Appendix I

Fluvial Geomorphology Addendum

REGIS RESOURCES LTD

McPhillamys Gold Project

Amended Project

Fluvial Geomorphology Addendum

Dr Christopher J Gippel

August 2020

LFB Resources NL

FLUVIAL SYSTEMS

McPhillamys Gold Project

Amended Project

Fluvial Geomorphology Addendum

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Executive Summary

LFB Resources NL is seeking State Significant Development consent under Division 4.7 of Part 4 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act) to develop and operate a greenfield open cut gold mine, associated mine infrastructure and a water supply pipeline in Central West NSW. LFB Resources NL is a 100% owned subsidiary of Regis Resources Limited.

The McPhillamys Gold Project (the project) is comprised of two key components; the mine site where the ore will be extracted, processed and gold produced for distribution to the market (the mine development), and an associated water pipeline which will enable the supply of water from approximately 90 km away near Lithgow to the mine site (the pipeline development).

An Environmental Impact Statement (EIS) was prepared in 2019 to assess the potential environmental, economic and social impacts of the project. The EIS included a fluvial geomorphology assessment of locations where the pipeline was proposed to cross watercourses (termed 'crossings') (Gippel 2019a). The development application and accompanying EIS was submitted to the NSW Department of Planning, Industry and Environment (DPIE) and subsequently publicly exhibited.

In response to issues raised in submissions received, as well as a result of further detailed mine planning and design, LFB Resources NL has made a number of refinements to the project. Accordingly, an Amendment Report has been prepared by EMM Consulting Pty Ltd to outline the changes to the project that have been made since the public exhibition of the EIS and to assess the potential impacts of the amended project, compared to those that were presented in the EIS.

This report forms part of the Amendment Report and presents an assessment of the fluvial geomorphic impacts of the revised pipeline alignment options for the pipeline development component of the amended project. This report undertook an assessment of the crossings associated with the amended options using the same approach undertaken for the assessment of the pipeline corridor assessed in the EIS.

The assessment focused on geomorphic characteristics of the watercourses in the vicinity of the pipeline crossings that were relevant to the main risks associated with the pipeline during its operational phase. These risks were that:

- geomorphic change could lead to exposure of the pipeline to fluvial forces, thereby putting the integrity of the pipeline at risk, and
- the presence of the pipeline (usually in combination with being exposed through geomorphic change) could interfere with natural geomorphic processes.

In addition, this report addresses a recommendation in the submission by Department of Planning, Industry and Environment – Water (DPIE Water) that the proponent use the hierarchy of vulnerable rivers set out in the NSW River Styles database to identify the priority for protective works in any pipeline crossings that occur. This database includes only named watercourses, so for the revised pipeline alignment options assessed in this Addendum, the River Styles methodology was applied to an assessment of all potential crossings.

River Styles assessment was also carried out for named watercourse across the unchanged portions of pipeline corridor assessed in Gippel (2019a).

Hydrolines, which are the same as the 'blue lines' on topographic maps, are generalised representations of the drainage network that do not always correspond with the position of watercourses on the ground. For this assessment, more accurately defined watercourses that emulated hydrolines were auto-generated from topographic data using terrain analysis. The EIS pipeline route assessed by Gippel (2019a) crossed 112 auto-generated watercourses. The Southern amended option, combined with the unaltered portion of the EIS route, crossed 109 auto-generated

watercourses. The Northern amended option, combined with the unaltered portion of the EIS route, crossed 101 auto-generated watercourses.

The watercourses were classified into small- and large-sized (Third and higher Order and area >1.33 km^2) streams on the basis of Stream Order and catchment area. Small-size streams were considered low risk of geomorphic impact, while large-size streams were inspected in the field and individually assessed for risk of geomorphic impact.

The key differences between the EIS (Gippel, 2019a) and this amended project assessment are listed below:

Aspect	Key differences
Methodology	• The same method was applied, except that the amended project assessed large-sized crossings for River Styles, for both the unaltered portion of the EIS pipeline route and the amended option routes.
Number of watercourses crossed	• The EIS pipeline route crossed 23 large-size watercourses. • The Southern amended option, combined with the unaltered portion of the EIS route, crossed 27 large-size watercourses. • The Northern amended option, combined with the unaltered portion of the EIS route, crossed 26 large-size watercourses.
Results	• The unaltered portion of the EIS pipeline route had one crossing with evidence of a knickpoint with potential to migrate upstream to the pipeline intersection. • The amended options had five crossings with evidence of a knickpoint with potential to migrate upstream to the pipeline crossing.

The key findings of this study were:

1. The amended pipeline options reduced the total number of watercourse crossings compared to the route assessed in the EIS, but they increased the number of crossings at large-sized watercourses.
2. Five crossings on the amended options were in locations where a downstream knickpoint had potential to migrate upstream to the pipeline crossing. This risk can be mitigated by monitoring the position of the downstream knickpoints, stabilising the knickpoints using structural works, or re-locating the crossings further upstream.
3. If trenching is to be employed at sites with sand beds, the base of the sand bed should be regarded as the top of the trench. The depth of sand should be comprehensively surveyed as part of the geotechnical assessment.
4. Trenched crossings present a low risk of geomorphic impact on most watercourses during the operational phase, provided the pipeline is buried a sufficient depth from the consolidated bed, and distance from the banks, of the watercourses, the backfill is composed of the same material that was excavated (replaced in layers, as appropriate), the backfill is compacted, and effective restoration of the disturbed area is undertaken.
5. Pipeline crossings constructed using directional drilling (underboring) present a negligible risk of geomorphic impact during the operational phase. This low risk approach would be most applicable to crossings at the largest watercourses.
6. A number of crossings were identified that had multiple geomorphic risks. It would be prudent to undertake further geotechnical assessment of these crossings to assist with selection of the most appropriate pipeline construction method or mitigation measures.

7. Potential geomorphic impacts during the construction phase would primarily relate to occurrence of a significant storm runoff event flood when a trench is exposed, and/or ground surrounding the site is disturbed from the action of machinery.
8. Monitoring of geomorphic aspects of the pipeline watercourse crossings should focus on significant storm runoff events, as impacts are only likely under conditions of heavy rainfall and fast flowing deep water in the channel. An inspection should be undertaken of a random sample of 6 crossings on First Order streams and 4 on Second Order streams, and all Third and higher Order streams, as soon as possible following a 20% annual exceedance probability regional storm event. If an issue of concern is observed at any of the sampled First or Second Order streams, all other crossings of minor streams should be inspected. Otherwise, inspection of watercourse crossings should be incorporated in the routine pipeline inspection and maintenance procedures developed for the operational phase.

1 Introduction

1.1 Project background

LFB Resources NL is seeking State significant development consent under Division 4.7 of Part 4 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act) to develop and operate a greenfield open cut gold mine, associated mine infrastructure and a water supply pipeline in Central West NSW. LFB Resources NL is a 100% owned subsidiary of Regis Resources Limited (herein referred to as Regis).

The McPhillamys Gold Project (the project) is comprised of two key components; the mine site where the ore will be extracted, processed and gold produced for distribution to the market (the mine development), and an associated water pipeline which will enable the supply of water from approximately 90 km away near Lithgow to the mine site (the pipeline development). The mine development is around 8 km north-east of Blayney, within the Blayney and Cabonne local government areas (LGAs) (Figure 1).

Up to 8.5 Million tonnes per annum (Mtpa) of ore will be extracted from the McPhillamys gold deposit over a total project life of 15 years. The mine development will include a conventional carbon-in-leach processing facility, waste rock emplacement, an engineered tailings storage facility (TSF) and associated mine infrastructure including workshops, administration buildings, roads, water management infrastructure, laydown and hardstand areas, and soil stockpiles (Figure 2).

In accordance with the requirements of the EP&A Act, the NSW Environmental Planning & Assessment Regulation 2000 (EP&A Regulation) and the Secretary's Environmental Assessment Requirements (SEARs) for the project, an Environmental Impact Statement (EIS) was prepared to assess the potential environmental, economic and social impacts of the project. The development application and accompanying EIS was submitted to the NSW Department of Planning, Industry and Environment (DPIE) and subsequently publicly exhibited for six weeks, from 12 September 2019 to 24 October 2019. During this exhibition period Regis received submissions from government agencies, the community, businesses and other organisations regarding varying aspects of the project.

In response to issues raised in submissions received, as well as a result of further detailed mine planning and design, Regis has made a number of refinements to the project. Accordingly, an Amendment Report has been prepared by EMM Consulting Pty Ltd (EMM 2020a) to outline the changes to the project that have been made since the public exhibition of the EIS and to assess the potential impacts of the amended project, compared to those that were presented in the EIS. This geomorphology assessment report forms part of the Amendment Report and presents an assessment of the fluvial geomorphic impacts of the pipeline development component of the amended project. References to 'the project' throughout this report are therefore referring to the pipeline development only.

1.2 Project amendment overview

A summary of the key amendments to the pipeline development since the exhibition of the EIS are summarised below and described in detail in Chapter 2 of the Amendment Report (EMM 2020a):

- **Pipeline route** – has been amended for a section of the corridor west of Bathurst, primarily in consideration of land access. Two options for the amended pipeline route have been included and assessed in the amended project; the northern option and the southern option (Figure 3). The pipeline alignment changes approximately 3 km west of pumping station facility No. 4. The new alignment continues for around 3 km, where it then splits into two options before re-joining the original route. The northern option is approximately 11 km long from where the two options split, and the southern option is approximately 6 km long, before re-joining the original alignment. The amended section of the pipeline route is therefore around 14 km long if the northern option is adopted, and approximately 9 km if the southern option is constructed.

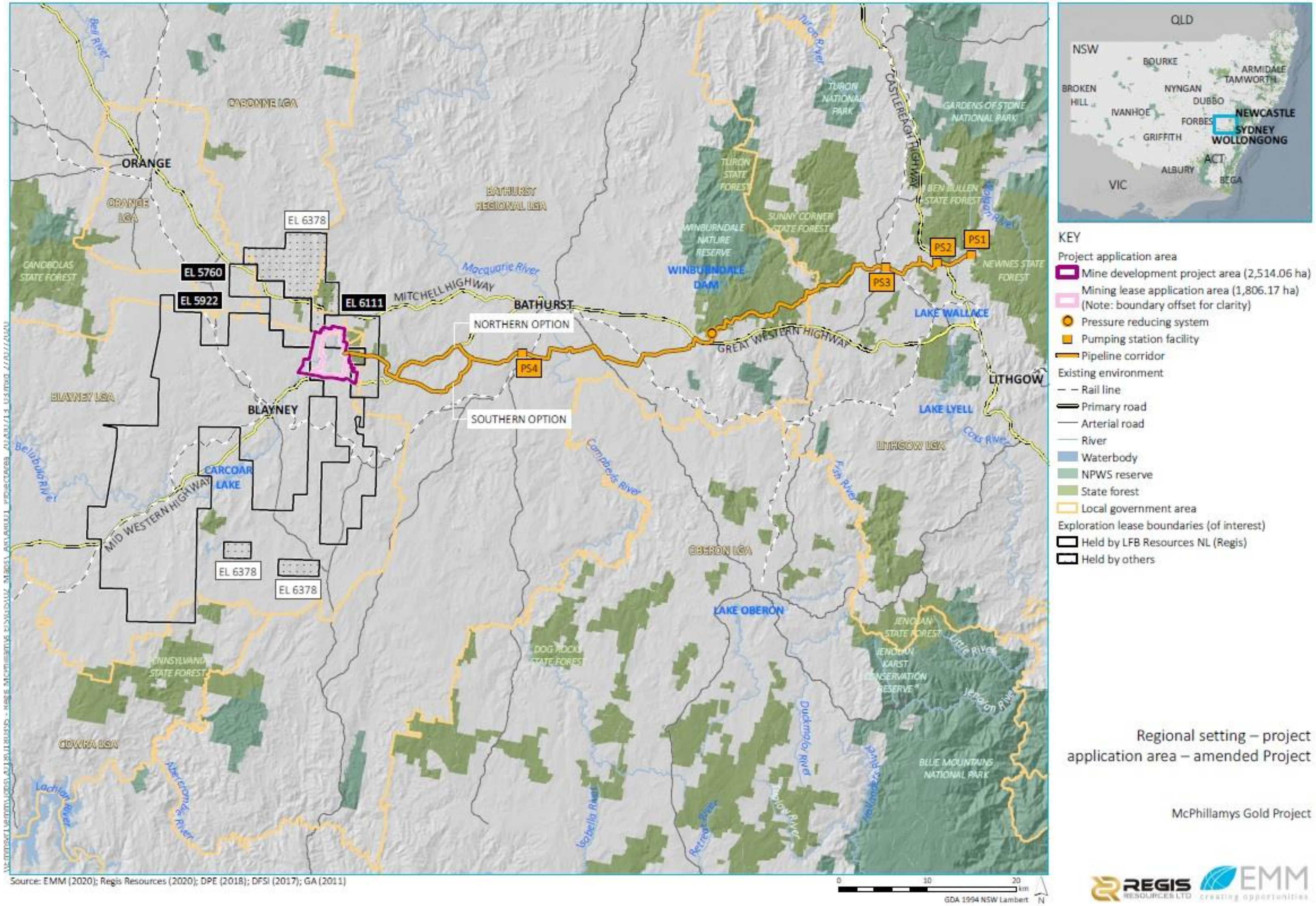

Figure 1. Regional setting of project application area for the amended project. Source: EMM (2020a).

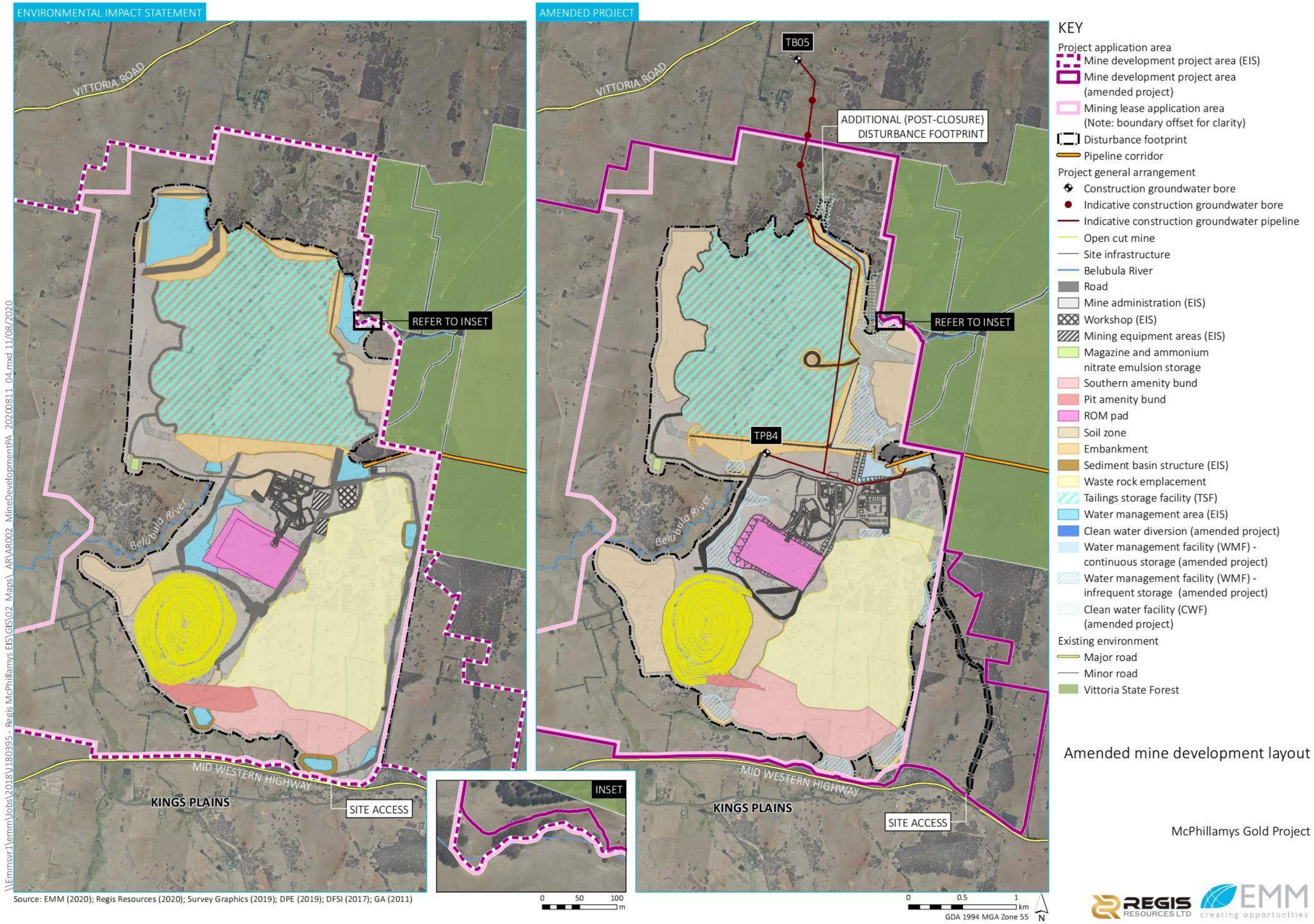

Figure 2. Mine development layout of project application area for the amended project. Source: EMM (2020a).

