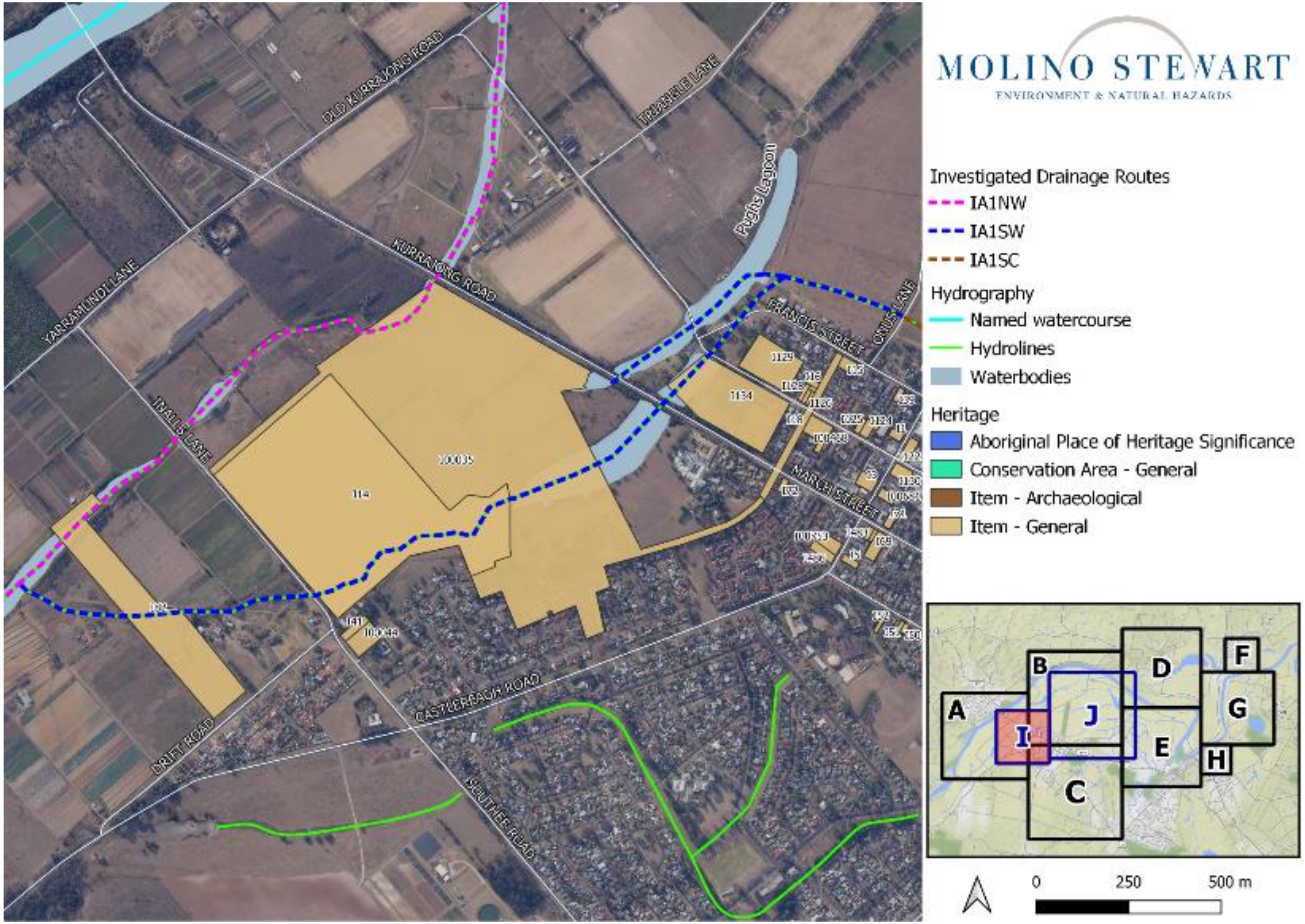

Figure 46: HLEP Heritage Places, Areas and Items (Extent I)

