Horsley Park, Keyhole Site

Biodiversity Assessment

prepared for

Frasers Property Industrial

écologique | environmental consulting

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Revision Schedule

Rev No	Date	Description	Issued to
1	26/05/2021	Draft Report	Frasers
2	30/05/2021	Final Report	Frasers

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1. Introduction

1.1. Background

Frasers Property Industrial (Frasers) is preparing a planning proposal to rezone approximately 60 hectares of land in Horsley Park from RU2 Rural Landscape to an industrial zone to facilitate an industrial estate.

The subject land, known as the Keyhole Site, spans 29 allotments located to the east of the M7 motorway, west of Ferrers Road, south of Chandos Road and north of The Horsley Drive.

The subject land is dissected from east to west by Redmayne Road, which forms two separate continuous areas of potential future development, shown in Figure 1-1.

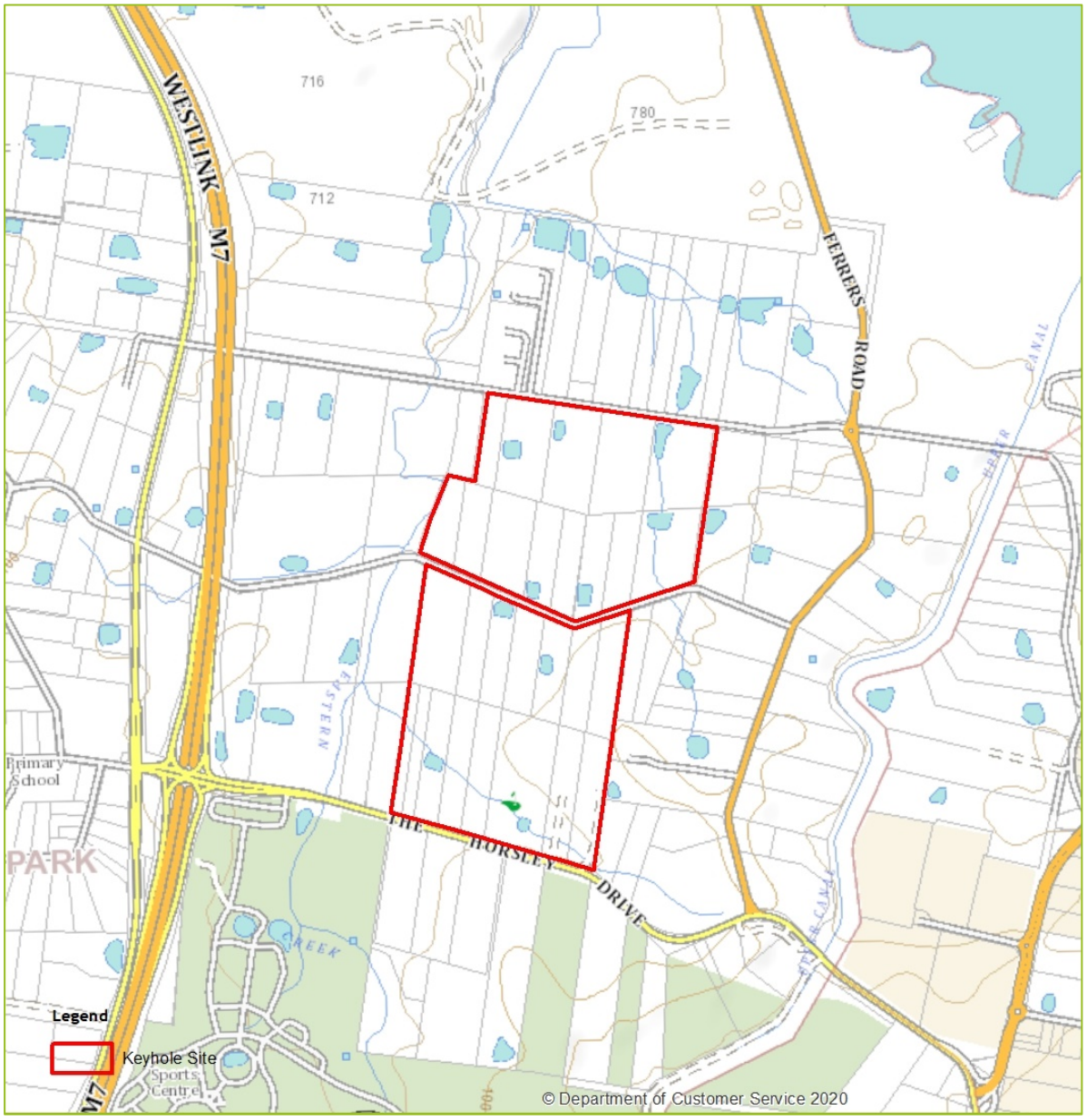


Figure 1-1. Subject site

1.2. Planning proposal requirements

In accordance with the NSW guidelines provided in 2018 by the then Department of Planning and Environment, a planning proposal is required to:

- Explain the intended effect of amending the relevant local environmental plan (LEP) and set out the justification for making that plan. In this instance, the relevant LEP is the Fairfield LEP (2013);
- Contain sufficient information to identify relevant environmental, social, economic and other site-specific considerations;
- Describe the scope of investigations undertaken for the initial planning proposal; and
- Identify any additional studies that may be considered necessary to justify the suitability of the proposed LEP amendment.

Relevant to biodiversity matters, Section C - Environmental, social and economic impact Q7 of the guidelines specifically requires the following:

- Identify if the land subject to the proposal has the potential to contain critical habitat or threatened species, populations or ecological communities, or their habitats; and
- If it is likely that the land may contain critical habitat or threatened species, populations or ecological communities, or their habitats the proposal should identify what studies are necessary to confirm the presence of these species or habitats and their significance.

An assessment of significance and / or consultation is likely may then be necessary in accordance with Part 7 of the *Biodiversity Conservation Act 2016* and Part 7A of the *Fisheries Management Act 1994* and the 'Threatened Species Assessment Guidelines' after a Gateway determination is issued.

1.3. Relevant legislation

The subject land's biodiversity values assessed in this report relate to the following legislation:

- NSW *Biodiversity Conservation Act 2016* and *Biodiversity Conservation Regulation 2017*;
- Federal *Environment Protection and Biodiversity Conservation Act 1999*;
- NSW *Fisheries Management Act 1994*; and
- NSW *Water Management Act 2000* and *Water Management (General) Regulation 2018*; and

1.3.1 Biodiversity Conservation Act 2016

The *Biodiversity Conservation Act 2016* (BC Act) is the main legislation that identifies and protects threatened species populations and ecological communities in NSW. The BC Act, together with the *Biodiversity Conservation Regulation 2017* (BC Reg.), outlines the framework for addressing impacts on biodiversity from development and clearing. It establishes a framework to avoid, minimise and offset impacts on biodiversity from development through the Biodiversity Offsets Scheme (the Scheme).

The Scheme's threshold is a test used to determine when is necessary to engage an accredited assessor to apply the Biodiversity Assessment Method (the BAM) to assess the impacts of a proposal. The BC Reg. sets out threshold levels for when the Scheme will be triggered. The threshold has two elements:

1. Whether the amount of native vegetation being cleared exceeds a threshold area, or
2. Whether the impacts occur on an area mapped on the Biodiversity Values map published by the Minister for the Environment

A 'test of significance' is required for all local development proposals that do not exceed the Scheme's Threshold. The test considers whether there will be a significant impact on threatened species, populations ecological communities and their habitats, through the development assessment process.

In the context of a Part 4 development (not including major projects) if the 'test of significance' assessment indicates that there will be a significant impact, the proponent must carry out a BAM assessment.

Major projects automatically require a BAM assessment and preparation of a BDAR unless a BDAR waiver is granted. Remnant vegetation within the subject land is commensurate with threatened ecological communities and a BDAR waiver is not applicable. Therefore, application of the BAM and the preparation of a BDAR will be required.

1.3.2 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as matters of national environmental significance (MNES).

If an action is likely to have a significant impact on a MNES, the development must be referred to the Australian environment minister for approval.

The subject land contains remnant vegetation that are listed endangered ecological communities under the EPBC Act and will require referral to the Australian environment minister for approval.

1.3.3 Fisheries Act 1994

NSW Department of Primary Industries (DPI) administers the *Fisheries Management Act 1994* (FM Act) and associated Regulations (FM Regulations). The DPI has jurisdiction over all fish and marine vegetation in state waters and these powers also extend to Commonwealth waters for some species and fishing methods under the Offshore Constitutional Settlement negotiated between the Australian and State governments.

The primary objectives of the FM Act are to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations, and in particular: to conserve fish stocks and key fish habitats; to conserve threatened species, populations and ecological communities of fish and marine vegetation; and to promote ecologically sustainable development, including the conservation of biological diversity.

To meet these primary objectives, Part 7 of the FM Act deals with the protection of aquatic habitats and Part 7A deals with threatened species conservation.

The subject land does not contain any areas of key fish habitat as mapped by the DPI and Part 7 of the FM Act does not apply. The subject land does not contain any areas that would provide habitat for threatened species and Part 7A of the FM Act also does not apply.

1.3.4 Water Management Act 2000

The *Water Management Act 2000* (WM Act) and *Water Management (General) Regulation* 2018 (WM Reg.) provide the relevant definitions and mechanisms for implementation of the WM Act. Relevant to the subject site is the definition of "waterfront land' under the WM Act, which is defined as follows:

'*the bed of any river, together with any land lying between the bed of the river and a line drawn parallel to, and the prescribed distance inland of, the highest bank of the river*'.

The WM Act is administered by the NSW Natural Resource Access Regulator (NRAR) and local development activities in or on 'waterfront land' require a Controlled Activity Approval (CAA) from the NRAR pursuant to Section 91(2) of the WM Act. In turn, the development becomes integrated as local government must refer the development application to the NRAR.

If the value of any proposed development warrants a State significant development approval pathway, NRAR will still be consulted and request similar conditions as if it were a CAA under local development. The only difference being that an application for a CAA is not required.

A watercourse assessment is provided in Section 4 of this report.

2. Assessment Methods

2.1. Biodiversity assessment methods

For the purpose of this assessment, it has been assumed that any future development of the subject land would be undertaken as major project or State significant development (SSD), which require the application of the BAM and preparation of a Biodiversity Development Assessment Report (BDAR). Unless a BDAR waiver is accepted.

A combination of desktop assessment and field survey has been undertaken to meet the planning proposal requirements identified in Section 1.2.

2.1.1 Desktop assessment

Desktop assessment of the subject land was undertaken to identify relevant biodiversity values that require investigation. The following information sources were used for field survey and reporting preparation:

- Aerial imagery: NearMap (April 2021)
- NSW Department of Planning, Industry and Environment (DPIE), Environment, Energy and Science (EES) Group, formerly the Office of Environment and Heritage (OEH)
    - Biodiversity Values BVMap_V102_SEED.gdb
    - Remnant Vegetation of the western Cumberland subregion, 2013 Update. VIS_ID 4207
    - BioNet Threatened Biodiversity Data Collection
    - Biodiversity Investment Opportunities Map: Mapping Priority Investment Areas for the Cumberland Subregion (2018)
    - Department of Environment and Climate Change, 2008, Soil and Land Resources of the Hawkesbury-Nepean Catchment, Department of Environment and Climate Change, Sydney.
- NSW Department of Industry (2018) Hydro Line spatial data
- NSW Spatial Services Historical Imagery Viewer: https://www.spatial.nsw.gov.au/products_and_services/aerial_and_historical_imagery
- NSW Department of Industry (2020) Fisheries habitat mapping
- EcoPlanning (2019) Ecological Constraints Assessment, 'Keyhole Site', Horsley Park, NSW.

2.1.2 Historical aerial photography

Aerial photographic interpretation of historical photography was undertaken for the purpose of both native vegetation and watercourse assessments of the subject land. This method is particularly useful in determining the origins of natural vs artificial construct across extensively modified land.

2.1.3 Site investigations

Areas within the subject land requiring site investigations were identified during the desktop assessment. At the time of investigations not all areas were able to be accessed. However, due to the highly cleared nature of the subject land, a level of visual assessment was still possible from adjacent lots, roads and easements.

Site investigations were undertaken on the 12th May 2021 by two ecologists and one fluvial geomorphologist (refer Section 1.4).

Assessment of vegetated areas included the following:

- Collection of Biodiversity Assessment Method (BAM) applicable data from larger patches of native vegetation;
- Groundtruthing of scattered paddock trees to determine whether native or exotic and assess for hollow bearing trees;

- Binocular assessment of scattered paddock trees and smaller patches of native vegetation on lots where access was not possible;
- Qualitative assessment of pastureland to determine whether any derived native grasslands (DNGs) were present;
- Opportunistic recording of fauna species; and
- GPS tracking and waypoint measurements and photographic records.

Table 2-1 provides a summary of the areas identified for investigation and the survey method on which this assessment is based on.

Table 2-1. Summary of investigation areas

Location	Street frontage	Survey type	Survey method
Lot A DP 361393	Chandos Road	Biodiversity	Ground truthed
Lot 54 DP 13961	Chandos Road	Watercourse	Visual assessment from street
Lot 63 DP 1396	Redmayne Road	Watercourse & Biodiversity	Visual assessment from street
Lot 59B DP 360222	Redmayne Road	Watercourse & Biodiversity	Visual assessment from easement
Lot 77 DP 13961	Redmayne Road	Biodiversity	Visual assessment from easement & street
Lot C DP 398446	The Horsley Drive	Watercourse	Not asssessed
Lot D DP 398446	The Horsley Drive	Watercourse & Biodiversity	Visual assessment from adjacent lot
Lot 78B DP 348873	The Horsley Drive	Watercourse	Ground truthed
Lot 79A DP 17288	The Horsley Drive	Watercourse	Ground truthed
Lot 79B DP 17288	The Horsley Drive	Watercourse	Ground truthed
Lot 1 DP 849699	The Horsley Drive	Watercourse & Biodiversity	Ground truthed
Lot 81A DP 348110	The Horsley Drive	Watercourse & Biodiversity	Ground truthed
Lot 81B DP 348110	The Horsley Drive	Watercourse & Biodiversity	Ground truthed

2.2. Watercourse assessment methods

A watercourse assessment was undertaken by Peter Johnston, BSc. MSc. Fluvial Geomorphologist. The assessment comprised two investigation stages, as follows:

1. Desktop assessment:
    a. review of contemporary aerial photographs
    b. review of historical aerial photography
    c. review of historic parish map
    d. review of GIS data
2. Detailed site investigation

2.2.1 Aerial photography

Aerial photography for the study area was acquired from Nearmap for the 22nd of January 2020 and the 15th of April 2021. These dates were selected due to the following:

- Imagery for the 22nd of January 2020 was captured prior to a period of increased rainfall. Ground cover was at a minimum at this time and surface morphology was more apparent because of reduced ground cover; and
- Imagery for the 15th of April 2021 represents the latest available capture of aerial photography.

Site specific Nearmap imagery for drainage pathways within the study area was sourced at the highest possible resolution of 0.075m per pixel. This resolution allowed the best possible interpretation of the surface morphology. Larger scale aerial photography that provides an overview of the study area and surrounds was acquired at 0.149 and 0.299 metres per pixel.

2.2.2 Digital Elevation Model (DEM)

New South Wales Government Spatial Services 1 metre DEM and LiDAR Point Cloud were sourced through the ELVIS web site. The 1 metre DEM had sufficient resolution for the interpretation of surface morphology and it was deemed not necessary to construct a higher resolution DEM from the point cloud.

The DEM was sourced as 32 individual tiles that covered the entire catchments of the flow paths extant within the study area. These tiles were imported into QGIS and merged into one tile. QGIS was then used to fill sinks and data gaps in the DEM so that a Strahler Stream Order could be generated that defined flow pathways within the study area. This process produced a raster image which was then converted into a shape file.

2.2.3 Limitations

GIS interpretation of flow pathways using a high resolution LiDAR DEM uses an algorithm that identifies a series of the lowest continuous points to define flow pathways. At their highest stream order these pathways may represent pathways of overland flow during periods of rainfall but they may not represent what can be referred to as a river or a stream. Further interpretation is essential to make this determination and verification is often impossible from even the highest resolution aerial photography. Often, only onsite investigations can identify the presence, or absence, of the assemblage of geomorphic units from which channel, or bank, morphology can be defined.

3. Biodiversity Assessment

3.1. Subject land description

The subject land is currently zoned for rural residential land use and has been extensively cleared (historically) for agricultural purposes, although the majority of the observed pasture lands do not appear to be operational.

Other observed land uses include: market gardens; a golf driving range, places of worship; partial use of allotments for residential; and various commercial activities. Several variably sized farm dams are also scattered throughout the subject land.

3.1.1 Subject land history

Historical aerial photography from 1930 to current day provides a time-line of land use change, which is summarised below and aerial photographs provided in Appendix A.

- By 1930 much of the subject land had been substantially thinned, potentially for timber as agricultural land use not evident;
- The Horsley Drive and Redmayne Road were evident along the existing alignments by 1950, with Chandos Road more akin to its current alignment by 1961;
- By 1965 approximately two thirds of the subject land is evident as market gardens;
- The current gas easement adjacent to Eastern Creek (along the western boundary of the subject land) had been cleared by 1975;
- The current extent of native vegetation is evident by the early 1990s; and
- Evidence of planted native vegetation is shown in photography dated 1998.

3.2. Existing vegetation

Existing vegetation on the subject land is predominately exotic vegetation, which includes large areas of pastural grasses and weeds, and widespread introduced shrub species.

3.2.1 Native vegetation

Native vegetation comprises several patches of remnant plant community types (PCTs), scattered and isolated paddock trees, and commonly occurring emergent aquatic species that have colonised farm dams. No areas of derived native grassland were observed.

Remnant PCTs within the subject land include the following:

- Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion (PCT 835);
- Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion (PCT 849)

Application of the BAM requires that all naturally occurring native vegetation must be allocated to a plant community type as classified within the NSW Bionet Vegetation Classification Database.

Scattered paddock trees comprising remnant native species that are constituent species of PCTs 835 and 849. For the purpose of this assessment the aerial extent of these trees has been included in the total area for either PCT 835 or PCT 849.

Emergent aquatic species that have colonised farm dams is also required to be allocated to the most closely associated PCT in the NSW Bionet Vegetation Classification Database, which has corresponded with *Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin Bioregion (PCT 1071).

PCTs occurring within the subject land are shown in Figure 3-1 and discussed further in Section 3.4.1.

3.2.2 Planted native vegetation

A number of non-endemic native trees occur within the subject land, such as *Eucalyptus microcorys* (Tallowwood), *Corymbia citriodora* (Lemon-scented gum) *Grevillea robusta* (Silky oak).

Examples of planted trees are found on Lot 1 DP 849699 along the western boundary and car park of the golf driving range on The Horsley Drive. This vegetation becomes evident following the construction of the driving range in 1998 aerial photography.

Appendix D of the BAM (2020) provides a decision-making key for the assessment of planted native vegetation, which can be used for that part of the subject land that contains planted native vegetation.

The decision-making key provides a step through process that enables the assessor to determine whether or not planted native vegetation must be included or excluded from the BAM assessment.

Preliminary assessment of the subject land's planted native vegetation indicates that it will not require assessment under the BAM but must still be assessed for its potential to provide threatened species habitat. This is due to the following results from the decision-making key:

1. The planted native vegetation does not occur within an area that contains a mosaic of planted and remnant native vegetation and which can be reasonably assigned to a PCT known to occur in the same IBRA subregion as the proposal;
2. The planted native vegetation has not been planted for:
    a. the purpose of environmental rehabilitation or restoration under an existing conservation obligation listed in BAM Section 11.9(2.), nor
    b. to replace or regenerate a plant community type or a threatened plant species population or its habitat
3. The planted native vegetation has not been planted for:
    a. a species recovery project
    b. Saving our Species project
    c. other types of government funded restoration project
    d. condition of consent for a development approval that required those species to be planted or translocated for the purpose of providing threatened species habitat
    e. legal obligation as part of a condition or ruling of court. This includes regulatory directed or ordered remedial plantings (e.g. Remediation Order for clearing without consent issued under the BC Act or the Native Vegetation Act)
    f. ecological rehabilitation to re-establish a PCT or TEC that was, or is carried out under a mine operations plan, or
    g. approved vegetation management plan (e.g. as required as part of a Controlled Activity Approval for works on waterfront land under the NSW Water Management Act 2000)
4. The planted native vegetation was undertaken voluntarily for revegetation, environmental rehabilitation or restoration without a legal obligation to secure or provide for management of the native vegetation.

