Assessment of surface water storage options in the Victoria and Southern Gulf catchments

A technical report from the CSIRO Victoria River and Southern Gulf Water Resource Assessments for the National Water Grid

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Important disclaimer

CSIRO Victoria and Southern Gulf Water Resource Assessments acknowledgements

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Aspects of the Assessments have been undertaken in conjunction with the Northern Territory and Queensland governments.

The Assessments were guided by three committees:

i. The Governance Committee: CRC for Northern Australia/James Cook University; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Agriculture and Fisheries; Queensland Department of Regional Development, Manufacturing and Water

ii. The joint Roper and Victoria River catchments Steering Committee: Amateur Fishermen's Association of the NT; Austrade; Centrefarm; CSIRO; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Land Council; NT Cattlemen's Association; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; NT Farmers; NT Seafood Council; Office of Northern Australia; Parks Australia; Regional Development Australia; Roper Gulf Regional Council Shire; Watertrust

iii. The Southern Gulf catchments Steering Committee: Amateur Fishermen's Association of the NT; Austral Fisheries; Burketown Shire; Carpentaria Land Council Aboriginal Corporation; Health and Wellbeing Queensland; National Water Grid (Department of Climate Change, Energy, the Environment and Water); Northern Prawn Fisheries; Queensland Department of Agriculture and Fisheries; NT Department of Environment, Parks and Water Security; NT Department of Industry, Tourism and Trade; Office of Northern Australia; Queensland Department of Regional Development, Manufacturing and Water; Southern Gulf NRM

Responsibility for the Assessments' content lies with CSIRO. The Assessments' committees did not have an opportunity to review the Assessments' results or outputs prior to their release.

This report was reviewed by Kevin Devlin.

Photo

Julius Dam on the Leichhardt River. Source: CSIRO

Director’s foreword

Sustainable development and regional economic prosperity are priorities for the Australian, Queensland and Northern Territory (NT) governments. However, more comprehensive information on land and water resources across northern Australia is required to complement local information held by Indigenous Peoples and other landholders.

Knowledge of the scale, nature, location and distribution of likely environmental, social, cultural and economic opportunities and the risks of any proposed developments is critical to sustainable development. Especially where resource use is contested, this knowledge informs the consultation and planning that underpin the resource security required to unlock investment, while at the same time protecting the environment and cultural values.

In 2021, the Australian Government commissioned CSIRO to complete the Victoria River Water Resource Assessment and the Southern Gulf Water Resource Assessment. In response, CSIRO accessed expertise and collaborations from across Australia to generate data and provide insight to support consideration of the use of land and water resources in the Victoria and Southern Gulf catchments. The Assessments focus mainly on the potential for agricultural development, and the opportunities and constraints that development could experience. They also consider climate change impacts and a range of future development pathways without being prescriptive of what they might be. The detailed information provided on land and water resources, their potential uses and the consequences of those uses are carefully designed to be relevant to a wide range of regional-scale planning considerations by Indigenous Peoples, landholders, citizens, investors, local government, and the Australian, Queensland and NT governments. By fostering shared understanding of the opportunities and the risks among this wide array of stakeholders and decision makers, better informed conversations about future options will be possible.

Importantly, the Assessments do not recommend one development over another, nor assume any particular development pathway, nor even assume that water resource development will occur. They provide a range of possibilities and the information required to interpret them (including risks that may attend any opportunities), consistent with regional values and aspirations.

All data and reports produced by the Assessments will be publicly available.

Chris Chilcott

Project Director

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Note: Assessment team as at September, 2024. All contributors are affiliated with CSIRO unless indicated otherwise. Activity Leaders are underlined. For the Indigenous water values, rights, interests and development goals activity (Victoria catchment), Marcus Barber was Activity Leader for the project duration except August 2022 – July 2023 when Kirsty Wissing (a CSIRO employee at the time) undertook this role.

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Shortened forms

SHORT FORM	FULL FORM
AEP	annual exceedance probability
AHD	Australian Height Datum
ALOS	Advanced Land Observing Satellite
AMTD	adopted middle thread distance
ANCOLD	Australian National Committee on Large Dams
APSIM	Agricultural Production Systems sIMulator
AWRA-L	Australian Water Resources Assessment landscape model
AWRA-R	Australian Water Resources Assessment river system model
AWRC	Australian Water Resources Council
BHA	behaviour analysis
CC	conventional concrete
DEM	digital elevation model
DEM-H	national 1 second hydrological digital elevation model
DKIS	Darwin–Katherine Interconnected System
DIWA	Directory of Important Wetlands in Australia
EGM96	Earth Gravitational Model 1996 geoid, which is the datum upon which SRTM and DEM-H are based
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999* (Cth)
FSL	full supply level
GCM	global climate model
GDG	Gould–Dincer Gamma algorithm (or method)
GIS	geographic information system
IPA	Indigenous Protected Area
IUCN	International Union for Conservation of Nature
IWSC	Irrigation and Water Supply Commission
MSCL	mild steel cement lined
NCA	*Nature Conservation Act 1992* (Qld)
O&M	operation and maintenance
OSO	on-site overheads
OTR	other than rock
PMF	probable maximum flood
PMST	Protected Matters Search Tool
RCC	roller compacted concrete
SGG	soil generic group
SILO	Scientific Information for Land Owners (database)

SHORT FORM	FULL FORM
SRTM	Shuttle Radar Topographic Mission
SSP	Shared Socio-economic Pathway
TDC	total direct costs
TOC	total out turn costs
TPC	total project costs
UNESCO	United Nations Educational, Scientific and Cultural Organization
$VpUC_{max}$	maximum volume per unit cost
$YpUC_{max}$	maximum yield per unit cost

Units

UNIT	DESCRIPTION
GL	gigalitre
ha	hectare
km	kilometre
m^2	square metre
m^3	cubic metre
mEGM96	EGM96 geoid height in metres
ML	megalitre
ML/year	megalitres per year (ML/y)
mm	millimetre
Mt	million tonnes
MWh	megawatt hour
t	tonne
y	year

Preface

Sustainable development and regional economic prosperity are priorities for the Australian, NT and Queensland governments. In the Queensland Water Strategy, for example, the Queensland Government (2023) looks to enable regional economic prosperity through a vision which states 'Sustainable and secure water resources are central to Queensland's economic transformation and the legacy we pass on to future generations.' Acknowledging the need for continued research, the NT Government (2023) announced a Territory Water Plan priority action to accelerate the existing water science program 'to support best practice water resource management and sustainable development.'

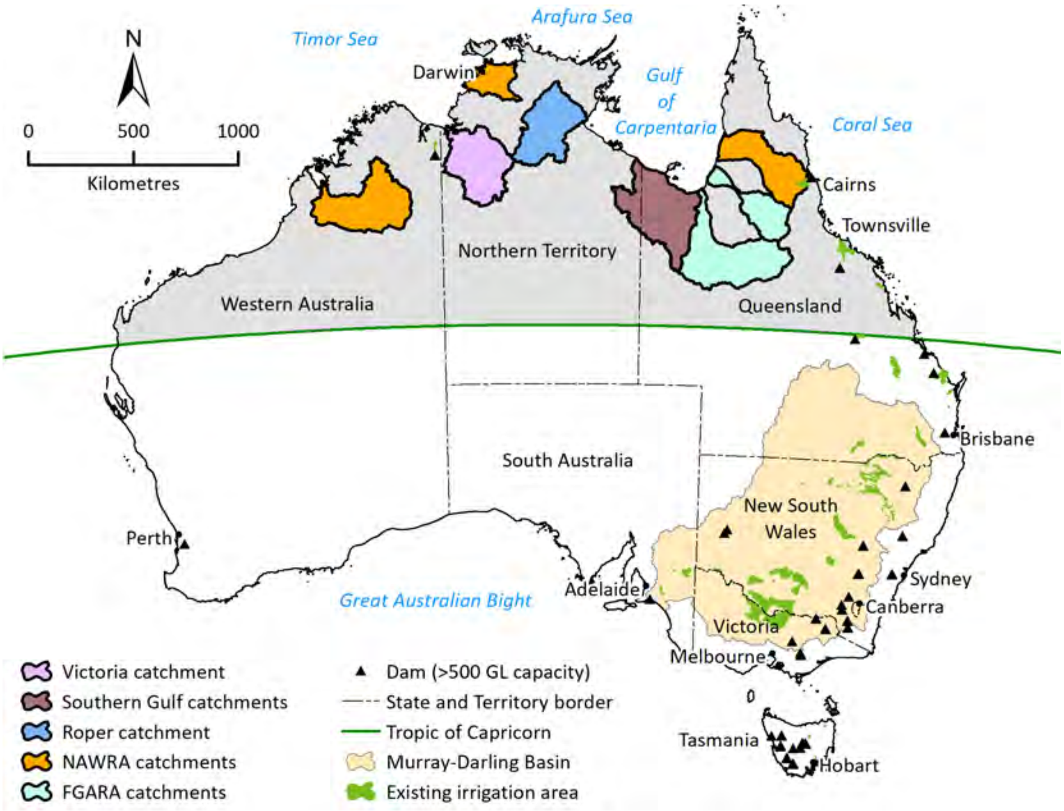
Governments are actively seeking to diversify regional economies, considering a range of factors, including Australia's energy transformation. The Queensland Government's economic diversification strategy for north west Queensland (Department of State Development, Manufacturing, Infrastructure and Planning, 2019) includes mining and mineral processing; beef cattle production, cropping and commercial fishing; tourism with an outback focus; and small business, supply chains and emerging industry sectors. In its 2024–25 Budget, the Australian Government announced large investment in renewable hydrogen, low-carbon liquid fuels, critical minerals processing and clean energy processing (Budget Strategy and Outlook, 2024). This includes investing in regions that have 'traditionally powered Australia' – as the North West Minerals Province, situated mostly within the Southern Gulf catchments, has done.

For very remote areas like the Victoria and Southern Gulf catchments, the land (Preface Figure 1-1), water and other environmental resources or assets will be key in determining how sustainable regional development might occur. Primary questions in any consideration of sustainable regional development relate to the nature and the scale of opportunities, and their risks.

How people perceive those risks is critical, especially in the context of areas such as the Victoria and Southern Gulf catchments, where approximately 75% and 27% of the population (respectively) is Indigenous (compared to 3.2% for Australia as a whole) and where many Indigenous Peoples still live on the same lands they have inhabited for tens of thousands of years. About 31% of the Victoria catchment and 12% of the Southern Gulf catchments are owned by Indigenous Peoples as inalienable freehold.

Access to reliable information about resources enables informed discussion and good decision making. Such information includes the amount and type of a resource or asset, where it is found (including in relation to complementary resources), what commercial uses it might have, how the resource changes within a year and across years, the underlying socio-economic context and the possible impacts of development.

Most of northern Australia's land and water resources have not been mapped in sufficient detail to provide the level of information required for reliable resource allocation, to mitigate investment or environmental risks, or to build policy settings that can support good judgments. The Victoria and Southern Gulf Water Resource Assessments aim to partly address this gap by providing data to better inform decisions on private investment and government expenditure, to account for intersections between existing and potential resource users, and to ensure that net development benefits are maximised.



Preface Figure 1-1 Map of Australia showing Assessment areas (Victoria and Southern Gulf catchments) and other recent CSIRO Assessments

FGARA = Flinders and Gilbert Agricultural Resource Assessment; NAWRA = Northern Australia Water Resource Assessment.

The Assessments differ somewhat from many resource assessments in that they consider a wide range of resources or assets, rather than being single mapping exercises of, say, soils. They provide a lot of contextual information about the socio-economic profile of the catchments, and the economic possibilities and environmental impacts of development. Further, they consider many of the different resource and asset types in an integrated way, rather than separately.

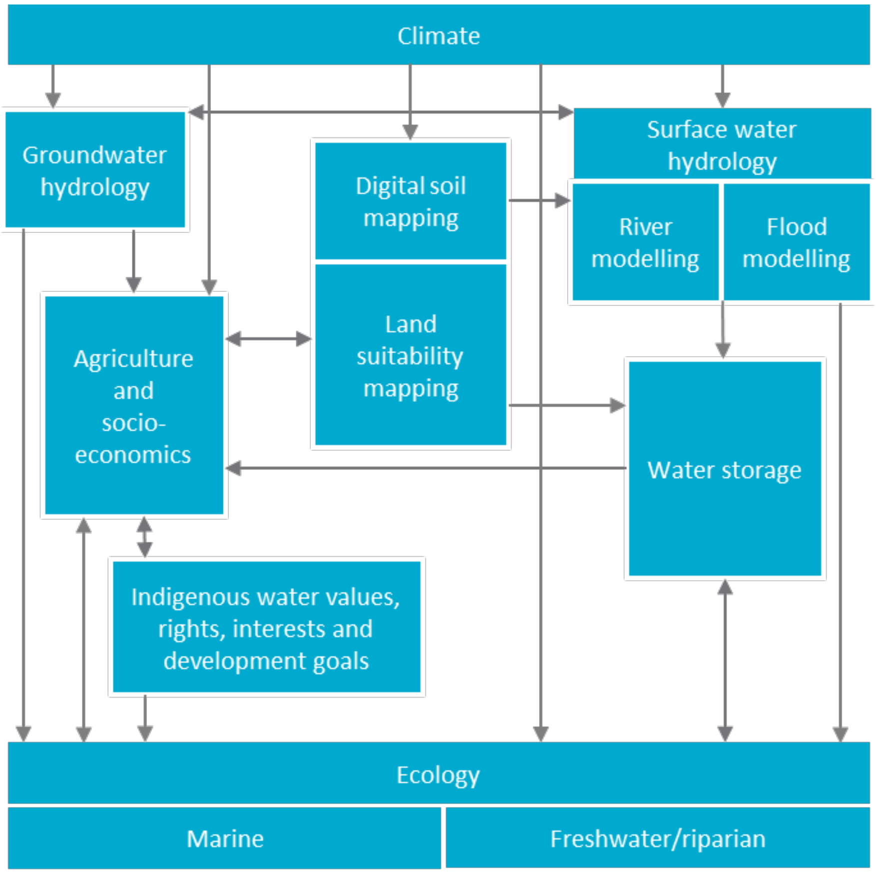
The Assessments have agricultural developments as their primary focus, but they also consider opportunities for and intersections between other types of water-dependent development. For example, the Assessments explore the nature, scale, location and impacts of developments relating to industrial, urban and aquaculture development, in relevant locations. The outcome of no change in land use or water resource development is also valid.

The Assessments were designed to inform consideration of development, not to enable any particular development to occur. As such, the Assessments inform – but do not seek to replace – existing planning, regulatory or approval processes. Importantly, the Assessments do not assume a given policy or regulatory environment. Policy and regulations can change, so this flexibility enables the results to be applied to the widest range of uses for the longest possible time frame.

It was not the intention of – and nor was it possible for – the Assessments to generate new information on all topics related to water and irrigation development in northern Australia. Topics not directly examined in the Assessments are discussed with reference to and in the context of the existing literature.

CSIRO has strong organisational commitments to Indigenous reconciliation and to conducting ethical research with the free, prior and informed consent of human participants. The Assessments allocated significant time to consulting with Indigenous representative organisations and Traditional Owner groups from the catchments to aid their understanding and potential engagement with their requirements. The Assessments did not conduct significant fieldwork without the consent of Traditional Owners.

Functionally, the Assessments adopted an activities-based approach (reflected in the content and structure of the outputs and products), comprising activity groups, each contributing its part to create a cohesive picture of regional development opportunities, costs and benefits, but also risks. Preface Figure 1-2 illustrates the high-level links between the activities and the general flow of information in the Assessments.



Preface Figure 1-2 Schematic of the high-level linkages between the eight activity groups and the general flow of information in the Assessments

Assessment reporting structure

Development opportunities and their impacts are frequently highly interdependent and, consequently, so is the research undertaken through these Assessments. While each report may be read as a stand-alone document, the suite of reports for each Assessment most reliably informs discussion and decisions concerning regional development when read as a whole.

The Assessments have produced a series of cascading reports and information products:

- Technical reports present scientific work with sufficient detail for technical and scientific experts to reproduce the work. Each of the activities (Preface Figure 1-2) has one or more corresponding technical reports.
- Catchment reports, one for each of the Victoria and Southern Gulf catchments, synthesise key material from the technical reports, providing well-informed (but not necessarily scientifically trained) users with the information required to inform decisions about the opportunities, costs and benefits associated with irrigated agriculture and other development options.
- Summary reports, one for each of the Victoria and Southern Gulf catchments, provide a shorter summary and narrative for a general public audience in plain English.
- Summary fact sheets, one for each of the Victoria and Southern Gulf catchments, provide key findings for a general public audience in the shortest possible format.

The Assessments have also developed online information products to enable users to better access information that is not readily available in print format. All of these reports, information tools and data products are available online at https://www.csiro.au/victoriariver and https://www.csiro.au/southerngulf. The webpages give users access to a communications suite including fact sheets, multimedia content, FAQs, reports and links to related sites, particularly about other research in northern Australia.

Executive summary

Current licensed entitlements of surface water in the Victoria and Southern Gulf study areas are less than 0.01% and 3% of their respective median annual discharge. The development of the surface water resources of these highly seasonal catchments to enable industry and regional economic development, as has occurred in the south of Australia, would in many instances require rivers to be regulated and water stored. This report presents information on the broad-scale opportunities for and risks of storing surface water across the entire Victoria and Southern Gulf catchments, including large, engineered dams, large farm-scale offstream storages (i.e. ringtanks) and large farm-scale gully dams. The information is provided to support informed deliberations and discussions around the construction of surface water storages in the Victoria and Southern Gulf catchments and complements information undertaken by other activities in these Assessments, as outlined in the Preface.

There are a wide range of methods by which water can be stored, including large instream and offstream dams, farm-scale dams, weirs and other within-bank structures, natural water bodies, and, below the ground surface, using managed aquifer recharge. However, decisions regarding river regulation and water storage are complex, and the consequences of decisions can be inter-generational. Even relatively small inappropriate releases of water may preclude the development of other more appropriate developments in the future. Consequently, the benefits to government and communities of having a wide range of consistent and reliable information available prior to making decisions, including the manner of ways water can be stored, can have long-lasting benefits and facilitate an open and transparent debate. This report presents information on the broad-scale opportunities for storing surface water in the Victoria and Southern Gulf catchments.

It is important to note that, in undertaking these Assessments, CSIRO did not take into consideration existing regulatory frameworks (with the exception of existing water entitlements). The Assessments are primarily a resource assessment, and these resources remain relatively static through time. However, legislation and regulation, which are tied to government and community values, can and do change rapidly. By deliberately setting aside most regulatory issues, the Assessment is better placed to provide useful information over the longest time frame possible, enabling others to overlay legislative and regulatory frameworks at any point in time.

Large instream dams

Large instream dams were investigated in a three-step process. First, an opportunity analysis was undertaken by reviewing the existing literature for past studies on dams in the Victoria catchment and the Southern Gulf catchments (the two study areas). Simultaneously, the DamSite model, a series of algorithms that automatically determines favourable locations in the landscape as sites for large instream and offstream dams, was used to objectively assess over 50 million potential dam sites in each of the Victoria and Southern Gulf catchments. Second, a long-list of potential dam sites was established by selecting more favourable sites in terms of cost per megalitre released from the dam wall in distinct geographic parts of each of the two study areas. While a prospective dam site depends on a physiographic constriction of the river channel, it also requires favourable foundation geology. Generally, favourable foundation conditions include a relatively shallow layer of unconsolidated materials such as alluvium, and rock that is relatively strong and non-erodible, has low permeability, and is capable of being grouted. In both the Victoria and Southern Gulf catchments, potentially feasible dam sites occur where resistant ridges of rock that have been incised by the river systems outcrop on both sides of river valleys. The rocks are generally weathered to varying degrees, and the depth of weathering, the amount of outcrop on the valley slopes, the occurrence of dolomitic rocks (which may contain solution features), and the width and depth of alluvium in the base of the valley are fundamental controls on the suitability of the potential dam sites.

Consequently, a broad-scale desktop geological assessment was undertaken on the long-list of potential dam sites. The third step involved selecting a 'short-list' of potential dams for a desktop pre-feasibility analysis. This was undertaken by simultaneously considering purpose (e.g. water supply, flood mitigation, hydro-electric power), modelled yield and modelled cost, potential broad-scale geological data, proximity to land suitable for irrigated agriculture (see companion technical reports on land-suitability analysis in the Victoria (Thomas et al., 2023a) and Southern Gulf (Thomas et al., 2023) catchments) and ensuring the sites had a broad geographic spread to give an indication of the opportunities and risks of large instream dams in different parts of the study area. Short-listed sites had a more rigorous cost modelling and were also evaluated for their risk of sediment infill and ecological considerations associated with the creation of an instream barrier and reservoir. The implications of changes in flow regime arising from hypothetical dams and water harvesting developments on existing downstream ecological assets is evaluated in the companion technical reports on ecological analysis (Stratford et al., 2024a, Merrin et al., 2024). Two of the short-listed sites in each of the Victoria and Southern Gulf areas were selected for manually derived cost estimation.

Selected 'short-listed' sites are not necessarily the 'best' potential dam sites, but rather should be considered representative of the better potential dam sites in various geographic locations. The potential sites were selected to better understand the opportunities and risks of dam development in distinct geographic regions of the study area, not to identify potential dam sites that should be the first to be prioritised for construction.

It should be noted that the investigation of a potential large dam site generally involves an iterative process of increasingly detailed studies over a period of years, occasionally over as few as 2 or 3 years but often over 10 or more years. For any of the options listed in this report to advance to construction, far more comprehensive studies would be needed. Studies at that detail are beyond the scope of this regional-scale resource Assessment.

Potential instream dam sites in the Victoria catchment

No previous studies of large dams have been undertaken in the Victoria catchment. Based on the DamSite modelling results for the Victoria catchment, 43 potential dam sites geographically spread across the Victoria catchment were selected for inclusion in the long-list of potential dam sites for broad-scale geological evaluation. Based on a high-level desktop analysis, a moderate proportion (38%) of the potential dam sites on the long-list for the Victoria catchment had a 'good' geological grade (i.e. '1' or '2').

Four potential dam sites were selected from the long-listed sites based on their potential to supply water for irrigation, one potential dam site was selected to investigate its potential for flood mitigation, and one potential dam site was selected to investigate its potential for supplying water for hydro-electric power generation. The findings for these sites are summarised using a consistent tabular format in terms of their ability to supply water for irrigation in Executive summary Table 1-1. An evaluation of Victoria River AMTD 283 km for flood mitigation potential and Victoria River AMTD 97 km for hydro-electric power potential are detailed in the companion technical report on river model simulation in the Victoria catchment (Hughes et al., 2024). Two potential sites, Leichhardt Creek AMTD 26 km and Victoria River AMTD 283 km were short-listed to develop conceptual arrangements and preliminary manually derived cost estimates. The costs for the remaining dams were modelled using the dam cost algorithm used in the DamSite model.

Executive summary Table 1-1 Short-listed potential dam sites in the Victoria catchment

Potential dam site Victoria River AMTD 97 km was selected for the purpose of hydro-electric power generation. Potential dam site Victoria River AMTD 283 km was selected for the purpose of flood mitigation.

DAM ID	NAME	DAM TYPE	FULL SUPPLY LEVEL HEIGHT ABOVE BED * (M)	CAPACITY AT FSL (GL)	CATCHMENT AREA (KM²)	ANNUAL WATER YIELD ** (GL)	CAPITAL COST# ($ MILLION)	UNIT COST## ($/ML)	LEVELISED COST### ($/ML)
38	Victoria River AMTD 97 km §	Pg-RCC	46	6,633	54,605	2,419	3,805☐	1,573	118
121	Wickham River AMTD 63 km	Pg-RCC	28	547	5,431	209	1593☐	7,603	565
131	Leichhardt Creek AMTD 26 km	Pg-RCC	33	193	1,220	64	396◘	6,188	458
150	Bullo River AMTD 57 km	Pg-RCC	34	127	605	55	232☐	4,199	312
186	Victoria River AMTD 283 km §§	ER	9	17	4,413	17	740◘	43,529	3,051
230	Gipsy Creek AMTD 56 km	Pg-RCC	29	56	645	43	384☐	8,993	662

FSL = full supply level; O&M = operation and maintenance; Pg-RCC = Concrete gravity roller compacted concrete.; ER = Rockfill embankment dam
* The height of the dam abutments and saddle dams will be higher than the spillway height.
** Water yield is based on 85% annual time-based reliability using a perennial demand pattern for the baseline river model under Scenario A. This is yield at the dam wall (i.e. does not take into account distribution losses or downstream transmission losses). These yield values do not take into account downstream existing entitlement holders or environmental considerations.
# ◘ Indicates manually derived preliminary cost estimate, which is likely to be –10% to +50% of 'true cost'. ☐ Indicates modelled preliminary cost estimate, which is likely to be –25% to +75% of 'true' cost. Should site geotechnical investigations reveal unknown unfavourable geological conditions, costs could be substantially higher.
This is the unit cost of annual water supply and is calculated as the capital cost of the dam divided by the water yield at 85% annual time reliability.
Assuming a 7% real discount rate and a dam service life of 100 years. Includes operation and maintenance costs, assuming operation and maintenance costs are 0.4% of the total capital cost.
§ There is insufficient land suitable for irrigated agriculture below this potential dam site. This site was investigated to explore the potential for hydroelectric power in the Victoria catchment.
§§ The yield, unit cost and levelised cost is based on the spillway height of 10 m noting this potential dam was evaluated for flood mitigation.

The Victoria catchment has topography suited to large instream dams. However, the semi-arid climate means only those sites situated on large rivers such as the Victoria, East Baines and Wickham rivers have sufficient inflows to have a low cost-per-megalitre yield. Parts of all three of these rivers flow through the Judbarra National Park. The Victoria River around 50 km up- and down-stream of the Victoria River Roadhouse has the most favourable sites in terms of topography and hydrology; however, there is limited land downstream of these sites suitable for irrigated agriculture.

The largest contiguous areas of land suitable for irrigated agriculture is along the south-eastern margin of the Victoria catchment, where surface water resources are highly intermittent and there are no potential dam sites. The largest contiguous areas of land suitable for irrigated agriculture that also coincide with potential dam sites are along the West Baines River upstream of the Victoria Highway to Kununurra and along the Victoria River downstream of the Buchanan Highway and upstream of the Judbarra National Park. However, potential dam sites investigated in the latter location have a poor geology grade (i.e. ‘4’), and those potential dam sites in the catchment of the upper West Baines River are low yielding.

Although there are sites on the Victoria River that could generate large quantities of hydro-electric power, the Victoria catchment is in a remote part of the NT that does not have access to major electricity networks. The small communities rely on diesel generators or hybrid diesel–solar systems provided by the Power and Water Corporation. The largest electricity network in the NT is the Darwin–Katherine Interconnected System (DKIS), which connects the capital of Darwin to Katherine further south by a 132-kV transmission line. Katherine is approximately 200 km from the Victoria River Roadhouse. The DKIS is electrically isolated from other grids, and hence the electricity market in Australia.

Excluding potential dam sites on the Victoria River AMTD 97 km (potential hydro-electric power generation) and Victoria River AMTD 283 km (potential flood mitigation), for which yields greatly exceed the quantity of water required to irrigate land potentially suitable for irrigated agriculture immediately downstream, levelised costs of potential dams in the Victoria catchment that coincide with moderately large contiguous areas of land suitable for irrigated agriculture were found to be between a $340/ML and $660/ML.

Potential instream dam sites in the Southern Gulf catchments

The Leichhardt River catchment in the Southern Gulf catchments has five large instream dams: Julius Dam (reservoir of 108 GL capacity) and Lake Moondarra Dam (reservoir of 107 GL capacity), which are used conjunctively to supply water for urban, mining and industrial use around Mount Isa and Cloncurry, and Rifle Creek Dam (reservoir of 9.5 GL capacity), which is used as a backup water supply for Mount Isa. Lake Moondarra is also used by the residents of Mount Isa and others for recreation. The East Leichhardt Dam, capacity 12.1 GL, was constructed in 1960 to supply water to the Mary Kathleen mine is currently unused other than recreation. Greenstone Creek Dam (Lake Waggaboonyah), capacity 13.5 GL was constructed in 1969, also for mine water supply in the Gunpowder area. Other small private dams in the catchment supply water for mining, and several offstream storages supply water for agriculture. Most notably, several large offstream storages at Lorraine Station and a large farm-scale gully dam on Wernadinga Station supply water for irrigation. The only instream water storage in the Nicholson and Gregory catchments is the

Doomadgee Weir, a long (~850 m) low weir parallel to the Doomadgee Road crossing of the Nicholson River.

A review of the published and unpublished literature available from the Queensland and NT governments' libraries revealed that two dam sites in the Southern Gulf catchments had previously been investigated by the Queensland Government Irrigation and Water Supply Commission. One was on Gunpowder Creek (AMTD 109 km) to supply water to the development of BH South Ltd's Lady Annie phosphate deposits. The second was on the Gregory River upstream of the town of Gregory. The primary purpose of the investigation for the latter dam site was for the supply of water for mineral development in the area, with a secondary purpose to determine what additional supplies could provide water for irrigated agriculture. The latter site was identified by the DamSite model as being the most favourable location for a large instream dam in terms of topography and hydrology in the Southern Gulf catchments.

Based on the DamSite modelling results for the Southern Gulf catchments, 29 potential dam sites geographically spread across the Southern Gulf catchments were selected for inclusion in the long-list of potential dam sites for broad-scale geological evaluation. In the Southern Gulf catchments, potentially feasible dam sites occur where resistant ridges of rock that have been incised by the river systems outcrop on both sides of river valleys. The rocks are generally weathered to varying degrees, and the depth of weathering, the amount of outcrop on the valley slopes, the occurrence of dolomitic rocks (which may contain solution features), and the width and depth of alluvium in the base of the valley are fundamental controls on the suitability of the potential dam sites. Based on a high-level desktop analysis, a large proportion (85%) of the potential dam sites on the long-list for the Southern Gulf catchments were assigned a 'good' geological grade (i.e. '1' or '2').

Seven potential dam sites were selected from the long-listed sites, based on their potential to supply water for irrigation. These sites are summarised using a consistent tabular format in terms of their ability to supply water for irrigation in Executive summary Table 1-2. Two of the seven potential dam sites were short-listed to develop conceptual arrangements and preliminary manually derived cost estimates. The manually derived cost estimates were in part based on location-specific, 'post-covid' unit cost information provided in the companion technical report on surface water storage unit costs (Rider Levett Bucknall, 2024). The costs for the remaining potential dams were modelled using the dam cost algorithm used in the DamSite model. There was no time to update the DamSite model dam cost algorithms with the latest unit costs provided by consultants Rider Levett Bucknall; rather, dam costs were inflated using the Bureau of Statistics heavy and civil construction index.

Executive summary Table 1-2 Short-listed potential dam sites in the Southern Gulf catchments

DAM ID	NAME	DAM TYPE*	FULL SUPPLY LEVEL HEIGHT ABOVE BED * (M)	CAPACITY AT FSL (GL)	CATCHMENT AREA (KM²)	ANNUAL WATER YIELD ** (GL)	CAPITAL COST# ($ MILLION)	UNIT COST## ($/ML)	LEVELISED COST### ($/ML)
1	Gregory River AMTD 174 km	Pg-RCC	19	118	11,381	180	683■	3,794	281
3	Nicholson River AMTD 198 km	Pg-RCC	34	1,403	13,870	289	3,344□	11,156	857
28	Gunpowder Creek AMTD 66 km	Pg-RCC	51	716	3,516	129	773■	5,992	444
165	Mistake Creek AMTD 60 km	Pg-RCC	30	158	1,161	40	659□	16,545	1,220
206	Gold Creek AMTD 58 km	Pg-RCC	34	119	422	24	367□	15,154	1,133
275	Ewen Creek AMTD 6 km	Pg-RCC	30	245	706	29	466□	16,158	1,190
290	South Nicholson River AMTD 9 km	Pg-RCC	37	382	3,113	42	1089□	26,199	1,921

FSL = full supply level; O&M = operation and maintenance; Pg-RCC = Concrete gravity roller compacted concrete.
* The height of the dam abutments and saddle dams will be higher than the spillway height.
** Water yield is based on 85% annual time-based reliability using a perennial demand pattern for the baseline river model under Scenario A. This is yield at the dam wall (i.e. does not take into account distribution losses or downstream transmission losses). These yield values do not take into account downstream existing entitlement holders or environmental considerations.
# ■ Indicates manually derived preliminary cost estimate, which is likely to be –10% to +50% of 'true cost'. □ Indicates modelled preliminary cost estimate, which is likely to be –50% to +100% of 'true' cost. Should site geotechnical investigations reveal unknown unfavourable geological conditions, costs could be substantially higher.
This is the unit cost of annual water supply and is calculated as the capital cost of the dam divided by the water yield at 85% annual time reliability.
Assuming a 7% real discount rate and a dam service life of 100 years. Includes operation and maintenance costs, assuming operation and maintenance costs are 0.4% of the total capital cost.

Although the upstream areas of the Leichhardt and Gregory–Nicholson catchments are generally topographically and geologically suitable for large instream dams, the catchment areas of potential dams are relatively small and the climate semi-arid. Consequently, their yields are modest relative to other parts of northern Australia. Although these modest yields could meet the needs of the mining industry, which are largely restricted to the hard-rock areas of the Southern Gulf catchments, in most cases the long distances to large contiguous areas of soil suitable for irrigated agriculture means that a large proportion of water released from potential dams in the Southern Gulf catchments is likely to be lost during transmission. Opportunities for potential dams in the Southern Gulf catchments to be used conjunctively for mining and agriculture are limited, because the hard-rock areas to which mining activity is largely restricted are too remote from those areas with soils suitable for irrigated agriculture. Of the three largest rivers in the Southern Gulf catchments, the Nicholson River is particularly remote, with little supporting infrastructure, the Gregory River has a highly valued national park in its upper reaches (Boodjamulla National Park), and Leichhardt River already has the five large reservoirs detailed above.

The levelised costs of potential large dams in the Southern Gulf catchments that coincide with moderate-to-large contiguous areas of land suitable for irrigated agriculture were found to be between approximately $280/ML and $1200/ML.

Cultural heritage considerations

No information relating to sacred sites or cultural heritage values of the potential dam sites was made available to the Assessment. The Victoria and Southern Gulf catchments are very likely to contain a large number of Indigenous cultural sites, including archaeological pre-contact sites some of which are likely to be of national scientific significance. Previous studies in northern and southern Australia clearly show that Indigenous Peoples lived along major watercourses and drainage lines. The cultural heritage value of these landforms and their immediate surrounds is therefore assumed to be moderate to very high.

Ecological considerations

A desktop assessment of potential environmental issues associated with large potential dam sites in the Victoria and Southern Gulf catchments was undertaken. Ecological habitat modelling was undertaken to model the likely distribution of water-dependent ecological species in the two study areas. Assessment of potential impacts was based on fish distribution and passage, for which reasonable information exists, reservoir inundation, and consideration of general environmental issues that commonly arise in dam developments in similar habitats elsewhere, particularly the Burdekin Falls Dam (Lake Dalrymple) and the Ord River Dam (Lake Argyle).

In the Victoria catchment, large dams constructed on the Victoria River, and in the Southern Gulf catchments a large dam constructed on the Gregory River, may limit the migration, movement or colonisation of habitat by fish species. Potential dam sites in the headwaters of the West Baines River (e.g. Leichhardt Creek AMTD 26 km) in the Victoria catchment and Gunpowder Creek AMTD 66 km in the Southern Gulf catchments, for example, will have less impact, because the restriction on species movement is small relative to the downstream areas and the number of fish species typically decreases with distance from the coast.

Ecological impacts of perturbations to flow by large instream dams are reported in the companion technical reports on ecological modelling in the Victoria (Stratford et al., 2024b) and Southern Gulf (Ponce Reyes et al., 2024) catchments.

Sedimentation considerations

Potential dams in the Victoria and Southern Gulf catchments, which were examined as part of the Assessment, were estimated to have between 0.5% and 3% sediment infilling after 30 years and between 2% and 10% sediment infilling after 100 years. If any of the potential dams examined in the Assessment were to be constructed, sediment yields would need to be recomputed by undertaking a detailed field measurement and modelling program of downstream impacts on river channels and an assessment of estuarine and coastal geomorphology.

Farm-scale gully and hillside dams and offstream storages in the Victoria and Southern Gulf catchments

This report provides a broad-scale assessment of the suitability of farm-scale gully and hillside dams and offstream water storage locations in the Victoria and Southern Gulf catchments. It does not attempt to produce individual engineering designs for farm dam or water harvesting infrastructure for individual producers.

A desktop assessment of the suitability of farm-scale offstream storages in the Victoria and Southern Gulf catchments was undertaken based on soil parameter grids developed by the Assessment. These data were sourced from the companion technical reports on digital soil mapping (Thomas et al., 2024a,b). Because the Assessment only sampled soil to a depth of 1.5 m, this suitability assessment does not give consideration to the nature of subsurface material below 1.5 m depth.

In the Victoria catchment, the largest contiguous areas suitable for farm-scale offstream storages are the poorly drained coastal marine clay plains, the cracking clay soils on the alluvial plains of the Victoria River and tributaries, and the Cenozoic clay plains of the upper catchment. The poorly drained coastal marine clay plains, while unlikely to be suitable for irrigated agriculture, may be suitable for pond-based aquaculture (see companion technical report on digital soil mapping and land suitability, Thomas et al., 2024a). This area is, however, very remote. The West Baines River and Angalarri River have the largest contiguous areas of land suitable for offstream storages. However, the mid-to-lower reaches of these catchments are susceptible to flooding waters, which means that in areas closer to the channel, where water velocities may be higher, riprap protection may be required, increasing the construction costs. Soils along the Angalarri and the mid-to-lower reaches of the West Baines are also subject to seasonal wetness, limiting the variety of cropping options. The rivers and streams adjacent to the Cenozoic clay plains of the upper catchment have highly intermittently flows, and water harvesting is likely to be unreliable. The rivers in the Victoria catchment with the most reliable flows are the Victoria, the West Baines and the Wickham.

In the Southern Gulf catchments, the large contiguous areas suitable for farm-scale offstream storages occur primarily on the level, slowly permeable, rock-free cracking clay soils of the Armraynald Plain, but also parts of the Barkly Tableland and the northern parts of Donors Plateau. The very poorly drained saline coastal marine plains are also likely to be suitable; however, they are subject to storm surge from cyclones. The rivers with the most reliable flow are the mid-to-lower reaches of the Leichhardt, Gregory and Nicholson. Rivers and streams on the Barkly Tablelands and northern Donors Plateau are intermittent and water harvesting would be unreliable.

Farm-scale gully and hillside dams were modelled using the DamSite model. Those areas that are more topographically favourable for gully dams have the smallest areas of soil suitable for irrigated agriculture. The cumulative effect of water extraction for farm-scale ringtanks is examined in the companion technical reports on river system simulation in the Victoria (Hughes et al., 2024) and Southern Gulf catchments (Gibbs et al., 2024), and the change in ecological flow dependencies is reported in the companion technical reports on ecological modelling in the Victoria (Stratford et al., 2024b) and Southern Gulf (Ponce Reyes et al., 2024) catchments.

Assuming a mean seepage loss of 2 mm/day, a 4.25-m-high ringtank in the Victoria catchment was calculated to have a levelised cost of $208, $266 and $399/year per ML/year for irrigating crops with short, medium and long/perennial growing seasons. In the Southern Gulf catchments, the equivalent levelised costs were $212, $274 and $475/year per ML/year. For crops with short- and medium-length growing seasons, the levelised cost of potential dams in the Victoria and Southern Gulf catchments is considerably less than that for large engineered dams. For crops with a long growing season (i.e. double-cropping system or perennial), the levelised cost of a 4.25-m-high ringtank is slightly higher than the most cost-effective large engineered dams in the Victoria and Southern Gulf catchments. However, at most other locations large engineered dams have a higher levelised cost than ringtanks, even when having to store water for 10 months of the year.

For gully dams in the Victoria and Southern Gulf catchments, assuming a mean seepage loss of 2 mm/day, the levelised cost was found to be between $50 and $90/year per ML/year. Gully dams were found to be considerably more cost effective than ringtanks and large engineered dams. However, this is under idealised conditions, where suitable soils for construction are readily available and the site is upstream of soils suitable for irrigated agriculture. The combination of suitable topography for gully dams with soils for construction and irrigated cropping in the Victoria catchment in particular are rare. In the Southern Gulf catchments, there is opportunity for gully dams with low, wide walls along distributary channels to capture flood waters flowing across the Armraynald Plain.

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Part I Introduction

1 Introduction

Current licensed entitlements of surface water in the Victoria and Southern Gulf study areas are less than 3% of their respective median annual discharge. Large-scale development of the surface water resources in these highly seasonal catchments to enable regional economic development would generally require rivers to be regulated and water stored. In southern Australia, constructing large reservoirs (Preface Figure 1-1) has effectively delivered reliable water supplies in a dry and variable temperate climate. The elaborate series of dams and tunnels constructed as part of the Snowy Mountains Hydro-electric Scheme has enabled watering of much of the irrigated land in the Murray–Darling Basin. A number of commentators have observed that no country or region in a tropical or subtropical climate has made significant economic progress without harnessing adequately its water resources (Bisawas, 2012).

Large instream dams are not the only methods of storing water. Although Petheram et al. (2014) found that large dams presented the greatest opportunity for enabling broad-scale irrigated agriculture across northern Australia, they also stated that other methods, while capable of supplying far smaller volumes of water than instream dams, may play a role in maximising the cost-effectiveness of water supply. Furthermore, the large, often public, capital expenditure requirements and often unpredictable environmental and social changes associated with large instream dams have led some sectors of the public to question whether they are an appropriate pathway for development (O'Donnell and Hart, 2016; International Rivers, 2014; WCD, 2000).

Thus, decisions around river regulation and water storage are complex, and the consequences of decisions are inter-generational.

Plausibility of large dam–based development pathways

Accurately determining change in irrigated area over time is difficult for a number of reasons. However, preliminary analysis suggests that the mean net increase in irrigated area across all of northern Australia was approximately 1300 ha per year over the last 24 years. For context the average sized cotton farm in Australia grows 576 ha of cotton (Cotton Australia 2021). This indicates that changes in irrigation across northern Australia have been modest over the last couple of decades.

Figure 1-1 shows the number of large dams (defined here as dams listed in the Australian National Committee on Large Dams (ANCOLD) database with a storage capacity of 10 GL or greater) constructed across Australia and northern Australia (west and east of the Great Dividing Range) over time. Over the last 40 years, there have been only nine large dams constructed across all of northern Australia (including along the east coast), and only three of these nine dams were constructed for the supply of water for irrigation, rather than for supplying water for mining or urban use. Furthermore, one of those three dams was also listed as intended for flood mitigation, recreation, and water supply for urban use. All three of the dams that have been constructed to supply water for irrigation are east of the Great Dividing Range. No large dam has been constructed anywhere in northern Australia for the supply of water for irrigation for more than

25 years, and no large dam has been constructed for the supply of water for irrigation west of the Great Dividing Range in over 50 years.

Irrespective of the physical resources that may support water and irrigated agricultural development in the Victoria and Southern Gulf catchments, based on historical trends and current patterns of development in the NT and Queensland, the scale of future irrigation development in the Victoria and Southern Gulf catchments is likely to be modest and not likely to encompass large dam development. It is more likely to consist of incremental small-scale developments based on offstream storages, gully dams, and groundwater. Nonetheless, large dams remain topical, and it is important that robust and independent analysis addresses the opportunities and the risks that large-scale dam developments present to help facilitate an informed debate.

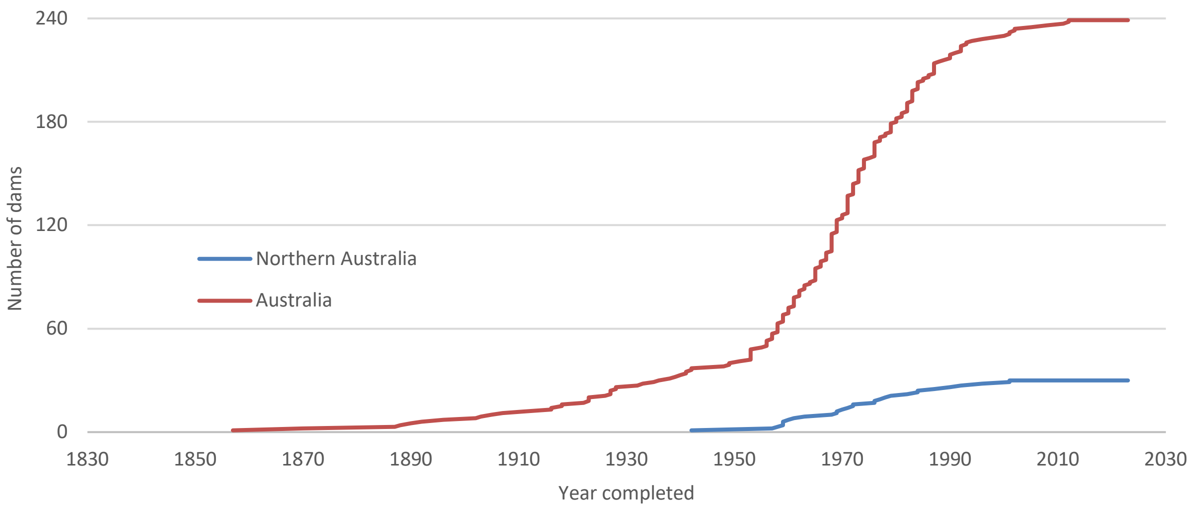

Figure 1-1 Number of dams constructed in Australia and northern Australia over time

Large dams are defined as dams listed in the ANCOLD database. ANCOLD = Australian National Committee on Large Dams.

Report objectives

The primary purpose of this report was to provide a comprehensive overview of the different surface water storage options available in the Victoria and Southern Gulf catchments to help decision makers take a long-term (i.e. >30-year) view of water resource development, which will also inform shorter-term regional planning and allocation decisions.

Having a wide range of reliable information prior to making decisions, including information on all the different ways water can be stored, can have long-lasting benefits to government and communities and facilitate an open and transparent debate. The broad types of dams and water storage options likely to be used in northern Australia are described in Section 1.1.

The first step in assessing potential water storage options in a catchment is to examine existing water storages. Any available unused water in these storages is likely to be the most cost-effective source of additional water.

It is important to note that this surface water storage analysis was of a pre-feasibility nature. The broad steps involved in investigating a large dam are described in Section 1.2. The information in this report is complemented by that obtained from other activities undertaken in the Assessment (see Preface Figure 1-2).

More specifically this report sought to:

- review all previous studies (published and unpublished) on large dams in the Victoria and Southern Gulf catchments
- identify and assess every location in both study areas for their potential for the construction of large instream and offstream dams, including an estimate of water yield and modelled cost
- evaluate the risks associated with large dam construction in the Victoria and Southern Gulf catchments
- undertake a pre-feasibility assessment of the best opportunities for farm-scale instream (i.e. gully and hillside dams) and offstream (i.e. ringtank) storages
- identify the more promising surface water storage options in the study area in terms of yield per unit cost and proximity to soil suitable for irrigated agriculture
- undertake a manual cost estimate (for two short-listed sites in each study area) at a nominated full supply level (FSL)
- present the results in a consistent tabulated format that facilitates site comparisons
- provide a conceptual layout and indicative costs for two scheme-scale reticulation systems in more promising parts of each study area.

Site-specific field investigations of individual farm-scale storage sites were beyond the scope of this pre-feasibility assessment. However, the performance of hypothetical farm-scale water storage is discussed, generalised cost estimates are provided, and farm-scale storages have been modelled using the best available information.

Report outline

This report is divided into four parts and two appendices.

Part I Introduction contains three chapters. Chapter 1 provides introductory material on aspects of large instream and offstream dams and farm-scale dams, and key terminology and concepts. Chapter 2 provides details about the geology, soils, hydroclimate, ecology, and existing dams in the two study areas. Chapter 3 details the methods undertaken to assess dams in the Assessment area, including the DamSite modelling process.

Part II Large instream and offstream dams contains two chapters. Chapters 4 and 5 analyse large dams in the Victoria and Southern Gulf catchments, respectively, and presents a long-list of dams used to identify potential sites for pre-feasibility analysis.

Part III Weirs and on-farm storages contains Chapter 6, which provides general information on re-regulation structures, such as weirs and sand dams, and Chapter 7, which examines farm-scale storages.

Part IV Summary comments contains the collective analysis in Chapter 8 and summary comments in Chapter 9.

Appendix A provides detailed costings for development of the two short-listed potential dam sites in each of the Victoria and Southern Gulf catchments.

Appendix B provides summary tables for the potential dam sites that were selected for pre-feasibility analysis but were not short-listed for a more detailed costing.

Section outline

The remainder of this introductory chapter is structured so as to give well-informed but non-technical readers some of the background information on surface water storage infrastructure needed to understand subsequent technical sections of the report. Large parts of this section are reproduced from Petheram et al. (2017a), as the material is generic and provides good contextual information for the specific analysis of the Victoria and Southern Gulf study areas presented in Part 2. Section 1.1 provides an overview of the different types of large dams and farm-scale water storage infrastructure in the Victoria and Southern Gulf catchments. Section 1.2 outlines the broad steps in the investigation of a large dam site, which provides the context for the additional work needed in order for a site to be considered 'shovel ready'. In Section 1.3, a brief overview of dam safety provides the context for a discussion on who might build different types of dams, which influences their cost. Section 1.4 defines key terminology and concepts used in the report.

Introductory information on environmental and cultural heritage considerations and on deriving dam axis elevation profiles and reservoir volumes using Shuttle Radar Topographic Mission (SRTM) data are provided in Petheram et al. (2013). McMahon and Petheram (2020) present an analysis of Australian dams and reservoirs within a global setting and Petheram and McMahon (2019) report on historical dam costs and cost overruns in Australia.

Key linkages with other activities of the Victoria and Southern Gulf Water Resource Assessments

This report draws heavily on information and models generated by other activities in the Assessments, in particularly the companion technical report on river modelling calibration (Gibbs et al., 2024a, Hughes et al., 2024a), river model simulation (Gibbs et al., 2024b, Hughes et al., 2024b) the companion technical report on ecology asset description (Stratford et al., 2024, Merrin et al., 2024), and the digital soil-mapping and land-suitability report (Thomas et al., 2024a,b). Based on selected potential storages outlined in this report a companion technical report on reticulation scheme infrastructure seeks to highlight the types of considerations necessary in designing potential irrigation schemes in northern Australia and their likely cost (Devlin, 2024). A companion technical report on hydro-electric power generation examines the opportunities for hydro-electric power generation in the Southern Gulf catchments (Entura, 2024). The ecological impacts of perturbations to flow by large instream dams are reported in the companion technical reports on ecological modelling in the Victoria (Stratford et al., 2024b) and Southern Gulf (Ponce Reyes et al., 2024) catchments.

1.1 Types of water storages

The Assessment undertook a pre-feasibility-level assessment of three types of constructed surface water storage options. These were: (i) large dams that could supply water to multiple properties, (ii) farm-scale or on-farm dams that supply water to a single property, (iii) re-regulating structures such as weirs.

Both large dams and farm-scale dams can be further classified as either instream or offstream water storages. In this Assessment, instream water storages are defined as structures that intercept a drainage line (creek or river) and are not supplemented with water from other drainage lines. Offstream water storages are defined as structures that: (i) do not intercept a drainage line, or (ii) intercept a drainage line and are supplemented with water extracted from another larger drainage line. Ringtanks and turkey nest tanks are examples of offstream storages with a continuous earth embankment. Large dams, farm-scale dams, offstream storage and re-regulating structures are briefly discussed below.

Large instream dams are usually constructed from earth, rock, or concrete materials and act as a barrier across a river to store water in the reservoir created. They need to be able to safely discharge the largest flood flows likely to enter the reservoir, and the structure must be designed so the dam meets its purpose, generally for at least 100 years. Note, however, that some dams have been in continuous operation for over 1000 years. For example, the Kofini Dam in Greece and the Anfengtang Reservoir in China are still in operation 3300 and 2600 years, respectively, after their construction (Schnitter, 1994). Schnitter (1994) consequently described dams as 'the useful pyramids'.

An attraction of large dams is that, if large enough relative to the demands (i.e. water supplied for consumptive use, evaporation, and seepage), when full they contain water that can last two or more years. This has the advantage of providing water during dry seasons and mitigating against years with low inflows to the reservoir. For this reason, large dams are sometimes referred to as carry-over storages.

An advantage of large instream dams is that they provide a very efficient way of intercepting the flow in a river, effectively trapping all flow until the FSL is reached. However, they also provide a very effective barrier to the movement of fish and other species within a river system, and they can inundate large areas of land.

Two types of dams are particularly suited to northern Australia: embankment dams and concrete gravity dams.

In the hazard framework outlined in Section1.3, large dams fall within Category 3, and it is necessary that their investigation and design be undertaken by an engineering consultant specialising in large dams.

Embankment dams

Embankment dams are usually the most economical, provided that suitable construction materials can be found locally, and they are best suited to smaller catchment areas where the spillway capacity requirement is small. There are two major types of embankment dams: (i) earthfill embankment dams, and (ii) rockfill embankment dams. Earthfill embankment dams are the most popular dams worldwide (61%), because they can be built on a wide range of foundation conditions. In Australia, however, only 33% of large dams are classified as earthfill, while 40% are rockfill (McMahon and Petheram 2020).

Like earthfill dams, rockfill dams can be built on a wide range of foundation conditions, but they require less material as they can be built with much steeper side slopes. They can also be constructed during rain and remain stable even under high seepage conditions. Rockfill embankment dams also have an advantage over earthfill embankment dams in that methods have been devised for reinforcing the downstream rockfill slope to protect it from erosion if overtopped during construction. Indeed, several rockfill dams in Australia have survived overtopping by flood events during construction with minimal damage.

Two common types of rockfill dams for which there are examples in northern Australia are shown in Figure 1-2 and Figure 1-3. In the first case, the dam has a central earth core within the embankment that provides a watertight barrier to prevent water percolating through the rockfill (e.g. Belmore Creek Dam -officially known as Lake Belmore, in the catchment of the Norman River). In the second case, the seepage barrier is a thin reinforced concrete slab placed on the upstream face of the rockfill (e.g. Boondooma Dam in the Burnett catchment or Awoonga Dam on the Boyne River near Gladstone).

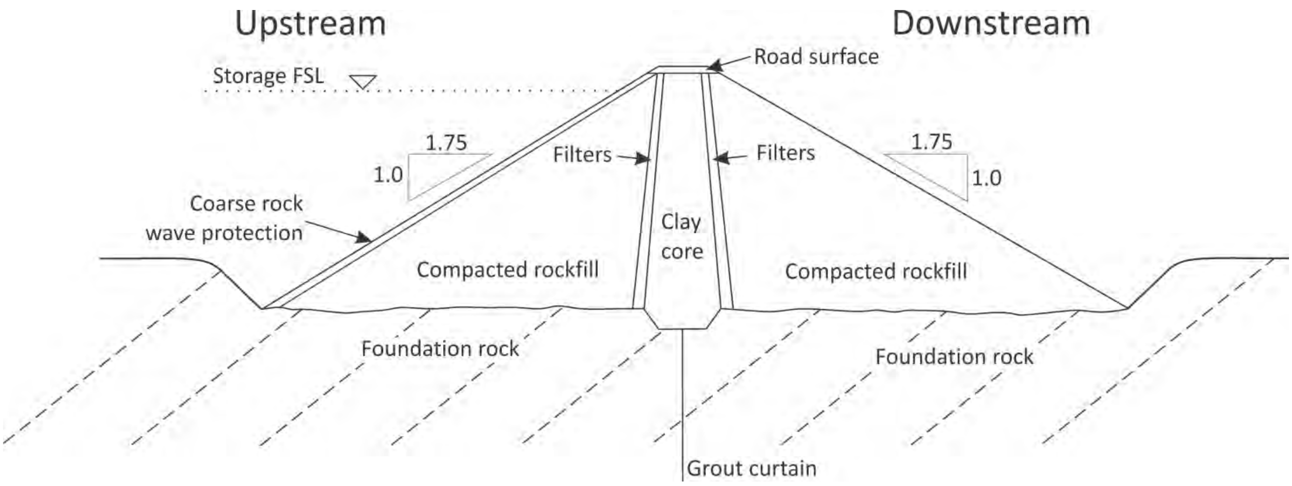

Figure 1-2 Schematic cross-section diagram of a rockfill embankment dam with a clay core

FSL = full supply level.

Source: Petheram et al. (2013)

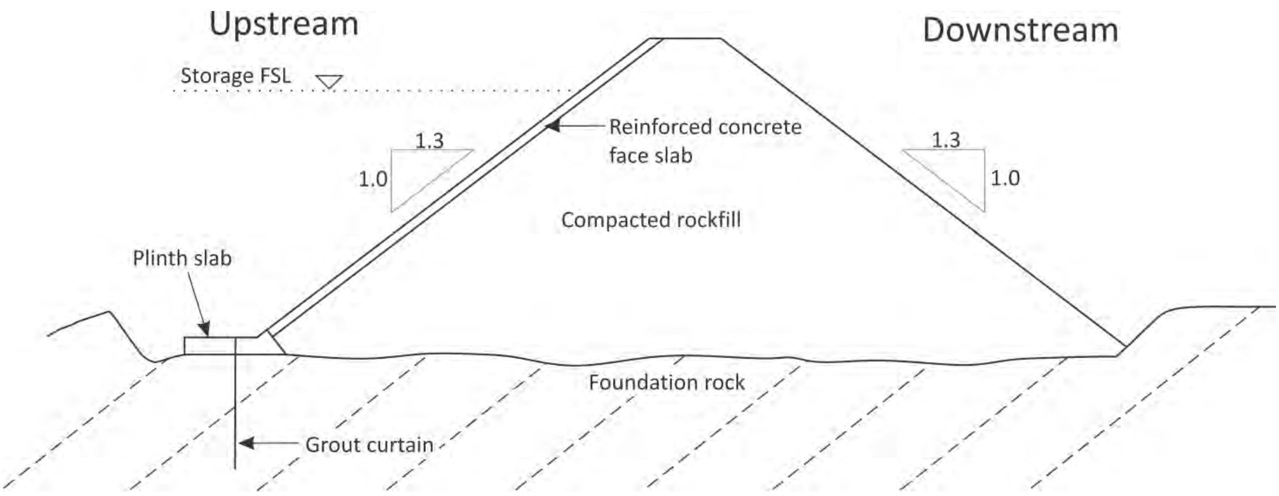

Figure 1-3 Schematic cross-section of a concrete-faced rockfill dam

FSL = full supply level.

Source: Petheram et al. (2013)

Where sound foundation rock is not available at reasonable depth, an embankment-type dam can be founded on a ‘soft’ foundation, provided that any permeable layers in the foundation can be cut off effectively and water pressures within the foundation limited, for example, by pressure relief wells. Many offstream storage embankment dams are founded on soil foundations where spillway requirements are minimal.

Concrete gravity dams

In contrast to embankment dams, concrete gravity dams require sound foundation rock, because the loading on the foundation is much higher and the leakage path through the foundation under the water barrier is short. Where a large capacity spillway is needed for discharging flood inflows, a concrete gravity dam with a central overflow spillway is generally the most suitable type. Traditionally, concrete gravity dams were constructed by placing conventional concrete (CC) in formed 'lifts'. However, Kidston Dam (officially known as the Copperfield River Gorge Dam) in the catchment of the Gilbert River was the first dam in Australia where roller compacted concrete (RCC) was used, with low-cement concrete being placed in continuous thin layers from bank to bank and compacted with vibrating rollers. This approach allows large dams to be constructed in a far shorter time frame than is required for CC construction. The use of RCC over CC was estimated to reduce the cost of the concrete gravity dam at Copperfield Gorge by approximately 40% (Doherty, 1999), and the introduction of this technique resulted in an increase in the proportion of concrete gravity-type dams built in Australia.

RCC is best used for high dams where a larger-scale plant can provide significant economies of scale. This is now the favoured type of construction in Australia whenever foundation rock is available within reasonable depth, and where a larger capacity spillway is required.

Other types of large dams

Two other major types of large dams are concrete buttress and arch dams. These types can be favourable when concrete is expensive and labour is cheap (i.e. they require more formwork and are of greater complexity), such as occurred during the Great Depression and after World War II. However, in recent decades the high cost of labour has made these types of dams less economical than concrete gravity or embankment dams. Furthermore, arch dams are generally not very suitable in Australia due to a lack of suitable topography; they have the greatest benefits over concrete gravity dams at sites where the valley width is narrow and the rock is structurally sound.

A note on offstream storages

Offstream water storages are not a new concept; they were among the first constructed water storages, because people initially lacked the capacity to build structures that could block rivers and withstand large flood events. For example, in the 12th Dynasty of Ancient Egypt, water was diverted from the Nile River into the El Fayyum Depression (Nace, 1972), while one of the largest Mayan cities was constructed around offstream water storages (Scarborough and Gallopin, 1991). In Australia, there is evidence that Indigenous Peoples, prior to European settlement, engineered structures in the Roper catchment to divert dry-season baseflow into adjacent wetlands (Barber and Jackson, 2011).

Offstream water storages can take the form of farm-scale ringtanks (e.g. 100 to 10,000 ML storage capacity). Figure 1-4 shows an example of an approximately 4000 ML ringtank. The most suitable type of offstream water storage depends on a number of factors, including topography, availability of suitable soils, excavation costs, and source of water (e.g. groundwater or surface water pumping, flood harvesting).

One of the advantages of offstream storages is that, if properly designed, they can cause less disruption of the natural flow regime than do large instream dams, provided that water is extracted from the river using pumps or there is a diversion structure with raisable gates that allows water and aquatic species to pass when not in use. However, raisable gates are typically expensive to operate and maintain, particularly in remote areas, and the structures supporting the gates need to be designed to withstand large flood events, which increases the cost of the diversion structure considerably.

Weirs can also be used in conjunction with offstream water storages, whereby the weir is used to raise the upstream water level to allow diversion into an offstream storage, or the creation of a pumping pool. However, an often-overlooked aspect of offstream storages is that the amount of water that can be diverted into an offstream storage using a diversion structure in a river depends on the relative difference between the height of the water in the river and the height of the water in the storage. Water must run downhill from the point of diversion to the storage location. To achieve adequate flow rates in the diversion channel, the diversion structure has to be sufficiently high to generate the required head of water. This is particularly the case in northern Australia, where river water levels rise and fall very rapidly (Petheram et al., 2008) and there is little time for extraction or diversion. Kim et al. (2013) provide an example of a 'hydraulic' analysis for an offstream storage and diversion structure in the Flinders catchment.

Because the risk of failure of offstream storages due to overtopping is typically lower than for an instream dam, it is more feasible that a regionally based contractor overseen by a regionally based engineer (i.e. suitable to build a Category 2 dam) could construct a large offstream storage rather than a large instream dam.

Figure 1-4 Rectangular ringtank in the Flinders catchment
Photo: CSIRO

1.1.1 Re-regulating structures

Re-regulating structures such as weirs differ from dams in that they are lower barriers located entirely within stream banks and are totally overtopped during flood events. Weirs are typically used as re-regulating structures downstream of large dams to allow for more efficient releases from the storages and for some additional water yield from the weir storage itself, thereby reducing the transmission losses normally involved in supplemented river systems. Re-regulating structures can range from concrete gravity weirs to sheet piling weirs to simple sand dams – mounds of river sand within the bed of a river designed to create a pumping pool. These types of structures are discussed in more detail in Chapter 6.

1.1.2 Farm-scale dams and water storages

Farm-scale dams, also referred to as on-farm dams, are typically used to supply water for stock and domestic purposes, or for mosaics of small-scale irrigation supplying the one property. They can take the form of gully and hillside dams, ringtanks, turkey nest tanks, and excavated tanks. A summary of the different types of on-farm dams and indicative storage-to-excavation ratios is provided in Table 1-1. These structures are evaluated in Chapter 7.

Table 1-1 Types of farm-scale water storages

TYPE OF ON-FARM DAM	DESCRIPTION	STORAGE-TO-EXCAVATION RATIO
Gully dam	Earth embankment built across a drainage line. Dams are normally built from material located in the storage area upstream of the dam site. Gully dams can also be used in conjunction with offstream water storages, where the weir is used to raise the upstream water level to allow diversion into offstream storage or the creation of a pumping pool	10:1 (favourable conditions)
Hillside dam	An earth dam located on a hillside or slope and not in a defined depression or drainage line	5:1 (on flatter terrain) 1:1 (on steeper slopes)
Ringtank	A storage confined entirely within a continuous embankment built from material obtained within the storage basin	1.5:1 (small tank) 4.5:1 (large tank) 10:1 (very large tank)
Turkey nest tank	A storage confined entirely within a continuous embankment but built from material borrowed from outside the storage area. All water is therefore held above ground level	Usually smaller than ringtanks and lower storage-to-excavation ratio
Excavated tank	Restricted to flat sites and comprise excavations below the natural surface. Excavated material is wasted. Generally limited to stock and domestic use and irrigation of high-value crops	Low storage-to-excavation ratio

Source: Adapted from Lewis (2002)

1.2 Stages of investigation in design, costing and construction of dams

The investigation of a potential dam site involves an iterative process of increasingly detailed studies, sometimes occurring over as few as 2 or 3 years but often over 10 or more years. It is not unusual for the cost of the geotechnical investigations for a dam site alone to exceed several million dollars. Given the high costs and time involved and the likelihood of many potential dam sites in a catchment, an important stage in developing the surface water resources of a catchment is a pre-feasibility assessment.

The pre-feasibility assessment is the first of five stages of a dam project. Fell et al. (2015) outlined these five stages as pre-feasibility, feasibility and site selection, design and specification, construction, and operation.

The pre-feasibility stage, including this Assessment, typically involves a detailed desktop investigation and site visit to acquire significant information for numerous dam sites in an area, including determining whether:

- the topography favours the creation of a large storage volume by a dam of a height and length likely to be economically viable
- the regional and local geology are likely to impose constraints or additional cost to construction
- the streamflow characteristics are appropriate for a storage to meet the forecast demand
- the dam site location is in the vicinity of the forecast demand for water and soils suitable for irrigation
- storage would affect existing land uses, existing infrastructure, or environmental, social or cultural values
- impacts are likely to be acceptable to investors and other stakeholders.

The geological assessment should include a visit to each site by an experienced engineering geologist.

The likelihood of dam sites being suitable for future detailed evaluation can often be determined from a preliminary assessment of the available information, including maps, geology, and streamflow data, and particularly from site inspections. An initial desktop assessment of the impacts of a storage development on existing land uses, existing infrastructure, and environmental values may indicate at an early stage whether the impacts are likely to be acceptable to investors or other stakeholders. More promising potential dam sites may have been the subject of earlier investigations, in which case the available study reports can be particularly useful in any reassessment.