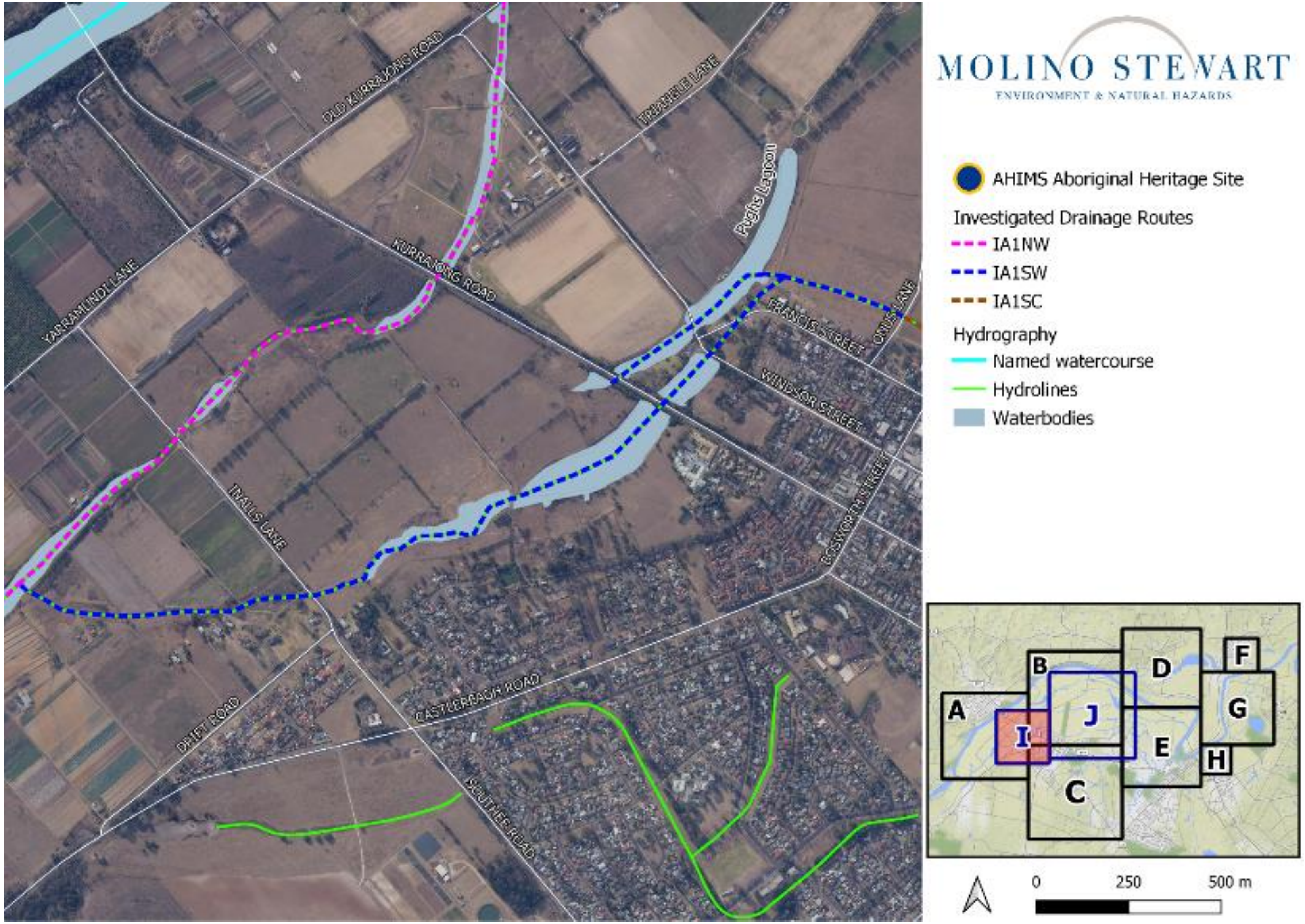

Figure 47: AHIMS Aboriginal Sites (Extent I)