3.2.3 Exotic vegetation

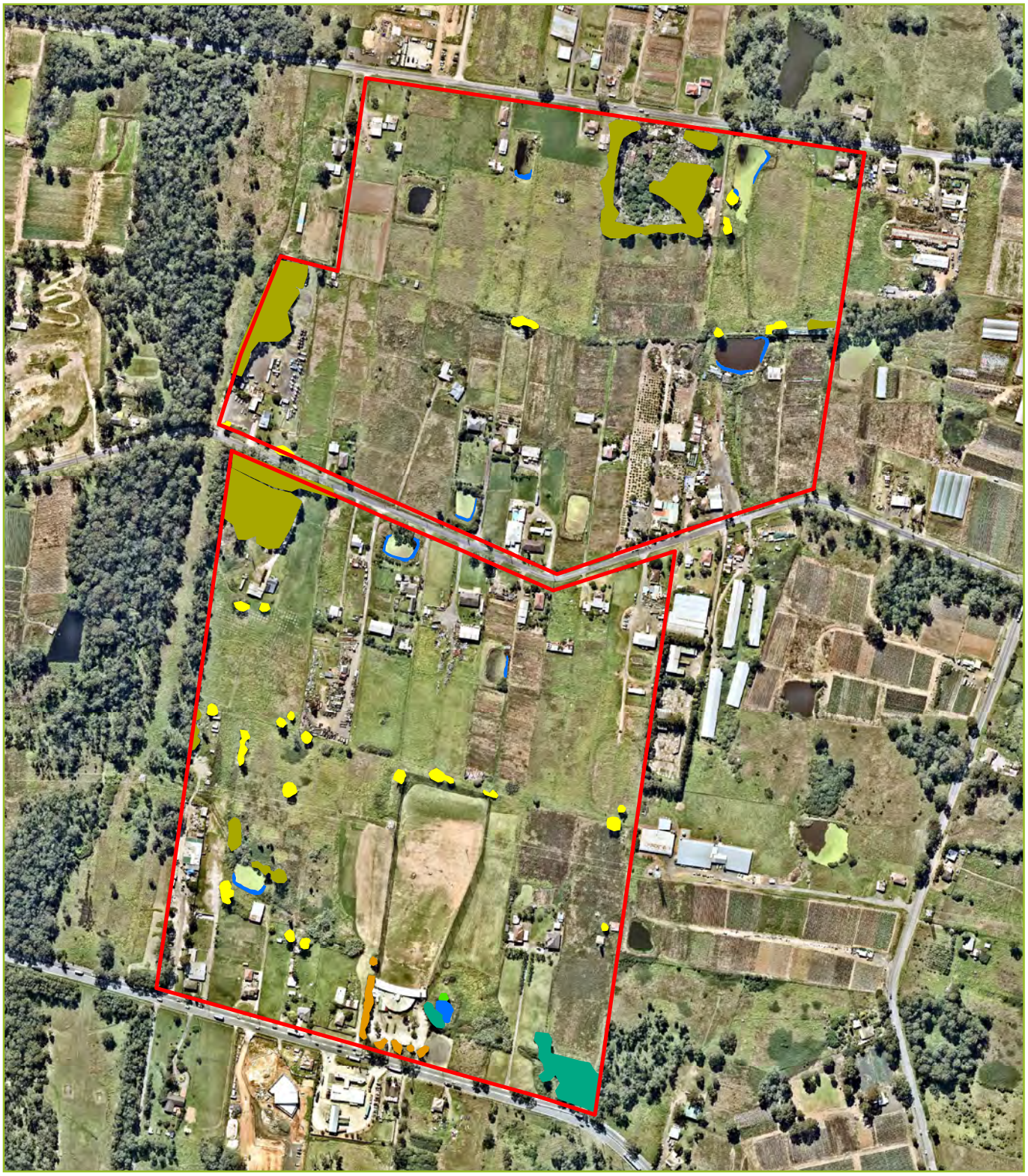
Vegetation within the subject land is predominantly exotic, with many of the widespread shrub and groundlayer species listed as priority weeds both in NSW and the Sydney Metropolitan region under the Biosecurity Act 2015 (Biosecurity Act). Under the Biosecurity Act, landowners have a general biosecurity duty (GBD) to eradicate, control or suppress the spread of priority weeds. Future development of the subject lands will require a strategy for ensuring compliance with the landowner's GBD.

Introduced species observed on the subject land, along with their status under the Biosecurity Act are summarised in Table 3-1.

Table 3-1. Introduced species observed within the subject land

Scientific name	Common name	Status
Woody weeds		
Arundo donax	Giant reed	Priority weed
Cestrum parqui	Green cestrum	Priority weed
Lantana camara	Lantana	Priority weed
Ligustrum lucidum	Broad-leaf privet	Priority weed
Ligustrum sinense	Narrow-leaf privet	Priority weed
Lycium ferocissimum	African boxthorn	Priority weed
Morus alba	Mulberry	Environmental weed
Olea europaea subsp. *cuspidata*	African olive	Priority weed
Ricinus communis	Castor oil plant	Priority weed
Rubus fruticosus	Blackberry	Priority weed
Toxicodendron succedaneum	Rhus tree	Environmental weed
Ground layer		
Ageratina adenophora	Crofton weed	Environmental weed
Anagallis arvensis	Scarlet Pimpernel	Environmental weed
Asparagus aethiopicus	Asparagus weed	Priority weed
Avena sativa	Wild oats	Pasture grass
Bromus cartharticus	Soft brome	Pasture grass
Chloris gayana	Rhodes grass	Pasture grass
Cirsium vulgare	Spear thistle	Environmental weed
Conyza sp.	Fleabane	Environmental weed
Cyperus eragrostis	Umbrella sedge	Environmental weed
Eragrostis curvula	African love grass	Environmental weed
Ehrharta erecta	Panic veldt grass	Environmental weed
Foeniculum vulgare	Fennel	Environmental weed
Juncus acutus	Spiny rush	Environmental weed
Malva parviflora	Small-flowered Mallow	Environmental weed
Opuntia stricta	Prickly pear	Priority weed
Paspalum dilatatum	Paspalum	Pasture grass
Phytolacca octandra	Inkweed	Environmental weed
Plantago lanceolata	Lambs tongues	Environmental weed
Plumbago auriculata	Cape Plumbago	Garden escape
Rumex crispus	Curly leaved Dock	Environmental weed
Setaria sp.	Pigeon grass	Pasture grass

Scientific name	Common name	Status
Solanum pseudocapsicum	Jerusalem cherry	Environmental weed
Sonchus oleraceus	Common sowthistle	Environmental weed
Sorghum halepense	Johnson grass	Pasture grass
Stenotaphrum secundatum	Buffalo grass	Pasture grass
Taraxacum officinale	Dandelion	Environmental weed
Trifolium repens	White clover	Environmental weed
Verbena spp.	Purple top	Environmental weed
Vines/scramblers		
Anredera cordifolia	Madeira vine	Priority weed
Araujia sericifera	Moth vine	Priority weed
Asparagus asparagoides	Bridal creeper	Priority weed
Cardiospermum grandiflorum	Balloon vine	Priority weed
Ipomoea indica	Morning glory	Priority weed
Vitia sativa	Vetch	Environmental weed



Legend

- Keyhole Site
- 835, Scattered tree
- 835, Patch
- 849, Scattered tree
- 849, Planted
- 849, Patch
- 1071, Patch

N

0 45 90 180 270 360

m

Keyhole Lands, Horsley Park - Rezoning

Figure 3-1. Subject land vegetation

Coordinate System: MGA Zone 56 (GDA 94)

Imagery: Nearmap April 2021

3.3. Fauna habitat

3.3.1 Terrestrial habitat

The subject land contains limited habitat and microhabitat features that would support most native fauna species, this due to:

- The absence of larger and structurally diverse areas of vegetation;
- Limited tree hollow bearing trees;
- The absence of large woody debris, bush rocks and other habitat features that provide shelter for ground dwelling fauna species;
- A lack of connectivity to potential wildlife corridors outside of the subject land; and
- The presence of feral animals (such as the European red fox and cats) along with numerous properties that are home to both domestic and guard dogs.

The scope of works undertaken for this assessment did not include targeted fauna surveys but opportunistic observations were recorded, which are provided in Table 3-2.

Table 3-2. Fauna species observed within subject land

Scientific name	Common name	Nature of observation
Acridotheres tristis	Common mynah	Observed
Cacatua sanguinea	Little Corella	Observed
Corvus coronoides	Australian Raven	Observed
Cracticus tibicen	Australian Magpie	Observed
Grallina cyanoleuca	Magpie-lark	Observed
Hirundo neoxena	Welcome Swallow	Observed
Macropus giganteus	Eastern Grey Kangaroo	Characteristic scats observed
Manorina melanocephala	Noisy miner	Observed
Mus muculus	House mouse	Potential evidence of bones in owl pellet
Rattus rattus	Black rate	Potential evidence of bones in owl pellet
Rhipidura leucophrys	Willie Wagtail	Observed
Felis catus	Cat	Observed
Canis lupus familiaris	Dog	Observed
Vulpes vulpes	European red fox	Characteristic scats observed
Unidentified snake species		Observed
Unidentified owl species		Pellet

3.3.2 Aquatic habitat

Aquatic habitat within the subject land is provided by way of drainage lines and farm dams, most of which are highly degraded and choked with exotic species. Despite such, habitat is provided for more commonly found native species, including eels, turtles and a number of frog species, with *Crinia signifera* (Common Eastern Froglet) the only aquatic (frog) species evident during site inspections (not observed but heard calling).

3.4. Legislative considerations

3.4.1 Threatened ecological communities

Two PCTs and a further third allocated PCT (within the subject land) are listed as threatened ecological communities (TECs).

Table 3-3. PCTs within the subject land

PCT no.	PCT name	Status		Approx. area (ha) in subject land
		BC Act	EPBC Act	
835	Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion	E	CE	0.37
849	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion	CE	CE	2.37
1071	*Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin Bioregion	E		0.12

Excluding scattered paddock trees and planted native trees, some areas of PCT 835 and PCT 849 will be commensurate with TECs listed under the EPBC Act.

While only one patch of PCT 849 is greater than 0.5 ha in extent, the remaining patches of PCTs 849 and 835 are located within proximity to larger areas of intact native vegetation (located to the east and west of the subject land) and subsequently meet the thresholds for MNES prescribed in the EPBC Act Significance of Impact guidelines policy.

Under the BAM, clearing of native vegetation must also demonstrate how a development proposal has been located to avoid or minimise direct and indirect impacts on biodiversity values. An important component of the BAM is assessing impacts on biodiversity values at risk of a serious and irreversible impact (SAII).

PCT 849 is a listed SAII entity, which will require additional assessment in this respect.

SAII entities and MNES are located along the western, northeastern and southeastern boundaries of the subject land as shown in **Error! Reference source not found.**.

PCT 1071 occurs as patches of *Typha orientalis*, which has colonised the edges of several farm dams. While the subject land's farm dams are considered highly degraded environments, the Bionet Vegetation Classification Database identifies PCT 1071 as occurring in man-made water bodies. Therefore, this PCT has been included in this assessment.

3.4.2 Threatened flora species

Preliminary interrogation of the BAM calculator (BAM-C) was undertaken to generate a list of threatened flora species associated with the PCTs within the subject land and that will requirement assessment for future development activities. Table 3-3 lists these species and identifies the PCTs that are known to provide habitat for each species.

Table 3-4. Threatened flora species that will require further assessment

Species name	PCTs	Status		Recorded from locality
		BC Act	EPBC Act	
Epiphytes / Climbers				
Cynanchum elegans	835, 849	E	E	NO
Marsdenia viridiflora subsp. - endangered population	849	E		YES
Ferns and Cycads				
Pilularia novae-hollandiae	835, 849	E		NO
Herbs and Forbs				
Hibbertia sp. Bankstown - endangered population	849	CE	CE	NO
Maundia triglochinoides	835, 1071	V		NO
Persicaria elatior	835, 1071	V	V	NO
Thesium australe	849	V	V	NO
Wahlenbergia multicaulis - endangered population	835, 849	E		NO
Zannichellia palustris	1071	E		NO
Orchids				
Caladenia tessellata	849	E	V	NO
Pterostylis saxicola	849	E	E	NO
Shrubs				
Acacia bynoeana	849	E	V	NO
Acacia pubescens	849	V	V	YES
Callistemon linearifolius	835	V		YES
Commersonsia prostrata	1071	E	E	NO
Dillwynia tenuifolia	849	V		NO
Dillwynia tenuifolia - endangered population	849	E		NO
Grevillea juniperina subsp. *juniperina*	849	V		YES
Haloragia exalata subsp. *exalata*	1071	V	V	NO
Persoonia bargoensis	849	E	V	NO
Persoonia hirsuta	835	E	E	NO
Pimelea curviflora var. *curviflora*	849	V	V	NO
Pimelea spicata	849	E	E	YES
Pimelea spicata - endangered population	849	E		YES

Species name	PCTs	Status		Recorded from locality
		BC Act	EPBC Act	
Pomaderris brunnea	849	E	V	NO
Pultenaea pedunculata	849	E		YES
Trees				
Eucalyptus benthamii	835, 849	V	V	NO
Melaleuca biconvexa	835, 1071	V	V	NO

Due to the highly degraded environment the likelihood of threatened flora species occurring within the subject land is considered a low probability.

The potential for any of these species to occur cannot be discounted without adequate justification or targeted surveys in accordance with NSW and EPBC Act related threatened species guidelines (Refer Section 5).

3.4.3 Threatened fauna species

Preliminary interrogation of the BAM calculator (BAM-C) also generates a list of threatened fauna species associated with the PCTs within the subject land and that will requirement assessment for future development activities. Table 3-4 lists these species and identifies the PCTs that are known to provide habitat for each species.

Table 3-5. Threatened fauna species that will require further assessment

Species Name	PCTs	Status		Recorded from locality
		BC Act	EPBC Act	
Bats				
Miniopterus australis	835, 849	V		YES
Miniopterus orianae oceanensis	835, 849	V		YES
Micronomus norfolkensis	835, 849, 1071	V		YES
Myotis macropus	835, 849	V		YES
Pteropus poliocephalus	835, 849	V	V	YES
Birds				
Anthochaera phrygia	835, 849	CE	CE	NO
Artamus cyanopterus cyanopterus	1071	V		YES
Botaurus poiciloptilus	835	E	E	NO
Calidris ferruginea	1071	E	CE	NO
Chthonicola sagittata	835, 849	V		NO
Climacteris picumnus victoriae	835, 849	V		NO

Species Name	PCTs	Status		Recorded from locality
		BC Act	EPBC Act	
Ephippiorhynchus asiaticus	1071	E		NO
Epthianura albifrons	1071	V		NO
Glossopsitta pusilla	835, 849	V		YES
Haliaeetus leucogaster	835, 849, 1071	V		YES
Iredippara gallinacea	1071	V		NO
Lathamus discolor	835, 849	E	CE	YES
Limicola falcinellus	1071	V		NO
Limosa limosa	1071	V		NO
Melanodryas cucullata cucullata	835, 849	V		NO
Pandion cristatus	835, 1071	V		NO
Petroica boodang	835, 849	V		NO
Petroica phoenicea	835, 849	V		NO
Rostratula australis	1071	E	E	NO
Stagonopleura guttata	835, 849	V		NO
Stictonetta naevosa	1071	V		NO
Marsupials				
Dasyurus maculatus	835, 849, 1071	V	E	NO
Phascolarctos cinereus	835, 849	V	V	NO
Amphibians				
Litoria aurea	835, 849	E	V	NO

As is the case for threatened flora species, the potential for any of these species must be investigated in accordance with with NSW and EPBC Act related threatened species guidelines (Refer Section 5).

4. Watercourse Assessment

4.1. Overview

4.1.1 Legislative definitions

NSW Hydroline Spatial Data mapping (hydroline mapping) indicates two first order watercourses and one second order watercourse in the subject land, as shown in Figure 4-1.

A watercourse has the same definition as a 'river' in the WM Act dictionary, which states:

a. *any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved, and*

b. *any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows, and*

c. *anything declared by the regulations to be a river.*

The WM Act also defines "waterfront land' (relevant to a 'river') as:

'the bed of any river, together with any land lying between the bed of the river and a line drawn parallel to, and the prescribed distance inland of, the highest bank of the river'.

Activities on "waterfront land' require a Controlled Activity Approval (CAA) from the NRAR - pursuant to Section 91(2) of the WM Act.

The correct identification of "waterfront land' is therefore critical for planning and decision-making processes.

4.1.2 Guidelines

The NRAR 'Guidelines for controlled activities on waterfront land - Riparian corridors' (2018) recommend a vegetated riparian zone (VRZ) width based on watercourse order as classified under the Strahler System of ordering watercourses. The watercourse (stream) order also influences what other development activities can be undertaken as summarised in Table 4-1.

Table 4-1. Riparian corridor matrix

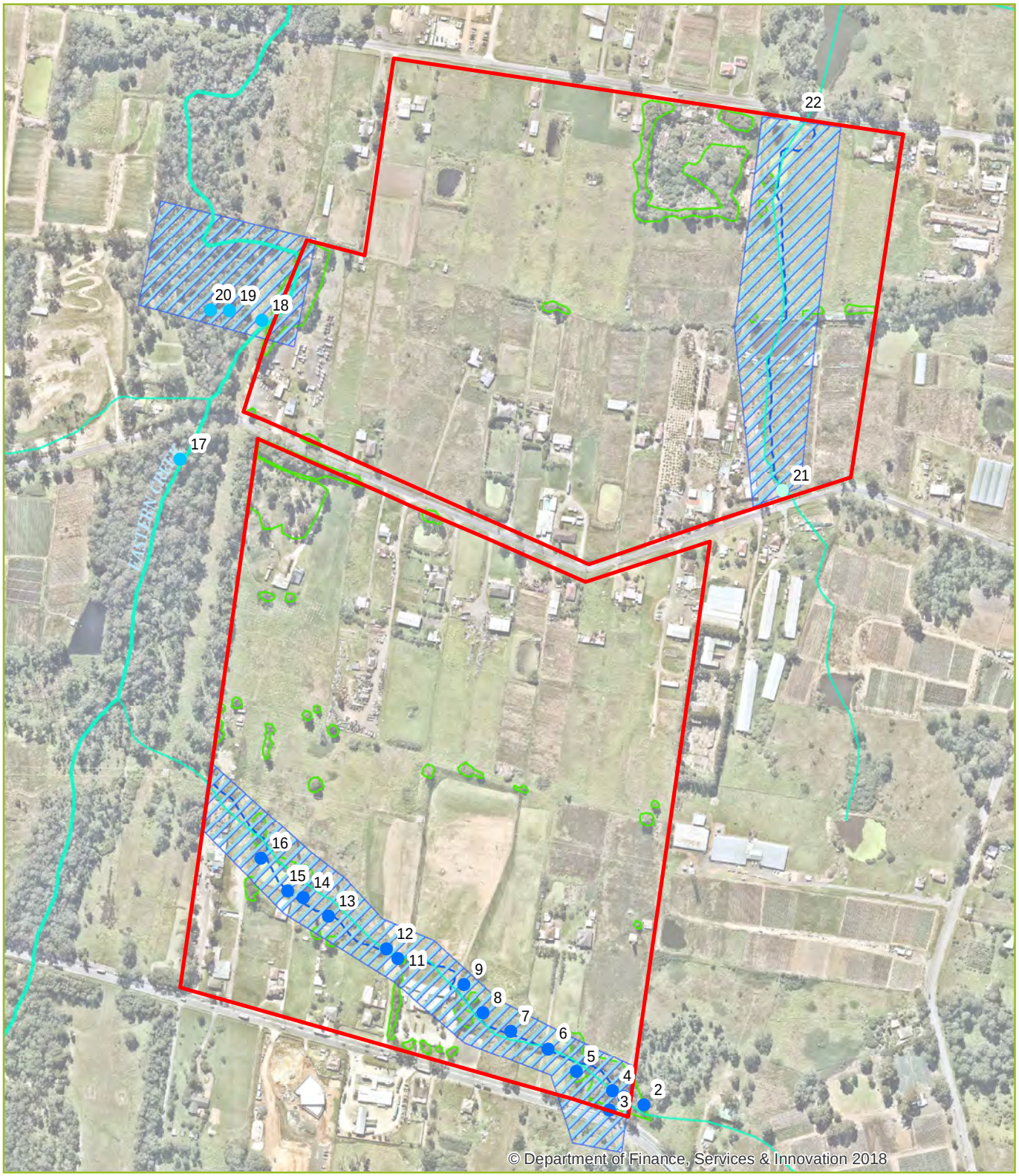
Stream order	Vegetated riparian zone(VRZ)	RC offsetting for non-RC users	Cycleways andpaths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10 m	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
2nd	20 m	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No

Source: 'Guidelines for controlled activities on waterfront land - Riparian corridors' (NRAR, 2018)

As can be seen in Table 4-1, a 2nd order stream requires a 20m VRZ zone (either side of the stream's top of bank) and cannot be realigned. Whereas a 1st order stream requires a 10m VRZ zone and can be realigned. The NRAR 'Guidelines for controlled activities on waterfront land - Riparian corridors' (2018) also state:

"Where a watercourse does not exhibit the features of a defined channel with bed and banks, the NRAR may determine that the watercourse is not waterfront land for the purposes of the WM Act."