A pre-feasibility analysis commonly short-lists the better sites for a more detailed desktop analysis, including more time-demanding analyses such as preliminary flood design assessment (e.g. to assess the additional height required above the FSL (or freeboard), which can significantly affect dam cost). One such preliminary assessment was undertaken in northern Australia in the Flinders and Gilbert catchments (Petheram et al., 2013) and the Darwin and Mitchell catchment (Petheram et al., 2017a). This process makes it possible to confidently select the most appropriate dam sites on which to undertake more detailed and costly ground-based investigations.

To progress a dam proposal from a desktop assessment to the commencement of construction requires a series of comprehensive and often iterative studies. These include:

- detailed topographic surveys
- detailed hydrological studies calculating the reservoir yield and reliability and the magnitude of flood inflows that could be experienced during the period of construction and operation of the dam
- geotechnical studies, including geological mapping of the site and inundated area, seismic surveys, and trenching and drilling (to assess foundation conditions for each of the proposed structural elements, and to assess potential sources of construction materials). Geotechnical assessments are required at all five stages of a dam project (Fell et al., 2015)
- engineering studies of dam type and layout, including requirements for the main cross-river wall, any necessary saddle dams, spillways, and outlet works, as well as provisions for addressing impacts, particularly in the storage area
- engineering studies of any reticulation works required to deliver water to the areas of demand
- impact assessment studies, including environmental, social and cultural heritage impacts and the development of strategies for avoiding or managing impacts
- consideration of needs and costs for processing, transport and marketing of the products of irrigated agriculture
- economic and financial studies that compare estimated costs and benefits and which develop proposals for funding the construction and operation of the works, including the water supply charges proposed.

Ultimately, the studies need to acquire the necessary level of detail and certainty in order to obtain the required approvals. The final step should consider how implementation of the project should proceed, including institutional arrangements for construction and ongoing operation and maintenance of the scheme, for the entire operational life of the dam.

1.3 Dam safety and models of dam construction

The ANCOLD is an incorporated voluntary association of organisations and individual professionals with an interest in dams in Australia. It organises technical working groups and issues guidelines on topics related to dams. The ANCOLD dam consequence categories (ANCOLD, 2012) define seven hazard groups (Very low, Low, Significant, High C, High B, High A and Extreme). A higher hazard category being assigned to a dam means that more work is required to ensure the risk to downstream communities is mitigated to an acceptable level.

These seven hazard groups can be grouped into three categories that broadly reflect the amount of work required for the operation of a safe dam:

1. Category 1: Dams in the ‘Very low’ or ‘Low’ hazard category. Depending upon the jurisdiction and the dimensions of the structure and reservoir, these dams may require a permit to undertake dam works, but in general these require the least amount of detail in order to satisfy statutory planning, construction, maintenance and reporting requirements.
2. Category 2: Dams that fall into a hazard category of ‘Significant’ and ‘High C’, or all dams that are over 10 m but less than 25 m in height and not in Category 3. These require considerably more detail in order to satisfy planning, construction, maintenance and reporting requirements than do dams in Category 1.
3. Category 3: Dams that are at the higher end of the hazard category scale. These dams include ‘High B’, ‘High A’ and ‘Extreme’ hazard dams and dams that are over 25 m in height. These generally require the services of an engineering consultancy service specialising in the design and construction of large dams, require considerable planning and approval, and usually require an environmental impact statement and approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

In the context of the Assessment, these three categories are useful for helping to broadly categorise dam labour construction models, the capital costs, and ongoing operation and maintenance costs.

The safety of referable dams in Queensland is regulated under the state *Water Supply (Safety and Reliability) Act 2008*, the responsible agency being the Department of Regional Development Manufacturing and Water.

There is no specific dam safety regulation in the NT.

Dam construction models and implications for cost

Most on-farm dams fall into Category 1, but larger farm-scale dams may be Category 2. It is technically feasible for on-farm dams that fall into Category 1 to be constructed by the landholder. They may own their own plant or can purchase a new or second-hand plant and compaction equipment, and the structure satisfies jurisdictional requirements.

There are no jurisdictional regulations covering the construction of farm dams in the NT.

Construction by landholders using their own plant and equipment may often be a cheaper form of surface water storage construction because:

- landholders often employ lower design standards, preferring to pay intermittent annual costs associated with maintaining a structure rather than high upfront costs (e.g. preferring to repair batter slopes with their own equipment as needed, rather than to use rock protection)
- contractor and other project overheads (e.g. ensuring access and operation of the structure comply with health and safety regulations) are substantially lower than if a regionally based contractor and engineer were used
- the cost of maintenance and repair of machinery, and the opportunity cost of the landholder undertaking their own design, survey and project management of the structure, are rarely considered by landholders.

Although farm dams constructed by a landholder may in some circumstances be cheaper than those using a regionally based contractor and engineer, the dam’s service life is typically lower, and the ongoing maintenance costs and risk of failure are typically higher. For example, ANCOLD (1992) report that a study in NSW found a 23% failure rate for farm dams in that state.

Dams that fall within Category 2 could feasibly be constructed by a regionally based contractor, with investigation and design being undertaken by a regionally based engineering consultant. Under this model of construction, the upfront cost of constructing the dam would be higher than for a Category 1 dam but probably less than for a Category 3 dam. Category 2 dams are generally cheaper than Category 3 dams because they require less technical design and investigation, and typically have lower contractor overheads, such as project risk and site accommodation, because of the smaller scale and complexity of the operation.

Larger dams such as Julius Dam and Moondarra Dam in the Southern Gulf catchments are Category 3 dams. These dams are the domain of professional engineering companies that specialise in the design and construction of large dams. Costs are usually high, because investigation costs are expensive and the structures are generally designed and constructed to a very high standard, usually with at least a 100-year service life. Contingency is typically high because these structures carry the highest risk, as considerable subsurface works are required.

1.4 Key terminology and concepts

1.4.1 Dam terminology

In this report the word ‘dam’ refers to the structure including the dam wall, primary and secondary spillways, and outlet structures. ‘Reservoir’ is reserved for the water body upstream of the dam wall. Dam volume is defined here as the volume of material in the dam wall, and the reservoir capacity is the volume of the reservoir at FSL. The total freeboard is the sum of the wet freeboard and the dry freeboard, where the wet freeboard is the level above e FSL below which a design flood event may pass (also referred to as flood surge), and the dry freeboard is the height above the wet freeboard to account for wind-generated waves.

1.4.2 Water yield

Yield is the amount of water that can be released in a controlled manner from a reservoir system. Yield values are accompanied by a reliability value where, for all other factors held constant, increasing the reliability decreases the yield. Other terms used synonymously with yield are release, draft and regulation. In this report, all yield and reliability values are expressed in terms of annual time reliability, which is calculated as per Equation 1.

$$R_t = \frac{N_S}{N} \tag{1}$$

Where R_t is the time-based reliability, N_S is the total number of intervals during which the demand was met; and N is the total number of time intervals in the simulation. For annual time reliability, N_S becomes the number of successful years and N becomes the number of years in the simulation period.

1.4.3 Water year and wet and dry seasons

Northern Australia has a highly seasonal climate, with most rain falling from December to March. Unless specified otherwise, this Assessment defines the wet season as the 6-month period from 1 November to 30 April and the dry season as the 6-month period from 1 May to 31 October.

All results in the Assessment are reported over the water year, defined as the period 1 September to 31 August, unless specified otherwise. This allows each individual wet season to be counted in a single 12-month period, rather than being split over two calendar years (i.e. counted as two separate seasons). This is more realistic for reporting climate statistics from a hydrological and agricultural assessment viewpoint.

1.4.4 Scenario definitions

Four scenarios are presented in this report:

- Scenario A – historical climate and current development
- Scenario B – historical climate and hypothetical future water resource development
- Scenario C – future climate and current development
- Scenario D – future climate and hypothetical future water resource development.

Scenario A

Scenario A is historical climate and current development. The historical climate series is defined as the observed climate (rainfall, temperature and potential evaporation for water years from 1 September 1890 to 31 August 2022). All results presented in this report are calculated over this period, unless specified otherwise. The current levels of surface water, groundwater, and economic development were assumed (as at 2023). In the case of the Southern Gulf catchments, full use of existing entitlements was assumed. Scenario A was used as the baseline against which assessments of relative change were made. Historical tidal data were used to specify downstream boundary conditions for the flood modelling.

Historical climate data were sourced from the Scientific Information for Landowners (SILO) Data Drill database, http://www.longpaddock.qld.gov.au/silo/ (Jeffrey et al., 2001). SILO provides surfaces of daily climate data interpolated and infilled from point measurements made by the observation network developed and maintained by the Bureau of Meteorology.

Scenario B

Scenario B is historical climate and future development, as generated in the Assessment. Scenario B used the same historical climate series as Scenario A. River inflow was modified to reflect potential hypothetical future development. All price and cost information was indexed to 2023. The impacts of changes in flow due to this future development were assessed, including impacts on:

- instream, floodplain and near-shore ecology
- Indigenous water values
- economic costs and benefits
- opportunity costs of expanding irrigation
- institutional, economic and social considerations that may impede or enable adoption of irrigated agriculture.

Scenario C

Scenario C is future climate and current levels of surface water and ground development assessed at around 2060. It is based on the 132-year climate series (as in Scenario A) derived from global climate model (GCM) projections for an approximate 1.6 °C global temperature rise (by ~2060) relative to the 1990 scenario, representing Shared Socio-economic Pathway SSP2-4.5, as defined in the United Nations Intergovernmental Panel on Climate Change Sixth Assessment Report. The GCM projections will be used to modify the observed historical daily climate sequences.

Scenario D

Scenario D is future climate and future development. It used the same future climate series as Scenario C. River inflow was modified to reflect potential future development, as in Scenario B. Therefore, in this report, the climate data for Scenarios A and B are the same (historical observations from 1 September 1890 to 31 August 2022), and the climate data for Scenarios C and D are the same (the above historical data scaled to reflect a plausible range of future climates).

1.4.5 Reporting DEM-H elevation and height data

Elevation data are fundamental to assessing dam design and evaluating water storage capacities. For the Victoria and Southern Gulf catchments, the national 1 second hydrological digital elevation model (DEM-H) (~30 m horizontal grid), derived from the SRTM data (Gallant et al., 2011), is the finest-resolution digital elevation dataset available. This dataset covers the entire continent and constitutes the best available data over most of Australia, particularly northern Australia.

The SRTM is based on the Earth Gravitational Model 1996 (EGM96) geoid, for which there is a vertical datum difference with the Australian Height Datum (AHD). The difference between the datum of the two elevation datasets is poorly defined, due to the lack of a well-defined AHD surface across the Australian continent; however, it is generally less than 1 m. For this reason, all heights and elevations derived using the DEM-H are reported here as EGM96 geoid height in metres (mEGM96). It is important to understand the strengths and weaknesses of any elevation dataset used, and the reader is referred to Petheram et al. (2013) for a brief discussion of the DEM-H.

2 Study areas

2.1 Victoria catchment

The Victoria catchment Assessment area in western NT extends from the Timor Sea to approximately 380 km south-east and encompasses a total area of approximately 82,400 km^2 (Preface Figure 1-1). The population of the Assessment area is approximately 2000, with small population centres at Timber Creek, Yarralin, Kalkarindji and Pigeon Hole (ABS, 2021).

The main land use in the Assessment area is for grazing native vegetation (62%), with nature conservation (9%) and other protected areas including Indigenous use (15%) also significant land uses. In the north of the Assessment area lies the Bradshaw Field Training Area, an Australian Government owned facility with its southern boundary following the Victoria River. Cropping (both dryland and irrigated) are very sparsely practised (<0.02%).

2.1.1 Geology

The catchment of the Victoria River is relatively featureless landscape apart from the major river valleys which are incised into a generally flat to undulating topography. The river system drains from the higher ground in the south-east, around 280 m above sea level, towards north-west where it empties into the Joseph Bonaparte Gulf (Figure 2-1). The landscape is characterised by broad alluvial plains associated with the Victoria River and its tributaries, and low hills formed by more resistant strata, which tend to run south-west to north-east. The vegetation cover is dominated by open woodland, with denser stands of trees along major watercourses, and soil plains supporting grasses and low shrubs.

The oldest rocks in the area are of Proterozoic age (2500 to 540 million years old) and consist of repeated thick sequences of sediments, including some units containing significant amounts of dolostone (dolomite-rich rocks that are prone to solution over a geological timescale). These sediments of these units were deposited in a series of basins extending across the area and then gently folded, faulted and uplifted to form highlands. By the end of the Proterozoic, the highlands had been eroded down to a level not far above that of the current topography.

During the Cambrian, 540 to 485 Ma (million years ago), there was widespread extrusion of basalt lava onto the eroded surface of the Proterozoic sediments. This event was followed by deposition of a sequence of limestones and dolomites. Further gentle folding, faulting and uplift then occurred, followed by another cycle of erosion, which started after the Cambrian and continued to the mid-Cretaceous (approximately 100 Ma), again resulting in erosion down to a level not far above that of the current topography. During the remainder of the Cretaceous (to approximately 66 Ma), subsidence and high global sea levels resulted in deposition of a thin succession of Cretaceous shallow marine sandstone, conglomerate and mudstone layers. These layers were probably deposited across the whole area but are now only preserved in the south-east of the catchment.

The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started in the Late Cretaceous, about 70 Ma, and ended in the mid-Cenozoic, about 25 Ma. During this time, stable crustal conditions, subaerial exposure, and prolonged subaerial weathering of the remaining Proterozoic, Cambrian and Cretaceous rocks resulted in the formation of deep weathering profiles and associated iron-cemented cappings on those rocks.

Between the mid-Cenozoic and the present day, there has been gentle uplift and warping of the various surfaces and their weathered cappings. Continued erosion has led to the emergence of the present-day landscape, which has involved the development of incised valley systems that have been superimposed on the underlying Proterozoic rocks. Erosion has produced broader valleys in which the dolomite-rich sediments have been exposed and weathering and solution could occur. Extensive floodplains and coastal deposits have been built up, marginal to modern drainage systems and the coastline.

Potentially, feasible dam sites occur where resistant ridges of rock that have been incised by the river systems outcrop on both sides of river valleys. The rocks are generally weathered to varying degrees, and the depth of weathering, the amount of outcrop on the valley slopes, the occurrence of dolomitic rocks (which may contain solution features), and the width and depth of alluvium in the base of the valley are fundamental controls on the suitability of the potential dam sites.

Where the rocks are relatively unweathered and outcrop on the abutments of the potential dam site, less stripping will be required to achieve a satisfactory founding level for the dam. In general, where stripping removes the more weathered rock, it is anticipated that the Proterozoic sandstones, siltstones, mudstones and conglomerates will form a reasonably watertight dam foundation, requiring conventional grout curtains and foundation preparation. However, because dolostones are soluble over a geological time-scale, it is possible that, where they occur within the Proterozoic sequences, potentially leaky dam abutments and reservoir rims may be present, which would require specialised and costly foundation treatment such as extensive grouting. Where this condition is possible, based on review of the 1:250,000 geological map sheets, it has been noted. The extent and depth of the Cenozoic or Quaternary alluvial sands and gravels in the floor of the valley are also important geological controls on dam feasibility, as these materials will have to be removed to achieve a satisfactory founding level for the dam.

Figure 2-2 shows mineral occurrences and exploration licences in the Victoria catchment.

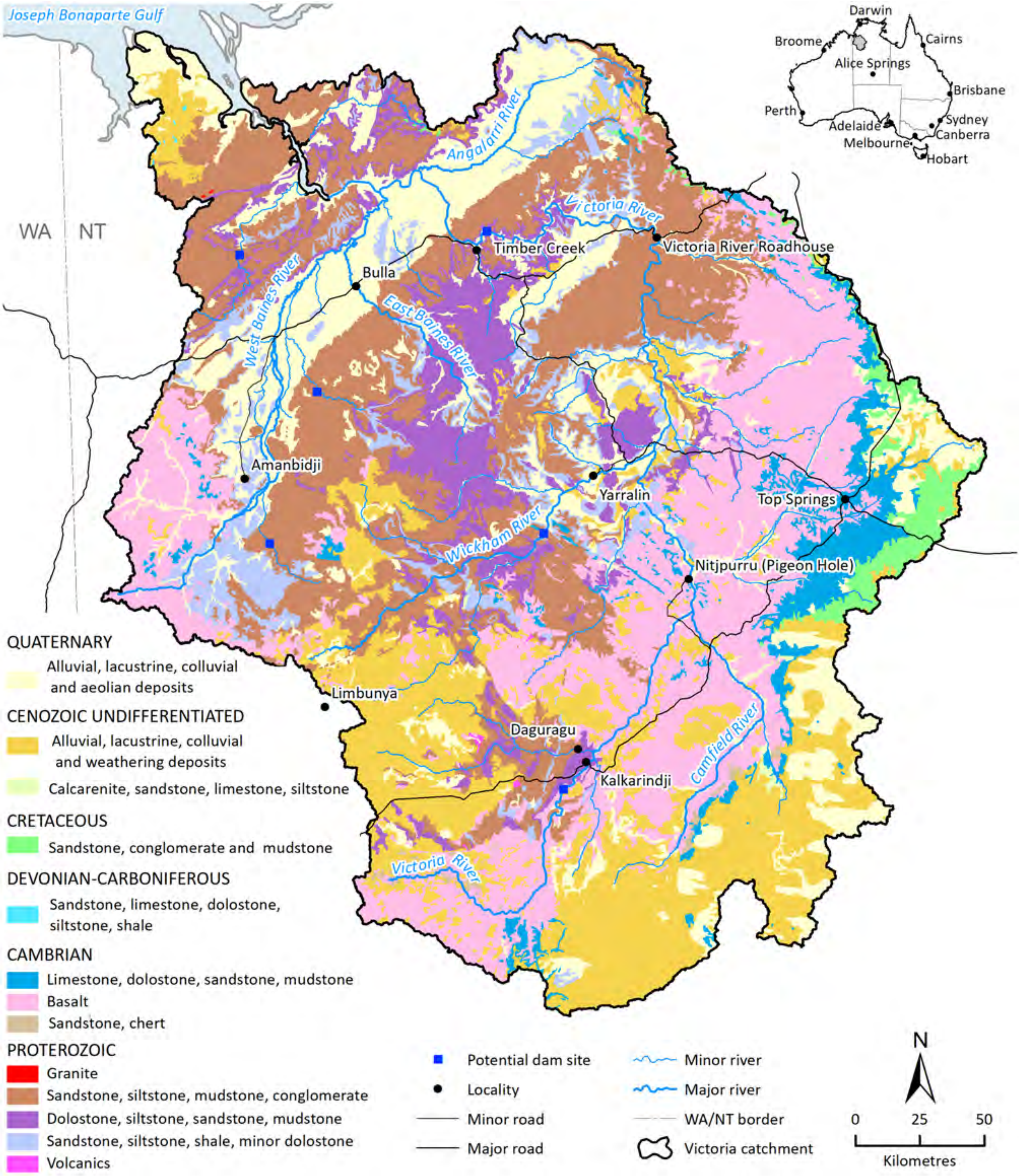

Figure 2-1 Main geological units of the Victoria catchment

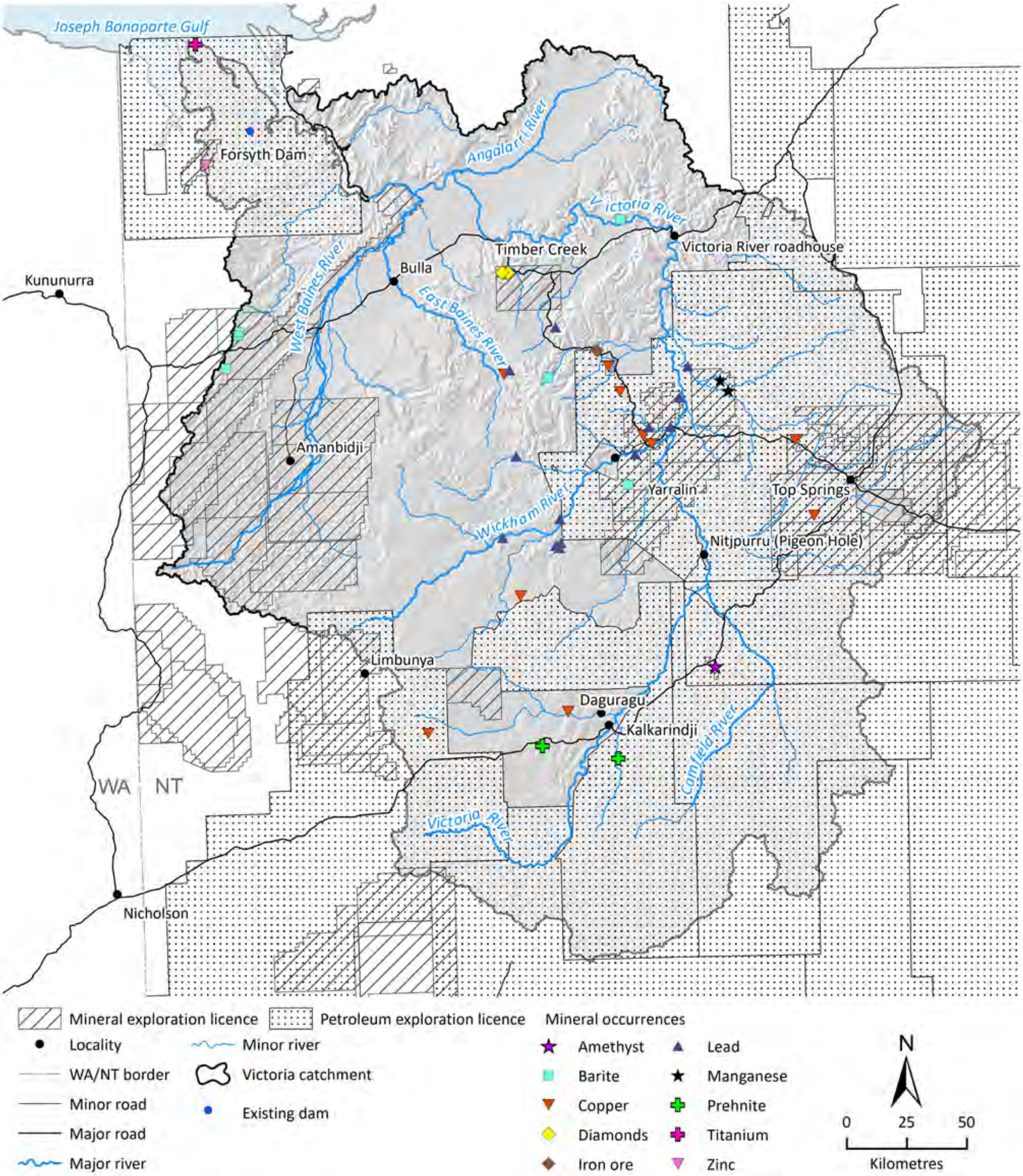

Figure 2-2 Mineral occurrences, exploration licences, and existing dams in the Victoria catchment

Only dams with reservoirs greater than or equal to 5 GL are shown.

Source: companion technical report on socio-economics in the Victoria catchment (Webster et al., 2024a).

2.1.2 Soils

Extensive areas of deep cracking clay soils are found on the broad alluvial plains of the major rivers, particularly the Victoria and Baines. These clay soils are suitable for furrow- or spray-irrigated sugarcane (*Saccharum officinarum*), dry-season cotton (*Gossypium* spp.), grain, pulse and forage crops. Flooding, access, and soil workability limit wet-season cropping, and management needs to consider crop tolerance to seasonal wetness. Deep cracking clay soils are also found scattered throughout the eastern, southern and western parts of the upper Victoria River and are also subject to seasonal wetness. Deep gilgais may restrict land-levelling operations in some of these areas. Areas of very friable loams are found along the Victoria and Wickham rivers, mainly on narrow levees with broader areas scattered throughout the catchment. Although suitable for a range of spray-irrigated grain and forage crops and trickle-irrigated horticultural crops, the levees are generally long thin units of land, restricting irrigation layout and machinery use. These soils are also susceptible to severe sheet and gully erosion and wind erosion. Tertiary level plains and plateaux in the upper catchment contain deep loamy soils, which are suitable for a diverse range of irrigated horticulture, and spray-irrigated grain, pulse and forage crops, timber crops, sugarcane and cotton.

Nearly 60% of the catchment is dissected hills, outcrop, plateaux and scarps, with rocky and/or shallow soils of little agricultural potential. These higher-relief areas give way to lower-relief, lower-sloping land and alluvial plains. The coastal marine plains are seasonally or permanently wet saline soils with potential acid sulfate risks. These poorly drained soils are unsuitable for cropping, although they are prospective for aquaculture. The soils of the Victoria catchment are discussed in more detail in the companion technical report on digital soil mapping and land suitability in the Victoria catchment (Thomas et al., 2024a).

Figure 2-3 presents an index of agricultural versatility for the Victoria catchment, and essentially shows those parts of the Victoria catchment that are considered more and less versatile for agriculture. Versatile agricultural land was calculated by identifying where the highest number of the 14 selected land use options were mapped as being suitable (i.e. suitability classes 1 to 3). See the companion technical report on land suitability in the Victoria catchment for more information (Thomas et al., 2024a).

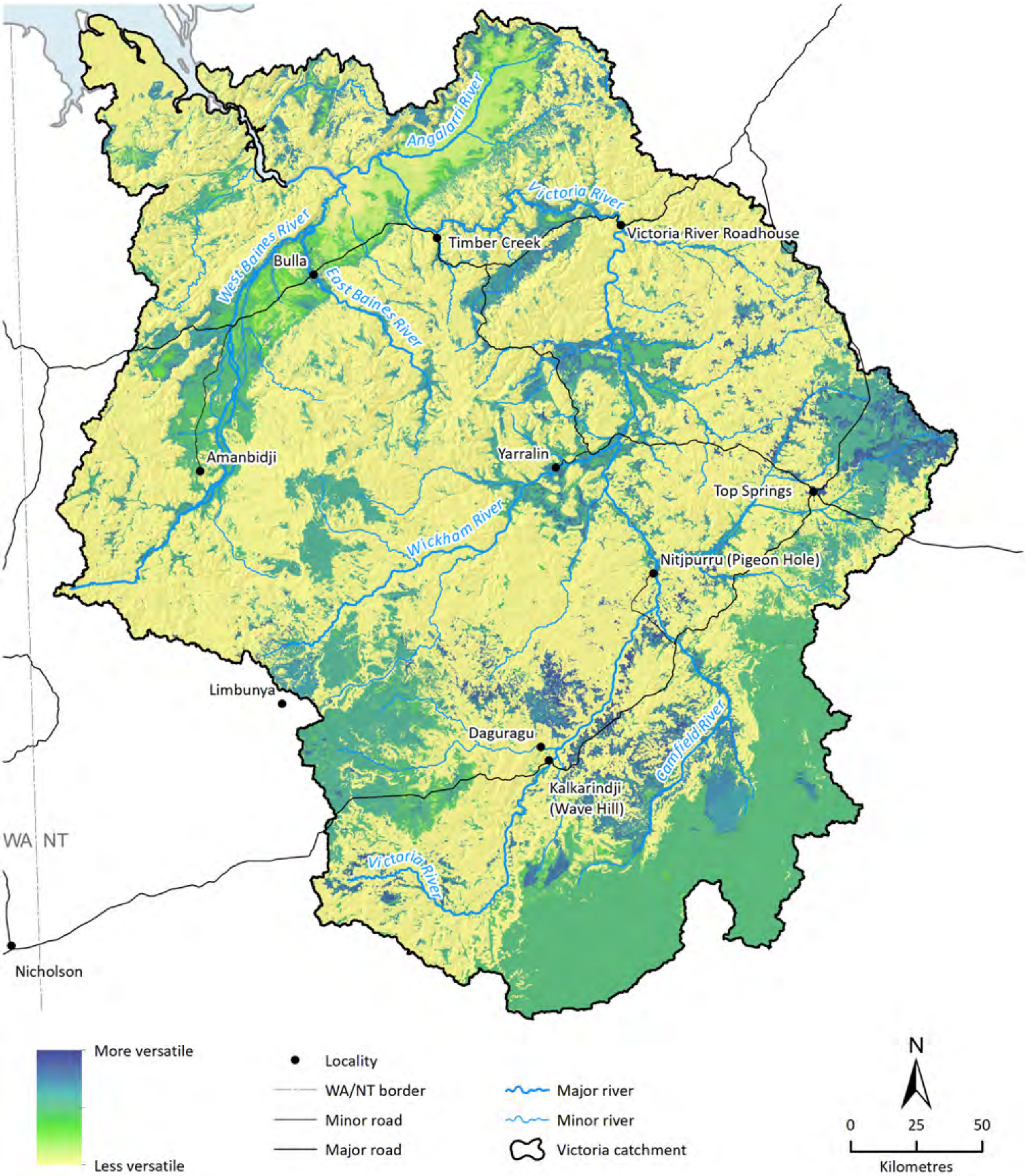

Figure 2-3 Agricultural versatility index map for the Victoria catchment

High index values denote land that is likely to be suitable for more of the 14 selected land use options. Note that the versality index mapped here does not consider flooding, risk of secondary salinisation, or availability of water.

Source: Companion technical report on land suitability, Thomas et al. (2024a)

2.1.3 Hydroclimate

The Victoria catchment has a hot and arid climate. The catchment has a highly seasonal climate with an extended dry season. It receives, a mean annual rainfall of 681 mm, 95% of which falls during the wet season. Mean daily temperatures and potential evaporation are high relative to other parts of Australia. The mean potential evaporation is approximately 1900 mm/year. Overall, the climate of the Victoria catchment generally suits the growing of a wide range of crops, though in most years rainfall would need to be supplemented with irrigation. The variation in rainfall from one year to the next is moderate compared with elsewhere in northern Australia, yet is high compared to other parts of the world with similar mean annual rainfall. The number of consecutive dry years is not unusual in the Victoria catchment, and the intensity of the dry years is similar to that of many centres in the Murray–Darling Basin and the east coast of Australia. Since the 1969 to 1970 cyclone season, the Victoria catchment experienced one tropical cyclone in 21% of cyclone seasons and two tropical cyclones in 6% of seasons.

The Victoria River and its tributaries, the most substantial of which are the Baines, the Wickham, the Armstrong, the Camfield and the Angalarri rivers, define a catchment area of 82,400 km^2. The Victoria River itself has a length of approximately 560 km, from Entrance Island at its mouth to Kalkarindji in the far south of the catchment. Tidal variation at the mouth of the Victoria River is up to 8 m, and these tides propagate upstream to just downstream of Timber Creek (Power and Water Authority Directorate, 1987).

The catchment has a north-to-south rainfall gradient, which influences the local hydrological response. The Camfield River in the drier far south of the catchment has an estimated mean runoff coefficient of 5%, while the Angalarri River in the north-east of the catchment has an estimated mean runoff coefficient of 17%.

The mean annual flow at the catchment outlet of the Victoria River is estimated at 6990 GL, while the median annual flow is estimated at 5730 GL. Annual variation is high, with the annual flow estimated to range between 800 and 23,000 GL. Flow is highly seasonal, with 93% of all flow occurring in the months December to March inclusive.

Approximately 13% of the global climate models (GCMs) project an increase in mean annual rainfall of more than 5%, half project a decrease in mean annual rainfall by more than 5% and about a third indicate ‘little change’ (McJannet et al., 2023).

2.1.4 Ecology

The protected areas located in the Victoria catchment and the marine region include one gazetted national park (Judbarra), a proposed extension to an existing national park (Keep River), two marine national parks, two Indigenous Protected Areas and two Directory of Important Wetlands in Australia (DIWA) sites (Figure 2-4). Judbarra National Park is the second-largest national park in the NT, covering approximately 1,300,000 ha (Australian Government, 2022). Once fully gazetted, the Keep River National Park, including the proposed extension from the neighbouring Keep River catchment into the Victoria catchment, will cover a total area of approximately 272,000 ha, with the goal to have the additional 215,000 ha gazetted by 2026 (Australian Government, 2022; Department of Environment Parks and Water Security, 2023). The two DIWA sites are the Bradshaw Field Training Area and the Legune Wetlands.

The freshwater sections of the Victoria catchment include diverse habitats including ephemeral and persistent rivers, anabranches, wetlands, floodplains, and groundwater-dependent ecosystems. Riparian habitats that fringe the rivers and streams of the Victoria catchment have been rated as having moderate to high cover and structural diversity for riparian vegetation, with some impacts at some locations (Kirby and Faulks, 2004). These riparian habitats include widespread *Eucalyptus camaldulensis* overstorey with *Lophostemon grandiflorus*, *Terminalia platyphylla*, *Pandanus aquaticus* and *Ficus* spp. *Acacia holosericea* and *Eriachne festucacea* occur as dominant understorey species across many parts of the catchment (Kirby and Faulks, 2004).

The Australian Government's Protected Matters Search Tool (PMST; Department of Agriculture, Water and the Environment (2021a)) lists 45 threatened species for the Victoria catchment, four of which are listed as critically endangered (nabarlek (*Petrogale concinna concinna*), rosewood keeled snail (*Ordtrachia septentrionalis*), curlew sandpiper (*Calidris ferruginea*) and the eastern curlew (*Numenius madagascariensis*)). Also listed in the Victoria catchment are 49 migratory species.

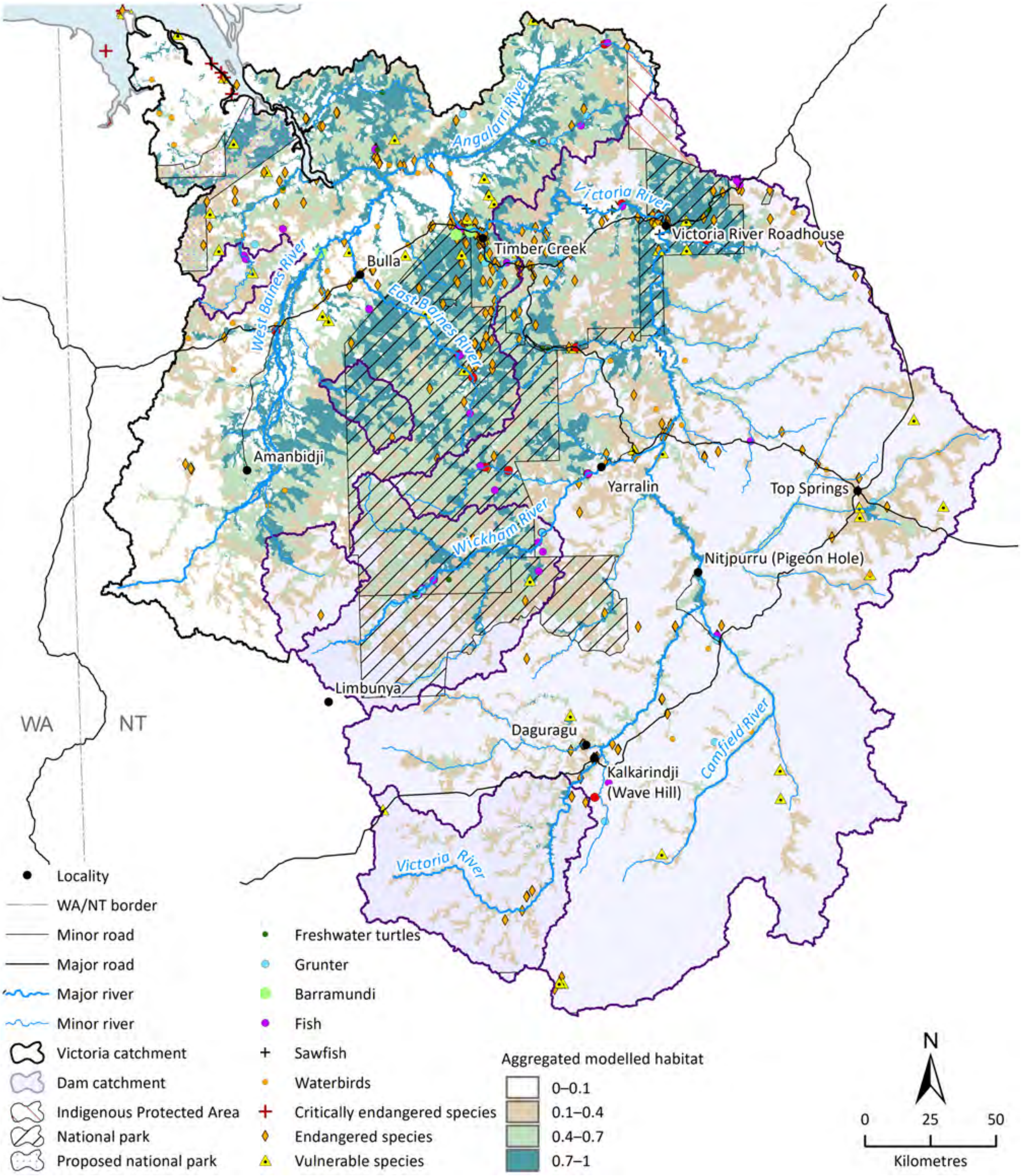

Figure 2-4 Locations of protected areas, important wetlands, listed species, and aggregated modelled asset habitat within the Victoria catchment Assessment area

Protected areas include management areas, mainly for conservation through management intervention as defined by the International Union for Conservation of Nature (IUCN). Endangered species include both national and state/territory listings.

Source: Companion technical report on ecological assets in the Victoria catchment, Stratford et al., 2024.

2.1.5 Existing dams

Forsyth Dam on Legune Station is the only large dam in the Victoria Australian Water Resources Council (AWRC) River Basin, though it is not technically in the catchment of the Victoria River. Rather, the dam (reservoir capacity approximately 35 GL) is sited in a small coastal catchment adjacent to the Victoria River. Water from the dam is released along a creek line and diversion channel system to surface irrigate natural and improved pastures downstream of the dam.

2.2 Southern Gulf catchments

The Southern Gulf catchments have a total area of 108,200 km^2 and are comprised of five AWRC River Basins, all of which discharge into the Gulf of Carpentaria. In order of size these are the (i) Gregory–Nicholson (52,200 km^2); (ii) Leichhardt (33,400 km^2); (iii) Settlement Creek, a collection of small north-east-draining creeks (17,600 km^2), (iv) Morning Inlet (3690 km^2); and (v) the Wellesley Islands in the Gulf of Carpentaria (1200 km^2).

2.2.1 Geology

The landscape of the Southern Gulf catchments is relatively featureless, apart from the major river valleys, which are incised into a generally flat to undulating topography. The river systems drain from the higher ground in the south-west and south, around 250 to 350 m above sea level, towards the north-east, where they cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria (Figure 2-5). The landscape is characterised by broad alluvial plains and low hills formed by more resistant strata. An area of karst limestone occurs in the higher ground to the south-west. Vegetation cover is dominated by open woodland, with denser stands of trees along major watercourses, and soil plains supporting grasses and low shrubs.

The oldest rocks in the area are of Proterozoic age (2500 to 540 million years old) and consist of a thick sequences of sediments, volcanics and minor dolostones. These sediments were deposited in a series of basins extending across the area, and then tightly folded, in places metamorphosed, intruded by granites, dolerites and gabbros, faulted, and finally uplifted to form highlands. By the end of the Proterozoic, the highlands had been eroded down to a level not far above that of the current topography.

During the Cambrian, 540 to 485 Ma, there was minor extrusion of basalt lava onto the eroded surface of the Proterozoic sediments. This event was followed by deposition of a sequence of limestones and dolomites. Further gentle folding, faulting and uplift then occurred followed by another cycle of erosion, which started after the Cambrian and continued to the late Jurassic (approximately 150 Ma) and again resulted in erosion down to a level not far above that of the current topography. During the remainder of the Jurassic and into the Cretaceous, subsidence and high global sea levels resulted in deposition of a thick succession of shallow marine sandstone, conglomerate, mudstone and limestone, with some volcanics, in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria. Thinner Cretaceous sediments that were deposited across the eroded surface of the older formations are now only locally preserved.

The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started in the Late Cretaceous (about 70 Ma) and ended in the mid-Cenozoic (about 25 Ma). During this time, stable crustal conditions, subaerial exposure, and prolonged subaerial weathering of the remaining Proterozoic, Cambrian and Cretaceous rocks resulted in the formation of deep weathering profiles and associated iron-cemented cappings on those rocks. Deposition continued in the broad plains running down to the coast.

Between the mid-Cenozoic and the present day, there has been gentle uplift and warping of the various surfaces and their weathered cappings. Continued erosion has led to the emergence of the present-day landscape, which involved the development of incised valley systems that have been superimposed on the underlying Proterozoic rocks, with erosion producing broader valleys. Extensive floodplains and coastal deposits have been built up, marginal to modern drainage systems and the coastline.

Potentially feasible dam sites occur where resistant ridges of rock that have been incised by the river systems outcrop on both sides of river valleys. The rocks are generally weathered to varying degrees, and the depth of weathering, the amount of outcrop on the valley slopes, the occurrence of limestone or dolomitic rocks (which may contain solution features that could cause leakage), and the width and depth of alluvium in the base of the valley are fundamental controls on the suitability of the potential dam sites.

Where the rocks are relatively unweathered and outcrop on the abutments of the potential dam site, less stripping will be required to achieve a satisfactory founding level for the dam. In general, where stripping removes the more weathered rock, it is anticipated that the Proterozoic sandstones, siltstones, mudstones and conglomerates will form a reasonably watertight dam foundation requiring conventional grout curtains and foundation preparation.

However, because dolostones are soluble over a geological time-scale, it is possible that, where they occur within the Proterozoic sequences, potentially leaky dam abutments and reservoir rims may be present, which would require specialised and costly foundation treatment such as extensive grouting. Where this condition is possible, based on review of the 1:250,000 geological map sheets, it has been noted. The extent and depth of the Cenozoic or Quaternary alluvial sands and gravels in the floor of the valley are also important geological controls on dam feasibility, as these materials will have to be removed to achieve a satisfactory founding level for the dam.

Figure 2-6 shows mineral occurrences and exploration licences in the Southern Gulf catchments.

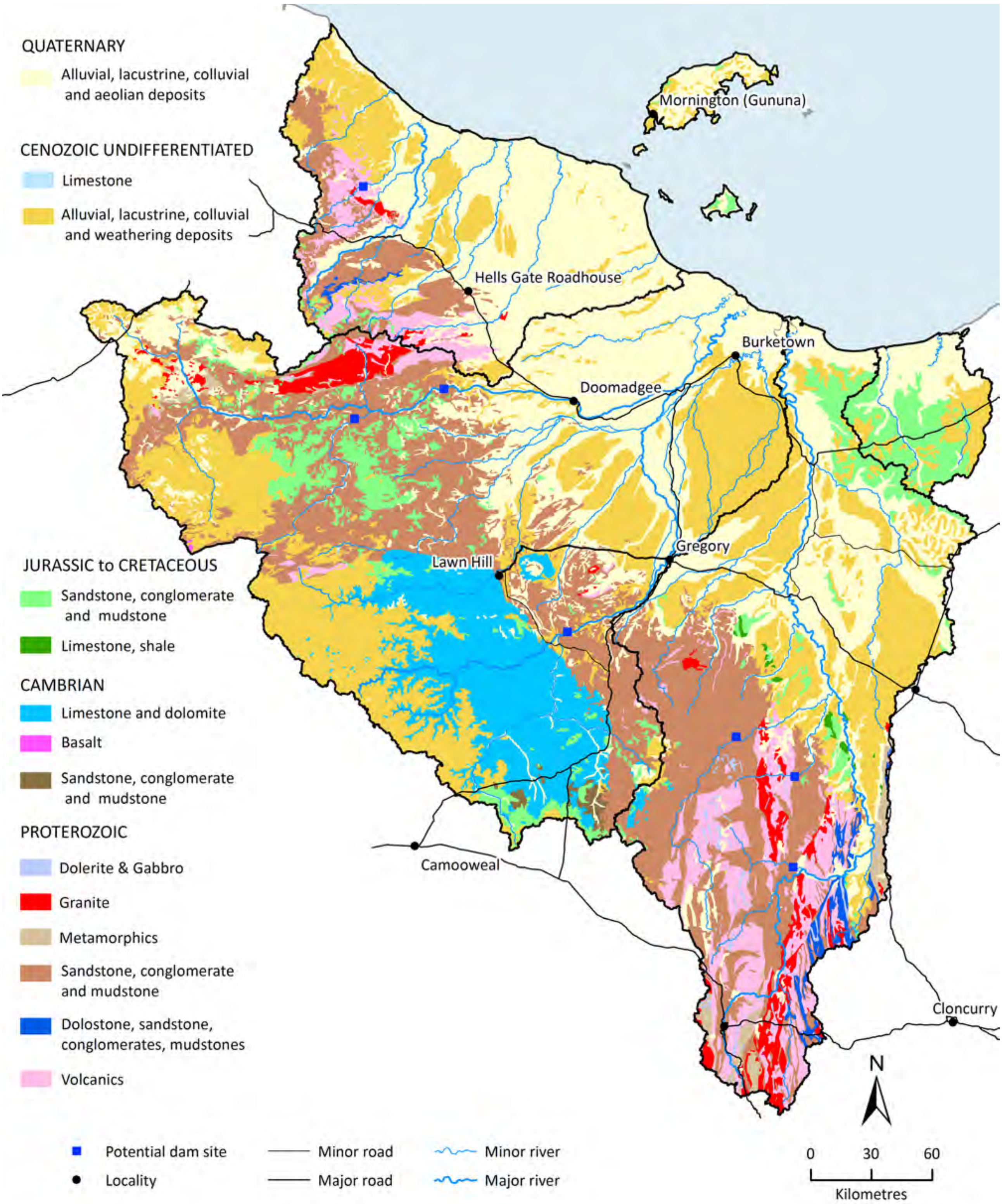

Figure 2-5 Main geological units of the Southern Gulf catchments

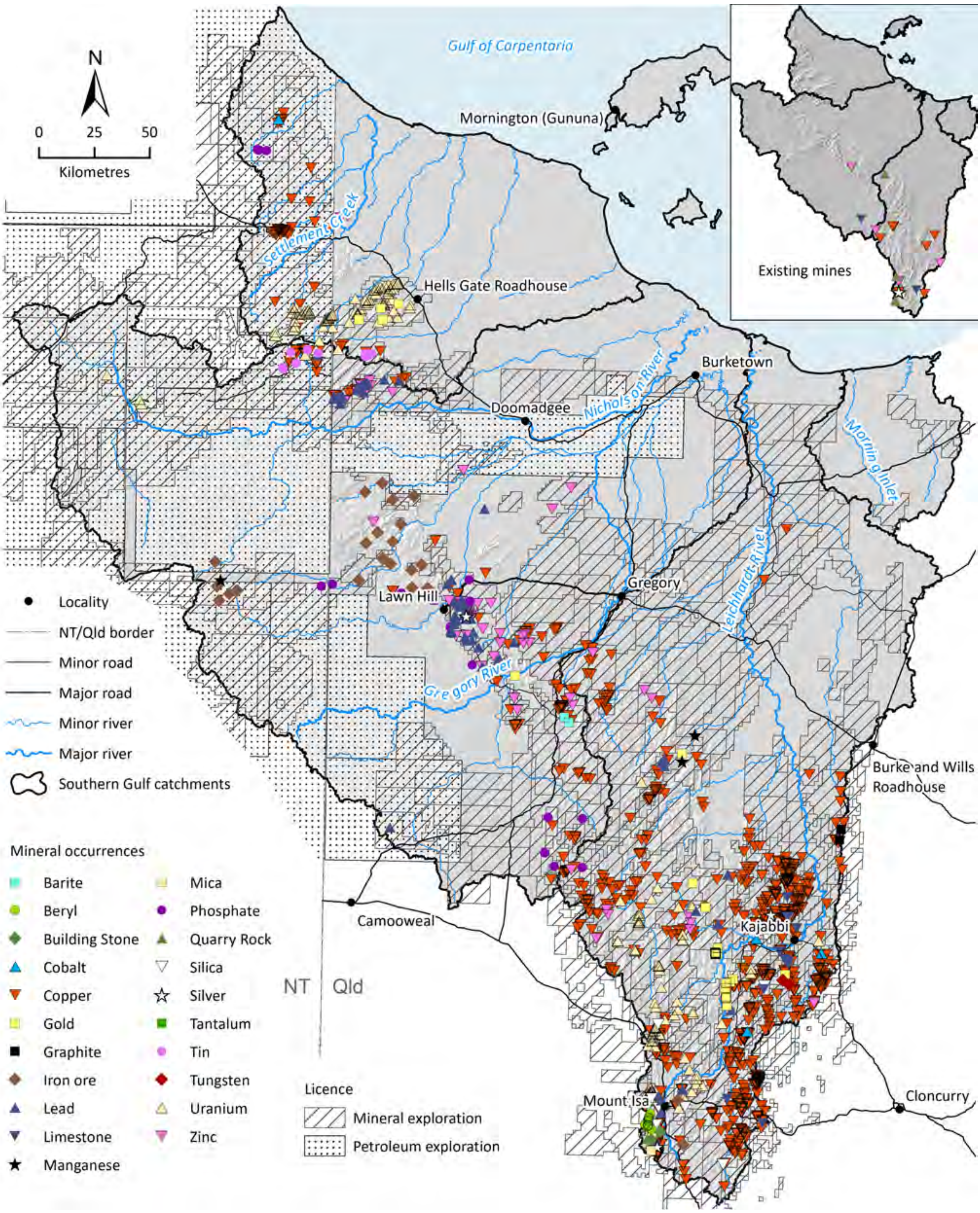

Figure 2-6 Mines, mineral occurrences, and exploration licences in the Southern Gulf catchments

Existing mines shown in inset.

Source: companion technical report on socio-economics in the Southern Gulf catchments, Webster et al., 2024b.

2.2.2 Soils

A diverse range of soils occurs from shallow and/or rocky soils on the ranges to deep cracking clay soils on the Carpentaria plain and Barkly Tableland. The cracking clays consist of medium to heavy clays that crack when dry and swell when wet. They have a high soil water–holding capacity, and the cracking clays on the Armraynald Plain are suited to a variety of vegetables (except root crops), rice (*Oryza* spp.), sugarcane (*Saccharum officinarum*) and dry-season grain, forage, pulse crops, sweetcorn (*Zea mays* convar. *saccharata* var. *rugosa*) and cotton (*Gossypium* spp.). On the Barkly Tableland, the cracking clays are suited to trickle-irrigated mangoes (*Mangifera indica*) and vegetables as well as wet-season cotton, grain and forage crops. Along the middle reaches of the Leichhardt River a moderately well-drained, friable non-cracking clay or clay loam soil has formed on the floodplains. On the floodplains of the upper reaches of the Leichhardt River a well-drained, sandy loam over a structured red clay subsoil has formed. Both soils along the Leichhardt are suited to vegetables, sugarcane, oilseed, sweetcorn and dry-season grain, forage, pulse crops and cotton. On the Doomadgee Plain, Donors Plateau, in the Gulf Fall and on the elevated terraces north of the Nicholson River, sandy soils have formed. In the absence of irrigation, the agricultural potential of these soils is low, but there is potential for irrigated horticulture utilising trickle or micro-irrigation systems. Loamy soils have formed along the Nicholson River and also on the Doomadgee and Cloncurry plains and other isolated areas. These soils are highly suited to irrigated agriculture, but the characteristically narrow, ribbon-like distribution of these soils along the Nicholson River may limit infrastructure layout and consequently agricultural opportunities. The red loamy soils on the Cloncurry Plain are shallower, sandier, and commonly have gravel and ironstone throughout the profile. Consequently, these soils have lower water-holding capacity, and irrigation potential is limited to spray- and trickle-irrigated crops on the moderately deep to deep soils.

Wet soils occur on local alluvia along creeks and in swamps, particularly between Lilly and Moonlight creeks on the Doomadgee Plain and the tidal flats and wetlands of the Karumba Plain. The soils are very poorly drained, and their agricultural potential is limited. Shallow soils or rocky soils occur extensively in more than half of the Assessment area, particularly in the mountainous Isa Highlands, Gulf Fall, dissected Barkly Tableland and Donors Plateau. Their agricultural potential is very low. The soils of the Southern Gulf catchments are discussed in more detail in the companion technical report on land suitability in the Southern Gulf catchments (Thomas et al., 2024b).

Figure 2-7 presents an index of agricultural versatility for the Southern Gulf catchments, and essentially shows those parts of the Southern Gulf catchments that are considered more and less versatile for agriculture. Versatile agricultural land was calculated by identifying where the highest number of the 14 selected land use options were mapped as being suitable (i.e. suitability classes 1 to 3). See the companion technical report on digital soil mapping and land suitability in the Southern Gulf catchments for more information (Thomas et al., 2024b).

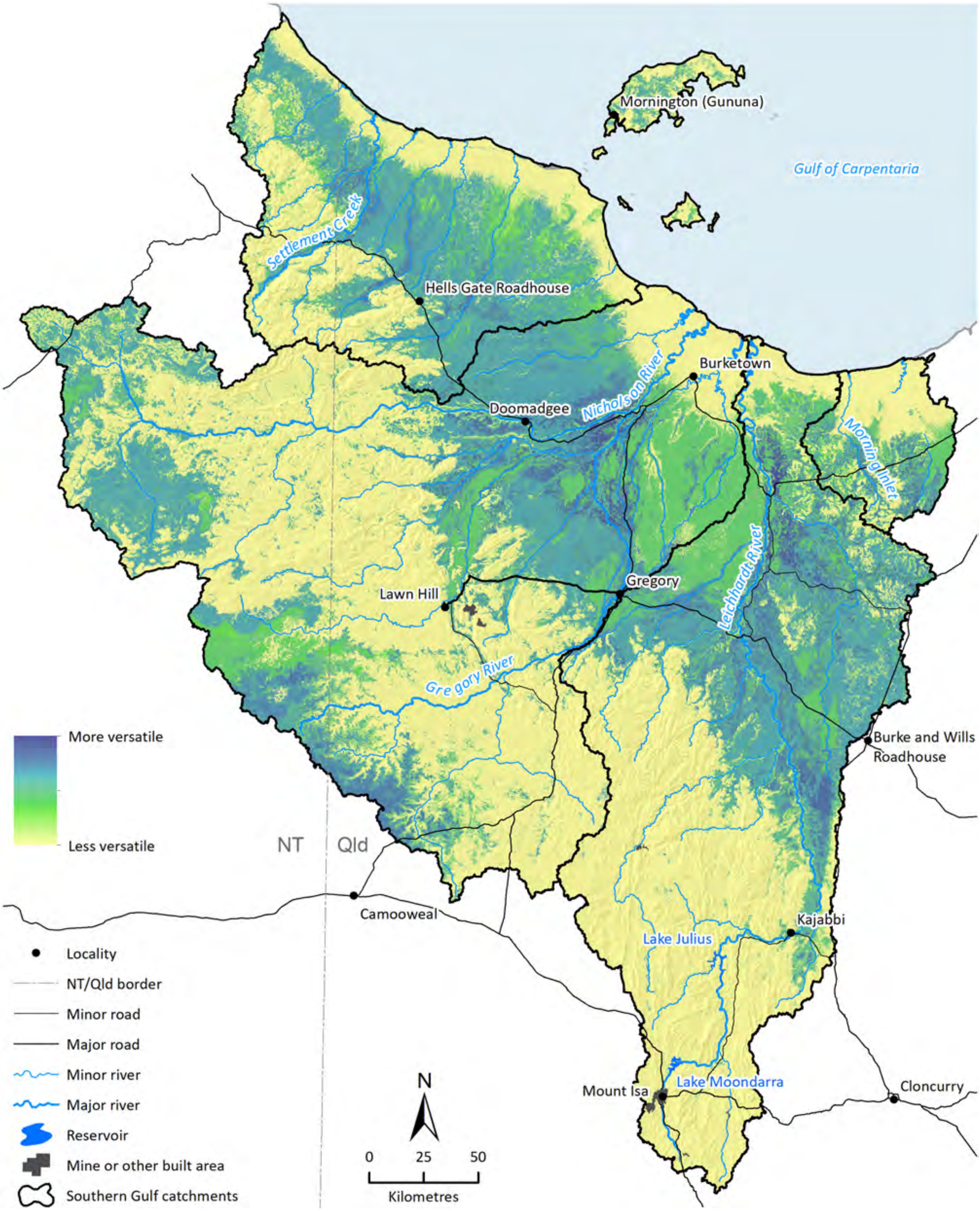

Figure 2-7 Agricultural versatility index map for the Southern Gulf catchments

High index values denote land that is likely to be suitable for more of the 14 selected land use options. Note that the versality index mapped here does not consider flooding, risk of secondary salinisation, or availability of water.

Source: Companion technical report on land suitability in the Southern Gulf catchments, Thomas et al. (2024b)

2.2.3 Hydroclimate

The Southern Gulf catchments have a hot and arid climate. The catchment has a highly seasonal climate with an extended dry season. It receives a mean rainfall of 602 mm, 94% of which falls during the wet season. The mean daily temperatures and potential evaporation are high relative to other parts of Australia. The mean potential evaporation is approximately 1900 mm/year.

Overall, the climate of the Southern Gulf catchments generally suits the growing of a wide range of crops, though in most years rainfall would need to be supplemented with irrigation. The variation in rainfall from one year to the next is moderately high compared with elsewhere in northern Australia and high compared with other parts of the world with similar mean annual rainfall. The number of consecutive dry years is not unusual in the Southern Gulf catchments, and the intensity of the dry years is similar to that of many centres in the Murray–Darling Basin and along the east coast of Australia. Since the 1969 to 1970 cyclone season, the Southern Gulf catchments experienced one tropical cyclone in 36% of cyclone seasons and two tropical cyclones in 4% of seasons.

The flow paths of the Nicholson, and more particularly the Gregory River, are complex in the lower portions of the catchment on the flatter Armraynald Plain. The lower Gregory River has multiple distributary flow paths, which suggest some mixing with the Nicholson, if only at high flows. One branch of the Gregory takes the name 'Albert River' and is assumed to be the main channel of the Gregory River that empties into the Gulf of Carpentaria. The median annual discharge from the Gregory–Nicholson rivers and associated coastal waterways was estimated to be 1873 GL (Gibbs et al., 2024a,b). The median annual discharge from the Leichhardt River was estimated to be 1211 GL.

The median annual flow of Settlement Creek and its associated coastal waterways was estimated to be 1304 GL. Similarly, the Morning Inlet catchment has an area of 3690 km^2 and an estimated median annual flow of 195 GL.

Approximately 16% of the GCMs project an increase in mean annual rainfall by more than 5%, 40% project a decrease in mean annual rainfall by more than 5%, and about 44% indicate 'little change' (McJannet et al., 2023).

2.2.4 Ecology

The protected areas located in the Southern Gulf catchments include the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage–listed Australian Fossil Mammal Sites (Riversleigh), three Indigenous Protected Areas, namely Ganalanga-Mindibirrina, Nijinda Durlga and Thuwathu/Bujimulla, and Boodjamulla (Lawn Hill) and Finucane Island national parks and other conservation parks (Figure 2-8). In addition to these protected areas, the Southern Gulf catchments contain 13 nationally significant wetlands listed in the DIWA: Bluebush Swamp, Buffalo Lake Aggregation, Forsyth Island Wetlands, Gregory River, Lake Julius, Lake Moondarra, Lawn Hill Gorge, Marless Lagoon Aggregation, Musselbrook Creek Aggregation, Nicholson Delta Aggregation, Southern Gulf Aggregation, Thorntonia Aggregation and Wentworth Aggregation (Figure 2-8) (Department of Agriculture, Water and the Environment, 2021b). These DIWA-listed wetlands include a variety of wetland types, ranging from estuarine wetlands with salt flats and saltmarshes to man-made lakes and spring-fed creeks and rivers, and together with other freshwater-dependent systems they provide important habitat for a range of species, including the largetooth sawfish (*Pristis pristis*; vulnerable) and the Gulf snapping turtle (*Elseya lavarackorum*; endangered).

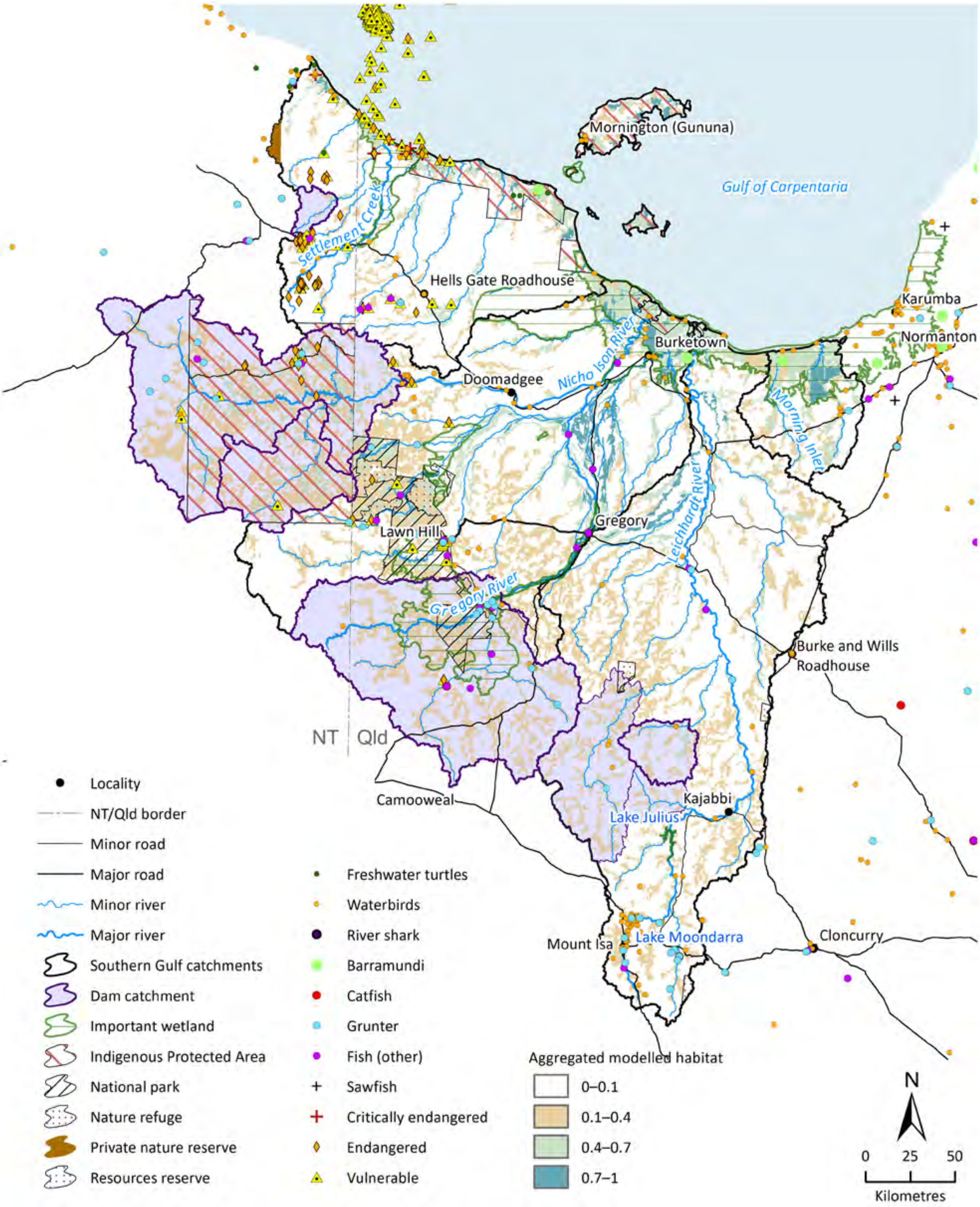

Figure 2-8 Locations of protected areas, important wetlands, listed species, and aggregated modelled asset habitat within the Southern Gulf catchments Assessment area

Protected areas include management areas mainly for conservation through management intervention as defined by the International Union for Conservation of Nature (IUCN). Endangered species include both national and state/territory listings.

Source: Companion technical report on ecological assets in the Southern Gulf catchments, Merrin et al., 2024.

The marine and estuarine environments of the Southern Gulf catchments, including the mainland area adjacent to Mornington and Sweers islands, have extensive intertidal flats and estuarine communities, including mangroves, salt flats and seagrass habitats. These habitats are highly productive, have high cultural value, and are often of national significance (Poiner et al., 1987) and provide important food and habitat for species including dugongs (*Dugong dugon*), green turtles (*Chelonia mydas*) and prawns (Loneragan et al., 1997; Poiner et al., 1987).

The Australian Government's PMST (Department of Agriculture, Water and the Environment, 2021c) lists 40 threatened species for the Southern Gulf catchments, four of which are listed as critically endangered (curlew sandpiper (*Calidris ferruginea*), great knot (*Calidris tenuirostris*), eastern curlew (*Numenius madagascariensis*) and speartooth shark (*Glyphis glyphis*)). Also listed are 64 migratory species that use the Southern Gulf catchments as a feeding ground/nesting area.

2.2.5 Existing dams

Five dams in the Leichhardt catchment are listed in the Australian National Committee on Large Dam database.

The two dams with the largest reservoirs are Julius Dam and Leichhardt Creek Dam (Lake Moondarra). Julius Dam forms Lake Julius, a reservoir of approximately 108 GL capacity on the Leichhardt River that is used in conjunction with Lake Moondarra , a reservoir of 107 GL capacity further upstream, to supply water for urban, mining and industrial use around Mount Isa and Cloncurry.). The three other large instream dams are Greenstone Creek/Lake Waggaboonyah (13.6 GL capacity), East Leichhardt Dam/Lake Mary Kathleen (12 GL capacity) and Rifle Creek Dam (9.5 GL capacity). With the exception of East Leichhardt Dam, which is now only used for recreation, the dams supply water for mining, industry and town water supply. Rifle Creek dam was the original water supply for Mount Isa.

There are no large instream dams elsewhere in the Southern Gulf catchments although there are a number of on-farm dams are in the Leichhardt catchment; notably, several large offstream storages at Lorraine Station and a large farm-scale gully dam on Wernadinga Station, which can supply water for irrigated agriculture. The only instream water infrastructure in the Nicholson catchment is the Doomadgee Weir, a long (~850 m) low weir (capacity < 1 GL) parallel to the Doomadgee Road crossing of the Nicholson River. Across the study area there are numerous small dams used for stock and domestic use.

3 Methods

3.1 Large instream and offstream dams

The first phase of the investigation into large dams involved: (i) reviewing reports describing all large dam proposals that had been the subject of earlier or current investigations, and (ii) running the DamSite model (Petheram et al., 2017a) to ensure no potential dam options had been overlooked. These two activities were undertaken concurrently and are described in Section 3.1.1 and Section 3.1.2 respectively.

Based on the review of the existing literature and the DamSite model results, Section 3.1.3 lists the sites selected for pre-feasibility analysis, and Section 3.1.4 summarises the methods by which each potential dam site was assessed and outlines the method by which potential dam sites were selected for pre-feasibility analysis.

3.1.1 Review of past literature

Victoria catchment

The only study identified in the literature that looked at surface water storage in the Victoria catchment was a study undertaken in 1995 by the NT Government (Tickell and Rajaratnam, 1995) who undertook a water resource survey of Legune Station in the Victoria catchment. This evaluation included evaluating small gully dams, excavated tanks and modified waterholes.