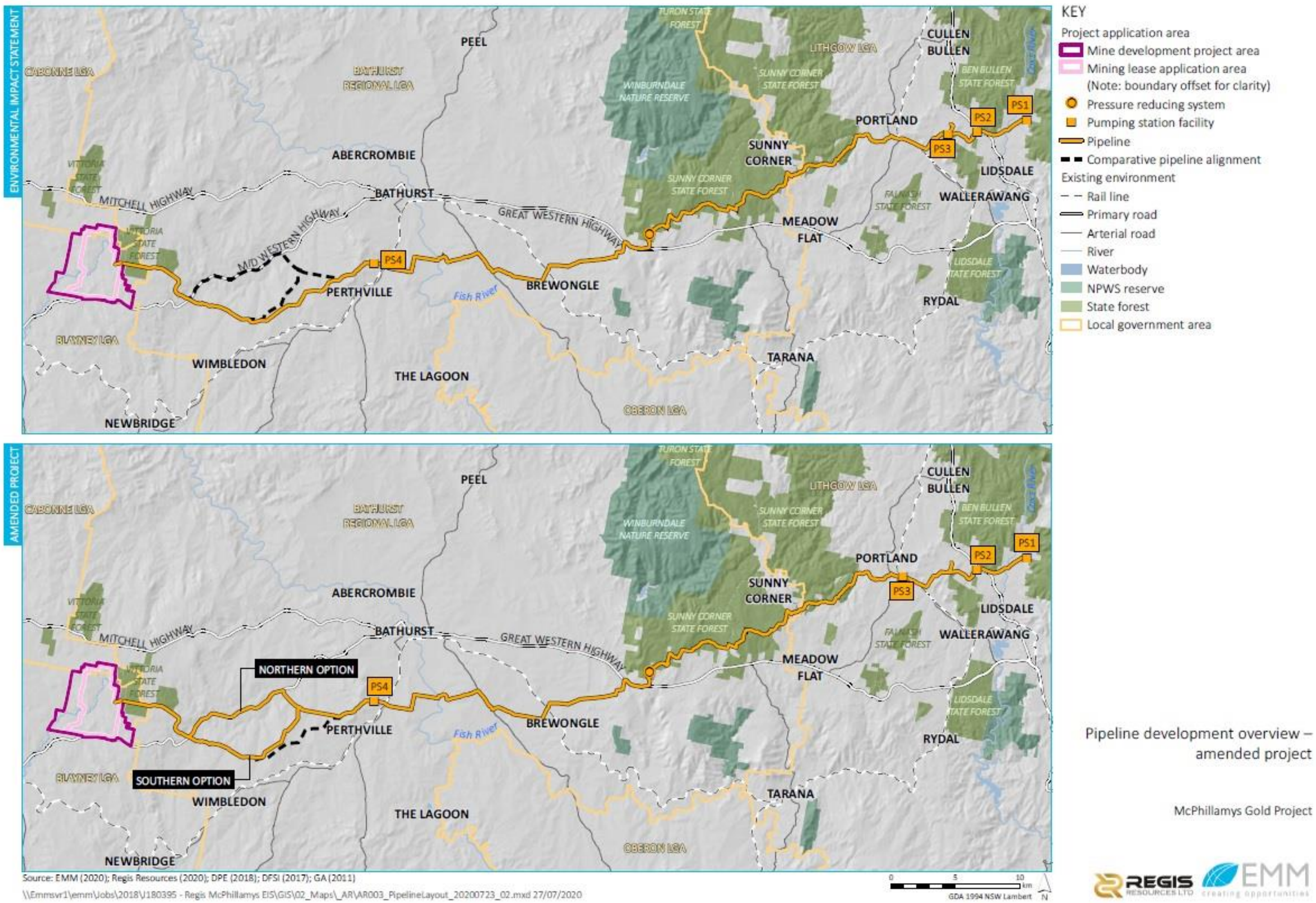

Figure 3. Overview of the pipeline development of the amended project. Source: EMM (2020a).

- **Pipeline corridor/disturbance footprint –** Pipeline corridor has been differentiated from the disturbance footprint with small changes to the pipeline corridor disturbance footprint made in consideration of biodiversity impacts. While the alignment of pipeline sections outside the realigned options hasn't changed, there have been minor variations in the width of the corridor to provide flexibility in the detailed design and subsequent construction phases of the project.
- **Pumping station facilities** – pumping station facility No.3 has been relocated from the vicinity of Energy Australia's Mount Piper Power Station (MPPS), to approximately 4.3 km to the west and adjacent to Pipers Flat Road.

No amendments have been made to other key aspects of the pipeline development as presented in the EIS for which approval is sought, such as the proposed construction methodology, and rehabilitation methods and outcomes.

The pipeline route is the only amendment relevant to this report.

1.3 Purpose of this report

This assessment considers and outlines the differences in fluvial geomorphic impacts of the amended project compared to the original project as presented in the EIS. In this way, it serves as an update to the McPhillamys Gold Project Fluvial Geomorphology Assessment (Gippel, 2019a), found in Appendix B of the Water Assessment Report, Appendix X of the McPhillamys Gold Project EIS (EMM, 2019). Specifically, this report:

- describes the existing geomorphic character of watercourses crossed by the new Northern pipeline and Southern pipeline option alignments and assesses the potential impacts of the project on these watercourses; and
- reports the River Styles classification of watercourses crossed by the pipeline over the entire pipeline corridor (as amended).

1.4 Submissions on the EIS

Issues relevant to fluvial geomorphic impacts of the pipeline development were raised in submissions received on the EIS. These issues were considered in this revised assessment. Detailed responses to all the submissions received are provided in the Submissions Report prepared for the project (EMM, 2020b), which was prepared in conjunction with the Amendment Report (EMM, 2020a). A summary of the key issues relevant to this fluvial geomorphic assessment are provided in Table 1, together with how each matter was addressed within this report.

Table 1. Relevant comments received in submissions relating to fluvial geomorphic impacts of the water pipeline development, and how they have been addressed.

Issue raised in Section 4.0 Pipeline Impacts / 4.3 Recommendations – Post Determination (Department of Planning, Industry and Environment - Water)	**How addressed**
It is recommended that the proponent use the hierarchy of vulnerable rivers to identify the priority for protective works in any pipeline crossings that occur. The hierarchy of fragility classes is set out in the NSW River Styles database.	Section 2.3 (Method) and section 3.2 (Classification). Each large watercourse crossing was classified in this report using River Styles, both for the original route and the options for the amended pipeline route.
Geomorphologic criteria should be required to prioritise those rivers and sections/reaches that are vulnerable to degradation on disturbance.	Section 4 (Impact). High fragility and Conservation recovery potential (in River Styles classification) were identified as two of seven geomorphic risk factors. Watercourses with multiple risk factors were identified as high priority for low impact construction techniques and protective works.

1.5 Watercourses assessed in this report

All development in NSW is assessed in accordance with the provisions of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and Environmental Planning and Assessment Regulation 2000 (EP&A Regulation). The EP&A Act is the principal planning legislation in NSW and provides the framework for environmental planning and assessment. The EP&A Regulation (EP&A Regulation) (NSW Government, 2016a) contains details for the various processes set out under the EP&A Act.

LFB Resources NL is seeking State significant development consent under Division 4.7 of Part 4 of the EP&A Act. Division 4.7 is Development that does not need consent. Under Division 5.2 State significant infrastructure, an environmental impact statement must be prepared by or on behalf of the proponent in the form prescribed by the regulations. This fluvial geomorphic assessment sought to determine the sites that would be assessed on the basis of a conventional definition of 'watercourse' (or similar term). While definitions provided in EP&A Regulation might strictly apply to designated development, not state significant development, this report used the definition of 'watercourse' provided by EP&A Regulation, as well as that provided by the *Water Management Act 2000* (WM Act), to guide the methodology.

In the EP&A Regulation – Schedule 3, Part 4 - What do terms used in this Schedule mean? Under item 38 Definitions 'waterbody' is defined as:

> *"(a) a natural waterbody, including:*
>
> > *(i) a lake or lagoon either naturally formed or artificially modified, or*
> >
> > *(ii) a river or stream, whether perennial or intermittent, flowing in a natural channel with an established bed or in a natural channel artificially modifying the course of the stream, or*
> >
> > *(iii) tidal waters including any bay, estuary or inlet, or*
>
> *(b) an artificial waterbody, including any constructed waterway, canal, inlet, bay, channel, dam, pond or lake, but does not include a dry detention basin or other stormwater management construction that is only intended to hold water intermittently."*

In this report, 'natural' is interpreted to mean that the work to form the channel was done by flowing water, with the water source being essentially unimpaired by direct human activity at the time the watercourse was formed (i.e. no diversions, dams or other significant works that alter that part of the flow regime which has sufficient power to mobilise the materials within which the watercourse is formed); and the sediment, soil or rock material transported to and by the waterbody, as well as through which it flows, experiencing essentially no direct interference from human activity at the time the watercourse was formed (i.e. no earthworks, sediment extraction or sediment dumping).

EP&A Regulation did not provide a definition of the terms 'perennial' and 'intermittent'. The binary stream hydrological classification 'perennial and intermittent' is equivalent to 'permanent and temporary', and the hydrological class 'ephemeral' is a sub-type of the primary intermittent class. Furthermore, the intermittent class can be subdivided into several sub-types, not just 'ephemeral', depending on degree of intermittency (Gordon et al., 2004). Following from that, this report assumes that EP&A Regulation, in defining a natural waterbody as "*a river or stream, whether perennial or intermittent…*", does not exclude any river or stream on the basis of its flow regime.

For the purpose of application of the EP&A Regulation, the requirement for an 'established bed' is a necessary condition of identifying a natural waterbody, not an alternative to the hydrological condition of 'perennial or intermittent'. The term 'established bed' appears rarely in academic literature, and when it has appeared, a definition was not supplied. An example is Taylor and Stokes (2005) who quoted the EP&A Regulation but did not elaborate in a direct way on the specific meaning of 'established bed'. The meaning of "established bed" has been the subject of debate in the courts, but no simple resolution has emerged. Dictionaries consistently suggest that 'established' in the context of a stream bed means that it has 'existed for a long time' (assuming a historical time scale ~10^0 – 10^2 years, not geological time). While such a stream bed could at the most simplistic level be considered stable, it is well accepted by geomorphologists that stream bed morphology can be highly variable over time, even if in the long-term it has a stable average condition. If a stream has a bed, then it logically follows that it also has 'banks', which together form a 'channel'. These terms lack standard definitions within the water resources industry. Merriam-Webster dictionary defines 'streambed' as "*the channel occupied or formerly occupied by a stream*", where a 'stream' is "*a body of running water (such as a river or creek)*". Collins dictionary defines 'streambed' as "*the channel in which a stream flows or formerly flowed*" (American) and "*the bottom of a stream*" (British). These typical dictionary definitions are based on hydraulics, suggesting that a streambed occurs in association with confined flow, as opposed to unconfined flow that is not within banks, which is referred to as sheetflow.

The above brief review suggests that, regardless of flow regime, and regardless of the materials forming the channel or its shape, the EP&A Regulation does not exclude any linear landform feature that conveys confined flow from being a 'waterbody'.

The focus of the WM Act is to provide for the sustainable and integrated management of the water sources. In administering the WM Act, it is common practice to accept the existence of a watercourse if it is represented by a blue line on a topographic map published by Land & Property Information, NSW Government. The current digital equivalent of blue lines are hydrolines.

It is commonly assumed in impact assessments that streams indicated by hydrolines of Third and higher Order have greater importance than First and Second Order streams. However, this is not prescribed by legislation or guidelines, and there is no geomorphic form or process threshold associated with the step from Second Order to Third Order streams. The basis of the assumption seems to be that permanence of water flow confers greater value than ephemeral or intermittent flow, and Third Order streams will generally flow more often than First and Second Order streams. Importance could relate to some aspect/s of ecosystem values, aesthetic values, or reliability of water supply for consumptive use, or the more dynamic and complex geomorphic character of Third and higher Order streams.

First and Second Order streams are likely to be found in headwaters, be relatively resilient to human disturbance (Cook and Schneider, 2006; Brierley et al., 2011), have intermittent flow, and often lack regular alluvial bedforms and floodplains. Streams of Third and higher Order are usually larger, are more likely to have permanent flow or pools (with potential for providing refugia during droughts), and could possess regular bedforms formed in unconsolidated sand, gravel or cobble (that might have particular habitat significance), and continuous or discontinuous floodplains (that might have an important ecosystem function).

Consistent with McPhillamys Gold Project Fluvial Geomorphology EIS (Gippel, 2019a), for the purpose of assessing potential geomorphic impact of the project, the convention adopted in this Addendum report was that hydrolines of Third and higher Order have greater importance than First and Second Order streams. This convention was adopted as a simple way to separate smaller from larger streams. For the EIS, Gippel (2019a) found that the pipeline crossed 131 hydrolines, which equated to 112 watercourses defined by terrain analysis (because not all hydrolines exist on the ground in the position they are mapped). The classification was used to prioritise sites for field inspection. The same classification was applied in this amended project report. It is acknowledged that this classification of watercourses based on a Third Order threshold is not strongly linked to geomorphic or hydrologic theory, and is not part of the core definition of 'river' under the WM Act or 'waterbody' under the EP&A Regulation.

1.6 Scope of this report

The scope of this report is limited to assessment of fluvial geomorphologic aspects of watercourses and their corridors, which includes bed, banks and floodplains, where present, at their intersections with the pipeline route. Thus, the Study Area for this geomorphic investigation is discontinuous, and excludes valley slopes between pipeline/watercourse intersections, even though these slopes might drain towards the intersected watercourses. Assessment of the impact of the project on valley slopes and other land that is not within the watercourse corridor falls within the scope of other expert reports, principally soils.

In this report, watercourses to be assessed were defined by hydrolines. Hydrolines do not include every drainage path that conveys confined water flow through a landscape. Thus, the pipeline route would intersect a number of small drainage lines not marked by hydrolines, and therefore not specifically considered here. These crossings can be managed during construction and operation phases according to the recommendations made for the smaller streams that were included in the assessment. Also, hydrolines are a simplified representation of the alignment of drainage paths, particularly for small streams, and some of them might be incorrect due to alterations of landforms and drainage since the date of mapping. Thus, hydrolines guided identification of watercourses for inclusion in the geomorphic assessment, but the detailed location of the watercourse/pipeline intersection points were determined independently of hydrolines.

The scope of the assessment included description of the existing environment, assessment of potential impacts, and recommendations for mitigation and monitoring. The potential fluvial geomorphic impact of the majority of the proposed amended pipeline route was assessed in the EIS geomorphology assessment (Gippel, 2019a). The pipeline route has been amended for a section of the corridor west of Bathurst, primarily in consideration of land access and potential impacts to biodiversity. Two options for the amended pipeline route have been included and assessed in the amended project; the northern option and the southern option. The pipeline alignment changes approximately 3 km west of pumping station facility No. 4. The new alignment continues for around 3 km, where it then splits into two options before re-joining the original route (Figure 1 and Figure 3). The northern option is approximately 11 km long from where the two options split, and the southern option is approximately 6 km long, before re-joining the original alignment. The amended section of the pipeline route is therefore around 14 km long if the northern option is adopted, and approximately 9 km if the southern option is constructed. This assessment uses the terms Northern pipeline option, Southern pipeline option, and Northern-Southern route for the section where the Northern and Southern options share the same alignment prior to joining the portion of the pipeline route unchanged from that proposed in the EIS (see later Figure 4). All three amended sections are assessed in this report. Note that if the Southern option were to be chosen, a longer length of the route proposed in the EIS would be retained.

Similar to the methodology carried out in the EIS geomorphological assessment (Gippel, 2019a), all watercourse/pipeline intersections (termed 'crossings') were assessed using a desktop analysis of remotely sensed imagery and available spatial layers. The EIS assessment included field inspection of the larger watercourses. This was not possible for the amended options assessment, but the desktop analysis was assisted by ground photography provided by EMM. Pipeline crossings of First and Second Order watercourses were expected to present a low, predictable risk of impact to geomorphic processes, while crossings of higher order watercourses could present a higher, and less predictable, risk. The assessment of potential impacts of the project on watercourses, and recommendations for mitigation and monitoring, were based on generic principles.

In addition to the assessment methodology carried out in the EIS assessment (Gippel, 2019a), as recommended in the submission by DPIE (Table 1), the hierarchy of fragility classes set out in the NSW River Styles database was used to identify the priority for protective works in the pipeline crossings across the entire amended project pipeline route, including the unchanged portions of pipeline corridor assessed in Gippel (2019a) and the revised pipeline route options.

2 Methodology

2.1 Variables of interest

This assessment focused on geomorphic characteristics of the watercourses in the vicinity of the pipeline crossings that were relevant to the main risks associated with the pipeline during its operational phase. These risks were that:

- Geomorphic change could lead to exposure of the pipeline to fluvial forces, thereby putting the integrity of the pipeline at risk, and
- The presence of the pipeline (usually in combination with being exposed through geomorphic change) could interfere with natural geomorphic processes.

In consideration of the established risks associated with pipeline crossings of watercourses, and the guidelines of NSW Office of Water (2012b), the variables of interest in this investigation were:

- Stream Order,
- Catchment area,
- River Style, geomorphic condition, recovery potential and fragility,
- The calibre of the bed material,
- The depth of sand in mobile sand-bed streams,
- The structure and extent of riparian vegetation cover, and
- The presence of knickpoints that could potentially migrate upstream to the crossing.

No attempt was made to ascertain, on the basis of a rapid visual assessment, the historical or current rate of channel migration, rate of erosion or deposition, or stability of bed and banks relative to what would be expected for the stream in an undisturbed setting.

2.2 Desktop geomorphic assessment of watercourses crossed by the amended project options

2.2.1 Topographic data

The delineation of watercourses and their catchments was based on the best available topographic data. The study area is covered by DEM (digital elevation model) tiles produced by NSW Spatial Services, Department of Finance, Services and Innovation, available from ELVIS - Elevation and Depth - Foundation Spatial Data, Version 0.1.1.0 (http://elevation.fsdf.org.au/). The DEMs were produced using the TIN (Triangular Irregular Network) method of averaging ground heights to formulate a regular grid and are not hydrologically enforced.