Determining the presence or absence of defined channel with bed and banks and the correct stream order is therefore critical for planning and decision-making processes.



Keyhole Lands, Horsley Park - Rezoning

Figure 4.1 Subject land watercourses

Legend

- Keyhole Site
- Watercourse_assessment_areas
- Study area 1
- Study area 2
- Study area 3

N

0 45 90 180 270 360
m

Coordinate System: MGA Zone 56 (GDA 94)

Imagery Source: Nearmap 15 April 2021

4.2. Investigation results

The subject land was divided into three study areas, which are shown in Figure 4-1 and discussed herein:

4.2.1 Area 1

Area 1 extends through Lots 54 and 63 of DP 13961 between Chandos Road and Redmayne Road. As access to these lots was not available, site inspection was limited to what could be viewed from the adjacent roadways. Inspection sites for Area 1 are sites 21 and 22 (see Figure 4-1).

There are currently two well defined lengths of channel within this study area that are separated by agricultural dams. The channels are not evident on the 1930 photograph and their appearance coincides with the advent of market gardening in the area (see Table 4-2). The channels are in very poor condition, with very low sinuosity, no channel variability and are completely colonised by luxuriant growth of weeds.

Table 4-2. Historical imagery interpretation of study area 1

Date of photography	Observations
10 February 1930	There is no discernible channel at this time. Vegetation is relatively sparse and does not mask hidden channels. Flow pathways that are not channelised still follow the valley axis and will retain water longer than the surrounding slopes. They are usually characterised by more dense vegetation because of this but there is no evidence of preferential vegetation growth along the valley axis.
27 June 1961	There has been almost ubiquitous development of market gardens by this time. An agricultural dam has been constructed upstream of site 21 and a continuous, very low sinuosity, channel extends down slope to site 22. The dam downslope of site 22 has been constructed by this and there is an incised channel exiting the dam through the spillway. This dam is not within the study area.
6 May 1978	The channel alignment has not changed since the last photo but it is more pronounced. There are now four dams evident within the area 1 study site and market gardens occupy more of the catchment area. There is no change in channel character or morphology since the 1961 image
22 January 2020	There has been almost no change in channel character or morphology since the 1978 image. The image was captured at the end of a period of intense drought. There does not appear to be preferential growth of vegetation along the channel line but all dam levels are high. The dam that was immediately upslope of site 21 appears to have been infilled.

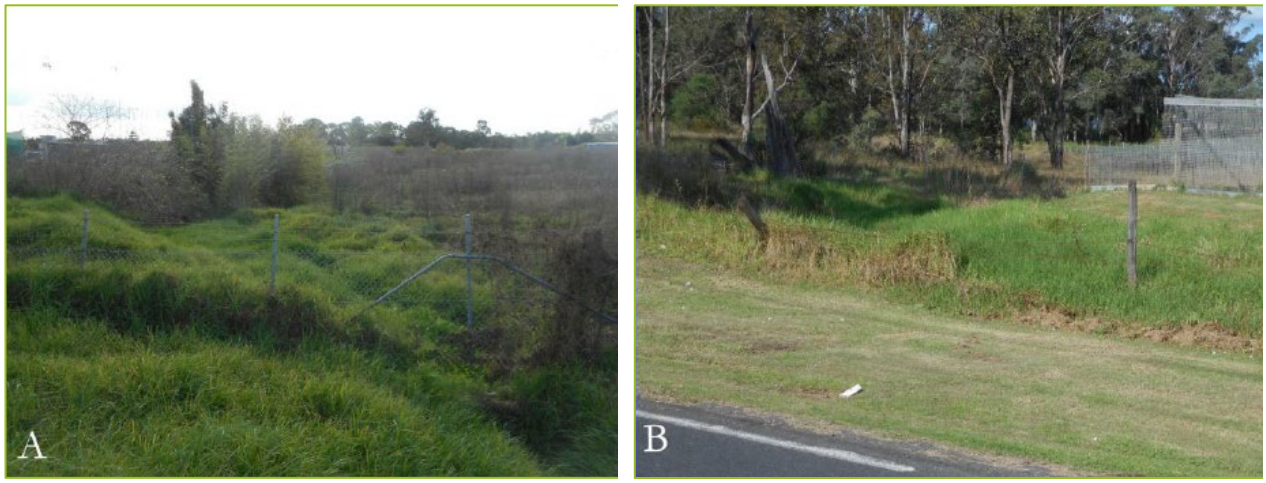
The contemporary position of flow pathways was determined by 1 m resolution LiDAR digital elevation model (DEM) and compared with the position of the mapped hydroline. The relative position of the flow lines is comparable, but not exact (e.g. the mapped hydroline passes through the centreline of the agricultural dams while the mapped pathways tend to follow more closely any existing spillway channel).

Desktop interpretation of contemporary aerial photography and DEM indicates that the reach between Chandos Road and Redmayne Road consists mainly of two agricultural dams, their associated spillways and connecting drainage pathways.

Within Area 1 the low gradient and fine-grained substrate would normally define a reach of moderate to high sinuosity but the sinuosity here is very low at 1.03 for the hydroline and 1.13 for the contemporary

mapped flow paths. With a very low sinuosity these channels are probably artificial and are essentially agricultural drains.

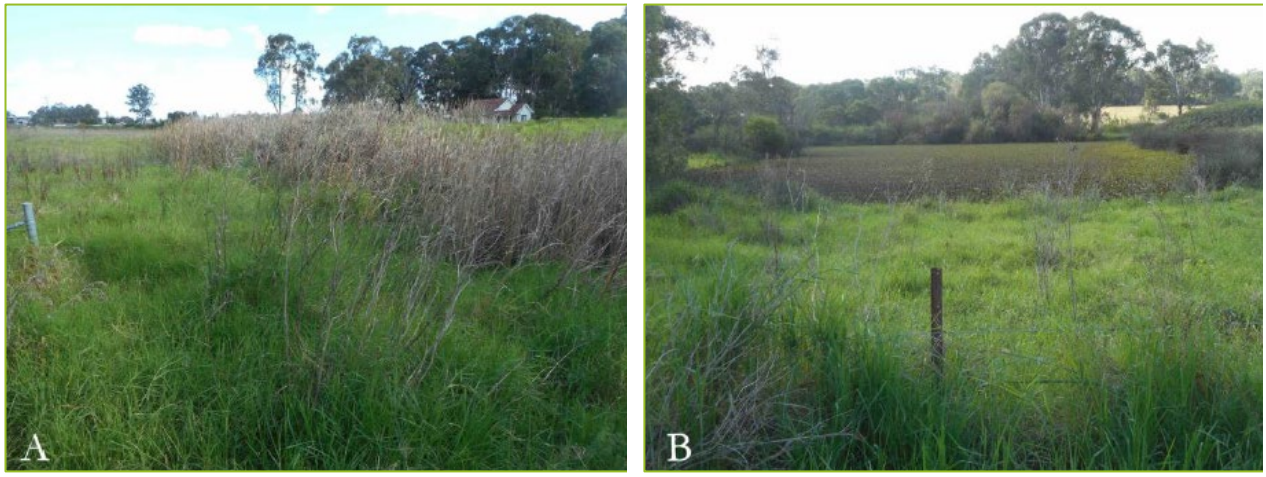
At site 21 there is a very low sinuosity drainage line extending downslope from the road, and upslope the channel passes around what appears to be an infilled agricultural dam. The channel cross section is trapezoidal which indicates anthropogenic modification.



Site 21: 'A' looking down slope and 'B' looking upslope

At site 22, downslope from the road, there is a minor flow path, which is less than 2 m wide and is completely obscured by weed infestation. The character of the channel cannot be determined. The flow path leads to weed choked dam down slope (see photo plates below).

There is a similar morphology on the upslope side of road where the drainage channel from an agricultural dam spillway is also choked. The upslope channel appears to be narrow, very low sinuosity, and anthropogenically modified.



Site 22: 'A' looking upslope and 'B' looking downslope

4.2.2 Area 2

Area 2 is where a meander loop of Eastern Creek, as per the mapped hydroline extends into the neighbouring Lot 59B (Figure 4-1). Eastern Creek at this location is mapped as a second order stream.

Table 4-3 provides a summary of historical aerial photography findings.

Table 4-3. Historical imagery interpretation of study area 2

Date of photography	Observations
10 February 1930	The quality of the 1930 photograph is insufficient to gain a clear insight into the existence of a continuous channel at this location. There appears to be some elongate patches of darker vegetation which may indicate water retention along flow paths but it is not conclusive. However, there is no evidence of a meander loop extending into lot 59B from Eastern Creek.
27 June 1961	The 1961 photograph is much clearer and has a good resolution. Market gardens occupy lot 59B and denser vegetation occupies the Eastern Creek corridor. While much of the meander channel length, as defined by the Hydroline, is masked by vegetation there is still sufficient gaps in the canopy to determine that there is no channel evident where indicates by hydroline mapping (that encroaches into lot 59B from Eastern Creek).
6 May 1978	The 1978 photo is clear and the resolution is good. There is a corridor that is cleared of vegetation along the western boundary of the study area and there is no channel in evidence.
22 January 2020	The 2020 aerial photograph has a high resolution and the quality is excellent. The cleared corridor along the path of the gas pipeline shows no evidence of a channel existing in the vicinity of the meander loop as mapped by the hydroline.

Desktop assessment of contemporary aerial photography found no evidence a channel at this location. To confirm the presence, or absence, of the meander bend of Eastern Creek a transect of three sites were assessed across the channel zone and these are sites 18, 19 and 20. As a check on the morphology and character of the Eastern Creek, as mapped for this study, an additional site, site 17, was assessed upstream.

Figure 4-1 shows the location of these sites and photo plates provided below illustrate the defined channel and banks of Eastern creek and absence of defined channel and banks where the hydroline is mapped as meandering into Lot 59B (at site 18).

Site 17: 'A' looking downstream

Site 18: 'A' looking downslope to the location of the mapped hydroline meander

Site 19: 'A' looking upstream

Site 20: 'A' looking upstream

4.2.3 Area 3

Area 3 extends laterally from west to east through Lot 78B of DP 255329, Lots C and D of DP 398446, Lots 79A and 79B of DP 17288, Lot 1 of DP 849699 and Lots 81A and 81B of DP 38110 (all with street frontage to The Horsley Drive).

The mapped hydroline in study area 3 extends upslope (outside of area 3) for another 360 m. The contemporary 2021 mapped channel also extends upslope of the study area for another 170 m. Sixteen sites were investigated as shown in Figure 4-1.

Table 4-4 provides a summary of historical aerial photography findings.

Table 4-4. Historical imagery interpretation of study area 2

Date of photography	Observations
10 February 1930	The 1930 imagery for area 3 is much clearer than at other areas of the image. Eastern Creek can be easily seen to be a discontinuous channel to the west of the study area. The area of the Keyhole Site has been largely cleared along the southern boundary and sparse vegetation does not mask the surface. There is no evidence of any channel existing in this area
27 June 1961	The 1961 imagery is of good quality and resolution. Market gardens extend across most of the study area and a low sinuosity continuous channel is also in evidence. The zone between sites 14 and 16 is masked by vegetation and there is no evidence of the dam that later occupies this location. The channel down slope of site 16 is poorly defined but the channel of Eastern Creek can clearly be seen in Lot 97B. There is a low sinuosity, continuous channel in evidence extending upslope from the vicinity of site 14 to site 1 with dams having been constructed at site 12 and site 8.
6 May 1978	At the date of capture there is very little vegetation masking the channel zone. By this time the channel morphology that largely exists today is in place. Highly modified and straightened sections of channel are in evidence downstream of site 16 where a dam has now been constructed. Dams are also in existence at sites 12, 10 and site 8. There is a continuous channel upstream

Date of photography	Observations
	of site 7 and it appears to be erosional at site 7 and site 2. Sheet erosion is evident at site 2. At site 10 is where the golf driving range is today and there is now a pipeline carrying the flow under sites 9 and 10. The sheet erosion evident at site 2 has now been re-contoured and the channel evident in the 1978 photo is no longer in existence.
22 January 2020	The market gardening prevalent in the previous imagery is largely absent in the 2020 image. The dams at sites 16 and 8 are now choked with abundant vegetation, as is much of the channel length, and the dam at site 10 has been filled in and a pipeline now conveys the flows subterraneously. Further channel straightening and piping has occurred at sites 13 and 6. The channel has a very low sinuosity and is generally in a very poor condition

Desktop review and analysis of contemporary aerial photography reveal a channel with remarkable little variation of character and morphology. Channel sinuosity measured from the confluence with Eastern Creek to the maximum upstream extent of the mapped hydroline and mapped length for this investigation were very low, again indicative of a highly modified channel.

Aerial photograph interpretation reveals what appears to be partially artificial channel and partly intact channel, especially in the upper reaches.

Analysis of recent aerial photography sequence shows artificial channel construction on Lots 78C and D after 27/12/2020 and prior to 26/01/2021, which is also apparent upslope of the dam on lot 78B.

Channel morphology is more apparent on the golf driving range where surface vegetation is kept low. Here there appears to be a remnant chain of ponds morphology which would be expected in this area prior to settlement. However, given the development that is apparent in the area, and how this development would have impacted catchment hydraulics, the apparent channel capacity on the driving range is too low.

The defined channel, modified or not, ends at the boundary of Lot 81B, which is the upstream limit of this study area and the boundary of the Keyhole Site.

Sites 1 – 5. Upper reach of study site

There is a short length of channel between site 5 and the upper boundary of the study area that has remnant chain of ponds morphology with a continuous channel. The channel ends at the boundary between Lots 73B and 81B which is also the boundary of the Keyhole Site. At this location the defined channel and has been stabilised by rock fill. Site 2 is located outside of the study area upslope on an area where there is no defined channel (see photo plates below).

The low flow channel through this reach is well defined with low angled and well vegetated banks. At some locations the banks appear to be two stage which may indicate the passage of a knickpoint through this reach.

Site 1: 'A' showing stabilised rock fill

Site 2: 'B' looking upslope and no defined channel

There is also some remnant pond morphology at site 3 where the channel widens out from 2 metres in width to more than 8 metres. The stagnant water that was evident at site 1 is not in evidence here. The channel and pond base has been dry for an extended period.

Sediment spear testing at sites 3 and 4 penetrated easily, with very little resistance to 1.05 m. There is a narrow, sub-horizontal, floodplain pocket at bank top left bank that has sediment to 0.40 m as indicated by sediment spear testing.

Site 3: 'A' looking upstream towards site 4

Site 4: 'B' shows recent deposition in the base of the channel

At site 5 there is a confluence with a well-defined channel entering from left margin. This new channel extends from south of The Horsley Drive out of the study area and enters the study area via a culvert under the road. The channel is 3 – 4 m wide with high angle to sub-vertical banks to 1.4 m high, with recent deposition of medium to coarse and granular sediment apparent in channel base. The channel base of the tributary from site 1 is perched 0.60 m above base of new channel entering from left margin. This indicates that the majority of flow enters from the unmapped channel and it is erosional.

Sites 6 – 8

At site 6 there is a length of channel that flows through a pipe that is approximately 9 m in length. Only the upstream end of the pipe is apparent as the downstream end is obscured by abundant weed growth (see photo plates).

There is a suspiciously straight channel extending upslope of crossing. A straight channel in this environment indicates anthropogenically modified channel or an artificial channel. Sub-vertical banks to 3 m high are vegetated and stable. The channel width, bank top to bank top, is between 5 and 6 m. Access to the channel zone downstream of site 6 is extremely difficult and limited by abundant and dense weed growth, notably blackberry. Site 8 is located on an old dam wall and is looking upstream.

Site 6: 'A' looking upstream from site 6

Site 6: 'B' looking downstream from site 6

Site 8: looking upstream across the impoundment of an old agricultural dam that is now choked with weeds

Sites 9 – 12

A piped section of channel with the upstream intake located between site 8 and site 9 but this area is completely overgrown and the exact location was unable to be determined. Most flows are diverted underneath the driving range through a subterranean pipe. There is a surface inlet grid at site 10 and at site 11. The end of the piped section is between sites 11 and 12 but is obscured by vegetation.

There is a surface low flow channel that has a low to moderate sinuosity with remnant ponds morphology. The low flow channel has a low capacity and discontinuous banks to 0.30 m. Flows that are unable to be contained within the pipe flow across the surface of the golf range. Interrogation of the historic aerial photography for 1978 shows an agricultural dam at this location.

Site 9: 'A' location at golf range boundary, looking upstream to site 8

'B' looking downstream to site 10

Sites 12 – 14

There is a very low sinuosity channel that shows evidence of anthropogenic realignment. Most of this reach was unable to be viewed and was largely inaccessible due to the abundant growth of blackberry, and other weed, obscuring the channel.

At site 12 the channel zone becomes visible through gaps in weed infestation with a deeply incised channel evident.

At site 13 there is a 15 m length of channel that passes through two pipes (see photo plates). The channel both upstream and downstream of site 13 is straight and has a trapezoidal profile that is indicative of anthropogenic realignment.

The channel emerges from weed infestation upstream, passes through a straight channel and into two concrete pipes. There is very minor base flow in evidence and appears to be stagnant. The channel emerges from the pipes into another straight section that has a trapezoidal profile. This profile indicates an anthropogenically modified stream.

The left bank downstream of the pipes is artificial and appears to be a fill of building waste; concrete and bricks.

The channel width, bank top to bank top, averages 6.0 m. Downslope, before flowing into a dam at site 14, the channel passes into a narrow slot that is 3 m wide and inset into two stage banks. The channel bank height is approximately 4 m.

Site 13: 'A' artificially straightened channel extending upstream

Site 13: 'B' looking downstream

Sites 14 - 16

Sites 14 – 16 comprises the end of the channel where it flows into the dam at site 15. Site 16 is at the dam wall at property boundary.

'A' looking downstream from site 15 across dam

'B' looking across the dam wall to a highly modified zone of degraded channel

4.3. Summary of findings

Based on the desktop and-detailed site investigations the following is concluded:

- Area 1

  The contemporary channel is generally well defined and continuous, but has low variability, low sinuosity and is trapezoidal in parts. All of which indicate anthropogenic modification or potentially anthropogenic in origin.

  Assessment of the historical origins of mapped hydroline show no discernible channel in 1930, with sparse vegetation. Flow paths that are not channelised will still retain water longer than the surrounding slopes and are usually characterised by more dense vegetation, which is historically absent.