Southern Gulf catchments

Excluding the existing dams in the Southern Gulf catchments, two past studies of potential dam sites in the Southern Gulf catchments were identified in the Queensland Government library, both undertaken by the Queensland Government Irrigation and Water Supply Commission (IWSC).

In 1969, the IWSC undertook a preliminary investigation of dam sites on Gunpowder Creek (AMTD 65.6 miles) and Gregory River (AMTD 106.7 miles) in the Leichhardt and Gregory–Nicholson catchments, respectively (IWSC 1969). Both sites were investigated by the IWSC for their potential to supply water for mineral development by the company Broken Hill South Pty Ltd. Secondary objectives of the investigation were to determine the possibility of ‘fuller development’ of the two sites (e.g. possibly enabling further mineral development or irrigation use).

A second study completed in 1974 investigated a dam site at Gunpowder Creek (AMTD 108.7 km) to supply water to a phosphate development. The study specifically focused on issues related to site access (IWSC 1974).

3.1.2 DamSite modelling

To ensure that potential dam sites across the Victoria and Southern Gulf catchments were objectively and consistently assessed, the DamSite model (Read et al., 2012; Petheram et al., 2017b) was applied across the entire study area. This model is a series of algorithms that automatically determines favourable locations in the landscape as sites for intermediate-to-large water storages and has been previously applied successfully to the Flinders and Gilbert catchments (Petheram et al., 2013).

Broadly, the approach involved calculating the potential dam and reservoir dimensions of every location in the Victoria and Southern Gulf catchments at 1 m height increments, constructing saddle dams as required, and using the national 1 second hydrological digital elevation model (DEM-H), the best freely available DEM across northern Australia.

The DamSite model then calculated a 'preliminary yield' (85% annual time reliability) at the dam wall, using the computationally efficient Gould–Dincer Gamma (GDG) method (McMahon and Adeloye, 2005; Petheram et al., 2008) for calculating the water yield of carry-over storages (i.e. large dams where water can be carried over from one year to the next) and a within-year storage yield method (Petheram et al., 2017a). This was done for each 1-m increment dam height at each site, and for over 100 heights at some sites. For each height increment, the 'preliminary yield' was selected from the larger of the GDG yield and within-year yield estimates. At each site and for each 1-m increment dam height, the model calculated an approximate unit cost for a dam structure based on DEM-H elevation profile along the dam and saddle dam axis and type, and the quantities of materials required and their unit cost rates. The cost algorithm effectively applies a penalty to higher and longer dam wall structures.

More detail on the DamSite model is provided by Read et al. (2012), Petheram et al. (2013) and Petheram et al. (2017a). Since these publications, however, the DamSite model dam cost algorithm has been substantially revised. The new cost algorithm is described in Petheram et al. (2017a).

DamSite model parameters as applied to the Victoria and Southern Gulf catchments

The DamSite model as applied to the Victoria and Southern Gulf catchments for assessing large dams was parameterised as follows:

- The minimum catchment area assessed was 2 km^2.
- The minimum wall height was 15 m.
- Gridded runoff data were sourced from the Sacramento model runs for each of the study areas with model parameters sourced from the companion technical reports on river modelling calibration in the Victoria (Hughes et al., 2024a) and Southern Gulf (Gibbs et al., 2024a) catchments.
- Skewness was 0.943 (based on Petheram et al., 2008).
- Dam yield was evaluated at 85% annual time reliability.
- Minimum and maximum spillway widths were 75 and 400 m, respectively.
- Cost of land was $750/ha.
- Generic cost of an access road was $75 million.
- Generic cost of power supply was $2.5 million.
- River bed foundation depth was assumed to be 6 m.
- Contingency factor was 40%.

- Abutment foundation depth was 7 m for the Victoria catchment and 4 m for the Southern Gulf catchments.

The results of the DamSite model were summarised to identify the most cost-effective potential dam sites. This was done by presenting the results in terms of:

- the ratio of reservoir capacity (i.e. reservoir volume at full supply level (FSL)) to cost of dam construction, also referred to as maximum volume per unit cost ($VpUC_{max}$). This measure is useful for identifying parts of the landscape that are particularly topographically suitable for large offstream storages
- the ratio of reservoir yield to cost of dam construction, also referred to as maximum yield per unit cost ($YpUC_{max}$). This measure is particularly useful for identifying sites that are topographically and hydrologically suitable for the construction of large instream dams.

The results of the DamSite analysis in the Victoria and Southern Gulf catchments are presented in sections 4.1 and 5.1.

Note that the DamSite model was also used to assess on-farm dams using a smaller catchment area and wall height. The method and parameters used to assess on-farm dams are detailed in Section 3.2.2.

3.1.3 Potential dam site selection

Based on the DamSite modelling, a 'long-list' of approximately 43 and 29 potential dam sites geographically spread across the Victoria and Southern Gulf catchments, respectively, were selected for an initial cursory desktop geological evaluation. The sites were selected based on having a relatively favourable ratio of reservoir yield to unit cost, as calculated by the DamSite model, and a broad geographic spread across each of the study areas. The geological desktop evaluation was undertaken using satellite imagery and 1:250,000 geological mapping data.

Taking into consideration the initial desktop geological evaluation, general geographic location, water yield, modelled dam cost, and proximity to soil potentially suitable for irrigated agriculture, a short-list of potential dams was selected for pre-feasibility analysis in each of the study areas. In the Victoria catchment, six sites were short-listed and in the Southern Gulf catchments seven sites were short-listed.

For the short-listed sites, dam yields were revised using inflows directly from the Victoria (Hughes et al., 2024b) and Southern Gulf (Gibbs et al., 2024b) river system models. Modelled costs were also revised, using the ALOS (Advanced Land Observing Satellite) DEM to extract the dam site axis elevation profile (as opposed to the DamSite model costing, which was based on the SRTM based DEM-H). Based on the revised yields and modelled cost data, four and seven sites were selected for pre-feasibility analysis in the Victoria and Southern Gulf catchments, respectively. In the Victoria catchment, an additional dam site was evaluated based on its potential to mitigate flooding of downstream communities, and another dam site was evaluated based on its potential to generate hydro-electric power.

For any of these options to advance to construction, far more comprehensive studies would be required, as outlined in Section 1.2. Studies of that level of detail were beyond the scope of this pre-feasibility-level Assessment. It is also important to note that while these sites represent some of the more promising large instream dams in the Victoria and Southern Gulf catchments, other sites may be more favourable depending upon the location and nature of the demand, and land tenure and regulatory considerations.

3.1.4 Summary of criteria used to assess large dams as part of pre-feasibility analysis and methods used to select sites

The short-listed sites in each study area were assessed and reported against a standard set of 17 criteria (listed in Table 3-1) to facilitate comparison of different sites. Table 3-1 summarises the methods by which the criteria were investigated.

From the short-listed sites in each of the Victoria and Southern Gulf catchments, two sites were selected for a manual detailed dam cost estimate at a nominal FSL (FSL selection being informed using the DamSite modelling results and area of soil suitable for irrigated agriculture downstream). Data for these sites are presented in sections 4.3 and 5.3 for the Victoria and Southern Gulf catchments, respectively. Data tables and associated figures for the remaining short-listed sites in the Victoria and Southern Gulf catchments are presented in appendices B1 and B2, respectively.

Table 3-1 Criteria used to assess potential dam sites

PARAMETER	DESCRIPTION
Previous investigations	Web-based searches and library searches of NT and Queensland government databases.
Description of potential dam configuration	An overview of a dam configuration based on recent data, methods and contemporary thinking.
Regional geology	The regional geology for each dam site was assessed using satellite imagery and the NT and Qld 1:250,000 geology series. All geological interpretations are based on viewing existing geological maps and satellite imagery and reading regional geological survey memoirs.
Site geology	The site geology for each dam site was assessed using the NT and Qld 1:250,000 geology series. No geological field studies were undertaken in the Victoria or Southern Gulf study areas. All geological interpretations are based on viewing existing geological maps and satellite imagery and reading regional geological survey memoirs.
Reservoir rim stability and leakage potential	These parameters were assessed by overlaying the inundated area at the selected full supply level (FSL) and 1% annual exceedance probability (AEP) flood event on satellite imagery and 1:250,000 geology data.
Potential structural arrangement	Potential conceptual arrangements were developed by the Assessment’s water infrastructure planner, based on contemporary dam design concepts and thinking.
Availability of construction materials	Based on 1:250,000 geology data and proximity to known quarry locations.
Catchment area	Catchment areas were derived from the Shuttle Radar Topographic Mission (SRTM) national 1 second hydrological digital elevation model (DEM-H).
Flow data	Simulated streamflow metrics were calculated using output from the Australian Water Resources Assessment river system model (AWRA-R) models produced by the Assessment (see river modelling companion technical reports for the Victoria catchment (Hughes et al. (2024b) and Gibbs et al. (2024b)).
Storage capacity	Storage capacity was derived from the DEM-H, unless stated otherwise. For potential dams, the dead storage volume was assumed to occur at 5 m above the river bed (typically 1% to 2% of the reservoir capacity at FSL).

PARAMETER	DESCRIPTION
Reservoir yield assessment at dam wall	A behaviour analysis (BHA) model (McMahon and Adeloye, 2005) was used to assess the relationship between yield, reliability and storage volume under Scenario B (historical daily climate data, potential dam development) for a range of dam wall heights (i.e. yield was assessed at 1-m height increments from 5 m above river bed to a maximum height beyond which a dam would not be feasible) and a perennial crop demand pattern (Figure 3-1) using the baseline river model (Hughes et al., 2024b and Gibbs et al., 2024b). Inflows to the BHA model were generated by the locally calibrated AWRA-R (river system) model and the AWRA-L (landscape) model (see companion technical report on river modelling simulation (Hughes et al. (2024b) and Gibbs et al. (2024b)). Table 3-2 and Table 3-3 lists the AWRA-R nodes from the Victoria and Southern Gulf river models respectively, which simulated streamflow data were extracted for input into the BHA model. A generic perennial crop demand pattern was assumed. The performance of each reservoir was reported in terms of the annual time reliability and the volumetric reliability (McMahon and Adeloye, 2005). These performance criteria are sensitive to particular aspects of unsatisfactory operation during periods of low reservoir inflows. The inability of a reservoir or system of reservoirs to provide the target demand during a given period is commonly described as a supply failure. For selected shortlisted sites in the Southern Gulf catchments reservoir yields are reported assuming full use of existing entitlements. These are reproduced from the companion technical report on river model simulation in the Southern Gulf catchments (Gibbs et al., 2024b).
Potential use of supply	Based on soil- and land-suitability information compiled by the Assessment (see companion technical report on digital soil mapping and land suitability for the Victoria and Southern Gulf catchments, Thomas et al. (2024a,b)). Note, water may also potentially be used for mining and town water supply though the quantities of water for these uses is considerably less than irrigated agriculture (see companion technical report on socio-economics in the Victoria and Southern Gulf catchments, Webster et al., 2024a,b).
Estimated rates of reservoir sedimentation	Sedimentation rates were calculated using estimated sediment yields and the FSL dam capacity for each site. Sediment yields were calculated using an empirical relationship derived from sediment yield studies across northern Australia (Tomkins, 2013). Rates of reservoir sedimentation are presented for 30 and 100 years and the number of years taken to 100% infill. Minimum (best-case), expected and maximum (worst-case) estimates are provided.
Environmental considerations	Data on the ecology and distributions of ecological assets for the Victoria and Southern Gulf catchments were obtained from the companion technical reports on aquatic ecology in the Victoria (Stratford et al. (2024) and Southern Gulf (Merrin et al. (2024)) catchments. These datasets were supplemented with information on endangered species at both national and state/territory levels. Modelled species distribution data were generated using ‘generalised linear models,’ utilising presence-only data from across northern Australia and relevant environmental variables. The models used a threshold of 0.5 and above to indicate suitable habitat for each modelled species. A cumulative map of asset-suitable habitat was then created by aggregating all assets for each catchment and subsequently rescaling. It should be noted that, due to a range of factors, records of species are sparse across these catchments. Key datasets used are described in the companion technical reports on ecological assets in the Victoria (Stratford et al., 2024) and Southern Gulf (Merrin et al., 2024) catchments. This was a desktop analysis.

PARAMETER	DESCRIPTION
	Habitat fragmentation and barrier to movement of aquatic species The potential effects of a dam wall in impeding the movement of aquatic species were evaluated by determining the percentage of the modelled suitable habitat within the dam catchments compared with the species' suitable habitat across the entire Victoria (11 species) or Southern Gulf (10 species) catchments. Species modelled for both catchments were: the mouth almighty (*Glossamia aprion*), western rainbow fish (*Melanotaenia australis*), eastern rainbow fish (*Melanotaenia splendida*), the fork-tailed catfish (*Neoarius graeffei*), the largetooth sawfish (*Pristis pristis*), barramundi (*Lates calcarifer*), spangled grunter (*Leiopotherapon unicolor*) and the northern snake-necked turtle (*Chelodina oblonga oblonga*). In addition, the Victoria catchment included the northern snapping turtle (*Elseya dentata*), the speartooth shark (*Glyphis glyphis*) and the northern river shark (*Glyphis garricki*); and the Southern Gulf catchments included the sooty grunter (*Hephaestus fuliginosus*) and the bull shark (*Carcharhinus leucas*). **Ecological implications of inundation** The ecological implications of inundation were assessed in terms of potential habitat loss for the local biodiversity. This was done by intersecting the species datasets against the catchment boundary and the inundation region. Of special interest were species listed as 'of concern', 'vulnerable', 'endangered', 'critically endangered' or 'migratory' at national (EPBC Act), state or territory (NT, WA and Queensland) and/or international level (in particular, migratory birds). **Water quality and stratification considerations** No specific assessment of water quality and stratification was made as part of the Assessment. It has been assumed that selective withdrawal baulks will be included in the intake works so that best-quality water can be drawn from the storage when releases are made. **Changes to downstream flow regimes** The ecological implications of changes to downstream flow regimes that may arise as a result of dam construction are documented in the companion technical reports on potential ecological outcomes of water resource development in the Victoria (Stratford et al., 2024b) and Southern Gulf catchments (Ponce Reyes et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment from the NT Government. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal.
Estimated cost	For the two short-listed potential dam sites, cost estimates were calculated manually by the Assessment's water infrastructure planner. This was done by developing conceptual arrangements for each of the storages. Dam and saddle dam profile axes were calculated using the Advanced Land Observing Satellite (ALOS) DEM. Unit cost rates applied for each item of work were originally derived from earlier estimates during studies of the proposed Green Hills and Connors River dams and the existing Wyaralong Dam and then using more recent estimates from the Hells Gates and Palmer River dam studies. The uncertainty in cost associated with the quantity of material for short-listed sites was estimated to be between −10% and +50%. However, if non-trivial geological issues were identified as part of a feasibility analysis or during dam construction, then the final cost of construction could be increased by considerably more than 30%. For those three pre-feasibility dams that were not short-listed, modelled dam costs were obtained using the cost algorithm in the DamSite model using a dam axis elevation profile derived from the ALOS DEM. The uncertainty in cost associated with the quantity of material estimated by the DamSite model is estimated to be between −25% and +75%. However, if non-trivial geological issues were identified as part of a feasibility analysis or during dam construction, then the final cost of construction could be increased by considerably more than 50%.
Estimated cost/ML of supply	Estimated capital cost divided by the water yield at 85% reliability as computed by the Assessment under the nominated structural arrangement.
Summary comment	As provided by Assessment personnel.

Table 3-2 River model node streamflow data used in behaviour analysis modelling in the Victoria catchment

A catchment area scaling factor was used to scale simulated streamflow where the river model node did not correspond exactly with the potential dam site.

DAM ID	VICTORIA POTENTIAL DAM SITES	NODE IDENTIFIER	CATCHMENT AREA SCALING FACTOR
39	Victoria River AMTD 97 km	81100002	0.99
118	Wickham River AMTD 283 km	81102321	1.00
122	Victoria River AMTD 283 km	81100160	0.96
140	Leichhardt Creek AMTD 26 km	81100063	1.00
153	Bullo River AMTD 57 km	81101070	2.74
341	Gipsy Creek AMTD 56 km	81101010	1.27

Table 3-3 River model node streamflow data used in behaviour analysis modelling in the Southern Gulf catchments

A catchment area scaling factor was used to scale simulated streamflow where the river model node did not correspond exactly with the potential dam site.

DAM ID	SOUTHERN GULF POTENTIAL DAM SITES	NODE IDENTIFIER	CATCHMENT AREA SCALING FACTOR
3	Gregory River AMTD 174 km	9121050	1.00
10	Nicholson River AMTD 198 km	9121070	1.00
24	Gunpowder Creek AMTD 66 km	9130030	0.98
87	South Nicholson River AMTD 9 km	9121075	0.93
129	Mistake Creek AMTD 60 km	9130080	0.99
174	Ewen Creek AMTD 6 km	Gridded runoff	na
216	Gold Creek AMTD 58 km	Gridded runoff	na

na = not applicable.

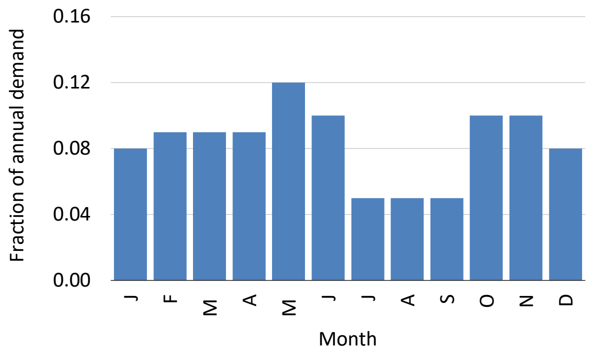

Figure 3-1 Nominal constant monthly demand pattern used in the behaviour analysis modelling for the Victoria and Southern Gulf catchments

3.2 Farm-scale storages

Because large farm-scale water storages are typically no more than several gigalitres in capacity and are constructed to serve one farm or paddock/location, they could feasibly occur at multiple locations within a landscape. For a catchment-scale investigation of farm-scale water storages, it was not feasible to visit and assess the many hundreds of possible locations.

Rather, the Assessment used a broad-scale analysis to identify areas with the greatest (and least) potential for farm-scale storages, to help focus on ground assessments and guide policy and planning decisions related to farm-scale storages.

The high-level catchment-scale investigations analysed:

- earth embankment offstream storage suitability
- locations most suitable for gravity drainage
- topographic and hydrological characteristics of suitable locations for gully dams.

The methods employed in these investigations are briefly discussed in turn below.

3.2.1 Identification of areas suitable for farm-scale offstream storages

The suitability of landscapes and soil for the construction of earth embankment farm dams (both ringtanks and gully or hillside dams) was assessed using 30 × 30 m gridded data of selected soil attributes generated for the Victoria and Southern Gulf catchments (see companion technical report on digital soil mapping on land suitability for the Victoria (Thomas et al., 2024a) and Southern Gulf (Thomas et al., 2024b) catchments). These gridded datasets were generated using a relatively new approach called digital soil mapping, which makes use of advances in computing and statistics.

Digital soil mapping allows soil properties (variables), such as clay content, sampled at specific locations, to be related to an expanding Australian database of national covariates. Covariates, which are geographic information system (GIS)-format datasets, are selected because they directly correlate to landscape and soil properties. Examples of covariates are slope, correlating to soil depth, and rainfall deficit, correlating to leaching intensity and pH. Digital soil mapping: (i) enables discovery of relationships at the geographic intersection of the sampled variable (e.g. pH) and multiple 'stacked' covariate datasets; (ii) builds statistical models from these relationships; and then (iii) applies the models to predict (map) the variable values at all other unsampled locations in the Assessment area from the covariates (McBratney et al., 2003). Unlike traditional soil mapping used to map soil types, digital soil mapping produces maps of individual soil properties (e.g. pH or permeability). As a result, the approach is especially suited to land-suitability assessment. A particular strength of digital soil mapping methods over the traditional mapping methods is that the former produces spatial statistical measures of the quality of the mapped parameter that can be readily displayed.

The assessment of the suitability of earth embankment structures across the study area was undertaken on a grid cell by grid cell basis and by examining all possible combinations of four gridded soil parameters. The four parameters and the categories, listed from least to most favourable, used for each parameter are:

- clay content – zero % to 10%, 10% to 25%, 25% to 35%, 35% to 50% and greater than 50%
- permeability – rapid, moderate, slow and very slow (NCST, 2009)
- soil depth – less than 1 m, 1 to 1.5 m and greater than 1.5 m
- slope – greater than 5%, 2% to 5%, 1% to 2% and less than 1%.

Those grid cells characterised as being most suitable for the construction of farm-scale earth embankment structures were assigned a suitability score of 1, and those least suitable were assigned a 4 (Table 3-4). A subset of rules to illustrate the concept is provided in Table 3-5.

Table 3-4 Suitability scores for the construction of farm-scale earth embankment structures

SUITABILITY SCORE	DESCRIPTION
1	Likely to be suitable
2	Possibly suitable
3	Unlikely to be suitable
4	Not suitable

Table 3-5 Subset of rules used to assess suitability of land for construction of farm-scale earth embankment structures

CLAY CONTENT	PERMEABILITY	SOIL DEPTH	SLOPE	SUITABILITY SCORE
25% to 35%	Slow	1 to 1.5 m	<1%	2
25% to 35%	Slow	1 to 1.5 m	1% to 2%	2
25% to 35%	Slow	1 to 1.5 m	2% to 5%	3
25% to 35%	Slow	1 to 1.5 m	>5%	4
25% to 35%	Moderate	1 to 1.5 m	<1%	3
25% to 35%	Moderate	1 to 1.5 m	1% to 2%	3
25% to 35%	Moderate	1 to 1.5 m	2% to 5%	3
25% to 35%	Moderate	1 to 1.5 m	>5%	4

Irrespective of the values of the other parameters, a grid cell was assigned a suitability score of 4 if at that location the:

- soil depth was less than 1 m
- slope was greater than 5%
- permeability was rapidly draining, or
- clay content was between zero % and 10%.

In total, there were 240 possible permutations of the clay content, permeability, soil depth and slope classes. Eight of these permutations resulted in a suitability score of 1, 19 permutations resulted in a suitability score of 2, 41 permutations resulted in a suitability score of 3, and 172 permutations resulted in a suitability score of 4.

3.2.2 Topographic and hydrological analysis of suitable locations for gully and hillside dams

The topographic and hydrological potential for gully and hillside dams across the study area was assessed using the DamSite model. As outlined in Section 3.1.2 for large instream and offstream dams, the DamSite model requires hydroclimate data (i.e. runoff, rainfall and evaporation), a DEM and an algorithm for costing the structure.

The DamSite model was run using 85% gridded annual exceedance runoff datasets generated by the Assessment for the study area (Hughes et al., 2024a, Gibbs et al., 2024a), and net evaporative losses were calculated by multiplying the reservoir surface area at 0.7 capacity by the median net evaporation between March and August (inclusive) for the Victoria and Southern Gulf catchments.

Seepage losses were assumed to be 2 mm/day over the reservoir surface area at 0.7 capacity, roughly aligned with the mean wetted area.

Every Shuttle Radar Topographic Mission (SRTM) grid cell location with a catchment area greater than 1 km^2 and less than 40 km^2 was assessed for its potential as a farm-scale dam by constructing earth embankment structures at 1-m height intervals between 5 and 20 m in height, including freeboard. Dam wall heights of less than 5 m were not examined in this analysis, because the uncertainty in the national 1 second DEM-H elevations were deemed to be too large relative to the height of the dam and the capacity of the reservoir.

Dam walls were constructed assuming a 3:1 (horizontal to vertical) ratio on the upstream face and a 2.5:1 ratio on the downstream face, with a crest width of the square root of the height +1. These values are broadly in line with the recommendations in the farm water supplies design manual (QWRC, 1984).

The results are reported in terms of gigalitres per 1000 m^3 of earth moved. The dry freeboard was a function of the reservoir surface area plus 0.5 m wet freeboard. It should be noted that although topographically more favourable gully dam sites are individually identified by the DamSite model, specific sites may be erroneously due to artefacts in the DEM-H (e.g. due to incorrect vegetation removal). Rather this analysis should be used to identify general areas topographically suitable for gully dams from clusters of modelled potential gully dam sites.

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Part II Large instream and offstream dams

4 Victoria catchment

The opportunity analysis of potential dam sites in the Victoria catchment involved a three-tier analysis (see Section 3.1).

Opportunity analysis

To ensure that no options had been overlooked, the DamSite model (see Section 3.1.2) was used to undertake a preliminary assessment of over 50 million potential dam sites in the Victoria catchment.

Long-list of potential dam sites

Next, a desktop geological suitability assessment was undertaken on a long-list of potential dam sites identified using the DamSite model results by overlaying the dam locations on 1:250,000 geology data (see Section 3.1.3).

Short-list of potential dam sites

The final stage of the analysis involved establishing a short-list of potential dam sites, of which a pre-feasibility analysis was undertaken, and manual dam costings were undertaken on two of the sites.

4.1 DamSite modelling

DamSite modelling was undertaken to evaluate potential for large offstream and instream dams for irrigation and water supply (Section 4.1.1) and for hydro-electric power generation (Section 4.1.2).

4.1.1 Large dams for irrigation and water supply in the Victoria catchment

Potential sites topographically suitable for large storages for water supply in the Victoria catchment

Figure 4-1 displays the most promising sites across the Victoria catchment in terms of storage volume (GL) per million dollars of construction cost. Only locations with a ratio of cost to storage capacity of less than $5000/ML are shown. This provides a simple way of displaying locations in the Victoria catchment with the most favourable topography for a large reservoir relative to the size (i.e. cost) of the dam wall necessary to create the reservoir. This figure is particularly useful for identifying more promising sites for offstream storage (i.e. where some or all of the water is pumped into the reservoir from an adjacent drainage line). The threshold value of $5000/ML is nominal and is used to minimise the amount of data displayed. Note that this analysis does not consider evaporation, hydrology or geology.

Figure 4-1 shows that the parts of the Victoria catchment with the most favourable topography for storing water are predominantly along the lower Victoria River, East Baines River and the Wickham River.

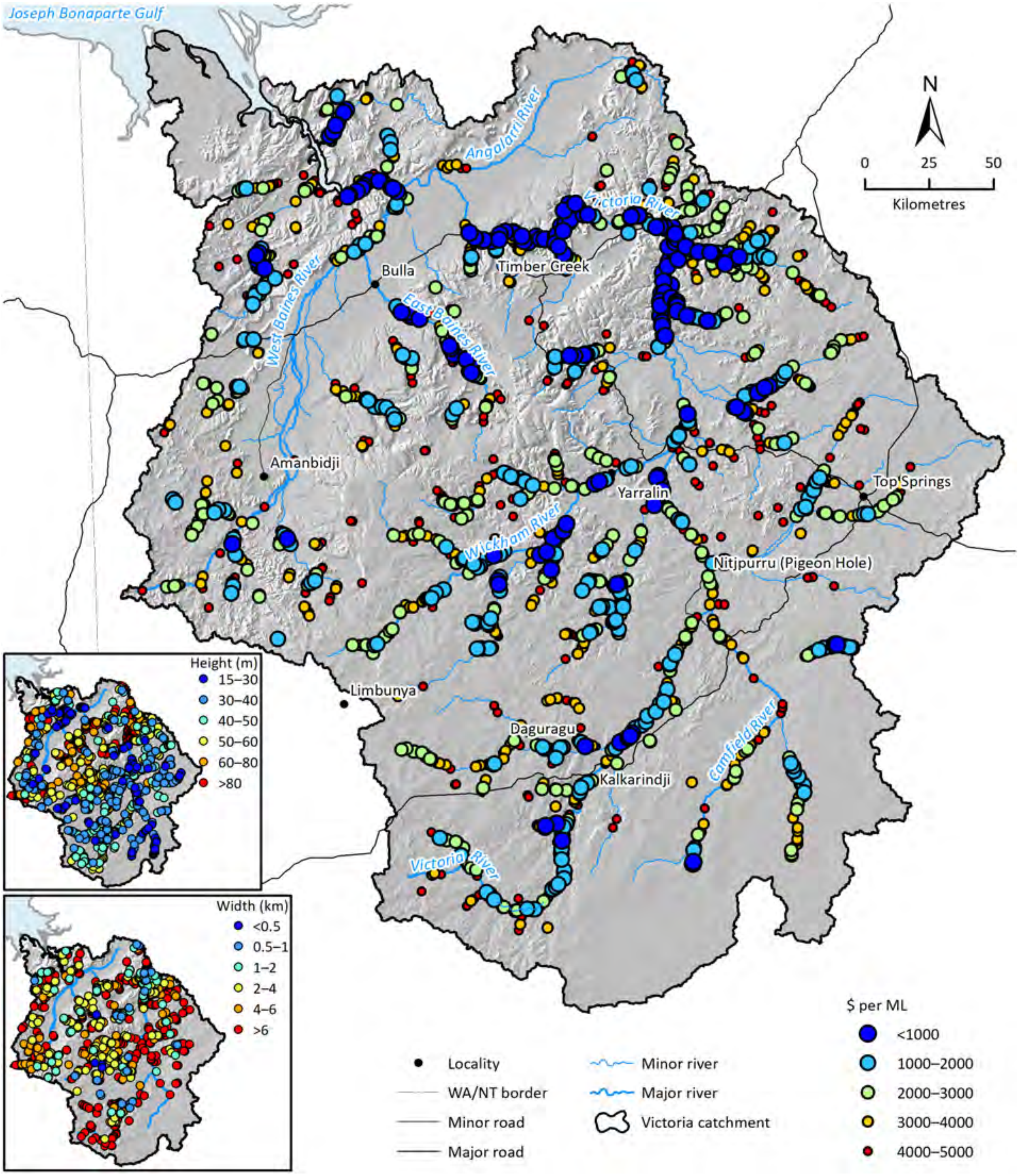

Figure 4-1 Topographically more favourable potential storage sites in the Victoria catchment based on minimum cost per megalitre storage capacity

This figure can be used to identify locations where the topography is suitable for large offstream storages. At each location the minimum cost per megalitre storage capacity is displayed. The smaller the minimum cost per megalitre storage capacity ($/ML), the more suitable the site for a large offstream storage. Analysis did not take into account geological considerations, hydrology, or proximity to water. Only sites with a minimum cost-to-storage-volume ratio of less than $5000/ML are shown. A ratio of $1000/ML is equivalent to 1 GL per million dollars. Costs are based on unit rates, quantities of material, and site-establishment costs for a roller compacted concrete (RCC) dam. Data are underlain by a shaded topographic relief map. Inset displays height and width of dam wall at full supply level (FSL) at the minimum cost per megalitre storage capacity.

Large instream storages in the Victoria catchment

In addition to suitable topography (and geology), instream dams require sufficient inflows to meet a potential demand. Potential dams that command smaller catchments with lower runoff have smaller yields. The results relating to this criterion can be summarised and conveniently presented in terms of cost of constructing the dam per megalitre of yield. This is very similar to the cost of constructing a dam per megalitre of storage volume described above. The DamSite model was initially run using a preliminary storage-yield-reliability calculation method, the Gould–Dincer Gamma (GDG) method (Petheram et al., 2017b), which is very rapid to apply. Only for the top 10,000 sites for the Victoria catchment, ranked in terms of the cost per megalitre GDG yield, was the yield recalculated using the more numerically intensive behaviour analysis. Figure 4-2 only shows those sites with a cost less than $10,000/ML. The DamSite modelling indicates that the most cost-effective potential dam sites are along the lower reaches of the Victoria River. However, as shown on Figure 4-2 there is very little land that is suitable for irrigated agriculture below these potential dam sites.

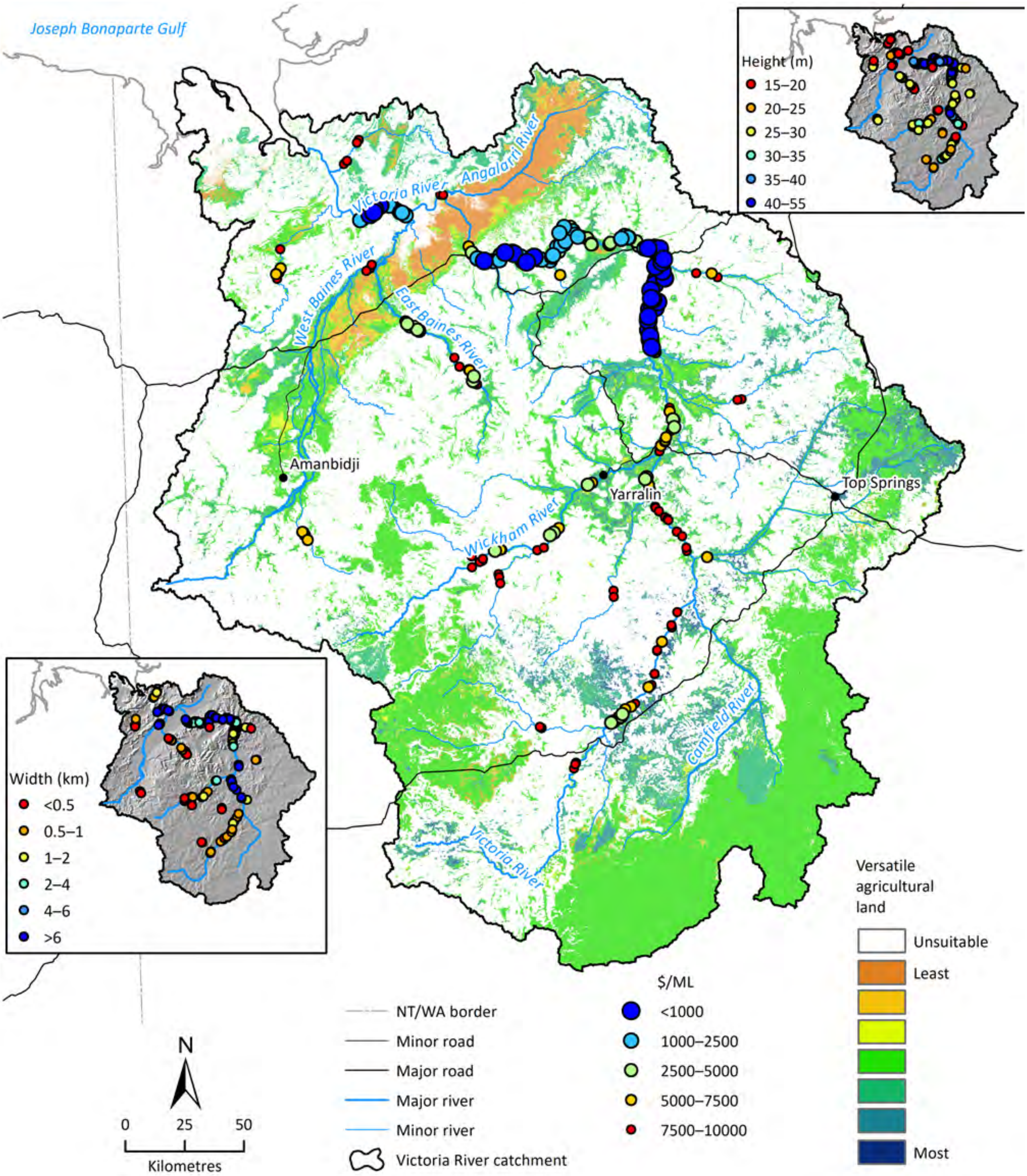

Figure 4-2 Topographically and hydrologically more favourable potential storage sites in the Victoria catchment based on minimum cost per megalitre yield at the dam wall

This figure indicates those sites more suitable for major dams in terms of cost per megalitre yield at the dam wall in 85% of years, overlaid on versatile agricultural land (see companion technical report on digital soil mapping and land suitability, Thomas et al., 2024a). At each location the minimum cost per megalitre storage capacity is displayed. The smaller the cost per megalitre yield ($/ML), the more favourable the site for a large instream dam. Only sites with a minimum cost-to-yield ratio of less than $10,000/ML are shown. Costs are based on unit rates and quantity of material required for a roller compacted concrete (RCC) dam with a flood design of 1 in 10,000. Top inset displays height of full supply level (FSL) at the minimum cost per megalitre yield, and bottom inset displays width of FSL at the minimum cost per megalitre yield.

4.1.2 Large dams for hydro-electric power generation potential

The potential for major instream dams to generate hydro-electric power is presented in Figure 4-3, following a reconnaissance assessment of more than 50 million sites in the Victoria catchment. This figure provides indicative estimates of hydro-electric power generation potential but does not consider the costs of supporting infrastructure (e.g. transmission lines). Figure 4-3 shows those sites with a cost less than $20,000/MWh. The only sites that meet this criteria in the Victoria catchment are on the lower reaches of the Victoria River, where high dam walls could potentially be constructed to provide the necessary head. It should be noted, however, the Victoria catchment is in a remote part of the NT that does not have access to major electricity networks and the small communities rely on diesel generators or hybrid diesel – solar systems provided by Power and Water Corporation. The largest electricity network in the NT is the Darwin–Katherine Interconnected System (DKIS), which connects the capital of Darwin to Katherine a 132 kV transmission line. Katherine, is about 200 km from the Victoria River Roadhouse. Even if transmission lines were to connect the Victoria catchment to the DKIS, the DKIS is electrically isolated from other grids in Australia and hence any large-scale electrical generation infrastructure in the Victoria catchment would still be disconnected from the National Electricity Market.

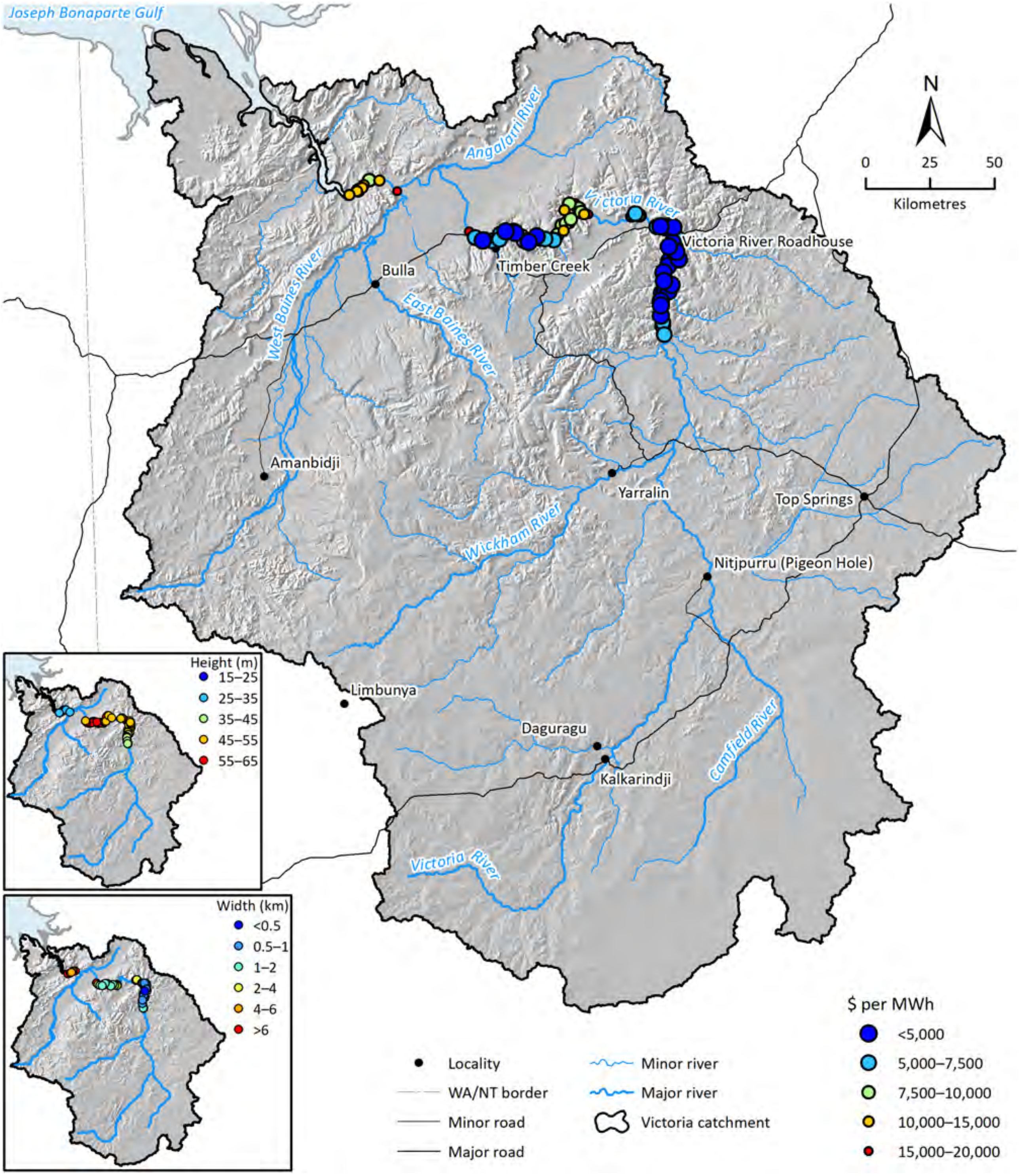

Figure 4-3 Victoria catchment hydro-electric power generation opportunity map

Costs are based on unit rates and quantity of material required for a roller compacted concrete (RCC) dam, with a flood design of 1 year in 10,000. Cost includes site establishment, fish lifts/traps (high dams), fish locks (low dams) or ladders (weirs) and land resumption for the area of land impounded by a flood event of 1% annual exceedance probability (AEP). Data are underlain by a shaded topographic relief map. Top inset displays height of full supply level (FSL) at the optimal cost per megawatt hour and bottom inset displays width of FSL at the optimal cost per megawatt hour.

4.2 Long-list of potential dam sites

The characteristics of the long-list of potential dam sites in the Victoria catchment are summarised in Table 4-1 and Table 4-2. Table 4-1 provides a summary of the yield and cost of potential dam sites at their optimum FSL. Table 4-2 provides a high-level geological summary of the long-listed potential dam sites. The geological summary was based on a desktop study. No site visit was undertaken.

Table 4-1 Long-list of potential dam sites in the Victoria catchment

Data as calculated by the DamSite model at the optimum FSL irrespective of whether there was a potential demand (e.g. soil suitable for irrigated agriculture downstream). Note FSLs for short-listed sites were refined based on revised dam cost modelling using the ALOS DEM and BHA modelling. DamSite assigns Site ID based on largest yield per unit cost, where yield is calculated using the Gould–Dincer Gamma method (see Petheram et al., 2017). The model then re-evaluates yield using a more accurate but numerically intensive behaviour analysis model for the top 10,000 sites in the study area. Hence the order of the Site ID does not exactly correspond to the ranked order by unit cost. Location of potential dam sites is shown in Figure 4-4.

SITE ID	SPILLWAY HEIGHT ABOVE BED† (M)	CAPACITY AT FSL (GL)	CATCHMENT AREA (KM²)	ANNUAL WATER YIELD‡ (GL)	CAPITAL COST§ ($ MILLION)	UNIT COST* ($/ML)	EQUIVALENT ANNUAL UNIT COST & O&M†† ($/Y PER ML/Y)
0	41	8,236	86,774	3,057	1,084	355	26
27	53	10,519	93,085	4,061	3,321	818	58
38‡‡	46	6,633	54,605	2,419	3,805	1,573	69
91	30	281	2,326	168	558	3,310	256
92	29	304	2,310	171	596	3,486	253
95	25	274	2,282	164	571	3,476	250
97	17	727	7,305	270	1,065	3,950	282
99	26	465	5,388	203	902	4,442	322
100	32	194	2,862	108	524	4,859	362
107	25	286	2,307	166	678	4,074	295
108	31	298	2,329	173	715	4,127	333
120	20	212	10,663	145	1,339	9,221	662
121‡‡	28	547	5,413	209	1,593	7,603	401
125	43	7,502	91,307	3,503	13,833	3,949	277
126	30	194	2,332	149	836	5,619	403
130	29	133	1,226	59	404	6,830	498
131‡‡	33	193	1,220	64	396	6,188	591
134	35	5,899	70,945	1,906	7,495	3,932	276
137	29	135	1,226	59	430	7,238	530

SITE ID	SPILLWAY HEIGHT ABOVE BED† (M)	CAPACITY AT FSL (GL)	CATCHMENT AREA (KM^2)	ANNUAL WATER YIELD‡ (GL)	CAPITAL COST§ ($ MILLION)	UNIT COST* ($/ML)	EQUIVALENT ANNUAL UNIT COST & O&M†† ($/Y PER ML/Y)
145	17	573	6,333	235	1,543	6,564	483
150‡‡	34	127	605	55	232	4,199	462
152	34	7,680	80,222	2,579	9,952	3,859	271
153	28	105	1,678	58	467	8,059	601
161	28	145	1,170	45	368	8,127	594
165	28	141	1,168	45	386	8,528	639
167	25	354	1,459	101	730	7,211	528
181	16	144	942	71	484	6,809	494
186‡‡	9	17	4,413	17	740	43,529	602
199	35	88	649	47	532	11,438	837
202	25	269	1,387	81	737	9,142	641
204	35	85	640	45	526	11,647	816
230‡‡	29	56	645	43	384	8,993	906
241	30	69	651	41	585	14,209	996
260	18	170	1,281	64	780	12,225	857
473	17	180	903	41	643	15,837	1,110
492	16	136	1,268	59	1,253	21,141	1,481
496	16	304	1,604	52	791	15,141	1,061
553	16	333	1,603	64	1,450 Δ	22,672	1,589
563	18	850	5,644	278	6,609	23,812	1,669
566	29	25	248	18	521	29,516	2,068
649	19	60	317	21	575	28,026	1,964
740	18	454	3,252	153	5,049	33,088	2,319
1270	18	38	164	14	830	58,953Δ	4,132

(refer next page for Table notes)

ALOS = Australian Land Observing Satellite; DEM = digital elevation model; FSL = full supply level; OAM = operation and maintenance; SRTM = Shuttle Radar Topographic Mission; SRTM-H =

†The height of the dam abutments and saddle dams will be higher than the spillway height. Note these heights above river bed are based on the DEM-H, which does not accurately capture incised channels.

‡Water yield is based on 85% annual time-based reliability using a perennial demand pattern for the baseline river model under Scenario A. This is yield at the dam wall (i.e. does not take into account distribution losses or downstream transmission losses). These yield values do not take into account downstream existing entitlement holders or environmental considerations.

§Modelled preliminary cost estimate based on the DEM-H –derived cross-section, which is likely to be –50% to +100% of 'true' cost. Should site geotechnical investigations reveal unknown unfavourable geological conditions, costs could be substantially higher.

*This is the unit cost of annual water supply and is calculated as the capital cost of the dam divided by the water yield at 85% annual time reliability.

††Assuming a 7% real discount rate and a dam service life of 100 years. Includes operation and maintenance costs, assuming operation and maintenance costs are 0.4% of the total capital cost.

‡‡Short-listed potential dam site.

§§TThere is limited soil suitable for irrigated agriculture downstream of this potential dam site.

†††This site was short-listed to examine the flood mitigation potential of the dam. However, the data specified in this table (from the DamSite model) assume the potential dam was used to supply water. The yield from this potential dam if used for flood mitigation purposes would be considerably less.

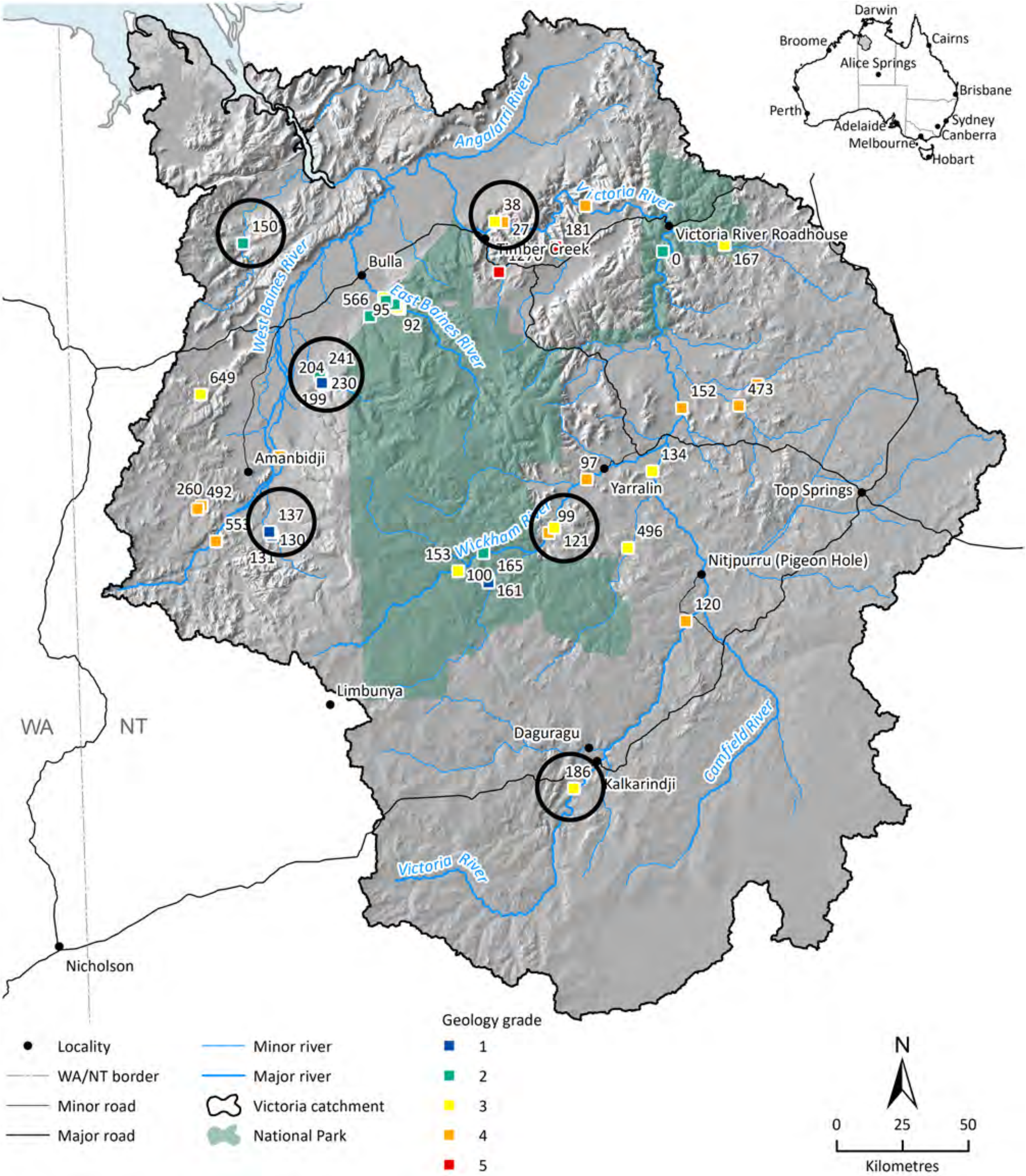

Figure 4-4 Long-list of potential dam sites in the Victoria catchment

Note: Geology grade 1 is most favourable geology; grade 5 is least favourable geology – holistic assessment based on whether bedrock is exposed at site, likely depth of weathering/stripping on abutments, likely depth of cut-off and presence of deep alluvium, and overall height-to-width assessment. Potential short-listed dam sites circled (38, 121, 131, 150, 186, 230).

Table 4-2 Rapid desktop geological evaluation of long-listed potential dam sites in the Victoria catchment

Note: Grade 1 is most favourable geology; grade 5 is least favourable geology – holistic assessment based on whether bedrock is exposed at site, likely depth of weathering/stripping on abutments, likely depth of cut-off and presence of deep alluvium, and overall height-to-width assessment. Geology abbreviations detailed in NTGS (2023).

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
0	Paj/Pct	Silica cemented sandstone/siltstone, shale, minor sandstone	Narrow	Extensive outcrop on both abutments; possible rockbars; Qa appears shallow; deep slow-moving river with ponded water at dam site	Storage appears stable and watertight	Flat-lying sandstones, prominent jointing pattern, some loose large blocks, adjacent to the Coolibah Fault zone	2	Likely suitable for RCC, provisional foundation stripping of 5–10 m in river and 5–10 m on abutments
27	Paj/Pbt/Pbs	Silica cemented sandstone/dolomitic siltstone, silty dolostone and sandstone, minor dolostone and chert/Silty and quartztic dolostone, dolostone, dolomitic sandstone, dolomitic siltstone, sandstone minor dolarenite	Wide 180 m of alluvial tract with 120-m-wide river of ponded water	Possible outcrop on abutments, deeply weathered, possible rock bar	Possibly leaky, especially left abutment ridge due to carbonate-rich Skull Creek Formation	Gently dipping sandstone and siltstone, rock bar – Palm Island, deep river, possibly leaky abutments and foundation	4	RCC possible, provisional foundation stripping of 10 m in river and 10 m on abutments, CFRD with lined chute spillway may be better option, possible deep grouting required for 5 km of left abutment
38†	Paj/Pbt/Pbs	Silica cemented sandstone/dolomitic siltstone, silty dolostone and sandstone, minor dolostone and chert	Wide 220 m of alluvial tract with 130-m-wide river of ponded water	Possible outcrop on abutments, deeply weathered	Possibly leaky due to carbonate-rich Skull Creek Formation occurring in south-east part of storage, would depend on FSL relative to topography, considered unlikely	Gently dipping sandstone and siltstone, rock bar – Palm Island 2 km upstream, deep river	3	RCC possible, provisional foundation stripping of 10 m in river and 10 m on abutments, CFRD with lined chute spillway may be better option, potential leakage problem on left abutment for site 31 is avoided by moving downstream

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
91	Paj	Silica cemented sandstone	Wide, 150 m	Outcrop on both abutments, no rockbar visible	Although carbonate in storage, unlikely to leak as surrounded by higher ground. However, subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	Moderate weathering	2	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones
92	Paj	Silica cemented sandstone	Wide, 150 m	Outcrop on both abutments, no rockbar visible, swamp on right abutment?	Although carbonate in storage, unlikely to leak as surrounded by higher ground. However, subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	High-level swamps on right bank require further consideration	2	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones
95	Paj/Piu	Silica cemented sandstone/undifferentiated micaceous siltstone, sandstone, minor dolostone/dolomitic siltstone, silty dolostone, dolostone, purple-green micaceous siltstone, minor orange water-laid tuffite	Very wide, 250 m	Subdued outcrop at mid-levels on both banks, with drainage lines at base of slope break	Although carbonate in storage, unlikely to leak as surrounded by higher ground. However, subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	Deeply weathered? Possible leakage paths in deep alluvium or bedrock?	3	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
97	Qa/Pby	Dolomitic siltstone and sandstone, dolostone, minor chert	550 m wide, river 60 m	No outcrop on abutments, deeply weathered, incised planation surface with prominent mesas capped by sandstones (ferricreted?), deep pools suggest deep low-gradient channel	Possibly some carbonate in storage, conceivable leaky, depends on topographic and groundwater levels; 5–25 km south-east of dam site there is complex of Proterozoic carbonates with Tertiary capping, numerous dams, bores suggest karst aquifer	Gently dipping sandstones on both abutments, damsite itself appears potentially watertight	4	RCC possible, provisional foundation stripping of >10 m in river and 10 m on abutments, CFRD with lined chute spillway may be better option, possible leakage path through karst and deep Tertiary deposits 4.5 km SE of dam with width of 1.5 km
99	Paj/Pby/Pbs	Silica cemented sandstone/dolomitic siltstone, silty dolostone and sandstone, minor dolostone and chert/Silty and quartztic dolostone, dolostone, dolomitic sandstone, dolomitic siltstone, sandstone minor dolarenite	Wide 500 m of alluvial tract with 30-m-wide river of ponded water	No outcrop on abutments, deeply weathered	Possibly leaky if Skull Creek Formation in foundation, but if dipping downstream could be remedied by conventional grout curtain?	Possibly leaky if Skull Creek Formation in foundation, but if dipping downstream could be remedied by conventional grout curtain? However 4 km to south-east is a potentially leaky saddle formed in Skull Creek Formation	4	RCC possible, provisional foundation stripping of 10 m in river and 10 m on abutments, CFRD with lined chute spillway may be better option, potential leaky saddle may require extensive grout curtain but could be a lined spillway
100	Pim/Pig	Massive fine and medium quartz sandstone, possibly some fine siltstone and sandstone with rare dolostone (Pig)	Medium, 160 m wide, heavily vegetated, river channel varies between 50-m wide and not observed	Outcrop on both abutments	Storage appears stable and watertight	Gently dipping sandstones on both abutments	2	RCC, provisional foundation stripping of 5–10 m in river and 5–10 m on abutments, 30-m-high saddle dam possibly required on left abutment 1 km north of dam site? Possibly change to 113 ~2.5 km downstream with similar conditions and no saddle dam required

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
107	Paj	Silica cemented sandstone	120-m wide but mapped as no Qa, river 20-m wide	Outcrop on both abutments, no rockbar visible, swamp on right abutment?	Although carbonate in storage, unlikely to leak as surrounded by higher ground. However, subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	High-level swamps on right bank require further consideration	3	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones
108	Paj	Silica cemented sandstone	300-m wide, river 30 m, possible outcrop at river level	Outcrop on both abutments, no rockbar visible	Although carbonate in storage, unlikely to leak as surrounded by higher ground. However, subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	Gently dipping sandstones on both abutments	2	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones
120	Qt/Cla	Quaternary alluvial terrace over massive basalt	Wide alluvium 600-m wide with river ponded 60-m wide	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Deep river, deep weathering may be suited to embankment	4	May not be stiff enough for RCC, possible CFRD or embankment with separate lined chute spillway on either abutment, 10–15 m of alluvium in river bed, 5–10 m of stripping on abutments
121†	Qt/Paj/Pby	Quaternary terrace/Silica cemented sandstone/dolomitic siltstone, silty dolostone and sandstone, minor dolostone and chert	Wide 300 m of alluvial tract with 30-m wide river of ponded water, plus 300-m wide alluvial terrace on left bank	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Gently dipping sandstones and siltstones. Skull Creek Formation may occur at depth but does not appear to present a potential leakage path	3	RCC possible, provisional foundation stripping of 10 m in river, 15 m in alluvial terrace on left bank, and 10 m on abutments, CFRD with lined chute spillway may be better option

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
125	Qt/Pbs, possibly Czs	Alluvial terrace over silty and quartzitic dolostone, dolostone, and dolomitic sandstone and siltstone	4-km wide alluvial terrace 10-m deep but rock exposed in river bed?	Wide terrace incise by river channel	Possibly leaky dam site due to Skull Creek Formation carbonates below terrace	Left abutment in Skull Creek Formation carbonates, wide alluvial terrace potentially underlain by karst	4	Consider 10-m-deep stripping over length of dam then 55-m-high RCC structure founded on sound rock. Leakiness could be assessed by site visit and observation of river bed outcrop
126	Paj	Silica cemented sandstone	Wide	No outcrop on abutments, deeply weathered, some alluvial terraces? Downstream?	Although carbonate in storage, unlikely to leak as surrounded by higher ground. However, subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	Deep river	3	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones
130	Paj	Silica cemented sandstone	Narrow, 30-m wide with ponded river 20-m wide	Outcrop on both abutments, possible rockbars downstream, Qa appears shallow	Storage appears stable and watertight	Gently dipping sandstones on both abutments	1	Likely suitable for RCC, provisional foundation stripping of 5 m in river and 5 m on abutments
131†	Paj	Silica cemented sandstone	Narrow, 30-m wide with ponded river 20-m wide	Outcrop on both abutments, possible rockbars, Qa appears shallow	Storage appears stable and watertight	Gently dipping sandstones on both abutments	1	Likely suitable for RCC, provisional foundation stripping of 5 m in river and 5 m on abutments
134	Pbw/Pby	Quartz sandstone, minor granular and pebbly sandstone at base/Dolomitic siltstone and sandstone, dolostone, minor chert	Wide 600 m alluvium, river 20 m	No outcrop on both abutments, braided alluvium	Possible some carbonate in storage, conceivably leaky, depends on levels	Gently dipping sandstones on both abutments	3	Likely suitable for RCC, provisional foundation stripping of 5–10 m in river and 5 m on abutments
137	Paj	Silica cemented sandstone	Narrow, 60-m wide with ponded river 40-m wide	Outcrop on both abutments, possible rockbars downstream, Qa appears shallow	Storage appears stable and watertight	Gently dipping sandstones on both abutments	1	Likely suitable for RCC, provisional foundation stripping of 5 m in river and 5 m on abutments

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
145	Wide Qa/Cla, some Pco	Massive basalt, possibly some sandstone and mudstone	Wide (440 m) heavily vegetated with active channels	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Deep weathering of basalts producing a clay-rich profile, deep alluvium	4	Soil profile of weathered basalt and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?
150†	Pb	Quartz sandstone and conglomerate	70-m-wide pooled water, bouldery alluvium	Outcrop on both abutments, incised gorge with pools downstream of dam site	Storage appears stable and watertight	Gently dipping sandstones	2	Likely suitable for RCC, provisional foundation stripping of 5–10 m in river and 5 m on abutments
152	Qt/Czb/Pby	Quaternary terrace/Black and grey soil/Dolomitic siltstone and sandstone, dolostone, minor chert	2.7-km-wide alluvium and terrace deposits	No outcrop on abutments, deeply weathered	Possibly leaky dam site	Deeply weathered? Possible leakage paths in deep alluvium, Tertiary or bedrock?	4	May not be stiff enough for RCC, possible CFRD or embankment with separate lined chute spillway on either abutment, 10 m of terrace and alluvium in river bed, 5–10 m of stripping on abutments
153	Pim	Massive fine and medium quartz sandstone	140-m-wide alluvium, 20 m irregular river channel	Possible outcrop on abutments, incised planation surface	Storage appears stable and watertight	Gently dipping ferricreted sandstones	3	Likely suitable for RCC, provisional foundation stripping of 5–10 m in river and 5 m on abutments
161	Pim	Massive fine and medium quartz sandstone	Medium alluvium 90-m wide with river ponded 60-m wide	Incised gorge with pools at dam site	Storage appears stable and watertight	Gently dipping sandstones outcrop on right abutment	1	Likely suitable for RCC, provisional foundation stripping of 5 m in river and 5 m on abutments
165	Pim	Massive fine and medium quartz sandstone	Medium alluvium 90-m wide with river ponded 60-m wide	Incised gorge with pools at dam site	Storage appears stable and watertight	Gently dipping sandstones outcrop on both abutments	1	Likely suitable for RCC, provisional foundation stripping of 5 m in river and 5 m on abutments

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
167	Qa/Pct	Siltstone, shale, minor sandstone	400-m-wide alluvium with 20-m wide river channel	No clear outcrop on abutments, but possibly a little outcrop, deeply weathered	Storage appears stable and watertight	Gently dipping siltstones and shales	3	Likely suitable for RCC, provisional foundation stripping of 5–10 m in river and 5–10 m on abutments
181	Pbs	Quaternary alluvium/Silty and quartztic dolostone, dolostone, dolomitic sandstone, dolomitic siltstone, sandstone minor dolarenite	250-m wide alluvium	No outcrop on abutments, deeply weathered, undersized channel	Storage and dam site probably leaky, due to being underlain by potentially karstic Skull Creek Formation	Possibly karst, very difficult constructability, possibly unsuitable for dam site	5	Soil profile of alluvium anticipated to >10 m over irregular karstic bedrock, possible embankment with lined side channel chute spillway, upstream blanket, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain, etc. May still be leaky
186†	Cla	Massive basalt	Wide 250 m pooled water and gravel bars	Some outcrop on abutments, deeply weathered	Storage appears stable and watertight	Weathering in basalts could be deep	3	May not be stiff enough for RCC, possible CFRD or embankment with separate lined chute spillway on either abutment, 5–10 m of alluvium in river bed, 5–10 m of stripping on abutments
199	Paj	Silica cemented sandstone	150-m-wide shallow alluvium, but possible rock bars, 30-m wide river, ponded water	Limited outcrop on both abutments, no rockbar visible	Storage appears stable and watertight	Gently dipping sandstones	2	
202	Qa/Cla	Quaternary alluvium/massive basalt	220-m-wide alluvium, no clear river channel	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Meandering alluvial tract, possibly more suited to an embankment	4	Soil profile of weathered basalt and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
204	Paj	Silica cemented sandstone	150-m-wide shallow alluvium, but possible rock bars, 30-m wide river, ponded water	Outcrop on both abutments, possible rockbar downstream, Qa appears shallow	Storage appears stable and watertight	Gently dipping sandstones	2	
230†	Paj	Silica cemented sandstone	150-m-wide shallow alluvium, but possible rock bars, 20-m wide river	Outcrop on both abutments, possible rockbar downstream, Qa appears shallow	Storage appears stable and watertight	Gently dipping sandstones	1	Likely suitable for RCC, provisional foundation stripping of 2–5 m in river and 5 m on abutments
241	Paj	Silica cemented sandstone	160-m-wide shallow alluvium, 20-m wide river	Outcrop on both abutments, possible rockbar downstream, Qa appears shallow	Storage appears stable and watertight	Gently dipping sandstones	2	
260	Qa/Cla	Quaternary alluvium/massive basalt	300-m-wide alluvium, no clear river channel	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Meandering alluvial tract, possibly more suited to an embankment	4	Soil profile of weathered basalt and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?
473	Cla	Massive basalt	250-m-wide alluvium, no clear river channel	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Meandering alluvial tract, possibly more suited to an embankment	4	Soil profile of weathered basalt and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
492	Qa/Cla	Quaternary alluvium/massive basalt	300-m-wide alluvium, no clear river channel	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Meandering alluvial tract, possibly more suited to an embankment	4	Soil profile of weathered basalt and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?
496	Qa/Pco	Glauconitic quartz sandstone, claystone, siltstone mudstone	180-wide alluvium	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Deep weathering may be suited to embankment	3	May not be stiff enough for RCC, possible CFRD or embankment with separate lined chute spillway on either abutment, 5–10 m of alluvium in river bed, 10 m of stripping on abutments
553	Qa/Paa	Quaternary alluvium siltstone, shale, minor dolostone and sandstone	Very wide (1.5 km) alluvium and small terraces	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Deep braided alluvial tract, very difficult constructability, suited to embankment	4	Soil profile of weathered shale and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?
563	Paj-fault-Paa	Silica cemented sandstone-fault-siltstone, shale, minor dolostone and sandstone	2 km (very wide) alluvium, very deep	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Deep anastomosing alluvial tract, very difficult constructability, suited to embankment	4	Soil profile of weathered sandstone and shale and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT
566	Paj	Silica cemented sandstone	Very wide (200 m) alluvium with 20-m-wide river channel	Outcrop on both abutments, no rockbar visible	Storage appears stable and watertight, but subdued depressions along drainage lines in Paj plateau suggest that could be affected by karst in underlying Skull Creek Formation. Need to check regional groundwater systems	Gently dipping sandstones	2	RCC, provisional foundation stripping of 10 m in river and 10 m on abutments. Need to check regional groundwater gradients in carbonates below Paj sandstones
649	Cla/Pom-Pek	Massive basalt/Diamictite, laminated dolostone at top – red-brown medium sandstone, minor calcareous sandstone	300-m-wide, river	No outcrop on abutments, deeply weathered	Storage appears stable and watertight	Shallow active alluvial tract, possibly more suited to an embankment with a left bank chute spillway using a saddle	3	RCC possible, provisional foundation stripping of 10 m in river and 10 m on abutments, CFRD with lined chute spillway may be better
740	Qa/Paa	Quaternary alluvium/siltstone, shale, minor dolostone and sandstone	Very wide, 900 m of braided alluvium, no discernible river channel	No outcrop on abutments, deeply weathered, braided Qa	Storage appears stable and watertight	Deep braided alluvial tract, deeply weathered shales, very difficult constructability, suited to embankment	4	Soil profile of weathered shale and alluvium anticipated to >10 m, possible embankment with lined side channel chute spillway, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain?
1270	Qa/Pbs	Quaternary alluvium/Silty and quartztic dolostone, dolostone, dolomitic sandstone, dolomitic siltstone, sandstone minor dolarenite	250-m-wide alluvium	No outcrop on abutments, deeply weathered, undersized channel	Storage and dam site probably leaky due to being underlain by potentially karstic Skull Creek Formation	Possibly karst, very difficult constructability, possibly unsuitable for dam site	5	Soil profile of alluvium anticipated to >10 m over irregular karstic bedrock, possible embankment with lined side channel chute spillway, upstream blanket, cut-off trench/diaphragm wall 20-m deep in river bed and 5-m deep on abutments, plus conventional grout curtain, etc. May still be leaky

CFRD = concrete-faced rockfill dam; FSL = full supply level; RCC = roller compacted concrete.
† = short-listed potential dam site

4.3 Short-listed sites

Four potential dam sites from Section 4.1 were selected for pre-feasibility analysis based on having favourable yield to unit cost ratios in distinct geographical locations of the Victoria catchment. Two additional sites were short-listed, one for its potential to mitigate flooding to downstream communities and the second for its hydro-electrical power generation potential. Two of the short-listed sites (i.e. sections 4.3.1 and 4.3.2) were selected for a more detailed costing (see Appendix A). Details of the four remaining short-listed sites are provided in Appendix B.