In the study area, the data sets contained ground surface models in grid format at 1 m, 2 m and 5 m resolutions. The 1 m data were derived from C3 LiDAR (Light Detection and Ranging) from an ALS50ii (Airborne Laser Scanner). The 2 m data were derived from Spatial Services Category 2 (Classification Level 3) LiDAR from an ALS80 (SN8250) sensor. The data used to create the 1 m and 2 m DEMs has an accuracy of ±0.3 m (95% Confidence Interval) vertical and ±0.8 m (95% Confidence Interval) horizontal. The 5 m data were derived from Leica-Geosystems Airborne Digital Sensor (photogrammetry). The processed data was manually edited to achieve ICSM standard category 3 whereby the ground class contains minimal non-ground points such as vegetation, water, bridges, temporary features, jetties etc. This data has a vertical accuracy of ±0.9 metre on bare open ground (95% Confidence Interval 1.96 x RMSE) and horizontal accuracy of ±1.25 metre (95% Confidence Interval 1.96 x RMSE) on bare open ground.

The DEMs in the study area were from the Blayney (5 m DEM tiles), Bathurst (2 m DEM tiles), Orange (5 m DEM tiles), Oberon (5 m DEM tiles) and Wallerawang (1 m and 2 m DEM tiles) regions. In areas of overlap, the higher resolution DEMs were preferred. In Blayney and Bathurst regions, the 1 m and 2 m data were collected in Oct-Nov 2015; in Wallerawang region the 1 m data were collected in August 2008 and the 2 m data were collected Apr-Jul 2017; in Blayney and Orange regions the 5 m data were collected Feb-Jul 2014; in Oberon region the 5 m data were collected Nov 2013 – May 2014.

The DEM tiles were downloaded over an area about 80 km long and 12 km wide that contained the pipeline route and the majority of the catchments of watercourses that intersected the pipeline. The catchments of the larger rivers extended beyond the DEM tiles. These areas were covered by the Geoscience Australia 1 second SRTM derived DEM-H Version 1.0, a 1 arc second (~30 m) gridded DEM that has been hydrologically conditioned and drainage enforced. The low resolution and low accuracy SRTM DEM was used as supplementary data in the procedure to delineate catchment areas. Watercourse delineation in the vicinity of the pipeline development was based on the higher resolution DEMs.

2.2.2 Mapped hydroline network

The drainage network was represented by National Surface Hydrology Lines (Regional) downloaded from Australian Government (https://data.gov.au/dataset/surface-hydrology-lines-regional). The dataset is a collaborative effort by Geoscience Australia and state governments. Geoscience Australia manages a data aggregation from multiple jurisdictional sources. The scale of the data ranges from 1:25,000 to 1: 250,000 across the continent. Geoscience Australia aggregates the data into a National Model and forms the surface water components of the Foundation Spatial Data Framework. In the area covered by the Project, these lines correspond to the hydrolines, equivalent to 'blue lines' on the 1:25,000 topographic map sheet.

The blue lines on topographic maps, and thus the National Surface Hydrology Lines (Regional), would have been drawn mainly on the basis of whether a channel was visible on the aerial photographs available at the time of production, perhaps also guided by vegetation structure. Some important factors impact how well the mapped blue lines represent the existing channel network:

- The blue lines represent the channel network visible or assumed from aerial photographs; the resolution and quality of the photographs limits the scale of mapping.
- Distortion inherent in the original aerial photographs makes precise transfer of the locations of the stream lines to a undistorted map difficult.
- The blue lines are typically depicted as a smoothed representation of the actual stream lines.
- Channels can change in size and position over time.

Given these factors, the National Surface Hydrology Lines (Regional), referred to here as hydrolines, were not expected to accurately represent the existing drainage lines. Nevertheless, the hydroline network is the conventional standard used in impact assessments to identify streams of interest, and to classify streams by size using Strahler Stream Order. In this Report, the hydrolines were used for this purpose, and also to guide the terrain analysis procedure to generate an accurate representation of the existing watercourse positions.

2.2.3 Automatic watercourse delineation

Given the inadequacies of the hydroline network, a revised drainage network was automatically generated in the catchments of watercourses intersecting the pipeline route using Global Mapper™ GIS (geographic information system). The new drainage networks and catchment areas were generated by flow accumulation using the standard 8-direction pour point algorithm (D-8) (Jenson and Domingue, 1988). The drainage network was evaluated at 1 × 1 m resolution for the majority of catchments, and at 5 × 5 m resolution in the largest catchments. Depressions in the topography were filled prior to flow accumulation. Some drainage lines would have been inaccurate around road culverts and bridges that were not edited into the DEM, but this problem was unlikely to have affected the delineation of watercourse positions near pipeline intersections.

The automatically generated drainage network was intended to emulate the hydroline network. In some cases, hydrolines had no equivalent automatically generated watercourses. This arose because the hydroline drainage was grossly incorrect, a hydroline was not drawn on a significant catchment, or the area of land had been mined or impounded since the hydrolines were drawn.

The automatically generated drainage networks were different in detail to the hydroline network, but each watercourse intersecting the pipeline route was assigned the same Strahler Stream Order as the hydroline that it emulated. Catchment area was calculated on the basis of the DEM data.

2.2.4 Classification of watercourses by size

The EIS pipeline route had 131 hydroline crossings, which equated to 112 auto-generated watercourse crossings that could be identified on the ground. Many of these were on small streams that were at low risk of geomorphic impact, and were difficult to access in the field. It was not feasible to inspect all watercourse crossings in the field, so a desktop classification of watercourse size, based on stream order and catchment area, was used to prioritise streams for field inspection. Catchment area was used in addition to stream order because stream order was assigned on the basis of mapped hydrolines, not the existing drainage network, and could have been unreliable as a guide to stream size in some cases. Also, in connection with sediment supply, sediment transport, channel adjustment, and stream discharge processes, catchment area has a stronger theoretical link to geomorphic and hydrologic theory than stream order.

For the EIS assessment, watercourses of First and Second Order were automatically classified 'small'. These watercourses at EIS pipeline crossings all had catchment areas less than 1.33 km^2, so this was set as a threshold area to classify watercourses as 'small', regardless of stream order. Watercourses of Third and higher Order were subdivided into 'medium' and 'large' size on the basis of catchment area using a threshold of 5 km^2. The fieldwork was able to inspect all medium- and large-sized watercourse crossings, making the separation into medium- and large-size obsolete for the purpose of the impact assessment. Data concerning all the field-inspected crossings was tabulated in the EIS report of Gippel (2019a). There was one exception included in the tabulated results, being a small Second Order watercourse with a catchment area of 1.27 km^2 (at the EIS pipeline crossing number 70) that was opportunistically assessed in the field. In this amended project report, this small-size stream crossing was not included in the River Styles assessment.

The assessment of risk and recommendations for mitigation and monitoring made for the EIS (Gippel, 2019a) considered all available information, not just field collected data specific to the inspected crossings. However, small-size watercourses were likely to be resilient headwater streams, and were considered to be at relatively low risk of geomorphic impact from pipeline crossings. This risk was considered sufficiently low that it could be managed by following generic guidelines. Larger watercourses were considered to be at higher risk of geomorphic impact from pipeline crossings. Management of these risks was assessed on a case by case basis.

In assessing the amended pipeline options, field inspection was not feasible due to a combination of COVID 19 related constraints and land access. Although not needed for prioritisation of fieldwork, the size-based classification of watercourses was used in this report to separate the crossings into low geomorphic impact risk and higher geomorphic impact risk, with the latter warranting site-specific recommendations. The same criteria used in the EIS were applied to the crossings in this project report, except that medium- and large-size watercourses were merged into one class. The watercourses classified medium- and large-size in the EIS assessment were all re-classified as large-size. Thus, small- and large-size streams were classified as follows:

- Small-size watercourses: First and Second Order, or catchment area (A) $A < 1.33$ km^2
- Large-size watercourses: Third or higher Order, and catchment area (A) $A \geq 1.33$ km^2

While hydrolines are classified by Stream Order, Perennial/Non-perennial, and Minor/Major hierarchy, and in general, named streams are classified for River Styles and unnamed ones are not, there is no basis in legislation or geomorphic theory to include or exclude watercourses for impact assessment on the basis of these variables alone. This report uses the above described size-based classification, not to exclude small watercourses from the assessment, but to assign them a lower risk of geomorphic impact.

Note that the EIS assessment report (Gippel, 2019a) tabulated geomorphic data only for the field-inspected medium- and large-size (in this report combined to large-size) watercourse crossings, while this report of the amended project tabulates desktop-collected data for all crossings on the amended options. The exception was River Styles data, which were reported only for the large-size watercourse crossings on the amended options.

2.2.5 Channel morphology

Channel morphology was characterised at each pipeline crossing in the long profile and cross-section directions. This was done by extracting thalweg elevations from the DEM at 1 m intervals along the auto-generated drainage lines over profiles extending variable distances up- and downstream of the crossing points. The profiles were based on the minimum elevation in the perpendicular along a 10 m wide band. Valley cross-section profiles were drawn by extracting elevations at 0.5 m intervals along the pipeline, from west to east regardless of stream orientation.

2.2.6 Riparian vegetation type and geomorphic condition

Intactness of native riparian vegetation cover is a determinant of geomorphic condition in River Styles. This was assessed using the NSW Office of Environment and Heritage State Vegetation Type Map (http://www.environment.nsw.gov.au/vegetation/state-vegetation-type-map.htm). These data date from January to June 2014. Each polygon is described by a number of attributes. For this report, the attribute 'class' was used to identify the vegetation type. This attribute was chosen because the main objective was not botanical, but to determine whether the riparian vegetation at the crossing site was native or non-native (i.e. agriculture, urban, roads), whether it was forest, woodland or grassland.

The assessment of geomorphic condition was also informed by viewing aerial imagery from World Imagery, dated 30/04/2018 over the area covered by the Northern and Southern options and dated 7/06/2019 over the area covered by the Northern-Southern route. The extent and structure of the riparian vegetation at the crossing sites was assessed, and where the Northern option followed the Mid-Western Highway, this was noted.

2.3 Desktop River Styles assessment of crossings on amended project options and the unchanged portion of the EIS pipeline route

2.3.1 River Style classification of watercourses

River Styles is a system for classifying stream geomorphic type based on valley setting, level of floodplain development, bed materials and reach-scale physical features within the stream (Brierley et al., 2011). The potential for physical recovery after disturbance depends on stream geomorphic condition, whereby streams in good condition (undisturbed and close to natural state) are more likely to be resilient and recover faster than those that are already degraded (Outhet and Cook, 2004; Brierley et al., 2011).

The River Styles website (https://riverstyles.com/river-styles-framework/) explains the four stages of the River Styles Framework which encompass description of river morphology, interpretation of behaviour and prediction of river recovery potential. Stage 1 involves catchment-wide mapping River Styles, Stage 2 involves catchment-framed assessment of river evolution and geomorphic river condition, Stage 3 involves assessment of the future trajectory of change and geomorphic recovery potential, again, at the catchment scale, and Stage 4 uses information from Stages 1 – 3 to identify target conditions for river rehabilitation for different River Styles.

The River Styles website provides example applications of River Styles. All were undertaken at catchment, basin or regional scales. The applications concern assessment of geomorphic condition, monitoring geomorphic condition, and the main intended use, prioritising river rehabilitation works. Project impact assessment might not be a primary application of River Styles, but it has been applied to planning mineral sands mine closure (Ferguson et al., 2016), and has been used several times as part of the assessment of the geomorphic impact of coal mine development (e.g. Gippel, 2019b). River Styles was intended to classify watercourses over reaches, rather than at points, and the literature does not explain how it can be applied to point impact assessment.

The River Styles framework was designed to cover all Australian stream types, and it is normally applied over the basin or regional scale, often limited to Third or higher Order streams. Most of the styles apply to be partly-confined and unconfined (i.e. alluvial/lowland) valley settings where streams are relatively large and feature many distinctive units such as levees, pools and riffles, bars, islands, benches, cut-off channels, backswamps, wetlands and floodplains. Whilst in principle the classification system could be extended to smaller streams, some of the expected attributes are scale-dependent and might not be found on small streams. In most cases, First and Second Order streams with small catchments would be classified as Headwater style, even if they are found in lowland areas and lack the steep, rocky character normally associated with headwater streams.

DPIE and Macquarie University together developed the River Styles Spatial Layer for New South Wales (NSW Office of Water, 2012b). The database provides River Style, fragility, sensitivity to disturbance, condition, rarity and recovery potential rivers in NSW. The data were derived from a number of sources depending on the Catchment Management Authority area. The spatial layer appears to include named streams rather than those of a particular minimum Strahler Order, although this could vary over the state, as the database is a compilation of independent basin assessments.

2.3.2 Geomorphic condition, fragility and recovery potential

Geomorphic condition is strongly linked to the degree of naturalness and extent of cover of riparian vegetation (Outhet and Cook, 2004; Outhet and Young, 2004a). Fragility is the ease of adjustment of bed material, channel geometry, and channel planform when subjected to degradation or certain threatening activities, and resilience is the property of having low fragility (Cook and Schneider, 2006; Brierley et al., 2011). The determination of stream fragility is based on the adjustment potential of three main characteristics of each geomorphic category. These include the adjustment potential of each category's channel attributes (geometry, size and connection to floodplain), planform (lateral stability, number of channels and sinuosity) and bed character (bedform and bed materials) (Cook and Schneider, 2006). Different stream types have characteristic levels of fragility (Outhet and Young, 2004b; Healy et al., 2012). Stream types with 'low fragility' are resilient or "unbreakable", those with 'medium fragility' have local adjustment potential, and those with 'high fragility' have significant adjustment potential (Cook and Schneider, 2006). Following on from this, the conservation and rehabilitation priority of stream reaches can be determined on the basis of geomorphic fragility and condition (Table 2).

Streams reaches with low fragility that are in good geomorphic condition are rated the highest priority for protection, 'Conservation', which means protect from human disturbance (Table 2). As explained by Cook and Schneider (2006), at a national scale, it is generally considered headwater reaches are the closest to being in an intact condition or have recovered to a near pre-disturbance state. Such streams are typically more resilient to change and are protected by their relative inaccessibility. However, streams of varied fragility can fall within the highest priority 'Conservation' category. For example, in the Hunter catchment, Cook and Schneider (2006) classified as high priority reaches that were high fragility (LUV DC Confluence Wetland and SMG Cut and Fill), and moderate fragility (PCVS Planform controlled, Low sinuosity, gravel and OCVS Planform controlled, Low sinuosity, cobble). The second priority for conservation and rehabilitation, 'Strategic', can contain streams with varied fragility. Reaches of moderate to low recovery potential are generally associated with areas that are more intensively used for agriculture. The lowest priority category of recovery potential is likely to contain high fragility streams in poor condition that have changed or are on the verge of changing to a different style.

2.3.3 Application of River Styles to watercourses at pipeline crossings

The River Styles approach was applied to large-size watercourses for both the amended options and the unchanged portion of the EIS route, with two exceptions (explained below).

Watercourses with high fragility were considered to be at the greatest risk of geomorphic change if disturbed. Thus, crossings over high fragility watercourses were identified as high priority for low impact construction techniques and/or monitoring.

Of the total 22 hydroline pipeline crossings on the new alignments for the Northern option, Southern option and Northern-Southern route, 7 were classified large-size, and of these only 4 were on named watercourses that had been previously classified on the River Styles Spatial Layer for New South Wales (see next chapter, Table 3).

Of the 23 crossings on large-size watercourses on the original EIS pipeline route assessed by Gippel (2019), 3 (crossings numbered 14, 16 and 25) would be bypassed by the Northern but not the Southern option, so these were retained in the assessment in this report (see next chapter, Table 3). One crossing on an unnamed Third Order watercourse (crossing number 31) would be bypassed by both the Northern and Southern options, so it was not included in the assessment in this report. Of the 22 previously assessed crossings on the potentially unchanged portion of the EIS pipeline route, 13 were on named watercourses that were classified on the River Styles Spatial Layer for New South Wales. The remaining 9 unclassified large-size watercourses were classified in this report on the basis of available data.

Small First and Second Order streams on hillslopes, not normally included in River Styles classifications, would mostly be considered Headwater style, even though they lacked most of the attributes River Styles normally associated with this stream type. Headwater streams have low fragility and would generally be considered low risk of geomorphic impact from pipeline crossings. Small Headwater streams would have Moderate recovery potential on the basis that, in general, they are not structurally degraded and their condition could be improved through re-establishment of a riparian vegetation corridor. The exception to this would be where Headwater streams are on hillslopes prone to gullying. There were two cases on the amended project options of small-size (Second Order) streams in headwater catchment positions that were gullied. These two cases were classified Channelised fill style with moderate fragility and were included in the River Styles assessment, even though they were classified small-size.

For previously unclassified watercourses, River Styles Fragility category was taken from Healey et al. (2012, p. 82-84). River condition was judged to be Poor for sites situated on cleared agricultural land or that had been gullied, and Moderate if native vegetation (as defined) was present or if the site was on valley fill that had not been incised.

Table 2. Definitions of geomorphic recovery potential listed in decreasing order of priority (from Cook and Schneider, 2006, Table 5; originally adapted from Outhet et al 2004). Some punctuation and minor text edits were made.

Recovery Potential	Geomorphic Condition	Recovery Potential Criteria	Actions Required
Conservation	Good	Must contain **all** of the following: • Good geomorphic condition, and • No recovery occurring or required, and • Has not been recently disturbed or has fully recovered from past disturbances.	Protect from human disturbance, provide fencing if required, establish a native vegetation maintenance program and prevent debris removal. Encourage conservation agreements where these reaches occur on private land.
Strategic	Specific locations of rapid change from good to moderate or poor, with the potential to impact both upstream and downstream	Must contain **one or more** of the following: • Specific locations of rapid change from good geomorphic condition to moderate or poor condition with the effects usually detrimentally affecting upstream and/or downstream reaches; or • A headcut or bend cutoff present or imminent; or • A site of recent bed material extraction, vegetation clearing or large woody debris removal; or • A site of accelerated bank erosion or a gully that is supplying excess sediment to downstream reaches; or • Poorly represented riparian vegetation community; or • Upstream or downstream of a poorly represented / unique / fragile stream category and has the potential to impact upon the poorly represented / unique / fragile stream category or; Small reach in moderate/poor condition separating larger upstream or downstream conservation reaches; or • Poorly represented, unique or fragile stream category.	Control the disturbance agent, e.g. headcut, extraction or further clearing, and plan control works, e.g. bed controls and revegetation programs.
Rapid recovery potential	Moderate	Must contain **all** of the following: • Moderate geomorphic condition as it has not fully recovered from past disturbances; and • Recovery presently occurring quickly due to a connection with upstream reaches in good condition (e.g. supplying seed, large woody debris and sediment if required to allow channel contraction recovery) and; • No excess sediment supply, i.e. sediment balance neutral; and • Generally degradation has stopped or has been reduced so that natural recovery is occurring at a relatively quick pace.	Stop further human induced disturbances, erect fencing, encourage revegetation with the focus of maintenance of planting and weed removal/ management.