Channels become evident following the creation of agricultural dams, which correlate to the emergence of market gardens, which further suggests that the existing channels are anthropogenic in origin and not a first order watercourse as indicated by hydroline mapping.

- Area 2

  The mapped hydroline encroaching into Lot 59B is not evident historically nor contemporarily and it can be confidently concluded that a second order watercourse within this allotment does not exist. Therefore, a Controlled Activity under the WM Act is not required as Lot 59B does not occur on waterfront land.

- Area 3

  The contemporary channel is generally well defined and continuous but is considered for the most part to artificial and anthropogenically modified.

  What appears to be intact valley fill at head of catchment in this study area is at the interface of colluvial margin and flow path. This area is not natural and sheet erosion evident in the historical aerials has been re-profiled.

  The existing modified and piped flow paths do not appear to extend or discharge into Eastern Creek. Historical aerial photography from 1930 also shows no evidence of any naturally occurring watercourse in this area.

  On the mapped first order hydroline is also contested, however this would need to be determined in consultation with the NRAR.

  A first order watercourse allocation would require a 10 m VRZ either side of the top of each bank, however realignment of a first order watercourse is permissible (refer Section 5.2 and Figure 5-1).

It is important to note that the NSW Hydroline Database is an artificial construct generated by GIS analysis with limited ground truthing. Information on the layer's metadata webpage (NSW Hydroline) states that the database is automatically and continuously updated as new information becomes available "…from relevant stakeholders and custodians…" but no information is provided what this means for the temporal recurrence of physical updates, or corrections, of the mapped hydrolines.

It is considered that the fluvial geomorphic assessment undertaken for the proposed rezoning of the Keystone Site (Johnstone 2021) is an example of 'new information' that would result in an update of the database.

5. Conclusion

With relevance to biodiversity values and mapped watercourses within the subject land, this assessment has concluded that the potential for future development of the Keyhole Site would not result in significant effects that would preclude the rezoning proposal.

Figure 5-1 provides an overview of the subject land's potential developable constraints as they relate to biodiversity values and watercourse assessment.

5.1. Biodiversity assessment

Remnant native vegetation within the subject land represents a relatively small cumulative extent (approximately 4% of the subject land), which is comprised of several isolated patches of poor condition PCTs and scattered paddock trees.

Notwithstanding, PCTs within the subject land are commensurate with TECs listed under both the BC Act and EPBC Act and have the potential to provide habitat for threatened species. Consequently, further investigations will be required. However, it is understood that the following listed investigations should not take place until after the Gateway determination:

- Application of the BAM and preparation of a BDAR in accordance with the NSW BC Act, which must include:
    - Assessment of SAII entities,
    - Targeted surveys for threatened flora and fauna species,
    - Justification that avoidance and minimisation of impacts on biodiversity values has been considered within the design stage of future development proposals, and
    - Determination of offsetting obligations in accordance with the NSW Biodiversity Offset Scheme, for direct and indirect impacts on biodiversity values that are unable to be avoided or minimised.
- Referral to the Australian Minister for the Environment and a controlled action approval under the EPBC Act.

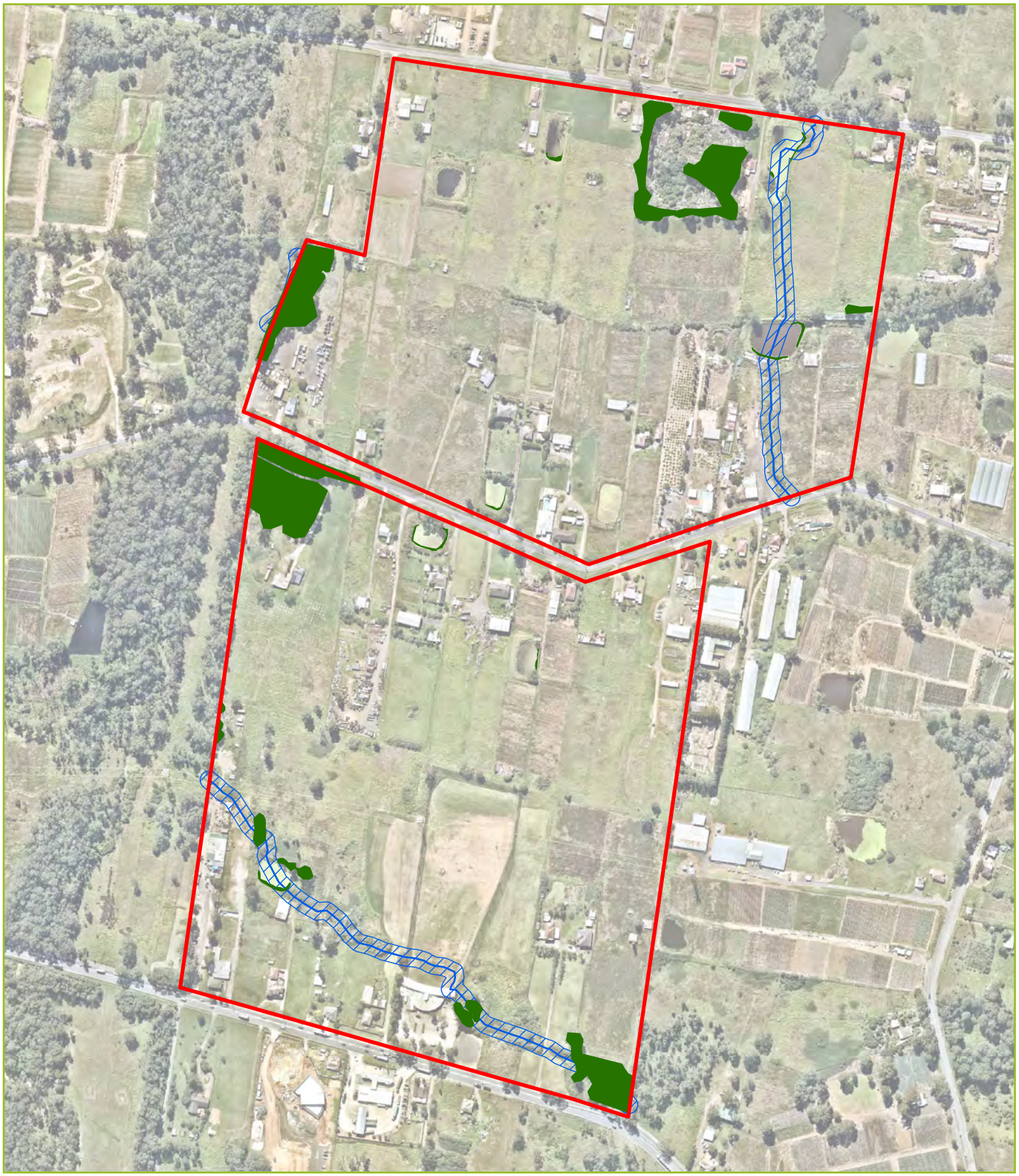
5.2. Watercourse assessment

The watercourse assessment undertaken to support the Keyhole rezoning proposal (Johnston 2021) provides a comprehensive fluvial and geomorphological investigation of the subject land's existing drainage lines.

This report provides a summary of its key findings as they relate to planning and approval considerations under the WM Act and WM Reg. and which demonstrates that future development of the Keyhole Site is unlikely to result in significant effects that would preclude the rezoning proposal.

The Johnston (2021) report is provided in Appendix B and provides an evidence-based document for regulatory consultation post-Gateway determination.

Additional investigations that may improve on the assessment already undertaken, would be further onsite assessment of the watercourse 'study area 1', which was not accessible at the time of the field assessments.



Keyhole Lands, Horsley Park - Rezoning

Figure 5.1 Subject land development considerations

Legend

- Keyhole Site
- Remnant native patches
- 10m riparian zone

N

0 45 90 180 270 360

m

Coordinate System: MGA Zone 56 (GDA 94)

Imagery Source: Nearmap 15 April 2021

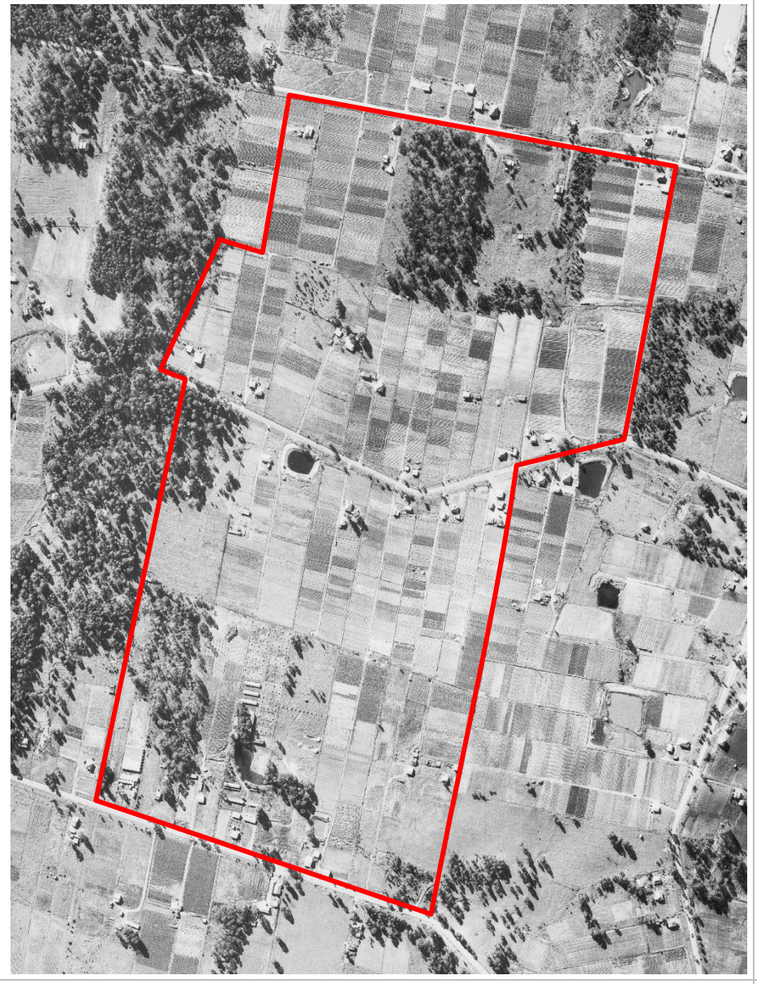
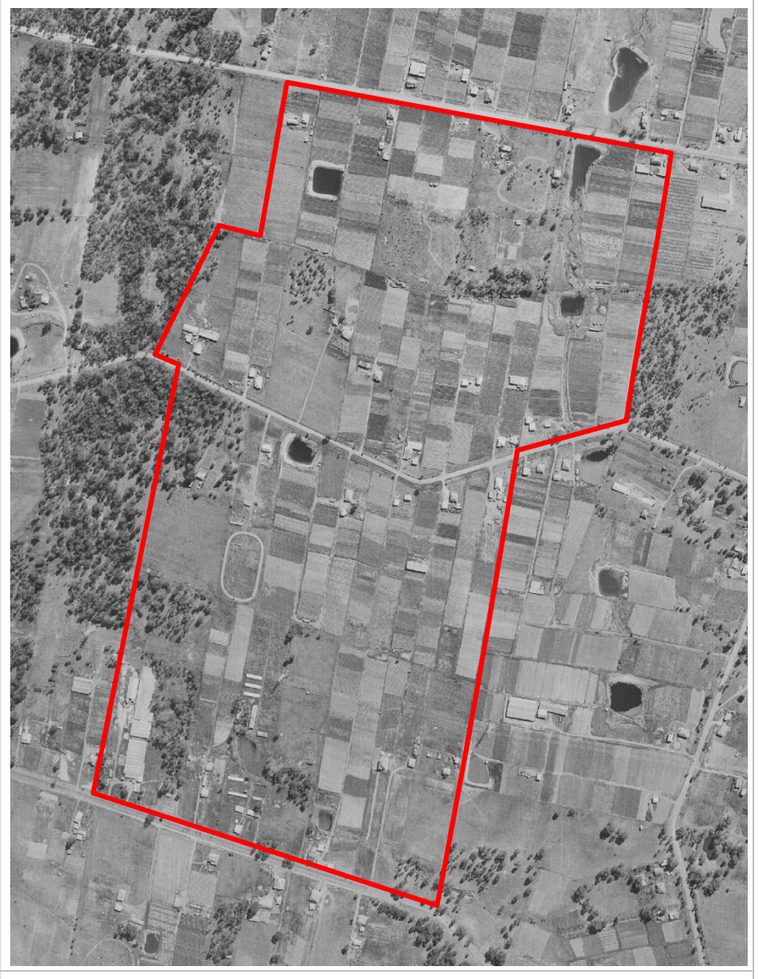
6. References

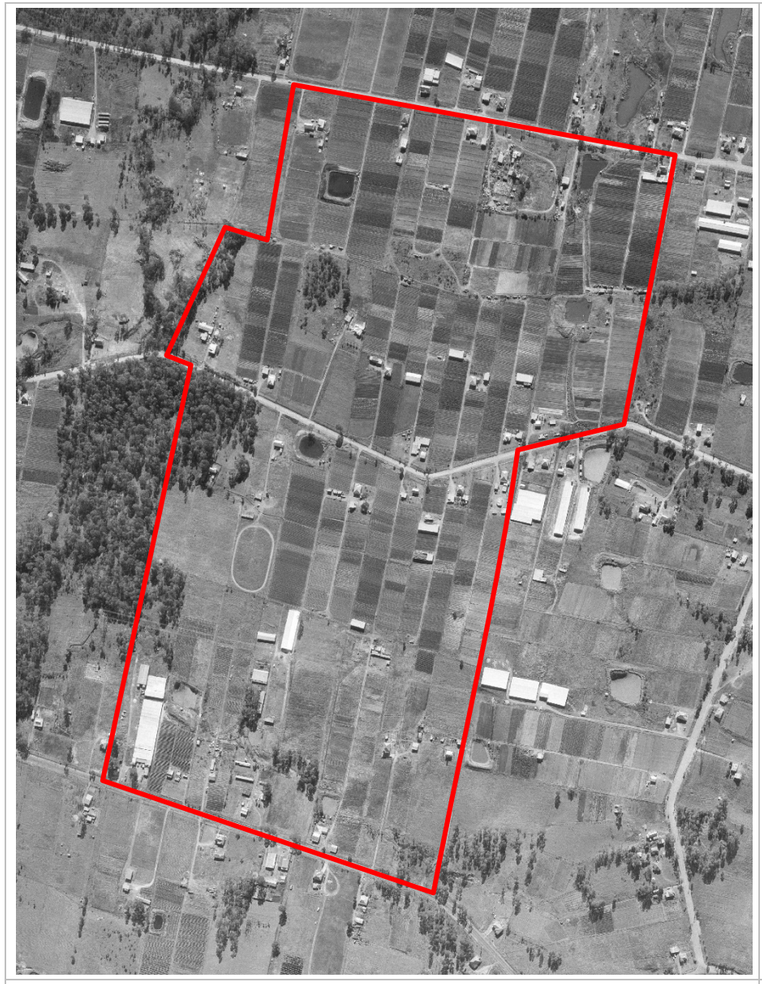
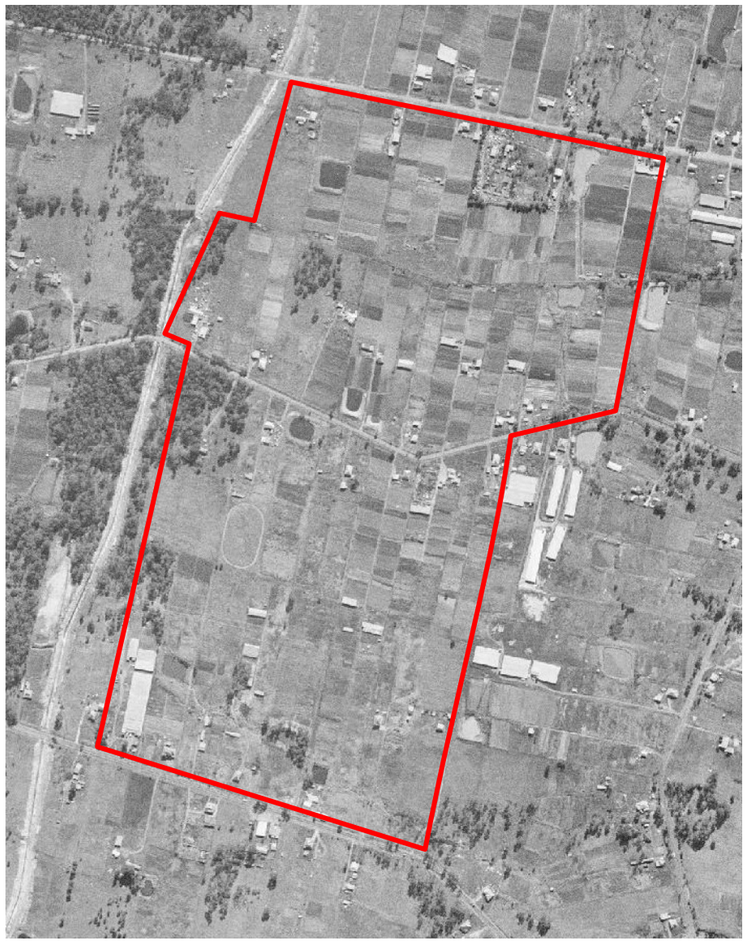
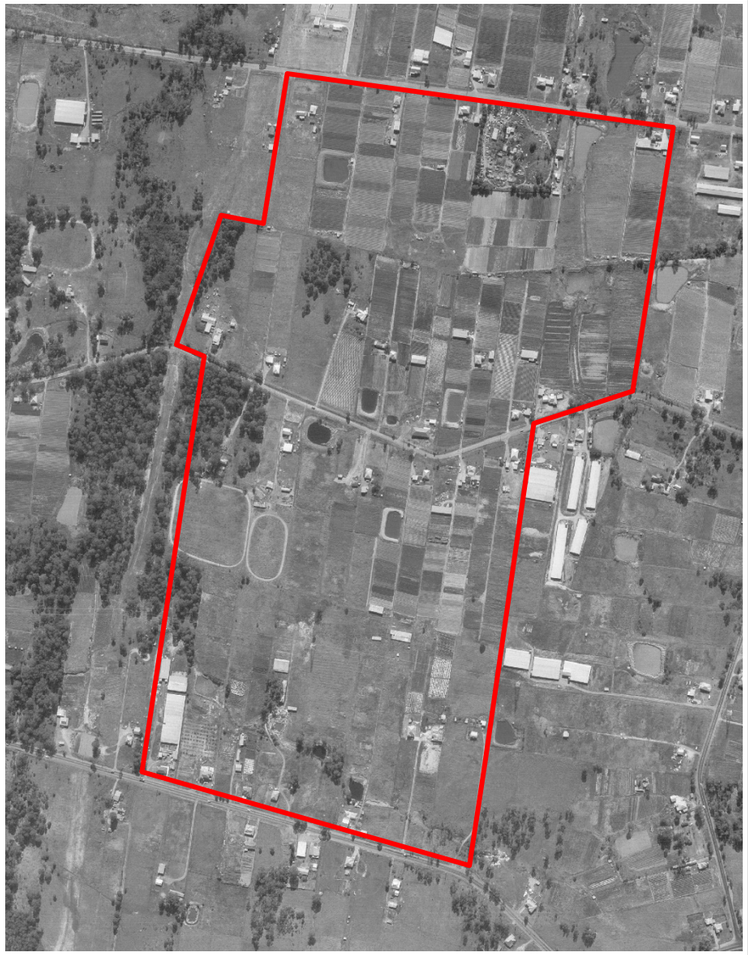
NSW Department of Planning and Environment (2018) A guide to preparing planning proposals. ISBN 978-0-7313-3585-5