4.3.1 Victoria River AMTD 283 km (Site 186) FSL 187 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies in the Victoria catchment were identified in web-based searches or searches of NT Government databases.
Description of potential dam	The potential Victoria River dam site is an instream development investigated for its potential to provide a flood mitigation benefit to the Kalkarindji and other communities downstream. A flood mitigation dam at this site could also provide sufficient water to meet local demands. The site was identified from a CSIRO DamSite model run, and this analysis is predominantly based on an assumed spillway crest level 200 mEGM96. Although this site was not selected for its potential to supply water, yield information is provided at the nominated FSL for completeness. Figure 4-5 and Figure 4-6 show the location of the site nd the extent of the reservoir area.
Regional geology	The Victoria catchment has a generally flat to undulating topography that drains to the north-west into the Joseph Bonaparte Gulf. The oldest rocks are Proterozoic sediments, including potentially soluble dolostone units, which were folded, faulted, uplifted and then eroded to a level not far above that of the current topography. In the higher ground to the west and south-east, they are overlain by a Cambrian sequence of basalts with overlying potentially soluble limestones and dolomites of limited occurrence, mainly in the south-east part of the catchment. Cretaceous sediments occur on the south-east margins of the catchment. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma. This resulted in the formation of deep weathering profiles and associated iron-cemented cappings on the older rocks, and broad valleys infilled with alluvium.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (Figure 4-7) and satellite imagery. The dam site is located on Cambrian rocks of the Antrim Plateau Volcanics (Cla), which consist of basalts with some minor sediments. There appeared to be some outcrop on the abutments, but the basalts are likely to be deeply weathered. In the river bed is a 250-m-wide area of pooled water and gravel bars. The foundations may not be stiff enough for a RCC dam. They may be more suitable for a concrete-faced rockfill dam or an embankment dam, with a separate lined chute spillway on either abutment. For estimating purposes, assume 5–10 m of alluvium in the river bed and 5–10 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the predicted foundation conditions, a concrete-faced rockfill embankment dam is proposed rather than a roller compacted concrete dam. Diversion during construction would be via a tunnel constructed through the left abutment of the dam. Reinforced steel mesh protection on the downstream face of the embankment would also be used as a protection against overtopping during construction.

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td></td><td>An uncontrolled fully lined spillway channel would be excavated through the right abutment, with placement of the crest structure delayed until the embankment is raised to a safe height.

Nominally the potential dam would store water to a level 10 m above bed level with the storage to the spillway crest level serving as a temporary flood storage compartment.

Access to the dam would be via a 5-km-long new road branching from the Buntine Highway 13 km south-west of Kalkarindji. The total distance from the site to Kununurra would be some 524 km. Alternatively, the distance to Katherine via Delamere would be 462 km.</td></tr>
<tr><td>Availability of construction materials</td><td>Assume a CFRD could be built from processed gravels, which might be won and processed from a river bed or terrace deposit within 15 km of the dam site. For estimating purposes, assume a ratio of useful gravel excavated to total volume excavated of 0.5. For estimating purposes, assume a ratio of useful material excavated to total volume excavated of 0.5. Higher-quality aggregate to construct a spillway or a concrete face for a concrete-faced rockfill dam could probably be sourced from Kununurra, a distance of 290 km but a tortuous road for haulage.</td></tr>
<tr><td>Catchment area</td><td>4413 km²</td></tr>
<tr><td>Modelled annual inflow data</td><td>
<table>
<tr><th>Parameter</th><th>Scenario A
(GL/y)</th><th>Scenario Cdry
(GL/y)</th><th>Scenario Cmid
(GL/y)</th><th>Scenario Cwet
(GL/y)</th></tr>
<tr><td>Max</td><td>2229</td><td>1655</td><td>2179</td><td>2596</td></tr>
<tr><td>Mean</td><td>206</td><td>148</td><td>196</td><td>270</td></tr>
<tr><td>Median</td><td>80</td><td>55</td><td>69</td><td>134</td></tr>
<tr><td>Min</td><td>16</td><td>16</td><td>16</td><td>19</td></tr>
</table>
</td></tr>
<tr><td>Reservoir characteristics</td><td>Reservoir characteristics are shown in Figure 4-8. Reservoirs with FSLs of selected heights are tabulated below. It should be noted these are the
<table>
<tr><th>FSL (mEGM96)</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>185</td><td>329</td><td>8</td></tr>
<tr><td>187</td><td>615</td><td>17</td></tr>
<tr><td>189</td><td>986</td><td>33</td></tr>
</table>
</td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>FSL 185 mEGM96 – estimated yield at 85% annual time reliability 4 GL
FSL 187 mEGM96 – estimated yield at 85% annual time reliability 17 GL
FSL 189 mEGM96 – estimated yield at 85% annual time reliability 28 GL
Reservoir characteristics and yields under current and projected future climates are shown in Figure 4-8, Figure 4-9 to Figure 4-10.
It should be noted that a FSL 187 mEGM96 corresponds to a 10 m high dam wall. The primary purpose of this potential dam being for flood mitigation purposes.</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at FSL 187 mEGM96</td><td>
<table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>8</td><td>12</td><td>13</td></tr>
<tr><td>100 years (%)</td><td>27</td><td>40</td><td>44</td></tr>
<tr><td>Years to fill</td><td>380</td><td>250</td><td>230</td></tr>
</table>
</td></tr>
<tr><td>Potential use of supply</td><td>A flood mitigation dam as discussed here would have limited potential to supply water for irrigated agriculture. Nonetheless a brief discussion of the soils downstream of the potential dam is provided.</td></tr>
</table>

PARAMETER	DESCRIPTION
	From 20 km below the potential dam site, the Victoria River is deeply incised into a gently undulating basalt landscape. Moderately deep (0.5–1 m) slowly permeable, neutral to alkaline cracking clay soils (SGG 9) with a high (100–25 mm) water-holding capacity (within 1 m of the surface) dominate the gently undulating plains. Soils have varying levels of surface and profile rock, limiting the extent suitable for agricultural development. On the level cracking clay plains, soils are relatively rock free and suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated cucurbits, and in the better-drained areas (red cracking clays) for tree crops such as mangoes (*Mangifera indica*) or lychee (*Litchi chinensis*). Also dry-season spray-irrigated perennial grasses for hay and forage, such as Rhodes grass (*Chloris gayana*); pulse crops such as mungbean (*Vigna radiata*), soybean (*Glycine max*) and chickpea (*Cicer arietinum*); and small-seeded crops such as chia (*Salvia hispanica*) and quinoa (*Chenopodium quinoa*). Also dry-season flood-irrigated rice (*Oryza* spp.) and furrow-irrigated grain and cotton (*Gossypium* spp.) and leguminous hay and forage crops on the elevated level basalt plains. Soils are also suitable (Class 3) for furrow-irrigated wet-season sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*) crops on the elevated level basalt plains. Downstream of this potential dam site there are several remote communities, however, their current water supply requirements are modest relative.
Environmental considerations	**Habitat fragmentation and barrier to movement of aquatic species** There were no records for ecology assets within the catchment of this potential dam site. However, the models predict that ~2% of the upstream catchment (8137 ha) has suitable habitat for at least 40% of the 11 species modelled, some of which have records in neighbouring streams. Species, including the mouth almighty (*Glossamia aprion*), spangled grunter (*Leiopotherapon unicolor*), the fork-tailed catfish *(Neoarius graeffei*) and the eastern rainbow fish (*Melanotaenia splendida*), may have their habitat fragmented and/or their movement impeded by a dam. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively small, depending on the species, and ranges from 0.04% to 6.8% of their total modelled suitable habitat in the Victoria catchment. Part of the Northern Tanami Indigenous Protected Area occurs in the catchment upstream of this site. Figure 4-11 shows the location of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Victoria River (AMTD 283 km) site. **Ecological implications of inundation** The purple-crowned fairy-wren (western) (*Malurus coronatus coronatus*), listed as endangered (EPBC Act) and vulnerable (NT), has been recorded at the reservoir of this potential dam site. Other listed species recorded in the potential catchment are the Gouldian finch (*Chloebia gouldiae*), also listed as endangered (EPBC Act) and vulnerable (NT), and the grey falcon (*Falco hypoleucos*), listed as vulnerable (EPBC Act and NT). Other listed species occurring near this the potential catchment are the golden bandicoot (*Isoodon auratus*), listed as vulnerable in the EPBC Act and as endangered (in the NT) and the greater bilby (*Macrotis lagotis*), listed as vulnerable at federal and territory level. Other waterbirds such as the royal spoonbill (*Platalea regia*) also occur near this catchment. The potential inundated area at FSL for this site (200 mEGM96) may have an effect on parts of the habitat for these species. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecological flow dependencies (Stratford et al., 2024b).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

PARAMETER	DESCRIPTION
Estimated cost	A manual cost estimate undertaken as part of the Assessment for a hypothetical concrete-faced rockfill embankment dam on the Victoria River AMTD 283 km at FSL 187 mEGM96 found the dam would cost approximately $740 million. Details of this cost estimate are provided in Appendix A. It should be noted that this cost estimate is based on a conceptual arrangement for a rock filled embankment dam for flood mitigation purposes, not water supply purposes. The damsite model was not used to cost potential dams at heights less than 15 m.
Estimated cost/ML of supply	Based on the manual cost estimate for a flood mitigation dam, the cost/ML of supply at FSL of 187 mEGM96 is $43,529/ML.
Summary comment	This potential dam site on the upper Victoria River is an instream development investigated for its potential to provide flood mitigation benefit to the Kalkarindji, Pidgeon Hole and other Indigenous communities downstream. A dam for flood mitigation at this site could also provide a limited water supply to meet local needs. The flood mitigation potential is reported in the companion technical report on river system simulations in the Victoria catchment (Hughes et al., 2024b). The foundations at this site may not be stiff enough for a RCC dam, and a rockfill embankment dam was considered instead, with a separate lined chute spillway on the right abutment. The catchment of the site has the lowest area of suitable habitat of the modelled water-dependent species expressed as a percentage of the catchment area (25%). There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AMTD = adopted middle thread distance; CFRD = concrete-faced rockfill dam; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.

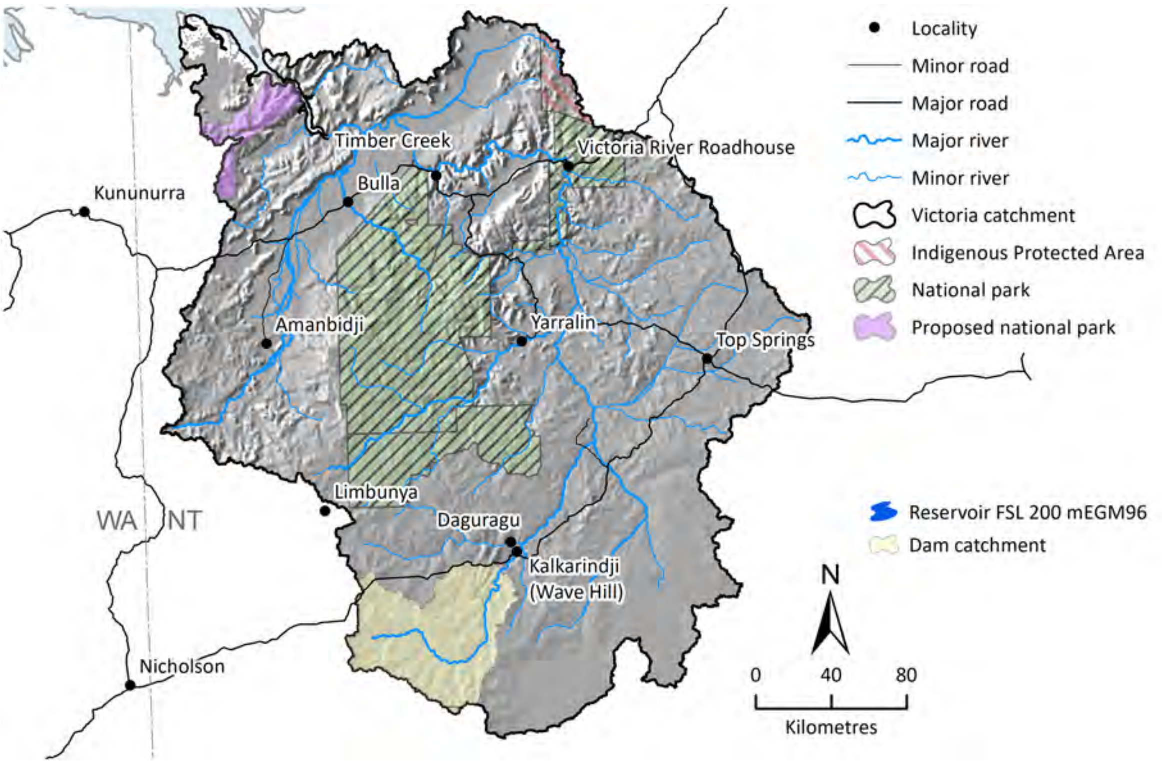

Figure 4-5 Location map of potential Victoria River dam site, reservoir extent, and catchment area

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

Figure 4-6 Potential Victoria River dam reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres. Note in this figure the FSL is the spillway crest.

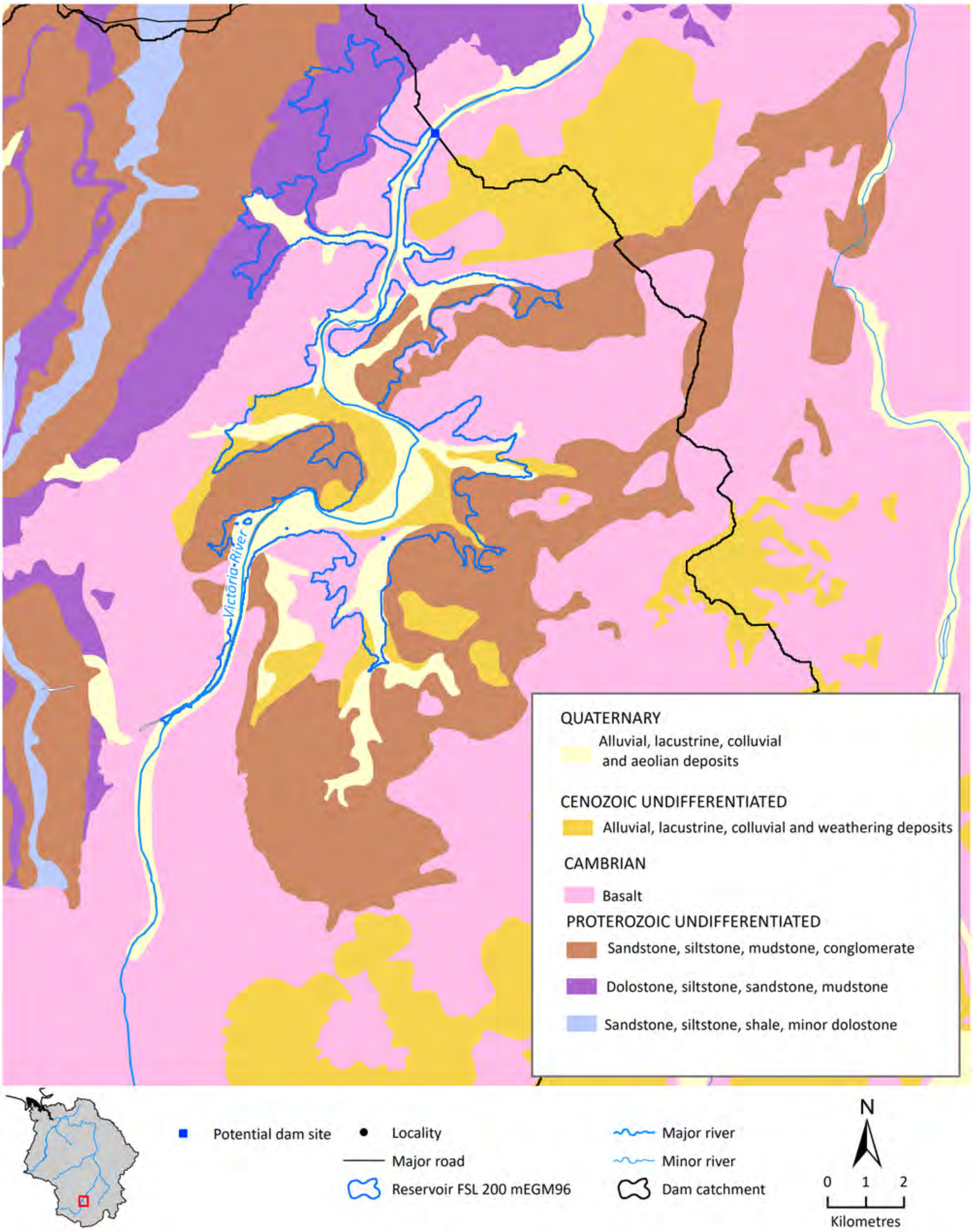

Figure 4-7 Geology underlying the potential Victoria River dam site and reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres. Note in this figure the FSL is the spillway crest.

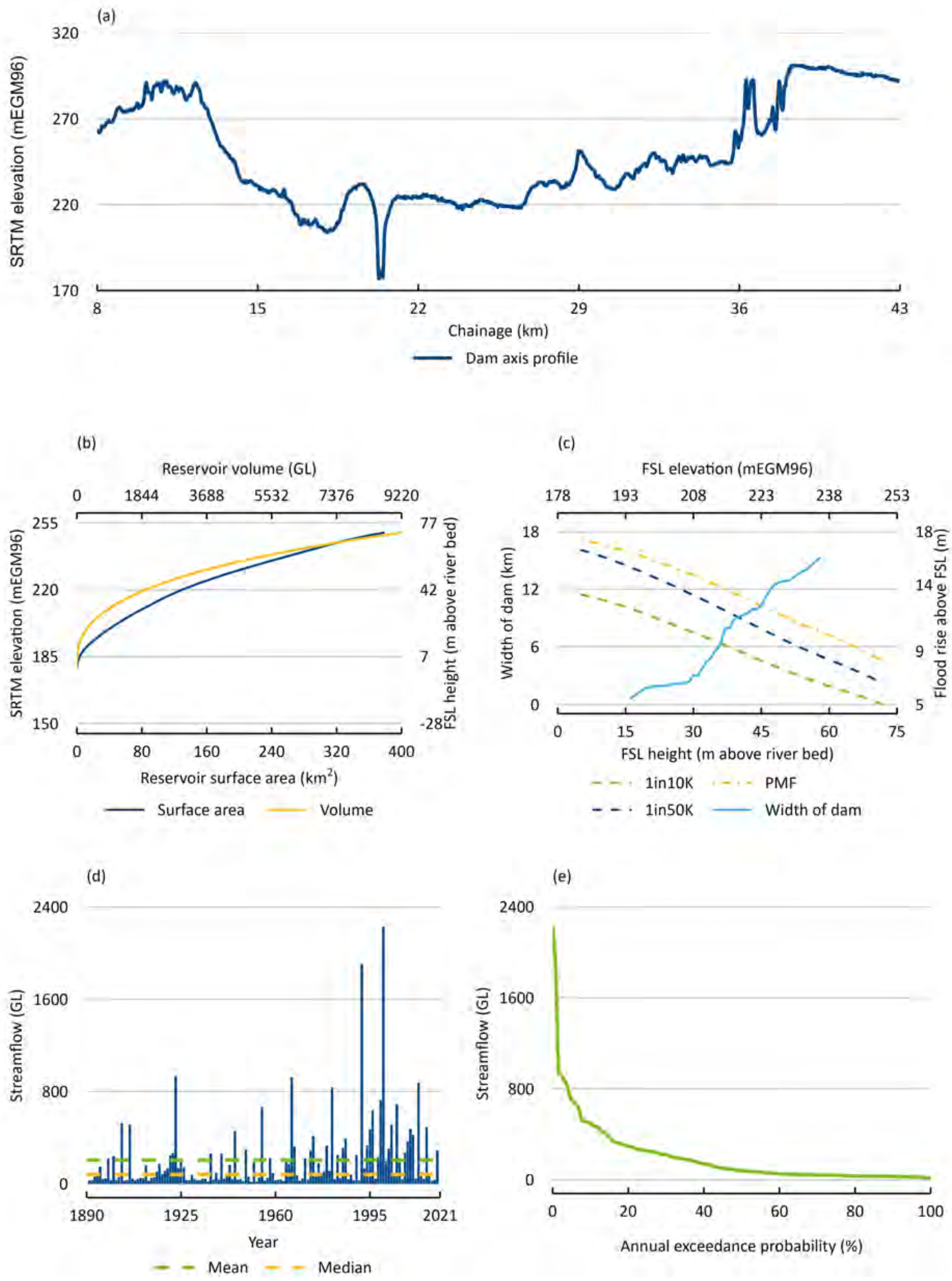

Figure 4-8 Victoria River potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width, and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

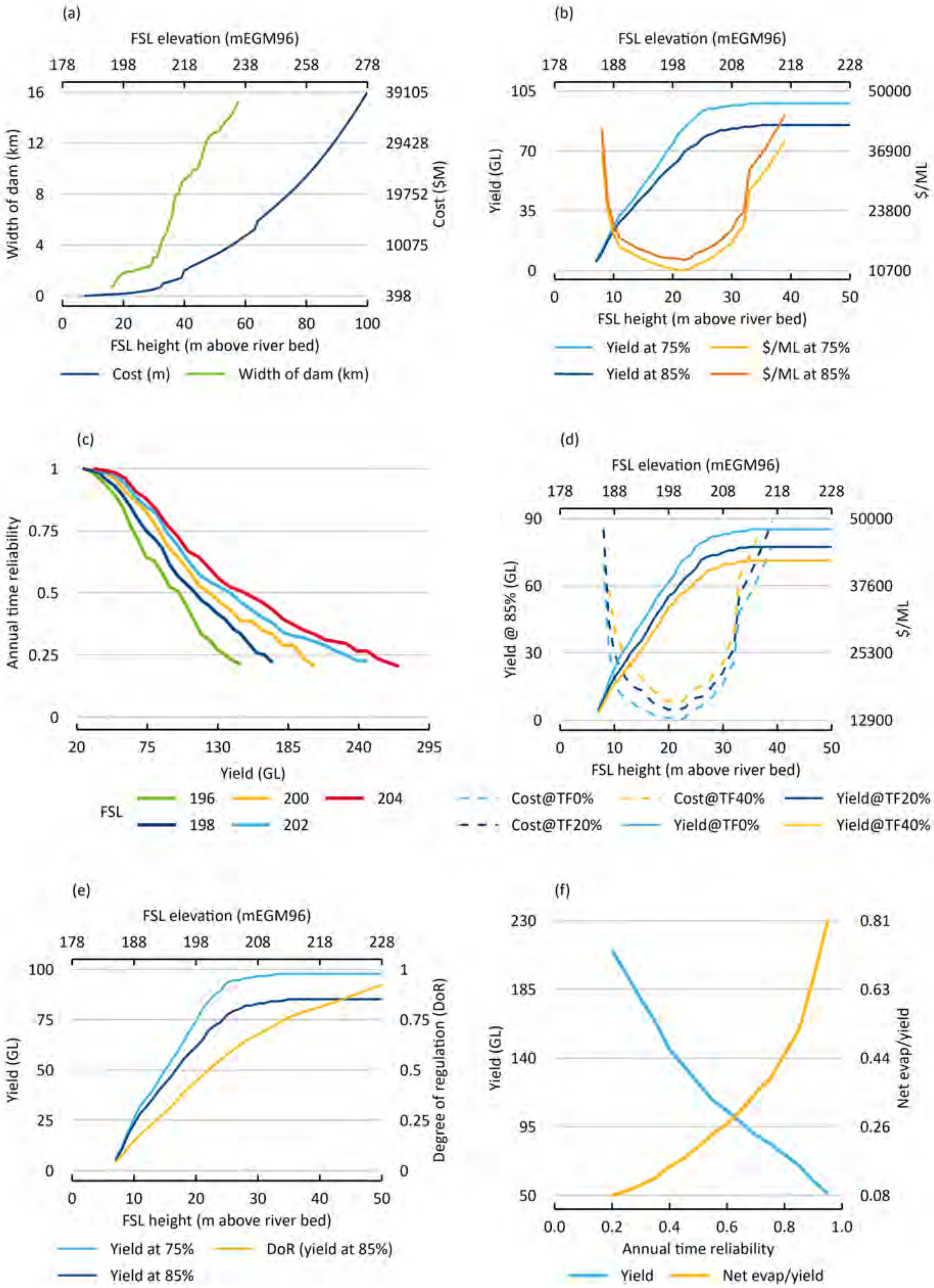

Figure 4-9 Victoria River potential dam site cost, water yield at the dam wall, and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability, and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield (Net evap/yield) plotted against annual time reliability. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

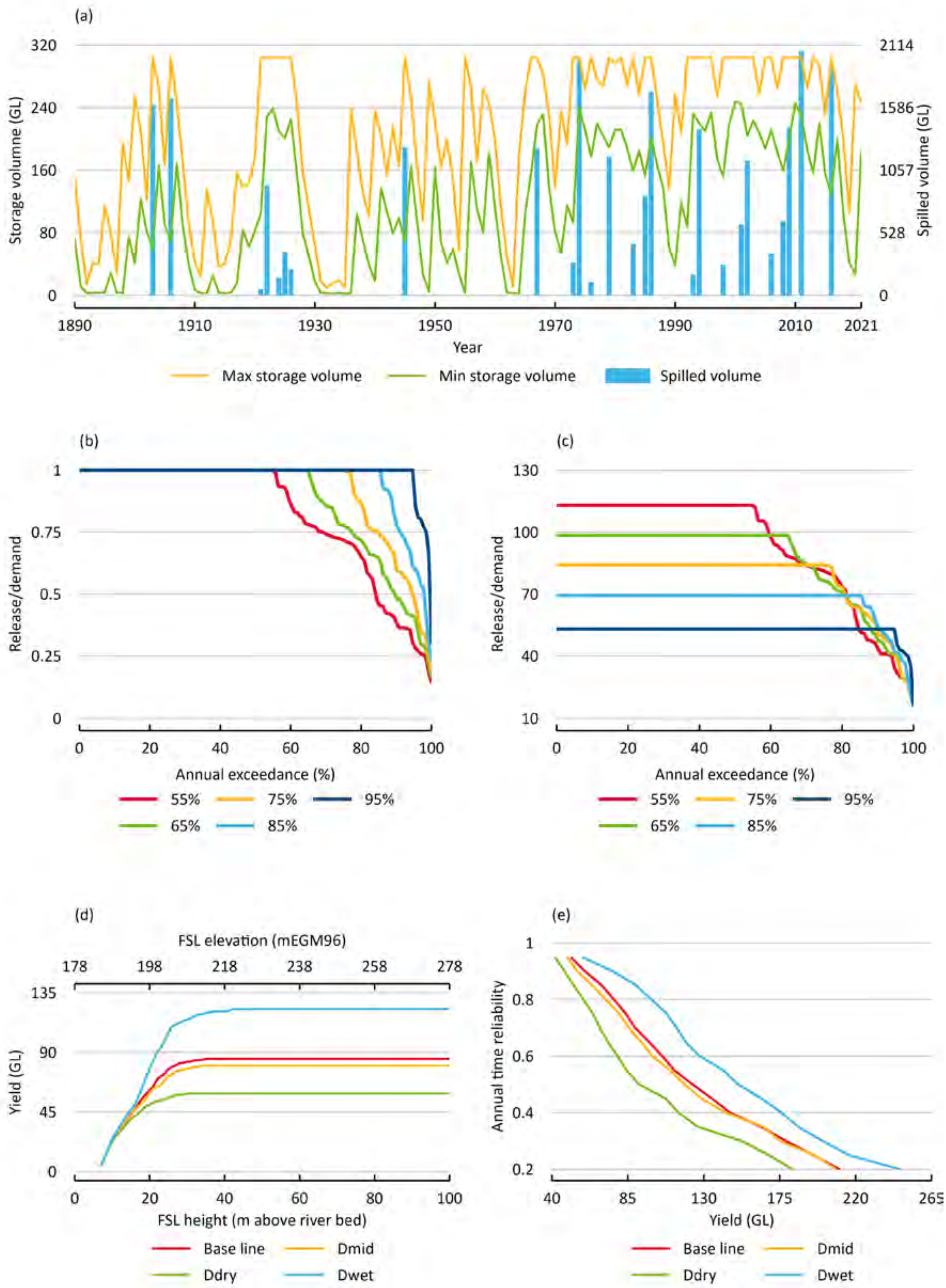

Figure 4-10 Victoria River potential dam site, storage levels and water yield

(a) Max. and min. annual storage trace at the selected full supply level (FSL) (200 mEGM96) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under scenarios A and D; (e) annual time reliability versus yield for FSL 187 mEGM96 under Scenario A (baseline) and Scenario D. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

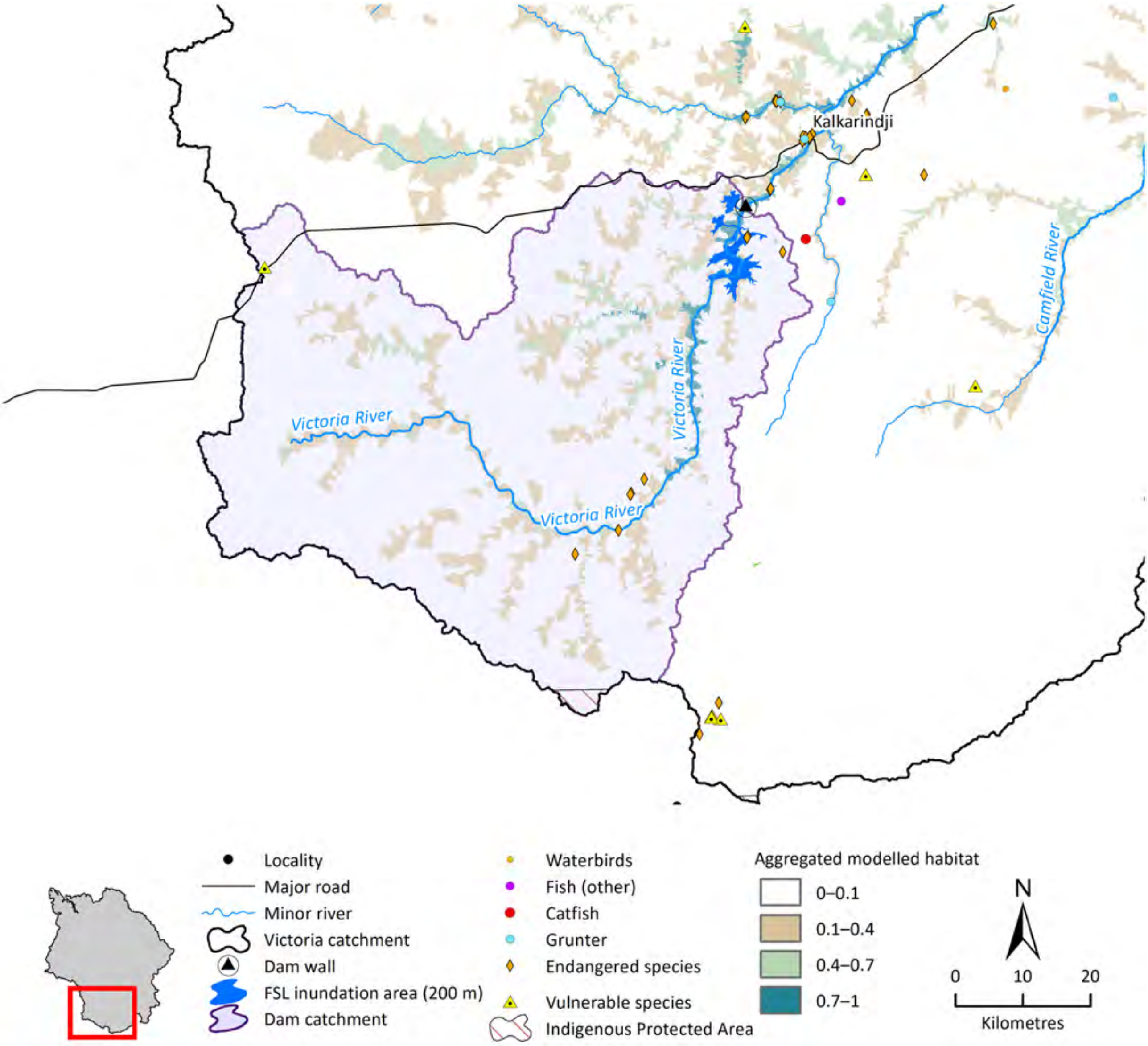

Figure 4-11 Locations of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Victoria River (AMTD 283 km) site

FSL = full supply level Note in this figure the FSL is the spillway crest.

4.3.2 Leichhardt Creek AMTD 26 km (Site 131) FSL 122 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies in the Victoria River catchment were identified in web-based searches or searches of NT Government databases.
Description of potential dam	The potential Leichhardt Creek dam site is an instream development with potential to provide irrigation supplies downstream along the creek and into the West Baines River area. The site was identified from the CSIRO DamSite model run, and this analysis is predominantly based on an assumed FSL of 122 mEGM96. Figure 4-12 and Figure 4-13 show the location of the site and the extent of the reservoir area.
Regional geology	The Victoria River catchment has a generally flat to undulating topography that drains to the north-west into the Joseph Bonaparte Gulf. The oldest rocks are Proterozoic sediments, including potentially soluble dolostone units, which were folded, faulted, uplifted and then eroded to a level not far above that of the current topography. In the higher ground to the west and south-east, they are overlain by a Cambrian sequence of basalts, with overlying potentially soluble limestones and dolomites of limited occurrence, mainly in the south-east part of the catchment. Cretaceous sediments occur on the south-east margins of the catchment. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma. This resulted in the formation of deep weathering profiles and associated iron-cemented cappings on the older rocks, and broad valleys infilled with alluvium.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Figure 4-14) and satellite imagery. The dam site is located on Proterozoic rocks of the Jasper Gorge Sandstone (Paj), which consist of medium quartz sandstone with minor siltstone. There appeared to be gently dipping outcrop on both of the abutments. The river bed was ~30 m wide, with ponded water ~20 m wide. In the river bed are possible rock bars, and the alluvium appears to be shallow. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 5 m of alluvium in the river bed and 5 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam with a 70-m-wide central uncontrolled spillway is proposed. The abutments would be set at a 1:50,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A 50-m-wide hydraulic jump-type spillway basin would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion conduit located in the right abutment of the dam. A fish lift transfer facility would also be installed in the right abutment of the dam. Access to the dam would be via an 85-km-long new road branching from Highway 1 east of the West Baines River crossing. The total distance from the site to Kununurra would be some 375 km.
Availability of construction materials	A quarry that could provide suitable fine and coarse aggregate might be found within 5 km of the dam site. For estimating purposes, assume a ratio of useful rock excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Kununurra, a distance of about 375 km.
Catchment area	1220 km^2

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td>Modelled annual inflow data</td><td>

Parameter	**Scenario A (GL/y)**	**Scenario Cdry (GL/y)**	**Scenario Cmid (GL/y)**	**Scenario Cwet (GL/y)**
Max	378	271	362	481
Mean	101	81	98	121
Median	93	77	88	112
Min	3	3	3	3

</td></tr>
<tr><td>Reservoir characteristics</td><td>

Reservoir characteristics are shown in Figure 4-15.

Reservoirs with FSLs of selected heights are tabulated below.

FSL (mEGM96)	Surface area (ha)	Capacity (GL)
120	1720	156
122	2024	193
124	2399	237

</td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>

FSL 120 mEGM96 – estimated yield at 85% annual time reliability 60 GL

FSL 122 mEGM96 – estimated yield at 85% annual time reliability 64 GL

FSL 124 mEGM96 – estimated yield at 85% annual time reliability 66 GL

Reservoir characteristics and yields under current and projected future climates are shown in Figure 4-15, Figure 4-16 and Figure 4-17.

</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at FSL 122 mEGM96</td><td>

	Best case	Expected	Worst case
30 years (%)	0.7	1.1	1.2
100 years (%)	2.4	3.6	4.0
Years to fill	4198	2799	2519

</td></tr>
<tr><td>Potential use of supply</td><td>

The potential dam site is located 15 km upstream of a floodplain above the junction with the West Baines River. Red loamy (SGG 4.1) and friable non-cracking clay loam to clay (SGG 2) soils dominate this floodplain. These soils are suitable, with minor limitations (Class 2), for dry-season trickle-irrigated intensive horticulture such as cucurbits and dry-season spray-irrigated root crops such as sweet potato (*Ipomoea batatas*) and peanuts (*Arachis hypogaea*). The red loamy soils are also suitable, with minor limitations (Class 2), for spray-irrigated perennial grasses such as Rhodes grass (*Chloris gayana*) and pulse crops such as mungbean (*Vigna radiata*), soybean (*Glycine max*) and chickpea (*Cicer arietinum*). The friable non-cracking clay loam to clay soils are also suitable, with moderate limitations (Class 3), for spray-irrigated perennial grasses and pulse crops.

At 25 km downstream of the potential dam site, past the junction with the West Baines River, similar soils occur. However, the floodplain is braided with a series of channels, swales and levees, making this part of the floodplain largely unsuitable for irrigated cropping. At 50 km downstream of the potential dam site, the narrow valley opens onto a large alluvial plain that is dominated by friable non-cracking clay loam (SGG 2) soils, cracking clay (SGG 9) soils and shallow and/or rocky soils on rises (SGG 7) in the river plain.

The friable clay loam soils (SGG 2) occur adjacent to the river and side creeks on levees. They are very deep (>1.5 m), imperfectly drained, moderately permeable, mottled brown friable clay loam soils.

Deep (1 to >1.5 m) imperfectly to moderately well-drained, very slowly to slowly permeable grey and brown hard-setting cracking clay soils (SGG 9), frequently with small (<0.3 m) normal gilgai depressions that occur on a large part of the plain. Soils have a neutral to alkaline pH and have a very high (>140 mm) water-holding capacity (over a 1-m depth). However, rooting depth may be restricted locally by very high salt levels in the subsoil. The shallow and/or rocky soils within the valley are on elevated remnants of older sediments.

</td></tr>
</table>

PARAMETER	DESCRIPTION
	The cracking clay soils (SGG 9) are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated intensive horticulture, dry-season spray-irrigated perennial grasses for hay and forage, pulse crops and small-seeded crops, dry-season flood-irrigated rice (*Oryza* spp.) and dry-season furrow-irrigated lablab (*Lablab purpureus*). The friable clay loam soils (SGG 2) adjacent to the river and creeks are suitable, with minor limitations (Class 2), to dry-season spray-irrigated pulse crops, small-seeded crops and root crops.
Environmental considerations	**Habitation fragmentation and barrier to movement of aquatic species** There were no records for ecology assets within the catchment of this potential dam site. However, the models predict that ~4% of the catchment upstream of this dam site (5372 ha) has suitable habitat for at least 40% of the 11 species modelled. Some of these species are also found in neighbouring streams, including the northern snapping turtle (*Elseya dentata*), spangled grunter (*Leiopotherapon unicolor*), western rainbow fish (*Melanotaenia australis*), eastern rainbow fish (*Melanotaenia splendida*), the fork-tailed catfish *(Neoarius graeffei*) and mouth almighty (*Glossamia aprion*), which may have their habitat fragmented and/or their movement impeded by a dam. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is very small; depending on the species, it ranges from zero % to 1.5% of their total modelled suitable habitat in the Victoria catchment. Figure 4-18 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Victoria River (AMTD 283 km) site. **Ecological implications of inundation** Only one listed species has been species recorded in the potential catchment, the Gouldian finch (*Chloebia gouldiae*), listed as endangered (EPBC Act) and vulnerable (NT). Waterbirds such as the royal spoonbill (*Platalea regia*), western cattle egret (*Bubulcus ibis*) and magpie goose (*Anseranas semipalmata*) also occur near this site, upstream from the dam wall. The potential inundated area at FSL for this site (122 mEGM96) may have an effect on the species habitat of these species. Part of the catchment associated with the potential dam overlaps with the Judbarra National Park. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecological flow dependencies (Stratford et al., 2024b).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	A manual cost estimate undertaken as part of the Assessment for a RCC dam on the Leichhardt Creek AMTD 26 km potential dam site at a FSL of 122 mEGM96 found the dam would cost approximately $396 million. Details of this cost estimate are provided in Appendix A. To enable a like-for-like comparison with sites that are not short-listed, dam costs were calculated using CSIRO’s generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 120 mEGM96 – estimated cost = $551 million FSL of 122 mEGM96 – estimated cost = $574 million FSL of 124 mEGM96 – estimated cost = $598 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO behaviour analysis (BHA) modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 120 mEGM96 – estimated cost/ML of supply = $9135/ML

PARAMETER	DESCRIPTION
	FSL of 122 mEGM96 – estimated cost/ML of supply = $8896/ML FSL of 124 mEGM96 – estimated cost/ML of supply = $9056/ML Based on the manual cost estimate, the cost/ML of supply at a FSL of 122 mEGM96 is $6188/ML.
Summary comment	The hypothetical instream dam in the upper West Baines catchment is relatively low yielding and has a moderately high cost per megalitre released from the dam wall. The foundations appeared to be suitable for a RCC dam. Despite being one of the closer sites to large contiguous areas of soil suitable for irrigated agriculture in the Victoria catchment, the site is still located approximately 15 km upstream from the potential target location. An advantage of this potential dam site is its proximity to the Victoria Highway and Kununurra. Being located in a small headwater catchment, the impacts of a dam at this location on migratory species is small relative to other locations, and the relatively small yield from the dam means that impacts associated with changes in flow are largely localised. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.

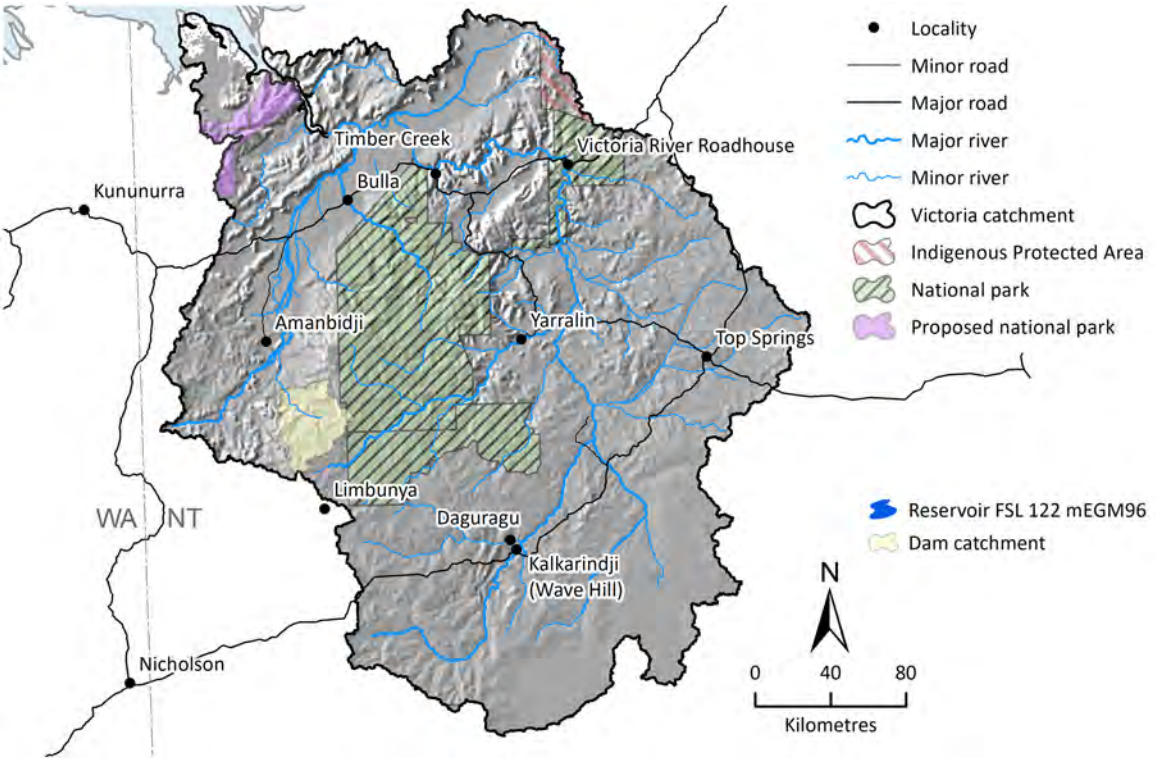

Figure 4-12 Location map of potential Leichhardt Creek dam site, reservoir extent, and catchment area

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

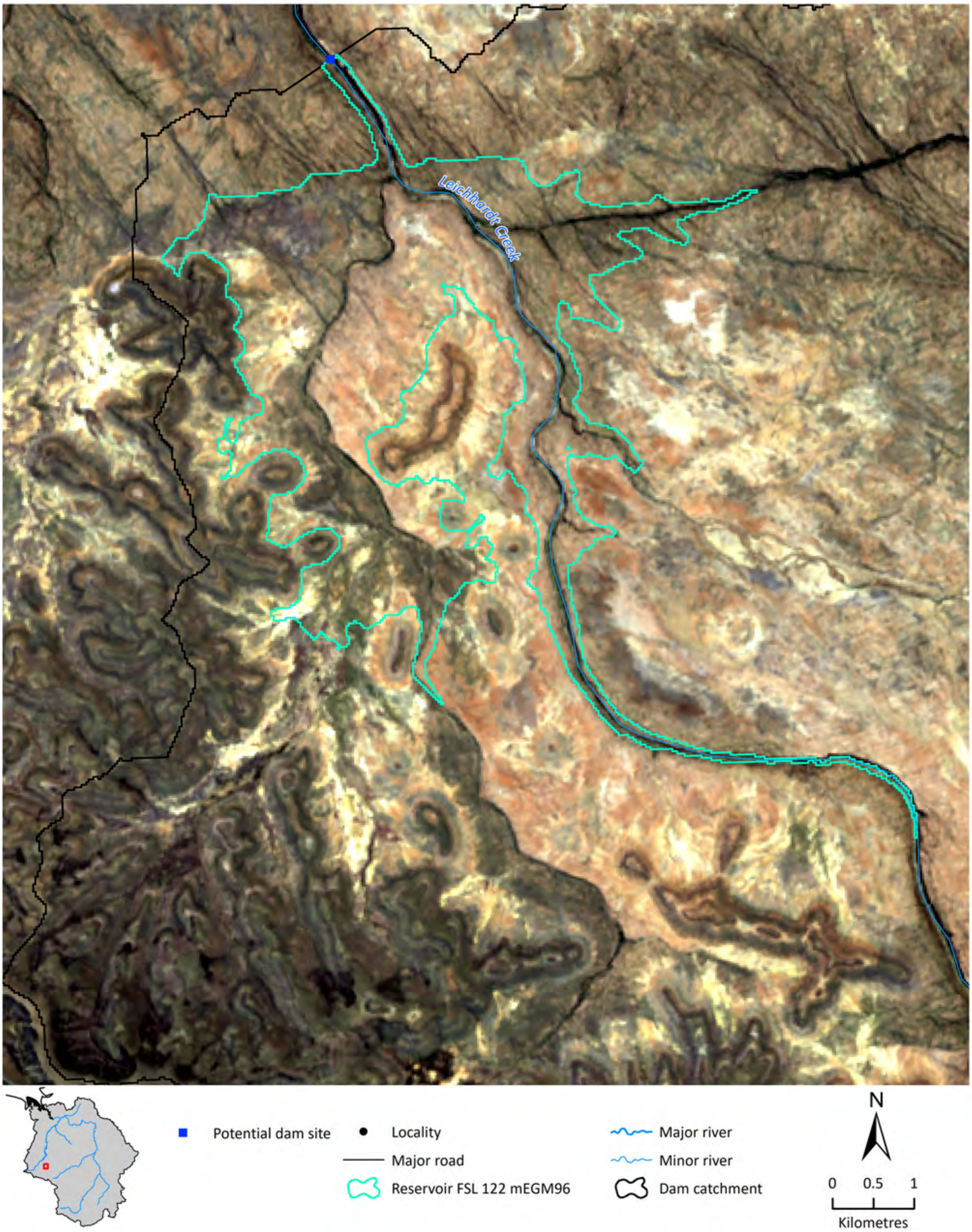

Figure 4-13 Potential Leichhardt Creek dam reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

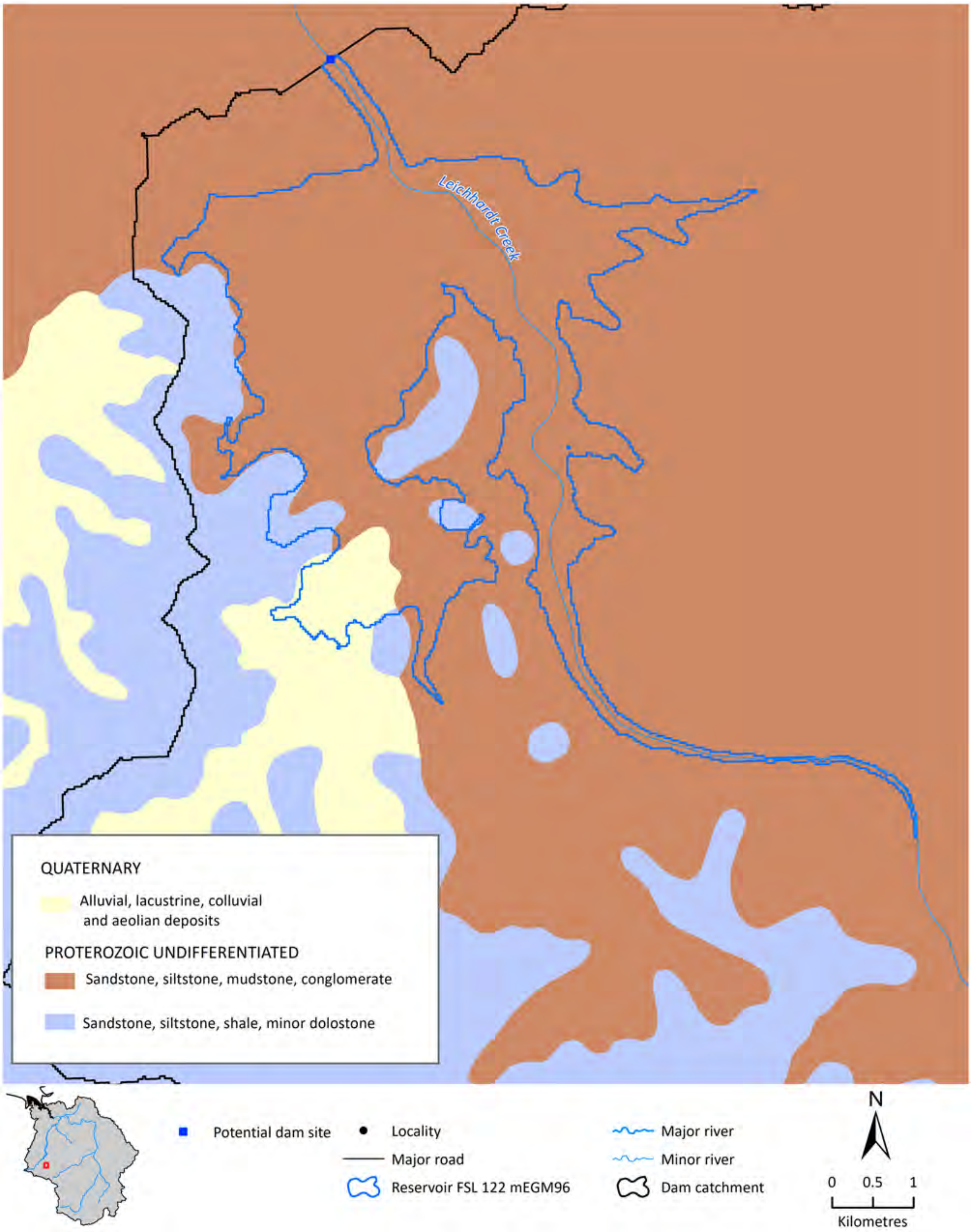

Figure 4-14 Geology underlying the potential Leichhardt Creek dam site and reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

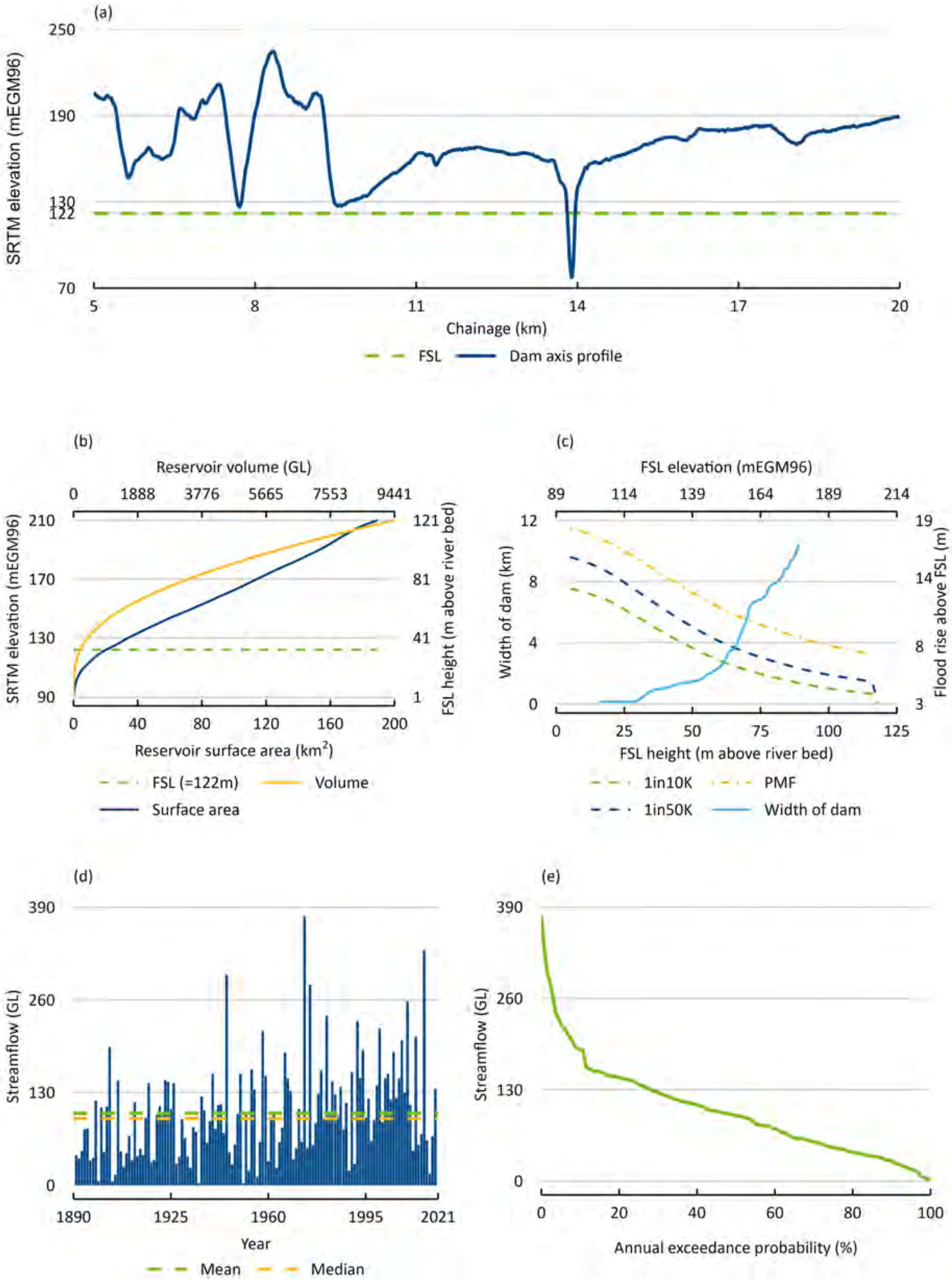

Figure 4-15 Leichhardt Creek potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

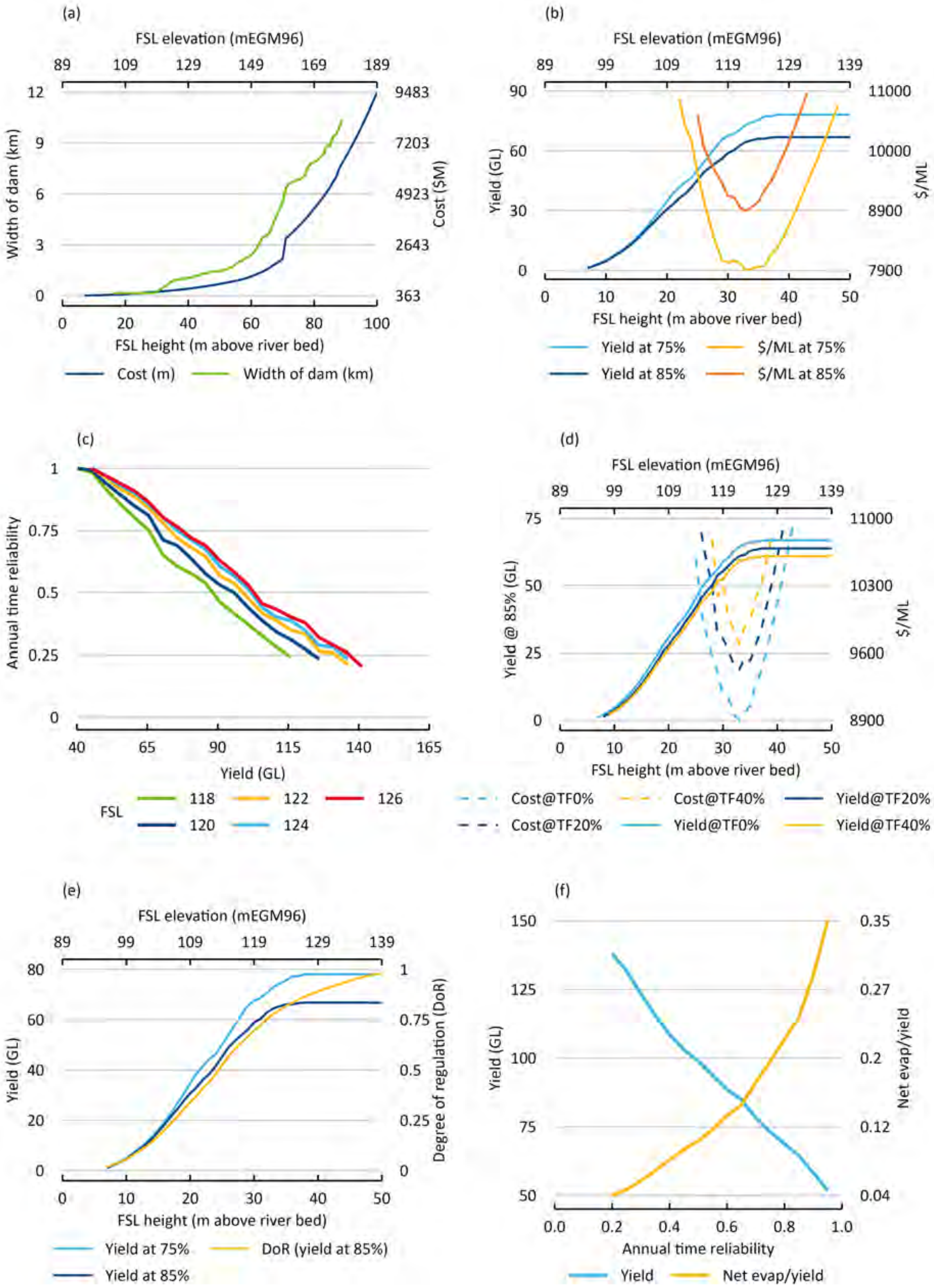

Figure 4-16 Leichhardt Creek potential dam site cost, water yield at the dam wall, and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) dam yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) dam yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

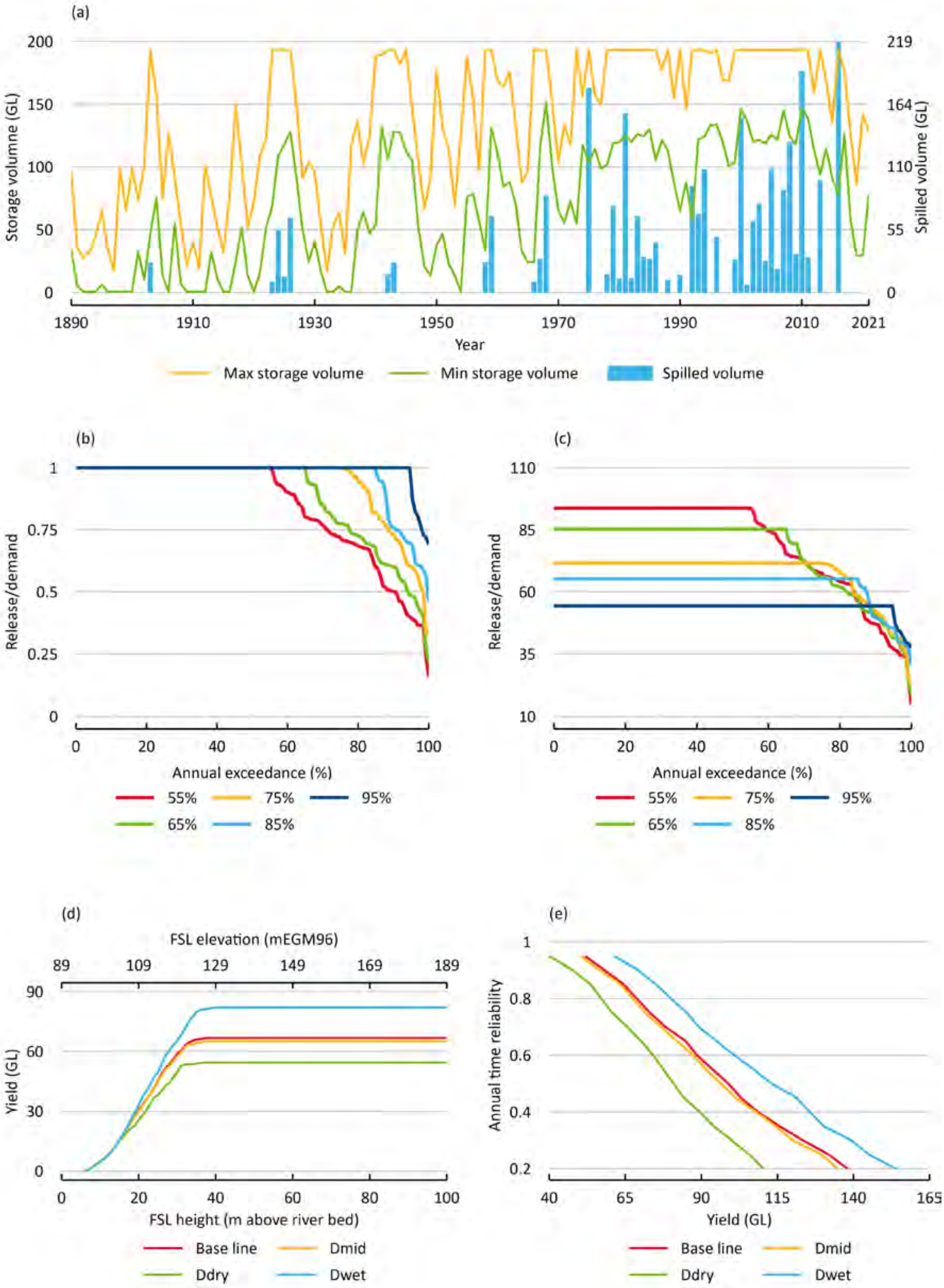

Figure 4-17 Leichhardt Creek potential dam site, storage levels, and water yield

(a) Max. and min. annual storage trace at the selected full supply level (FSL) (122 mEGM96) and annual spilled volume; (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under scenarios A (baseline) and D; (e) annual time reliability versus yield for FSL 122 mEGM96 under scenarios A and D. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

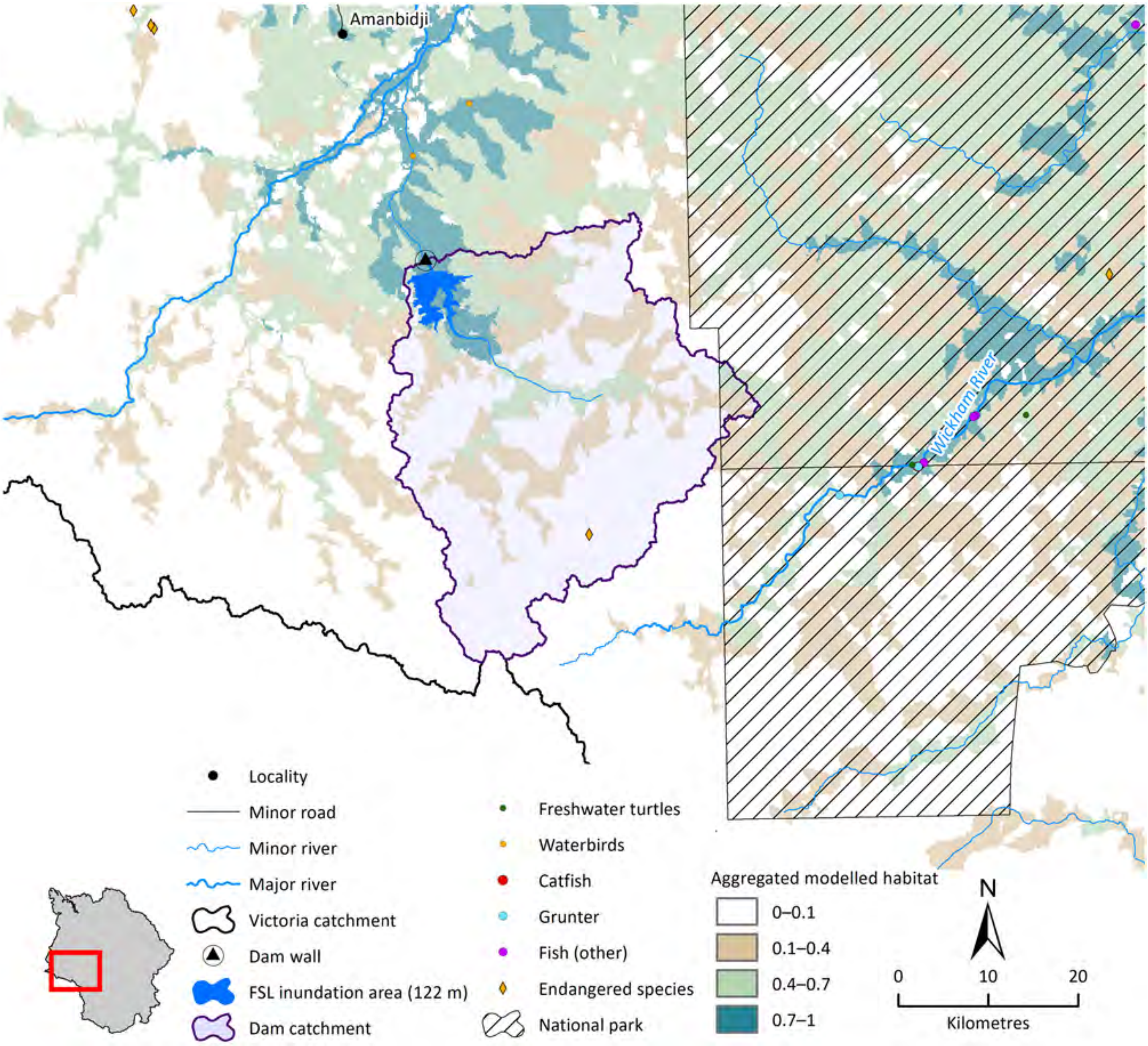

Figure 4-18 Location of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Leichhardt Creek dam site

FSL = full supply level.