Recovery Potential	Geomorphic Condition	Recovery Potential Criteria	Actions Required
High recovery potential	Moderate	Must contain **all** of the following: • Moderate geomorphic condition; and • Potential to recover quickly if existing pressures are removed (e.g. livestock access); or Recovery presently occurring at a moderate rate due to a lack of connection with good condition reaches upstream (e.g. supplying seed, large woody debris and sediment if required to allow channel contraction recovery); and • Excess sediment supply arriving in small slugs, e.g. inappropriate sediment distribution on bars or shallow pools; and • Will recover faster if connected to good condition upstream reaches or if recovery requirements are artificially provided in this reach; and • Generally these are reaches where a more intense level of land use is occurring or has recently ceased. They are in a relatively moderate condition with some degradation pressures still occurring and are usually downstream of a conservation or rapid recovery reach.	Ensure rehabilitation is occurring in upstream reaches, fence and revegetate and install large woody debris or bed controls in this reach and target weed management.
Moderate recovery potential	Moderate to Poor	Must contain **all** of the following: • Moderate to poor geomorphic condition; and • Potential to recover at a slow to moderate rate if existing pressures are removed (e.g. livestock access); or Recovery presently occurring at a slow rate; and • Little sediment, seed or large woody debris input (if required to allow channel contraction recovery) or; Excess sediment supply in moderate slugs; Can only recover faster if upstream reaches are rehabilitated and this reach receives rehabilitation works.	Ensure rehabilitation is occurring along upstream reaches. Plan revegetation, weed management and bed raising structures, e.g. large woody debris and bed controls.
Low recovery potential	Poor	Must contain **one or more** of the following: • Poor geomorphic condition; or • No or very little recovery occurring. Often degradation still occurring; or • Has recently changed or is on the verge of changing to a different style category; or • No sediment/seed/ large woody debris input (if required to allow channel contraction recovery) or; • Excess sediment supply large and continuous.	Ensure extensive rehabilitation has or is occurring upstream and in this reach, including bed raising structures, bank erosion control structures to reduce rates of change before vegetation can be established or large woody debris installed.

3 Existing environment

3.1 Desktop assessment of amended pipeline options

3.1.1 Location of crossings associated with the amended route options

Five pipeline routes (Figure 4), and their associated watercourse crossings (Figure 5), were assessed

- The unaltered portion of the EIS pipeline route (86 crossings),
- The Amended Northern option (12 crossings),
- The Amended Southern option (7 crossings),
- The Amended Northern-Southern route (3 crossings), and
- The unaltered portion of the EIS route that would apply only if the Southern option were to be chosen (13 crossings)

These crossings include intersections of the pipeline with all DEM auto-generated watercourses. While the hydrolines did not exactly match the position of the DEM auto-generated drainage lines, they were in reasonably close proximity.

The amended pipeline options recorded a total of 22 watercourse crossings (Figure 6, Table 3, Appendix 1 Figure 13 to Figure 17). The Northern option had 12 crossings, 4 of which were Third or higher Order. The southern option had 7 crossings, 1 of which was Third Order. The Northern-Southern route had 3 crossings, 2 of which were Third Order.

Note that the Southern option diverges northwards from the original route 5.1 km further east of where the Northern option diverges northwards (Figure 4). If the Southern option were to be chosen, this 5.1 km section of the original route would form part of the pipeline route. If the Northern Option were to be chosen, this 5.1 km section would not form part of the route. This 5.1 km section of the original route had 13 watercourse crossings that were assessed by Gippel (2019a) (having site identification numbers between 15 and 30) (Figure 6). However, of those, only two (Crossings 16 and 25) were considered high priority, with the others being on small First or Second Order watercourses.

3.1.2 Riparian vegetation characteristics of pipeline crossings

The riparian vegetation type at the pipeline crossings was overwhelmingly non native (Table 4). Note that the vegetation classification used here was based on broad-scale mapping, and field surveys could find native species present in a location classified as non native. Where trees or shrubs were present, they were sparse (Table 4), as evidenced from aerial imagery (Appendix 1 Figure 13 to Figure 17).

3.1.3 Stream Order and catchment area of watercourses at pipeline crossings

As expected, Stream Order was related to catchment area, but there was a large range of catchment areas within each Stream Order group (Figure 7). This relationship demonstrates that the method of classifying streams by Stream Order produces classes that contain a wide range of stream sizes.

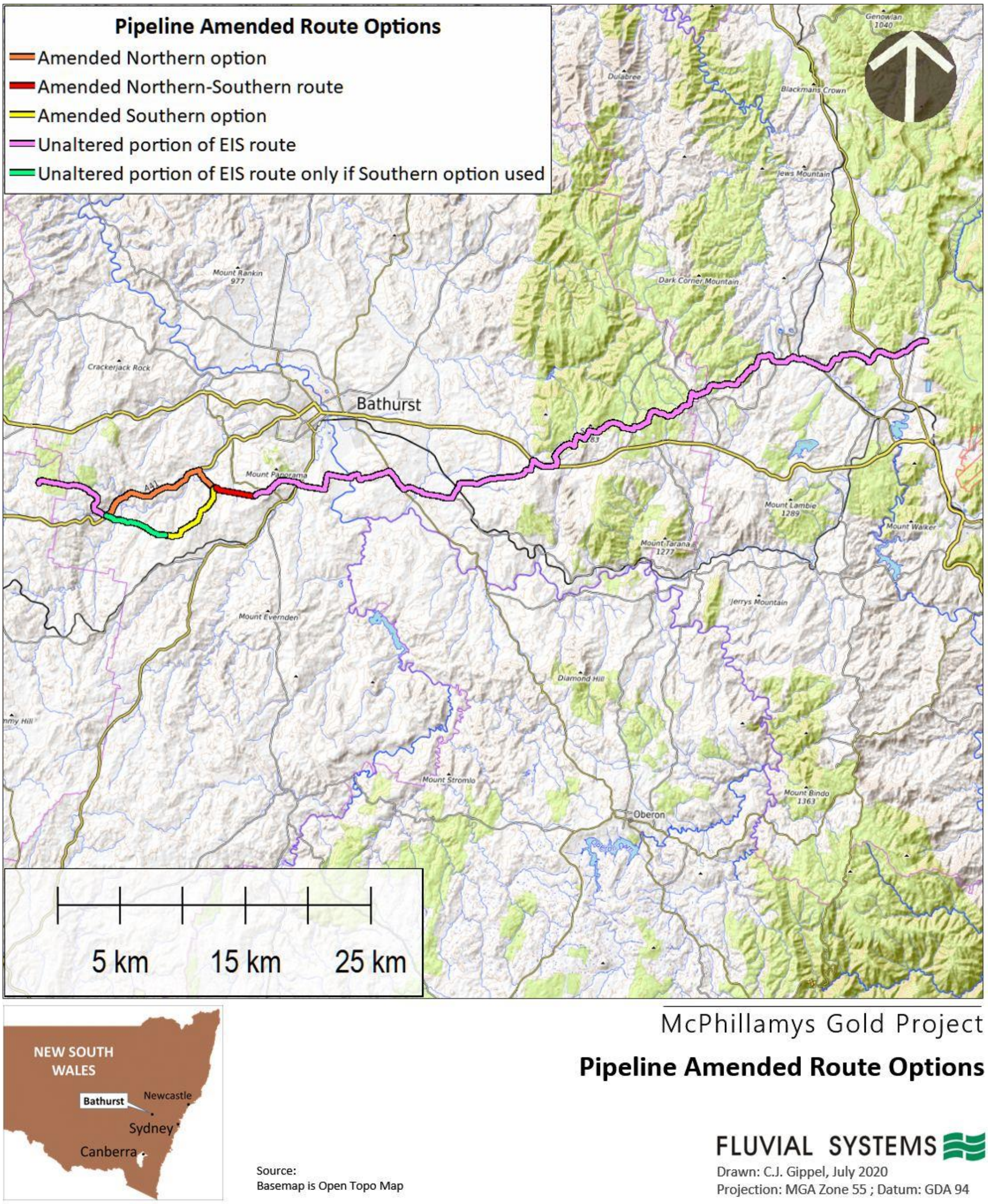

Figure 4. The five pipeline routes referred to in this report.

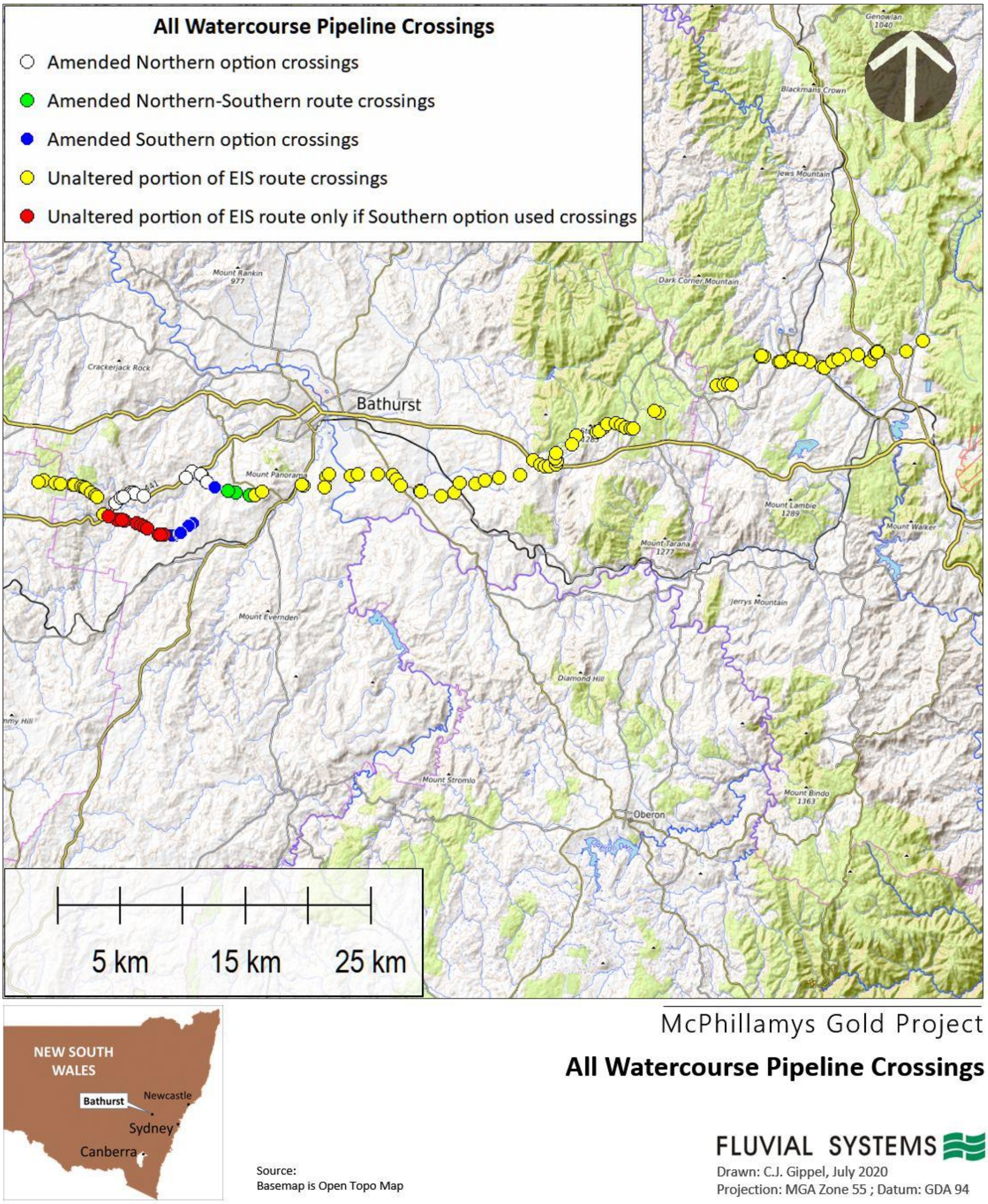

Figure 5. All intersections between the pipeline routes and auto-generated watercourses that emulated hydrolines.

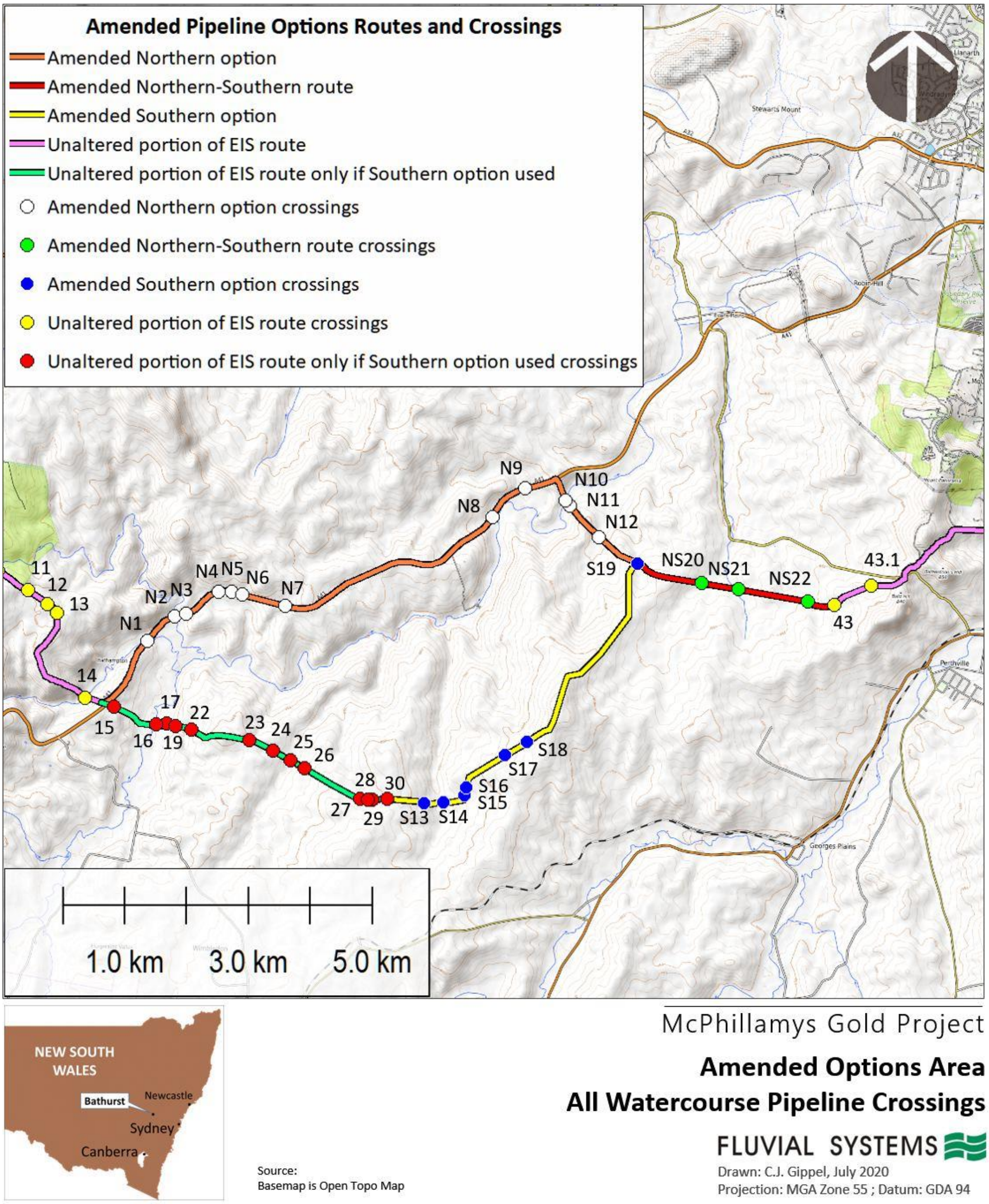

Figure 6. Detail of the amended options, showing all intersections between the pipeline routes and auto-generated watercourses that emulated hydrolines.

Table 3. Location of the points where the amended pipeline project crosses all watercourses and the name (if it exists) and the relative size of watercourses at the crossings. N = Northern option; S = Southern option; N-S = Northern-Southern route. * Crossing S19 was located on the intersection of the Northern option, Southern option and Northern-Southern route.

No.	Route	Location		Watercourse			
		Easting	Northing	Name	Stream Order	Catchment area (ha)	Size class
N1	N	723989.184	6292209.9	McLeans Ck	4	1307.0	Large
N2	N	724436.427	6292598.1	Dicks Creek	4	1614.5	Large
N3	N	724609.458	6292641.1	Unnamed	2	56.9	Small
N4	N	725143.299	6292998.6	Unnamed	1	5.3	Small
N5	N	725357.775	6292995.0	Unnamed	2	18.9	Small
N6	N	725517.977	6292953.9	Unnamed	2	15.2	Small
N7	N	726220.65	6292771.7	Unnamed	1	26.5	Small
N8	N	729562.304	6294208.5	Unnamed	2	74.7	Small
N9	N	730086.314	6294665.7	Unnamed	4	821.2	Large
N10	N	730737.819	6294479.2	Evans Plains Ck	5	20,801.6	Large
N11	N	730812.193	6294386.6	Unnamed	1	8.2	Small
N12	N	731282.336	6293881.9	Unnamed	2	210.0	Small
S13	S	728451.477	6289587.8	Unnamed	1	5.5	Small
S14	S	728764.679	6289593.2	Unnamed	3	420.8	Large
S15	S	729112.247	6289706.1	Unnamed	2	53.1	Small
S16	S	729136.926	6289829.9	Unnamed	1	4.0	Small
S17	S	729768.612	6290362.0	Unnamed	2	19.1	Small
S18	S	730119.147	6290580.0	Unnamed	1	5.0	Small
S19	S*	731907.486	6293448.5	Unnamed	2	33.3	Small
NS20	N-S	732938.475	6293136.1	Unnamed	3	433.9	Large
NS21	N-S	733530.507	6293033.6	Spring Creek	3	199.4	Large
NS22	N-S	734655.256	6292838.9	Unnamed	2	89.4	Small

Table 4. Riparian characteristics of the watercourses at the points where the amended pipeline project crosses all watercourses. N = Northern option; S = Southern option; N-S = Northern-Southern route. * Crossing S19 was located on the intersection of the Northern option, Southern option and Northern-Southern route.