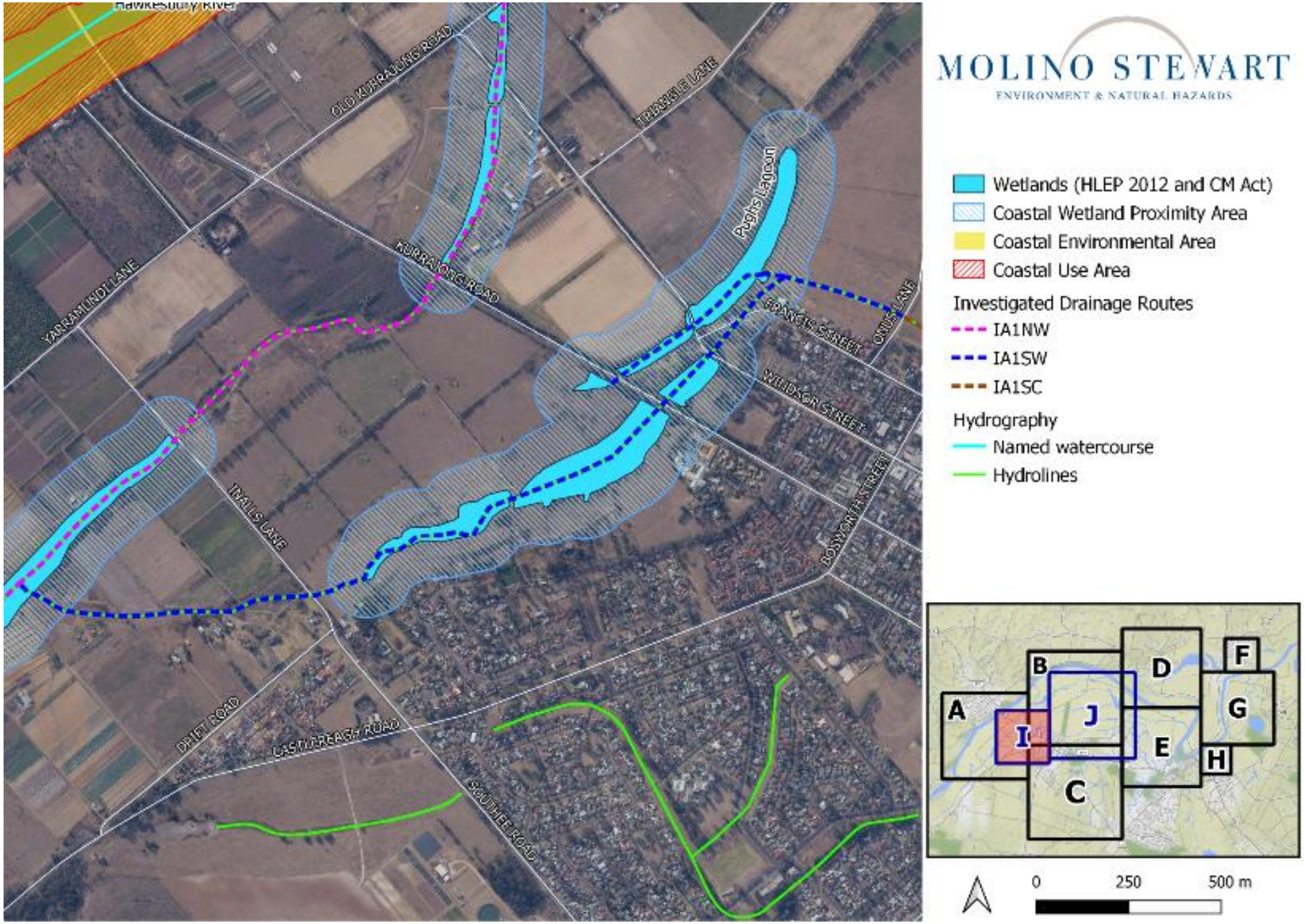

Figure 48: Wetlands and Coastal Management Areas (Extent I)

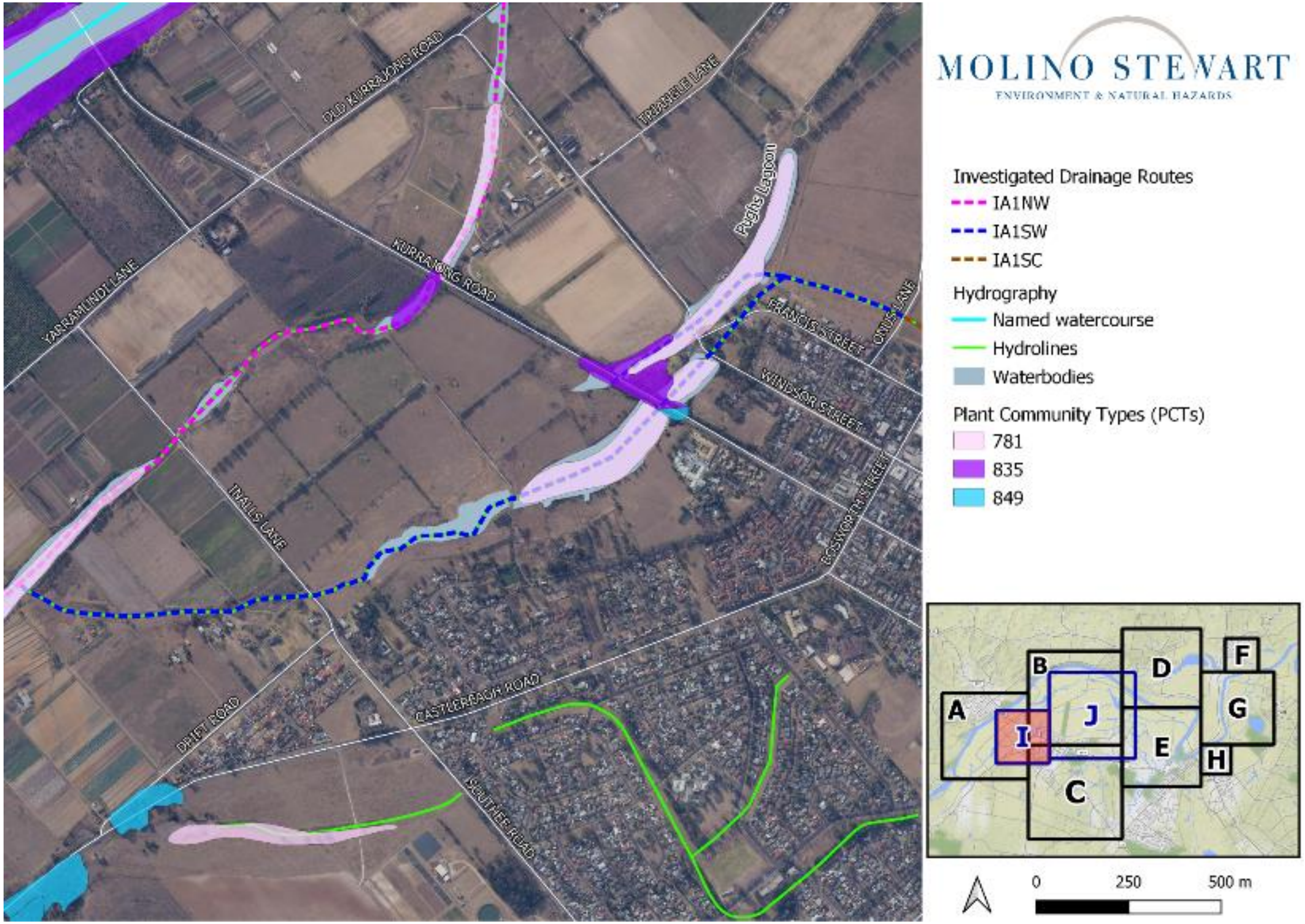

Figure 49: Plant Community Type Mapping (Extent I)