5 Southern Gulf catchments

The opportunity analysis of potential dam sites in the Southern Gulf catchments involved a three-tier analysis (see Section 3.1).

Opportunity analysis

To ensure that no options had been overlooked, the DamSite model (see Section 3.1.2) was used to undertake a preliminary assessment of over 50 million potential dam sites in the southern Gulf catchments.

Long-list of potential dam sites

Next, a desktop geological suitability assessment was undertaken on a long-list of potential dam sites identified using the DamSite model results by overlaying the dam locations on 1:250,000 geology data (see Section 3.1.3).

Short-list of potential dam sites

The final stage of the analysis involved establishing a short-list of potential dam sites, of which a pre-feasibility analysis was undertaken, and manual dam costings were undertaken on two of the sites.

5.1 DamSite modelling

To ensure that no options had been overlooked, the DamSite model (see Section 3.1.2) was used to undertake a preliminary assessment of over 50 million potential dam sites in the Southern Gulf catchments. A desktop geological suitability assessment of the results of the DamSite model was undertaken by overlaying the dam locations on 1:250,000 geology data (see Section 3.1.3). The DamSite model results were then ranked using various criteria, and the locations compared for likely arable land.

5.1.1 Large dams for irrigation and water supply in the Southern Gulf catchments

Potential sites topographically suitable for large storages for water supply in the Southern Gulf catchments

Figure 5-1 displays the most promising sites across the Southern Gulf catchments in terms of storage volume (GL) per million dollars of construction cost. Only locations with a ratio of cost to storage of less than $5000/ML are shown. This provides a simple way of displaying the locations in the Southern Gulf catchments with the most favourable topography for a large reservoir relative to the size (i.e. cost) of the dam wall necessary to create the reservoir. This figure is particularly useful for identifying more promising sites for offstream storage (i.e. where some or all of the water is pumped into the reservoir from an adjacent drainage line). The threshold value of $5000/ML is nominal and is used to minimise the amount of data displayed. Note that this analysis does not consider evaporation, hydrology or geology.

The mainland Assessment areas can be broadly split into the uplands and the Carpentaria Plains (Thomas et al., 2024b). Figure 5-1 shows that the parts of the Southern Gulf catchments with the most favourable topography for storing water is the uplands, which are comprised of elevated and rugged ranges and/or incised gorges.

Large instream storages in the Southern Gulf catchments

In addition to suitable topography (and geology), instream dams require sufficient inflows to meet a potential demand. Potential dams that command smaller catchments with lower runoff have smaller yields. Results relating to this criterion can be summarised and conveniently presented in terms of cost of constructing the dam per megalitre of yield. This is very similar to the cost of constructing a dam per megalitre of storage volume described above. The DamSite model was initially run using a preliminary storage-yield-reliability calculation method, the GDG method, which is very rapid to apply. Only for the top 10,000 sites for the Southern Gulf catchments, ranked in terms of the cost per megalitre GDG yield, was the yield recalculated using the more numerically intensive behaviour analysis. Figure 5-2 only shows those sites with a cost less than $10,000/ML. Also shown on this figure is the versatile agricultural land for the Southern Gulf catchments, with the most versatile agricultural land occurring on the Carpentaria Plains (Thomas et al., 2024b). The DamSite modelling indicates that the most cost-effective potential dam sites are on the Nicholson and Gregory rivers and Gunpowder Creek. It should be noted that the streamflow inputs to the DamSite modelling undertaken for the Southern Gulf catchments did not take into consideration existing storages on the Leichhardt River.

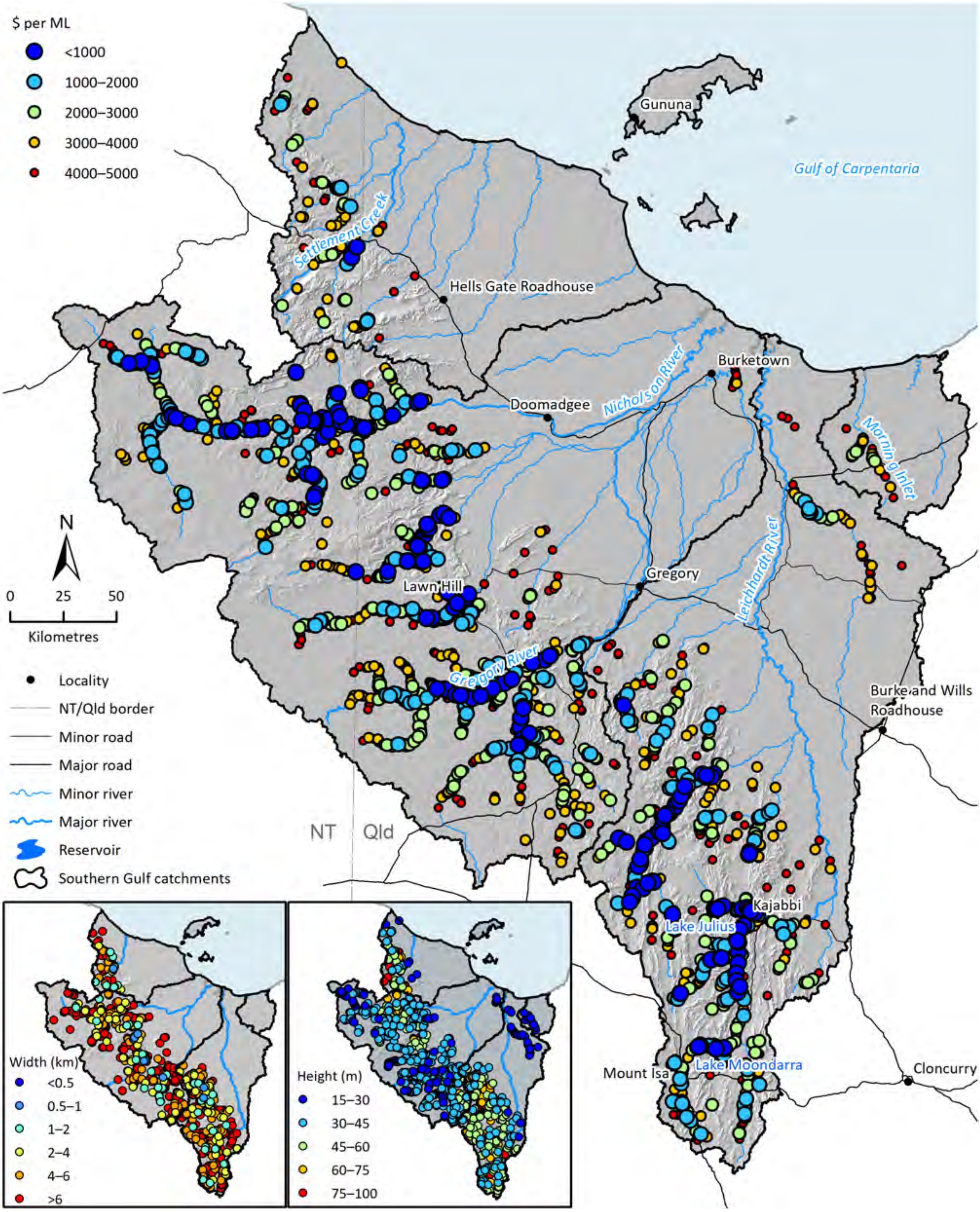

Figure 5-1 Topographically more favourable potential storage sites in the Southern Gulf catchments based on minimum cost per megalitre storage capacity

This figure can be used to identify locations where topography is suitable for large offstream storages. At each location the min. cost per megalitre storage capacity is displayed. The smaller the min. cost per megalitre storage capacity ($/ML), the more suitable the site for a large offstream storage. Analysis did not take into account geological considerations, hydrology, or proximity to water. Only sites with a minimum cost-to-storage-volume ratio of less than $5000/ML are shown. A ratio of $1000/ML is equivalent to 1 GL per million dollars. Costs are based on unit rates, quantity of material, and site-establishment costs for a roller compacted concrete (RCC) dam. Data are underlaid by a shaded relief map. Inset displays height of full supply level (FSL) at the min. cost per megalitre storage capacity.

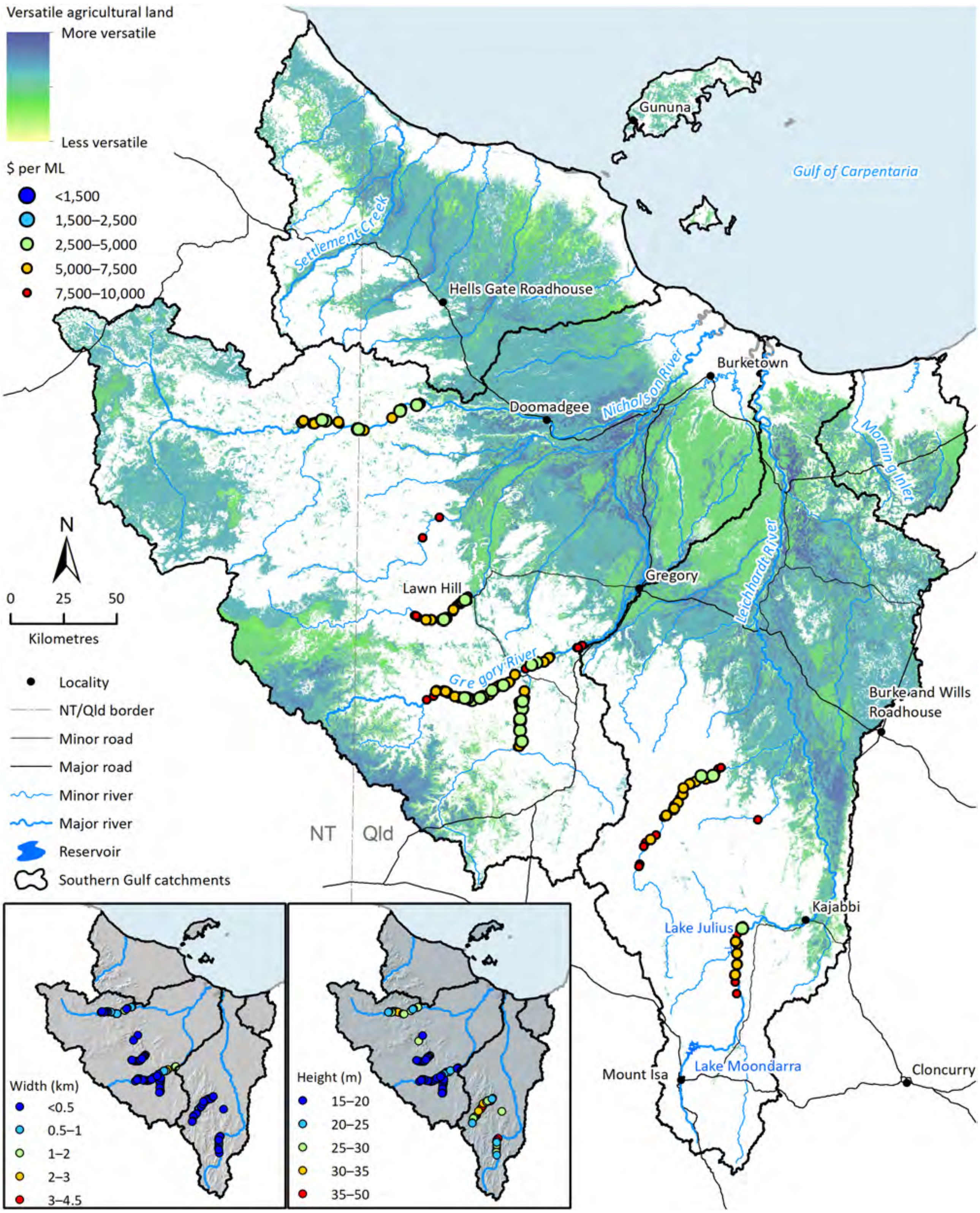

Figure 5-2 Topographically and hydrologically more favourable potential storage sites in the Southern Gulf catchments based on minimum cost per megalitre yield at the dam wall

This figure indicates those sites more suitable for major dams in terms of cost per megalitre yield at the dam wall in 85% of years, overlaid on map of versatile agricultural land (see Thomas et al., 2024b). At each location the min. cost per megalitre storage capacity is displayed. The smaller the cost per megalitre yield ($/ML), the more favourable the site for a large instream dam. Only sites with a min. cost-to-yield ratio of less than $10,000/ML are shown. Costs are based on unit rates and quantity of material required for a roller compacted concrete (RCC) dam with a flood design of 1 in 10,000. Right inset displays height of full supply level (FSL) at the minimum cost per megalitre yield and left inset displays width of FSL at the min. cost per megalitre yield.

5.1.2 Large dams for hydro-electric power generation potential

The potential for major instream dams to generate hydro-electric power is presented in Figure 5-3, following a reconnaissance assessment of more than 50 million sites in the Southern Gulf catchments. This figure provides indicative estimates of hydro-electric power generation potential but does not consider the costs of supporting infrastructure (e.g. transmission lines, grid connection). Although the topography of the Southern Gulf catchments is moderately suitable for water storage dams (i.e. narrow constrictions downstream of broad valleys), the topography appears to be less suitable for dams for hydro-electric power generation due to the lack of relief that is required to provide potential head. Gunpowder Creek, a major tributary of the Leichhardt River, was modelled to be the most favourable drainage line for dams for the purpose of hydro-electric power generation.

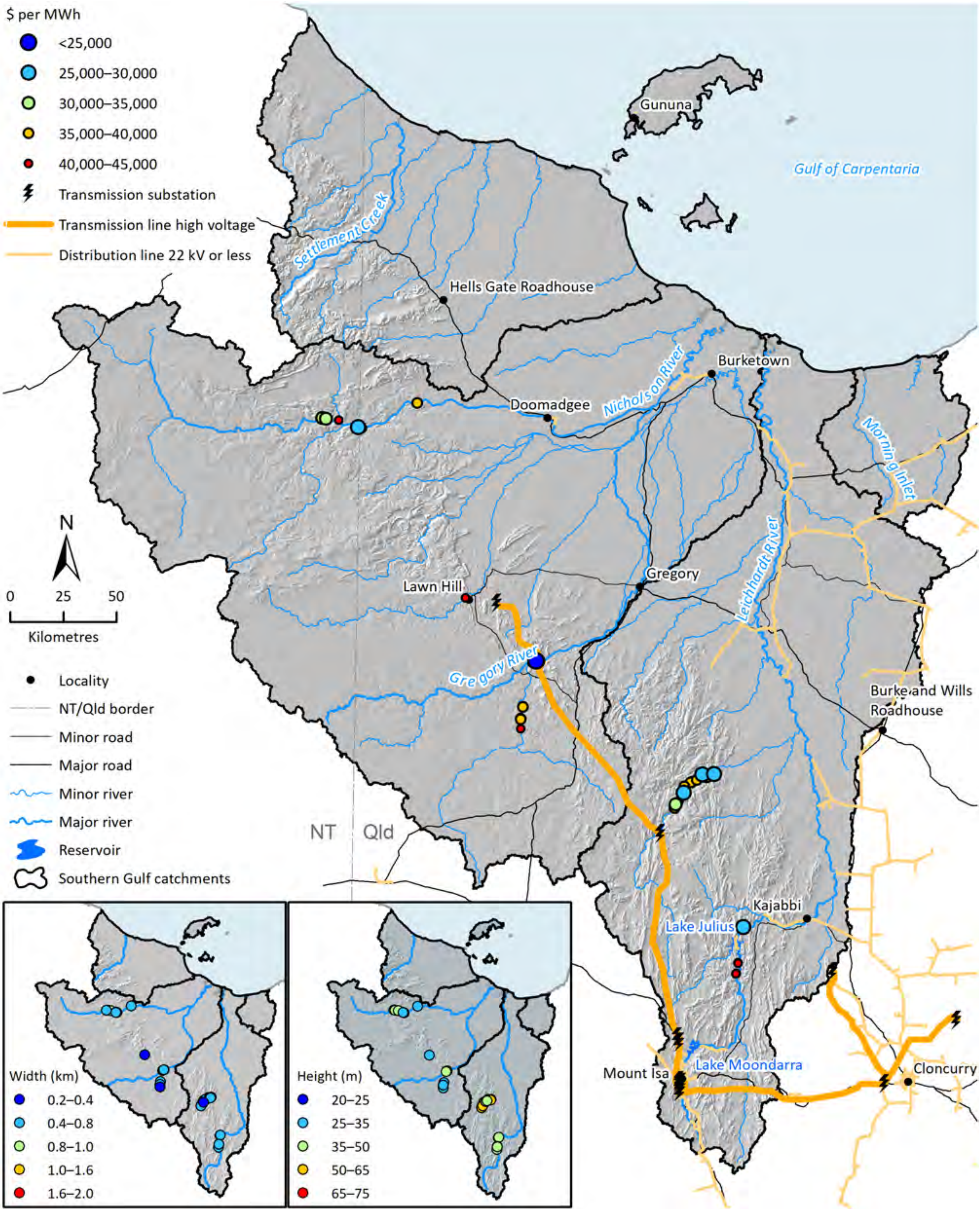

Figure 5-3 Southern Gulf catchments hydro-electric power generation opportunity map

Costs are based on unit rates and quantity of material required for a roller compacted concrete (RCC) dam with a flood design of 1 year in 10,000. Cost includes site establishment, fish lifts/traps (high dams) or ladders (low dams), and land resumption for the area of land impounded by a flood event of 1% annual exceedance probability (AEP). Data are underlain by a shaded relief map.

5.2 Long-list of potential dam sites

The characteristics of the long-list of potential dam sites in the Southern Gulf catchments are summarised in Table 5-1 and Table 5-2. Table 5-1 provides a summary of the yield and cost of potential dam sites at their optimum FSL. Table 5-2 provides a high-level geological summary of the long-listed potential dam sites. The geological summary was based on a desktop study. No site visit was undertaken.

Table 5-1 Long-list of potential dam sites in the Southern Gulf catchments

Data as calculated by the DamSite model at the optimum FSL irrespective of whether there was a potential demand (e.g. soil suitable for irrigated agriculture downstream). Note FSLs for short-listed sites were refined based on revised dam cost modelling using the ALOS DEM and BHA modelling. DamSite assigns Site ID based on largest yield per unit cost, where yield is calculated using the Gould–Dincer Gamma method (see Petheram et al., 2017). The model then re-evaluates yield using a more accurate but numerically intensive behaviour analysis model for the top 10,000 sites in the study area. Hence the order of the Site ID does not exactly correspond to the ranked order by unit cost. Site ID correspond to locations shown on Figure 5-4.

SITE ID	FSL ABOVE BED† (M)	CAPACITY AT FSL (GL)	CATCHMENT AREA (KM²)	ANNUAL WATER YIELD ‡ (GL)	CAPITAL COST§ ($ MILLION)	UNIT COST* ($/ML)	EQUIVALENT ANNUAL UNIT COST AND O&M†† ($/Y PER ML/Y)
0	27	646	12,351	200	668	3,344	248
1‡‡	19	118	11,381	180	683	3,794	191
3‡‡	34	1,403	13,870	289	3,344	11,156	306
21	35	658	8,213	146	597	4,074	302
24	22	123	3,319	69	378	5,455	404
28‡‡	51	716	3,516	129	773	5,992	342
34	43	295	3,595	119	583	4,908	364
48	26	154	3,585	79	367	4,627	343
51	27	110	3,502	76	416	5,502	408
119	31	460	11,516	286	1,887	6,603	489
163	17	42	1,357	29	347	11,965	886
165‡‡	30	158	1,161	40	659	16,545	734
185	20	82	1,320	28	333	11,741	870
192	19	259	1,903	32	268	8,385	621
197	16	42	2,109	32	521	16,430	1,217
206‡‡	34	119	422	24	367	15,154	1,387
211	28	599	6,024	186	1,929	10,389	770
232	18	124	934	26	316	12,198	904
275‡‡	30	245	706	29	466	16,158	967

SITE ID	FSL ABOVE BED† (M)	CAPACITY AT FSL (GL)	CATCHMENT AREA (KM²)	ANNUAL WATER YIELD ‡ (GL)	CAPITAL COST§ ($ MILLION)	UNIT COST* ($/ML)	EQUIVALENT ANNUAL UNIT COST AND O&M†† ($/Y PER ML/Y)
283	18	355	5,606	69	1,359	19,828	1,469
290‡‡	37	382	3,113	42	1,089	26,199	1,092
328	24	91	883	23	578	25,129	1,862
335	21	67	662	21	468	22,114	1,638
342	19	204	2,415	25	445	17,506	1,297
353	18	118	663	11	284	24,883	1,843
421	25	34	210	11	448	40,173	2,976
492	24	34	142	7	291	43,130	3,197
571	20	61	482	13	413	31,271	2,317
877	16	71	226	7	281	40,776	3,022

ALOS = Advanced Land Observing Satellite; DEM = digital elevation model; FSL = full supply level; OAM = operation and maintenance; SRTM = Shuttle Radar Topographic Mission.
‡‡Short-listed potential dam site.
†The height of the dam abutments and saddle dams will be higher than the spillway height.
‡Water yield is based on 85% annual time-based reliability using a perennial demand pattern for the baseline river model under Scenario A. This is yield at the dam wall (i.e. does not take into account distribution losses or downstream transmission losses). These yield values do not take into account downstream existing entitlement holders or environmental considerations.
§The height of the dam abutments and saddle dams will be higher than the spillway height. Note these heights above river bed are based on the DEM-H, which does not accurately capture incised channels.
*This is the unit cost of annual water supply and is calculated as the capital cost of the dam divided by the water yield at 85% annual time reliability.
††Assuming a 7% real discount rate and a dam service life of 100 years. Includes operation and maintenance costs, assuming operation and maintenance costs are 0.4% of the total capital cost.
Note there is limited soil suitable for irrigated agriculture downstream of this potential dam site.

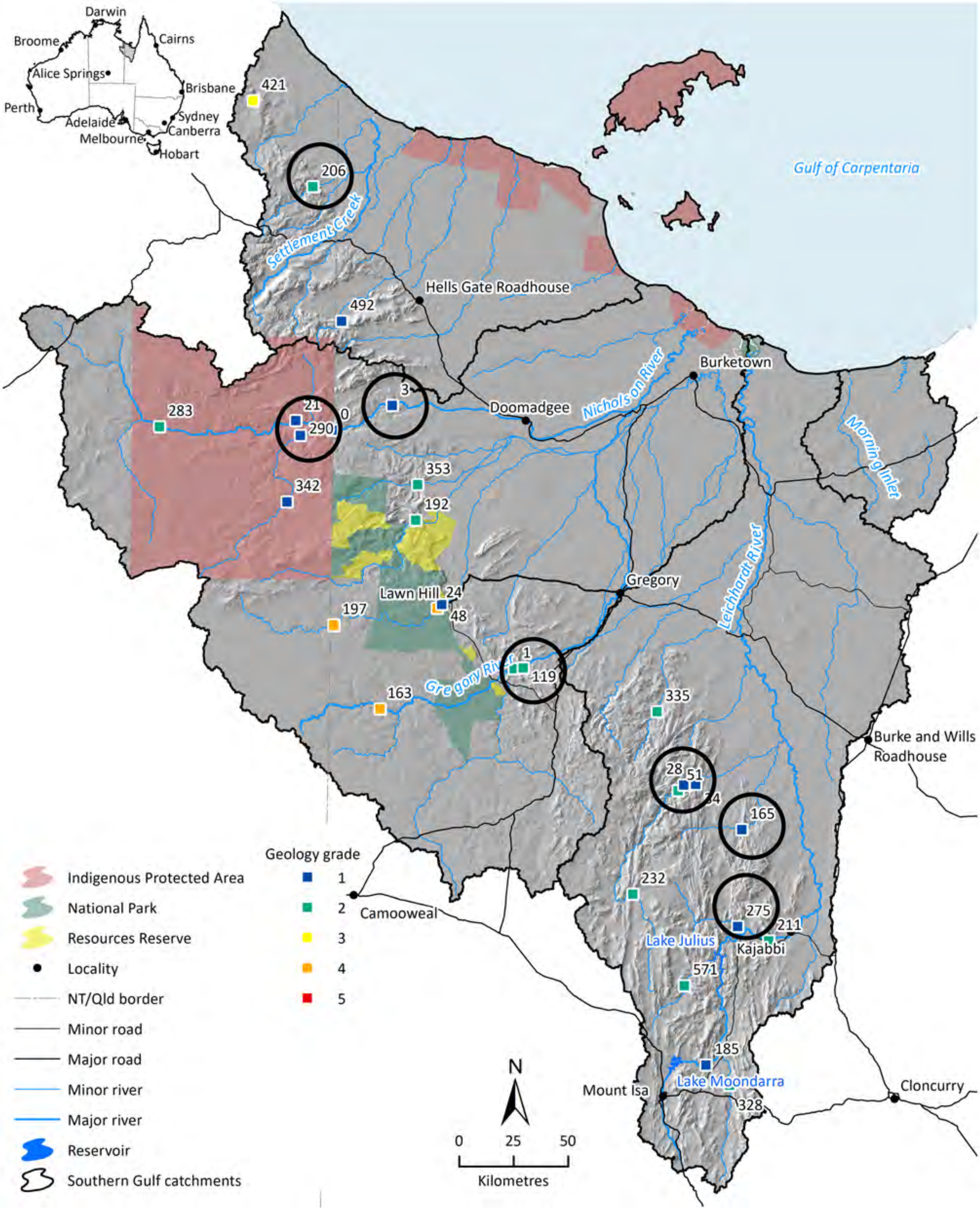

Figure 5-4 Long-list of potential dam sites in the Southern Gulf catchments

Note: Geology grade 1 is best; grade 5 is worst – holistic assessment based on whether bedrock is exposed at site, likely depth of weathering/stripping on abutments, likely depth of cut-off and presence of deep alluvium, and overall height-to-width assessment. Potential short-listed dam sites circled (1,3,28,165,206,275,290).

Table 5-2 Rapid desktop geological evaluation of long-listed potential dam sites in the Southern Gulf catchments

Note: Grade 1 is best; grade 5 is worst – holistic assessment based on whether bedrock is exposed at site, likely depth of weathering/stripping on abutments, likely depth of cut-off and presence of deep alluvium, and overall height-to-width assessment. Geology abbreviations detailed in NTGS (2023) and GeoResGlobe (2022).

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
0	Qa/Psa2/Pscu	Alluvium/Quartz and lithic sandstone, white, medium- to coarse-grained/White to pale yellow, silicified to friable, fine- to coarse-grained, quartzose to sublithic sandstone, with minor scattered granules and rare small pebbles of quartz	180-m-wide ponded water, rock bar downstream	Planation surface with structurally controlled erosion partially removing weathering profile and producing outcrop on lower slopes, swamps downstream	Storage appears stable and watertight but underlain by Fickling group, which contains dolomites that could provide leakage paths to downstream, and nearby swampy areas could be groundwater inflows/outflows	Folded sandstones outcropping on both abutments, no alluvium within this stretch of the river	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 5–7 m on abutments	May need to carefully consider regional groundwater conditions
1†	Qha/Pms	Younger alluvium: sand, silt and clay / White medium orthoquartzite, siltstone, dolomitic fine sandstone	400 m of braided and vegetated alluvium	Planation surface with structurally controlled erosion and deep weathering profiles on slopes	Storage appears stable and watertight	Gently folded sandstones dipping upstream and locally outcropping on both abutments but mainly covered with weathering profile, vegetated braided alluvium suggests an accumulating deposit	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–7 m on abutments	Heritage Sites – Lawn Hill (Gregory) Resources Reserve – upstream

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
3†	Psa	White and reddish brown, medium quartz sandstone; scattered pebbles and cobble conglomerate lenses	80-m-wide ponded water	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop with well-defined fault lineaments, swamps downstream	Appears stable and watertight but underlain by Fickling group, which contains dolomites which could provide leakage paths to downstream, and nearby swampy areas could be groundwater inflows/outflows	Gently folded sandstones outcropping extensively on both abutments, no alluvium within this stretch of the river	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	May need to carefully consider regional groundwater conditions
21	Psa2	Quartz and lithic sandstone, white, medium- to coarse-grained	30 m of ponded water	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop with well-defined fault lineaments, swamps downstream	Storage appears stable and watertight but underlain by Fickling group, which contains dolomites, which could provide leakage paths to downstream, and nearby swampy areas could be groundwater inflows/outflows	Gently folded sandstones outcropping extensively on both abutments, no alluvium within this stretch of the river	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	May need to carefully consider regional groundwater conditions

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
24	Cmt	Thin-bedded to massive dolomite, dolomitic limestone	70-m wide, possibly some ponded water but could be a karst-affected dry drainage line	Weathered depositional/planation surface incised by karst-affected drainage system	Storage formed in karst affected subhorizontal Cambrian Thorntonia Limestone (dolomite and dolomitic limestone) so will probably be leaky	Karstic-affected dolomite at dam site probable	4	RCC with extensive curtain grouting might be feasible but unlikely to be economic	Suggest develop groundwater resources within Cambrian dolomite unit
28†	Plu	Siltstone, shale and slate, sandstone, quartzite, dolomite	80 m of ponded water with rock bars downstream	Planation surface with structurally controlled erosion and weathering profiles on slopes	Storage appears stable and watertight	Gently folded sandstones dipping downstream and locally outcropping on both abutments but mainly covered with weathering profile, braided active alluvium suggests significant flood events. Check extent of any dolomite in the sequence	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	
34	Plu	Siltstone, shale and slate, sandstone, quartzite, dolomite	80 m of ponded water, possibly rock bars downstream	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop	Storage appears stable and watertight	Steeply dipping sandstones outcropping extensively on both abutments, no alluvium within this stretch of the river. Check the extent of any dolomite in the sequence	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
48	Psa	Quartzose sandstone, siltstone, conglomerate	60-m wide ponded water	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop	Storage formed in subhorizontal Cambrian Thorntonia Limestone (dolomite and dolomitic limestone) but should be stable and watertight by virtue of surrounding impermeable strata and may have enhanced storage within the karst system	Steeply dipping sandstones dipping upstream with blocky outcrop on both abutments	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	Lawn Hill National Park and camping close by
51	Plu/Ply	Siltstone, shale and slate, sandstone, quartzite, dolomite/Sandstone, quartzite, siltstone, conglomerate; acid to basic volcanics at top	190-m-wide active alluvium with some ponded water, possible rock bars	Planation surface with structurally controlled erosion and weathering profiles on slopes, possible 130-m-wide terrace on left side	Storage appears stable and watertight	Gently folded sandstones dipping downstream and locally outcropping on both abutments but mainly covered with weathering profile, braided active alluvium suggests significant flood events. Check extent of any dolomite in the sequence	2	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 5–7 m on abutments	
119	Qha/Pms	Younger alluvium: sand, silt and clay /White medium orthoquartzite, siltstone, dolomitic fine sandstone	460 m of braided and vegetated alluvium	Planation surface with structurally controlled erosion and deep weathering profiles on slopes	Storage appears stable and watertight	Gently folded sandstones dipping upstream and locally outcropping on both abutments but mainly covered with weathering profile, terraces of Tertiary sediments may affect abutment stripping, vegetated braided alluvium suggests an accumulating deposit	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–10 m on abutments	Heritage Sites – Lawn Hill (Gregory) Resources Reserve – upstream

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
163	Puc	Residual black soil over dolomite with chert nodules and some sandy beds, dolomite outcrops	100 m of braided alluvium, some ponded water could be karst-affected drainage line	Weathered depositional/planation surface incised by karst-affected drainage system	Storage formed in karst-affected subhorizontal Cambrian Thorntonia Limestone (dolomite and dolomitic limestone) so will probably be leaky	Karstic-affected dolomite at dam site probable	4	RCC with extensive curtain grouting might be feasible but unlikely to be economic	Suggest develop groundwater resources within Cambrian dolomite unit
165†	Plu	Siltstone, sandstone, dolomite	20 m of shallow ponded water, rock bars	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop	Storage appears stable and watertight	Steeply dipping rocks rock exposed on each abutment, amount of dolomite in foundation requires consideration to establish whether it represents a problem	1	Likely suitable for RCC, provisional foundation stripping of 2–3 m in river and 3–5 m on abutments	
185	Pq	Feldspathic and ferruginous sandstone, quartzite, siltstone, arkosic grit, minor dolomite	70-m wide, active, rock outcrop in river bed	Planation surface with structurally controlled erosion and deep weathering profiles on slopes	Storage appears stable and watertight	Folded sandstones locally outcropping on left abutment but mainly covered with weathering profile, active braided alluvium suggests significant flood events	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	Downstream of Lake Moondarra dam (concrete gravity dam)

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
192	Psa	Quartzose sandstone, siltstone, conglomerate	70-m-wide ponded water, no rock bars observed and appears to be a large amount of sediment/bedload in river system	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop with well-defined fault lineaments, swamps upstream and downstream	Storage may be underlain by Lawn Hill Formation, which could contain karstic dolomite strata and provide a leakage path to the groundwater swamp downstream. Prominent gully erosion of Quaternary sediments within storage area	Sandstones dipping gently upstream and outcropping extensively on both abutments, no alluvium within this stretch of the river	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 3–5 m on abutments	May need to carefully consider regional groundwater conditions. May be significant sediment load in river, which could affect the reservoir capacity in the long term
197	Cmd	Thin-bedded to massive dolomite with chert nodules	70-m-wide, vegetated, some ponded water	Weathered depositional/planation surface incised by karst-affected drainage system	Storage formed in karst-affected subhorizontal massive Cambrian Camooweal Dolomite so will probably be leaky	Karstic-affected dolomite at dam site probable	4	RCC with extensive curtain grouting might be feasible but unlikely to be economic	Suggest develop groundwater resources within Cambrian dolomite unit
206†	Pth/Ptg	Pink porphyritic massive to spherulitic rhyolite/Grey to red, vesicular to massive basalt; dolomitic sandstone, mudstone and peperite	180 m active alluvium, channel of standing water	Planation surface with structurally controlled erosion and deep weathering profiles on slopes, some outcrop downstream	Storage appears stable and watertight	Flat-lying sandstones or gently dipping volcanics with deep weathering profile developed	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–10 m on abutments	

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
211	Qha/TQr/Pea	Younger alluvium: sand, silt, clay/Residual and colluvial deposits: sand, gravel, silt, clay/Metamorphosed porphyritic rhyolite and dacite, metabasalt, quartzite, schist, metalimestone; minor siltstone, andesite	350-m-wide active and partially vegetated alluvium	Planation surface with structurally controlled erosion and weathering profiles on slopes, possible 130-m-wide terrace on left side	Storage appears stable and watertight	Folded sandstones covered with deep weathering profile, terraces of Tertiary sediments may affect abutment stripping, vegetated braided alluvium suggests an accumulating deposit	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–10 m on abutments	
232	Ple	Interbedded basalt and metasediment, mainly quartzite	30-m-wide ponded water, outcrop in river	Planation surface with structurally controlled erosion and weathering profile developed on slopes	Storage appears stable and watertight	Folded basalt and quartzite covered with deep weathering profile, some vegetated alluvium, steeply dipping ridge of resistant rock	2	Likely suitable for RCC, provisional foundation stripping of 2–3 m in river and 3–5 m on abutments	
275†	Qha/Pfy/Pra	Younger alluvium: sand, silt, clay/Purple ferruginous feldspathic sandstone, conglomerate, tuffaceous sandstone, quartzite, marl, dolomite /Conglomeratic sandstone, feldspathic quartzite, minor siltstone	140-m-wide active alluvium, no rock bars	Planation surface with structurally controlled erosion partially removing weathering profile and producing outcrop on lower slopes	Storage appears stable and watertight	Gently folded sandstones locally outcropping on both abutments but mainly covered with weathering profile , active braided alluvium suggests significant flood events. Check extent of any dolomite in the sequence	1		
283	Qa/Psa3	Alluvium/Lithic sandstone, reddish-brown and white, medium- to coarse-grained; greywacke	140 m braided alluvium with lines of trees	Planation surface with structurally controlled incision and weathering profile developed on slopes		Weathered abutments	2		

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
290†	Pscu	White to pale yellow, silicified to friable, fine to coarse grained, quartzose to sublithic sandstone, with minor scattered granules and rare small pebbles of quartz	Outcrop in river, 50-m-wide ponded water	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop with well-defined fault lineaments with ablation/weathering hollows, swamps downstream	Storage appears stable and watertight but underlain by Fickling group, which contains dolomites that could provide leakage paths to downstream, and nearby swampy areas could be groundwater inflows/outflows	Folded sandstones outcropping on both abutments, no alluvium within this stretch of the river, pronounced fault offset downstream	1	Likely suitable for RCC, provisional foundation stripping of 2–3 m in river and 3–5 m on abutments	May need to carefully consider regional groundwater conditions
328	Pkc1	Laminated calc-silicate rocks and siltstone, shale, limestone, scapolitic granofels, calc-silicate and quartzofeldspathic gneiss	30-m-wide ponded water, rock bar 800 m downstream site	Planation surface with structurally controlled erosion and deep weathering profiles on slopes	Storage appears stable and watertight	Folded sandstones covered with deep weathering profile, some vegetated alluvium, check extent of limestone in sequence	2	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 5–7 m on abutments	Downstream of East Leichhardt Dam
335	Ply	Quartzite, sandstone, siltstone, conglomerate, volcanics	250 m braided active alluvium	Planation surface with structurally controlled incision and weathering profile developed on slopes	Storage appears stable and watertight	Steeply dipping rocks exposed on the upstream part of each abutment, possibly deeply weathered volcanics on downstream part	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–10 m on abutments	
342	Psmm	Medium- to thick-bedded, fine- to medium-grained sublithic and ferruginous (glauconitic?) sandstone	110 m of ponded water with some braided streams and trees, rockbar and white water 1.2 km downstream	Planation surface with structurally controlled erosion removing weathering profile and producing extensive outcrop	Storage appears stable and watertight	Sandstones dipping gently downstream and outcropping extensively on both abutments, no alluvium within this stretch of the river	1	Likely suitable for RCC, provisional foundation stripping of 2–3 m in river and 3–5 m on abutments	

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
353	Psa	Quartzose sandstone, siltstone, conglomerate	50-m-wide ponded water with active alluvium downstream	Planation surface with structurally controlled erosion partially removing weathering profile, swamps downstream	Storage appears stable and watertight but dam site itself may be underlain by Lawn Hill Formation, which could contain karstic dolomite strata and provide a leakage path to the groundwater swamp downstream	Folded sandstones outcropping on both abutments, no alluvium within this stretch of the river	2	Likely suitable for RCC, provisional foundation stripping of 2–3 m in river and 3–5 m on abutments. Check for karst dolomite in dam foundation	
421	Czl	Pisolitic ferricrete over Proterozoic dolomites and sandstones	50 m ponded water, possible rock bars upstream and downstream	Deeply weathered depositional surface with ferricrete deposits and locally incised drainage lines	Appears stable but may not be watertight if permeable horizons exist within the pisolitic ferricretes, but unlikely to be massively permeable	Ferricreted Cenozoic sediments could be permeable and Proterozic dolomites could also be permeable, but entire system could be 'clogged up' with ferricrete cementation	3	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–10 m on abutments, may require extensive grouting	Possibly develop groundwater resources as an alternative
492	Ptwb	Medium and coarse argillaceous sandstone with scattered pebbles and conglomerate lenses	40-m-wide ponded water, possible partial rock bar downstream	Incised planation surface	Storage appears stable and watertight	Sandstones dipping gently upstream and outcropping extensively on both abutments, no alluvium within this stretch of the river, possible rockslide upstream of dam, resulting in partial blockage with rock blocks	1	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 3–5 m on abutments	

DAM ID	GEOLOGY	LITHOLOGY	ALLUVIAL TRACT	GEOMORPHOLOGY	STORAGE AREA COMMENT	GEOLOGICAL COMMENT	GRADE	DAM DESIGN COMMENT	ADDITIONAL COMMENT
571	Pha/Phb	Orthoquartzite, feldspathic quartzite, minor siltstone/Flaggy feldspathic sandstone, ferruginous and calcareous siltstone, chert	120-m-wide braided alluvium with some lines of vegetation	Planation surface with structurally controlled incision and weathering profile developed on slopes	Storage appears stable and watertight	Gently folded sandstones locally outcropping on both abutments but mainly covered with weathering profile , active braided alluvium suggests significant flood events	2	Likely suitable for RCC, provisional foundation stripping of 3–5 m in river and 5–7 m on abutments	
877	Ptl	Lithic and quartz sandstone, fine to medium-grained, flaggy, locally feldspathic, minor conglomerate	120-m braided vegetated alluvium, localised ponding	Planation surface with structurally controlled erosion and deep weathering profiles on slopes. Possibly superimposed meandering drainage	Storage appears stable and watertight	Flat-lying sandstones or gently dipping sandstones with deep weathering profile developed	2	Likely suitable for RCC, provisional foundation stripping of 5–7 m in river and 5–10 m on abutments	

RRC = roller compacted concrete.
†= short-listed potential dam site.

5.3 Short-listed sites

Seven potential dam sites from Section 5.2 were selected for pre-feasibility analysis and two short-listed for a more detailed costing. Details of the two short-listed sites are documented in sections 5.3.1 and 5.3.2. The five remaining sites selected for pre-feasibility analysis are documented in Appendix B.

5.3.1 Gregory River AMTD 174 km (Site 1) FSL 138 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	A number of studies of potential storage sites on the Gregory River were undertaken by the Irrigation and Water Supply Commission in the late 1960s and early 1970s (QIWS 1969). There has been no recent consideration of potential storage developments on the Gregory River.
Description of potential dam	The potential Gregory River dam site is an instream development with potential to supply water to the Armraynald Plain downstream of the dam. This analysis is predominantly based on an assumed FSL of 138 mEGM96, for which the reservoir does not extend into the Boodjamulla (Lawn Hill) National Park. Figure 5-5 and Figure 5-6 show the location of the site and the extent of the reservoir area.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, some basalt was followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains and coastal deposits where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Figure 5-7) and satellite imagery, supplemented by the reports from the previous investigation noted above. The dam site is located on Proterozoic rocks of the Shady Bore Quartzite (Pms), which consists of white medium orthoquartzite, siltstone and dolomitic fine sandstone, which appear to be gently folded and dipping upstream. They are locally outcropping on both abutments but mainly covered with weathering profile. The shape of the upper slopes suggests a planation surface with structurally controlled erosion and deep weathering profiles. The river bed was 400 m wide. It consists of braided and vegetated alluvium, which suggests an accumulating deposit. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 7–10 m of alluvium in the river bed (based on seismic traverses described in previous investigations) and 5–7 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Appears stable and watertight.

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td>Potential structural arrangement</td><td>Given the potential for significant flooding during construction and the spillway capacity required, a RCC dam with a 400 m wide central uncontrolled spillway is proposed.

The abutments would be set at a 1:10,000 AEP peak storage level although this should be reviewed if this proposal were to be considered further.

A hydraulic jump type spillway basin would be provided to protect the river bed against erosion during spillway overflows.

Releases downstream of the dam would be made via pipework installed in a diversion conduit located in the right abutment of the dam. A fish lift transfer facility would also be installed in the right abutment.

Access to the site would be via 27 km of new road branching from the Camooweal–Gregory Road some 58 km south-west of Gregory.

The total distance of the site from Mount Isa via Camooweal is 371 km.</td></tr>
<tr><td>Availability of construction materials</td><td>A quarry that could provide suitable coarse aggregate might be found within 5 km of the dam site. For estimating purposes, assume a ratio of useful rock excavated to total volume excavated of 0.5.

Assume fine aggregate might be won and processed from a river bed or terrace deposit within 20 km of the dam site. For estimating purposes, assume a ratio of useful aggregate excavated to total volume excavated of 0.5.

Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Mount Isa, at a distance of 371 km.</td></tr>
<tr><td>Catchment area</td><td>11,381 km^2</td></tr>
<tr><td>Modelled annual inflow data</td><td><table>
<tr><th>Parameter</th><th>Scenario A (GL/y)</th><th>Scenario Cdry (GL/y)</th><th>Scenario Cmid (GL/y)</th><th>Scenario Cwet (GL/y)</th></tr>
<tr><td>Max</td><td>2570</td><td>1975</td><td>2438</td><td>3009</td></tr>
<tr><td>Mean</td><td>475</td><td>356</td><td>440</td><td>567</td></tr>
<tr><td>Median</td><td>343</td><td>249</td><td>321</td><td>412</td></tr>
<tr><td>Min</td><td>102</td><td>73</td><td>80</td><td>123</td></tr>
</table></td></tr>
<tr><td>Reservoir characteristics</td><td>Reservoir characteristics are shown in Figure 5-8. Reservoirs with FSLs of selected heights are tabulated below.<table>
<tr><th>FSL (mEGM96)</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>136</td><td>1732</td><td>74</td></tr>
<tr><td>138</td><td>2622</td><td>118</td></tr>
<tr><td>140</td><td>3580</td><td>179</td></tr>
</table></td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>The following yield estimates do not take into consideration existing licence entitlement holders.

FSL of 136 mEGM96 – estimated yield at 85% annual time reliability = 152 GL

FSL of 138 mEGM96 – estimated yield at 85% annual time reliability = 180 GL

FSL of 140 mEGM96 – estimated yield at 85% annual time reliability = 195 GL

Reservoir characteristics and yields under current and projected future climates are shown in Figure 5-8 to Figure 5-10.

Taking into consideration existing licence entitlement holders and assuming a dry-season demand pattern and assuming FSL of 138 mEGM96 and 145 mEGM96 the yield at 85% annual time reliability was modelled to be 133 GL and 233 GL respectively (see Gibbs et al., 2024).</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at a FSL of 138 (mEGM96)</td><td><table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>10.2</td><td>15.4</td><td>17.1</td></tr>
<tr><td>100 years (%)</td><td>34.1</td><td>51.2</td><td>56.9</td></tr>
</table></td></tr>
</table>

PARAMETER	DESCRIPTION			
	Years to fill	293	195	176
Potential use of supply	The dam site is 30 km upstream of the Armraynald Plain, which is made up of Pleistocene sediments that have formed black and grey cracking clay soils (SGG 9). To the south of the Armraynald Plain is the gently sloping older Cloncurry Plain, which is made up of colluvial sediments. To the north of the Armraynald Plain is also the older gently undulating Doomadgee Plain, which is made up of Cenozoic sediments. South of Gregory Crossing and Augustus Downs Station there is a grey cracking clay that is moderately well-drained, non-sodic, light-medium to medium clay with calcareous nodules. The soil has a very deep (>1.5-m) effective rooting depth and a very high available water capacity (>160 mm) within the top 1 m of the soil. On the more recent sediments deposited on the alluvial plains of the Gregory River, a black cracking clay has developed that is moderately well-drained, sodic (at depth), medium to medium-heavy clay with calcareous nodules. It has an effective rooting depth of greater than 1.5 m, with a very high available water capacity (>160 mm) within the top 1 m of the soil. The better-drained cracking clays (SGG 9) on the Cloncurry Plain and Doomadgee Plain are suitable, with minor to moderate limitations (Class 2 to 3), for dry-season trickle-irrigated tree crops such as mangoes (*Mangifera indica*) and lychee (*Litchi chinensis*) and sandalwood plantations (*Santalum* spp.), dry-season spray-irrigated root crops such as sweet potato (*Ipomoea batatas*) and peanuts (*Arachis hypogaea*) and wet-season spray-irrigated oilseed crops such as sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*). Also, the better-drained cracking clays are suitable, with minor limitations (Class 2), for dry-season trickle-irrigated intensive horticulture such as cucurbits, dry-season spray-irrigated perennial grasses such as Rhodes grass (*Chloris gayana*) and annual grasses and small-seeded crops such as chia (*Salvia hispanica*) and quinoa (*Chenopodium quinoa*). Also, the better-drained cracking clays are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated citrus. The cracking clays of the Armraynald Plain are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated intensive horticulture, dry-season spray-irrigated perennial and annual grasses and small-seeded crops, dry-season furrow-irrigated pulse crops and leguminous hay and forage crops.			
Environmental considerations	**Habitat fragmentation and barrier to movement of aquatic species** In the catchment of this potential dam site, there were records for ecology assets, including the Gulf snapping turtle (*Elseya lavarackorum*), spangled grunter (*Leiopotherapon unicolor*), sooty grunter (*Hephaestus fuliginosus*) and eastern rainbow fish (*Melanotaenia splendida*). The models predict that ~3% of the catchment (35,144 ha) has suitable habitat for at least 40% of the 10 species modelled. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively small, depending on the species, and ranges from 0.04% to 6.8% of their total modelled suitable habitat in the Southern Gulf catchments. These species may have fragmentated habitat and/or their movement may be impeded by a dam. The potential reservoir capacity was selected such at its FSL the reservoir did not encroach into the Boodjamulla (Lawn Hill) National Park and Lawn Hill Resources Reserve, which are located about 9 km upstream of the dam wall. Parts of the Thorntonia Aggregation wetland, a DIWA nationally important wetland, overlaps the reservoir and extends downstream from the potential dam wall. Figure 4-11 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Victoria River (AMTD 283 km) site.			

PARAMETER	DESCRIPTION
	Ecological implications of inundation For this potential reservoir location, there are a few records of listed species, including the Gulf snapping turtle (*Elseya lavarackorum*), listed as endangered in the EPBC Act and as vulnerable at state level, the ghost bat (*Macroderma gigas*) and the purple-crowned fairy-wren (western) (*Malurus coronatus coronatus*), both listed as vulnerable in the EPBC Act and as endangered at territory/state level. There are also records of the red goshawk (*Erythrotriorchis radiatus*), listed as vulnerable in the EPBC Act and as endangered at territory/state level, respectively, upstream in the catchment. Other listed species nearby include the grey falcon (*Falco hypoleucos*), listed as vulnerable at federal and state level, and the orange leaf-nosed bat (*Rhinonicteris aurantia*), listed as vulnerable in Queensland. The potential inundated area at FSL for this site (138 mEGM96) may have an effect on these species. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Ponce Reyes et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	A manual cost estimate undertaken as part of the Assessment for a hypothetical RCC dam on the Gregory River AMTD 174 km site at a FSL of 138 mEGM96 found the dam would cost approximately $683 million. Details of this cost estimate are provided in Appendix A. To enable a like-for-like comparison with sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 136 mEGM96 – estimated cost = $467 million FSL of 138 mEGM96 – estimated cost = $506 million FSL of 140 mEGM96 – estimated cost = $546 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 136 mEGM96 – estimated cost/ML of supply = $3079/ML FSL of 138 mEGM96 – estimated cost/ML of supply = $2819/ML FSL of 140 mEGM96 – estimated cost/ML of supply = $2793/ML Based on the manual cost estimate, the cost/ML of supply at FSL of 138 mEGM96 is $3794/ML. Based on the manual cost estimate and the Southern Gulf river system model yield, the cost/ML of supply at FSL of 138 mEGM96 is $5,135/ML.

PARAMETER	DESCRIPTION
Summary comment	The potential Gregory River dam site is an instream development with potential to supply water to the large contiguous areas of black and grey cracking clay soils on the Armraynald Plain immediately downstream of the dam. Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam with a 400-m-wide central uncontrolled spillway would be most suitable. The site is one of the largest yielding and most cost-effective potential dam sites in the Southern Gulf catchments, and the foundations of this site appeared to be suitable for a RCC dam. A major limitation of the site is its proximity to the Boodjamulla (Lawn Hill) National Park (upstream of the site), and the Thorntonia Aggregation wetland which is downstream of and overlaps the potential reservoir. Despite being on a major river, the potentially suitable habitat suitable for the four modelled migratory species was relatively small. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. Limiting the FSL of the potential dam so that the area inundated did not extend into the Boodjamulla National Park resulted in a modelled yield of 180 GL in 85% of years at the dam wall. However, taking into consideration existing downstream users and assuming a dry-season crop resulted in a modelled yield of 133 GL in 85% of years.

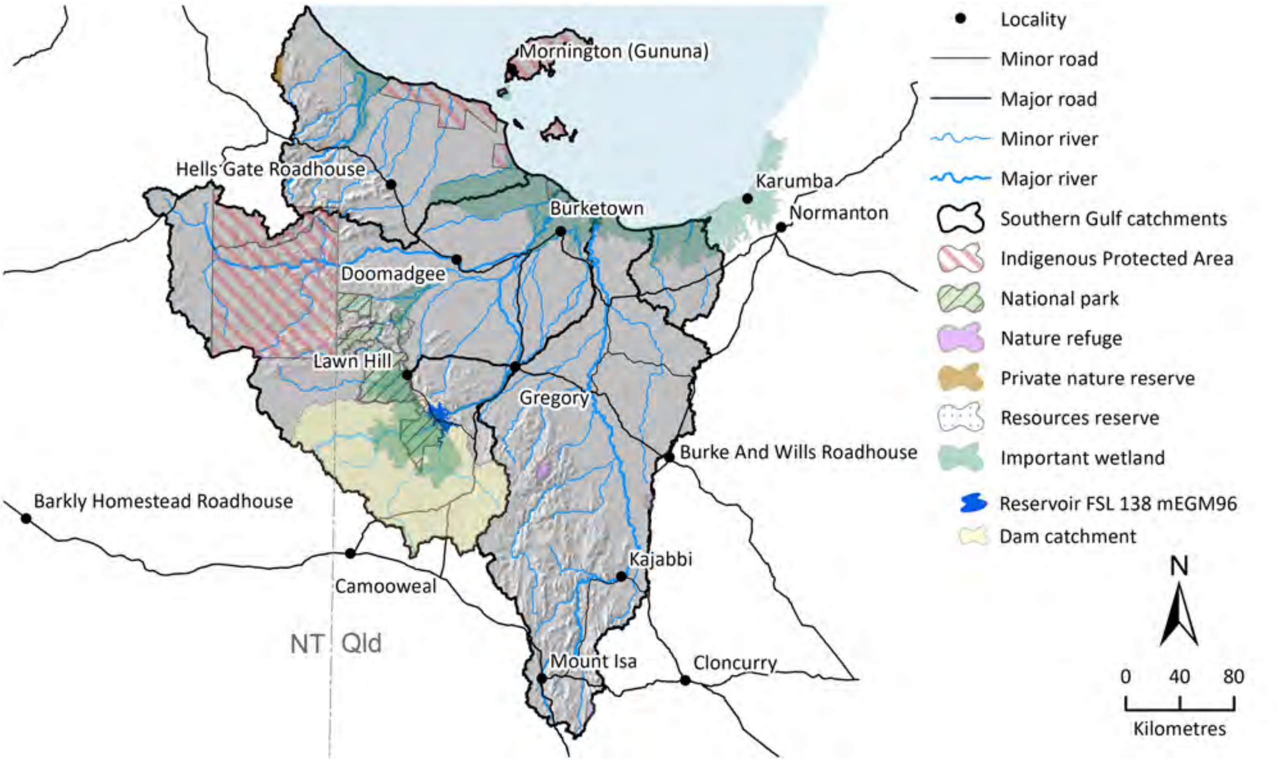

Figure 5-5 Location map of potential Gregory River dam site, reservoir extent, and catchment area

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

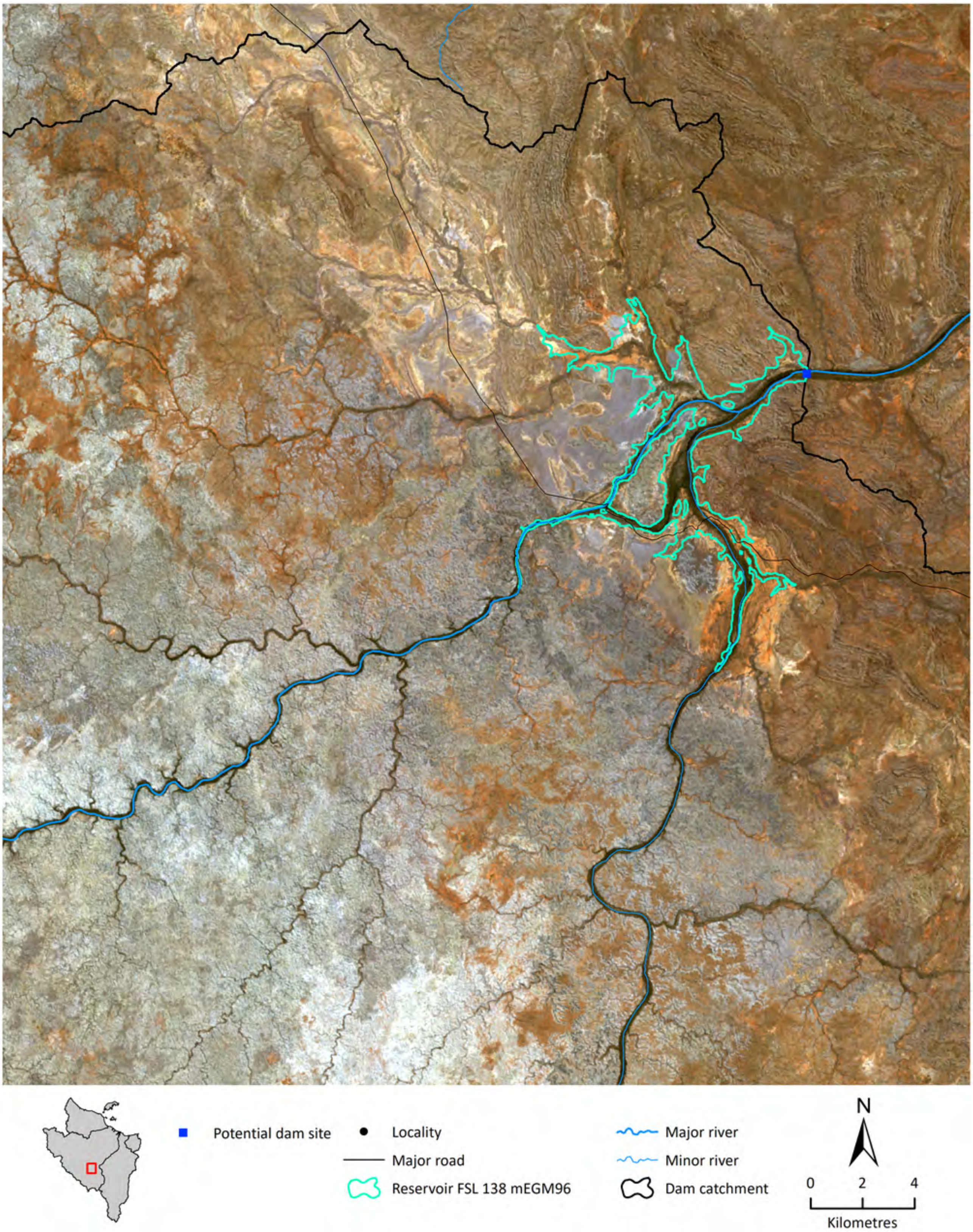

Figure 5-6 Potential Gregory River dam reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

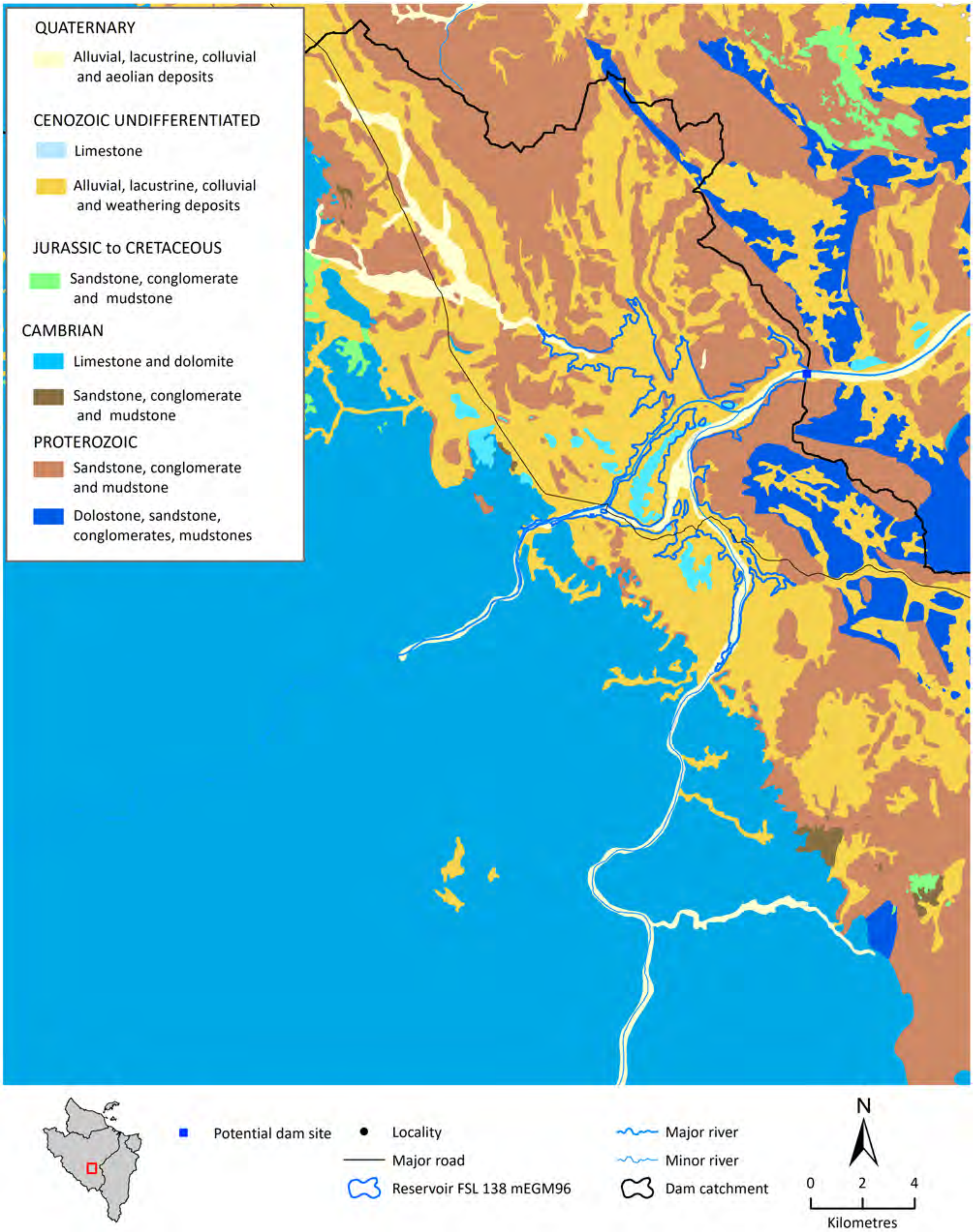

Figure 5-7 Geology underlying the potential Gregory River dam site and reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