No.	Route	Size class	Riparian vegetation class	Aerial imagery observations
N1	N	Large	Non Native	Roadside verge/Sparse trees
N2	N	Large	Non Native	Roadside verge/Sparse trees
N3	N	Small	Non Native	Roadside verge/Pasture
N4	N	Small	Southern Tableland Grassy Woodlands	Roadside verge/Sparse trees
N5	N	Small	Southern Tableland Grassy Woodlands	Roadside verge/Sparse trees
N6	N	Small	Southern Tableland Grassy Woodlands	Roadside verge/Sparse trees
N7	N	Small	Non Native	Roadside verge/Pasture
N8	N	Small	Non Native	Roadside verge/Pasture
N9	N	Large	Non Native	Roadside verge/Pasture
N10	N	Large	Non Native	Sparse trees
N11	N	Small	Non Native	Pasture
N12	N	Small	Non Native	Grassland/Sparse shrub
S13	S	Small	Temperate Montane Grasslands	Grassland
S14	S	Large	Temperate Montane Grasslands	Grassland/Sparse trees/4.1 m knickpoint 175 m downstream
S15	S	Small	Non Native	Pasture
S16	S	Small	Non Native	Pasture
S17	S	Small	Non Native	Pasture
S18	S	Small	Temperate Montane Grasslands	Grassland
S19	S	Small	Non Native	Pasture/localised 200 m long gully with 10 m knickpoint 240 m upstream
NS20	N-S	Large	Non Native	Sparse tree/gullied/2.5 m knickpoint 1600 m downstream on Spring Ck
NS21	N-S	Large	Non Native	Sparse tree/partly gullied/dammed/4.0 m knickpoint 300 m downstream/2.5 m knickpoint 1400 m downstream on Spring Ck
NS22	N-S	Small	Southern Tableland Grassy Woodlands	Sparse tree/gullied/6 m knickpoint 150 m downstream

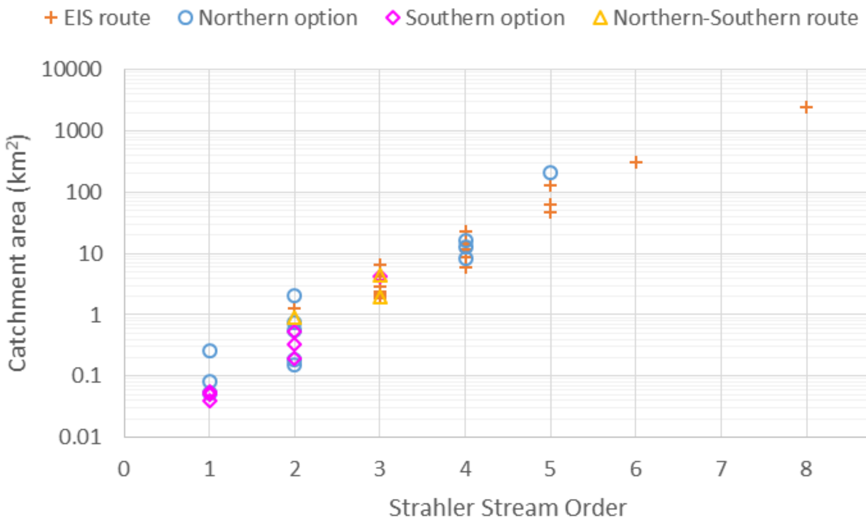

Figure 7. Relationship between Stream Order and catchment area at intersection points of the auto-generated drainage network and the pipeline crossings. Includes amended project options and crossings from the EIS route.

3.1.4 Morphology of watercourses at pipeline crossings

For each crossing, long-profiles were drawn by extracting elevation and chainage from the DEM-generated drainage line thalwegs at 1 m spacing (Appendix 2, Figure 18 to Figure 21). Knickpoints were identified by searching the thalweg for significant falls in elevation over short distances. Also, at each crossing, cross-section profiles were drawn by extracting elevation and chainage from the DEM along a transect that followed the pipeline route from west to east, regardless of watercourse orientation, at 0.5 m spacing (Appendix 3, Figure 22 to Figure 24).

The channel at Crossing 14 was about 4 m deep, but only 175 m downstream, the bed elevation dropped 4.1 m over a distance of only 50 m. This appeared to be an active gully (Figure 8).

Crossings 20, 21 and 22 were on channels that appeared to be actively gullying, as evidence by bare soil and complex convex bank edges. A 2.5 m high knickpoint was located about 1.5 km downstream of Crossings 20 and 21 on Spring Creek (Table 4, Figure 21). Crossing 22 had a 6 m high knickpoint only 150 m downstream (Table 4, Figure 21). There was no indication of active gullies at, or downstream of, other crossings, but some of the channels might have experienced incision at a previous time and then stabilised.

Figure 8. At gully 230 m downstream of Crossing S14. Photograph supplied by EMM.

Figure 9. At Crossing NS20, showing gullied morphology. Photograph supplied by EMM.

Figure 10. At 50 m upstream of Crossing NS22, just upstream of deep gully. Here, the channel is about 2 m deep. Just downstream at Crossing 22 the channel is about 5 m deep. Photograph supplied by EMM.

3.2 Desktop River Styles classification

River Styles classification was applied to the large-size crossings (Figure 11). Two Second Order watercourse crossings on the amended options (S19 and NS22) were also included, as they occurred on gullied reaches.

The watercourses at pipeline crossings covered a limited range of geomorphic stream types (Table 5). Crossings S14, S19, NS20, NS21 and NS22 were classified Channelised fill due to deep gullying. Crossing N9 was assigned moderate condition because, although the vegetation was predominately non native, the physical structure of the valley fill was intact.

Only one site on the EIS route showed evidence of a knickpoint with potential to migrate upstream to the pipeline intersection. Downstream of Site 68, the channel was incised, with three knickpoints of 0.8 – 1.5 m depth present within 1000 m downstream of the crossing.

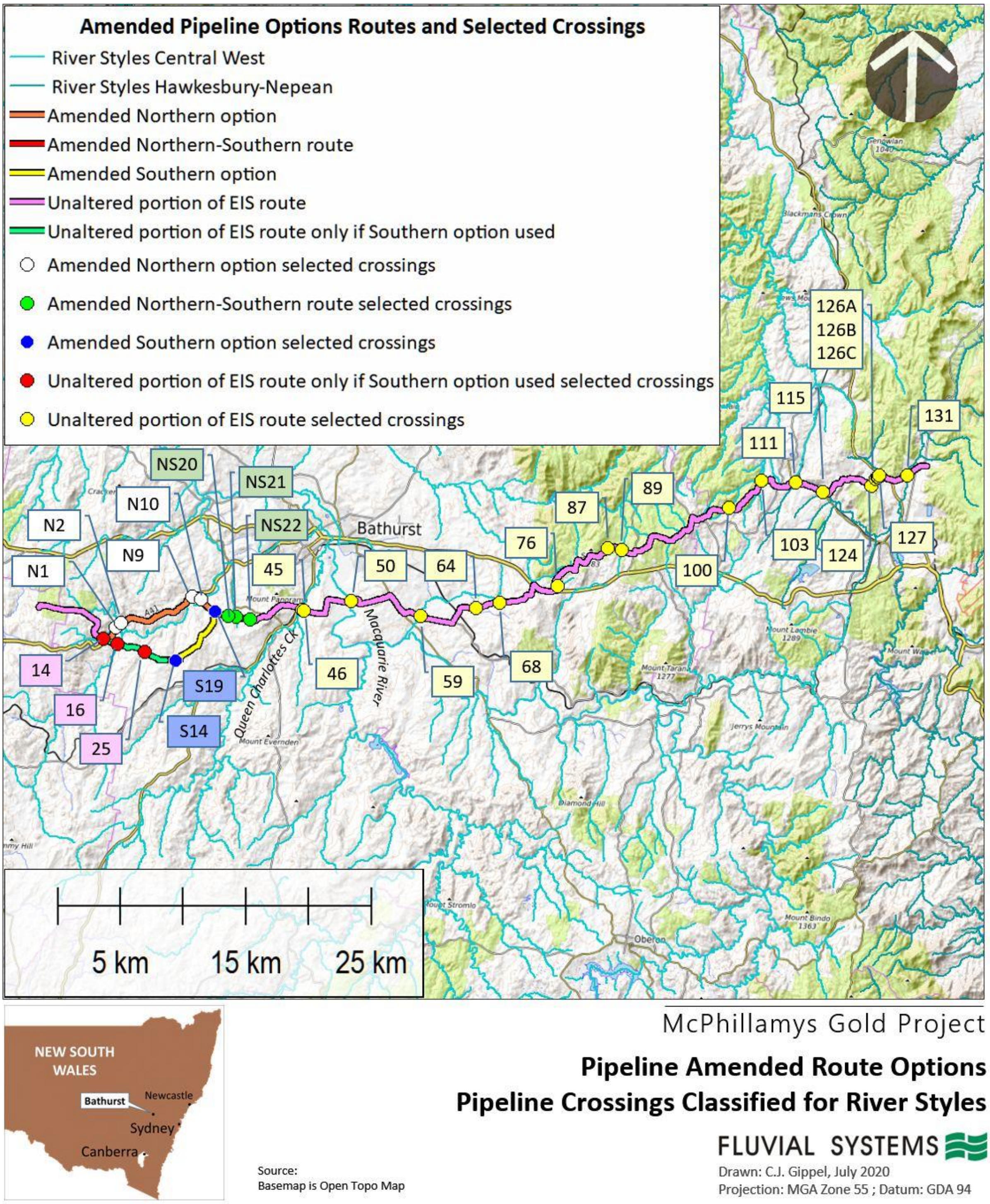

Figure 11. Pipeline crossings classified for River Styles. Watercourses are those classified for River Styles on the River Styles Spatial Layer for New South Wales.

Table 5. River Styles at amended pipeline options crossings and pipeline crossings assessed by Gippel (2019a) for the EIS pipeline route. Items in blue text are from River Styles Spatial Layer for New South Wales. N = Northern option; S = Southern option; N-S = Northern-Southern route; EIS = unchanged EIS route; EIS-S = unchanged EIS route only if Southern option is chosen. * Crossing S19 was located on the intersection of the Northern option, Southern option and Northern-Southern route. For flow, P = perennial; NP = non perennial.

No.	Route	Order	Flow	Code	River Style	Condition	Recovery potential	Fragility
N1	N	4	P	PCVS	Planform controlled, low sinuosity, sand	Moderate	Moderate	High
N2	N	4	P	PCVS	Planform controlled, low sinuosity, sand	Poor	Low	High
N9	N	4	NP	SMG	Valley fill, fine grained	Moderate	High	High
N10	N	5	P	PCVS	Planform controlled, low sinuosity, sand	Poor	Low	High
S14	S	3	NP	LUV CC	Channelised fill	Poor	Low	Moderate
S19	S	2	NP	LUV CC	Channelised fill	Poor	Low	Moderate
NS20	N-S	3	NP	LUV CC	Channelised fill	Poor	Low	Moderate
NS21	N-S	3	NP	LUV CC	Channelised fill	Poor	Low	Moderate
NS22	N-S	2	NP	LUV CC	Channelised fill	Poor	Low	Moderate
14	EIS-S	4	P	CVS	Floodplain pockets, gravel	Moderate	Low	Moderate
16	EIS-S	5	P	PCVS	Planform controlled, low sinuosity, sand	Poor	Low	High
25	EIS-S	4	NP	CVS	Headwater	Poor	Moderate	Low
45	EIS	6	P	PCVS	Planform controlled, low sinuosity, sand	Moderate	Moderate	High
46	EIS	3	NP	CVS	Headwater	Poor	Moderate	Low
50	EIS	8	P	PCVS	Bedrock controlled, gravel	Moderate	Low	Moderate
59	EIS	5	P	LUV CC	Low sinuosity, sand	Moderate	Moderate	High
64	EIS	4	NP	CVS	Headwater	Poor	Moderate	Low
68	EIS	3	NP	CVS	Headwater	Poor	Moderate	Low
76	EIS	3	NP	CVS	Headwater	Moderate	Low	Low
87	EIS	3	NP	SMG	Valley fill, fine grained	Moderate	High	High
89	EIS	3	NP	SMG	Valley fill, fine grained	Good	Conservation	High
100	EIS	3	NP	CVS	Floodplain pockets, sand	Good	Conservation	Moderate
103	EIS	4	NP	PCVS	Planform controlled, low sinuosity, sand	Good	Conservation	High
111	EIS	4	P	PCVS	Planform controlled, low sinuosity, fine grained	Moderate	Moderate	Moderate
115	EIS	4	P	LUV CC	Low sinuosity, fine grained	Poor	Low	Moderate
124	EIS	3	NP	CVS	Headwater	Moderate	Moderate	Low
126A	EIS	3	NP	CVS	Headwater	Poor	Moderate	Low
126B	EIS	3	NP	CVS	Headwater	Poor	Moderate	Low
126C	EIS	3	NP	CVS	Headwater	Poor	Moderate	Low
127	EIS	4	P	SMG	Valley fill, fine grained	Poor	Low	High
131	EIS	5	P	LUV CC	Channelised fill	Moderate	High	Moderate

4 Impacts

The amended pipeline options reduced the number of watercourse crossings compared to the route assessed in the EIS (Gippel, 2019a). Over the part of the EIS route replaced by the Northern and Southern options plus the Northern-Southern route, the EIS route had 26 crossings. In comparison, the Northern option would involve a total of 16 watercourse crossings, while the Southern option would involve a total of 23 watercourse crossings.

The main risks of geomorphic impact at pipeline crossings are associated with:

- Large size (Fifth and higher Order), because these watercourses are likely to have extensive floodplains and be expected to naturally migrate through the alluvial sediments, which would pose a risk to the pipeline.
- Perennial flow, because these watercourses are more likely to have more complex physical habitat, which is often associated with higher ecological value, that could be impacted by disturbance.
- Sand bed, because these beds are mobile in high flow events, such that the bed of the watercourse can be significantly lower than the bed level that is apparent at times of low flow. Mobile sand beds expose the pipeline to risk of damage during high flow events.
- Gullies and knickpoints downstream of the crossing, because these can migrate upstream, undercutting and damaging the pipeline.
- Rock outcrops, because disturbance by trenching could lead to loss of baseflow from the watercourse.
- Conservation recovery potential (in River Styles classification), because ideally these would be protected from all human disturbance (Table 2).
- High fragility (in River Styles classification), because these styles are susceptible to changing to a different style when disturbed.

These presence/absence of these risks were assessed for each of the crossings that were classified using River Styles (Table 6).

Trenched crossings present a low risk of geomorphic impact on most watercourses during the operational phase, provided the pipeline is buried a sufficient depth from the consolidated bed, and distance from the banks, of the watercourses, the backfill is composed of the same material that was excavated (replaced in layers, as appropriate), the backfill is compacted, and effective restoration of the disturbed area is undertaken. Disturbance of the bank soil during and just after construction could expose the channel to enhanced risk of erosion if a significant storm runoff event occurred before vegetation had time to establish good coverage. This impact would be more likely at sites with steep bed and banks, and can be avoided by fortifying the banks with gabions or rip-rap.

Pipeline crossings constructed using directional drilling (underboring), with effective restoration of the disturbed area, present a negligible risk of geomorphic impact during the operational phase. This approach is most suited to the largest watercourse crossings, namely the Macquarie River (Crossing 50) and Queen Charlottes Creek (Crossing 45) (Figure 11, Table 6).

There are crossings at large watercourses other than Macquarie River (Crossing 50) and Queen Charlottes Creek (Crossing 45) with multiple geomorphic risks for which underboring might be considered. Examples are Evans Plains Creek (Crossing N10 or 16) and Salt Water Creek (Crossing 59). Under River Styles, Crossings 89, 100 and 103 are assigned the highest level of management protection. It would be prudent to undertake further geotechnical assessment of these crossings with multiple geomorphic risks to assist with selection of the most appropriate construction method or mitigation measures.

Table 6. Presence/absence of geomorphic risks to amended pipeline options crossings and pipeline crossings assessed by Gippel (2019a) for the EIS pipeline route. N = Northern option; S = Southern option; N-S = Northern-Southern route; EIS = unchanged EIS route; EIS-S = unchanged EIS route only if Southern option is chosen. * Crossing S19 was located on the intersection of the Northern option, Southern option and Northern-Southern route.