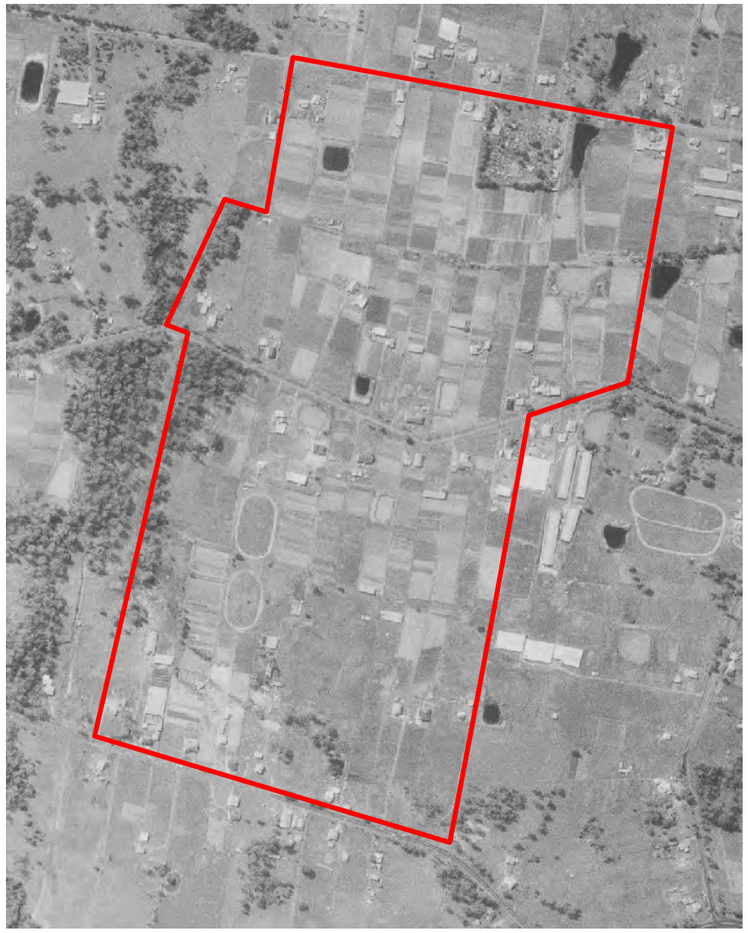
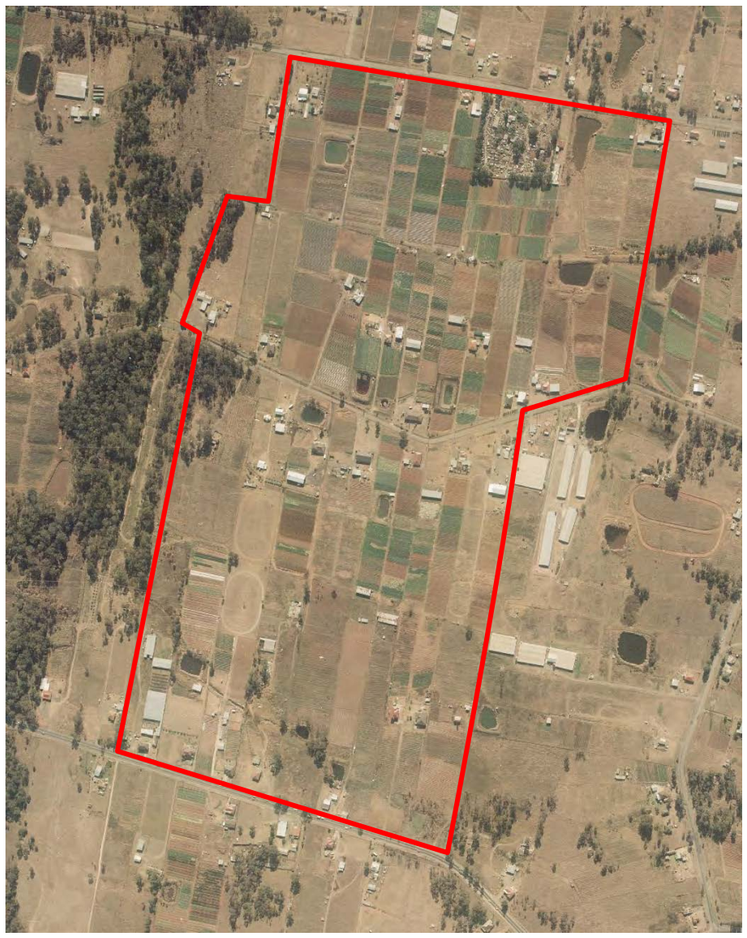
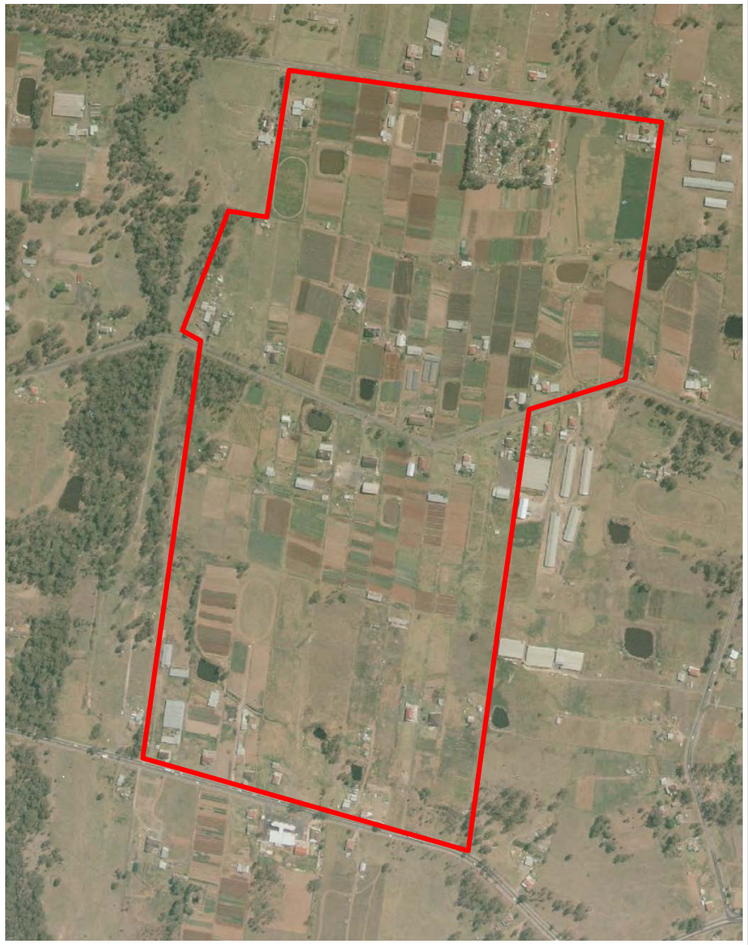
Natural Resources Access Regulator (NRAR) (2018). Guidelines for controlled activities on waterfront land Riparian corridors. Accessed at: https://www.industry.nsw.gov.au/natural-resources-access-regulator/policies-and-guidelines

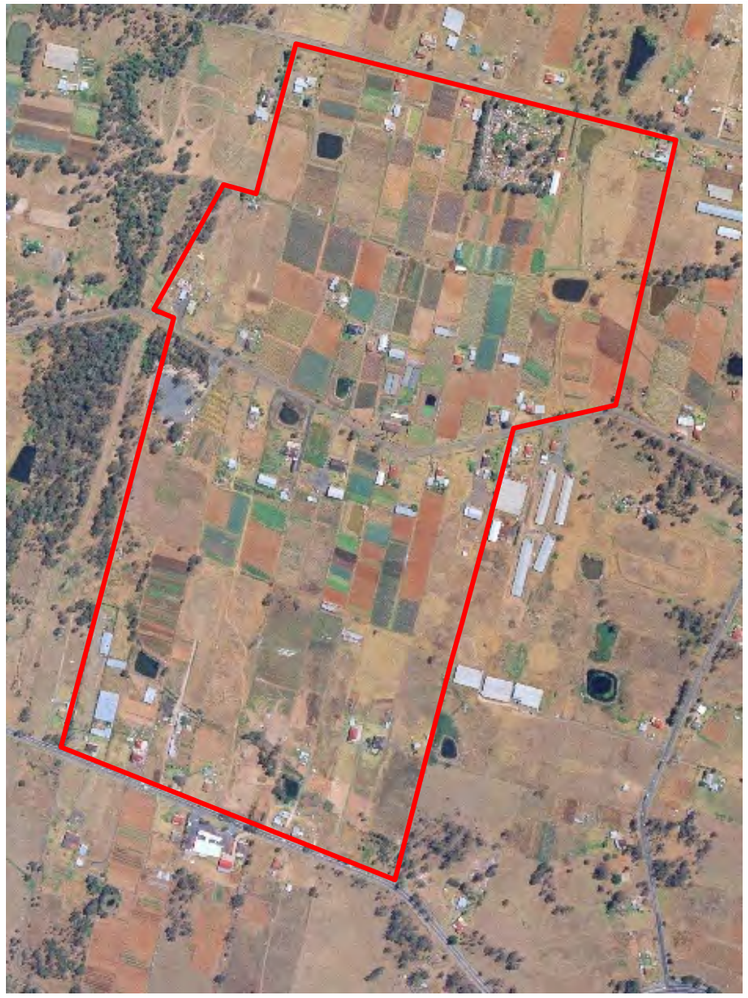
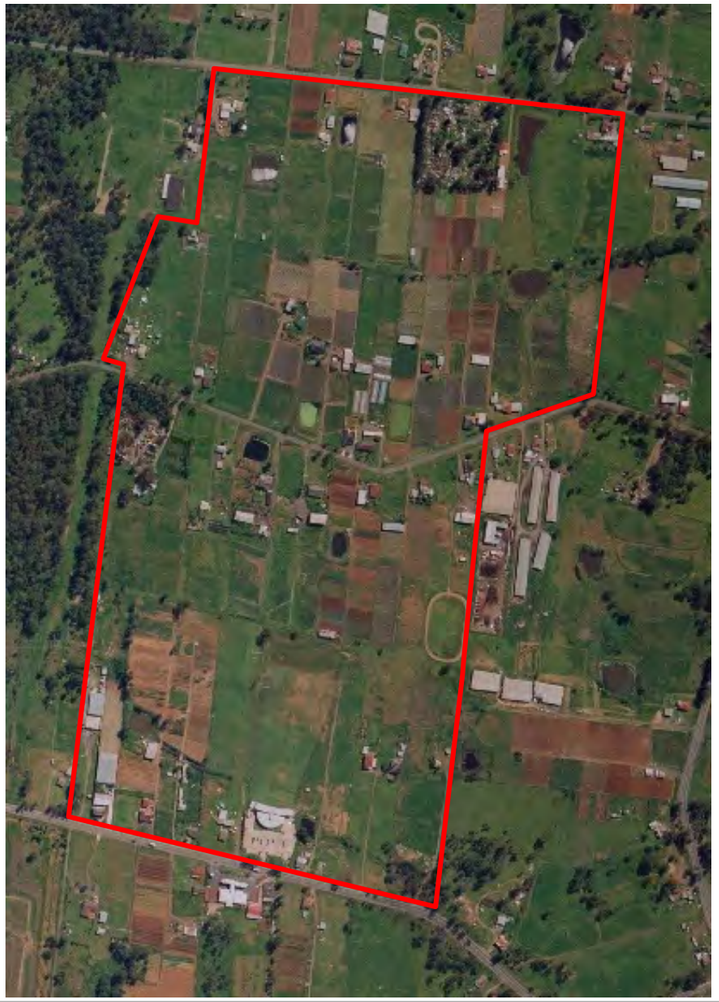
Johnston P (2021) A Geomorphic Assessment Keyhole Site Horsley Park NSW. Report prepared for: écologique by P. G. Johnston BSc, MSc Fluvial Geomorphologist Flow and Loam Environmental.

Appendix A. Historical aerial photography

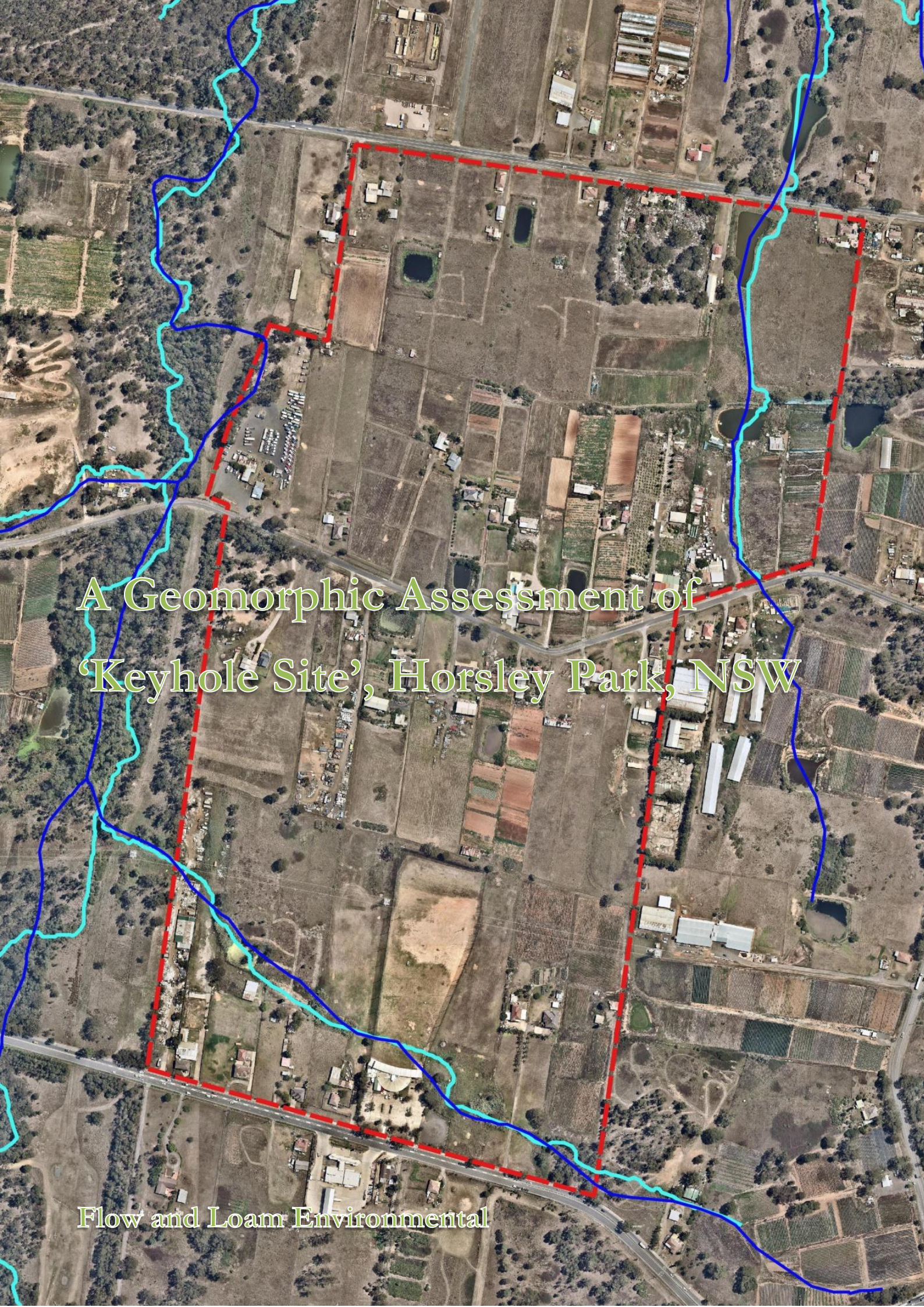
		
1950	1961	1965

		
1970	1975	1978

		
1983	1986	1991

		
1994	1998	2002

Appendix B. Johnston (2021) report



A Geomorphic Assessment of 'Keyhole Site', Horsley Park, NSW

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Document History

Issue	Date	Author/Reviewer
First Draft	17 May 2021	Peter Johnston
Review		Kathryn Duchatel

Cover Photograph.

Nearmap aerial photography of the Keyhole Study Site at scale 1:5,000

Table of Contents

List of Figures

Introduction

Flow and Loam Environmental has been contracted by écologique to provide an interpretation and assessment of the drainage patterns on the 'Keyhole Site' at Horsley Park, NSW (Figure 1).

There are three drainage pathways extending through the study area that have been identified as a 'river' by the Water Management Act 2000 (WM Act).

Schedule 2 of the Water Management Regulations 2018 (WM Reg.) specifies the Strahler system as the method to determine the stream order of watercourses shown on hydroline spatial data mapping published by the NSW Department of Planning, Industry, and Environment (DPIE) on their website.

Hydroline mapping indicates a first order watercourse extending through lots 63 and 54 on the north eastern (Area 1), a second order stream encroaching on to lot 59B on the western boundary and a first order stream extending laterally across the study area close to the southern boundary (Figure 1).

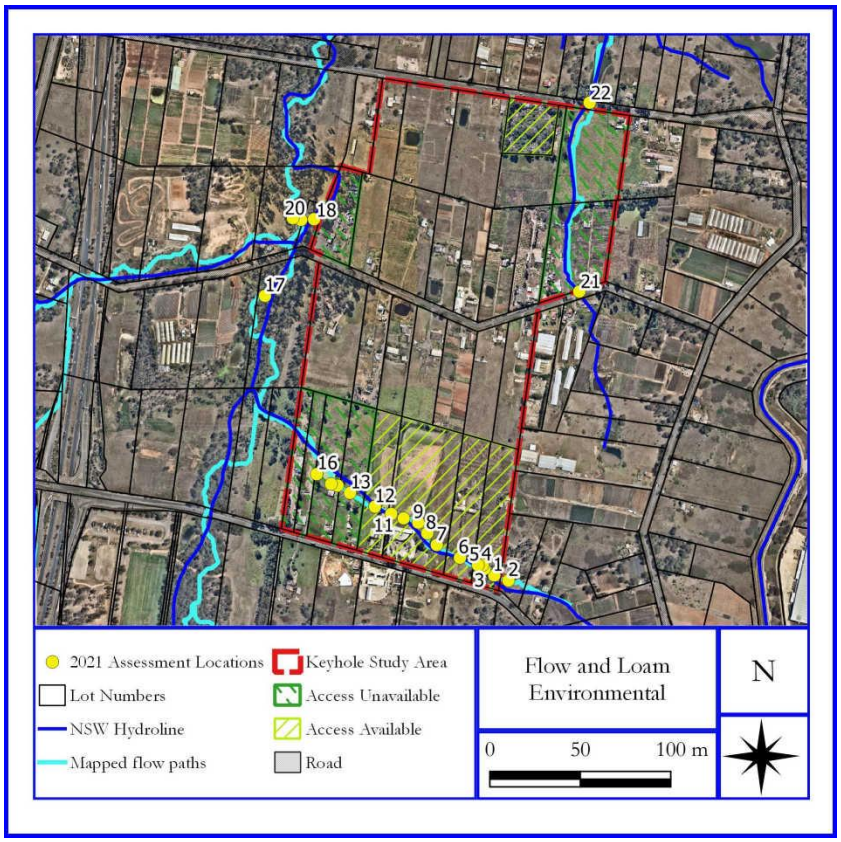

Figure 1. Location of study areas

Objectives

The objective of this investigation is to provide an assessment regarding whether the mapped Hydroline within the study area meets the definition of a 'river' as defined by The WM Act.

There are three areas within the 'Keyhole Site' that have drainage pathways as defined by the Hydroline data set. Access has been granted to only part of these areas and so it is necessary to evaluate the remainder by desktop assessment (Figure 1).

To complete this objective it was necessary to clarify the character and morphology of the drainage pattern within each area.

Study Method

The study method consists of three stages;

1. Desktop assessment;
    a. review of contemporary aerial photographs
    b. review of historical aerial photography
    c. review of historic parish map.
    d. review of GIS data.
2. Detailed site investigation
3. Reporting

Contemporary aerial photograph and GIS data interpretation was completed using QGIS cross-platform desktop geographic information system application.

Desktop Assessment Resources

This preliminary report and desktop assessment used the following data sources.

1. Aerial photography from Nearmap Australia Pty Ltd.
2. Historic aerial photography
3. The Paris map Preservation Project: NSW Spatial Information Exchange (SIX) viewer
4. ANZLIC Committee on Surveying and Mapping: ELVIS - Elevation and Depth - Foundation Spatial Data
5. New South Wales Government Spatial Information Exchange Cadastral and topographic data
6. New South Wales Government SEED website. Sharing and Enabling Environmental Data in NSW. Reliable Rivers and Regulated Rivers in NSW.