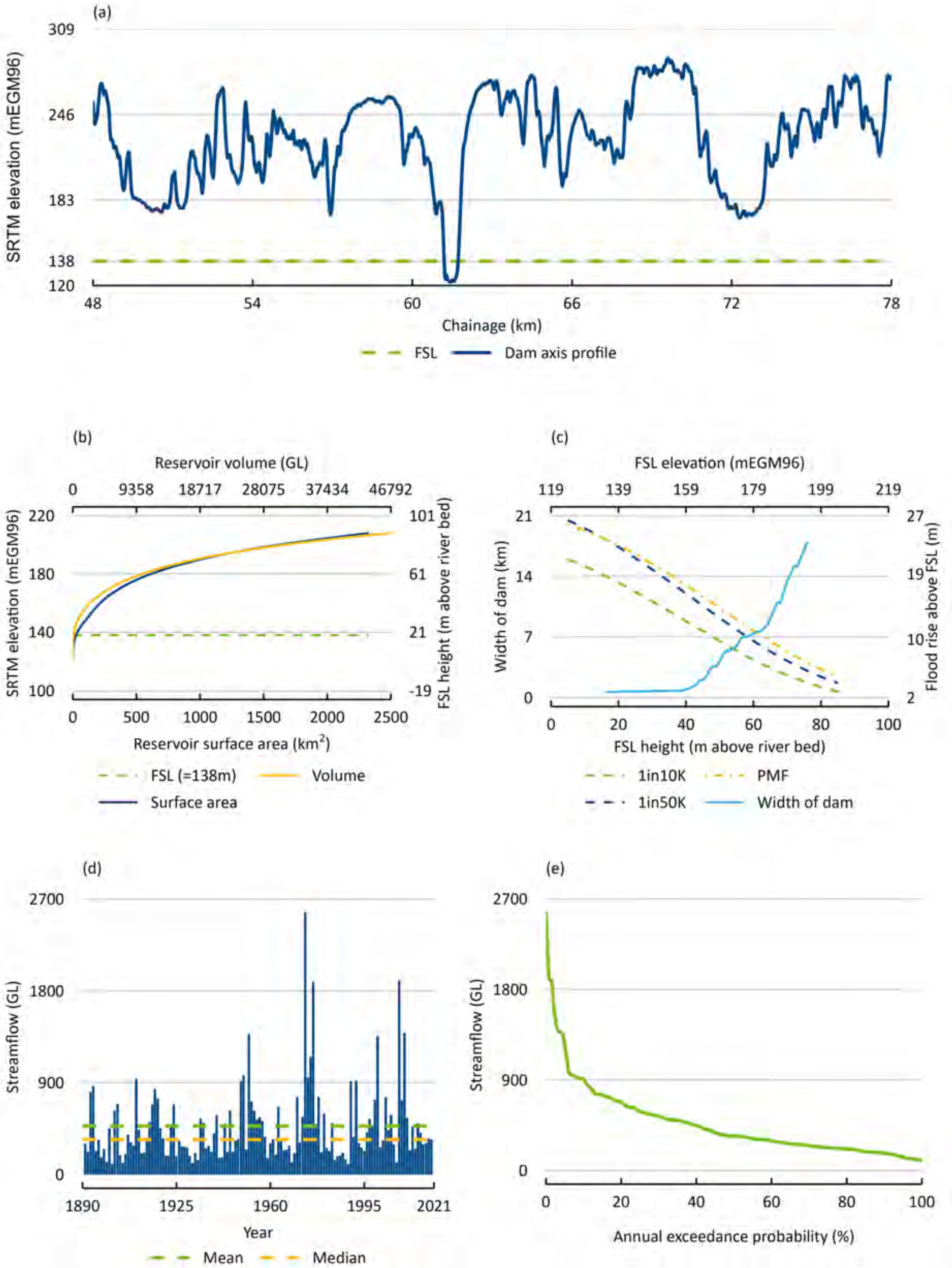

Figure 5-8 Gregory River potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

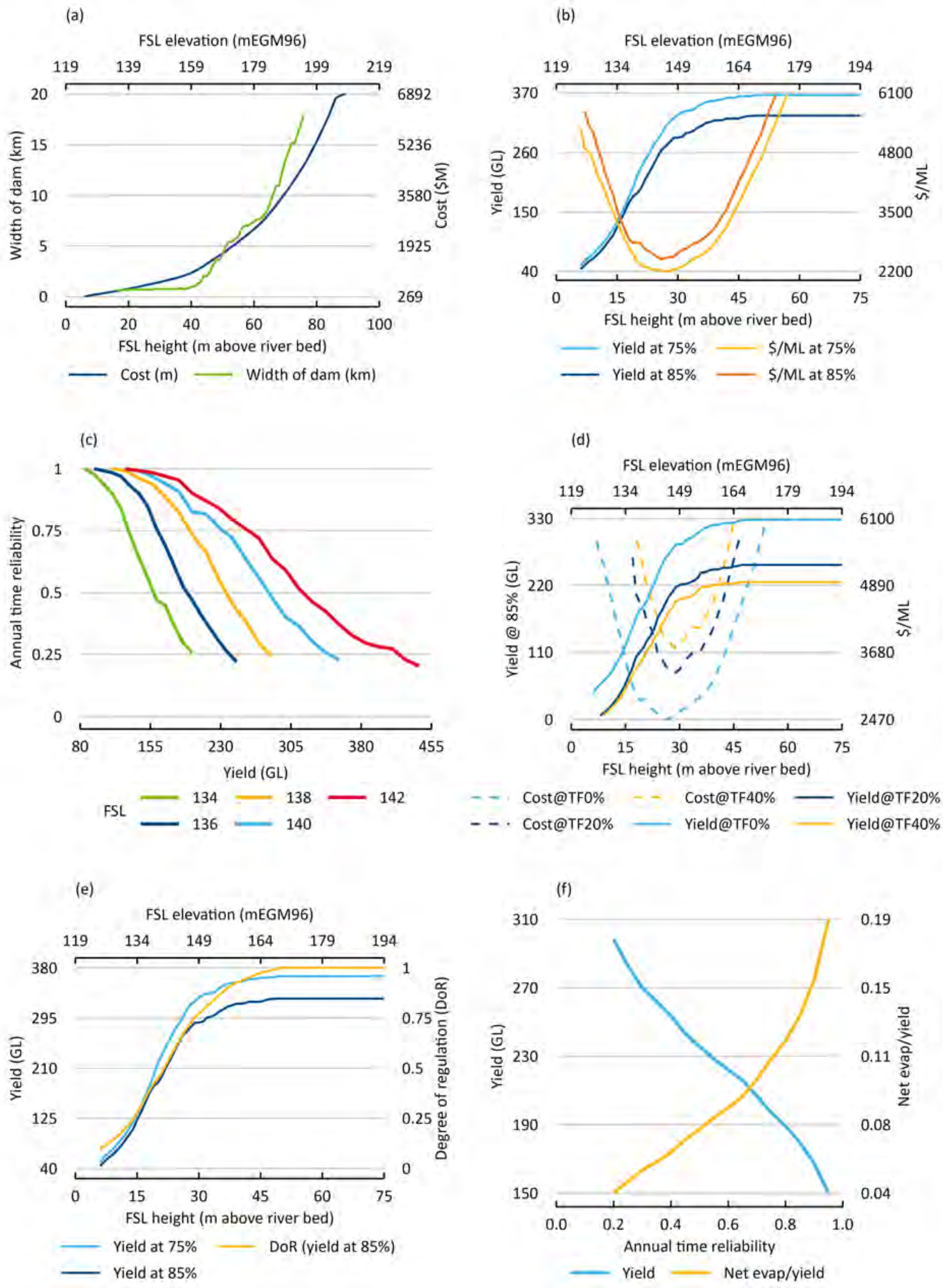

Figure 5-9 Gregory River potential dam site cost, water yield at the dam wall, and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

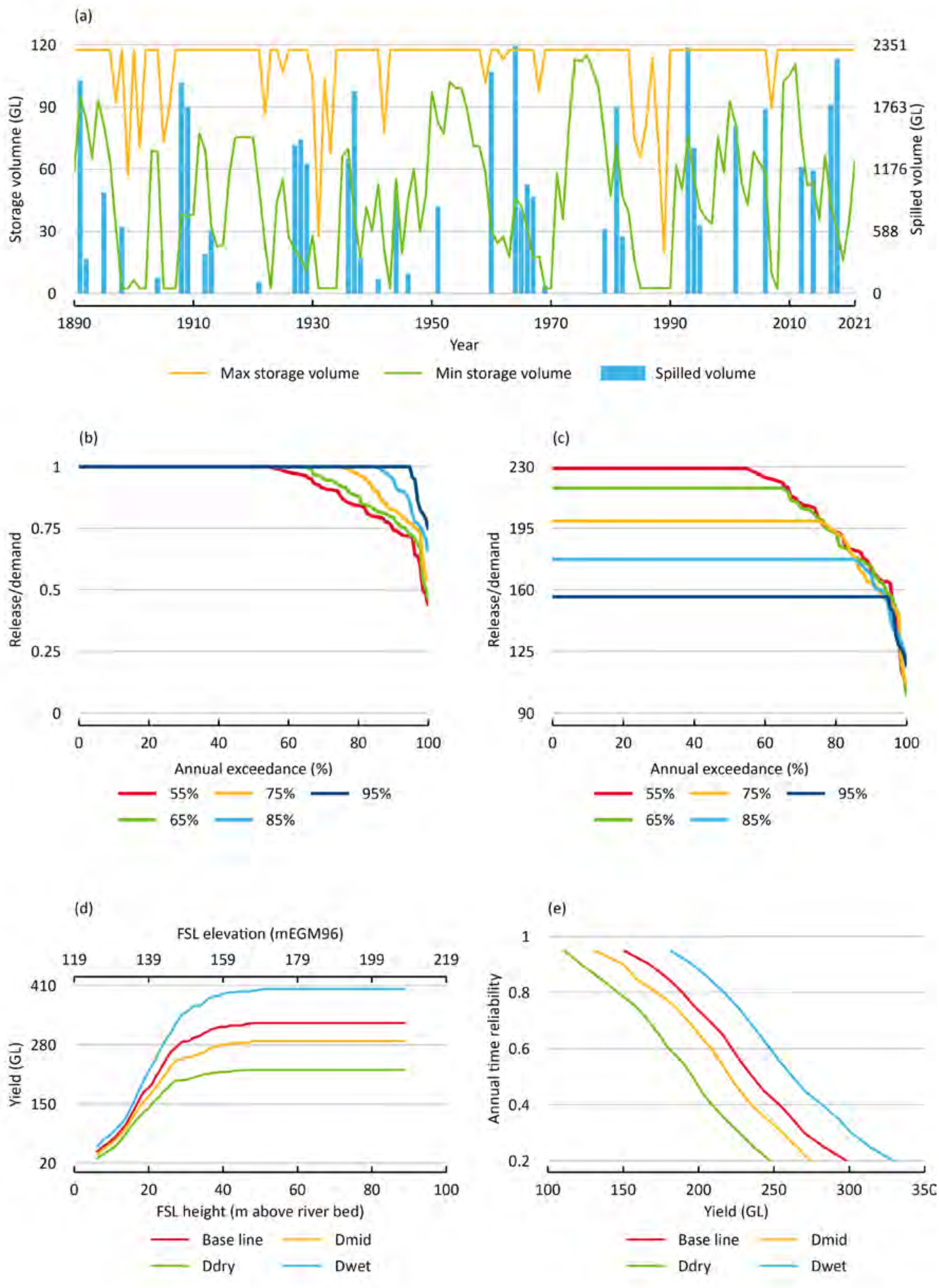

Figure 5-10 Gregory River potential dam site, storage levels, and water yield

(a) Max. and min. annual storage trace at the selected full supply level (FSL) (138 mEGM96) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 138 mEGM96 under scenario A and D. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

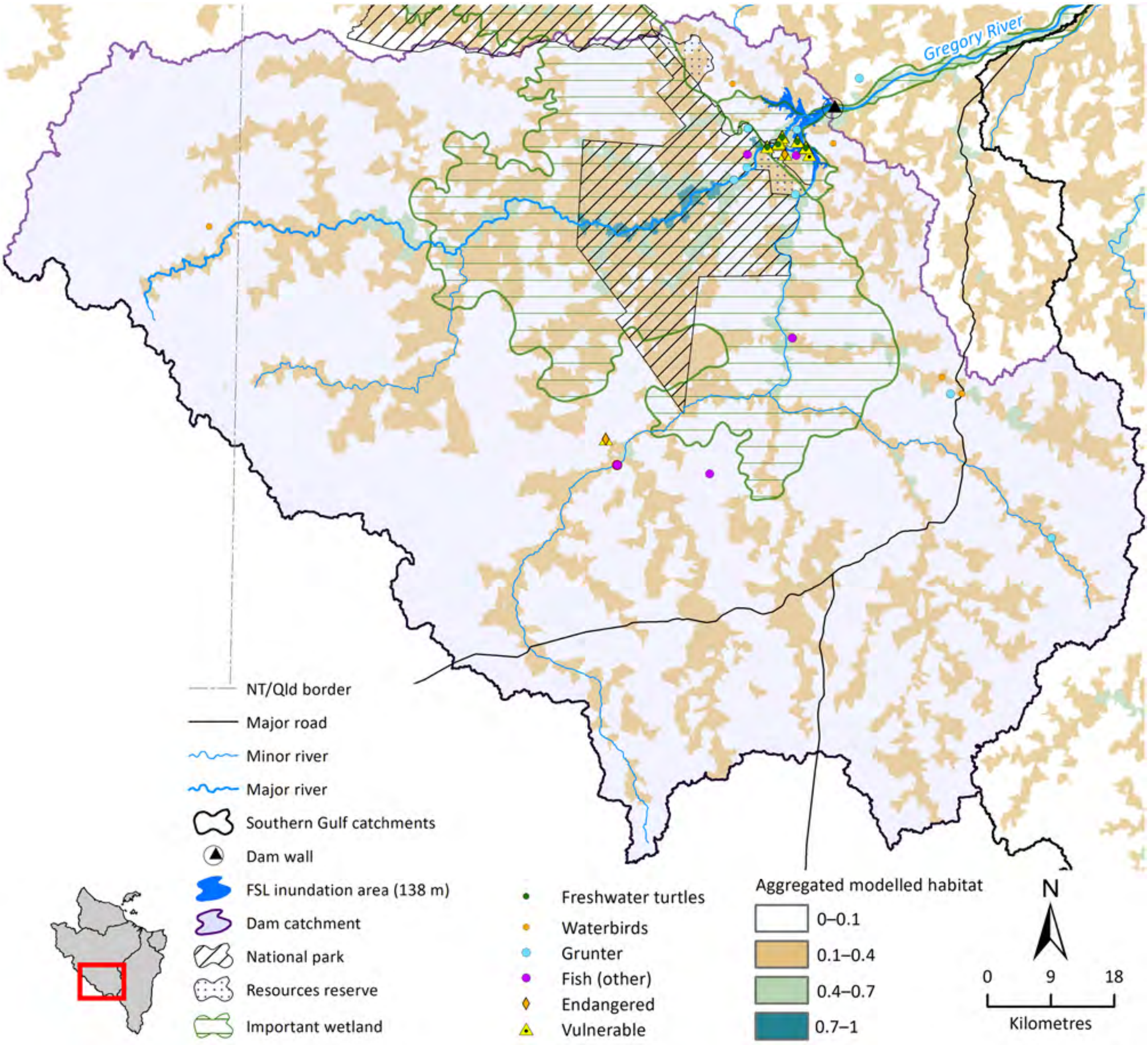

Figure 5-11 Location of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Gregory River dam site

FSL = full supply level.

5.3.2 Gunpowder Creek AMTD 66 km (Site 28) FSL 186 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	Previous investigations of a number of Gunpowder Creek sites as potential sources of supply for proposed mining developments were undertaken by the Irrigation and Wate Supply Commission in the 1970s (QWIS 1969, QWIS 1974). There has been no recent consideration of potential storage developments on Gunpowder Creek.
Description of potential dam	The potential Gunpowder Creek dam site is an instream development with the potential to provide irrigation supplies downstream along the river. This analysis is predominantly based on an assumed FSL of 186 mEGM96. Figure 5-12 and Figure 5-13 show the location of the site and the extent of the reservoir area.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, some basalt was followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains, and coastal deposits where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or region, so the following comments are based only on viewing geological maps (e.g. Figure 5-14) and satellite imagery, supplemented by the reports from the previous investigation noted above. The dam site is located on Proterozoic rocks of the Surprise Creek Beds (Plu), which consists of siltstone, shale, slate, sandstone, quartzite and dolomite, which appear to be gently folded and dipping downstream. They are locally outcropping on both abutments but mainly covered with weathering profile. The shape of the upper slopes suggests a planation surface with structurally controlled erosion and deep weathering profiles. The river bed was 80 m wide. It consisted of ponded water, rock bars and braided active alluvium, which suggests significant recent flood events. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 3–5 m of alluvium in the river bed and 3–5 m of stripping on the abutments. The extent of any dolomite in the sequence at the dam site should be checked in case there are strata with cavities, although the previous investigations did not note any problems.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a roller compacted concrete dam with a 140-m-wide central uncontrolled spillway is proposed. The abutments would be set at the 1:10,000 AEP peak storage level although this should be reviewed if this proposal is to be considered further.

PARAMETER	DESCRIPTION
	Releases downstream of the dam would be made via two conduits installed in the right abutment of the dam. Releases from the dam would be regulated by two 900 mm diameter fixed cone regulating valves. A fish lift transfer facility would also be installed in the right abutment of the dam. Access to the site could be via a 75-km-long extension of the existing Mount Isa to Gunpowder Road although this would require further investigation should this proposal be considered further. The total distance from Mount Isa to the dam site would be 205 km.
Availability of construction materials	A quarry that could provide suitable coarse aggregate might be found within 5 km of the dam site. For estimating purposes, assume a ratio of useful rock excavated to total volume excavated of 0.5. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 5 km of the dam site. For estimating purposes, assume a ratio of useful aggregate excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Mount Isa, a distance of 205 km.
Catchment area	3516 km^2
Modelled annual inflow data	(see table below)

Parameter	Scenario A (GL/y)	Scenario Cdry (GL/y)	Scenario Cmid (GL/y)	Scenario Cwet (GL/y)
Max	1901	1471	1856	2152
Mean	188	136	171	229
Median	123	86	106	149
Min	3	1	2	6

Reservoir characteristics

Reservoir characteristics are shown in Figure 5-15.

Reservoirs with full supply levels (FSLs) of selected heights are tabulated below.

FSL (mEGM96)	Surface area (ha)	Capacity (GL)
184	3708	639
186	4021	716
188	4370	800

Reservoir yield assessment at dam wall

FSL of 184 mEGM96 – estimated yield at 85% annual time reliability = 125 GL

FSL of 186 mEGM96 – estimated yield at 85% annual time reliability = 129 GL

FSL of 188 mEGM96 – estimated yield at 85% annual time reliability = 131 GL

Reservoir characteristics and yields under current and projected future climates are shown in Figure 5-15 to Figure 5-17.

Taking into consideration existing licence entitlement holders and assuming a dry-season demand pattern and assuming FSL of 186 mEGM96 the yield at 85% annual time reliability was modelled to be 119 GL (see Gibbs et al., 2024).

Estimated rates of reservoir sedimentation at a FSL of 186 mEGM96

	Best case	Expected	Worst case
30 years (%)	0.5	0.8	0.9
100 years (%)	1.8	2.7	3.0
Years to fill	5570	3714	3342

PARAMETER	DESCRIPTION
Potential use of supply	The dam site is located on Gunpowder Creek 30 km upstream of the Carpentaria plains where the creek has cut through the Cretaceous Cloncurry Plain leaving pediments of colluvial sediments either side of more recent sediments. Near the junction of Gunpowder Creek and the Leichhardt River, a large plain of recent alluvium has formed. Friable non-cracking clay or clay loam soils (SGG 2) and sand to loam over relatively friable red clay subsoils (SGG 1.1) have formed on the recent alluvium of the floodplain. Brown cracking clay soils (SGG 9) occur on the older Cloncurry plains. The friable non-cracking clays or clay loams (SGG 2) are moderately well to well drained, have a weak structure, have loamy to clayey surface soil over brown, red or grey structured, non-sodic, sandy clay loam or silty light to medium clay subsoils. Soil colour and drainage depends on proximity to stream channel. The soil has a very deep (>1.5 m) effective rooting depth and a moderate available water capacity (100–140 mm) within 1 m of the soil surface. The sand to loam over relatively friable red clay subsoils (SGG 1.1) are well drained, with moderately thick (<0.2 m), sandy loam surface soil over red, structured, non-sodic, light medium to medium clay subsoils. The soil has a very deep (>1.5 m) effective rooting depth and a low (80–120 mm) soil water–holding capacity within 1 m of the soil surface. The brown cracking clay soils (SGG 9) are imperfectly to moderately well drained, sodic at depth, light medium to medium clay, with calcareous nodules. Effective rooting depth is greater than 1.5 m, with a very high (>160 mm) soil water–holding capacity within 1 m of the soil surface. The friable (SGG 2) and cracking clays (SGG 9) and sand to loam over red clay subsoils (SGG 1.1) are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated tree crops such as mangoes (*Mangifera indica*) and lychee (*Litchi chinensis*), intensive horticulture such as cucurbits, and sandalwood (*Santalum* spp.) plantations, for dry-season spray-irrigated annual grasses, small-seeded crops such as chia (*Salvia hispanica*) and quinoa (*Chenopodium quinoa*) and root crops such as sweet potato (*Ipomoea batatas*) and peanuts (*Arachis hypogaea*), and wet-season spray-irrigated oilseed crops such as sunflower (*Helianthus annuus*) and sesame (*Sesamum indicum*). The friable non-cracking clays (SGG 2) and the sand to loam over red clay subsoils (SGG 1.1) are suitable, with minor limitations (Class 2), for dry-season spray-irrigated perennial grasses such as Rhodes grass (*Chloris gayana*) and suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated citrus. The cracking clays (SGG 9) are suitable, with moderate limitations (Class 3), for dry-season furrow-irrigated grain and fibre crops such as cotton (*Gossypium* spp.), pulse crops such as mungbean (*Vigna radiata*), soybean (*Glycine max*) and chickpea (*Cicer arietinum*), and leguminous hay and forage crops such as lablab (*Lablab purpureus*). In the companion technical report on hydro-electric power generation in the Southern Gulf catchments (Entura, 2024), this site was also evaluated for its potential to be used to generate hydro-electric power.
Impacts	In addition to the storage area, a flood margin area would also need to be acquired.
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** At this potential dam site, there were ecology asset records for sooty grunters (*Hephaestus fuliginosus*). In neighbouring streams, other asset species, including mouth almighty (*Glossamia aprion*) and the eastern rainbow fish (*Melanotaenia splendida*) have been found. The species distribution models predict that ~5% of the catchment (18,028 ha) has suitable habitat for at least 40% of the 10 species modelled. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively small, depending on the species, and ranges from zero % to 3% of their total modelled suitable habitat in the Southern Gulf catchments. These species may have their habitat fragmentated, and/or their movement may be impeded by a dam. Part of Chidna Nature Refuge occurs in the catchment, and 100 ha of the reservoir at the nominated FSL overlaps this nature refuge.

PARAMETER	DESCRIPTION
	Figure 5-18 shows the location of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Victoria River (AMTD 283 km) site. **Ecological implications of inundation** Two listed species have been recorded in the potential reservoir: Mertens' water monitor (*Varanus mertensi*) and the purple-necked rock-wallaby (*Petrogale purpureicollis*), listed as vulnerable (NCA). The northern blue-tongued skink (*Tiliqua scincoides intermedia*), listed as critically endangered (*Nature Conservation Act 1992* (Qld); NCA) has been found upstream of the reservoir, approximately 5 km from the border. The ghost bat (*Macroderma gigas*), listed as vulnerable in the EPBC Act and as endangered at territory/state level and the purple-necked rock-wallaby (*Petrogale purpureicollis*) occur also in the potential dam catchment. Waterbirds such as royal spoonbill (*Platalea regia*) and the western cattle egret (*Bubulcus ibis*) also occur in this catchment. The potential inundated area at FSL for this site (186 mEGM96) may have an effect on these species and extend into parts of the Chidna Nature Refuge. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Ponce Reyes et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	A manual cost estimate undertaken as part of the Assessment for a hypothetical RCC dam on the Gunpowder Creek AMTD 66 km site at a FSL of 186 mEGM96 is approximately \$773 million. Details of this cost estimate are provided in Appendix A. To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 184 mEGM96 – estimated cost = \$926 million FSL of 186 mEGM96 – estimated cost = \$957 million FSL of 188 mEGM96 – estimated cost = \$990 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 184 mEGM96 – estimated cost/ML of supply = \$7406/ML FSL of 186 mEGM96 – estimated cost/ML of supply = \$7433/ML FSL of 188 mEGM96 – estimated cost/ML of supply = \$7543/ML Based on the manual cost estimate, the cost/ML of supply at FSL of 186 mEGM96 is \$5992/ML. Based on the manual cost estimate and the Southern Gulf river system model yield, the cost/ML of supply at FSL of 186 mEGM96 is \$6496/ML.
Summary comment	This potential dam site is on Gunpowder Creek, a large tributary of the Leichhardt River, and has the second-lowest cost per megalitre of the short-listed sites in the Southern Gulf catchments. The foundations appear to be suitable for a RCC dam. The site would nominally supply water to a large plain of recent alluvium at the junction of Gunpowder Creek and the Leichhardt River. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. The potential suitable habitat for modelled migratory species upstream of this dam site is relatively small. Previous studies of dams on Gunpowder Creek focused on areas further upstream, predominantly to supply water for mining.

PARAMETER	DESCRIPTION
	In the companion technical report on hydro-electric power generation in the Southern Gulf catchments (Entura, 2024), this site was also evaluated for its potential to be used to generate hydro-electric power.

AMTD = adopted middle thread distance; BHA = behaviour analysis; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; FSL = full supply level; RCC = roller compacted concrete.

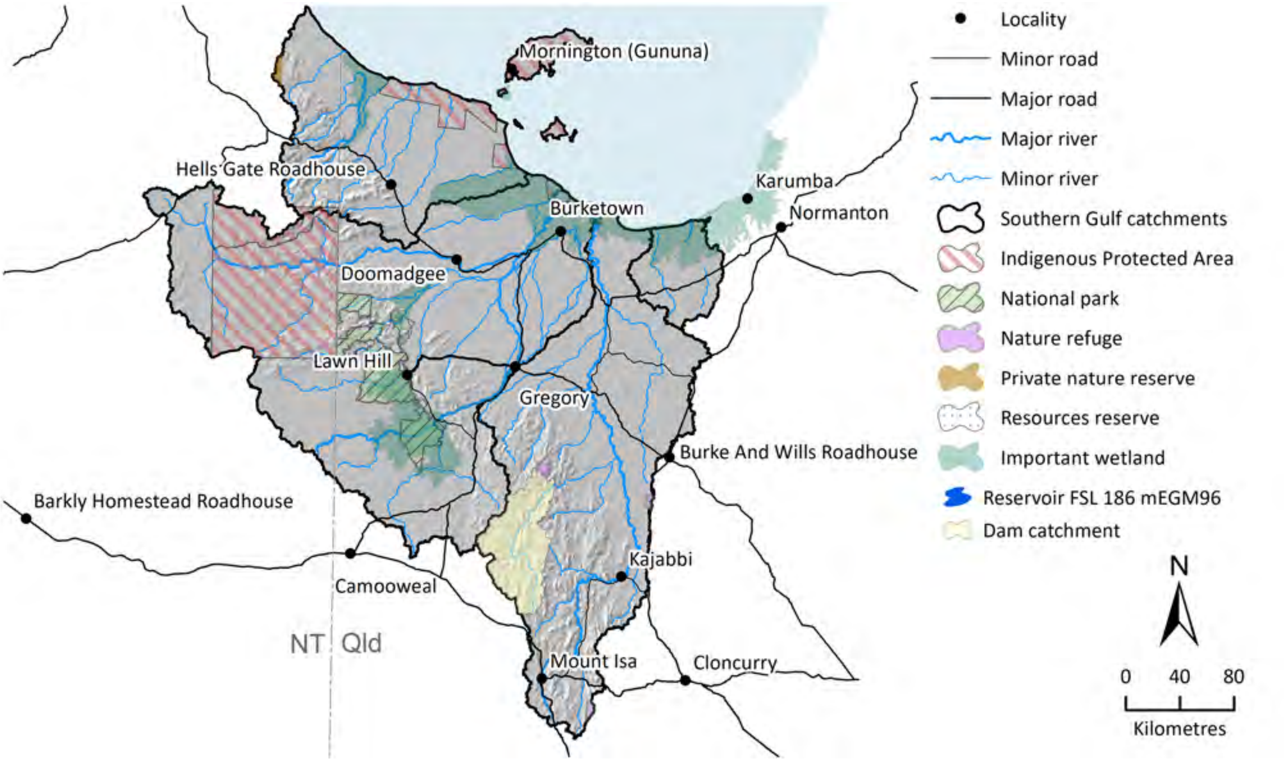

Figure 5-12 Location map of potential Gunpowder Creek dam site, reservoir extent, and catchment area

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

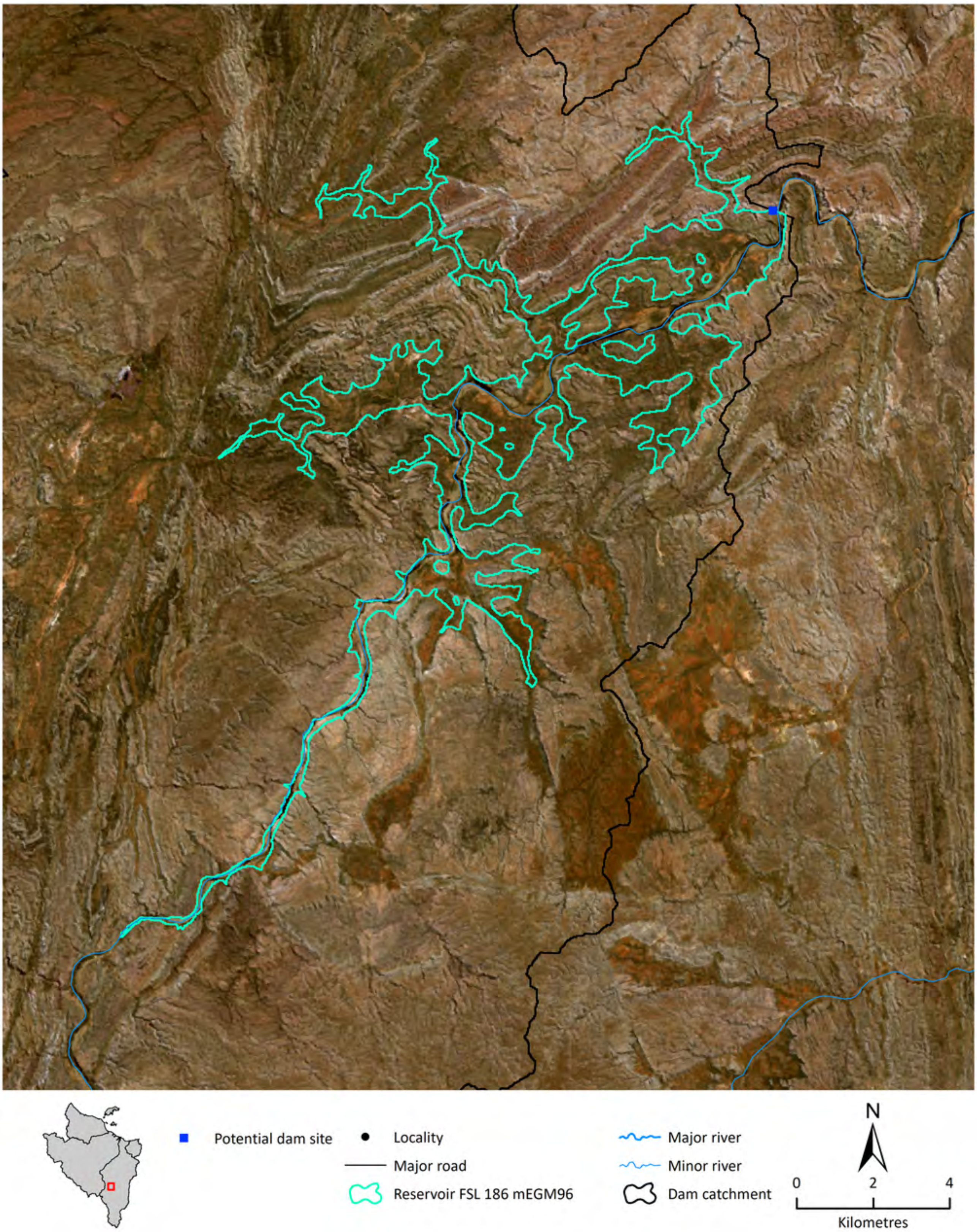

Figure 5-13 Potential Gunpowder Creek dam reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

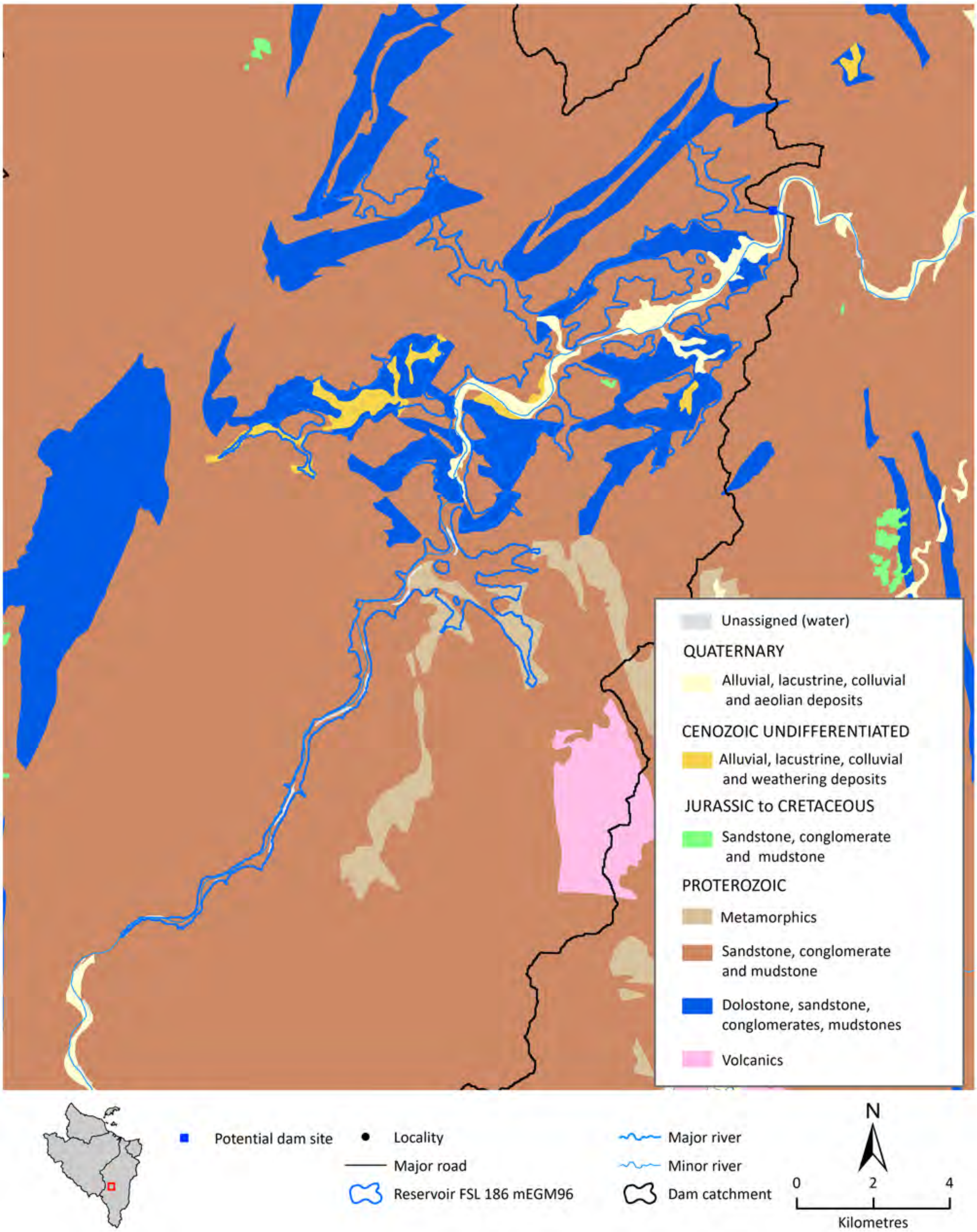

Figure 5-14 Geology underlying the potential Gunpowder Creek dam site and reservoir

AEP = annual exceedance probability; mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

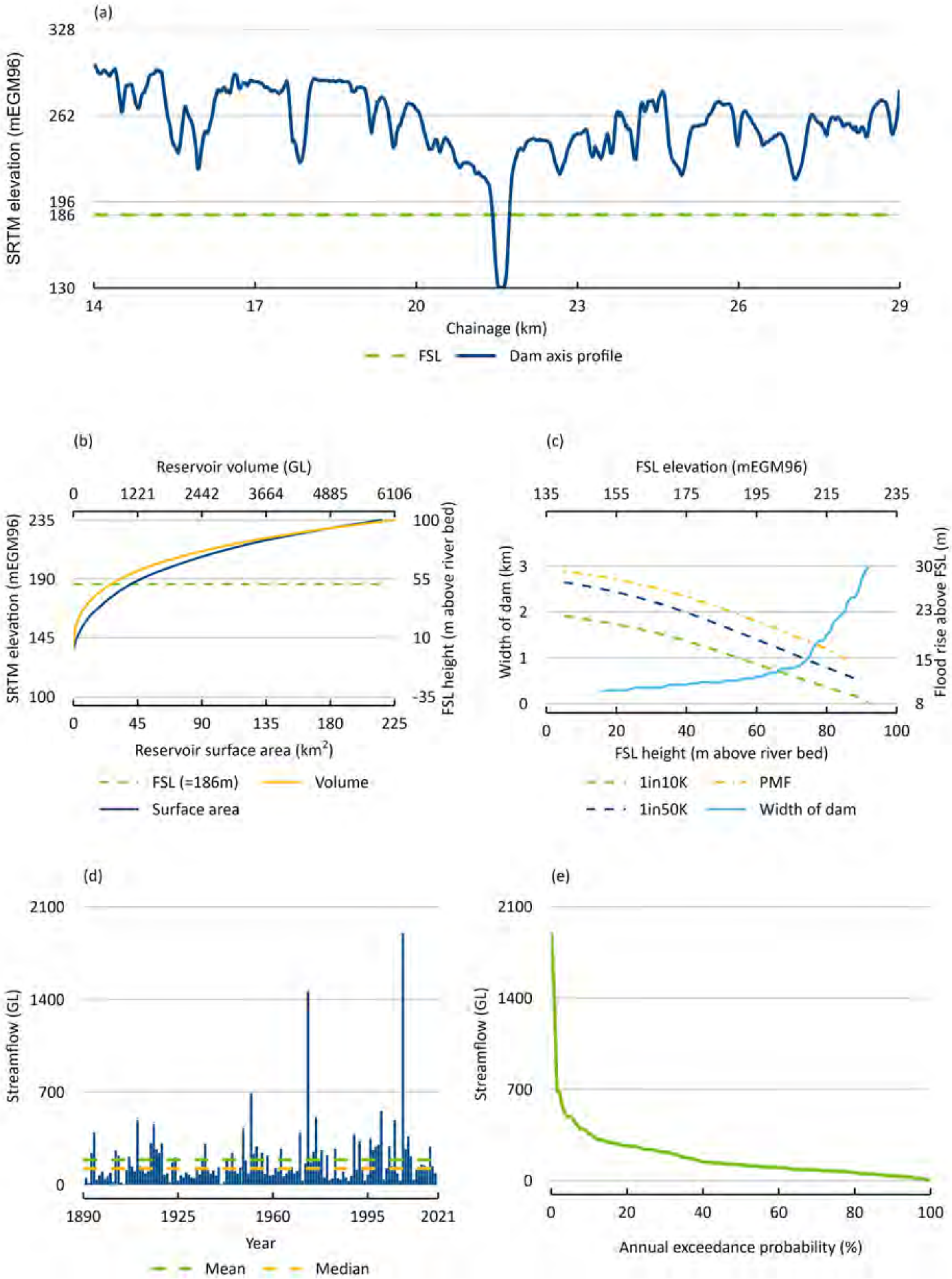

Figure 5-15 Gunpowder Creek potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

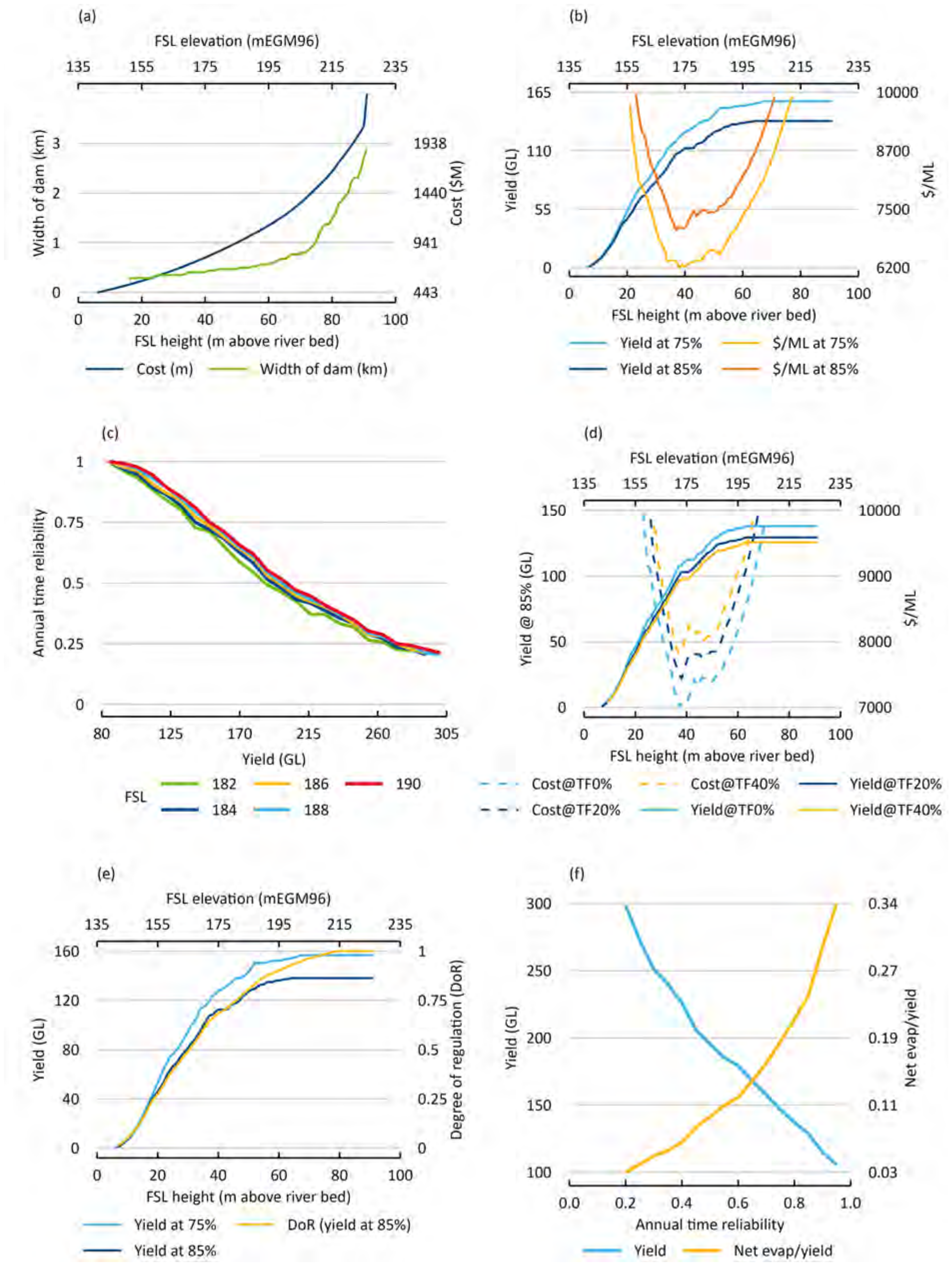

Figure 5-16 Gunpowder Creek potential dam site cost, water yield at the dam wall, and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

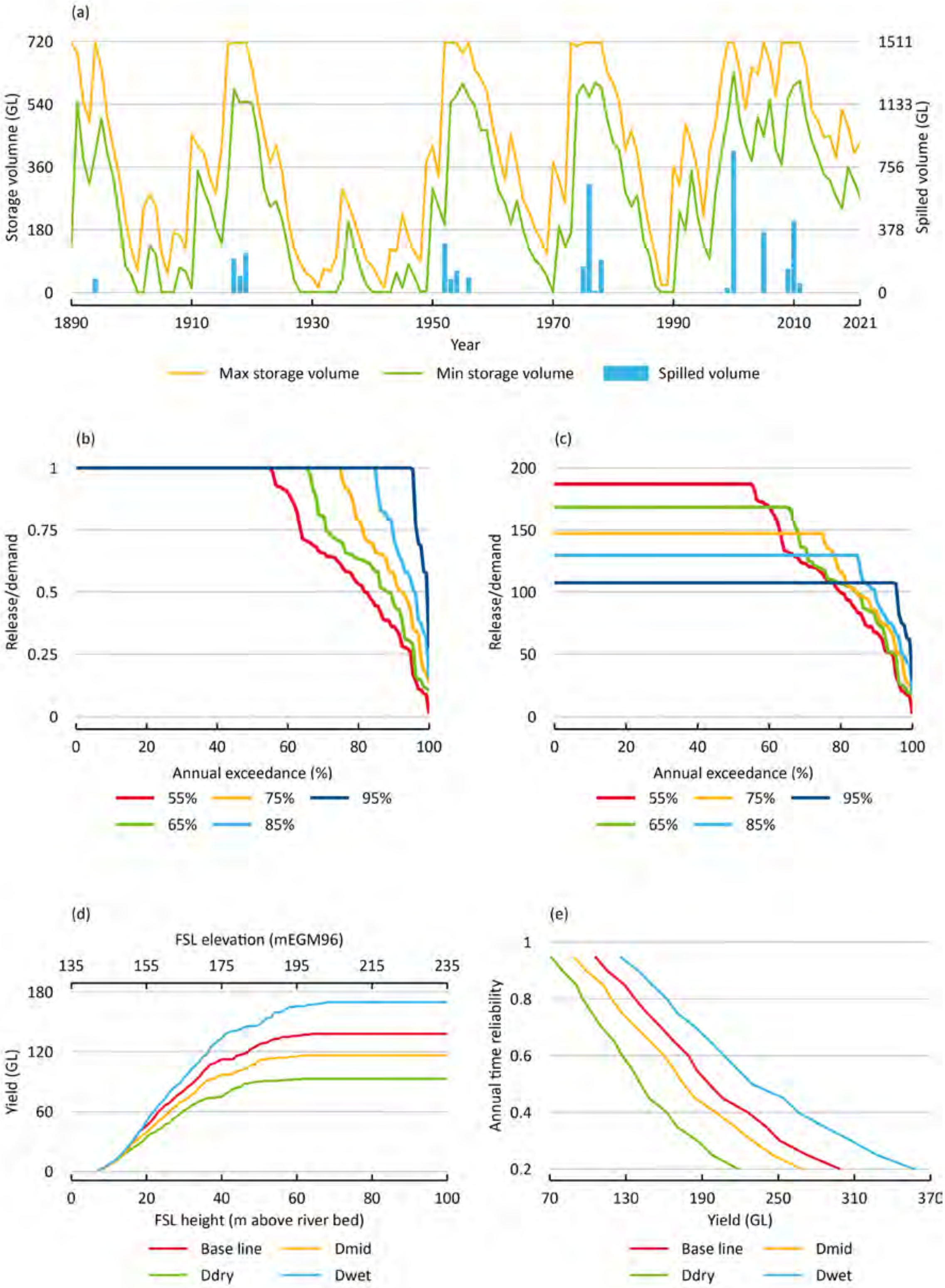

Figure 5-17 Gunpowder Creek potential dam site, storage levels, and water yield

(a) Max. and min. annual storage trace at the selected full supply level (FSL) (186 mEGM96) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 186 mEGM96 under scenarios A (baseline) and D. mEGM96 = Earth Gravitational Model 1996 geoid height in metres.

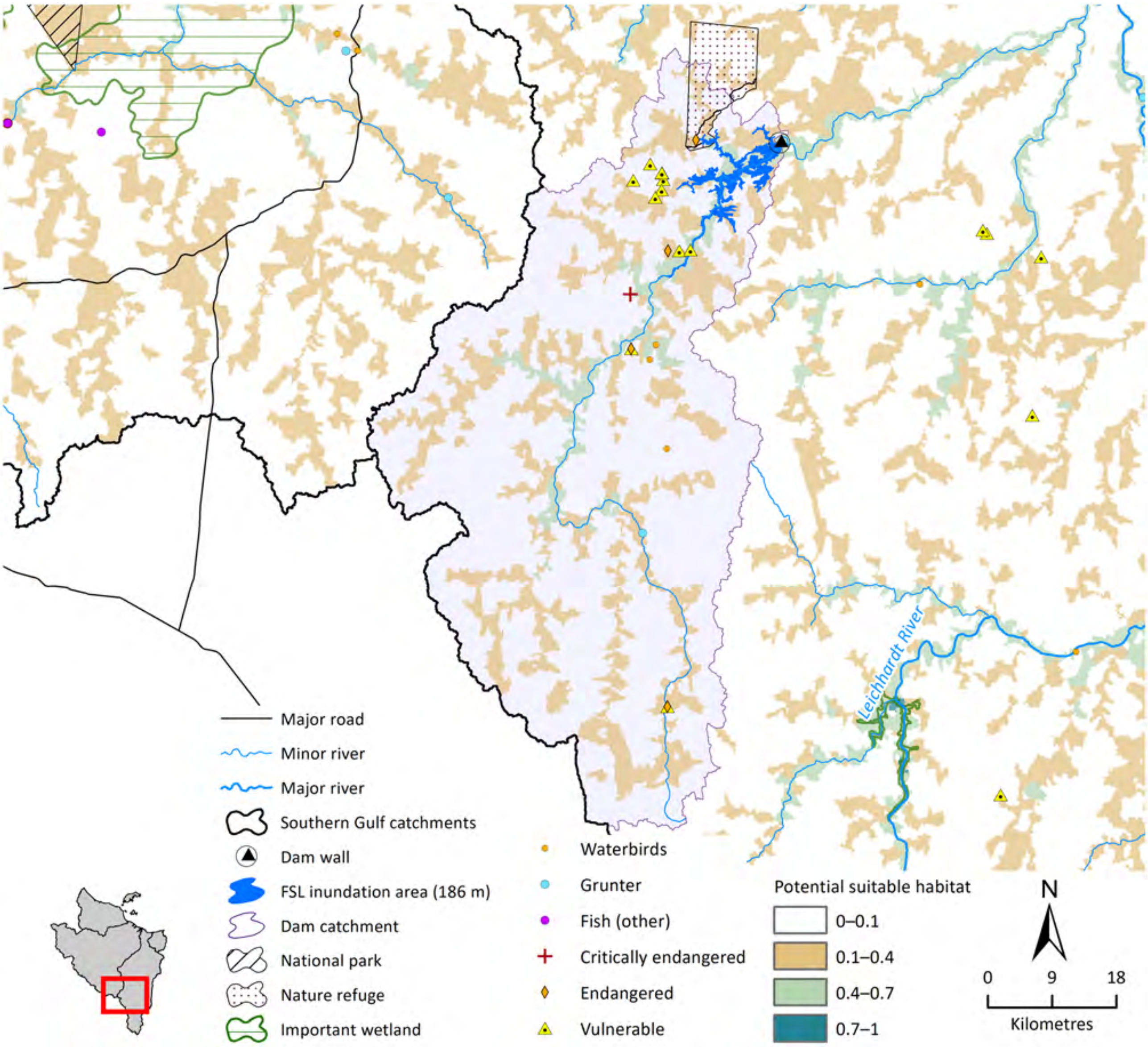

Figure 5-18 Location of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Gunpowder Creek dam site and reservoir extent

FSL = full supply level.

Part III Weirs and on-farm storages

6 Re-regulating structures

Re-regulating structures, such as weirs, are typically located downstream of large dams. They allow for more efficient releases from the storages and for some additional water yield from the weir storage itself, thereby reducing the transmission losses normally involved in supplemented river systems.

As a rule of thumb, weirs can be constructed at one-half to two-thirds the river bank height. This height allows the weirs to achieve maximum capacity while ensuring that the change in downstream hydraulic conditions does not result in excessive erosion of the banks or at the toe of the structure, and also that large flow events can still be passed without causing excessive flooding upstream.

Broadly speaking, there are two types of weir structure: concrete gravity weirs and sheet piling weirs. These are discussed below. Both weir types often use rock-filled mattresses on the stream banks, extending downstream of the weir to protect erodible areas from flood erosion. Sand dams are also briefly discussed.

Note that weirs, sand dams and diversion structures obstruct the movement of fish in a similar way to dams during the dry season.

6.1 Sheet piling weirs

Where rock foundations are not available, stepped steel sheet piling weirs have been successfully used in many locations across Queensland. These weirs consist of parallel rows of steel sheet piling, generally approximately 6 m apart, with a step of approximately 1.5 to 1.8 m high between each row. Reinforced concrete slabs placed between each row of piling absorb much of the energy as flood flows cascade over each step. The upstream row of piling is the longest, driven in to a sufficient depth to cut off the flow of water through the most permeable material (Figure 6-1). Indicative costs are provided in Table 6-1.

It should be noted, however, that in recent years Queensland Department of Agriculture and Fisheries have not approved stepped weirs on the basis that the steps result in fish mortalities. Sheet piling weirs would therefore have to have a sloping face with a more extensive dissipator at bed level.

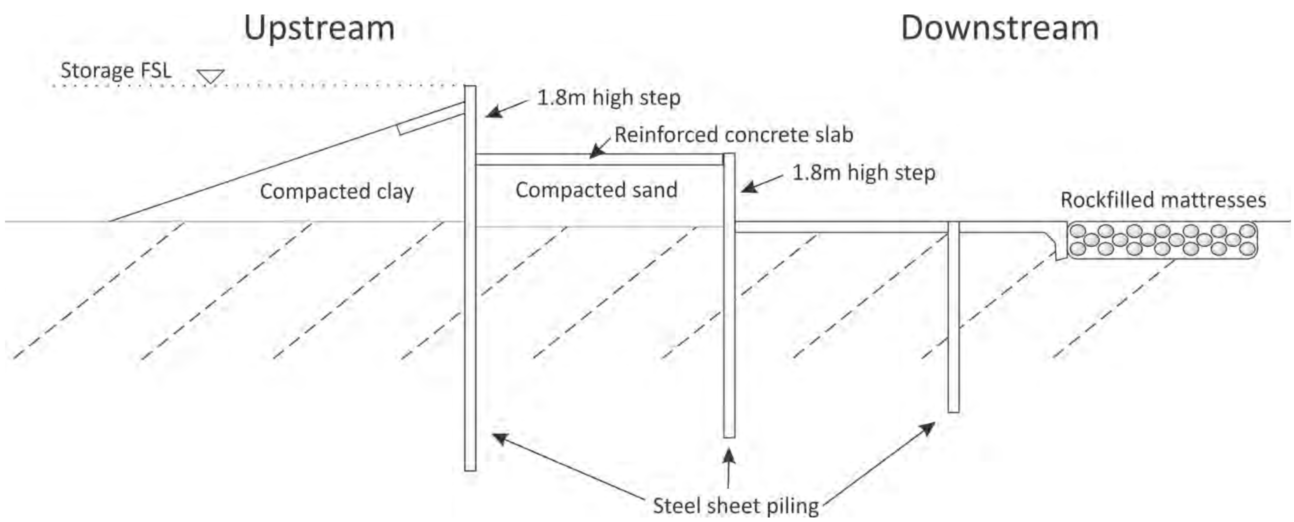

Figure 6-1 Schematic cross-section diagram of sheet piling weir

FSL = full supply level.

Source: Petheram et al. (2013a)

Table 6-1 Estimated generic construction cost of a 3-m-high sheet piling weir

Cost indexed to 2023.

WEIR CREST LENGTH (M)	ESTIMATED CAPITAL COST ($ MILLION)
100	32
150	42
200	50

6.2 Concrete gravity–type weirs

Where rock bars are exposed at bed level across the stream, concrete gravity–type weirs have been built on the rock at numerous locations across Queensland. This type of construction is less vulnerable to flood erosion damage, both during construction and in service. In Queensland similar consideration would need to be given to water over the spillway apron as sheet piling weirs.

Indicative costs are provided for a weir structure with only sufficient height (e.g. 0.75 m above river bed) to provide submergence of pumping infrastructure.

Assuming exposed bedrock across the riverbed and rock for aggregates and mattresses is available locally the cost of a low reinforced concrete slab with upstand (i.e. 0.75 m above river bed, nominally 150 m width along crest) for the purpose of providing pump station submergence is estimated to cost about $13 million. Nominal allowances were made for site access, services and construction camp costs on the basis that more substantial site establishment costs would be incurred by the nearby irrigation area development (see Appendix A).

6.3 Sand dams

As many of the large rivers in northern Australia are very wide (e.g. >300 m), weirs are likely to be impractical and expensive at many locations. Alternative structures are sand dams, which consists of low embankments built of sand constructed at the start of each dry season during periods of low or no flow, when heavy earth-moving machinery can access the bed of the river. A sand dam is constructed to form a pool of sufficient depth to enable pumping and this type of dam is widely used in the Burdekin River near Ayr.

Typically, sand dams take three to four large excavators approximately 2 to 3 weeks to construct, and no further maintenance is required until they need to be reconstructed again after the wet season. Bulldozers can construct a sand dam more quickly than can a team of excavators, but they have greater access difficulties. Because a sand dam only needs to form a pool of sufficient size and depth from which to pump water, it usually only partially spans a river and is typically constructed immediately downstream of large, naturally formed waterholes.

The cost of 12 weeks of hire for a 20-t excavator and float (i.e. for transportation) is approximately $100,000. Although sand dams are cheap to construct relative to a concrete or sheet piling weir, they require annual rebuilding and have much larger seepage losses beneath and through the dam wall. No studies are known to have quantified losses from sand dams.

7 Farm-scale storages

The primary aim of this section is to provide a broad-scale assessment of the suitability of farm-scale water storage locations in the Victoria and Southern Gulf catchments. It also provides a summary of farm-scale dam construction and operation and maintenance (O&M) costs detailed in the Northern Australia Water Resource Assessment technical report on farm-scale dam costs (Benjamin, 2018) indexed to 2021. Note, however, in assessing regional-scale economics of water harvesting schemes, local variations in scale and site-specific nuances (e.g. length of supply channel, amount of diesel required for pumping, removal of sediment deposited in diversion channels, replacement of worn and damaged equipment, availability of materials, remoteness) result in considerably different construction and operational costs from one site to the next. Hence, operationally, each site would require its own specifically tailored engineering design. Many landholders will have observed the way water moves across their land and will have given considerable thought to their most suitable water harvesting configurations. This report does not attempt to produce engineering water harvesting infrastructure designs for individual producers. Nor does this report seek to provide instruction on the design and construction of offstream water storages. Numerous other texts and online tools provide detailed information on nearly all facets of offstream water storage. For instructional information, the reader is directed in the first instance to QWRC (1984), Lewis (2002) and IAA (2007).

This section describes a desktop analysis of two types of farm-scale dams. Section 7.1 examines offstream storages, such as ringtanks, into which water is pumped from an adjacent drainage line, and Section 7.2 examines gully and hillside dams, which intercept and store runoff generated directly from the dam's catchment.

7.1 Offstream farm-scale storages (ringtanks)

In this section the following analyses are reported for each of the two study areas:

- an assessment of the suitability of the landscape for farm-scale offstream storage
- indicative evaporative and seepage losses from farm-scale offstream storages
- indicative capital, operating and maintenance costs of farm-scale offstream storages.

7.1.1 Land-suitability assessment for offstream water storages

This section presents the results of a desktop land-suitability assessment for farm-scale offstream storages in the Victoria and Southern Gulf catchments. This assessment is based on the soils data in the top 1.5 m of the soil profile, generated as part of the Assessment (see companion technical reports on digital soil mapping (Thomas et al., 2024a,b)). Because of a lack of data on soils below a depth of 1.5 m, this analysis does not consider the suitability of subsurface material below this depth.

Land-suitability requirements for ringtanks include impermeable soils, slopes of less than 5%, clay content of greater than 20%, no rock, and deep soils.

Suitability criteria include:

- slowly permeable to very slowly permeable soils (<50 mm/day) to reduce unnecessary water losses from deep drainage and avoid rising watertables or potential secondary salinisation in the vicinity of the tanks
- level to gentle slopes to enable construction of a 'large storage' and reduce unnecessary excavation into hillslopes
- soil texture of greater than 20% clay to the depth of excavation, to allow machinery to compact the tank floor and the walls to reduce deep drainage. Clay textures (>35% clay) are preferred
- non-rocky soils to enable ease of construction and uniform compaction
- deep soils, preferably greater than 1 m deep, to allow excavation of tanks with sufficient storage depth and wall height.

Farm-scale offstream water storages require consideration at a scale finer than is possible to assess in a regional-scale resource assessment. Hence, the results presented here are only indicative of potential suitable locations. Design and construction of offstream water storages should only be undertaken following a site investigation by a suitability qualified professional.

The majority of the Victoria and Southern Gulf catchments are unsuitable for offstream storages, predominantly due to excessive slope, shallow and permeable soils, and rockiness.

Suitability of soils for offstream storage in the Victoria catchment

In the Victoria catchment, several land types are likely to be suitable for ringtanks. These include the poorly drained coastal marine clay plains, the cracking clay soils on the alluvial plains of the Victoria River and tributaries, and the Cenozoic clay plains of the upper catchment (Figure 7-1). The very poorly drained saline coastal marine plains subject to tidal inundation have very deep, strongly mottled, grey non-cracking and cracking clay soils with potential acid sulfate deposits in the profile. They are likely to be suitable for ringtanks but are subject to storm surge from cyclones. The very deep (>1.5-m) alluvial clay plains of the Victoria River and upper Baines River are predominantly impermeable, imperfectly drained to moderately well-drained, grey and brown, hard-setting, cracking clay soils, frequently with small (<0.3 m) normal gilgai depressions. These soils on the Baines River alluvial plains grade to seasonally wet soils lower in the catchment and may be subject to regular flooding. Soils are usually strongly sodic at depth. The clay soils of the middle Victoria River alluvial plains are frequently dissected by severe gully erosion adjacent to the stream channels.

The Cenozoic clay plains are dominated by strongly sodic, impermeable, imperfectly drained self-mulching grey cracking clay soils grading to moderately well-drained grey-brown clay soils in the lower-rainfall southern parts of the catchment. This relict alluvium deposited over a diverse range of geologies, frequently has shallow (0.1 to 0.2 m) normal to linear gilgai and surface gravels/stones of various lithology. It frequently occurs in drainage depressions, enabling collection and storage of overland flows.

The moderately deep to deep (0.5 to <1.5 m), gilgaied, slowly permeable, non-sodic brown, black and red vertosols on Cambrian basalts are predominantly gravelly/stony, with slopes greater than 2%, but small areas of 'less rocky' soils occasionally occur on level to very gently undulating plains (slopes <1%) and are likely to be suitable for ringtanks. These less rocky soils are moderately well-drained self-mulching brown and black cracking clay soils in the north-eastern and far western parts of the catchment, grading to well-drained brown and red clay soils in the lower-rainfall southern part of the catchment. However, such areas are usually small and fragmented.

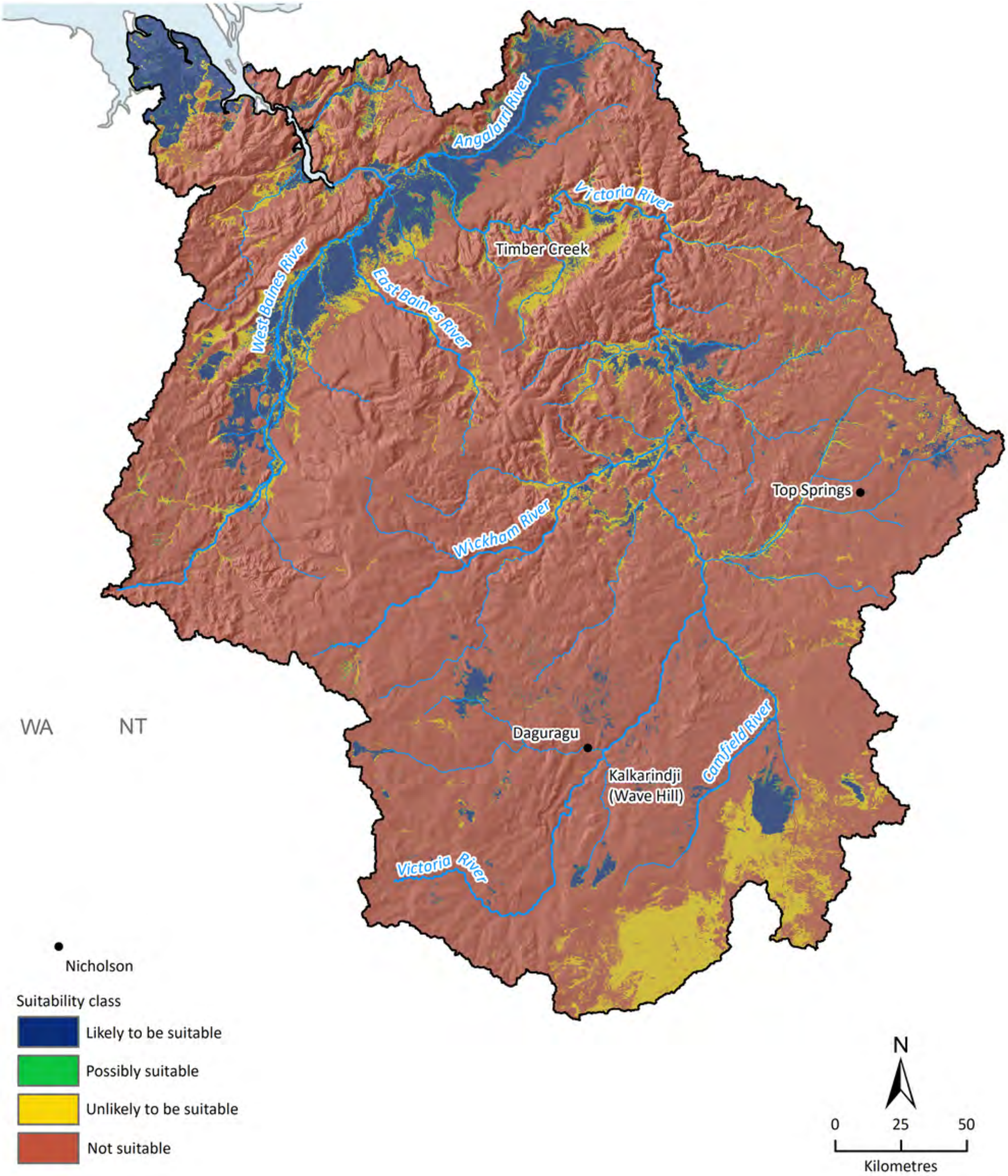

Figure 7-1 Suitability of farm-scale offstream water storage (ringtanks) in the Victoria catchment

Soil and subsurface data were only available to a depth of 1.5 m, so this Assessment does not consider the suitability of subsurface material below this depth. This figure does not take into consideration flood risk or the availability of water. Data are underlain by a shaded relief map.