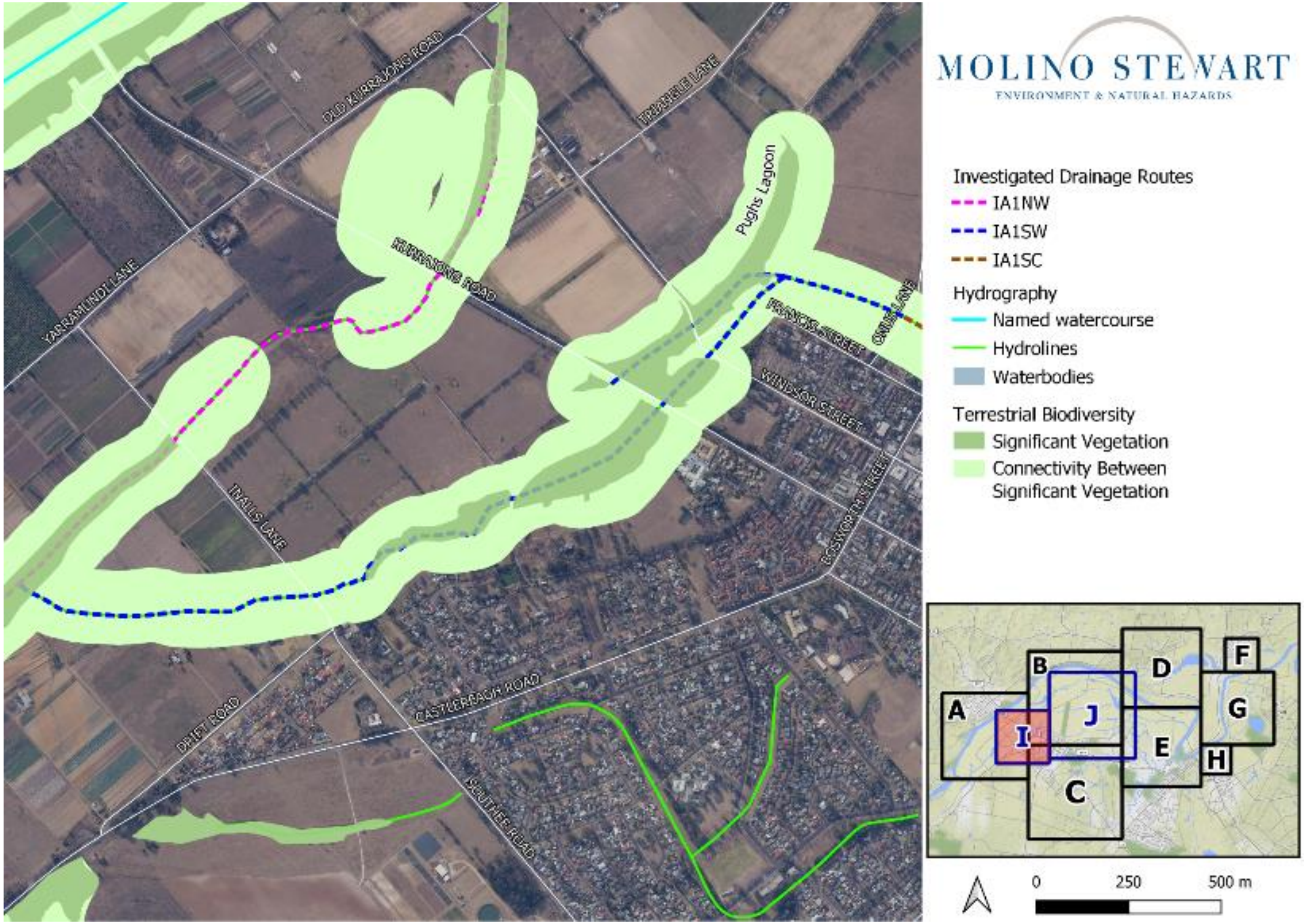

Figure 50: Terrestrial Biodiversity (Extent I)