No.	Route	Stream Order ≥5	Perennial flow	Sand bed	Bedrock outcrops	Gullies/ knickpoints	Conservation recovery potential	High fragility
N1	N		✓					✓
N2	N		✓					✓
N9	N							✓
N10	N	✓	✓	✓				✓
S14	S			✓		✓		
S19	S					✓		
NS20	N-S					✓		
NS21	N-S					✓		
NS22	N-S					✓		
14	EIS-S		✓					
16	EIS-S	✓	✓	✓				✓
25	EIS-S				✓			
45	EIS	✓	✓	✓				✓
46	EIS							
50	EIS	✓	✓	✓				
59	EIS	✓	✓	✓				✓
64	EIS							
68	EIS					✓		
76	EIS							
87	EIS							✓
89	EIS						✓	✓
100	EIS						✓	
103	EIS						✓	✓
111	EIS		✓					
115	EIS		✓		✓			
124	EIS							
126A	EIS							
126B	EIS							
126C	EIS							
127	EIS		✓					✓
131	EIS	✓	✓					

Some incised channels with deep valley walls might have sufficiently steep banks that a surface crossing above the channel might be considered as a lower impact alternative to trenching. This would present negligible risk of geomorphic impact during the operational phase. This should be interpreted as information to assist design and construction, not a recommendation to use surface crossings.

Potential geomorphic impacts during the construction phase would primarily relate to occurrence of a significant storm runoff event when a trench was exposed, and/or ground surrounding the site was disturbed from the action of machinery. When soils and sediments are exposed, there is a risk of suspended sediment entering the streams at an accelerated rate at any time that the streams are flowing, especially when It is raining.

5 Mitigation and Monitoring

The risk of geomorphic impacts can be mitigated by following NSW Office of Water (2012a) *Guidelines for laying pipes and cables in watercourses on waterfront land* for design, construction and operation phases. Also, Witheridge (2017) provided a comprehensive set of recommendations for mitigation measures, and standard techniques of erosion and sediment control outlined in International Erosion Control Association (IECA) Australasia (2008) *Best Practice Erosion & Sediment Control* should be followed during construction. If trenching is employed at sites with sand beds, the base of the sand bed should be regarded as the top of the trench.

At sites with sand beds (Crossings N10, S14, 16, 45, 50 and 59) the pipeline construction trench depth will be below the base of the sand bed. The depth of sand will be comprehensively surveyed as part of the geotechnical assessment to be undertaken during the detailed design stage.

Crossings 25 and 115 have exposed bedrock present. Bedrock confers geomorphic stability and its disturbance would pose a risk of bed instability. Additionally, Crossing 115 (Pipers Creek) is at a perennial watercourse where disturbance of bedrock could pose a risk of loss of surface flow. These sites will be comprehensively surveyed as part of the geotechnical assessment to be undertaken during the detailed design stage to determine the best approach to construction.

The risk of an upwards migrating knickpoint impacting the crossing at Crossing 68 (EIS route) and Crossings S14, S19, NS20, NS21 and NS22 can be mitigated by monitoring the position of the downstream knickpoints, stabilising the knickpoints using structural works, or re-locating the crossing further upstream.

Monitoring of geomorphic aspects of the pipeline watercourse crossings should focus on significant storm runoff events, as impacts are only likely under conditions of heavy rainfall and fast flowing deep water in the channel. An inspection should be undertaken of a random sample of 6 crossings on First Order streams and 4 on Second Order streams, and all Third and higher Order streams, as soon as possible following a 20% annual exceedance probability regional storm event. If an issue of concern is observed at any of the sampled First or Second Order streams, all other crossings of small streams should be inspected. Otherwise, inspection of watercourse crossings should be incorporated in the routine pipeline inspection and maintenance procedures developed for the operational phase.

6 References

Brierley, G.J. and Fryirs, K.A., Cook, N., Outhet, D., Raine, A., Parsons, L. and Healey, M. 2011. Geomorphology in action: Linking policy with on-the-ground actions through applications of the River Styles framework. *Applied Geography* **31**: 1132-1143.

Canadian Association of Petroleum Producers (CAPP) Canadian Energy Pipeline Association (CEPA) and Canadian Gas Association (CGA) 2005. Pipeline Associated Watercourse Crossings, 3rd Edition. Prepared by TERA Environmental Consultants and Salmo Consulting Inc. Calgary, A.B. URL: http://asapgas.agdc.us/pdfs/documents/eed2015/Attachment%209%20-%20Pipeline%20Stream%20Crossing%20Construction%20Mode%20Determination.pdf (accessed 29 Jan 2019).

Cook, N. and Schneider, G. 2006. River Styles® in the Hunter catchment. NSW Government, Department of Natural Resources.

EMM 2019. McPhillamys Gold Project, Environmental Impact Statement. EMM Consulting Pty Limited, LFB Resources NL, August.

EMM 2020a McPhillamys Gold Project, Amendment Report. EMM Consulting Pty Limited, LFB Resources NL.

EMM 2020b McPhillamys Gold Project, Submissions Report. EMM Consulting Pty Limited, LFB Resources NL.

Ferguson, C., White, K., Harding, M. and Hardie, R. 2016. Landscape-scale assessment of watercourses in remote arid South Australia to inform mine planning to mine closure. In Proceedings Life-of-Mine 2016 Conference, The Australasian Institute of Mining and Metallurgy, Melbourne, pp. 200–204.

Gippel, C.J. 2019a. McPhillamys Gold Project, Environmental Impact Statement, Fluvial Geomorphology. Fluvial Systems Pty Ltd, Stockton. Regis Resources Ltd, March.

Gippel, C.J. 2019b. Maxwell Project, Environmental Impact Statement, Technical Study Report, Geomorphology Assessment. Fluvial Systems Pty Ltd, Stockton, Malabar Coal Limited, Sydney, June. URL: https://www.planningportal.nsw.gov.au/major-projects/project/10151 (accessed 28/07/2020).

Gordon, N.D., McMahon, T.A., Finlayson, B.L., Gippel, C.J. and Nathan, R.J. 2004. *Stream Hydrology: An Introduction for Ecologists*. Second Edition, John Wiley & Sons, Chichester.

Healey, M., Raine, A., Parsons, L., and Cook, N. 2012. River Condition Index in New South Wales: Method development and application. NSW Office of Water, Sydney. URL: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0018/151173/River-Condition-Index-in-NSW.pdf (accessed 10/07/2020).

International Erosion Control Association (IECA) Australasia 2008. Best Practice Erosion and Sediment Control. Picton, NSW. URL: https://www.austieca.com.au/publications/best-practice-erosion-and-sediment-control-bpesc-document (accessed 29 Jan 2019).

Jenson, S.K. and Domingue, J.O. 1988. Extracting topographic structure from digital elevation model data for geographic information system analysis, Photogramm. Eng. Rem. S. 54(11): 1593–1600.

NSW Government 2016a. Environmental Planning and Assessment Regulation 2000, made under the Environmental Planning and Assessment Act 1979, as at 5 August 20161. Reg 557 of 2000. URL: http://www.austlii.edu.au/au/legis/nsw/consol_reg/epaar2000480/index.html#sch3 (accessed 29 Jan 2019).

NSW Government 2016b. Water Management Act 2000, as at 8 July 2016. Act 92 of 2000. URL: http://www.austlii.edu.au/au/legis/nsw/consol_act/wma2000166/ (accessed 29 Jan 2019).

NSW Office of Water 2012a. Controlled activities on waterfront land – Guidelines for laying pipes and cables in watercourses on waterfront land. State of New South Wales through the Department of Trade and Investment, Regional Infrastructure and Services. URL: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0019/160462/licensing_approvals_controlled_activities_laying_pipes_cables.pdf (accessed 29 Jan 2019).

NSW Office of Water 2012b. River Styles Spatial Layer for New South Wales. Bioregional Assessment Source Dataset. URL: http://data.bioregionalassessments.gov.au/dataset/06fb694b-d2f1-4338-ab65-a707c02f11d7 (accessed 10/07/2020).

Outhet, D. and Cook, N. 2004. Definitions of geomorphic condition categories for streams. Unpublished internal draft paper for use throughout NSW by the Department of Infrastructure, Planning and Natural Resources.

Outhet, D., Schneider, G. and Cook, N. 2004. Definitions of Stream Geomorphic Recovery Potential / Priority Categories. Unpublished internal draft paper for use throughout NSW by the Department of Infrastructure, Planning and Natural Resources.

Outhet, D. and Young, C. 2004a. Using reference reaches to suggest causes of poor river geomorphic condition. In Rutherfurd, I. (ed.), Proceedings 4th Australian Stream Management Conference, Launceston, Tasmania, 20-22 Oct., pp. 470-476.

Outhet, D. and Young, C. 2004b. River Style Geomorphic Fragility. Unpublished internal draft paper for use throughout NSW by the Department of Infrastructure, Planning and Natural Resources.

Witheridge, G. 2017. Erosion and Sediment Control Field Guide for Pipeline Projects – Part 2. Catchments and Creeks Pty Ltd., Brisbane, Queensland. URL: https://www.catchmentsandcreeks.com.au/docs/ESC-Field-Guide-for-Pipelines-Part-2-print.pdf (accessed 29 Jan 2019).

7 Appendix 1. Aerial imagery at crossings

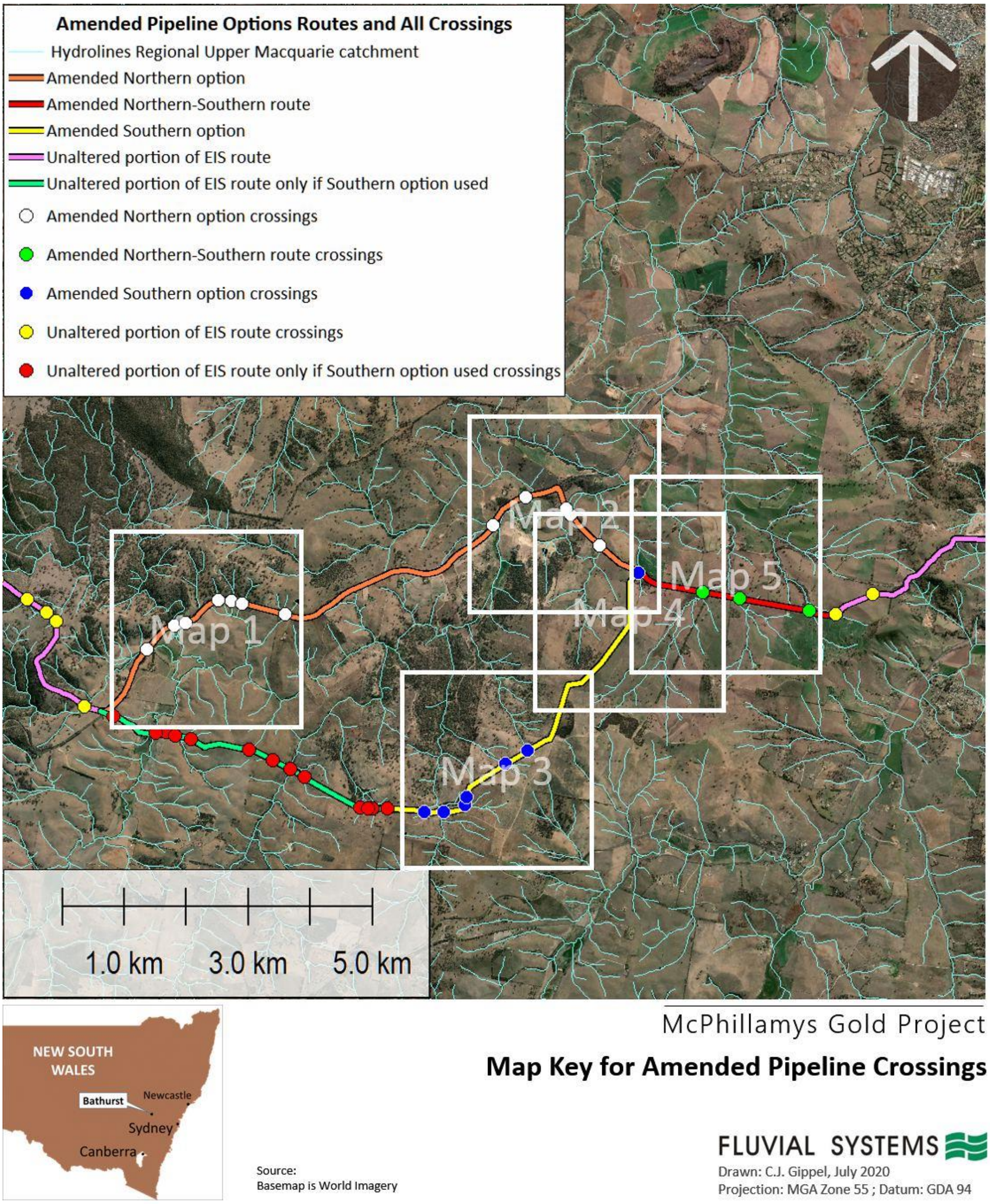

Figure 12. Key map for detailed maps of location and aerial imagery of crossings on amended pipeline options.

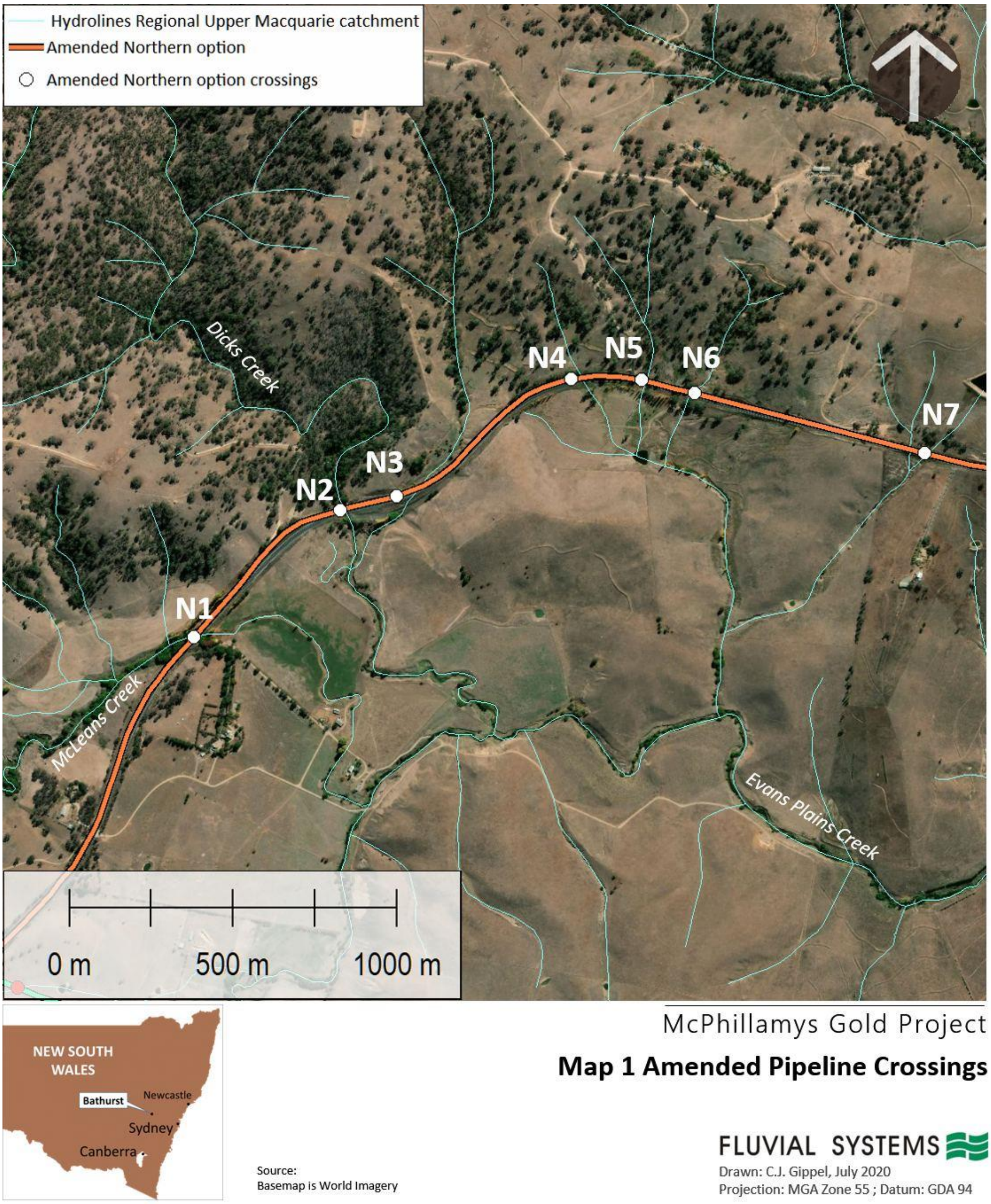

Figure 13. Detailed Map 1 of location and aerial imagery of crossings on amended Northern pipeline options. N3 is offset from the hydroline because its position was determined by intersection with the auto-generated drainage line