Suitability of soils for offstream storage in the Southern Gulf catchments

Those areas of the Southern Gulf catchments suitable for ringtanks are mainly restricted to the level, slowly permeable, rock-free cracking clay soils (SGG 9) of the Armraynald Plain, Barkly Tableland and northern parts of Donors Plateau (Figure 7-2). The very poorly drained saline coastal marine plains (Karumba Plain), which are subject to tidal inundation and have very deep, strongly mottled, grey non-cracking and cracking clay soils with potential acid sulfate deposits in the profile are likely to be suitable for ringtanks but are subject to storm surge from cyclones. The soils of the Armraynald Plain are very deep (>1.5 m), imperfectly drained, slowly permeable, medium to heavy clays that crack when dry and swell when wet, reducing the rate of deep drainage. Soils have a self-mulching clay surface with gilgai common. On the Barkly Tableland, the cracking clays are deep (1.2 to 1.5 m) and underlain by limestone and dolomite karst and hence are often moderately well drained with gravel common. On Donors Plateau, the cracking clay soils are shallower (<0.5 m).

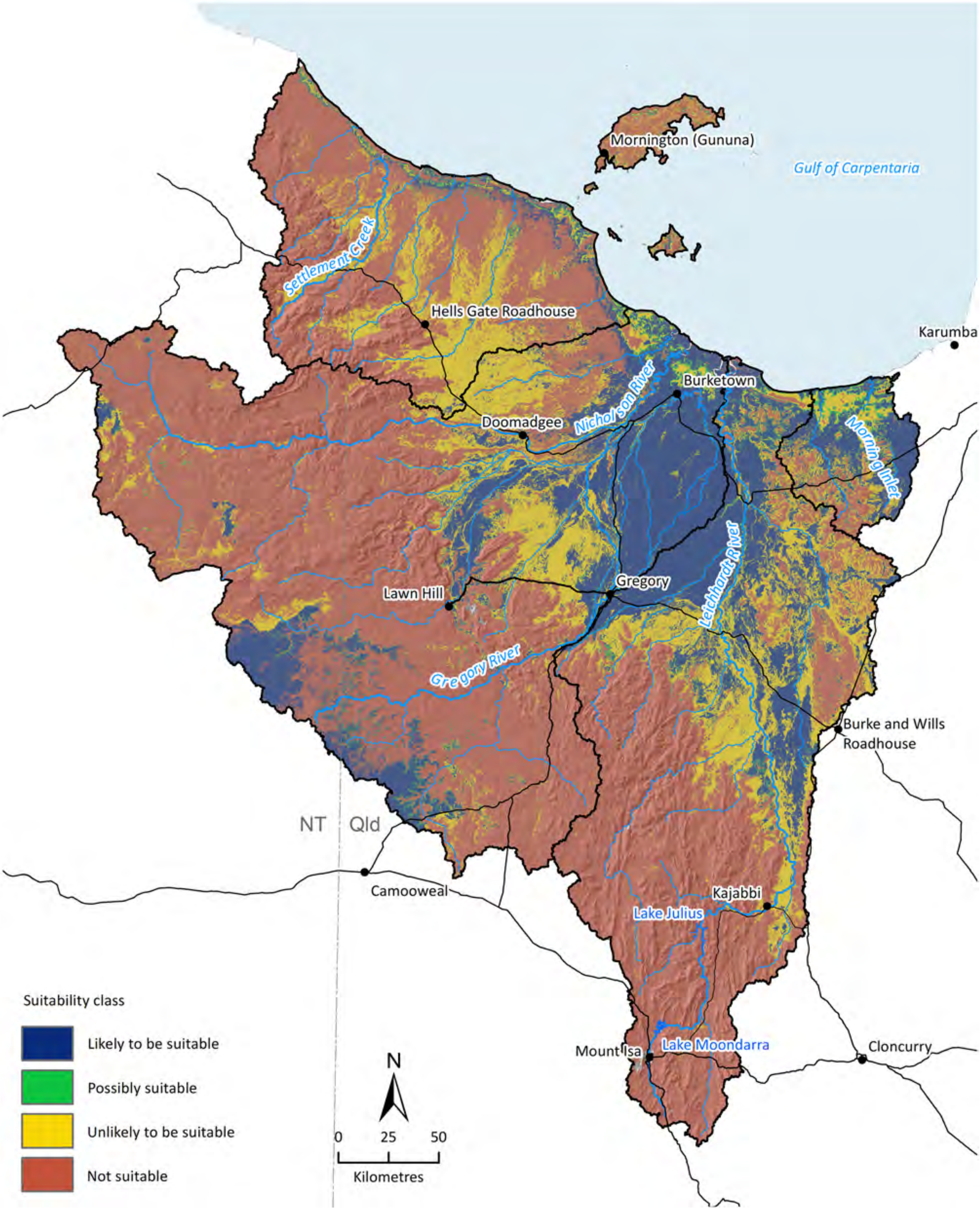

Figure 7-2 Suitability of farm-scale offstream water storage (ringtanks) in the Southern Gulf catchments

Soil and subsurface data were only available to a depth of 1.5 m, so this Assessment does not consider the suitability of subsurface material below this depth. This figure does not take into consideration flood risk or the availability of water. Data are underlain by a shaded relief map.

7.1.2 River flow exceeded in 80% of years

To enable a first-pass assessment of the potential for water harvesting in different parts of the Victoria and Southern Gulf catchments, information on annual streamflow exceeded in 80% of years under Scenario A is presented in Figure 7-3 and Figure 7-4, respectively. Note, however, that physical pumping constraints, environmental flow considerations, and existing downstream usage mean the actual amount of water available for extraction may be considerably less than that shown.

In the Victoria catchment, the largest 80% exceedance of annual streamflow occurs along the Victoria River. However, soil suitable for cropping and constructing ringtanks is limited adjacent to the Victoria River. Elsewhere in the catchment, with the exception of the West Baines and Wickham rivers, tributaries joining the Victoria River have relatively low 80% exceedance of annual streamflow. This is significant in terms of both offstream storage and gully dams, as it indicates that most of the tributaries of the Victoria River would only be able to support limited farm-scale water storage developments.

In the Southern Gulf catchments, the Leichhardt River has the largest 80% annual exceedance of annual streamflow, followed by the Gregory and Nicholson rivers. Lawn Hill Creek and Gunpowder Creek are the only other two tributaries that feature as having 80% exceedance of annual streamflow greater than 5 GL.

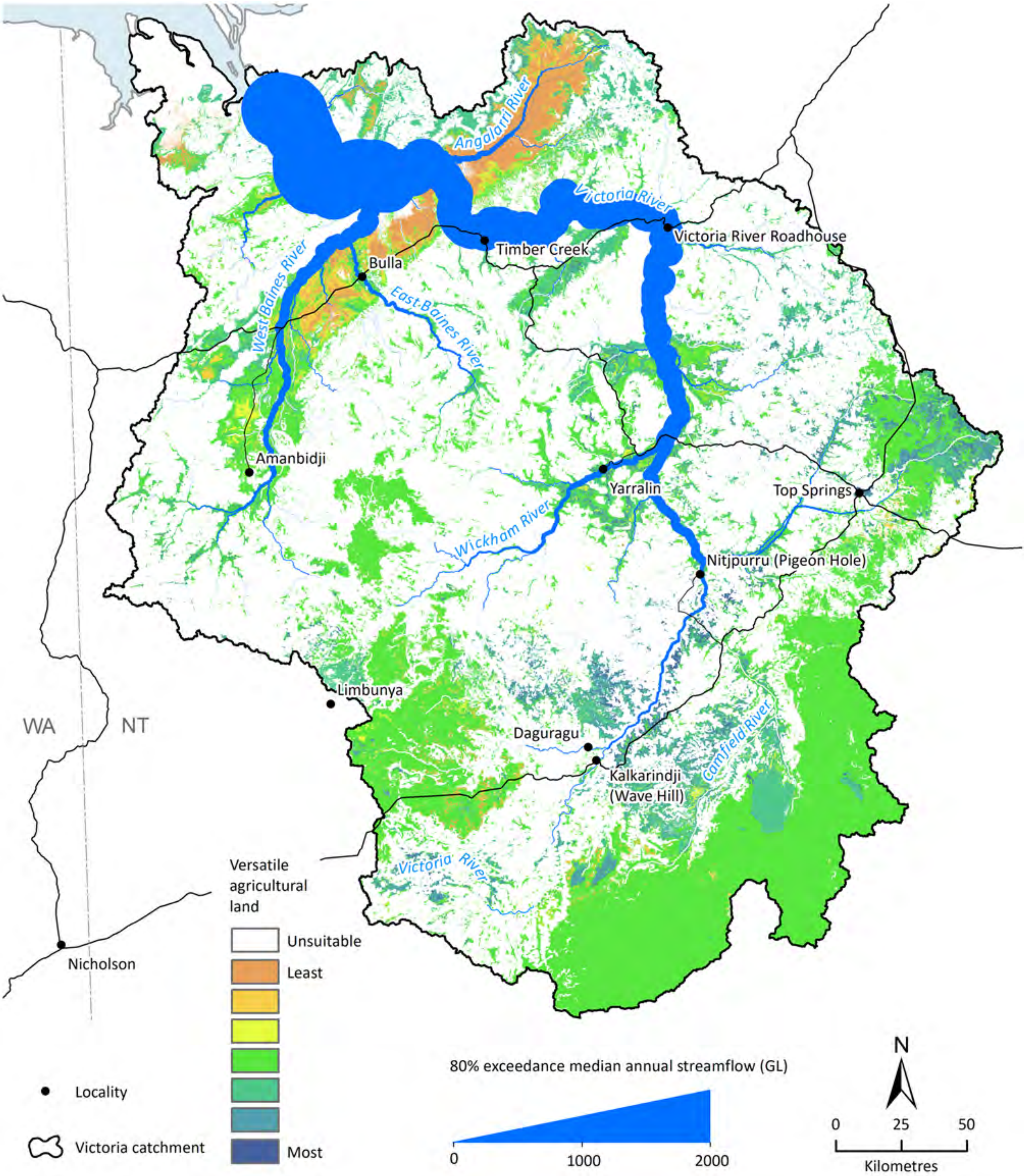

Figure 7-3 Map of 80% exceedance of annual streamflow in the Victoria catchment under Scenario AN and versatile agricultural land

Thickness of blue line corresponds to 80% exceedance annual streamflow.

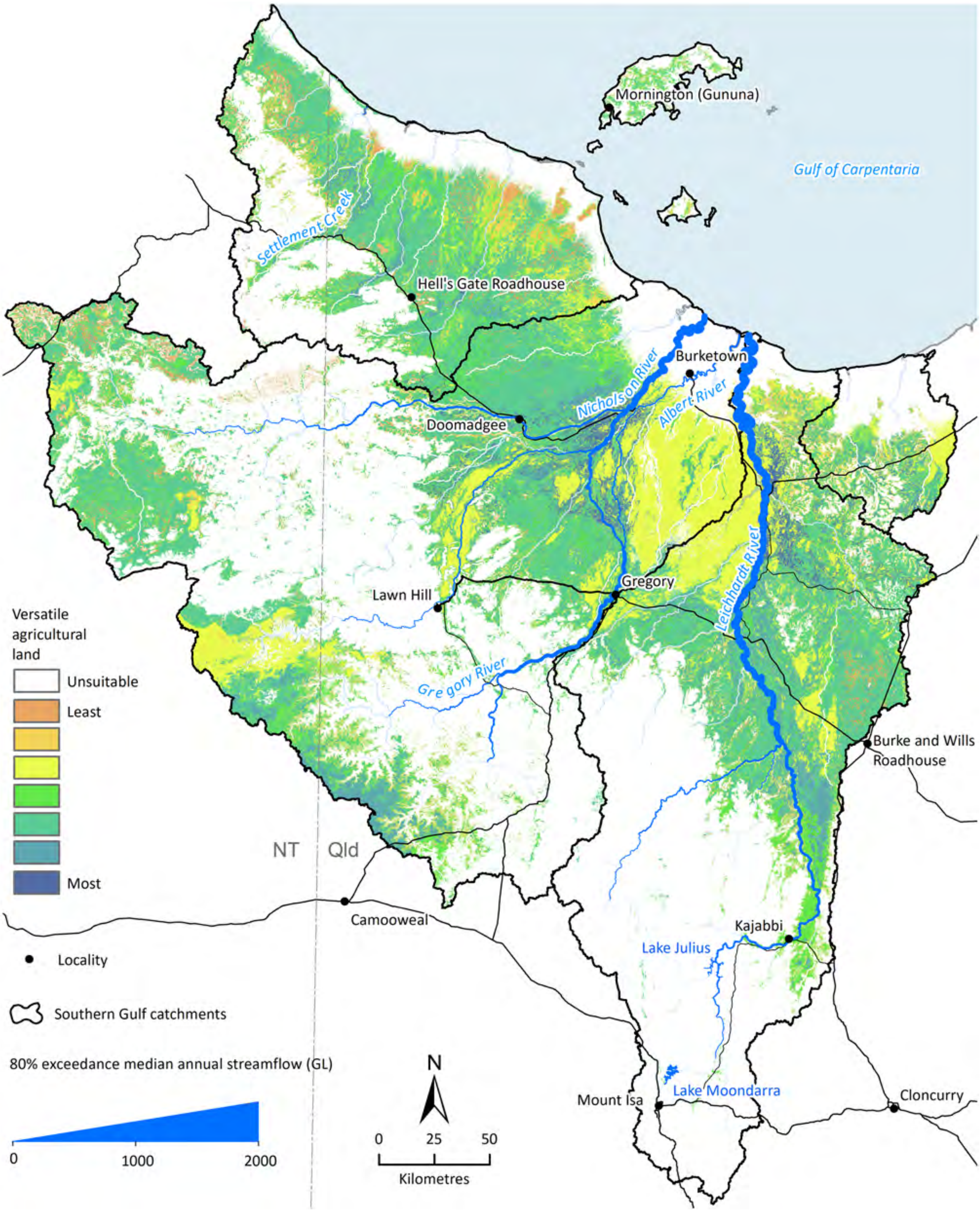

Figure 7-4 Map of 80% exceedance of annual streamflow in the Southern Gulf catchments under Scenario AN and versatile agricultural land

Thickness of blue line corresponds to 80% exceedance annual streamflow.

7.1.3 Evaporative and seepage losses

Losses from the reservoir of a farm-scale dam occur through evaporation and seepage. When calculating evaporative losses from a storage, it is important to calculate net evaporation (i.e.

evaporation minus rainfall) rather than just evaporation. Strategies to minimise evaporation include liquid and solid barriers, but these are typically expensive per unit of inundated area (e.g. \$12 to \$40/m^2). In non-laboratory settings, liquid barriers such as oils are susceptible to being dispersed by wind and have not been shown to reduce evaporation from a water body (Barnes, 2008). Solid barriers can be effective in reducing evaporation but are expensive. For example, covering the reservoir surface (110 ha) of the 4000-ML hypothetical ringtank detailed below with an impermeable barrier to prevent evaporation at a cost of \$25/m^2 would increase the capital cost of the storage from \$2 million to \$30 million (i.e. by more than a factor of ten). Evaporation losses from a ringtank can also be reduced slightly by subdividing the storage into multiple cells and extracting water from each cell in turn to minimise the total surface water area. However, constructing a ringtank with multiple cells requires more earthworks and incurs higher construction costs than outlined in this section.

A study of 138 farm dams ranging in capacity from 75 ML to 14,000 ML from southern NSW to central Queensland by the Cotton Catchment Communities CRC (2011) found mean seepage and evaporation rates of 2.3 and 4.2 mm/day, respectively. Of the 138 dams examined, 88% had seepage values of less than 4 mm/day, and 64% had seepage values of less than 2 mm/day. These results largely concur with the findings of the IAA (2007), which were that reservoirs constructed on suitable soils will have seepage losses equal to or less than 1 to 2 mm/day, and seepage losses will be greater than 5 mm/day if sited on less suitable (i.e. permeable) soils.

Ringtanks with greater mean water depth lose a lower percentage of their total storage capacity to evaporation and seepage losses; however, they have a smaller storage-capacity-to-excavation ratio. In Table 7-1 and Table 7-2, effective volume refers to the actual volume of water that could be used for consumptive purposes, after losses due to evaporation and seepage. For example, if water is stored in a ringtank in the Victoria catchment (near Victoria River Downs Station), with mean water depth of 3.5 m until October and a mean seepage loss of 2 mm/day, approximately 46% of the stored volume would be lost to evaporation and seepage. The examples provided in Table 7-1 and Table 7-2 are representative of 4000-ML ringtanks in the Victoria catchment and Southern Gulf catchments respectively, but the effective volume expressed as a percentage of the ringtank capacity is applicable to any storage (e.g. ringtanks or gully dams) of any capacity for mean water depths of 3.5, 6 and 8.5 m.

In the Victoria and Southern Gulf catchments, most moderate-to-large streamflow events occur before the end of March. Assuming the storage is full at this time, one strategy, assuming the soils are ‘trafficable’ is to sow suitable crops during the early dry season to minimise evaporative and seepage losses and enable crops to use the existing soil water. In the Victoria and Southern Gulf catchments, however, the alluvial clay soils may not be trafficable before May in some years. Hence, the configurations in the following tables provide general information on construction costs and effective volumes in these two study areas for three seepage rates (1, 2 and 5 mm/day) and for three storage durations (5, 7 and 10 months), assuming the ringtank is full at the end of March. Sorghum (*Sorghum* spp.) planted for hay is an example of a crop for which water may be required for irrigation for a 4-month period (i.e. May to August), sorghum planted for grazing is an example of a crop for which water may be required for irrigation for a 6-month period (May to October), and Rhodes grass (*Chloris gayana*) is an example of a perennial crop or a crop for which water is needed throughout the dry season (i.e. water may be required over a 10-month period).

Table 7-1 Effective volume after net evaporation and seepage for ringtanks of three mean water depths, under three seepage rates, near Victoria River Downs in the Victoria catchment

Effective volume refers to the actual volume of water that could be used for consumptive purposes as a result of losses due to net evaporation and seepage, assuming a storage capacity of 4000 ML. For storages of 4000 ML capacity and mean water depths of 3.5, 6 and 8.5 m, reservoir surface areas are 110, 65 and 45 ha, respectively. The S:E ratio is the storage-capacity-to-excavation ratio. Effective volumes were calculated based on the 20% exceedance net evaporation.

MEAN WATER DEPTH (M)	S:E RATIO	SEEPAGE LOSS (MM/DAY)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENTAGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENTAGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENTAGE OF CAPACITY (%)
				5 months (April to August)		**7 months (April to October)**		**10 months (April to January)**
3.5	14:1	1	2923	73	2393	60	1777	44
	14:1	2	2756	69	2159	54	1441	36
	14:1	5	2254	56	1456	36	435	11
6	7.5:1	1	3359	84	3044	76	2676	67
	7.5:1	2	3260	82	2906	73	2478	62
	7.5:1	5	2964	74	2490	62	1883	47
8.5	5:1	1	3554	89	3335	83	3079	77
	5:1	2	3486	87	3239	81	2941	74
	5:1	5	3281	82	2952	74	2530	63

Table 7-2 Effective volume after net evaporation and seepage for ringtanks of three mean water depths, under three seepage rates, near Century Mine in the Southern Gulf catchments

Effective volume refers to the actual volume of water that could be used for consumptive purposes as a result of losses due to net evaporation and seepage, assuming a storage capacity of 4000 ML. For storages of 4000 ML capacity and mean water depths of 3.5, 6 and 8.5 m, reservoir surface areas are 110, 65 and 45 ha, respectively. The S:E ratio is the storage-capacity-to-excavation ratio. Effective volumes were calculated based on the 20% exceedance net evaporation.

MEAN WATER DEPTH (M)	S:E RATIO	SEEPAGE LOSS (MM/DAY)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENTAGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENTAGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENTAGE OF CAPACITY (%)
				5 months (April to August)		**7 months (April to October)**		**10 months (April to January)**
3.5	14:1	1	2879	72	2327	58	1545	39
	14:1	2	2711	68	2093	52	1210	30
	14:1	5	2210	55	1390	35	203	5
6	7.5:1	1	3332	83	3004	75	2537	63
	7.5:1	2	3233	81	2865	72	2338	58
	7.5:1	5	2937	73	2450	61	1744	44
8.5	5:1	1	3535	88	3306	83	2981	75
	5:1	2	3467	87	3210	80	2843	71
	5:1	5	3262	82	2923	73	2432	61

7.1.4 Indicative capital, operation and maintenance costs of offstream storages

In this analysis, the cost of a farm-scale offstream storage scheme includes the cost of the water storage, pumping infrastructure, limited length of supply channel/piping, levee banks, and O&M of the scheme.

For a given storage capacity, the construction costs (and opportunity cost of land used in the construction) vary considerably, depending on the way the storage is built. For example, circular storages have a better storage-volume-to-cost ratio than rectangular or square storages. It is also considerably more expensive to double the height of an embankment wall than to double its length.

Table 7-3 provides a high-level breakdown of the capital and O&M costs of a large farm-scale ringtank, including the cost of the water storage, pumping infrastructure, up to 100 m of pipes, and O&M of the scheme. The costs and analyses presented in Table 7-3 and Table 7-4 are based on costs of $6.2/m^3 for earthfill and topsoil and $8.1/m^3 for compacted clay (Benjamin 2018), indexed to 2023. It was assumed those figures include the cost of compaction and that all earth can be obtained within close vicinity of the site. In this example, it is assumed that the ringtank is within 100 m of the river and pumping infrastructure. It should be noted that the cost of pumping infrastructure and conveying water from the river to the storage is particularly site-specific. For a more detailed breakdown of ringtank costs, see the Northern Australia Water Resource Assessment technical report on large farm-scale dams (Benjamin, 2018), and for more information on pumping infrastructure, see the companion technical report on pump stations for flood harvesting and irrigation downstream of storages (Devlin, 2023).

In flood-prone areas where flood waters move at moderate to high velocities, riprap protection may be required, and this may increase the construction costs presented in Table 7-3 and Table 7-4 by 10% to 20%, depending upon volume of rock required and proximity to a quarry with suitable rock.

Table 7-3 Indicative costs for a 4000-ML ringtank

Assumes a 4.25-m wall height, 0.75-m freeboard, 3:1 ratio on upstream slope, 3:1 ratio on downstream slope and crest width of 3.1 m, approximately 60% of material can be excavated from within storage, and cost of earthfill and compacted clay is $5.4/m^3 and $7/m^3, respectively. Earthwork costs include vegetation clearing, mobilisation/demobilisation of machinery, and contractor accommodation. For a more detailed costing, see the Northern Australia Water Resource Assessment technical report on large farm-scale dams (Benjamin, 2018). Pump station costs were derived from the companion technical report on pump stations in northern Australia (Devlin, 2023). Costs have been indexed to 2023. Pump station operation and maintenance (O&M) costs are based on a diesel cost of $1.49/L.

SITE DESCRIPTION/ CONFIGURATION	EARTHWORKS ($)	GOVERNMENT PERMITS AND FEES ($)	INVESTIGATION AND DESIGN FEES ($)	PUMP STATION ($)	TOTAL CAPITAL COST ($)	O&M OF RINGTANK ($/Y)	O&M OF PUMP STATION ($/Y)	TOTAL O&M ($/Y)
4000-ML ringtank	2,000,000	43,000	92,000	380,000	2,515,000	21,000	92,000	113,000

The capital costs can be expressed over the service life of the infrastructure (assuming a 7% discount rate) and combined with O&M costs to give an equivalent annual cost for construction and operation. This enables infrastructure with differing capital and O&M costs and service life to be compared. The total equivalent annual costs for the construction and operation of a 1000-ML ringtank with 4.25-m-high embankments and 55 ML/day pumping infrastructure are approximately $143,600 (Table 7-4). For a 4000-ML ringtank with 4.25-m-high embankments and 160 ML/day pumping infrastructure, the total equivalent annual cost is approximately $301,550. For a 4000-ML ringtank with 6.75-m-high embankments and 160 ML/day pumping infrastructure, the total equivalent annual cost is approximately $457,600.

Table 7-4 Annualised cost for the construction and operation of three ringtank configurations

Assumes freeboard of 0.75 m, pumping infrastructure can fill ringtank in 25 days, and a 7% discount rate. Costs have been based on those for a 4000-ML ringtank provided in the companion technical report on large farm-scale dams (Benjamin, 2018). Costs have been indexed to 2023. Pump station operation and maintenance (O&M) costs are based on a diesel cost of $1.49/L.

CAPACITY AND EMBANKMENT HEIGHT	ITEM	CAPITAL COST ($)	LIFE SPAN (Y)	ANNUALISED CAPITAL COST ($)	ANNUAL O&M COST ($)
1000 ML and 4.25 m	Ringtank	1,075,000	40	80,480	10,700
	Pumping infrastructure†	245,000	15	26,900	4,500
	Pumping cost (diesel)	na	na	na	21,000
4000 ML and 4.25 m	Ringtank	2,000,000	40	150,000	17,250
	Pumping infrastructure†	380,000	15	41,700	7,600
	Pumping cost (diesel)	na	na	na	85,000
4000 ML and 6.75 m	Ringtank	3,863,000	40	290,000	33,300
	Pumping infrastructure†	380,000	15	41,700	7,600
	Pumping cost (diesel)	na	na	na	85,000

na = not applicable.
†Costs include rising-main, large-diameter concrete or multiple strings of high-density polypipe, control valves and fittings, concrete thrust-blocks and headwalls, dissipator, civil works, and installation. Value assumes water is piped between river pumping infrastructure and ringtank.

Although ringtanks with a mean water depth of 3.5 m (embankment height of 4.25 m) lose a higher percentage of their capacity to evaporative and seepage losses than ringtanks of equivalent capacity with a mean water depth of 6 m (embankment height of 6.75 m) (Table 7-1 and Table 7-2), their levelised cost (i.e. annualised cost divided by water supplied) is lower (Table 7-5 and Table 7-6) due to the considerably lower cost of constructing embankments with lower walls.

In Table 7-5 and Table 7-6, the levelised cost or the equivalent annual unit cost of the water supplied from the ringtank takes into consideration net evaporation and seepage from the storage, which increase with the length of time water is stored (i.e. crops with longer growing seasons will require water to be stored longer). In these tables, levelised cost results are presented for ringtanks of various seepage rates and lengths of time for storing water.

Table 7-5 Equivalent annual cost per megalitre for two different capacity ringtanks under three seepage rates near Victoria River Downs Station in the Victoria catchment

Assumes a 0.75-m freeboard, 3:1 ratio on upstream slope, and 3:1 ratio on downstream slope. Crest widths are 3.1 and 3.6 m for embankments with heights of 4.25 and 6.75 m, respectively. Assumes earthfill and compacted clay costs of $5/m^3$ and $6.50/m^3$, respectively. Earthwork costs include vegetation clearing, mobilisation/demobilisation of machinery, and contractor accommodation. A 1000-ML ringtank reservoir has a surface area of 28 ha and a storage-volume-to-excavation ratio of approximately 7:1. A 4000-ML ringtank and 4.25-m embankment height reservoir has a surface area of 114 ha and a storage-volume-to-excavation ratio of approximately 14:1. A 4000-ML ringtank with a 6.75-m embankment height reservoir has a surface area of 64 ha and a storage-volume-to-excavation ratio of approximately 7.5:1.

CAPACITY AND EMBANKMENT HEIGHT	ANNUALISED COST ($)	SEEPAGE (MM/DAY)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)
			5 months (April to August)	7 months (April to October)	10 months (April to January)
1000 ML and 4.25 m	143,580	1	196	240	323
	143,580	2	208	266	399
	143,580	5	255	394	1321
4000 ML and 4.25 m	301,550	1	359	396	451
	301,550	2	370	415	487
	301,550	5	407	484	641
4000 ML and 6.75 m	457,600	1	515	549	595
	457,600	2	525	565	622
	457,600	5	558	620	724

Table 7-6 Equivalent annual cost per megalitre for two different capacity ringtanks under three seepage rates near the Century Zinc Mine in the Southern Gulf catchments

Assumes a 0.75-m freeboard, 3:1 ratio on upstream slope, and 3:1 ratio on downstream slope. Crest widths are 3.1 and 3.6 m for embankments with heights of 4.25 and 6.75 m, respectively, with assumed earthfill and compacted clay costs of $5/m^3 and $6.50/m^3, respectively. Earthwork costs include vegetation clearing, mobilisation/demobilisation of machinery, and contractor accommodation. A 1000-ML ringtank reservoir has a surface area of 28 ha and a storage-volume-to-excavation ratio of approximately 7:1. A 4000-ML ringtank and a 4.25-m embankment height reservoir has a surface area of 114 ha and a storage-volume-to-excavation ratio of approximately 14:1. A 4000-ML ringtank with a 6.75-m embankment height reservoir has a surface area of 64 ha and a storage-volume-to-excavation ratio of approximately 7.5:1.

CAPACITY AND EMBANKMENT HEIGHT	ANNUALISED COST ($)	SEEPAGE (MM/DAY)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)
			5 months (April to August)	7 months (April to October)	10 months (April to January)
1000 ML and 4.25 m	148,955	1	200	247	372
	148,955	2	212	274	475
	148,955	5	260	413	2828
4000 ML and 4.25 m	374,415	1	362	402	476
	374,415	2	373	421	516
	374,415	5	411	492	692
4000 ML and 6.75 m	457,600	1	518	554	614
	457,600	2	528	570	644
	457,600	5	561	626	753

Taking into consideration the cost of constructing ringtanks, and net evaporation and seepage losses, the optimal embankment height will vary depending upon the capacity of the storage and the time required to store water.

7.2 Farm-scale gully and hillside dams

Large farm-scale gully dams are generally constructed of earth or earth and rockfill embankments with compacted clay cores and are usually a maximum height of approximately 20 m. Dams with a crest height of over 10 or 12 m typically require some form of downstream batter drainage incorporated in the embankments. Large farm-scale gully dams typically have a maximum catchment area of approximately 40 km^2, due to the challenges in passing peak floods from large catchments (large farm-scale gully dams are generally designed to pass an event with an annual exceedance probability (AEP) of 1%), unless a site has an exceptionally good spillway option.

Like ringtanks, large farm-scale gully dams are a compromise between best-practice engineering and affordability. Designers need to follow accepted engineering principles relating to important aspects of materials classification, compaction of the clay core, and selection of an appropriate embankment cross-section. However, costs are often minimised where possible, for example, by employing earth bywashes and grass protection for erosion control, rather than the more expensive concrete spillways and rock protection found on major dams. This can compromise the integrity of the structure during extreme events, its longevity, and increase the ongoing maintenance costs, but it can considerably reduce the upfront capital costs.

In this section, the following assessments are reported:

- suitability of the landscape for large farm-scale gully dams
- indicative capital, operating and maintenance costs of large farm-scale gully dams.

7.2.1 DamSite model results

The DamSite model (Petheram et al., 2017) was used to assess every location in the Victoria and Southern Gulf catchments for their potential for a farm-scale earth embankment gully or hillside dam. As discussed in Chapter 3, the model was used to assess farm-scale dams of between 5 and 20 m in height and catchment areas less than 40 km^2.

Figure 7-5 and Figure 7-6 show locations where, assuming there is suitable soil nearby, it may be more economical to construct large farm-scale gully dams in the Victoria and Southern Gulf catchments, respectively, and the likely density of options. This analysis considers sites likely to have relatively favourable topography and inflows. It does not explicitly consider whether sites are underlain by soil that is suitable for the construction of the embankment, and which will minimise seepage from the reservoir base. Soil suitability is shown in Figure 7-7 and Figure 7-8 for the Victoria and Southern Gulf catchments, respectively. Dams can be constructed on eroded or skeletal soils, provided there is access to a clay borrow pit nearby for the cut-off trench and core zone. However, those sites are likely to be less economically viable.

In the Victoria and Southern Gulf catchments, 2617 and 1828 locations respectively were modelled as having a maximum water yield of 20 ML per 1000 m^3 of excavation or greater. However, note that in many of these locations the regional-scale digital soil modelling indicates that soils are likely unsuitable for constructing embankment dams, because the soil is too shallow to provide sufficient material for construction (Figure 7-7 and Figure 7-8). This means dam walls would have to be constructed using rockfill, cement and imported clay soils. The maximum yield per 1000 m^3 of excavation was observed to be independent of the catchment area. Data on farm-scale gully and hillside dams showing those locations with the highest yield-to-cost ratios are available through the Northern Australia Water Resource Assessment Explorer (https://nawra-explorer.csiro.au/).

It should be noted that the results presented in Figure 7-5 and Figure 7-6 are modelled, and consequently only indicative of the general locations where siting a gully dam may be most economically suitable. Due to the relatively low heights of these structures, this analysis may be particularly subject to errors in the underlying digital elevation model, such as effects due to the vegetation removal process. An important factor not considered in this analysis was the availability of a natural spillway. Site-specific investigations by a suitably qualified professional should always be undertaken prior to the construction of a gully dam.

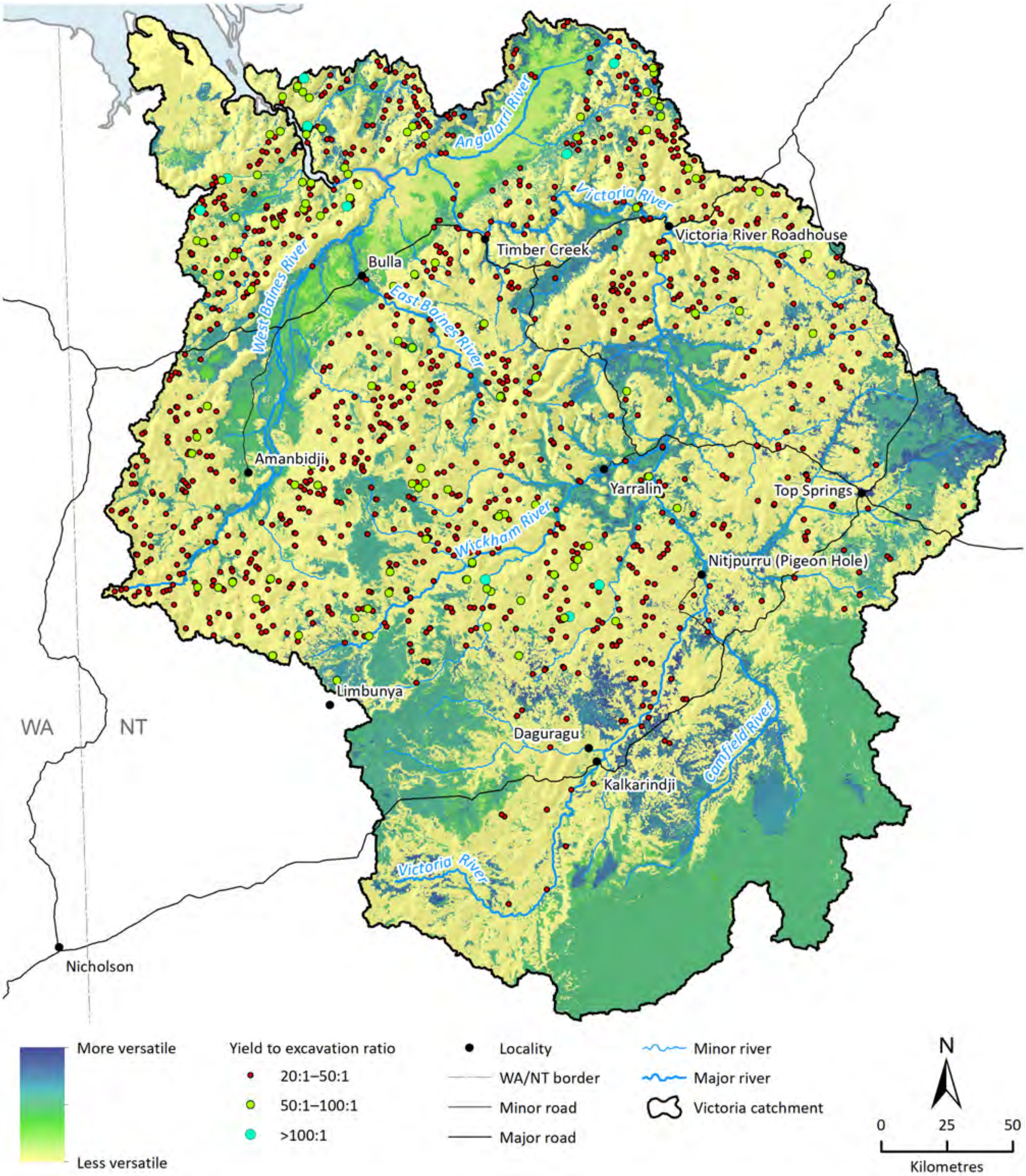

Figure 7-5 Most economically suitable locations for large farm-scale gully dams in the Victoria catchment overlaid on map of versatile agricultural land

Gully dam data overlaid on agricultural versatility data. Versatility data sourced from companion technical report on digital soil mapping and land suitability (Thomas et al., 2024a). Agricultural versatility data show the parts of the catchment that are more or less versatile for irrigated agriculture. This Assessment does not consider the suitability of the subsurface material. Sites with catchment areas greater than 40 km^2 or yield-to-excavation ratios of less than 20:1 are not displayed.

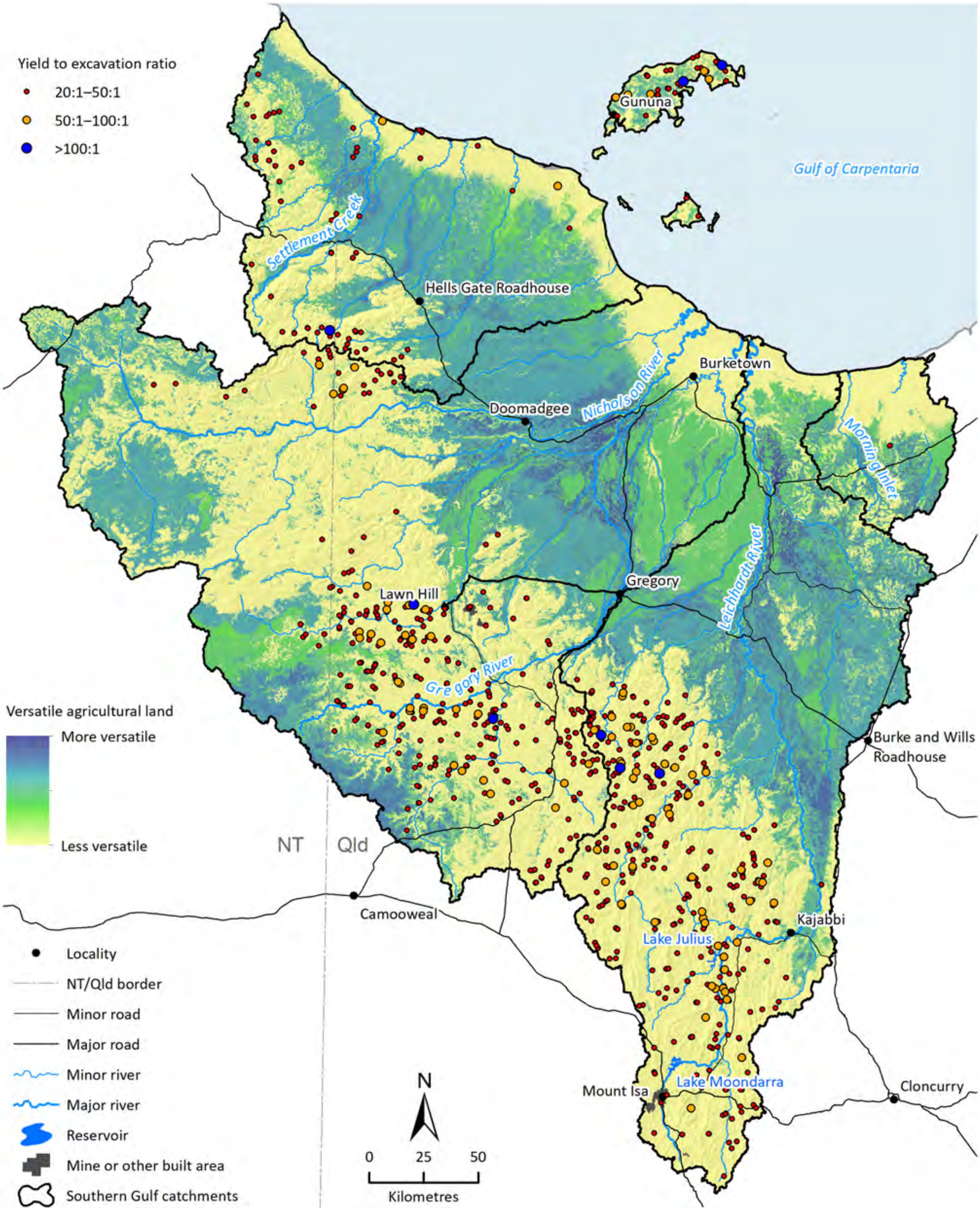

Figure 7-6 Most economically suitable locations for large farm-scale gully dams in the Southern Gulf catchments overlaid on map of versatile agricultural land

Gully dam data overlaid on agricultural versatility data. Versatility data sourced from companion technical report on digital soil mapping and land suitability (Thomas et al., 2024b). Agricultural versatility data show the parts of the catchment that are more or less versatile for irrigated agriculture. This Assessment does not consider the suitability of subsurface material. Sites with catchment areas greater than 40 km^2 or yield-to-excavation ratios of less than 20:1 are not displayed.

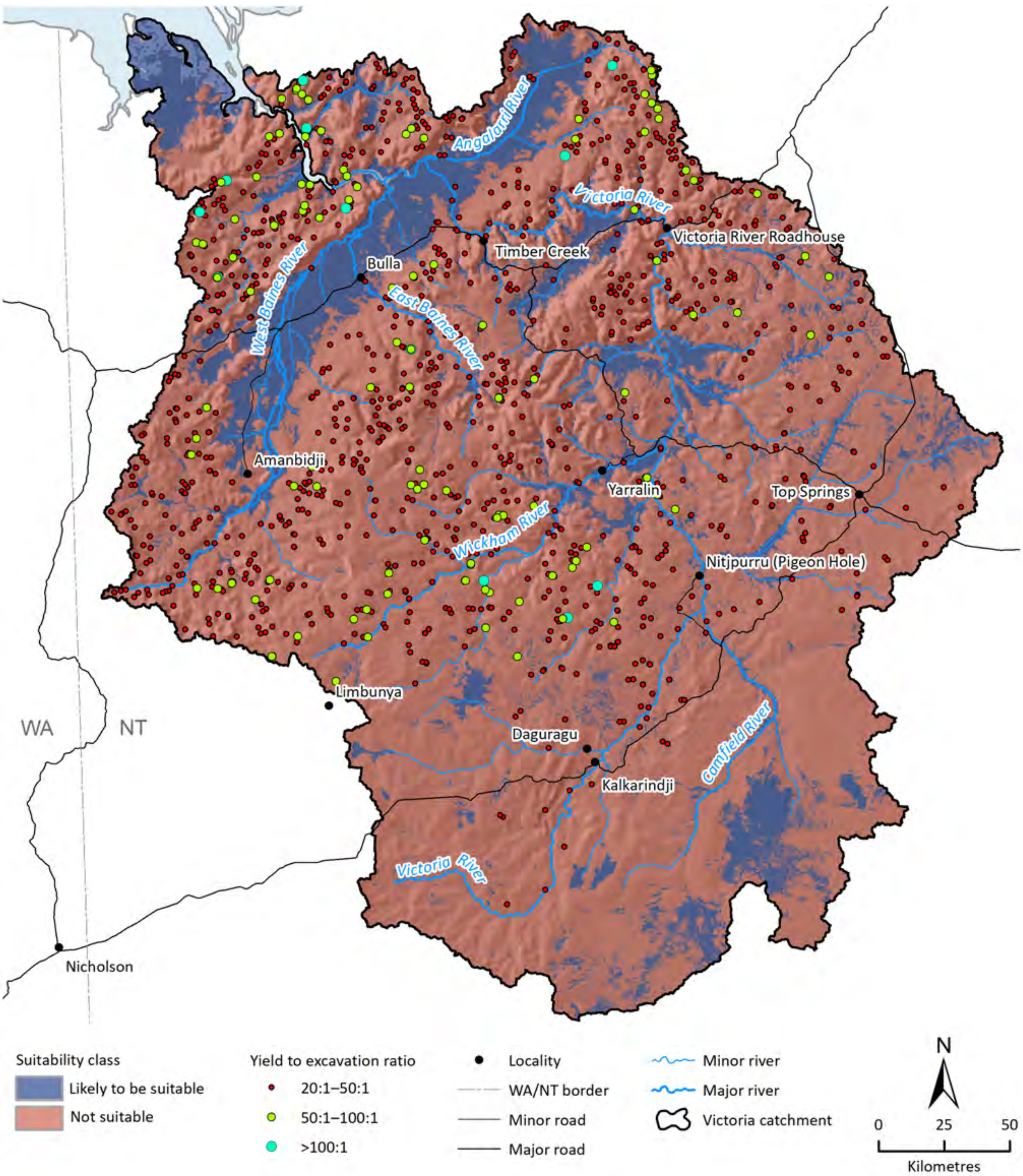

Figure 7-7 Suitability of soils for construction of gully dams in the Victoria catchment

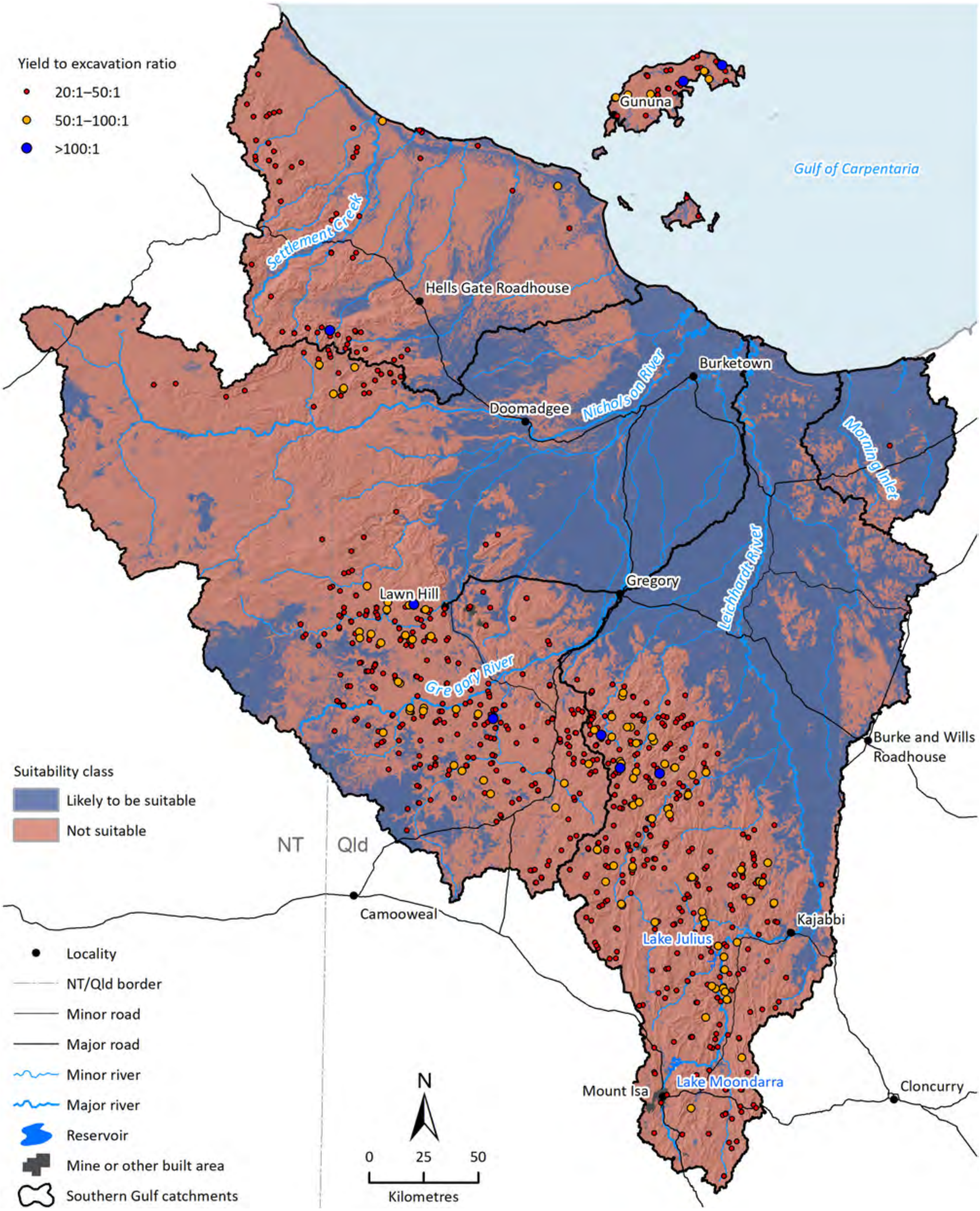

Figure 7-8 Suitability of soils for construction of gully dams in the Southern Gulf catchments

7.2.2 Indicative capital, operation and maintenance costs of farm-scale gully and hillside dams

The cost of a large farm-scale gully dam will vary depending upon a range of factors, including the suitability of the topography of the site, the size of the catchment area, the quantity of runoff, the proximity of the site to good-quality clay, the availability of durable rock in the upper bank for a spillway, and the size of the embankment. The height of the embankment, in particular, has a strong influence on cost. An earth dam to a height of 8 m is approximately 3.3 times more expensive to construct than a 4-m high dam. A dam to a height of 16 m will require 3.6 times more material than the 8-m-high version, but the cost may be more than five times greater, depending on design and construction complexity (Benjamin, 2018).

Performance and cost of three hypothetical farm-scale gully dams in northern Australia

Table 7-7 summarises the key parameters for three hypothetical farm-scale gully dam configurations, each with a capacity of 4 GL, and Table 7-8 provides a high-level breakdown of the major components of the capital costs for each configuration. Detailed costs for the three sites are provided in the companion technical report on large farm-scale dams (Benjamin, 2018).

Table 7-7 Cost of three hypothetical farm-scale gully dams of 4-GL capacity

Costs include government permits and fees, investigation and design, and fish passage construction. For a complete list of costs and assumptions, see the companion technical report on farm-scale dams (Benjamin, 2018). Costs have been indexed to 2023.

SITE DESCRIPTION/ CONFIGURATION	CATCHMENT AREA (KM²)	EMBANKMENT HEIGHT (M)	EMBANKMENT LENGTH (M)	STORAGE TO EXCAVATION RATIO	MEAN DEPTH (M)	RESERVOIR SURFACE AREA (HA)	TOTAL CAPITAL COST ($)	O&M COST ($)
Favourable site with large catchment, suitable topography and simple spillway (e.g. natural saddle)	30	9.5	1100	29:1	5.0	80	1,600,000	70,000
Unfavourable site with small catchment, challenging topography and limited spillway options (e.g. steep gully banks, no natural saddle)	15	14	750	21:1	6.3	63	1,844,000	44,000
Unfavourable site with moderate catchment, challenging topography and limited spillway options (e.g. steep gully banks, no natural saddle)	20	14	750	21:1	6.3	63	1,937,000	50,000

O&M = operation and maintenance

Table 7-8 High-level breakdown of capital costs for three hypothetical farm-scale gully dams of 4-GL capacity

Earthworks include vegetation clearing, mobilisation and demobilisation of equipment, and contractor accommodation. Investigation and design fees include design and investigation of fish passage devices and failure impact assessment (i.e. investigation of possible existence of fish population at risk downstream of site). Costs are based on experience in north Queensland – costs associated with government permits and fees in the NT may differ. For a complete list of costs and assumptions, see the companion technical report on farm-scale dams (Benjamin, 2018). Costs indexed to 2023.

SITE DESCRIPTION/CONFIGURATION	EARTHWORKS ($)	GOVERNMENT PERMITS AND FEES ($)	INVESTIGATION AND DESIGN FEES ($)	TOTAL CAPITAL COST ($)
Favourable site with large catchment, suitable topography and simple spillway (e.g. natural saddle)	1,447,000	46,000	107,000	1,600,000
Unfavourable site with small catchment, challenging topography and limited spillway options (e.g. steep gully banks, no natural saddle)	1,677,000	50,000	117,000	1,844,000
Unfavourable site with moderate catchment, challenging topography and limited spillway options (e.g. steep gully banks, no natural saddle)	1,770,000	50,000	117,000	1,937,000

Table 7-9 and Table 7-10 present calculations of the effective volume for three configurations of 4-GL capacity gully dams (with varying mean water depth/embankment height) for combinations of three seepage losses and three water storage time periods in the Victoria and Southern Gulf catchments, respectively.

Table 7-9 Effective volumes and cost per megalitre for three 4-GL gully dams with various mean depths and seepage loss rates based on climate data at Victoria River Downs Station in the Victoria catchment

Evaporation and seepage losses are based on losses occurring from 70% of the reservoir surface area.

MEAN DEPTH AND MAXIMUM RESERVOIR SURFACE AREA	CON-STRUCTION COST ($)	COST ($/ML)	SEEPAGE LOSS (MM/D)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENT-AGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENT-AGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENT-AGE OF CAPACITY (%)
				5 months (April to August)		**7 months (April to October)**		**10 months (April to January)**	
3 m and 133 ha	1,250,000	250	1	3087	77	2639	66	2113	53
	1,250,000	250	2	2946	74	2441	61	1830	46
	1,250,000	250	5	2522	63	1847	46	979	24
6 m and 66 ha	1,900,000	375	1	3545	89	3321	83	3057	76
	1,900,000	375	2	3475	87	3223	81	2917	73
	1,900,000	375	5	3265	82	2929	73	2496	62
9 m and 44 ha	2,500,000	500	1	3692	92	3540	88	3361	84
	2,500,000	500	2	3644	91	3474	87	3266	82
	2,500,000	500	5	3503	88	3276	82	2983	75

Table 7-10 Effective volumes and cost per megalitre for three 4-GL storages with various mean depths and seepage loss rates based on climate data at Century Zinc Mine in the Southern Gulf catchments

Evaporation and seepage losses are based on losses occurring from 70% of the reservoir surface area.

MEAN DEPTH AND MAXIMUM RESERVOIR SURFACE AREA	CON-STRUCTION COST ($)	COST ($/ML)	SEEPAGE LOSS (MM/D)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENT-AGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENT-AGE OF CAPACITY (%)	EFFECTIVE VOLUME (ML)	EFFECTIVE VOLUME AS PERCENT-AGE OF CAPACITY (%)
					5 months (April to August)		**7 months (April to October)**		**10 months (April to January)**
3 m and 133 ha	1,250,000	250	1	3049	76	2582	65	1918	48
	1,250,000	250	2	2908	73	2384	60	1634	41
	1,250,000	250	5	2484	62	1790	45	783	20
6 m and 66 ha	1,900,000	375	1	3525	88	3291	82	2958	74
	1,900,000	375	2	3455	86	3193	80	2818	70
	1,900,000	375	5	3245	81	2899	72	2397	60
9 m and 44 ha	2,500,000	500	1	3678	92	3519	88	3293	82
	2,500,000	500	2	3631	91	3453	86	3199	80
	2,500,000	500	5	3489	87	3255	81	2915	73

Table 7-11 presents cost information for three hypothetical farm-scale gully dams. Table 7-12 and Table 7-13 explore the sensitivity of the equivalent annual unit cost of three hypothetical farm-scale gully dams to changes in seepage rate and time of water storage.

Table 7-11 Cost of construction and operation of three hypothetical farm-scale gully dams of 4-GL capacity

Assumes operation and maintenance (O&M) cost of 3% of capital cost and a 7% discount rate. Figures have been rounded. Costs indexed to 2023.

MEAN DEPTH AND MAXIMUM RESERVOIR SURFACE AREA	ITEM	CAPITAL COST ($)	ANNUALISED CAPITAL COST ($)	ANNUAL O&M COST ($)	EQUIVALENT ANNUAL COST ($/Y)
3 m and 133 ha	Low embankment, wide gully dam	1,250,000	107,000	37,500	144,800
6 m and 66 ha	Moderate embankment, gully dam	1,900,000	163,000	57,000	220,000
9 m and 44 ha	High embankment, narrow gully dam	2,500,000	214500	75,000	290,000

Table 7-12 Equivalent annualised cost and effective volume for three hypothetical farm-scale gully dams of 4-GL capacity based on climate data at Victoria River Downs Station in the Victoria catchment

Assumes an equivalent annual cost, a 7% discount rate, and operation and a maintenance (O&M) cost of 3%.

MEAN DEPTH AND MAXIMUM RESERVOIR SURFACE AREA	EQUIVALENT ANNUAL COST ($/Y)	SEEPAGE LOSS (MM/D)	UNIT COST ($/ML)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	UNIT COST ($/ML)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	UNIT COST ($/ML)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)
			5 months (April to August)		7 months (April to October)		10 months (April to January)	
3 m and 133 ha	144,800	1	405	47	474	55	592	69
	144,800	2	424	49	512	59	683	79
	144,800	5	496	57	677	78	1277	148
6 m and 66 ha	220,000	1	536	62	572	66	622	72
	220,000	2	547	63	590	68	651	75
	220,000	5	582	67	649	75	761	88
9 m and 44 ha	290,000	1	677	78	706	82	744	86
	290,000	2	686	79	720	83	765	89
	290,000	5	714	83	763	88	838	97

Table 7-13 Equivalent annualised cost and effective volume for three hypothetical farm-scale gully dams of 4-GL capacity near the Century Zinc Mine in the Southern Gulf catchments

Assumes an equivalent annual cost, a 7% discount rate, and operation and maintenance (O&M) cost of 3%.

MEAN DEPTH AND MAXIMUM RESERVOIR SURFACE AREA	EQUIVALENT ANNUAL COST ($/Y)	SEEPAGE LOSS (MM/D)	UNIT COST ($/ML)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	UNIT COST ($/ML)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)	UNIT COST ($/ML)	EQUIVALENT ANNUAL UNIT COST ($/Y PER ML/Y)
			5 months (April to August)		7 months (April to October)		10 months (April to January)	
3 m and 133 ha	144,800	1	410	47	484	56	652	75
	144,800	2	430	50	524	61	765	89
	144,800	5	503	58	698	81	1596	185
6 m and 66 ha	220,000	1	539	62	577	67	642	74
	220,000	2	550	64	595	69	674	78
	220,000	5	585	68	655	76	793	92
9 m and 44 ha	290,000	1	680	79	710	82	759	88
	290,000	2	689	80	724	84	782	91
	290,000	5	716	83	768	89	858	99

Where the topography is suitable for large farm-scale gully dams and a natural spillway is present, large farm-scale gully dams are typically cheaper to construct than a ringtank of equivalent capacity.

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Part IV Summary comments

8 Summary comments

The relatively undeveloped state of the water resources across northern Australia represents a globally unique opportunity for governments and communities to take a long-term view of water resource development and undertake a considered evaluation of various potential development pathways, including ‘do nothing’. This report documents the results of a catchment-scale pre-feasibility Assessment of surface water storage options in the Victoria and Southern Gulf catchments. Larger sites were a major focus of this Assessment, as the design and construction of smaller farm-scale dams is highly site-specific.

Overall, the landscape of the Victoria catchment has topography suitable for large instream dams. However, the soils tend to be thin and rocky, and consequently there are few large contiguous areas of soils suitable for irrigated agriculture that would be suitable for development using large instream dams. In the Southern Gulf catchments, the topography and geology of the upland areas is generally suitable for large instream dams, but the semi-arid climate and relatively small catchments mean the yield from these sites is generally small. Large areas of contiguous soil suitable for irrigated agriculture occur on the plains downstream of these sites. The most cost-effective potential dam sites in the Southern Gulf catchments are in close proximity to national parks.

Potential dam sites examined as part of a pre-feasibility analysis in the Victoria and Southern Gulf catchments are summarised in Table 8-1 and Table 8-2 respectively.

Table 8-1 Summary comments for potential dams in the Victoria catchment

DAM ID	NAME	SUMMARY COMMENT
38	Victoria River AMTD 97 km	This potential instream dam site, ~10 km upstream of Timber Creek and the Victoria Highway, commands a large catchment area and consequently has a large yield. The foundations of the sites appeared possibly to be suitable for a RCC dam. The site was evaluated primarily for its potential to generate hydro-electric power, though it could also potentially mitigate flooding at Timber Creek. The hydro-electric generation potential of this site is reported in the companion technical report on river system simulations in the Victoria catchment (Hughes et al., 2024). Although the highest-yielding potential dam site, and the lowest in terms of cost per megalitre released from the dam wall, there is very little soil suitable for irrigated agriculture downstream of this site, and a smaller dam constructed to match the quantity of suitable soil downstream would still be one of the more expensive water storages in the catchment. Being situated low on the main river channel in the Victoria catchment, a potential dam at this site would have a large impact on migratory species. In addition, there is a high likelihood of unrecorded sites of cultural significance in the inundation area.
121	Wickham River AMTD 63 km	A hypothetical instream dam at this site has the potential to provide irrigation supplies downstream to riparian areas adjacent to the Wickham River. The foundations appeared possibly to be suitable for a RCC dam. Although one of the higher yielding potential dam sites in the Victoria catchment, the site is also one of the more expensive and is very remote. The headwaters of the catchment of this site include part of the Judbarra National Park. In addition, there is a high likelihood of unrecorded sites of cultural significance in the inundation area.

DAM ID	NAME	SUMMARY COMMENT
131	Leichhardt Creek AMTD 26 km	The hypothetical instream dam in the upper West Baines catchment is relatively low yielding and has a moderately high cost per megalitre released from the dam wall. The foundations appeared to be suitable for a RCC dam. Despite being one of the closer sites to large contiguous areas of soil suitable for irrigated agriculture in the Victoria catchment, the site is still located ~15 km upstream from the potential target location. An advantage of this potential dam site is its proximity to the Victoria Highway and Kununurra. Being located in a small headwater catchment, the impacts of a dam at this location on migratory species is small relative to those at other locations, and the relatively small yield from the dam means that impacts associated with changes in flow are largely localised. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
150	Bullo River AMTD 57 km	Although commanding the smallest catchment area of the short-listed potential dam sites, the yield of this site is comparable with that of other sites with larger catchment areas, due to the higher rainfall in the catchment of the Bullo River. With the lowest capital cost, it also has the lowest cost per megalitre released from the dam wall. However, the site is very remote, and considerable additional capital expenditure would be required to develop this location. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
186	Victoria River AMTD 283 km	This potential dam site on the upper Victoria River is an instream development investigated for its potential to provide flood mitigation benefit to the Kalkarindji, Pigeon Hole and other Indigenous communities downstream. A dam for flood mitigation at this site could also provide a limited water supply to meet local needs. The flood mitigation potential is reported in the companion technical report on river system simulations in the Victoria catchment (Hughes et al., 2024). The foundations at this site may not be stiff enough for a RCC dam, and a concrete faced rockfill embankment dam was considered instead, with a separate lined chute spillway on the right abutment. The catchment of the site has the lowest area of suitable habitat of the modelled water-dependent species expressed as a percentage of the catchment area (25%). There is a high likelihood of unrecorded sites of cultural significance in the inundation area. In the companion technical report on hydro-electric power generation in the Southern Gulf catchments (Entura, 2024), this site was also evaluated for its potential to be used to generate hydro-electric power.
230	Gipsy Creek AMTD 56 km	This potential dam site commands a relatively small catchment. Consequently, it is relatively low yielding and has one of the higher costs per megalitre yield released from the dam wall of the short-listed sites in the Victoria catchment. The dam site has potential to provide irrigation supplies downstream along the creek to land adjacent to the upper West Baines River. The foundations appear to be suitable for a RCC dam. Although the site is located on a small headwater catchment, this catchment has the highest area of suitable habitat of the modelled water-dependent species expressed as a percentage of the catchment area (99%). There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AMTD = adopted middle thread distance; AWRC = Australian Water Resources Council; FSL = full supply level; IPA = Indigenous Protected Area; RCC = roller compacted concrete.

Table 8-2 Summary comments for potential dams in the Southern Gulf catchments

DAM ID	NAME	SUMMARY COMMENT
1	Gregory River AMTD 174 km	The potential Gregory River dam site is an instream development with potential to supply water to the large contiguous areas of black and grey cracking lay soils on the Armraynald Plain immediately downstream of the dam. Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam with a 400-m-wide central uncontrolled spillway would be most suitable. The site is one of the largest yielding and most cost-effective potential dam sites in the Southern Gulf catchments, and the foundations of this site appeared to be suitable for a RCC dam. A major limitation of the site is its proximity to the Boodjamulla (Lawn Hill) National Park (upstream of the site), and the Thorntonia Aggregation wetland is classified as being up and downstream of the potential dam site. Despite being on a major river, the area of potentially suitable habitat for the four modelled migratory species was relatively small. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. Limiting the FSL of the potential dam so that the area inundated did not extend into the Boodjamulla National Park resulted in a modelled yield of 180 GL in 85% of years at the dam wall. However, taking into consideration existing downstream users and assuming a dry-season crop resulted in a modelled yield of 133 GL in 85% of years.
3	Nicholson River AMTD 97 km	This potential instream development has the potential to release water for irrigation along the Nicholson River to the Doomadgee and Armraynald plains and Doomadgee. The foundations appeared to be suitable for a RCC dam. Nonetheless, the site is very remote and is one of the more expensive potential dam sites examined in the Southern Gulf catchments. At the adopted FSL, the inundation extent of this potential dam site overlaps with parts of the Ganalanga-Mindibirrina IPA. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
28	Gunpowder Creek AMTD 66 km	This potential dam site is on Gunpowder Creek, a large tributary of the Leichhardt River, and it has the second-lowest cost per megalitre of the short-listed sites in the Southern Gulf catchments. The foundations appear to the suitable for a RCC dam. The site would nominally supply water to a large plain of recent alluvium at the junction of Gunpowder Creek and the Leichhardt River. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. The area of potentially suitable habitat for modelled migratory species upstream of this dam site is relatively small, Previous studies of dams on Gunpowder Creek focused on areas further upstream, predominantly to supply water for mining.
165	Mistake Creek AMTD 60 km	This potential dam site would supply water to large areas of contiguous soils suitable for irrigated agriculture on the Carpentaria Plains. Being a relatively small tributary of the Leichhardt River, the site has a low yield, and it has the highest cost per megalitre released from the dam wall of all the short-listed sites examined in the Southern Gulf catchments. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. For the migratory species modelled as part of the Assessment, the catchment of a dam at this potential site would constitute less than 1% of the total potentially suitable habitat modelled in the Southern Gulf catchments.
206	Gold Creek AMTD 58 km	This small potential instream dam site on a small catchment in the Settlement Creek AWRC river basin has a low yield and high cost per megalitre released from the dam wall. Downstream of the site, water could potentially be supplied to land with soils suitable for irrigated agriculture, with minor or moderate limitations, depending on the land use. Approximately 11% of the catchment was estimated as having habitat suitable for 40% or more of the (11) migratory species modelled. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

DAM ID	NAME	SUMMARY COMMENT
275	Ewen Creek AMTD 6 km	This low-yielding and relatively expensive potential dam site is located on the tributary that joins the Leichhardt River downstream of Lake Julius. The foundations appeared to be suitable for a RCC dam; however, the amount of dolomite rock in the foundation may represent a problem, due to cavities within dolomite strata. This would need to be investigated. Given the small catchment area and modest percentage of habitat suitable for migratory species upstream of the potential dam (22% for at least one species), a potential dam at this location would have an effect on 0 to 0.5% of the total potentially suitable habitat modelled in the Southern Gulf catchments. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
290	South Nicholson River AMTD 9 km	This potential dam site is the most expensive of those on the short-list and is a considerable distance upstream of the soil potentially suitable for irrigated agriculture. Furthermore, the site is very remote and access would require considerable additional infrastructure. At the adopted FSL, the inundation extent of this potential dam site overlaps with parts of the Ganalanga-Mindibirrina IPA. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. Asset models predicted that 46% of the catchment has habitat suitable for at least one of the ten modelled migratory species, which constitutes 0 to 6.4% of the total habitat modelled as suitable in the Southern Gulf catchments.