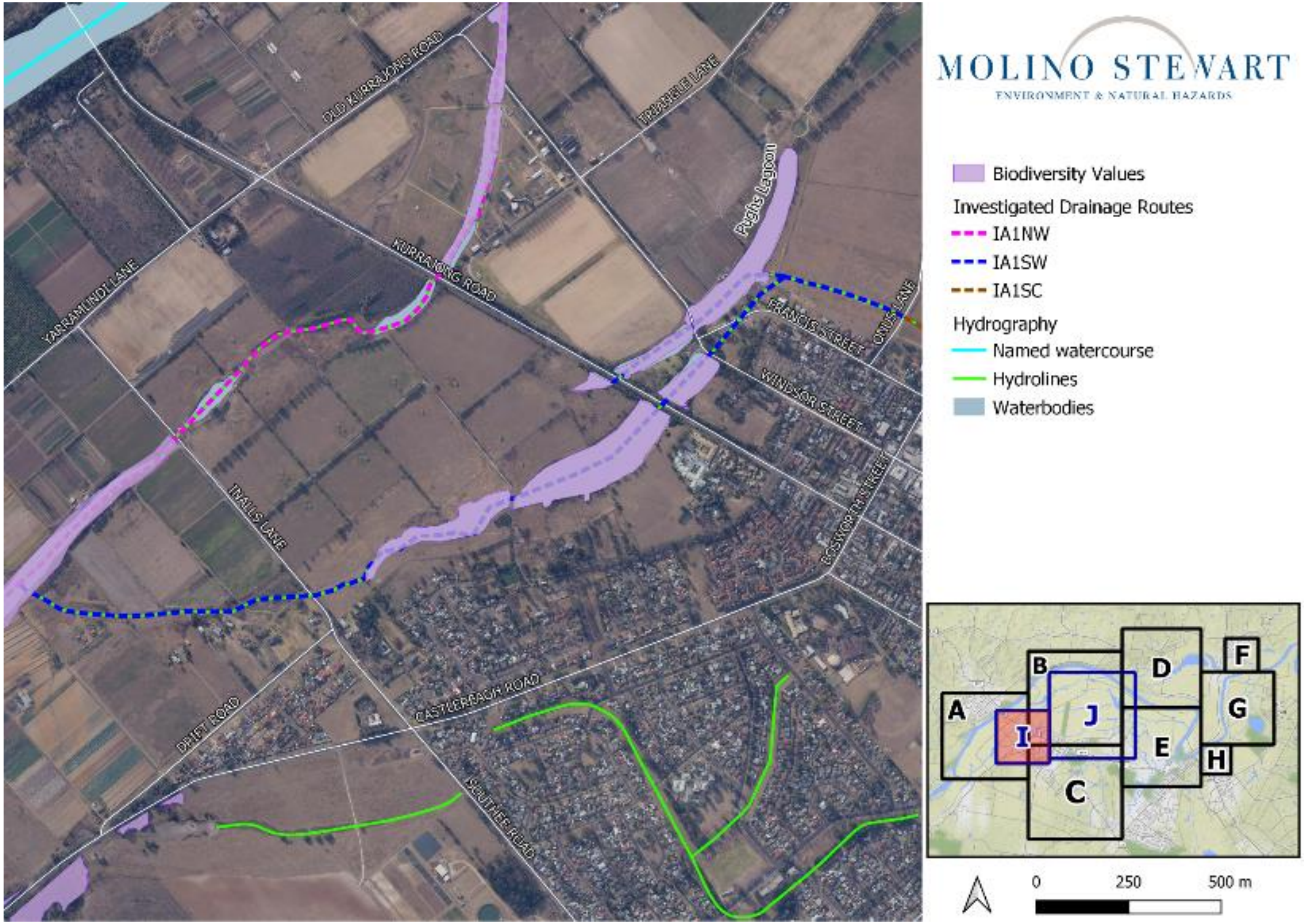

Figure 51: Biodiversity Values (Extent I)