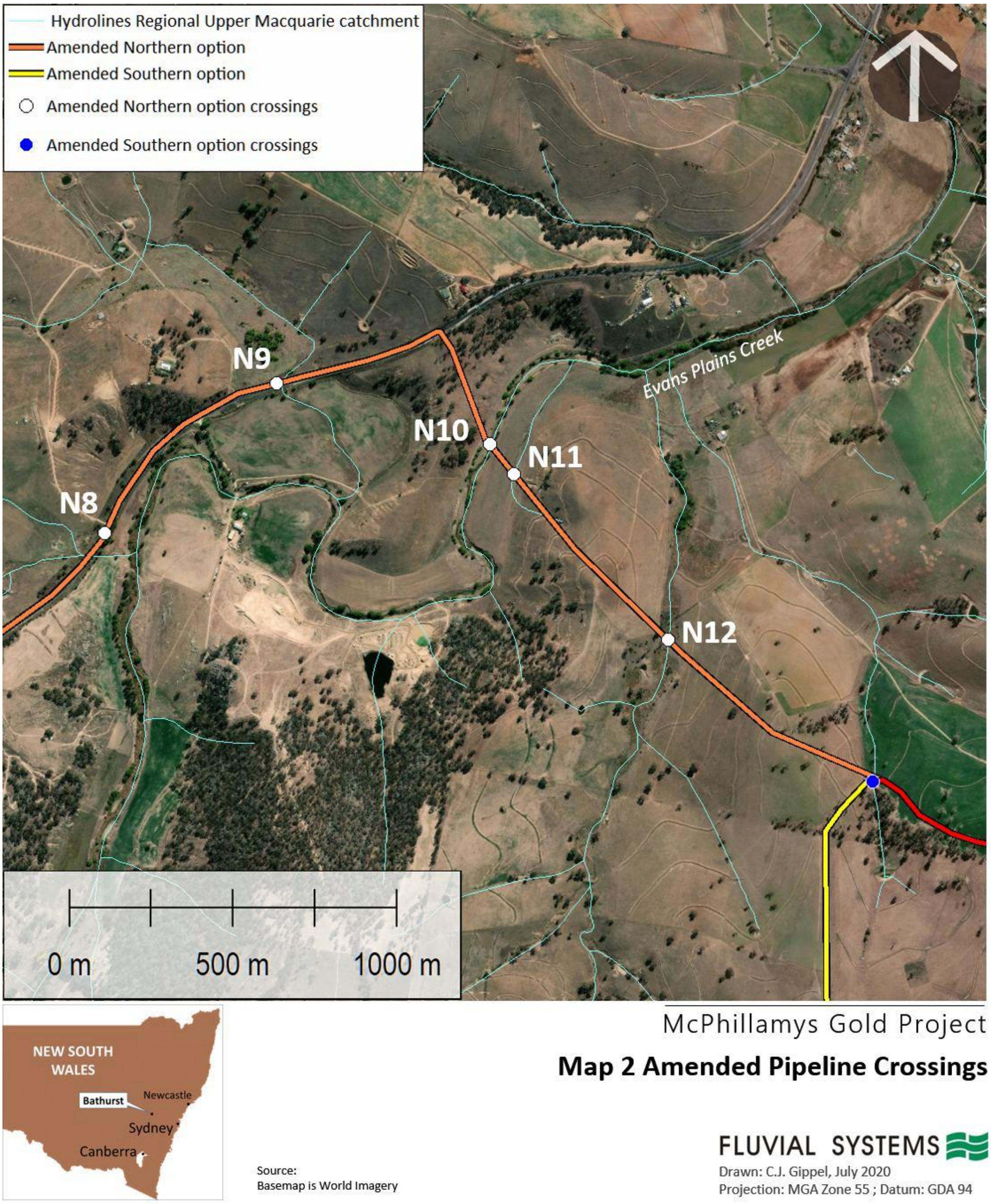

Figure 14. Detailed Map 2 of location and aerial imagery of crossings on amended Northern pipeline options. N8 is offset from the hydroline because its position was determined by intersection with the auto-generated drainage line

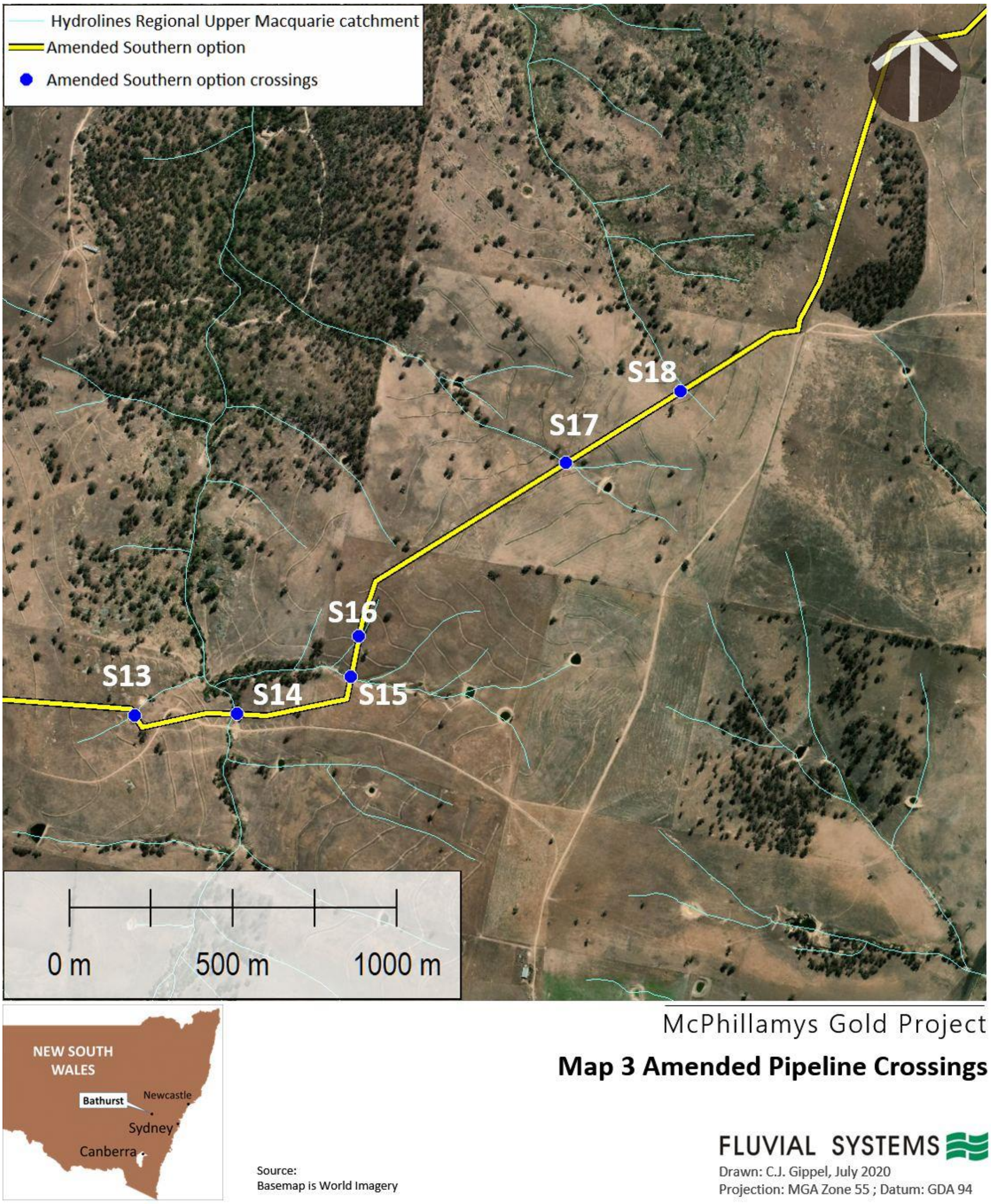

Figure 15. Detailed Map 3 of location and aerial imagery of crossings on amended Southern pipeline options.

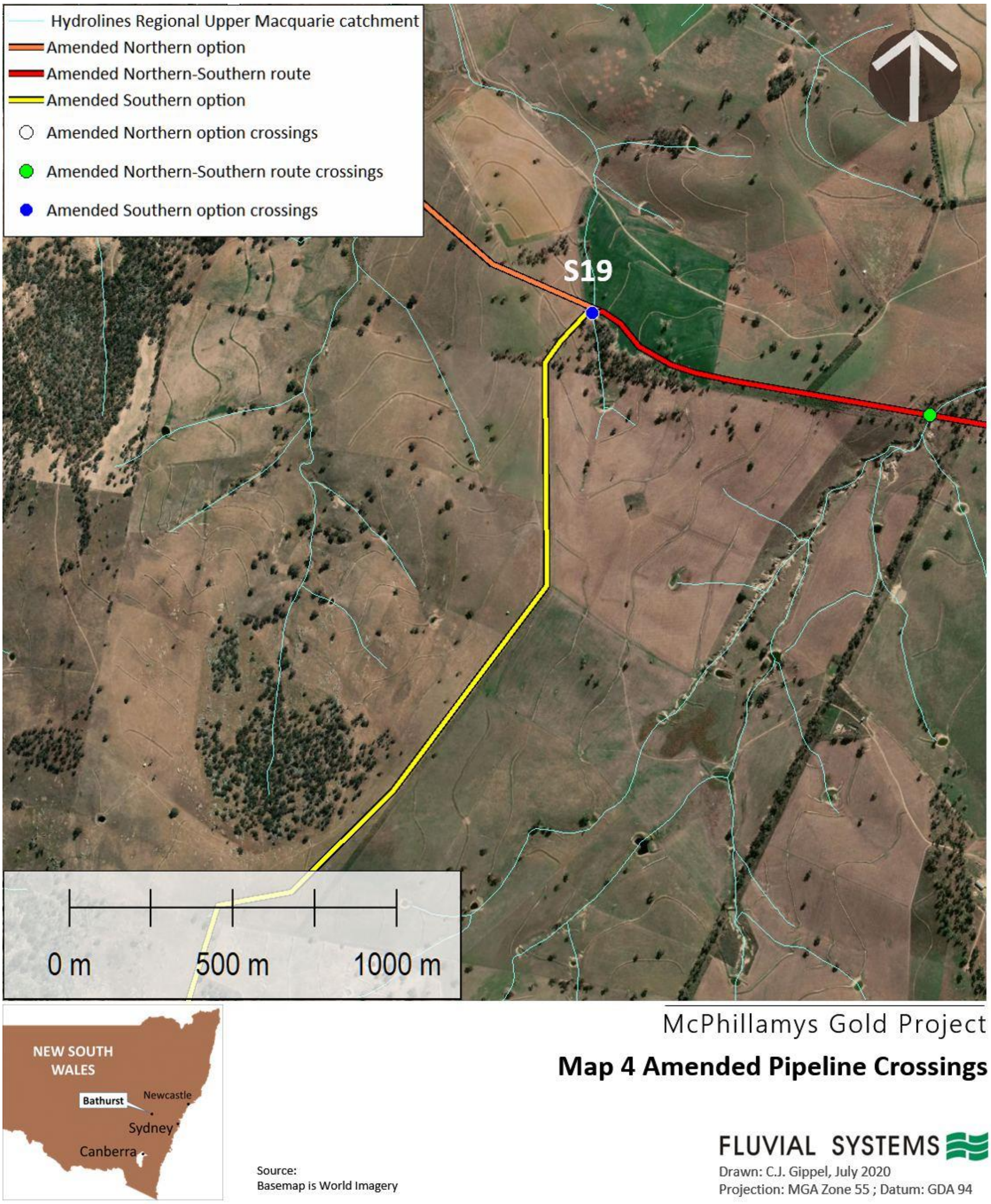

Figure 16. Detailed Map 4 of location and aerial imagery of crossings on amended Southern pipeline options.

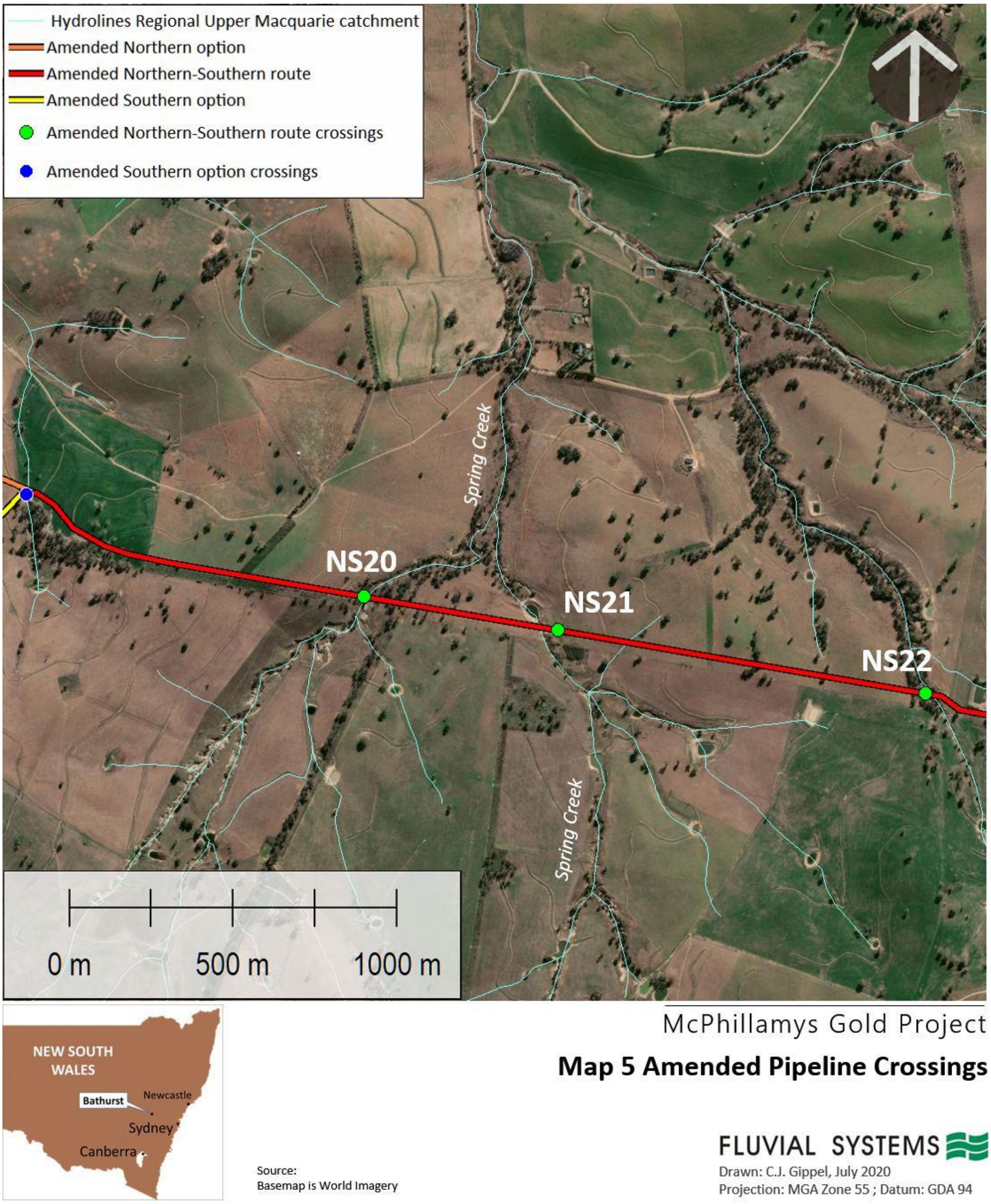

Figure 17. Detailed Map 5 of location and aerial imagery of crossings on amended Northern-Southern pipeline route. NS21 is offset from the hydroline because its position was determined by intersection with the auto-generated drainage line.

8 Appendix 2. Watercourse long profiles through pipeline crossings

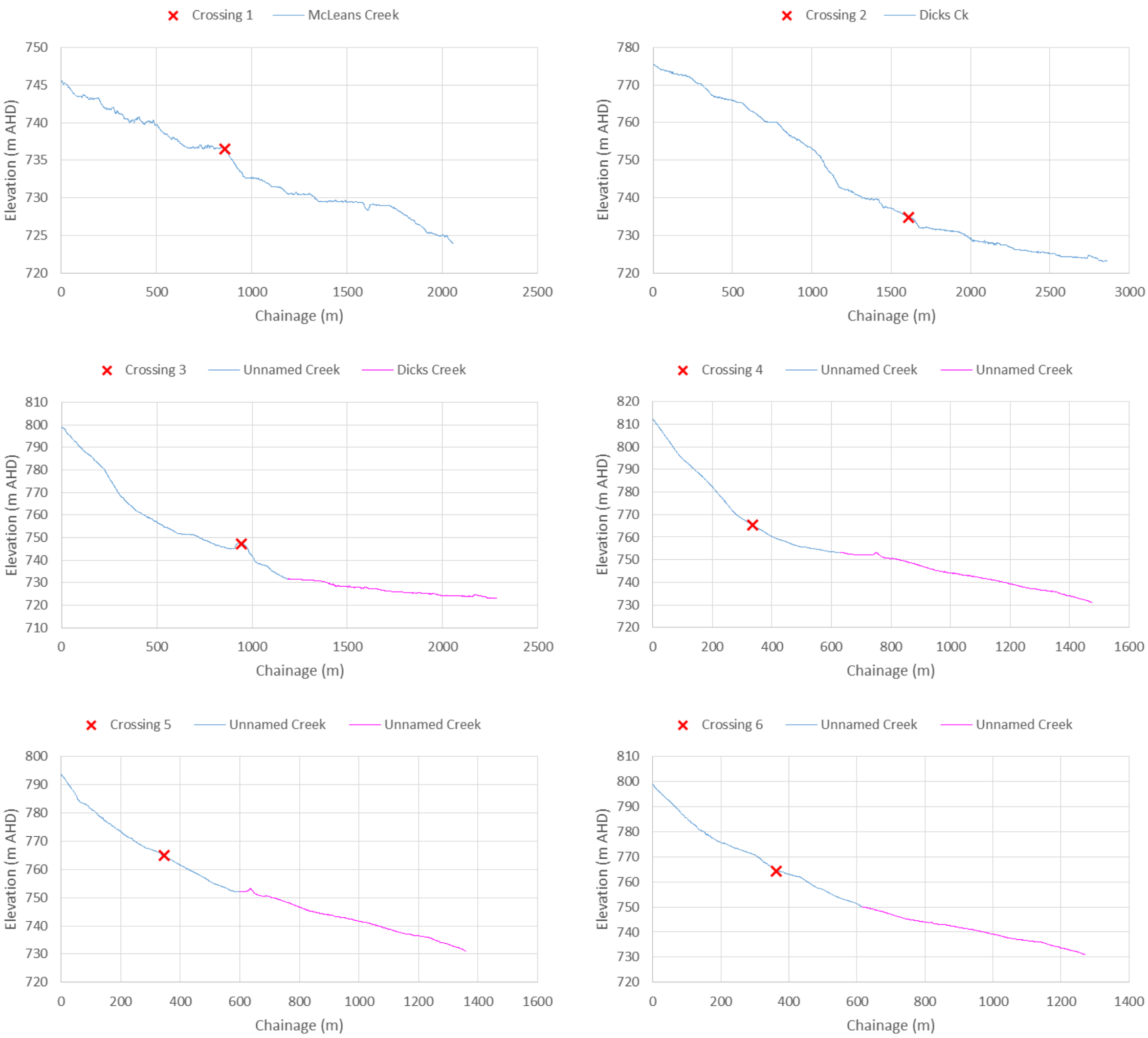

Figure 18. Long profiles of stream thalweg through crossings 1 to 6 on Northern option.