Aerial Photography

Aerial photography for the study area was acquired from Nearmap for the 22nd of January 2020 and the 15th of April 2021. These dates were selected because;

- Imagery for the 22nd of January 2020 was captured prior to a period of increased rainfall. Ground cover was at a minimum at this time and surface morphology was more apparent because of reduced ground cover.
- Imagery for the 15th of April 2021 represents the latest available capture of aerial photography.

Site specific Nearmap imagery for drainage pathways within the study area was sourced at the highest possible resolution of 0.075m per pixel. This resolution allowed the best possible interpretation of the surface morphology. Larger scale aerial photography that provides an overview of the study area and surrounds was acquired at 0.149 and 0.299 metres per pixel.

Digital Elevation Model (DEM)

New South Wales Government Spatial Services 1 metre DEM and LiDAR Point Cloud were sourced through the ELVIS web site. The 1 metre DEM had sufficient resolution for the interpretation of surface morphology and it was deemed not necessary to construct a higher resolution DEM from the point cloud.

The DEM was sourced as 32 individual tiles that covered the entire catchments of the flow paths extant within the study area. These tiles were imported into QGIS and merged into one tile. QGIS was then used to fill sinks and data gaps in the DEM so that a Strahler Stream Order could be generated that defined

flow pathways within the study area. This process produced a raster image which was then converted into a shape file.

Cadastral and Topographic Data

Cadastral and topographic data for the study area was sourced from the New South Wales Government Spatial Information Exchange 'clip and ship' facility. There are multiple layers included in each product but only some were relevant to this review. These were layers for;

- NSW Hydroline (flow paths) and Hydroarea (lakes and dams)
- Contours: 2 metre contour interval
- Roads
- Property plan and lot numbers

Reliable Rivers and Regulated Rivers

The Reliable Rivers and Regulated Rivers in NSW layers were sourced from the SEED website. The layers that were available were 150 m buffers around Strahler orders (SO) 3, 4, 5 and Regulated Rivers areas. These layers were sourced in order to determine agreeance with the NSW Hydroline but SO 3 was identified as extending from a confluence 470 metres to the north of the study area. The Reliable Rivers and Regulated Rivers layers do not apply within the study area.

Parish map

The historic maps for parish Melville were sourced from the SIX viewer. The earliest map available is dated circa 1841 (Appendix 4: Parish Melville circa 1841) and shows South Creek, Ropes Creek, Kemps Creek, Reedy Creek and Eastern Creek as well as some unnamed tributaries.

South Creek is shown to extend through Parish Melville as a continuous channel while other streams are shown as chains of ponds (CoP) with a continuous channel.

Reedy Creek is shown to extend further to the south than Eastern Creek and is shown as continuous channel in its lower reaches and as a CoP in its upper reaches.

Similarly, Eastern Creek is shown as a continuous channel for a short distance upstream of its confluence with Reedy Creek but is shown as a CoP in its upper reaches. The map confirms the existence of CoP that was a common morphology of streams in western Sydney at time of settlement. Eastern Creek is shown as extending into the vicinity of the study area as a continuous channel to the approximate location of Chandos Road and then for a short distance as a CoP.

Limitations

GIS interpretation of flow pathways using a high resolution LiDAR DEM uses an algorithm that identifies a series of the lowest continuous points to define flow pathways. At their highest stream order these pathways may represent pathways of overland flow during periods of rainfall but they may not represent what can be referred to as a river or a stream. Further interpretation is essential to make this determination and verification is often impossible from even the highest resolution aerial photography. Often, only on site investigations can identify the presence, or absence, of the assemblage of geomorphic units from which channel, or bank, morphology can be defined.

Discussion

Natural Resources Access Regulator (NRAR)

Guidelines for controlled activities on waterfront land.

The WM Act and WM Reg. are administered by the Natural Resource Access Regulator (NRAR). The NRAR is required to assess the impact of any controlled activity to ensure that no more than minimal harm will be done to waterfront land as a consequence of carrying out the controlled activity.

Waterfront land is defined in the WM Act as that land within 40 m of the highest bank of a river.

If it can be demonstrated that drainage patterns and flow paths are not a river then this would alter the stream order that has been assigned by the NSW Hydroline and therefore modify the requirements and restrictions on development and the provision of riparian buffer zones each side of the channel, as defined by the banks.

What constitutes a river, stream, or creek, can be a contentious issue and legislation has attempted to standardise and systematically codify the legal definition of a river (Taylor et al. 2007*)*. However, such attempts at standardisation have not always been successful.

Many fluvial geomorphologists have sought to clarify the definition of exactly what constitutes a river and these investigations, and subsequent definitions, are based on fundamental morphological constructs that identify multiple geomorphic elements that combine to form a river. However, the issue is complex, and this method of river definition requires detailed assessment which can be time consuming, expensive and site specific.

Leopold et al. (1964) and Leopold (1994) examine the complex characters of various forms of channel and critically evaluate methods of defining what constitutes a river. Kellerhals et al. (1976) offer a process driven classification of river morphology. David Knighton (1998) explores these concepts further and offers clear insights into the interpretation of what constitutes a river in his pivotal book *Fluvial Forms and Processes: A New Perspective.* Knighton employs empirical and theoretical approaches to examine the complexity of fluvial form and process, detailing the structure and assemblage of geomorphic units that combine to define what is a river. Knighton (1998) also examined the Strahler (1952) method of classifying rivers by stream order. An alternate method of stream ordering is offered where channel linkages are ordered by magnitude and stream order is calculated by adding confluent stream order values (Knighton 1998).

The clear message here is that the issue is complex and a simplified method of determining exactly what constitutes a stream, or river, was needed. Fluvial geomorphologists will have an almost instinctual understanding of what constitutes a river but for catchment managers, land use professionals, and any other profession that is required to deal with rivers, the definition is often not so clear cut. Especially as some opinions on what constitutes a river often has a decidedly Eurocentric view and does not account for the complexity, and variability, of Australian rivers. To fulfil this need for simplification, a modified Strahler system of stream ordering has been used in conjunction with Geographic Information Systems (GIS) to produce the New South Wales Hydroline (2018).

The New South Wales Hydroline Data Set is an attempt to standardise and simplify the definition of what constitutes a river in New South Wales. However, such an attempt at standardisation risks an oversimplification that will present its own unique set of problems.

The fundamental problem with the Hydroline is that it is an artificial construct generated by GIS analysis. Information on the layer's metadata webpage (NSW Hydroline) states that the database is automatically and continuously updated as new information becomes available *"…from relevant stakeholders and custodians…"* but no information is provided what this means for the temporal recurrence of physical updates, or corrections, of the Hydroline. Comparison of the position of contemporary drainage pathways, generated from high resolution LiDAR DEMs, with drainage pathway locations indicated by the Hydroline, show a marked inconsistency in most locations. The capture method also embedded inherent positional irregularities into the dataset as the capture source was standard topographic maps and orthophoto image trace. Used in conjunction these sources serve to reduce errors extant in one source alone but still contain substantial positional inconsistencies. The Hydroline database, because of its character and areal extent, is rarely subject to the ground truthing processes that are essential in confirming the veracity of the data presented.

The inherent problem with the application of this construct is that its practical implementation is inflexible and requirements for conformity are resolute. However, axiomatic application of Hydroline dataset ignores the inherent errors and the complexity and variability of Australian water courses that have been defined by professional fluvial geomorphologists over many decades.

Desktop assessment of the flow paths within the study area shows that the drainage lines are poorly defined in the upper reaches as defined by the Hydroline. Interrogation of the aerial imagery showed a lack of defined banks, and other structural geomorphic units, which would normally be associated with a river system. Well defined banks and beds, or anything that could be defined as aquatic habitat, were absent in these upper reaches, except in artificially constructed water storages. The upper catchment above that which had been defined as a first order stream could only best be described as poorly defined drainage depression. To determine the location of the interface between poorly defined drainage depression and first order stream is often problematic. A generalised location may be determined by desktop assessment but a more qualified location can only be determined by physical inspection.

Strahler (1952, 1964) indicates that only channel networks with intermittent and perennial stream flows should be used in stream ordering. Because the uppermost drainage lines in the study area would be more precisely described as ephemeral, they do not fit into the Strahler method of stream order.

While the NRAR and WM Act require adherence to stream classification is based on a Strahler stream order classification, throughout the guidelines reference is made to the banks of the river and buffer zones are measured from top of bank, *viz*

Waterfront land includes the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary. (P4)

…channel which comprises the bed and banks of the watercourse (to the highest bank) (P5)

The riparian corridor consists of:

•*the channel which comprises the bed and banks of the watercourse (to the highest bank) and*

•*the vegetated riparian zone (VRZ) adjoining the channel* (P5)

The width of the VRZ should be measured from the top of the highest bank on both sides of the watercourse (P5)

Therefore, to conform to the guidelines stipulated by the NRAR and WM Act, it is essential to identify these geomorphic features within the study area. i.e. *the bed and bank of any river, lake or estuary…*

2021 Study Sites

Overview

The Hydroline Data Set (Planning, Industry and Environment 2018) utilised Strahler Stream Order assessment to identify stream within the study area (Figure 1). During preliminary desktop assessment using QGIS, three study areas were defined by locations that the Hydroline extended within the Keyhole Site. The Hydroline defined first order streams in Areas 1 and 3 and a second order stream in Area 2.

In natural fluvial systems as the channel gradient, and dominant particle size, decreases there is usually a corresponding increase in sinuosity. Stream sinuosity is the ratio of stream length to valley length. A straight flow path, or channel, will have a sinuosity of 1.0 to 1.05. Low to moderate sinuosity is 1.06 to 1.3. Moderate to high sinuosity is 1.3 to 2.0 and tortuous sinuosity is greater than 2.0.

The substrate in all three study areas consists of weathered claystone, siltstone and fine laminates of the Bringelly Shale, part of the Wianamatta Group (Clarke and Jones 1991). This fine grained substrate, and low gradients endemic within the study area, would normally exert controls on any existing channel such that they would have a moderate to high sinuosity. Desktop review of the flow pathways within each study

area indicates that flow paths in areas 1 and 2 are highly modified. An assessment of sinuosity will give insights into the degree of anthropogenic flow path modification in each study area.

Site assessments of the study areas within the Keyhole Site were completed on the 12th of May 2021.

Area 1

Desktop Assessment

Area 1 extends through Lots 54 and 63 between Chandos Road and Redmayne Road (Figure 2). The contemporary position of flow pathways was determined by 1 m resolution LiDAR DEM and compared with the position of the NSW Hydroline. The relative position of the flow lines is comparable, but not exact. For example, the Hydroline passes through the centreline of the agricultural dams while the mapped pathways tend to follow more closely any existing spillway channel.

Desktop interpretation of contemporary aerial photography and DEM indicates that the reach between Chandos Road and Redmayne Road consists mainly of two agricultural dams, their associated spillways and connecting drainage pathways.

Within Area 1 the low gradient and fine grained substrate would normally define a reach of moderate to high sinuosity but the sinuosity here is very low at 1.03 for the Hydroline and 1.13 for the contemporary mapped flow paths.

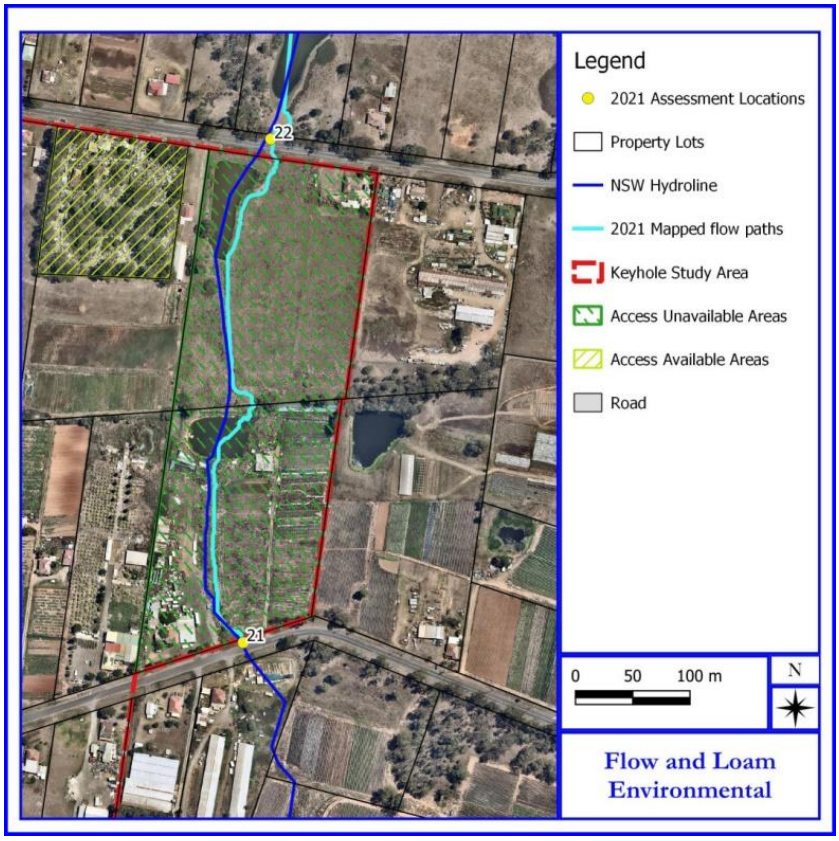

Figure 2. Study Area 1

An existing flow path can be identified from the aerial photographs but it is masked by dense growth of vegetation and its character cannot be determined by aerial photograph interpretation alone. With a very low sinuosity these channels are probably artificial and are essentially agricultural drains.

Site Assessment

There was no access for site assessment in lots 54 and 63 and therefore site inspection was limited to what could be viewed from the adjacent roadways. Inspection sites for area 1 are sites 21 and 22 (Figure 2).

At site 21 there is a very low sinuosity drainage line extending downslope from the road. Upslope, the channel passes around what appears to be an infilled agricultural dam. At road side the channel has a very narrow base with low angle stable banks. The channel cross section is trapezoidal which indicates anthropogenic modification (Figure 3).

Down slope there is a macro channel with width increasing to greater than 12 m. The inset base flow channel is masked by vegetation.

Figure 3. Site 21. 'A' Looking down slope and 'B' Looking upslope

At site 22, downslope from the road, there is a minor flow path is less than 2 m wide and is completely obscured by weed infestation. The character of the channel cannot be determined. The flow path leads to weed choked dam down slope (Figure 4).

There is a similar morphology on upslope side of road where the drainage channel from an agricultural dam spillway is choked with rushes.

The upslope channel appears to be narrow, very low sinuosity, and anthropogenically modified.

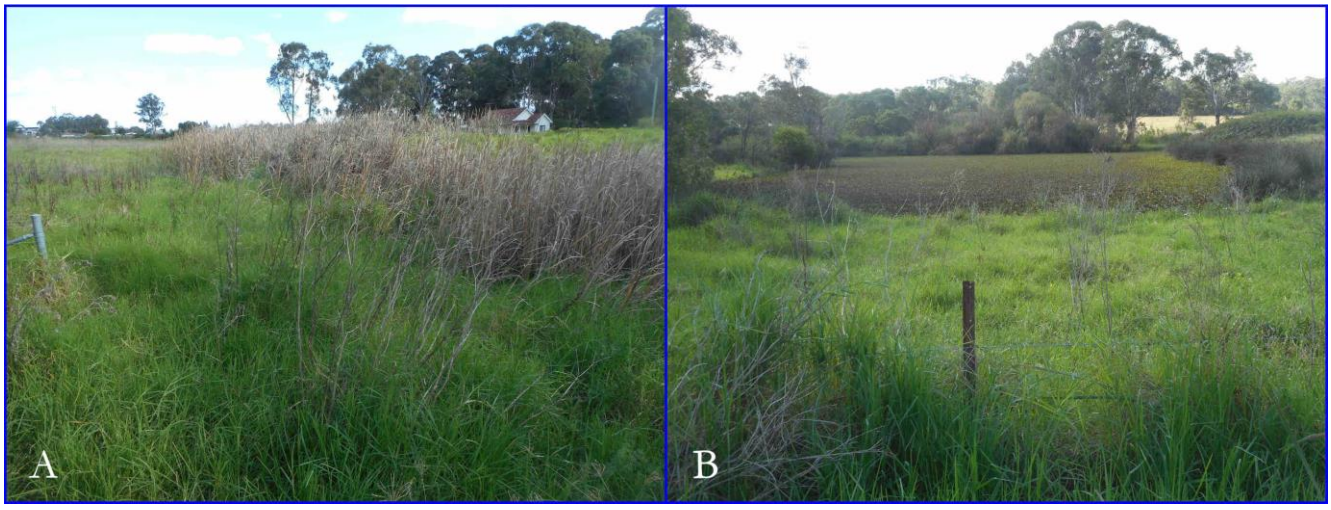

Figure 4. Site 22. 'A' Looking upslope and 'B' looking downslope

Area 2

Desktop Assessment

Study Area 2 is where a meander loop of Eastern Creek, as defined by the NSW Hydroline, extends into the neighbouring Lot 59B (Figure 5).

During desktop assessment there was no evidence found of a channel as at this location extending into Lot 59B. Mapping of the contemporary channel line indicates Eastern Creek as a well defined channel to the west.

Eastern Creek at this location is at least a second order stream but to define the stream order an assessment of upstream channels would be necessary as the Strahler Stream Order for the Hydroline is not included in the attribute table for the Hydroline layer. An assessment of upstream Stream Orders is not required for this assessment.

An assessment of channel sinuosity for Eastern Creek between Chandos Road and Redmayne Road was completed. The sinuosity of the Hydroline is 1.46 and the sinuosity of the 2021 mapped line is 1.37. The sinuosity for the Hydroline is artificially increased by the meander bend that has been mapped as extending into Lot 59B. This degree of sinuosity indicates a low level of anthropogenic channel modification. Ignoring channel incision processes as a function of changes in catchment hydraulics.

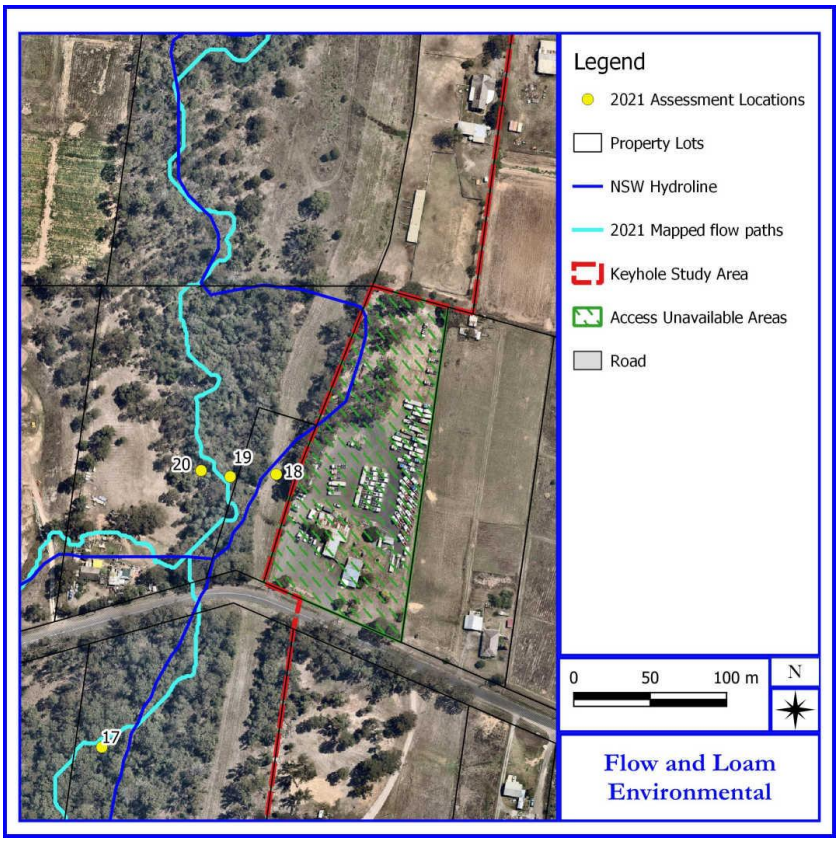

Figure 5. Study Area 2

Site Assessment

To confirm the presence, or absence, of a meander bend of Eastern Creek extending into Lot 59B a transect of three sites were assessed across the channel zone and these are sites 18, 19 and 20 (Figure 5). As a check on the morphology and character of the Eastern Creek, as mapped for this study, an additional site, site 17, was assessed upstream.