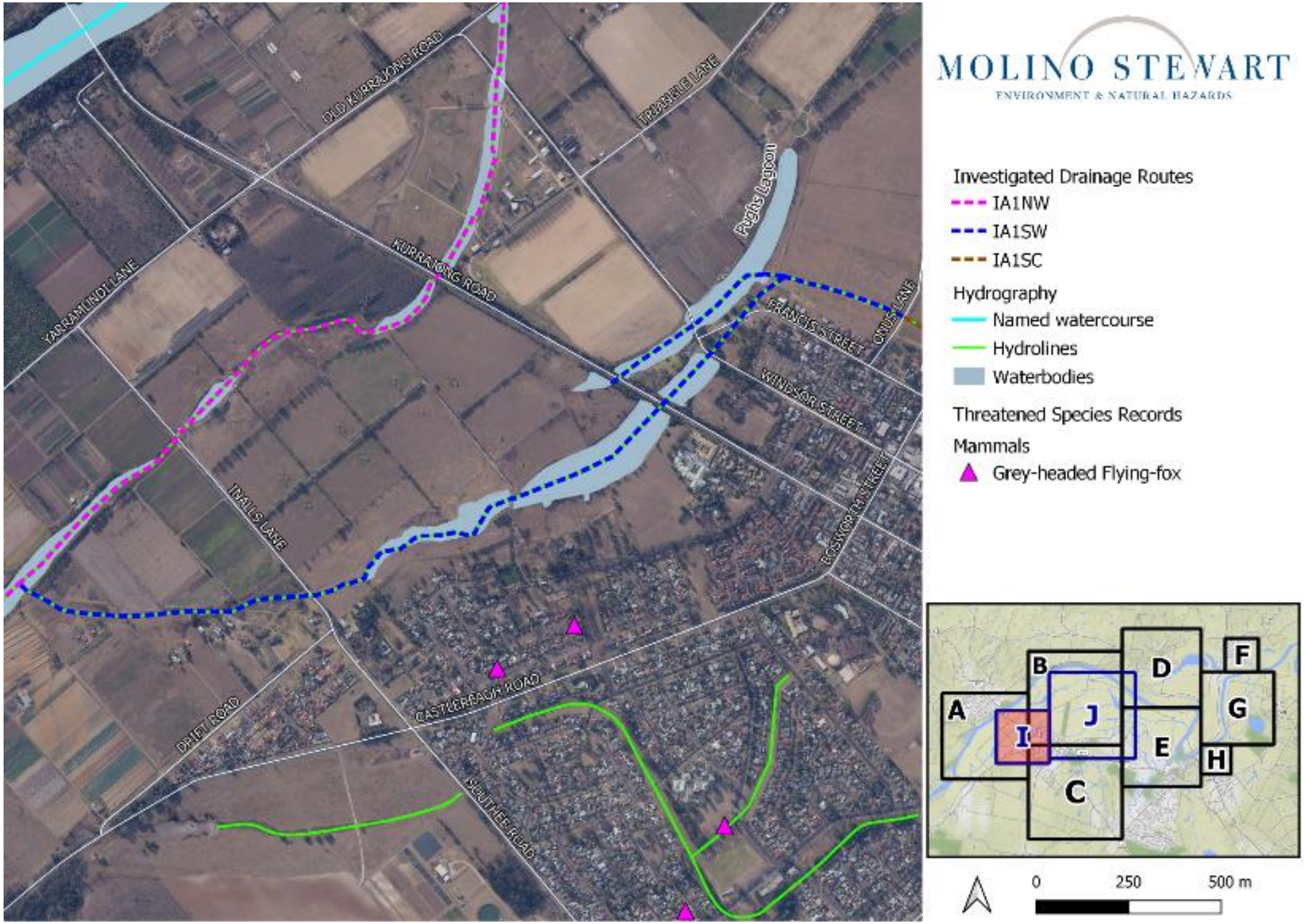

Figure 52: Threatened Species Records (Extent I)

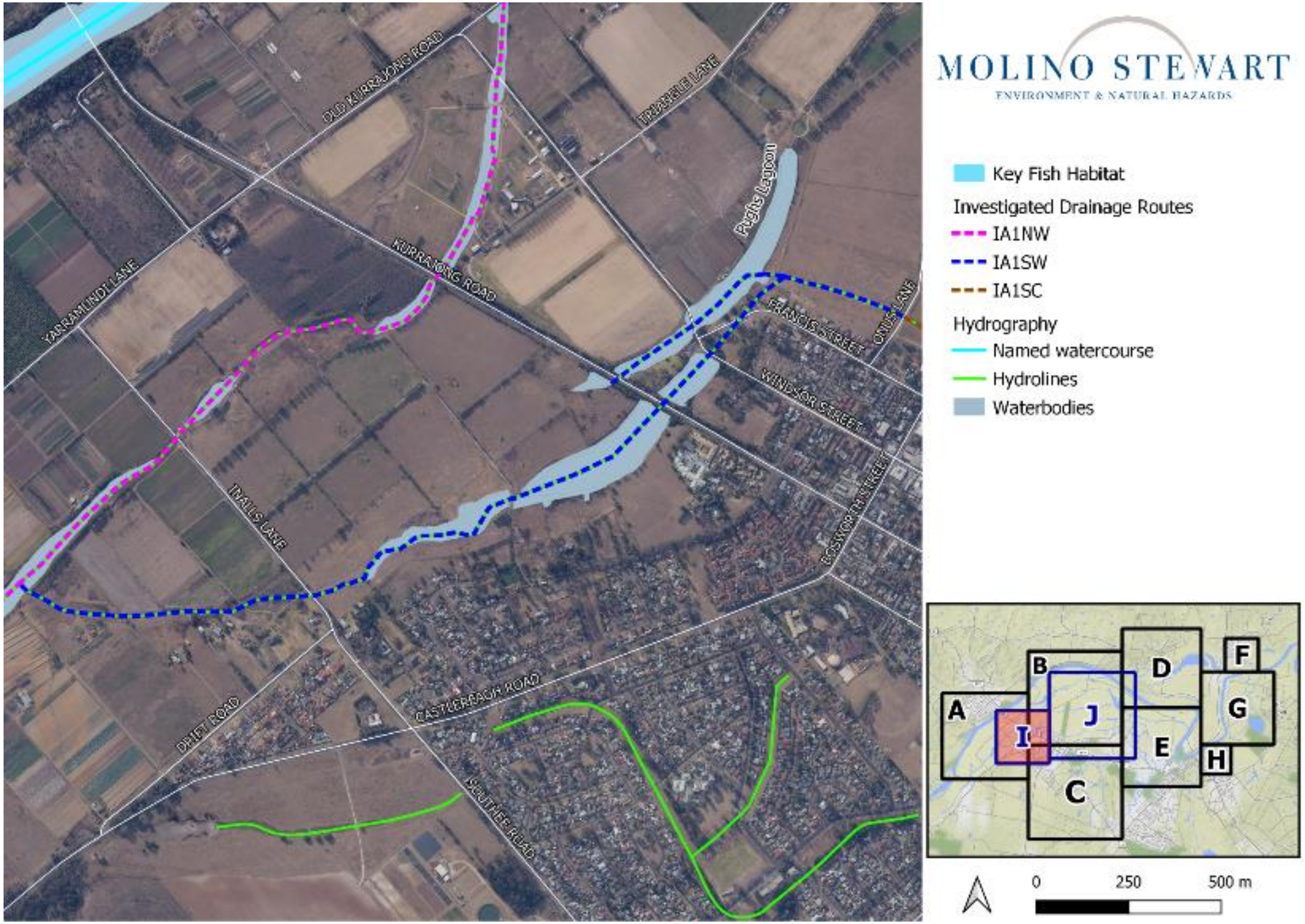

Figure 53: Key Fish Habitat (Extent I)

7| IA1 Southern Drainage Route Central

7.1 Drainage Issues

The central extent of the southern drainage route in IA1 (IA1SC) lies between Onus Lane and Cupitts Lane. In addition to the main drainage line this area includes a branch which joins the main channel about 450m west of Cupitts Lane. Photograph locations can be found in Figure 55.