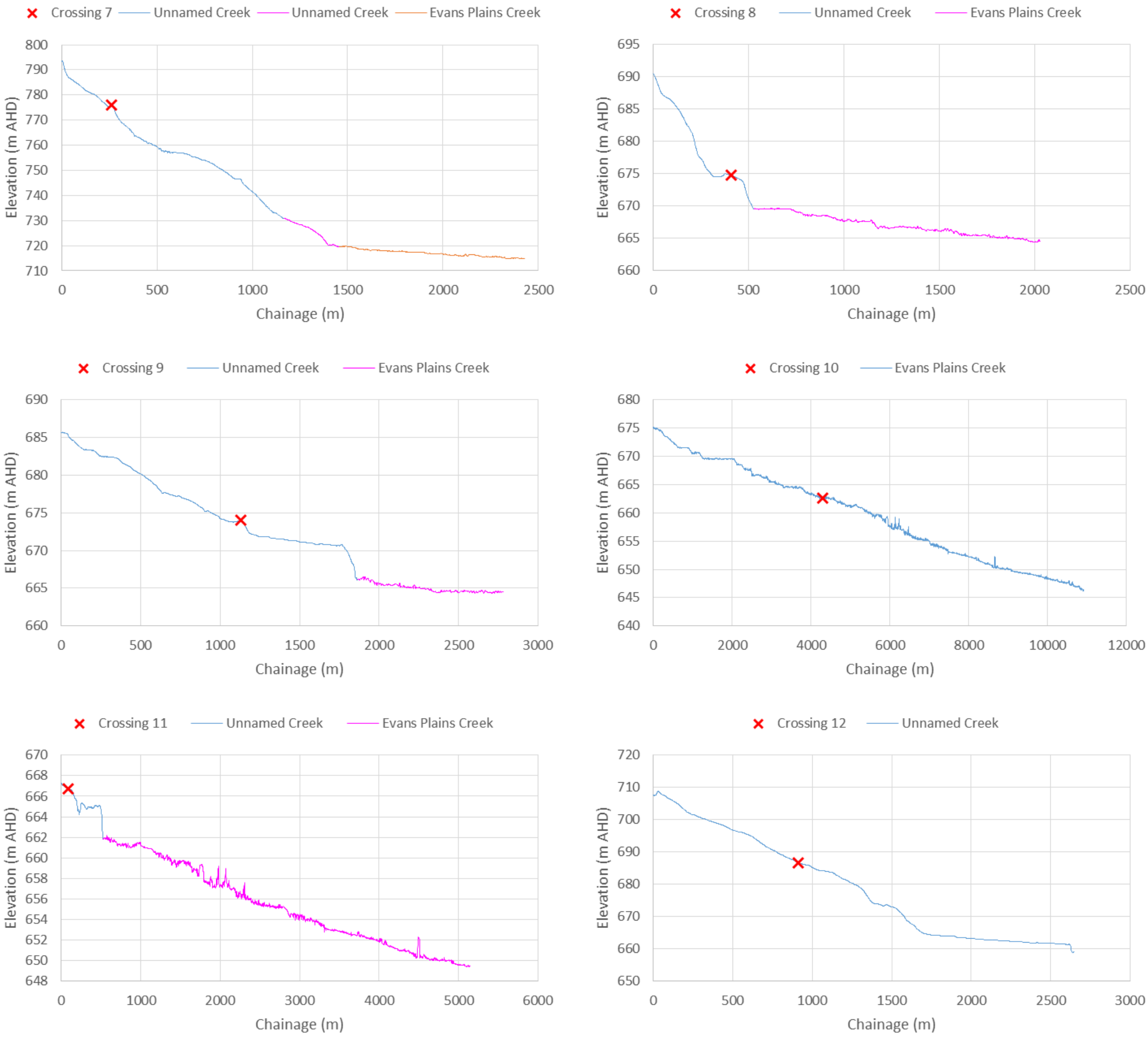

Figure 19. Long profiles of stream thalweg through crossings 7 to 12 on Northern option.

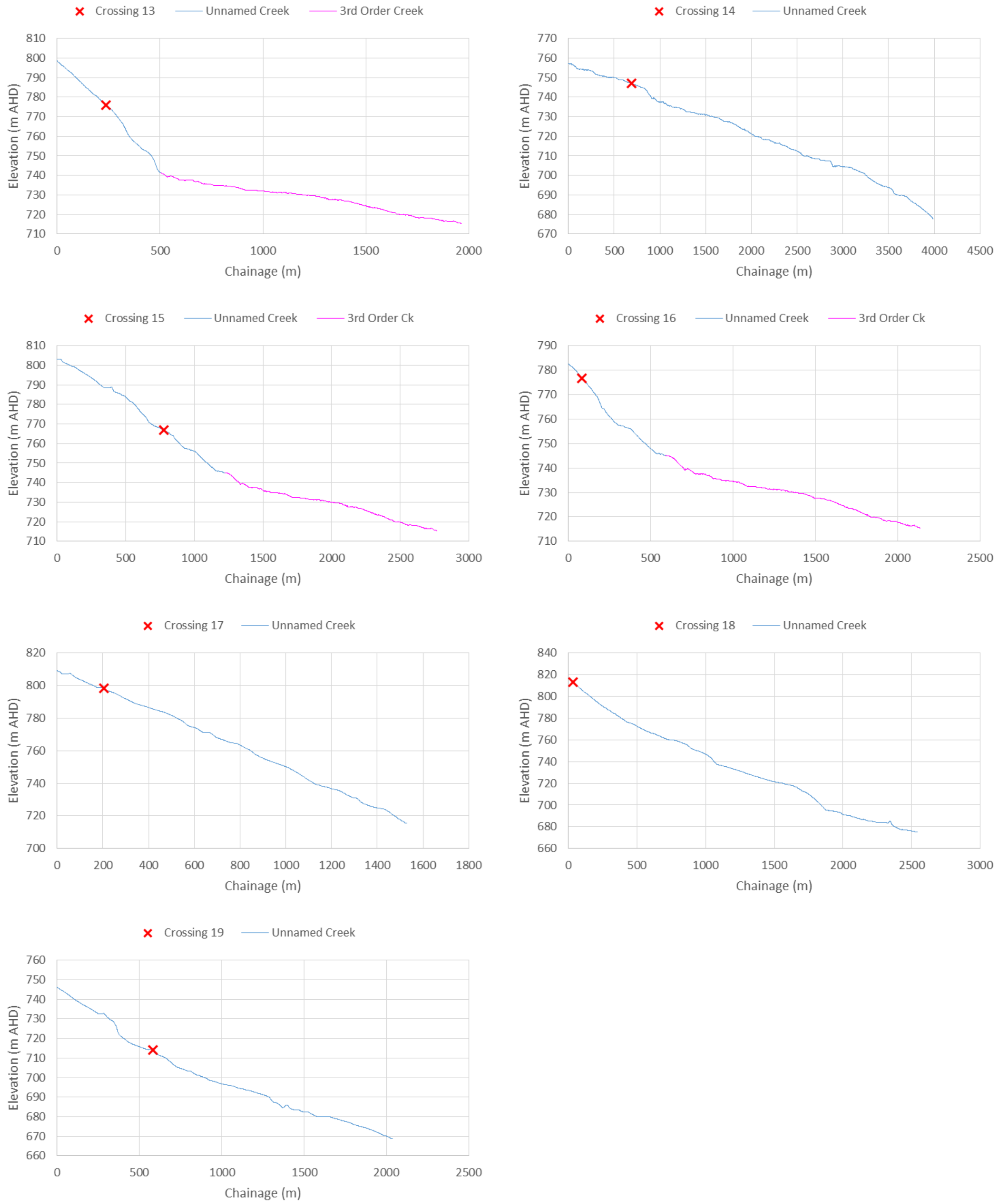

Figure 20. Long profiles of stream thalweg through crossings 13 to 19 on Southern option.

Figure 21. Long profiles of stream thalweg through crossings 20 to 22 on Northern-Southern route.

9 Appendix 3. Watercourse cross-sections along the pipeline through pipeline crossings

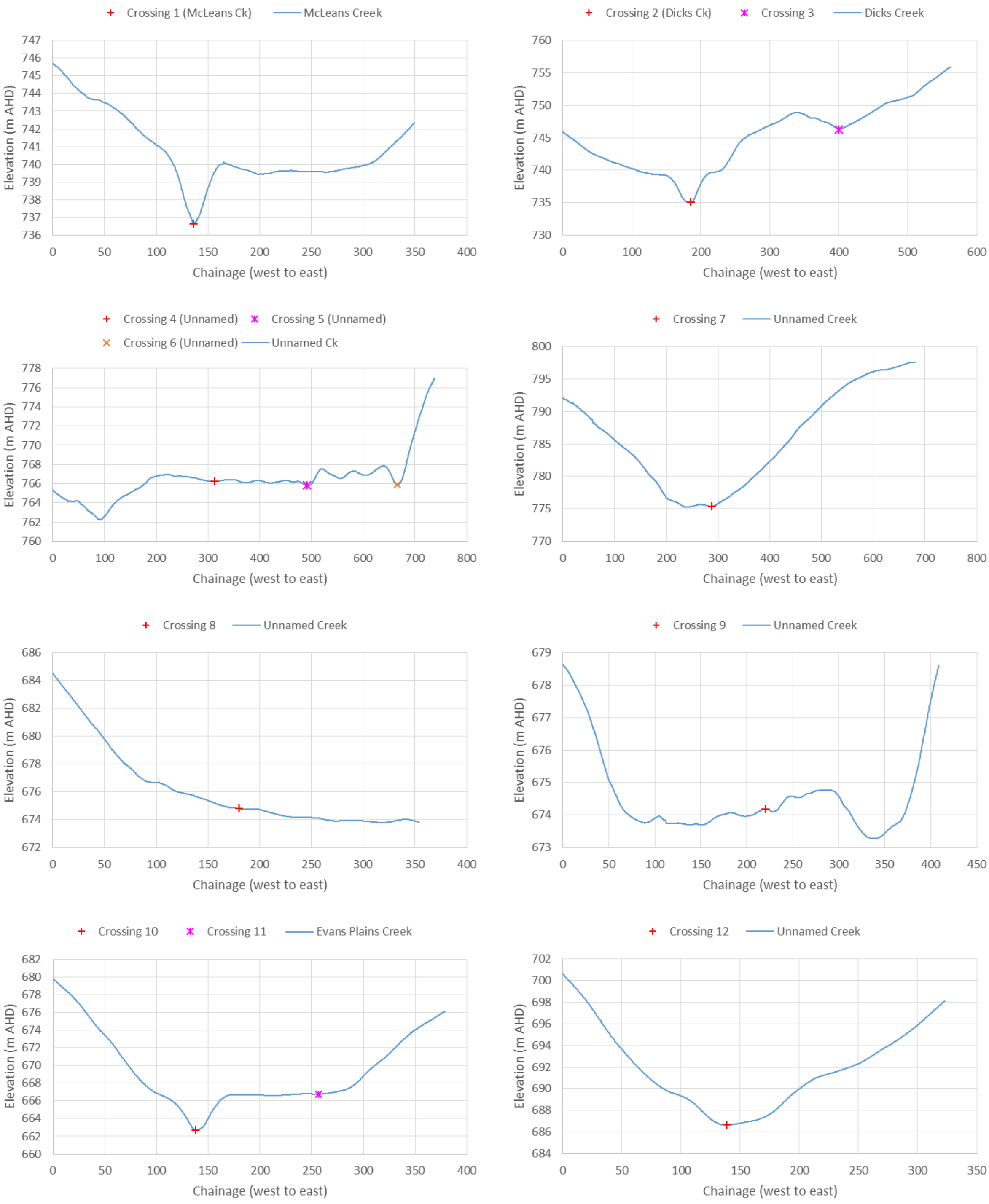

Figure 22. Cross-section profiles along the pipeline through pipeline crossings 1 to 12 on Northern option.

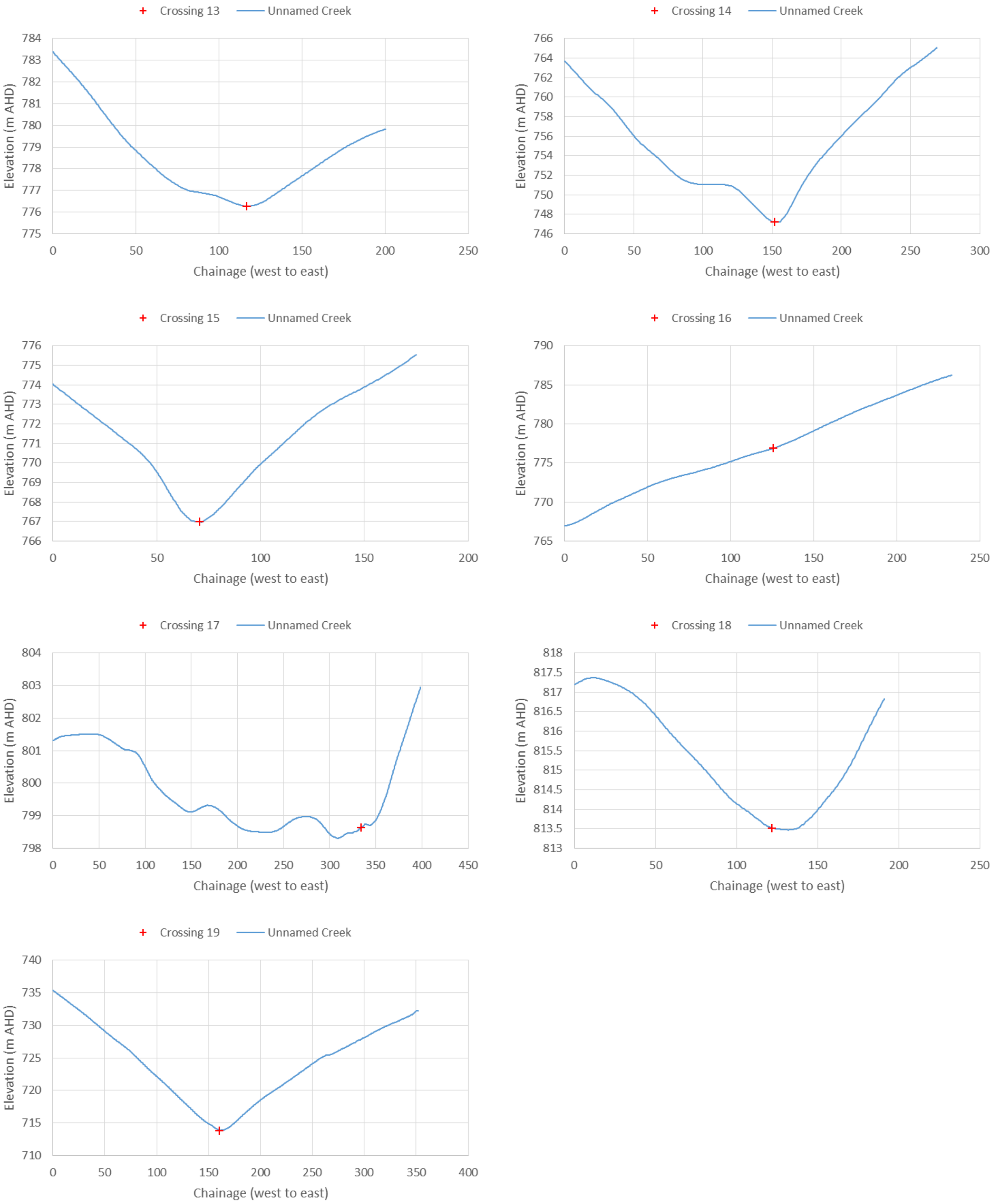

Figure 23. Cross-section profiles along the pipeline through pipeline crossings 13 to 19 on Southern option.

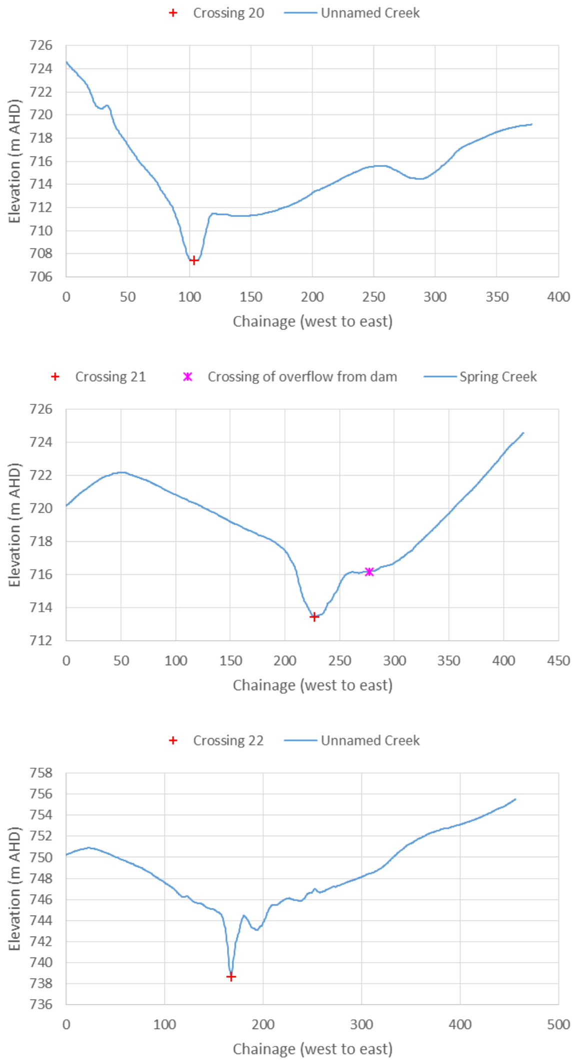

Figure 24. Cross-section profiles along the pipeline through pipeline crossings 20 to 22 on Northern-Southern route.