Site 17

At site 17 Eastern Creek exists as an elongate pool – glide – riffle sequence (Figure 6). Elongated pools and glides are separated by steps in the longitudinal profile varying between 0.40 and 0.80 m. There are three profile steps within 40m of site 17 location. The water surface over the riffles is not broken.

The low flow channel is moderately sinuous with multi step banks that are sub-vertical and erosional, in places. This morphology indicates that there has been multiple stages of incision pass through this reach.

There is a short length of, what may be, remnant floodplain inset within the low flow channel that has a scour feature around tree fall indicating an erosional environment.

Water depth is greater than 1.05 m in places and less than 0.10 m over riffles. The width of channel at water surface is variable from 0.40 m to a maximum of 3 m. The bank height is also variable to a maximum of 3.5 m. Channel width, bank top to bank top is 8 – 10 m.

Figure 6 Site 17 'A' Looking downstream and 'B' looking upstream

Site 18

The location of Site 18 is on the gas pipeline easement where the NSW Hydroline indicates a channel for Eastern Creek that crosses into Lot 59B.

Often, where channels are realigned for some reason, the old pre-existing channel is filled in. However, over time, there is often faint surface morphology reflecting the position of the old channel as the fill settles.

An assessment of historical aerial photography may reveal a pre-existing channel here but there is no indication or evidence of any pre-existing channel.

Figure 7 Site 18 looking down slope to the location of the Hydroline meander bend.

Site 19

The stream character and channel morphology is the same here as at Site 17 and Eastern Creek exists as an elongate pool – glide – riffle sequence (Figure 8). Riffles are over steps in longitudinal profile with localised relief of up to 0.80 m. The steps are commonly roots that have acted to trap woody debris and

other litter to form small dams and induce deposition (Figure 8B). The elongate pools are greater than 1.05 m deep, in places, and generally less than 0.10 m deep over the riffles.

Multi phase, sub-vertical banks extend to 3.5 m; the channel width at water level varies between 4 and 5 m and the channel width from bank top to bank top is variable between 7 and 9 m. The banks are erosional.

At proximal bank top, right bank, there are scour zones and litter dams in and around vegetation indicating recent overbank flows and that the channel is still coupled with the floodplain..

Figure 8. Site 19. 'A' looking upstream over a pool and 'B' showing a step in the longitudinal profile that has formed at roots crossing the channel

Site 20

While the transect of sites 18 – 20 extend across the channel zone from east to west, the orientation of the channel of Eastern Creek means that Site 20 is located downstream from Site 19. The channel character and morphology at Site 20 are the same as at Site 17 and Site 19 (Figure 9).

There are scour zones proximal to right bank top indicating recent overbank flows.

There is opportunistic deposition of sediment in backwater of small tributary at left margin.

Figure 9. Site 20. 'A' Looking upstream over an elongate pool and 'B' Riffles over root dam in base of channel

Area 3

Desktop Assessment

Study Area 3 extends laterally across the southern boundary of the Keyhole Estate, from West to East, through Lots 78B, C and D, 79A and 79B, Lot 1 and Lots 81A and 81B (Figure 10).

The NSW Hydroline extends through the study area and upslope for another 360 m. The contemporary 2021 mapped channel also extends upslope of the study area for another 170 m.

Desktop review and analysis of the aerial photography reveal a channel with remarkable little variation of character and morphology. Channel sinuosity was measured from the confluence with Eastern Creek to the maximum upstream extent of the mapped channels. The sinuosity of the Hydroline is 1.04 over a channel length of 1125.3 m. The sinuosity of the 2021 mapped channel 1.11 over a channel length of 962.3 m. Both sinuosities are very low and are indicative of a highly modified channel.

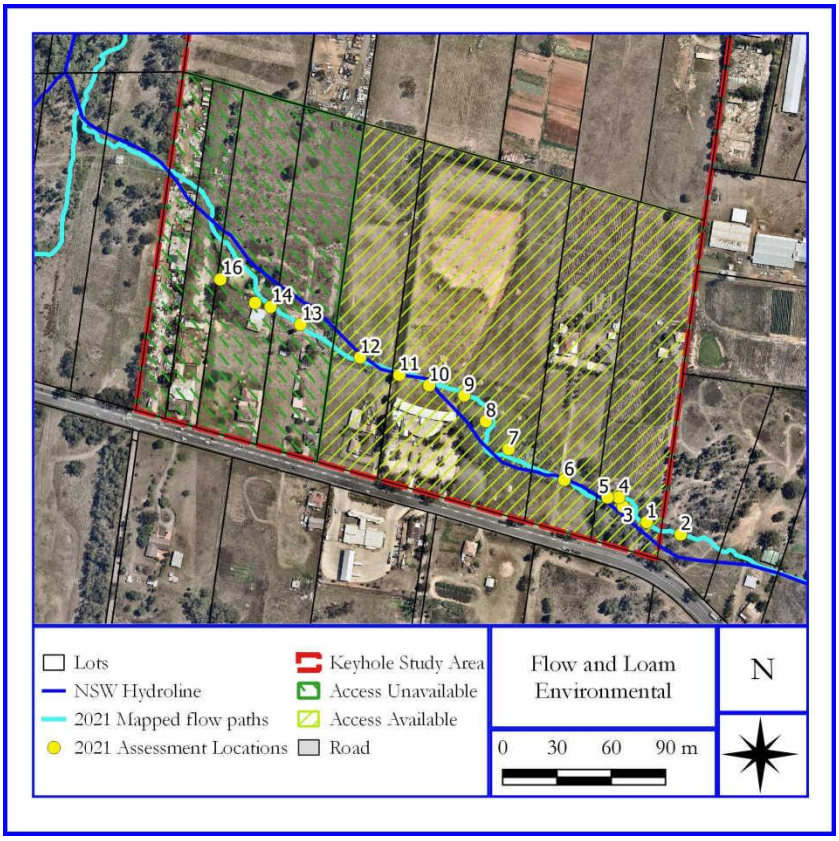

Figure 10. Study Area 3

Aerial photograph interpretation reveals what appears to be partially artificial channel and partly intact channel, especially in the upper reaches.

Analysis of recent aerial photography sequence shows artificial channel construction on Lots 78C and D after 27 12 2020 and prior to 26 01 2021. Artificial channel is also apparent upslope of the dam on lot 78B.

Channel morphology is more apparent on the golf driving range where surface vegetation is kept low. Here there appears to be a remnant chain of ponds morphology which would be expected in this area prior to settlement. However, given the development that is apparent in the area, and how this development would have impacted catchment hydraulics, the apparent channel capacity on the driving range is too low.

The defined channel, modified or not, ends at the boundary of Lot 81B, which is the upstream limit of the Keyhole study area.

Site Assessment

Sites 1 – 5. Upper reach of study site

There is a short length of channel between site 5 and the upper boundary of the study area that has remnant chain of ponds morphology with a continuous channel. The channel ends at the boundary between Lots 73B and 81B which is also the boundary of the study area. At this location the defined channel and has been stabilised by rock fill (Figure 11A). Site 2 is located outside of the study area upslope on an area where there is no defined channel (Figure 11B).

The low flow channel through this reach is well defined with low angled and well vegetated banks. At some locations the banks appear to be two stage which may indicate the passage of a knickpoint through this reach.

Figure 11. 'A' shows knickpoint stabilised by rock fill. Defined channel ends here. 'B' is looking up slope from Site 2; no defined channel

There is also some remnant pond morphology at site 3 where the channel widens out from 2 metres in width to more than 8 metres. The stagnant water that was evident at site 1 is not in evidence here. The channel and pond base has been dry for an extended period.

Sediment spear testing at sites 3 and 4 penetrates easily, with very little resistance to 1.05 m. There is a narrow, sub-horizontal, floodplain pocket at bank top left bank that has sediment over saprolite to 0.40 m as indicated by sediment spear testing.

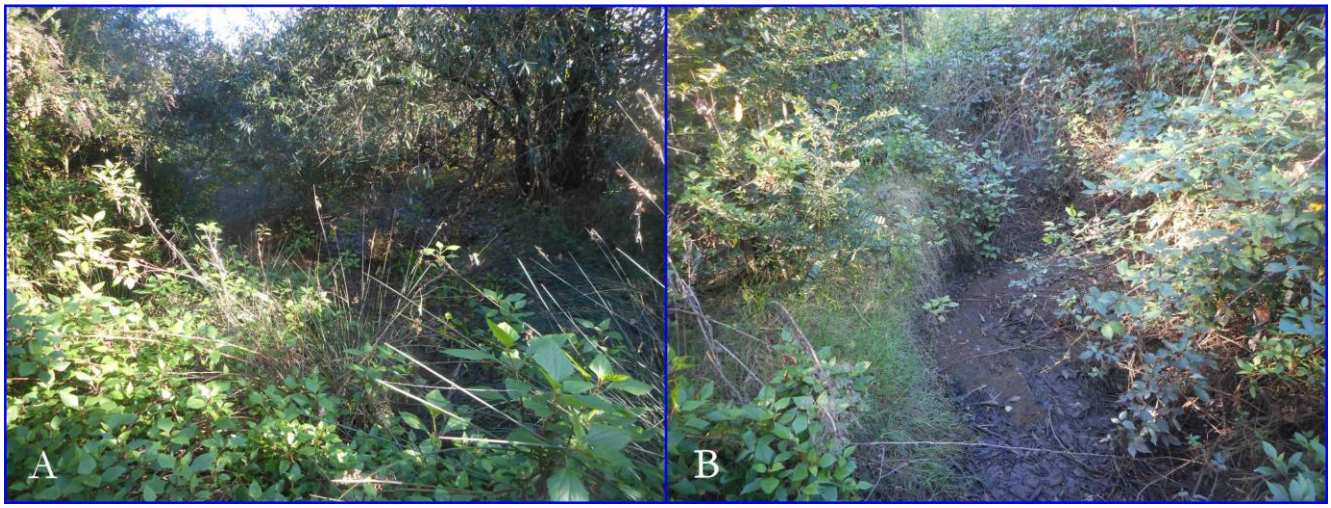

Figure 12. 'A' looking upstream along the tributary towards site 4 and 'B' the tributary joining from left margin with recent deposition in the base of the channel

At site 5 there is a confluence with a well-defined channel entering from left margin. This new channel extends from south of The Horsley Drive out of the study area. The channel is 3 – 4 m wide with high angle to sub-vertical banks to 1.4 m high. There is recent deposition of medium to coarse and granular sediment apparent in channel base.

The channel base of the tributary from site 1 is perched 0.60 m above base of new channel entering from left margin. This indicates that the majority of flow enters from this unmapped channel and it is erosional.

Sites 6 – 8

At site 6 there is a length of channel that flows through a pipe that is approximately 9 m in length. Only the upstream end of the pipe (Figure 13A) is apparent as the downstream end is obscured by abundant weed growth (Figure 13B).

There is a suspiciously straight channel extending upslope of crossing. A straight channel in this environment indicates anthropogenically modified channel or an artificial channel. Sub-vertical banks to 3 m high are vegetated and stable. The channel width, bank top to bank top, is between 5 and 6 m.

Access to the channel zone downstream of site 6 is extremely difficult and limited by abundant and dense weed growth, notably blackberry. Site 8 is located on an old dam wall and is looking upstream.

Figure 13 'A' looking upstream from site 6. 'B' looking downstream from site 6. In both instances the channel is straight and choked with weed infestation.

Figure 14 Site 8 looking upstream across the impoundment of the old agricultural dam that is now choked with weeds.

Sites 9 – 12

Piped section of channel.

The upstream intake of the pipe is located between site 8 and site 9 but this area is completely overgrown and the exact location was unable to be determined. Most flows are diverted underneath the driving range through a subterranean pipe. There is a surface inlet grid at site 10 and at site 11. The end of the piped section is between sites 11 and 12 but is obscured by vegetation.

There is a surface low flow channel that has a low to moderate sinuosity with remnant ponds morphology. The low flow channel has a low capacity and discontinuous banks to 0.30 m. Flows that are unable to be contained within the pipe flow across the surface of the golf range. Interrogation of the historic aerial photography for 1978 (Appendix 3) show an agricultural dam at this location.

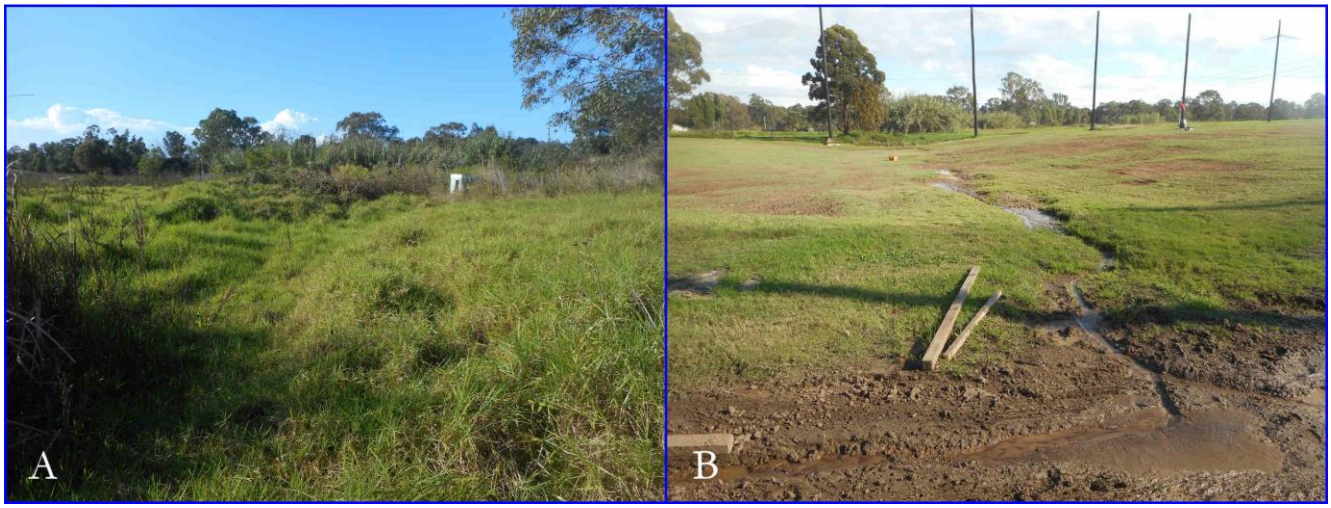

Figure 15. Location is site 9 at golf range boundary. 'A' is looking upstream to site 8 and 'B' is looking downstream to site 10.

Sites 12 – 14

There is a very low sinuosity channel that shows evidence of anthropogenic realignment. Most of this reach was unable to be viewed and was largely inaccessible due to the abundant growth of blackberry, and other weed, obscuring the channel.

Figure 16. Site 13. Artificially straightened channel extending upstream 'A' and downstream 'B'

At site 12 the channel zone becomes visible through gaps in weed infestation.

A deeply incised channel has a three stage right bank that indicates multiple stages of incision and possibly the passage of knickpoints upstream through this reach. The left bank is obscured by dense weed infestation. The stages of incision on right bank are from base to bank top, (approx.) 1.5 m, 1.4 m and 0.75 m

The base of the right bank is sub-vertical, erosional and is being undercut by channel migration of the low flow channel. At the time of inspection the low flow was low volume and was not impacting the base of the bank. During periods of elevated flow channel migration induces erosion. The upper stages of the right bank are vegetated and stable.

Immediately upstream the channel migration is undercutting the left bank where the low flow channel migrates from channel margin to channel margin.

The macro channel width, bank top to bank top, is variable between 16 and 18 m. A sub horizontal surface proximal to right bank top was tested with multiple spear points. Increasing resistance met with refusal at 0.35 m, on average. This is indicative of a thin layer of sediment over saprolite.

At site 13 there is a 15 m length of channel that passes through two pipes (Figure 16). The channel both upstream and downstream of site 13 is straight and has a trapezoidal profile that is indicative of anthropogenic realignment.

The channel emerges from weed infestation upstream, passes through a straight channel and into two concrete pipes. There is very minor base flow in evidence and appears to be stagnant. The channel emerges from the pipes into another straight section that has a trapezoidal profile. This profile indicates an anthropogenically modified stream.

The left bank downstream of the pipes is artificial and appears to be a fill of building waste; concrete and bricks.

The channel width, bank top to bank top, averages 6.0 m. Downslope, before flowing into a dam at site 14, the channel passes into a narrow slot that is 3 m wide and inset into two stage banks.

Channel bank height is approximately 4 m.

Sites 14 – 16

Agricultural dam (Figure 17). The channel ends where it flows into the dam at site 15. Site 16 is at the dam wall at property boundary.

Figure 17. 'A' Looking downstream from site 15 across the dam and 'B' is looking across the dam wall to a highly modified zone of degraded channel

Historic Aerial Photography Assessment

Overview

Historical imagery was sourced for the study areas from the New South Wales Government Historical Imagery Portal. Their availability and an assessment of quality are presented in Table 1.

Not all historical imagery was sourced. Sometimes this was because of insufficient change from the previous image or because the quality of resolution was insufficient to gain insight into changes of channel morphology.

Available Years	Acquired	Quality of Image	Notes
1930	Yes	Low	Earliest image available. Georeferencing completed using the upper canal as there are no other control points available in the image. Positional accuracy would be better with a broader spread control points.
1955	Yes	Good	Poor Georeferencing. Poor positional fix
1961	Yes	Very Good	Georeferenced
1965	Yes	Good	Georeferenced
1970	Yes	Good	Georeferenced
1975	No		Insufficient variation from 1970 image
1978	Yes	Very Good	Georeferenced
1983	No		Insufficient variation from 1978 image
1984	No		Insufficient variation from 1978 image
1986	Yes	Good	Georeferenced
1989	No		Insufficient variation from 1986 image
1991	No		
1998	Yes	Very Good	Georeferenced
2002	No		
2004	Yes	Low	Georeferenced. Low resolution
2005	Yes	Good	Georeferenced
2009	Yes	Very High	Nearmap
2020	Yes	Very High	Nearmap
2021	Yes	Very High	Nearmap

Table 1 Aerial photography used in this report

Area 1: Appendix 1

10 February 1930

There is no discernible channel at this time. Vegetation is relatively sparse and does not mask hidden channels. Flow pathways that are not channelised still follow the valley axis and will retain water longer than the surrounding slopes. They are usually characterised by more dense vegetation because of this but there is no evidence of preferential vegetation growth along the valley axis.

27 June 1961

There has been almost ubiquitous development of market gardens by this time. An agricultural dam has been constructed upstream of site 21 and a continuous, very low sinuosity, channel extends down slope to site 22. The dam downslope of site 22 has been constructed by this and there is an incised channel exiting the dam through the spillway. This dam is not within the study area.

6 May 1978

The channel alignment has not changed since the last photo but it is more pronounced. There are now four dams evident within the area 1 study site and market gardens occupy more of the catchment area.

There is no change in channel character or morphology since the 1961 image.

22 January 2020

There has been almost no change in channel character or morphology since the 1978 image. The image was captured at the end of a period of intense drought. There does not appear to be preferential growth of vegetation along the channel line but all dam levels are high. The dam that was immediately up slpoe of site 21 appears to have been infilled.

Summary

There are two well defined lengths of channel within this study area that are separated by agricultural dams. The channels are not evident on the 1930 photograph and their appearance coincides with the advent of market gardening in the area. The channels are in very poor condition, with very low sinuosity, no channel variability and are completely colonised by luxuriant growth of weeds.