7.1.1 Field observations

Downstream of the Onus Lake culvert there is a fence across the drain with reinforcing mesh and chicken wire which has caught a lot of debris (Photo 83). The channel is wide with some weed growth. It passes under two farm access tracks via piped crossings (Photo 84) and is joined by drains from adjacent paddocks (Photo 85). Those paddocks appeared to have ground levels lower than the water levels in the channel.

The channel passes under another access track via two pipes (Photo 86) and into a section of drain which is heavily infested with willows and other weeds (Photo 87 and Photo 88). It was not possible to get close to this reach of the creek to inspect it but it is possible that vegetation in this area is causing the water to backup in the channel upstream almost as far as Pughs Lagoon. The channel opens up again just upstream of Bensons Lane (Photo 89) under which it passes through two pipes (Photo 90). There was noticeable fall and flow in the water through this reach which further suggests that the vegetation upstream is blocking the channel.

Downstream of Bensons Lane the channel was wide, clear and ponded passing through large pipes under and access road 100m downstream (Photo 91). Downstream of this crossing the channel becomes more silted (Photo 92) and this silt appears to be constricting flow at this level. The paddock on either side of the drain here are lower than the top bank of the drain and are retaining water (Photo 93).

The channel passes under another access road (Photo 94) before becoming choked with reeds (Photo 95) which may be the cause of the water ponding. There are bridges over the channel further downstream (Photo 96, Photo 97). The reeds in the channel transition to a lower plant but the density is such that little open water can be seen (Photo 98) until the channel turns north east (Photo 99).

The channel continues in a north easterly direction with reeds and other vegetation with the channel which has a discernible flow (Photo 100). It passes under a bridge at the point where the channel turns east (Photo 101) but the fencing upstream of the bridge (Photo 102) is a trap for debris which could slow flows.

Downstream of this point the channel is wide, clear of vegetation and is ponded. It passes under a low bridge (Photo 103) and through piped crossings (Photo 104) but the cause of the ponding is a crossing where the pipes have been removed and the fill is constricting the flow (Photo 105 and Photo 106 and Photo 107). Downstream of this point water is ponded in the channel but at a lower level (Photo 108).

Downstream it passes through some pipes at a shallow depth (Photo 109) and there is discernible flow through here (Photo 110), suggesting the invert of these pipes is controlling the flow in the channel. Further downstream the channel is open but ponded (Photo 111) with fencing across the channel catching debris and restricting flow (Photo 112). As the channel continues east it is ponded (Photo 113) and is crossed by a wooden bridge (Photo 114) downstream of which is its cross connection north to Cooley Creek (Photo 115). As the channel flows east to Cupitts Lane it becomes heavily vegetated (Photo 116) before passing under the road through a culvert (Photo 117).

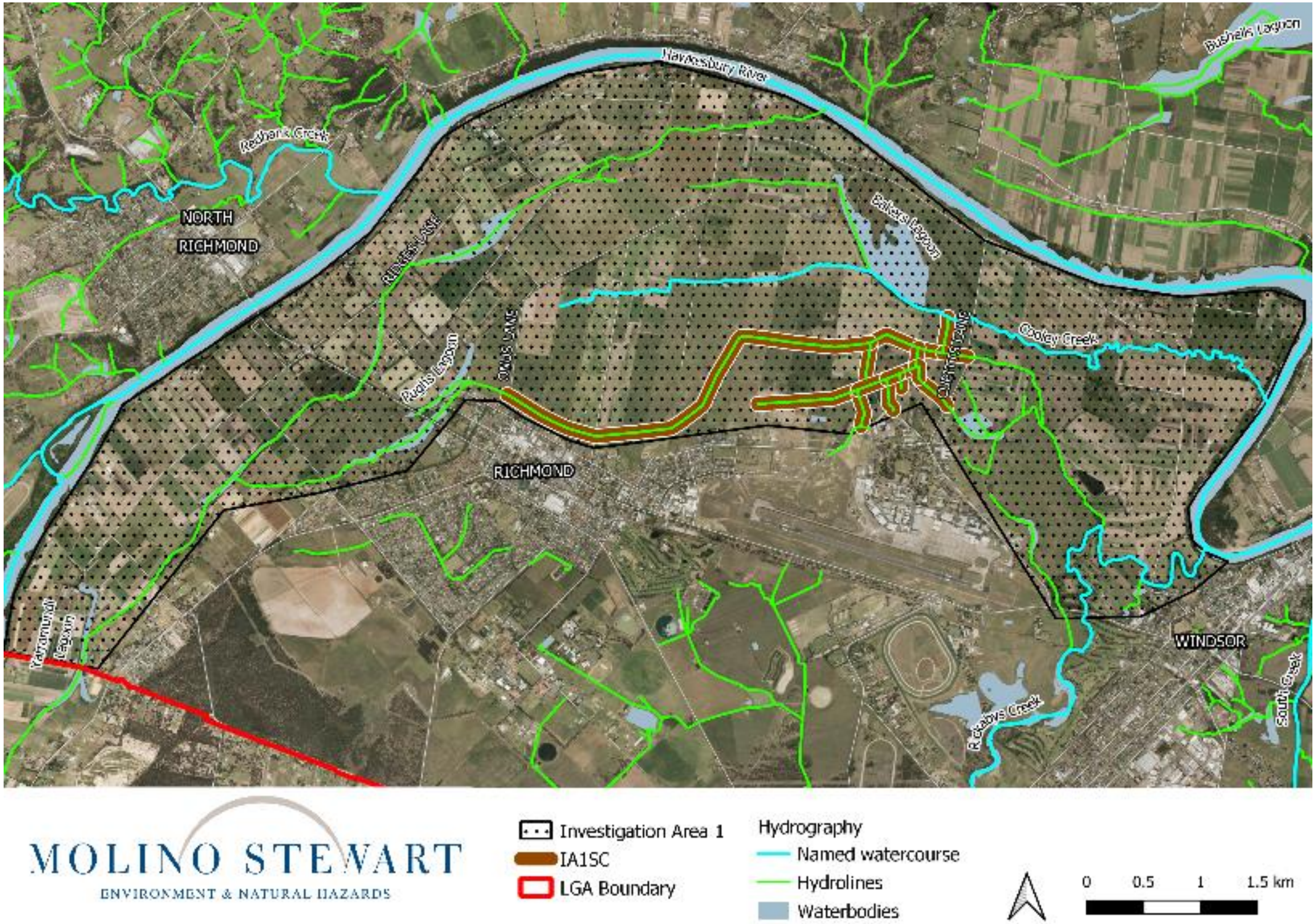

Figure 54: Investigation Area 1 Southern Drainage Route Central (IA1SC)

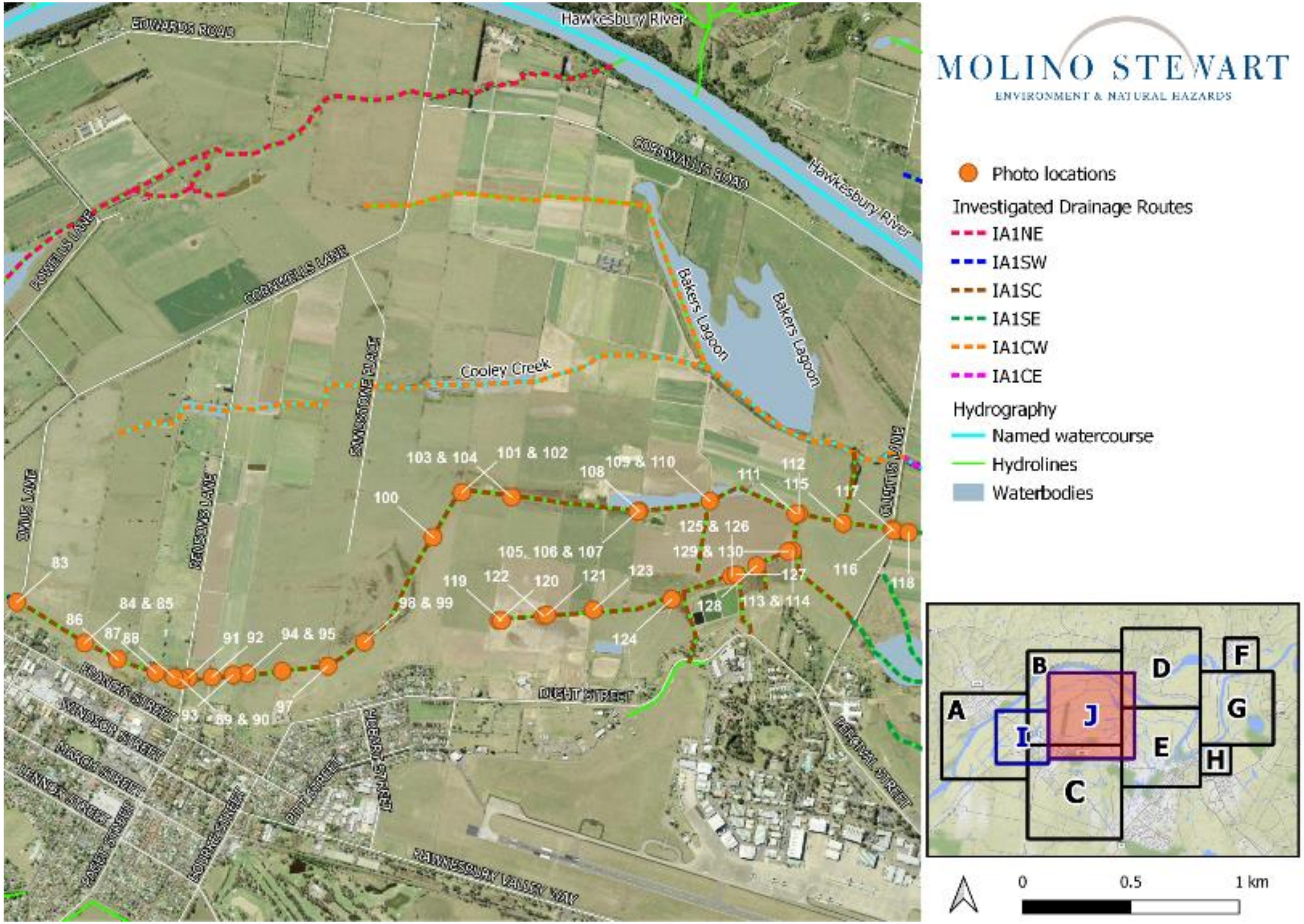

Figure 55: Photo locations for IA1SC