Area 2: Appendix 2

10 February 1930

The quality of the 1930 photograph is insufficient to gain a clear insight into the existence of a continuous channel at this location. There appears to be some elongate patches of darker vegetation which may indicate water retention along flow paths but it is not conclusive. However, there is no evidence of a meander loop extending into lot 59B from Eastern Creek.

27 June 1961

The 1961 photograph is much clearer and has a good resolution. Market gardens occupy lot 59B and denser vegetation occupies the Eastern Creek corridor. While much of the meander channel length, as defined by the Hydroline, is masked by vegetation there is still sufficient gaps in the canopy to determine that there is no channel in the vicinity of site 18.

6 May 1978

The 1978 photo is clear and the resolution is good. There is a corridor that is cleared of vegetation along the western boundary of the study area and there is no channel in evidence.

22 January 2020

The 2020 aerial photograph has a high resolution and the quality is excellent. The cleared corridor along the path of the gas pipeline shows no evidence of a channel ever existing in the vicinity of the meander loop as shown by the Hydroline.

Summary

There is no evidence shown on any of the aerial photographs of the existence of a meander loop in this area. Nor does the DEM show any remnant channel morphology of where the channel may have been. It is unlikely that there was ever a channel at the location of the meander loop as shown by the NSW Hydroline.

Area 3: Appendix 3

10 February 1930

The 1930 imagery for Area 3 is much clearer than at other areas of the image. Eastern Creek can be easily seen to be a discontinuous channel to the west of the study area. The area of the Keyhole Estate has been largely cleared along the southern boundary and sparse vegetation does not mask the surface. There is no evidence of any channel existing in this area

27 June 1961

The 1961 imagery is of good quality and resolution. Market gardens extend across most of the study area and a low sinuosity continuous channel is also in evidence. The zone between sites 14 and 16 is masked by vegetation and there is no evidence of the dam that later occupies this location. The channel down slope of site 16 is poorly defined but the channel of Eastern Creek can clearly be seen in Lot 97B.

There is a low sinuosity, continuous channel in evidence extending upslope from the vicinity of site 14 to site 1 with dams having been constructed at site 12 and site 8.

6 May 1978

At the date of capture there is very little vegetation masking the channel zone. By this time the channel morphology that largely exists today is in place.

Highly modified and straightened sections of channel are in evidence downstream of site 16 where a dam has now been constructed. Dams are also in existence at sites 12, 10 and site 8. There is a continuous channel upstream of site 7 and it appears to be erosional at site 7 and site 2. Sheet erosion is evident at site 2.

At site 10 is where the golf driving range is today and there is now a pipeline carrying the flow under sites 9 and 10. The sheet erosion evident at site 2 has now been re-contoured and the channel evident in the 1978 photo is no longer in existence.

22 January 2020

The market gardening prevalent in the previous imagery is largely absent in the 2020 image. The dams at sites 16 and 8 are now choked with abundant vegetation, as is much of the channel length, and the dam at site 10 has been filled in and a pipeline now conveys the flows subterraneously.

Further channel straightening and piping has occurred at sites 13 and 6. The channel has a very low sinuosity and is generally in a very poor condition.

Summary

The channel as shown in the 1961 and 1978 imagery appears to have a very low sinuosity and very little morphological diversity. The channel appears to be in a very poor condition and becomes colonised by impenetrable weed growth prior to the 2020 imagery. The contemporary channel condition has not improved and is still very poor with a lack of morphological diversity.

Conclusions

- The channels within the study areas 1 and 3 are generally well defined and continuous
- The channels in study areas 1 and 3 are artificial and anthropogenically modified
- The bank morphology is study areas 1 and 3 have low variability indicating anthropogenic modification
- The sinuosity of the channels in study areas 1 and 3 is very low and is indicative of anthropogenic modification
- At study area 2 there is no evidence of any existing, or pre-existing, channel or meander bend of Eastern Creek extending into Lot 59B. The channel, as defined by the NSW Hydroline, is non-existent.
- Study area 1 has a channel that is essentially ephemeral and would more properly be described as an agricultural drain rather than a first order stream as indicated by the NSW Hydroline
- Because of the brevity and transitory nature of the flows in the upper reaches of study areas 1 and 3 the drainage lines within the study areas 1 and 3 would more precisely be defined as ephemeral and are therefore not first order streams as defined by Strahler
- The channel through study area 3 is described as a first order stream but there is a confluence of two tributaries at site 5. The right bank tributary is ephemeral and is therefore not a first order stream. The tributary entering from left margin contributes the majority of the flow and constitutes a first order stream that extends downstream to the confluence with Eastern Creek
- The channel upstream of site 2 defined by the NSW Hydroline as a first order stream is non-existent. There is no defining assemblage of geomorphic units, channels or banks, and this reach is incorrectly labelled as a first order stream.
- What appears to be intact valley fill at head of catchment in study area 3 is at the interface of colluvial margin and flow path. This area is not natural and sheet erosion evident in the historical aerials has been re-profiled.

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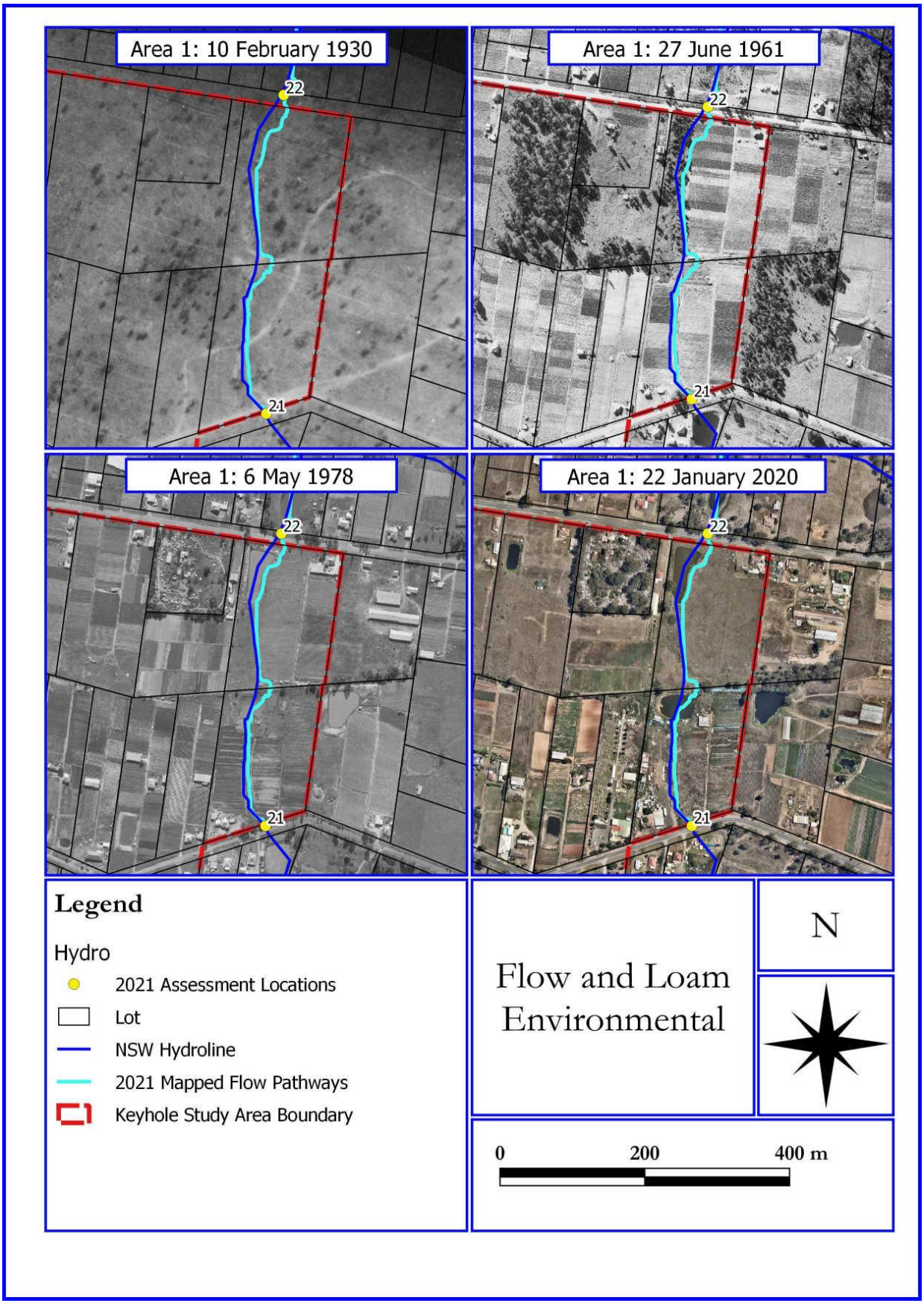
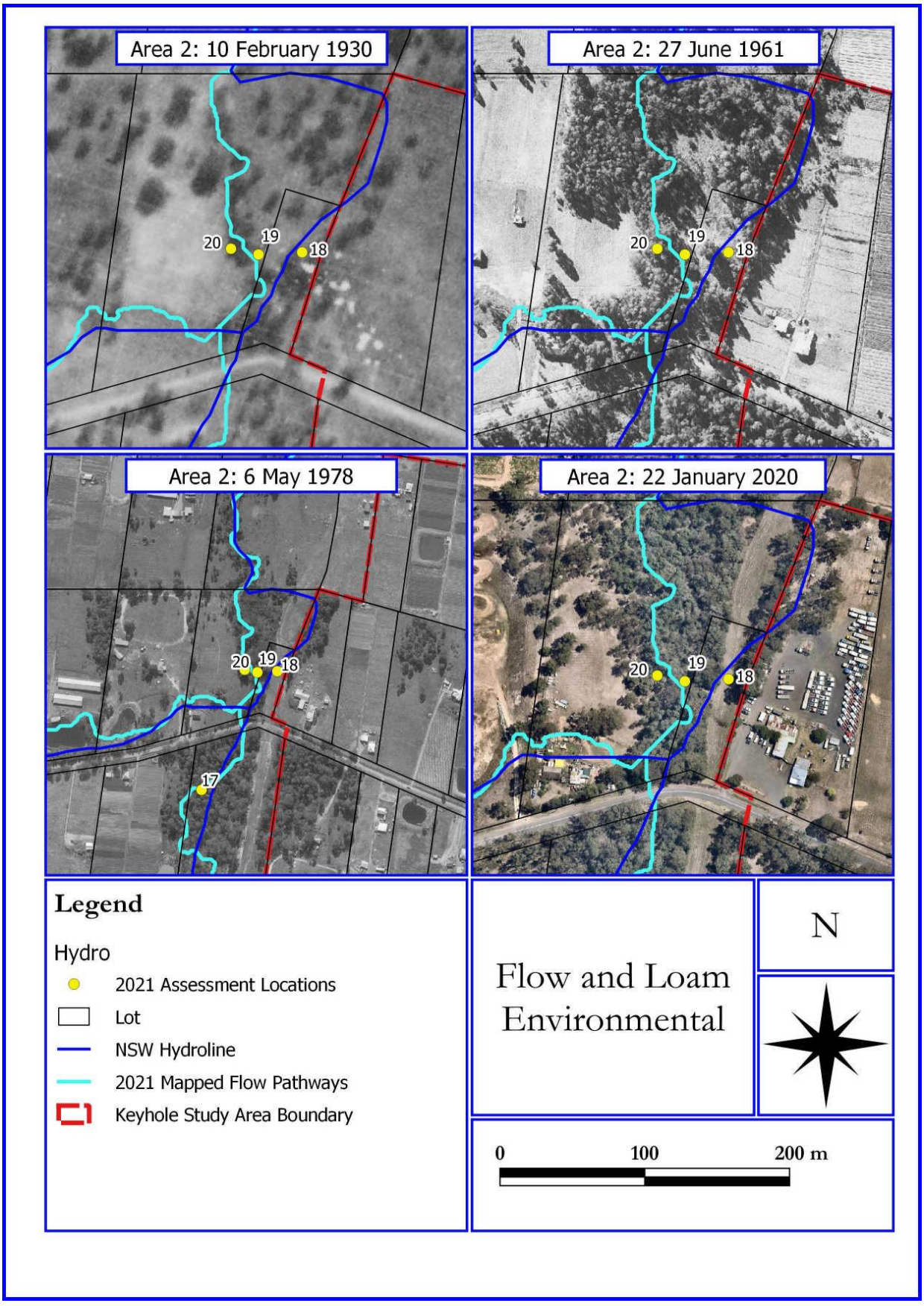
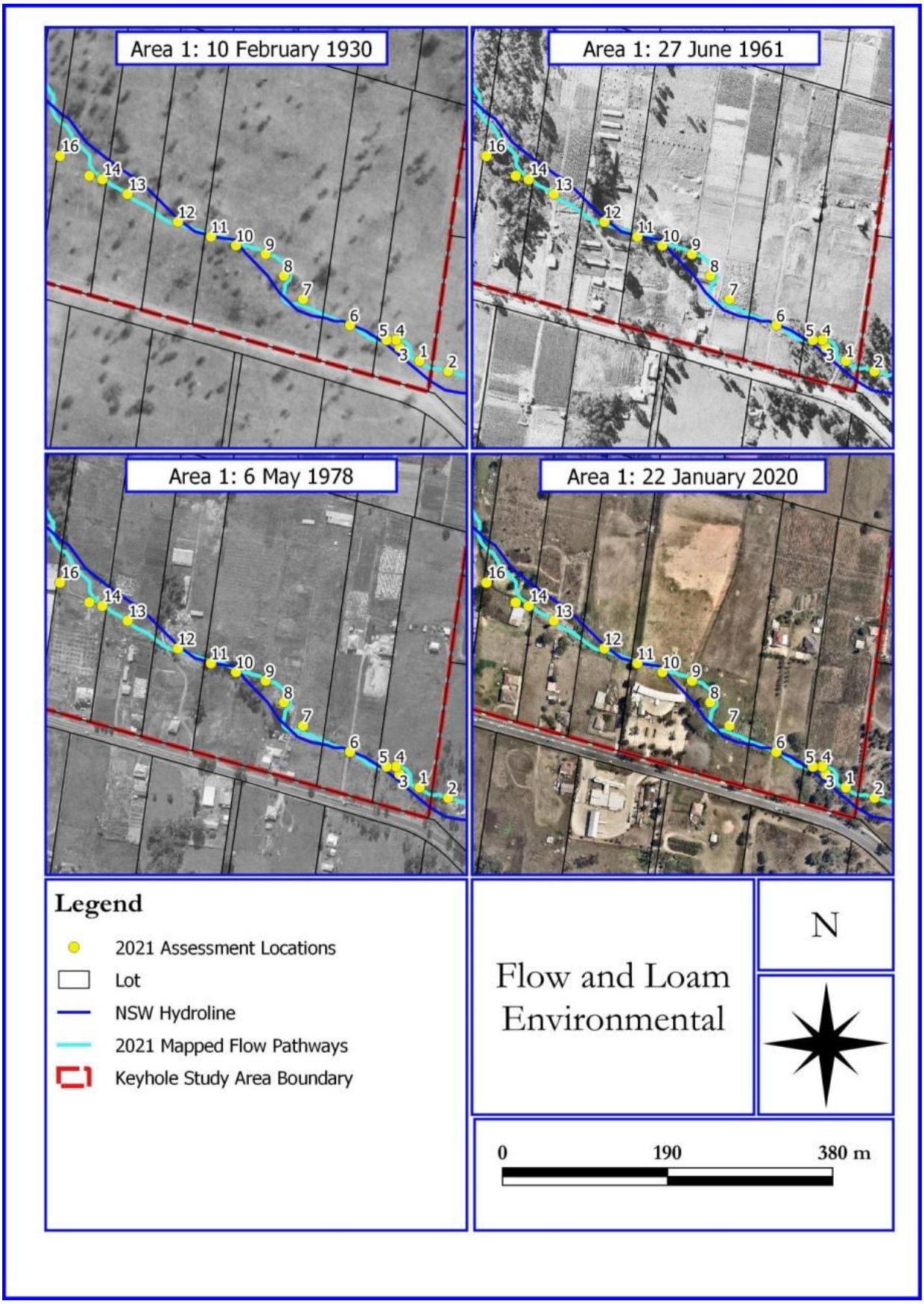
Appendix 1: Historical Aerial Photography Area 1



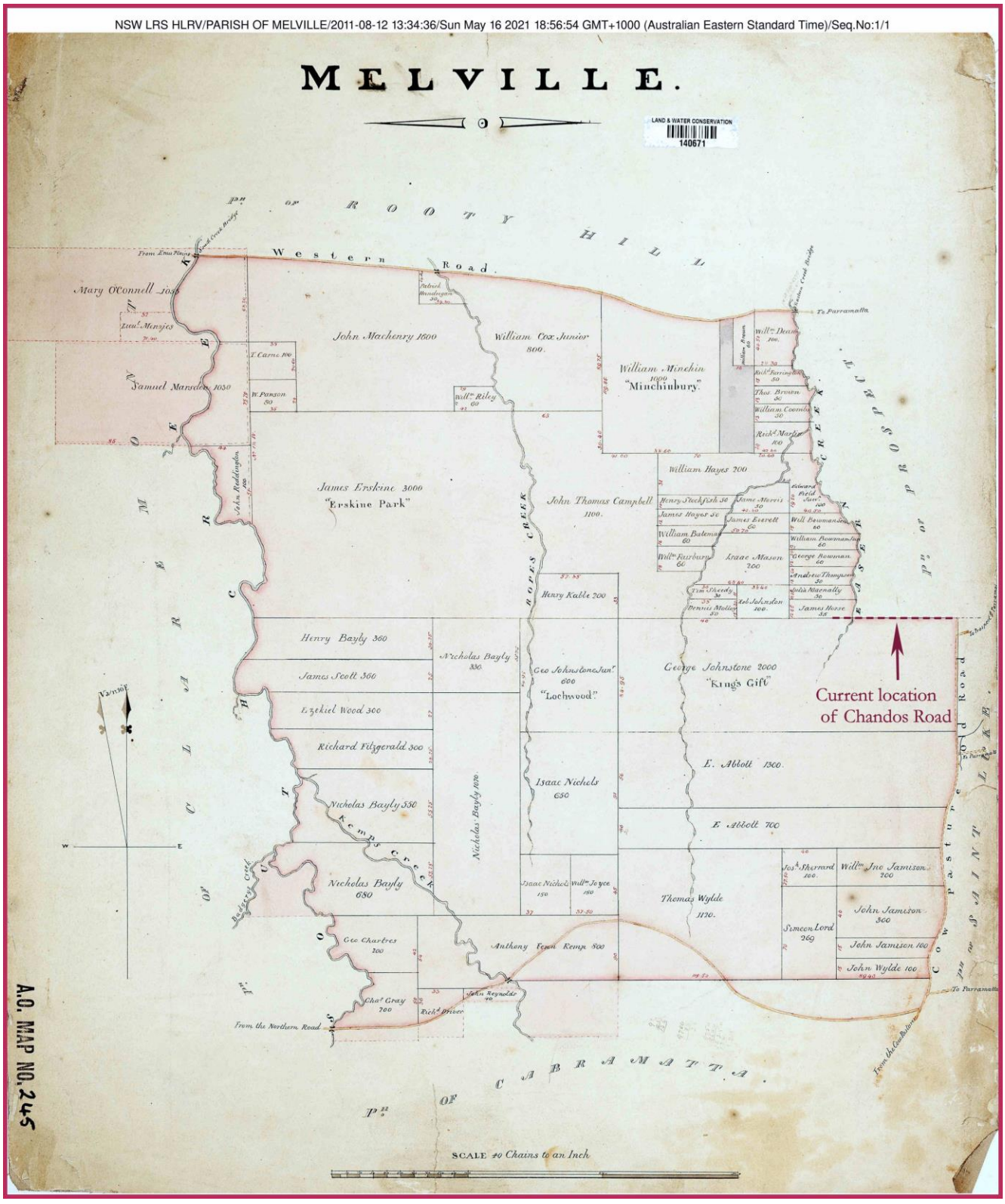
Appendix 2: Historical Aerial Photography Area 2



Appendix 3: Historical Aerial Photography Area 3



Appendix 4: Parish Melville circa 1841



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