AMTD = adopted middle thread distance; AWRC = Australian Water Resources Council; FSL = full supply level; IPA = Indigenous Protected Area; RCC = roller compacted concrete.

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Part V Appendices

Appendix A Detailed costings for short-listed dam sites in the Victoria and Southern Gulf catchments

A.1 Potential dam site on the Leichhardt Creek AMTD 26 km (Site 131)

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
General				
Environmental management	Lump sum			3,000,000
Cultural heritage management	Lump sum			1,800,000
Mobilisation and demobilisation				
Establishment of workforce accommodation	Lump sum			3,000,000
Establishment of major plant	Lump sum			1,500,000
Demobilisation of major plant	Lump sum			750,000
Demobilisation of workforce accommodation	Lump sum			800,000
Clear site and 50% of storage area	ha	930	3,000	2,790,000
Access				
Access to site from Highway 1	km	85	600,000	51,000,000
Develop sources of construction materials				
Quarry	Lump sum			1,000,000
Sand gravel sources	Lump sum			750,000
River diversion				
Excavate diversion channel	m^3	3,584	75	269,000
Upstream coffer dam excavation	m^3	2,120	25	53,000
Upstream coffer dam fill	m^3	7,110	30	213,000
Downstream coffer dam excavation	m^3	1,787	25	45,000
Downstream coffer dam fill	m^3	5,323	30	160,000
Foundation excavation and treatment				
Excavate OTR from river bed	m^3	32,738	20	655,000
Excavate rock from bed and abutments	m^3	74,473	60	4,468,000
Foundation treatment and clean-up	m^2	9,981	80	798,000
Construct grouting plinth	m^3	607	1,600	970,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Reinforcement to grouting plinth	tonne	24	6,000	144,000
Drilling for grout holes	m	3,843	30	104,000
Hookups	Item	427	280	120,000
Grout injection	Bags	7,686	90	692,000
RCC dam river section				
Establish RCC plant	Lump sum			2,000,000
Demobilise RCC plant	Lump sum			600,000
Conventional concrete to faces	m^3	10,524	2,400	25,258,000
RCC concrete to dam wall	m^3	152,870	565	86,372,000
Conventional concrete to spillway crest	m^3	4,980	1,600	7,968,000
Reinforcement to crest	tonne	199	6,000	1,194,000
Structural concrete to spillway apron and end sill	m^3	1,831	1,700	3,113,000
Reinforcement to apron and end sill	tonne	76	5,000	380,000
Drill-holes for apron anchors	m	1,360	30	41,000
Supply and install anchors	tonne	11	5,000	55,000
Structural concrete to training walls	m^3	4,783	2,200	10,523,000
Reinforcement to training walls	tonne	287	6,000	1,722,000
Form gallery	m	155	400	62,000
Drilled drain holes	m	2,117	30	64,000
Waterstops	m	785	800	628,000
Outlet works				
Intake tower structural concrete	m^3	1,218	2,200	2,680,000
Reinforcement to intake tower	tonne	73	7,000	511,000
Bellmouths	Item	2	20,000	40,000
Bulkhead gate, guides and seals	Lump sum			600,000
Selective withdrawal baulks and guides	Lump sum			250,000
Trashracks and guides	Lump sum			250,000
Lifting frames, monorails and hoists	Lump sum			250,000
Miscellaneous metalwork	Lump sum			200,000
Outlet conduits 1200-mm-diameter MSCL pipe	m	120	4,000	480,000
Outlet conduit concrete surround	m^3	638	2,000	1,276,000
Reinforcement to concrete surround	tonne	25	6,000	150,000
Valve house structural concrete	m^3	90	2,200	198,000
Reinforcement to valve house	tonne	6	7,000	42,000
Valve house pipework	Lump sum			150,000
900-mm-diameter butterfly guard valves	Item	2	200,000	400,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
750-mm-diameter fixed-cone regulating valves	Item	2	180,000	360,000
Miscellaneous metalwork	Lump sum			100,000
Valve house dissipator structural concrete	m^3	98	2,200	216,000
Reinforcement to valve house dissipator	tonne	6	7,000	42,000
Fish transfer facility				
Construct fish lift	Lump sum			5,000,000
Commission and monitoring	Lump sum			1,000,000
Permanent downstream crossing				
Access roads	km	2	600,000	1,200,000
Bridge	m^2	175	18,000	3,150,000
Total direct construction costs (TDC)				233,606,000

AMTD = adopted middle thread distance; MSCL = mild steel cement lined; RCC = roller compacted concrete.

ON-SITE OVERHEAD	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
On-site overheads				
Camp operations	Lump sum			2,500,000
Site office operations	Lump sum			600,000
Insurances, public liability	Lump sum			4,500,000
Total on-site overheads (OSO)				7,600,000
Total direct costs (TDC) and on-site overheads (OSO)				241,206,000
Profit and off-site overheads (10% of TDC and OSO)				24,120,600
Total Out Turn Costs (TOC)				265,326,600

AMTD = adopted middle thread distance.

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Investigation and design				
Preliminary design	Lump sum			600,000
Geotechnical and materials	Lump sum			2,500,000
Hydraulic model study	Lump sum			800,000

OWNERS’ COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Detailed design and documentation	Lump sum			5,000,000
Acquisition and approvals				
Environmental assessment and approvals	Lump sum			2,500,000
Storage area acquisition	ha	2,800	1,000	2,800,000
Storage area access relocations	Lump sum			750,000
Surveys and legals	Lump sum			1,000,000
Permanent on-site buildings and services	Lump sum			600,000
Principal’s insurances	Lump sum			500,000
Owners’ management and supervision	Lump sum			800,000
TOTAL OWNERS’ COSTS				17,850,000
TOTAL PROJECT COSTS (TPC)				283,176,600
Risk adjustment				113,270,640
TOTAL CAPITAL COST				**396,447,240**

AMTD = adopted middle thread distance.

A.2 Potential dam site on the Victoria River AMTD 283 km (Site 186)

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
General				
Environmental management	Lump sum			5,000,000
Cultural heritage management	Lump sum			3,000,000
Mobilisation and demobilisation				
Establishment of workforce accommodation	Lump sum			6,000,000
Establishment of major plant	Lump sum			2,000,000
Demobilisation of major plant	Lump sum			1,000,000
Demobilisation of workforce accommodation	Lump sum			1,500,000
Clear site and 50% of storage area	ha	2,100	3,000	6,300,000
Access				
Access to site from Buntine Highway	km	5	600,000	3,000,000
Develop sources of construction materials				
Quarry	Lump sum			1,500,000
Sand gravel sources	Lump sum			1,000,000
Earthfill sources	Lump sum			1,000,000
River diversion				
Excavate diversion tunnel upstream portal	m^3	11,240	50	562,000
Excavate diversion tunnel downstream portal	m^3	11,240	50	562,000
Rock bolt support	Item	100	800	80,000
Shotcrete	m^2	2,000	300	600,000
Excavate diversion tunnel	m^3	10,890	250	2,722,000
Rock bolt tunnel support	Item	250	1,000	250,000
Concrete lining to diversion tunnel	m^3	2,410	4,000	9,640,000
Reinforcement to diversion tunnel lining	tonne	145	7,000	1,015,000
Upstream coffer dam excavation	m^3	12,510	20	250,000
Upstream coffer dam fill	m^3	50,510	22.5	1,136,000
Downstream coffer dam excavation	m^3	11,200	20	224,000
Downstream coffer dam fill	m^3	39,700	22.5	893,000
Foundation excavation and treatment				
Excavate OTR from river bed and abutments	m^3	419,200	15	6,288,000
Excavate rock from river bed and abutments	m^3	179,650	45	8,084,000
Foundation treatment and clean-up	m^2	5,980	80	478,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Construct grouting plinth	m^3	2,508	1,600	4,013,000
Reinforcement to grouting plinth	tonne	100	6,000	600,000
Drilling for grout holes	m	8,576	25	214,000
Hookups	Item	1092	250	273,000
Grout injection	Bags	17,152	80	1,372,000
Concrete-faced rockfill embankment				
Place Zone 2A filter	m^3	59,570	25	1,489,000
Place Zone 2B transition	m^3	59,570	30	1,787,000
Place Zone 3A rockfill	m^3	579,450	35	20,281,000
Place Zone 3B rockfill	m^3	947,250	32.5	30,786,000
Mortar upstream face	m^2	23,830	75	1,787,000
Place face concrete	m^3	5,110	2,000	10,220,000
Reinforcement to face	tonne	204	5,000	1,020,000
Perimeter waterstops	m	2,230	800	1,784,000
Face slab water stops	m	5,530	800	4,424,000
Downstream face mesh protection				
Drill-holes for perimeter anchors	m	900	30	27,000
Supply and install perimeter anchors	tonne	7	6,000	42,000
Supply and install face anchors	tonne	272	5,500	1,496,000
Supply and install face mesh	tonne	75	4,500	338,000
Supply and install horizontal bars	tonne	115	5,000	575,000
Saddle dam embankment				
Foundation excavation	m^3	375,100	12	4,501,000
Impervious fill	m^3	911,400	25	22,785,000
Miscellaneous fill	m^3	650,800	20	13,016,000
Riprap	m^3	108,800	40	4,352,000
Outlet works				
Intake tower				
Intake tower base structural concrete	m^3	864	1,800	1,555,000
Intake tower base reinforcement	tonne	35	5,500	192,000
Intake tower structural concrete	m^3	2,200	2,200	4,840,000
Intake tower reinforcement	tonne	132	7,000	924,000
Deck structural concrete	m^3	288	2,200	634,000
Deck reinforcement	tonne	17	7,000	119,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Trashracks and guides	Lump sum			500,000
Bulkhead gate, guides and seals	Lump sum			1,000,000
Portal frames	Lump sum			150,000
Travelling hoist	Lump sum			50,000
Low-flow bypass outlet	Lump sum			100,000
Access bridge				
Pier and abutment structural concrete	m^3	80	2,200	176,000
Pier reinforcement	tonne	5	7,000	35,000
Decking units	m^2	160	18,000	2,880,000
Downstream dissipator				
Floor structural concrete	m^3	690	1,800	1,080,000
Floor reinforcement	tonne	28	5,500	154,000
Training walls concrete	m^3	2,645	1,900	5,025,000
Wall reinforcement	tonne	159	6,000	954,000
Spillway				
Excavate OTR for spillway channel	m^3	719,800	15	10,797,000
Excavate rock for spillway channel	m^3	2,250,000	30	67,500,000
Drilling for grout holes	m	885	25	22,000
Hookups	Item	98	250	24,000
Grout injection	Bags	1,770	80	142,000
Foundation clean-up for crest and floor slabs	m^2	44,000	75	3,300,000
Drill-holes for anchor bars	m	28,160	22	620,000
Supply and install anchor bars	tonne	222	5,000	1,110,000
Drain holes	m	9,460	22	208,000
Concrete in spillway crest	m^3	13,300	1,600	21,280,000
Concrete in side walls	m^3	12,020	1,800	21,636,000
Reinforcement in side walls	tonne	480	6,000	2,880,000
Concrete in chute floor	m^3	24,960	1,750	43,680,000
Reinforcement in chute floor	tonne	988	5,000	4,940,000
Concrete in dissipator side walls	m^3	3,200	2,000	6,400,000
Reinforcement in dissipator side walls	tonne	128	6,000	768,000
Concrete in dissipator floor	m^3	8,000	1,700	13,600,000
Reinforcement in dissipator floor	tonne	320	5,000	1,600,000
Concrete in dissipator baffles and end sill	m^3	450	2,000	900,000
Reinforcement in baffles and end sill	tonne	27	7,000	189,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Waterstops	m	9,685	800	7,748,000
Rockfill bank protection	m^3	8,550	40	342,000
Fish transfer facility				
Construct fish trap and transfer structure	Lump sum			5,000,000
Commission and monitoring	Lump sum			2,000,000
Permanent downstream crossing				
Access roads	km	3	600,000	1,800,000
Bridge	m^2	700	18,000	12,600,000
Total direct construction costs (TDC)				442,720,000

AMTD = adopted middle thread distance; OTR = other than rock.

ON-SITE OVERHEAD	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
ON-SITE OVERHEADS				
Camp operations	Lump sum			4,000,000
Site office operations	Lump sum			1,000,000
Insurances, public liability	Lump sum			9,000,000
Total on-site overheads (OSO)				14000000
Total direct costs (TDC) and on-site overhead costs (OSO)				451,720,000
Profit and off-site overheads 10% of TDC and OSO				45,172,000
Total Out Turn Costs (TOC)				496,892,000

AMTD = adopted middle thread distance.

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Investigation and design				
Preliminary design	Lump sum			1,000,000
Geotechnical and materials	Lump sum			5,000,000
Hydraulic model study	Lump sum			1,000,000
Detailed design and documentation	Lump sum			8,000,000
Acquisition and approvals				
Environmental assessment and approvals	Lump sum			5,000,000

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Storage area acquisition	ha	6,300	1,000	6,300,000
Storage area access relocations	Lump sum			1,000,000
Surveys and legals	Lump sum			1,500,000
Permanent on-site buildings and services	Lump sum			1,000,000
Principal's insurances	Lump sum			600,000
Owners' management and supervision	Lump sum			1,500,000
Total owners' costs				31,900,000
TOTAL PROJECT COSTS (TPC)				528,792,000
Risk adjustment				211,516,800
TOTAL CAPITAL COST				**740,308,800**

AMTD = adopted middle thread distance.

A.3 Potential dam site on the Gregory River AMTD 174 km (Site 1)

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
General				
Environmental management	Lump sum			3,000,000
Cultural heritage management	Lump sum			1,800,000
Mobilisation and demobilisation				
Establishment of workforce accommodation	Lump sum			5,000,000
Establishment of major plant	Lump sum			2,000,000
Demobilisation of major plant	Lump sum			1,000,000
Demobilisation of workforce accommodation	Lump sum			1,250,000
Clear site and 50% of storage area	ha	1,600	3,000	4,800,000
Access				
Access to site from Camooweal–Gregory Road	km	27	600,000	16,200,000
Develop sources of construction materials				
Quarry	Lump sum			1,500,000
Sand gravel sources	Lump sum			900,000
River diversion				
Excavate diversion channel	m^3	3,420	70	239,000
Upstream coffer dam excavation	m^3	19,480	18	351,000
Upstream coffer dam fill	m^3	78,200	20	1,564,000
Downstream coffer dam excavation	m^3	17,200	18	301,000
Downstream coffer dam fill	m^3	60,200	20	1,204,000
Foundation excavation and treatment				
Excavate OTR from river bed	m^3	312,400	12.5	3,905,000
Excavate rock from bed and abutments	m^3	205,100	40	8,204,000
Foundation treatment and clean-up	m^2	34,200	75	2,565,000
Construct grouting plinth	m^3	1,429	1,600	2,286,000
Reinforcement to grouting plinth	tonne	57	6,000	342,000
Drilling for grout holes	m	6,639	25	166,000
Hookups	Item	768	250	192,000
Grout injection	Bags	13,280	80	1,062,000
RCC dam river section				
Establish	Lump sum			1,500,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Demobilise RCC plant	Lump sum			450,000
Conventional concrete to faces	m^3	30,800	2,400	73,920,000
RCC concrete to dam wall	m^3	285,300	540	154,062,000
Conventional concrete to spillway crest	m^3	32,920	1,600	51,644,000
Reinforcement to crest	tonne	1,316	6,000	7,896,000
Conventional concrete to spillway apron and end sill	m^3	12,250	1,700	20,825,000
Reinforcement to apron and end sill	tonne	511	5,000	2,555,000
Drill-holes for apron anchors	m	8,960	30	269,000
Install anchors	tonne	71	5,000	355,000
Conventional concrete to training walls	m^3	1,571	2,200	3,456,000
Reinforcement to training walls	tonne	94	6,000	564,000
Form gallery	m	485	400	194,000
Drill drain holes	m	5,250	25	131,000
Waterstops	m	2,546	800	2,037,000
Outlet works				
Intake tower structural concrete	m^3	627	2,000	1,254,000
Reinforcement to intake tower	tonne	38	7,000	266,000
Bellmouths	Item	2	20,000	40,000
Bulkhead gate guides and seals	Lump sum			500,000
Selective withdrawal baulks and guides	Lump sum			150,000
Trashracks and guides	Lump sum			150,000
Lifting frames, monorails and hoists	Lump sum			150,000
Miscellaneous metalwork	Lump sum			100,000
Outlet conduits 1500-mm-diameter MSCL	m	100	3,800	380,000
Outlet conduit concrete surround	m^3	678	1,800	1,220,000
Reinforcement to concrete surround	tonne	27	6,000	162,000
Valve house structural concrete	m^3	126	2,000	252,000
Reinforcement to valve house	tonne	8	7,000	56,000
Valve house pipework	Lump sum			300,000
1500-mm-diameter butterfly guard valves	Item	2	350,000	700,000
1200-mm-diameter fixed-cone regulating valves	Item	2	300,000	600,000
Miscellaneous metalwork	Lump sum			150,000
Valve house dissipator structural concrete	m^3	109	2,000	218,000
Reinforcement to valve house dissipator	tonne	6	7,000	42,000
Fish transfer facility				
Construct fish lift	Lump sum			2,000,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Commission and monitoring	Lump sum			800,000
Permanent downstream crossing				
Access roads	km	2	600,000	1,200,000
Bridge	m^2	1,225	16,000	24,010,000
Total direct construction costs (TDC)				411,389,000

AMTD = adopted middle thread distance; MSCL = mild steel cement lined; RCC = roller compacted concrete.

ON-SITE OVERHEAD	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
On-site overheads				
Camp operations	Lump sum			3,350,000
Site office operations	Lump sum			800,000
Insurances, public liability	Lump sum			6,000,000
Total on-site overheads (OSO)				10,150,000
Total direct (TDC) and on-site overhead (OSO) costs				421,539,000
Profit and off-site overheads 10% of TDC and OSO				42,153,900
Total Out Turn Costs (TOC)				463,692,900

AMTD = adopted middle thread distance.

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Investigation and design				
Preliminary design	Lump sum			750,000
Geotechnical and materials	Lump sum			5,000,000
Hydraulic model study	Lump sum			1,000,000
Detailed design and documentation	Lump sum			5,000,000
Acquisition and approvals				
Environmental assessment and approvals	Lump sum			4,000,000
Storage area acquisition	ha	8,000	500	4,000,000
Storage area access relocations	Lump sum			1,000,000
Surveys and legals	Lump sum			1,500,000

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Permanent on-site buildings and services	Lump sum			750,000
Principal's insurances	Lump sum			500,000
Owners' management and supervision	Lump sum			1,000,000
Total owners' costs				24,500,000
TOTAL PROJECT COSTS (TPC)				488,192,900
Risk adjustment				195,277,160
TOTAL CAPITAL COST				**683,470,060**

AMTD = adopted middle thread distance.

A.4 Potential dam site on Gunpowder Creek AMTD 66 km (Site 28)

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
General				
Environmental management	Lump sum			3,000,000
Cultural heritage management	Lump sum			1,800,000
Mobilisation and demobilisation				
Establishment of workforce accommodation	Lump sum			4,500,000
Establishment of major plant	Lump sum			1,750,000
Demobilisation of major plant	Lump sum			875,000
Demobilisation of workforce accommodation	Lump sum			1,125,000
Clear site and 50% of storage area	ha	1,830	3,000	5,490,000
Access				
Access to site from Mount Isa–Gunpowder Road	km	75	600,000	45,000,000
Develop sources of construction materials				
Quarry	Lump sum			1,000,000
Sand gravel sources	Lump sum			650,000
River diversion				
Excavate diversion channel	m^3	3,100	70	217,000
Upstream coffer dam excavation	m^3	8,000	20	160,000
Upstream coffer dam fill	m^3	32,810	22.5	738,000
Downstream coffer dam excavation	m^3	6,580	20	132,000
Downstream coffer dam fill	m^3	25,650	22.5	577,000
Foundation excavation and treatment				
Excavate OTR from river bed	m^3	69,430	15	1,041,000
Excavate rock from bed and abutments	m^3	91,430	45	4,114,000
Foundation treatment and clean-up	m^2	23,610	80	1,889,000
Construct grouting plinth	m^3	570	1600	912,000
Reinforcement to grouting plinth	tonne	23	6,000	156,000
Drilling for grout holes	m	10,130	25	253,000
Hookups	Item	870	250	217,000
Grout injection	Bags	20,260	80	1,621,000
RCC dam river section				
Establish	Lump sum			2,500,000

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Demobilise RCC plant	Lump sum			750,000
Conventional concrete to faces	m^3	32,872	2,400	78,893,000
RCC concrete to dam wall	m^3	458,200	530	242,846,000
Conventional concrete to spillway crest	m^3	14 ,360	1,600	22,976,000
Reinforcement to crest	tonne	575	6,000	3,450,000
Structural concrete to spillway apron and end sill	m^3	5,410	1,700	9,197,000
Reinforcement to apron and end sill	tonne	217	5,000	1,085,000
Drill-holes for apron anchors	m	4,032	30	121,000
Install anchors	tonne	33	5,000	165,000
Structural concrete to training walls	m^3	3,765	2,200	8,283,000
Reinforcement to training walls	tonne	226	6,000	1,356,000
Form galleries	m	445	400	178,000
Formed drain holes	m	1,870	20	37,000
Drilled drain holes	m	5,920	40	237,000
Waterstops	m	1,574	800	1,259,000
Outlet works				
Intake tower structural concrete	m^3	1,218	2,000	2,436,000
Intake tower reinforcement	tonne	73	7,000	511,000
Bellmouths	Item	2	15,000	30,000
Bulkhead gate, guides and seals	Lump sum			500,000
Selective withdrawal baulks and guides	Lump sum			250,000
Trashracks and guides	Lump sum			250,000
Lifing frames, monorails and hoists	Lump sum			250,000
Miscellaneous metalwork	Lump sum			200,000
Outlet conduits 1350-mm-diameter MSCL	m	140	3,000	420,000
Outlet conduits concrete surround	m^3	326	1,800	587,000
Reinforcement to concrete surround	tonne	13	6,000	78,000
Valve house structural concrete	m^3	90	2,000	180,000
Reinforcement to valve house	tonne	6	7,000	42,000
Pipework	Lump sum			250,000
1200-mm-diameter butterfly guard valves	Item	2	250,000	500,000
900-mm-diameter fixed-cone regulating valves	Item	2	220,000	440,000
Miscellaneous metalwork	Lump sum			150,000
Valve house dissipator structural concrete	m^3	98	2,000	196,000
Reinforcement to valve house dissipator	tonne	6	7,000	42,000
Fish transfer facility				

DIRECT CONSTRUCTION COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Construct fish lift	Lump sum			4,000,000
Commission and monitoring	Lump sum			800,000
Permanent downstream crossing				
Access roads	km	2	600,000	1,200,000
Bridge	m^2	525	18,000	9,450,000
Total direct construction costs (TDC)				473,312,000

AMTD = adopted middle thread distance; MSCL = mild steel cement lined; RCC = roller compacted concrete.

ON-SITE OVERHEAD	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
On-site overheads				
Camp operations	Lump sum			3,000,000
Site office operations	Lump sum			750,000
Insurances, public liability	Lump sum			6,000,000
Total on-site overheads (OSO)				9,750,000
Total direct (TDC) and on-site overhead OSO) costs				483,062,000
Profit and off-site overheads 10% of TDC and OSO				48,306,200
Total Out Turn Costs (TOC)				531,368,200

AMTD = adopted middle thread distance.

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Investigation and design				
Preliminary design	Lump sum			750,000
Geotechnical and materials	Lump sum			3,000,000
Hydraulic model study	Lump sum			1,000,000
Detailed design and documentation	Lump sum			6,000,000
Acquisition and approvals				
Environmental assessment and approvals	Lump sum			3,500,000
Storage area acquisition	ha	5,000	500	2,500,000
Storage area access relocations	Lump sum			1,000,000
Surveys and legals	Lump sum			800,000

OWNERS' COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Permanent on-site buildings and services	Lump sum			750,000
Principal's insurances	Lump sum			500,000
Owners management and supervision	Lump sum			1,000,000
Total owners costs				20,800,000
TOTAL PROJECT COSTS (TPC)				552,168,200
Risk adjustment				220,867,280
TOTAL CAPITAL COST				**773,035,480**

A.5 Potential weir on Wickham River

COSTS	UNIT	QUANTITY	RATE ($)	AMOUNT ($)
Establish access	Lump sum			500,000
Establish services	Lump sum			500,000
Camp establishment and operation	Lump sum			600,000
Plant mobilisation and demobilisation	Lump sum			500,000
Diversion and care of stream	Lump sum			300,000
Excavation	cu m	760	50	38,000
Concrete slab	cu m	915	2500	2,287,500
Reinforcement to concrete slab	tonnes	37	10,000	370,000
Mattresses	sq m	270	240	65,000
Outlet works	Lump sum			50,000
Fish ladder	Lump sum			250,000
Minor items	Lump sum			150,000
Total construction cost				5,610,500
On site overheads @ 20%				1,122,100
TCC + OSO				6,732,600
Contractor profit at 10%				673,260
Total out turn costs				7,405,860
Total owners costs				1,851,465
TOTAL PROJECT COSTS (TPC)				9,257,325
Risk adjustment				3,702,930
TOTAL CAPITAL COST				**12,960,255**

Appendix B Potential dam site summary tables

B.1 Victoria catchment

B.1.1 Victoria River AMTD 97 km (site 38) FSL 52 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies in the Victoria River catchment were identified in web-based searches or searches of Northern Territory Government databases.
Description of potential dam	The hypothetical Victoria River AMTD 97 km dam site is evaluated primarily for its potential to generate hydro-electric power, though it could also potentially mitigate flooding at Timber Creek. There is limited soil suitable for irrigated agriculture downstream of this site. A hydro-electric power station at this site could supply well in excess of the baseload requirements of a city of 1 million people (see companion technical report on river system simulation in the Victoria catchment, Hughes et al., 2024). The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 52 mEGM96. Apx Figure B-1 and Apx Figure B-2 show the location of the site and the extent of the reservoir area.
Regional geology	The Victoria catchment has a generally flat to undulating topography that drains to the north-west into the Joseph Bonaparte Gulf. The oldest rocks are Proterozoic sediments, including potentially soluble dolostone units, which were folded, faulted, uplifted and then eroded to a level not far above that of the current topography. In the higher ground to the west and south-east, they are overlain by a Cambrian sequence of basalts with overlying potentially soluble limestones and dolomites of limited occurrence, mainly in the south-east part of the catchment. Cretaceous sediments occur on the south-east margins of the catchment. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma. This resulted in the formation of deep weathering profiles and associated iron-cemented cappings on the older rocks, and broad valleys infilled with alluvium.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Apx Figure B-3) and satellite imagery. The dam site is located on Proterozoic rocks of the Jasper Gorge Sandstone (Paj), which consists of medium quartz sandstone with minor siltstone, overlying Timber Creek Formation (Pbt), which consists of dolomitic siltstone, sandstone and minor dolostone. It is possible that Skull Creek Formation, which consists of dolostone and dolomitic sandstone and can contain karstic cavities, occurs at depth below the dam site. There appeared to be gently dipping outcrop on both of the abutments. The river bed was ~220 m wide, with 130 m of deep ponded water. In the river bed are possible rock bars, and the Palm Island rock bar is 2 km upstream. The foundations appeared possibly to be suitable for a RCC dam. For estimating purposes, assume 10 m of alluvium in the river bed and 10 m of stripping on the abutments. It is possible that a concrete-faced rockfill dam with lined chute spillway would be more suitable. The possibility that karst cavities in the Skull Creek Formation are present below the dam site cannot be precluded at this stage and would need to be investigated further to assess whether there is any leakage potential.
Reservoir rim stability and leakage potential	Possibly leaky, due to carbonate-rich Skull Creek Formation occurring in the south-east part of storage. Potential would depend on FSL relative to topography. Overall leakage from the storage to the south-east is considered unlikely.

PARAMETER	DESCRIPTION
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 500-m-wide central uncontrolled spillway. The abutments would be set at a 1:50,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. A hydro-electric power station would be installed in the left abutment of the dam. A fish lift transfer facility would also be installed in the left abutment of the dam. Access to the site would be via a 16-km-long new road branching from Highway 1 near the Timber Creek settlement. The total distance to the site from Kununurra would be some 242 km.
Availability of construction materials	A quarry that could provide suitable and coarse aggregate might be found within 30 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 30 km of the dam site. For estimating purposes, assume a ratio of useful rock or gravel excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC or conventional concrete for the dam could probably be sourced from Kununurra.
Catchment area	54,605 km^2

Modelled annual inflow data

Parameter	Scenario A (GL/y)	Scenario Cdry (GL/y)	Scenario Cmid (GL/y)	Scenario Cwet (GL/y)
Max	13,915	9,231	13,655	16,433
Mean	3,786	2,821	3,642	4,745
Median	2,896	2,180	2,778	3,687
Min	422	337	418	470

Reservoir characteristics

Reservoirs with FSLs of selected heights are tabulated below.

FSL (mEGM96)	Surface area (ha)	Capacity (GL)
50	48,930	5,599
52	54,553	6,633
54	60,300	6,855

PARAMETER	DESCRIPTION
Reservoir yield assessment at dam wall	FSL of 50 mEGM96 – estimated yield at 85% annual time reliability = 2306 GL FSL of 52 mEGM96 – estimated yield at 85% annual time reliability = 2419 GL FSL of 54 mEGM96 – estimated yield at 85% annual time reliability = 2504 GL Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-4 and Apx Figure B-5.

Estimated rates of reservoir sedimentation at a FSL of 52 mEGM96

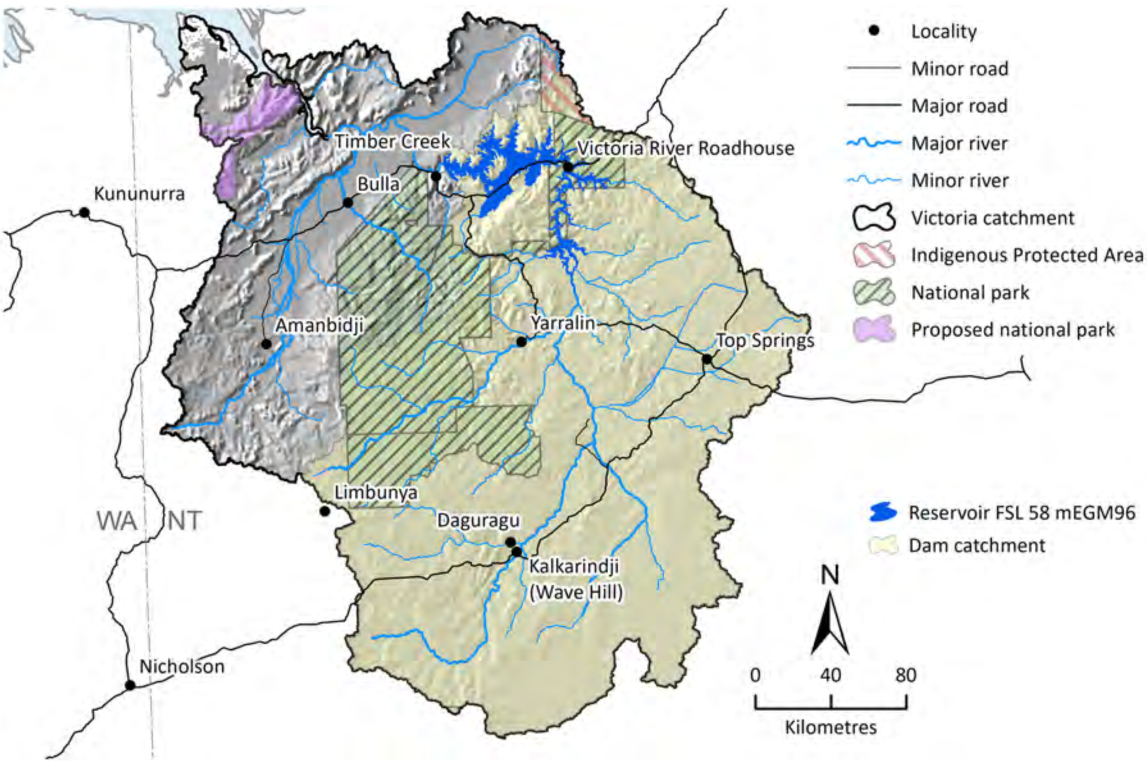
	Best case	Expected	Worst case
30 years (%)	0.2	0.4	0.4
100 years (%)	0.8	1.2	1.3
Years to fill	12619	8412	7571

PARAMETER	DESCRIPTION
Potential use of supply	The most versatile land for agriculture is the alluvial plain 25 km downstream of the potential dam site. The soils of the plain include friable clay loam soils (SGG 2), cracking clays (SGG 9), and clayey wet soils that remain wet for at least 2 to 3 months of the year (SGG 3). The friable red clay loam soils (SGG 2) adjacent to the river are suitable, with minor limitations (Class 2), for dry-season trickle-irrigated intensive horticulture such as cucurbits, and spray-irrigated perennial grasses, small-seeded crops such as chia (*Salvia hispanica*) and quinoa (*Chenopodium quinoa*) and root crops such as sweet potato (*Ipomoea batatas*) and peanuts (*Arachis hypogaea*).

PARAMETER	DESCRIPTION
	The cracking clay soils on the alluvial plain are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated intensive horticulture, dry-season spray-irrigated pulse crops such as mungbean (*Vigna radiata*), soybean (*Glycine max*) and chickpea (*Cicer arietinum*), and dry-season flood-irrigated rice (*Oryza* spp.).
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** In this potential dam site, there were records for ecology assets, including the largetooth sawfish (*Pristis pristis*), the northern snapping turtle (*Elseya dentata*), the northern snake-necked turtle (*Chelodina rugosa*), spangled grunter (*Leiopotherapon unicolor*), western rainbow fish (*Melanotaenia australis*), eastern rainbow fish (*Melanotaenia splendida*), the fork-tailed catfish *(Neoarius graeffei*) and mouth almighty (*Glossamia aprion*). Barramundi (*Lates calcarifer*) has been recorded near the potential dam wall. The asset distribution models predict that ~5% of the catchment (243,241 ha) has suitable habitat for at least 40% of the species. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively large, for most of the species, and ranges from 31% to 76% of their total modelled suitable habitat in the Victoria catchment (except for one species, with 1.5%). These species may have fragmented habitat and/or have movement impeded by a dam. Apx Figure B-6 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Victoria River (AMTD 97 km) site. **Ecological implications of inundation** In this site, many listed species have been recorded, including the Fitzroy Station rocksnail (*Mesodontrachia fitzroyana*), listed as critically endangered at the territory level and as endangered in the EPBC Act. The endangered (EPBC Act and NT) Australian painted snipe (*Rostratula australis*), purple-crowned fairy-wren (western) (*Malurus coronatus coronatus*) and the Gouldian finch (*Chloebia gouldiae*) are all listed as endangered (EPBC Act) and vulnerable (NT), and the grey falcon (*Falco hypoleucos*) is listed as vulnerable (EPBC Act and NT). There are also records for the golden bandicoot (*Isoodon auratus*), listed as vulnerable (in the EPBC Act) and endangered (NT), and the greater bilby (*Macrotis lagotis*), listed as vulnerable at federal and territory level; the largetooth sawfish (*Pristis pristis*), the princess parrot (*Polytelis alexandrae*) and the northern masked owl (*Tyto novaehollandiae kimberli*), all listed as vulnerable at federal and territory level; the bare-rumped sheath-tailed bat (*Saccolaimus saccolaimus nudicluniatus*) and the northern crested shrike-tit (*Falcunculus frontatus whitei*), both listed as vulnerable in the EPBC Act. Additionally, there were five other species only listed in the NT: the common brushtail possum (*Trichosurus vulpecula vulpecula*) as endangered, while the pale field rat (*Rattus tunneyi*), Mertens' water monitor (*Varanus mertensi*), Mitchell's water monitor (*Varanus mitchelli*) and the yellow-spotted monitor (*Varanus panoptes*) are all listed as vulnerable. Waterbirds including the royal spoonbill (*Platalea regia*), the endangered Australian painted snipe (*Rostratula australis*), the lesser sand plover (*Charadrius mongolus*), the cattle egret (*Bubulcus ibis*) and the magpie goose (*Anseranas semipalmata*) also occur near this site. The potential inundated area at FSL for this site (52 mEGM96) may have an effect on these species. Part of this potential catchment overlaps with the Judbarra National Park, the Wardaman Indigenous Protected Area and the Northern Tanami Indigenous Protected Area. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

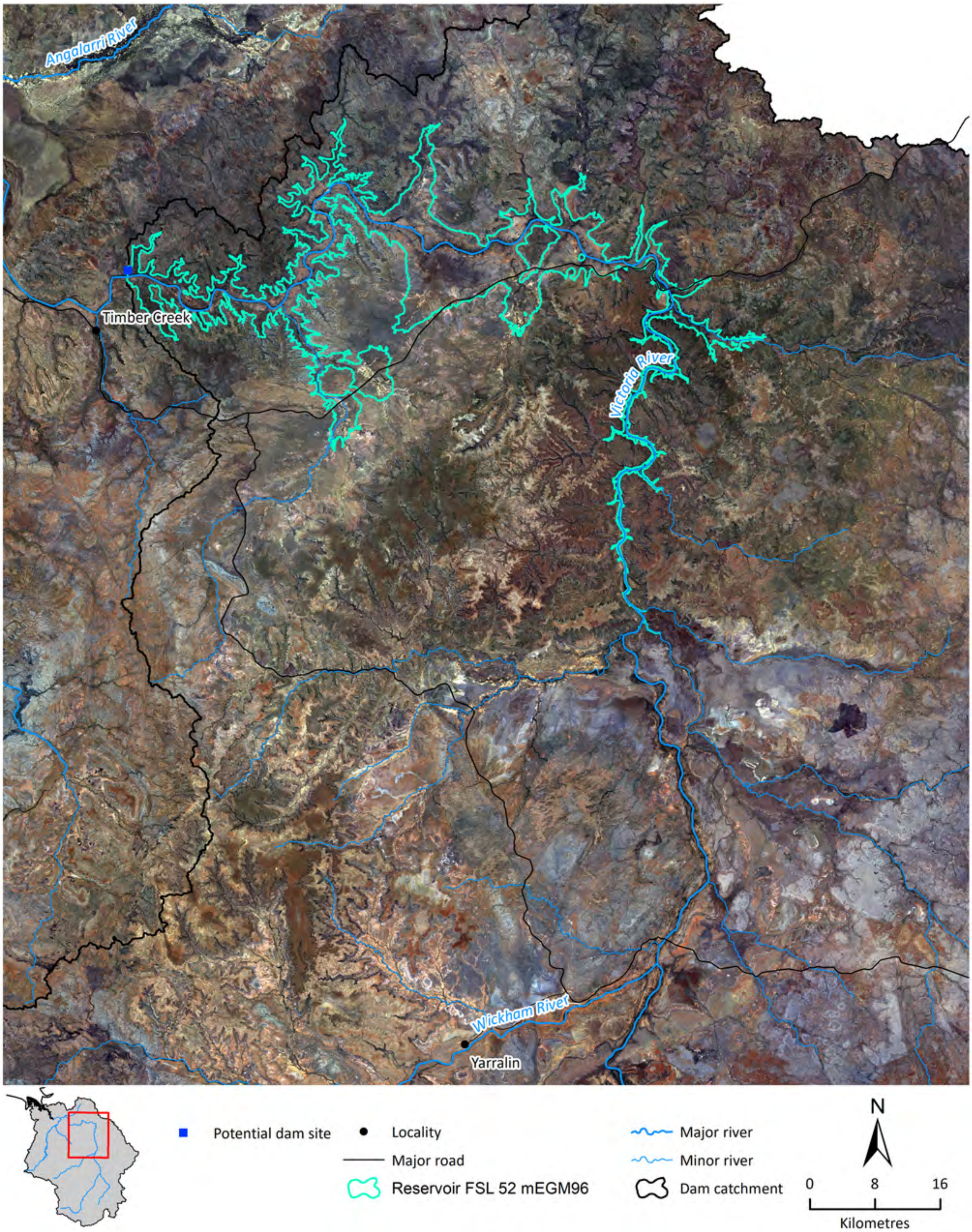
PARAMETER	DESCRIPTION
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 50 mEGM96 – estimated cost = $3694 million FSL of 52 mEGM96 – estimated cost = $3805 million FSL of 54 mEGM96 – estimated cost = $3907 million.
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 56 mEGM96 – estimated cost/ML of supply = $1602/ML FSL of 52 mEGM96 – estimated cost/ML of supply = $1573/ML FSL of 60 mEGM96 – estimated cost/ML of supply = $1561/ML
Summary comment	This potential instream dam site, ~10 km upstream of Timber Creek and the Victoria Highway, commands a large catchment area and consequently has a large yield. The foundations of the sites appear possibly to be suitable for a RCC dam. The site was evaluated primarily for its potential to generate hydro-electric power, though it could also potentially mitigate flooding at Timber Creek. The hydro-electric generation potential of this site is reported in the companion technical report on river system simulations in the Victoria catchment (Hughes et al., 2024). Although it is the highest-yielding potential dam site and lowest in terms of cost per megalitre released from the dam wall, there is very little soil suitable for irrigated agriculture downstream of this site, and a smaller dam constructed to match the quantity of suitable soil downstream would still be one of the more expensive water storages in the catchment. Being situated low on the main river channel in the Victoria catchment, a potential dam at this site would have a large impact on migratory species. In addition, there is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; MSCL = mild steel cement lined; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.



Apx Figure B-1 Location map of potential Victoria River dam site, reservoir extent and catchment area

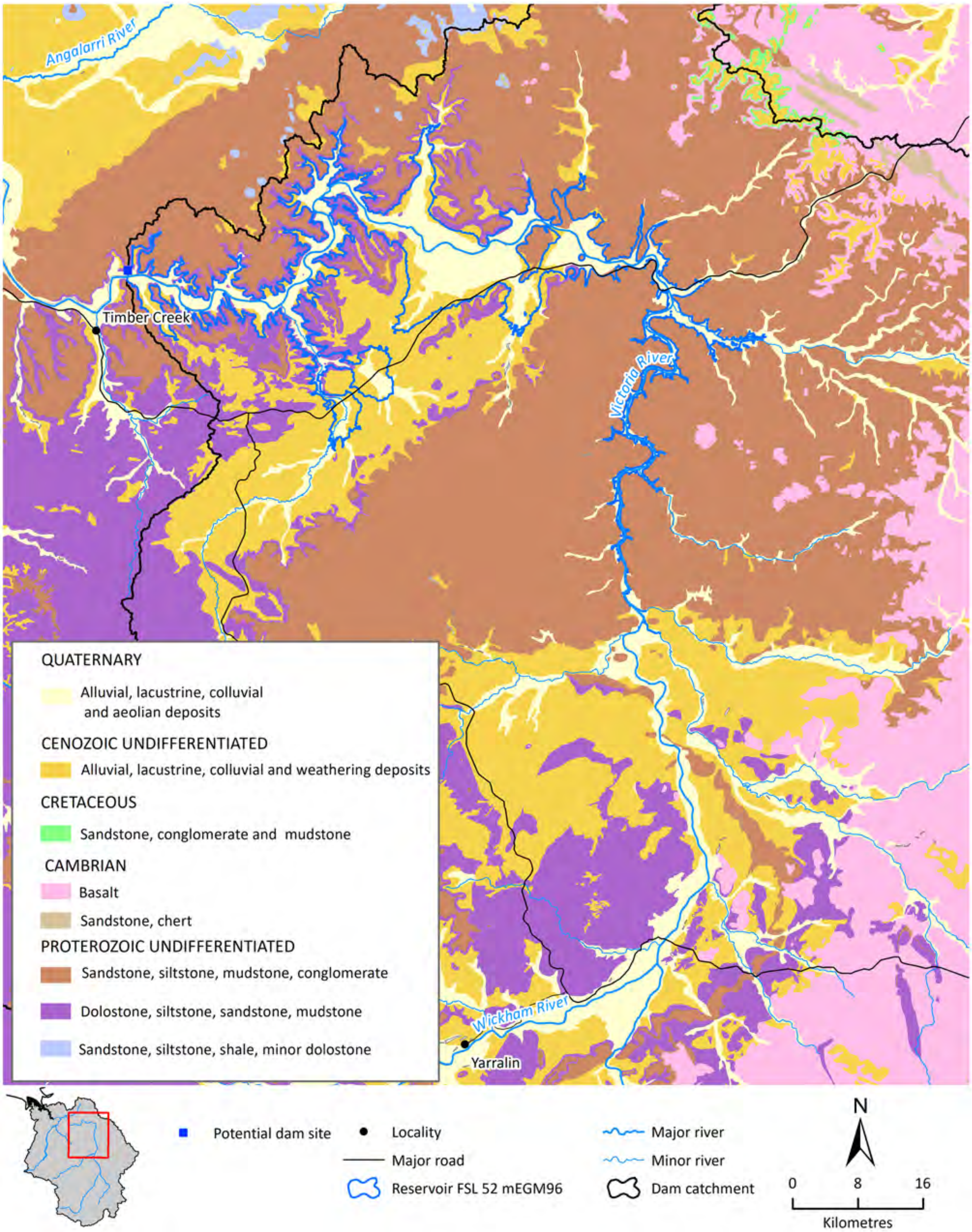
AEP = annual exceedance probability.



Apx Figure B-2 Potential Victoria River dam reservoir

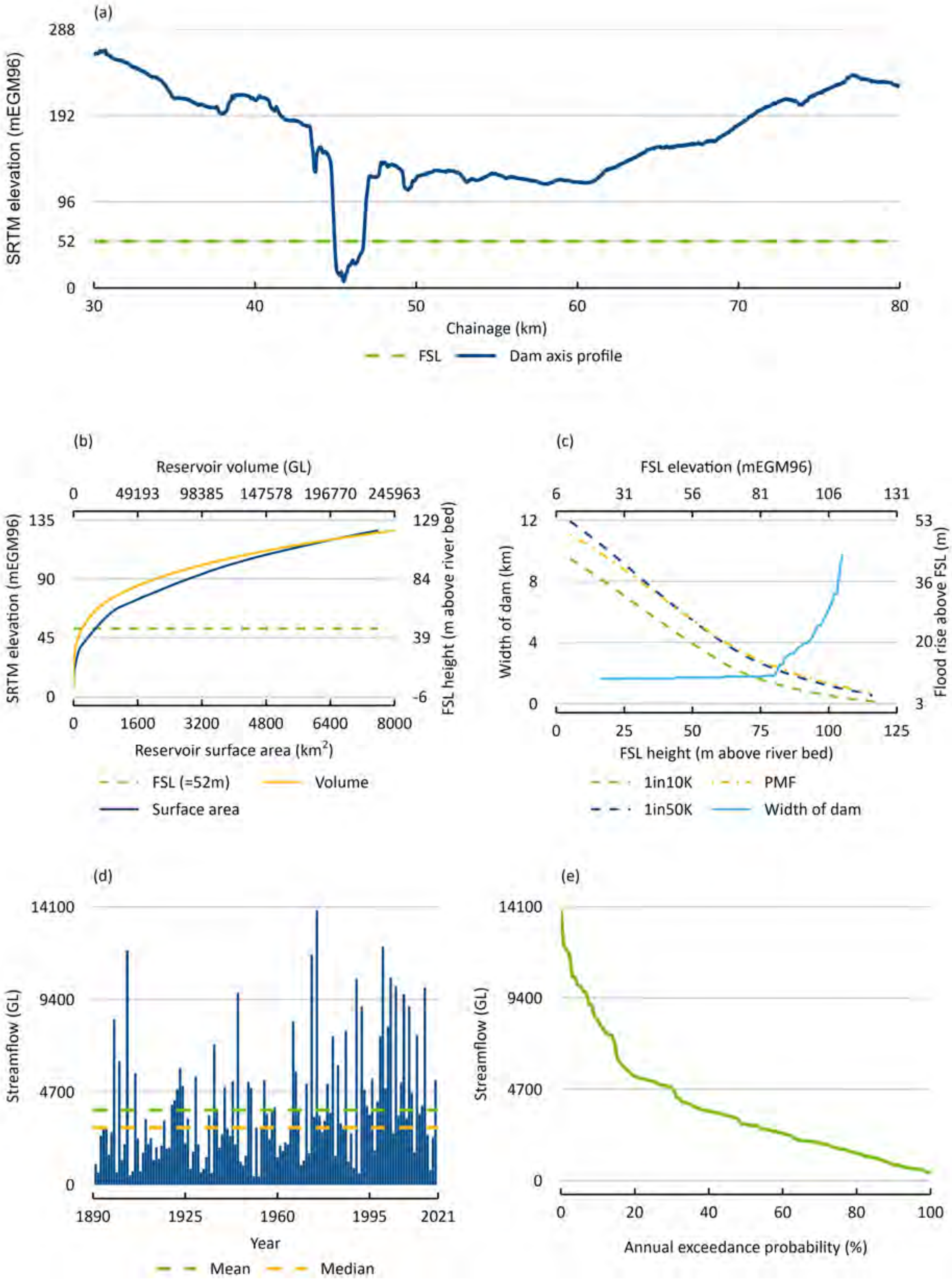
AEP = annual exceedance probability.

FSL = full supply level.



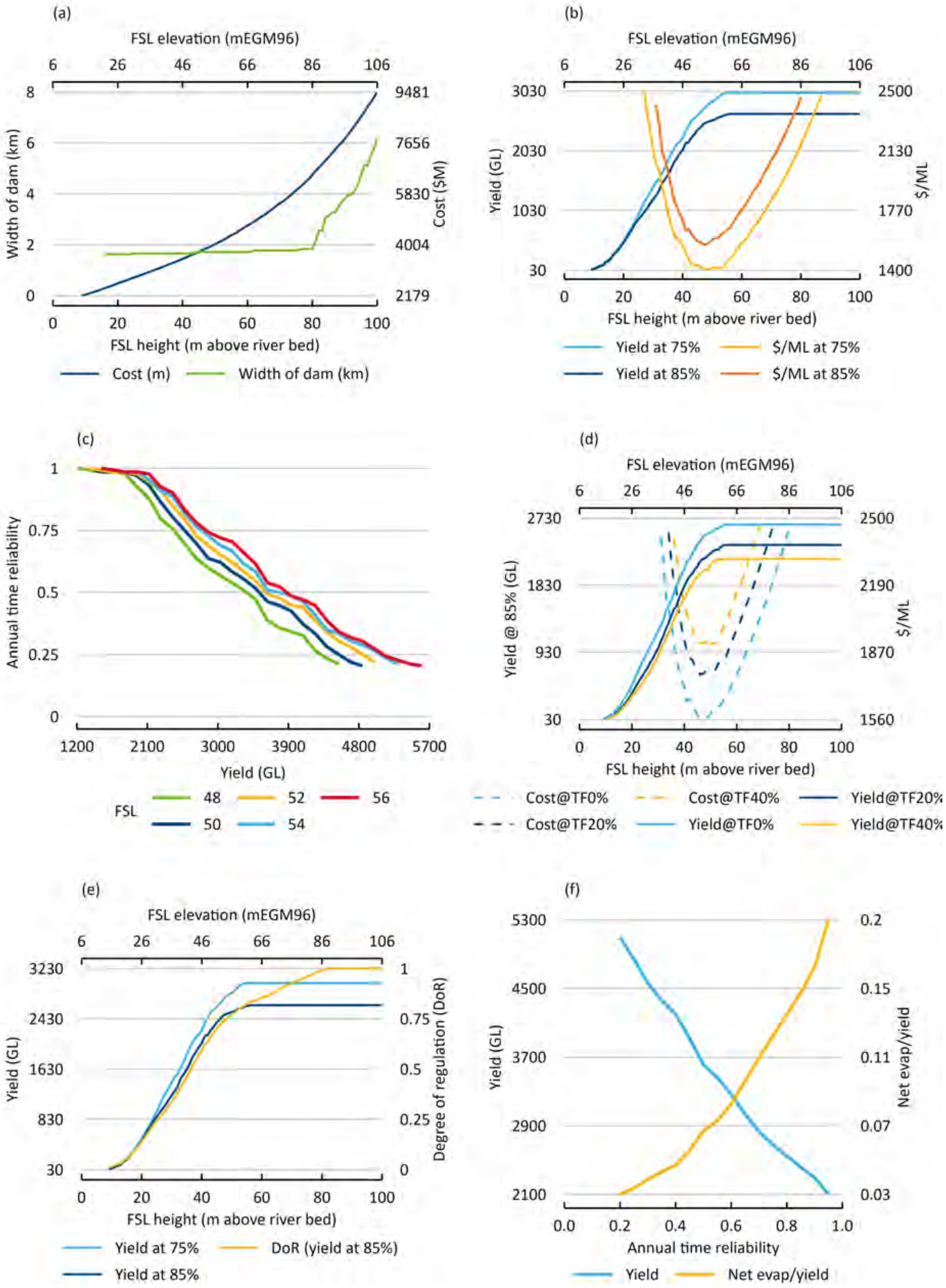
Apx Figure B-3 Geology underlying the potential Victoria River dam site and reservoir

AEP = annual exceedance probability.



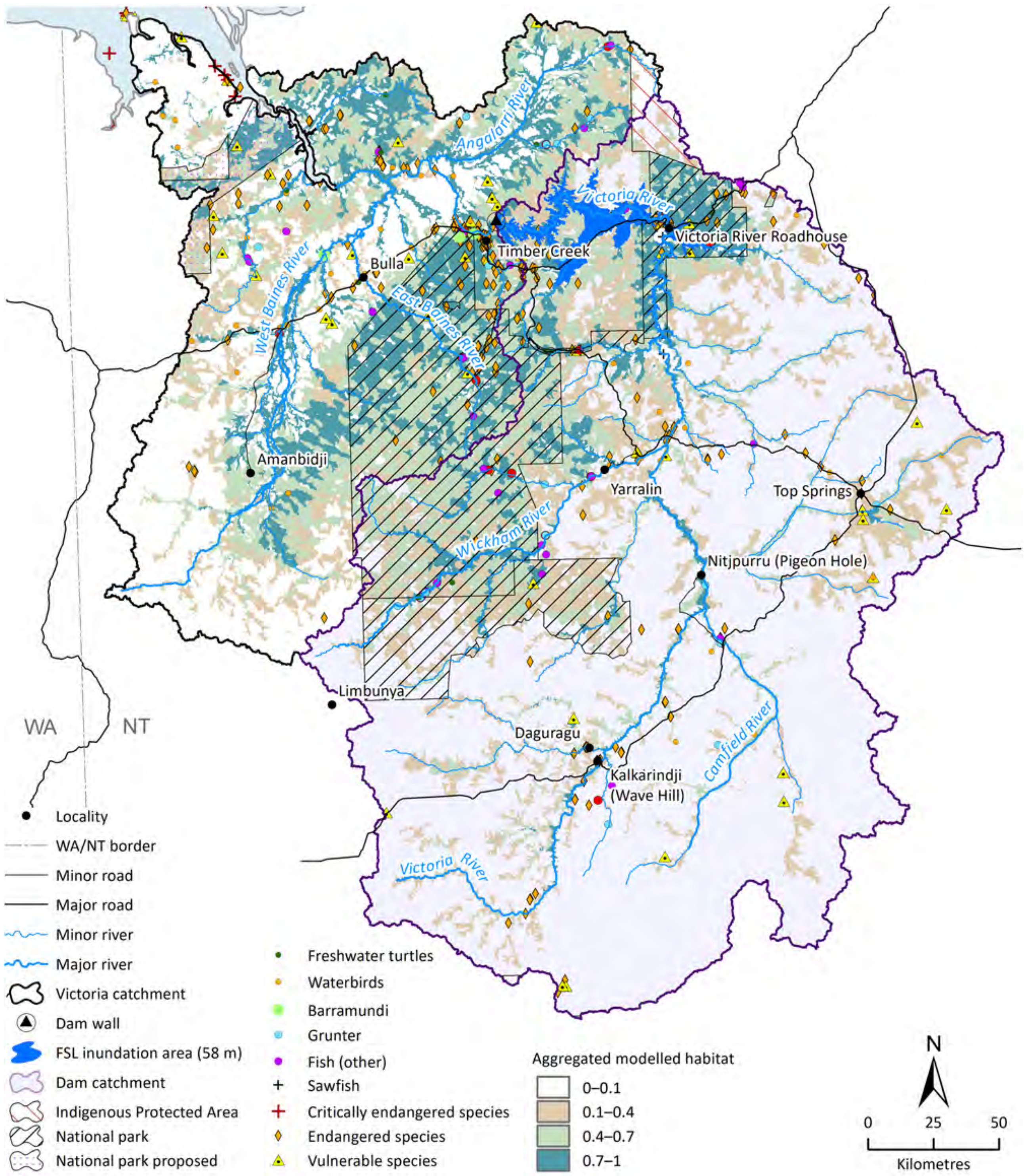
Apx Figure B-4 Victoria River dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance



Apx Figure B-5 Victoria River potential dam site cost, yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-6 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Victoria River West Branch dam site

B.1.2 Wickham River AMTD 63 km (Site 121) FSL 142 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies in the Victoria River catchment were identified in web-based searches or searches of Northern Territory Government databases.
Description of potential dam	The hypothetical Wickham River AMTD 63 km dam site is an instream development with potential to provide irrigation supplies downstream to riparian areas adjacent to the Wickham River. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 142 mEGM96. Apx Figure B-7 and Apx Figure B-8 show the location of the site and the extent of the reservoir area. Apx Figure B-9 shows the underlying geology, Apx Figure B-10 to Apx Figure B-12 report reservoir characteristics and Apx Figure B-13 shows water dependent assets in the vicinity of the potential dam show the location of the site and the extent of the reservoir area.
Regional geology	The Victoria catchment has a generally flat to undulating topography that drains to the north-west into the Joseph Bonaparte Gulf. The oldest rocks are Proterozoic sediments, including potentially soluble dolostone units, which were folded, faulted, uplifted and then eroded to a level not far above that of the current topography. In the higher ground to the west and south-east, they are overlain by a Cambrian sequence of basalts with overlying potentially soluble limestones and dolomites of limited occurrence, mainly in the south-east part of the catchment. Cretaceous sediments occur on the south-east margins of the catchment. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma. This resulted in the formation of deep weathering profiles and associated iron-cemented cappings on the older rocks and broad valleys infilled with alluvium.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps and satellite imagery. The dam site is located on gently dipping Proterozoic rocks of the Jasper Gorge Sandstone (Paj), which consists of medium quartz sandstone with minor siltstone, overlying the Bynoe Formation (Pby), which consists of siltstone, sandstone and dolostone. It is possible that Skull Creek Formation, which consists of dolostone and dolomitic sandstone and can contain karstic cavities, occurs at depth below the dam site, but it does not appear to present a potential leakage path. No outcrop was observed on the abutments, which appear to be deeply weathered. The river bed was ~300 m wide with ponded water ~30 m wide, and there is a 300-m-wide alluvial terrace on the left bank. The foundations appeared possibly to be suitable for a RCC dam. For estimating purposes, assume 10 m of alluvium in the river bed, 15 m of stripping in the alluvial terrace on the left abutment and 10 m of stripping on the right abutment. It is possible that a concrete-faced rockfill dam with lined chute spillway would be more suitable.
Reservoir rim stability and leakage potential	Storage appears stable and watertight, but it would be worthwhile checking whether there is any potential for leakage through the Skull Creek Formation, which outcrops within the reservoir, to an exit point north of the potential storage, where the same formation outcrops.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 300-m-wide central uncontrolled spillway. The abutments would be set at a 1:100,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the left abutment of the dam. A fish lift transfer facility would also be installed in the left abutment of the dam.

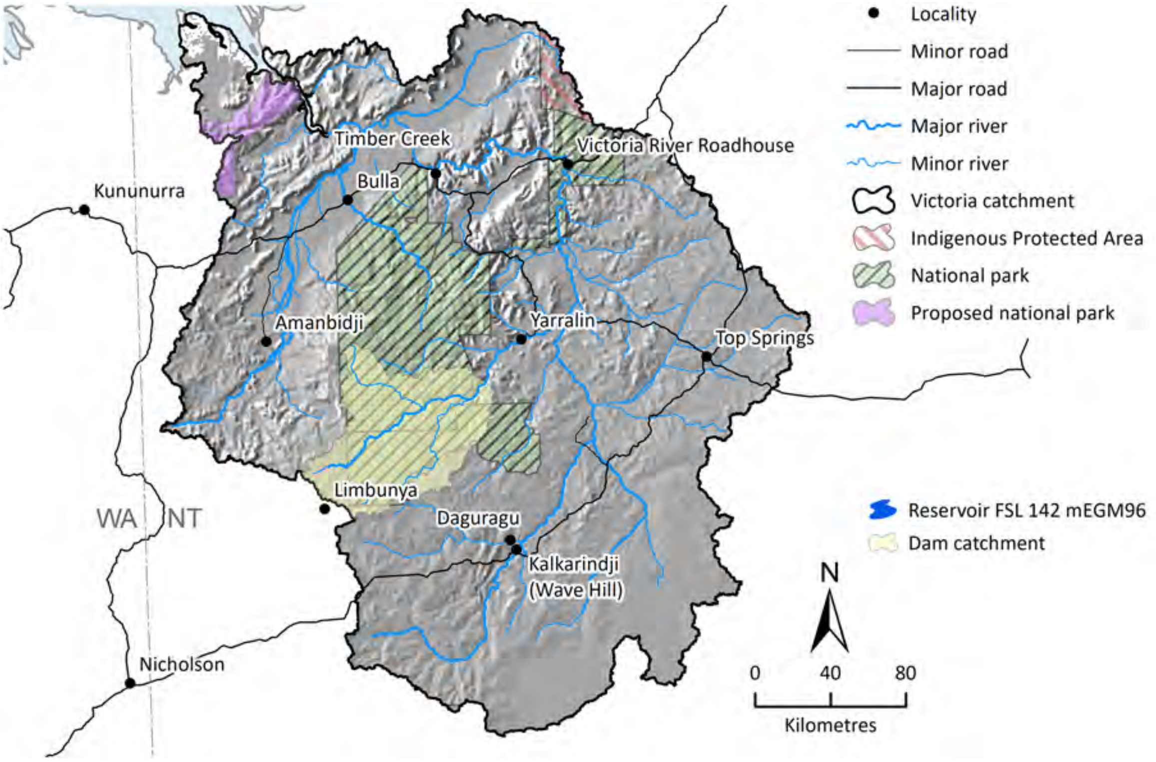
<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td></td><td>Access to the site requires further investigation. A possible route could be via the Yarralin settlement from Highway 1. From Yarralin, some 25 km of the Old Humbert Station access road is likely to require upgrading, A 20-km-long new road would then be required to the dam site. The total distance from the site to Kununurra via this route would be 427 km.</td></tr>
<tr><td>Availability of construction materials</td><td>A quarry that could provide suitable and coarse aggregate might be found within 30 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 30 km of the dam site. For estimating purposes, assume a ratio of useful rock or gravel excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC or conventional concrete for the dam could probably be sourced from Kununurra.</td></tr>
<tr><td>Catchment area</td><td>5413 km^2</td></tr>
<tr><td>Modelled annual inflow data</td><td>
<table>
<tr><th>Parameter</th><th>Scenario A (GL/y)</th><th>Scenario Cdry (GL/y)</th><th>Scenario Cmid (GL/y)</th><th>Scenario Cwet (GL/y)</th></tr>
<tr><td>Max</td><td>1770</td><td>1290</td><td>1708</td><td>2249</td></tr>
<tr><td>Mean</td><td>378</td><td>293</td><td>366</td><td>476</td></tr>
<tr><td>Median</td><td>295</td><td>247</td><td>294</td><td>362</td></tr>
<tr><td>Min</td><td>10</td><td>4</td><td>10</td><td>15</td></tr>
</table>
</td></tr>
<tr><td>Reservoir characteristics</td><td>Storages with FSLs of selected heights are tabulated below.
<table>
<tr><th>FSL</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>140</td><td>4861</td><td>442</td></tr>
<tr><td>142</td><td>5663</td><td>547</td></tr>
<tr><td>144</td><td>6525</td><td>668</td></tr>
</table>
</td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>FSL of 140 mEGM96 – estimated yield at 85% annual time reliability = 194 GL
FSL of 142 mEGM96 – estimated yield at 85% annual time reliability = 209 GL
FSL of 144 mEGM96 – estimated yield at 85% annual time reliability = 221 GL
Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-10, Apx Figure B-11 and Apx Figure B-12.</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at a FSL of 142 mEGM96</td><td>
<table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>1.1</td><td>1.6</td><td>1.8</td></tr>
<tr><td>100 years (%)</td><td>3.6</td><td>5.4</td><td>6.0</td></tr>
<tr><td>Years to fill</td><td>2799</td><td>1866</td><td>1680</td></tr>
</table>
</td></tr>
<tr><td>Potential use of supply</td><td>The most versatile land for agriculture downstream of the potential dam site is on the river floodplain and the elevated plains and pediments on dolomite rock either side of the river. The soils are a mixture of friable clay loams (SGG 2), red loamy soils (SGG 4.1) and cracking clays (SGG 9), with shallow and/or rocky soils (SGG 7) on the hills in between. The friable clay loams (SGG 2) have a severe erosion hazard due to their strongly slaking subsoils.

The friable red clay loam soils (SGG 2) and red loamy soils (SGG 4.1) are suitable, with minor limitations (Class 2), for dry-season trickle-intensive horticulture on the alluvial plains, and suitable, with moderate limitations (Class 3), for trickle-irrigated sandalwood (Santalum spp.) on the dolomite plains and pediments. These red soils are also suitable, with minor limitations (Class 2), for spray-irrigated perennial grasses, pulse crops, small-seeded crops and root crops.

The brown cracking clays (SGG 9) are suitable, with moderate limitations (Class 3), for trickle-irrigated tropical tree crops and cucurbits and spray-irrigated perennial grasses, pulse crops and small-seeded crops as well as flood-irrigated rice (Oryza spp.) on the level plains.</td></tr>
<tr><td>Environmental impacts</td><td>Habitat fragmentation and barrier to movement of aquatic species</td></tr>
</table>

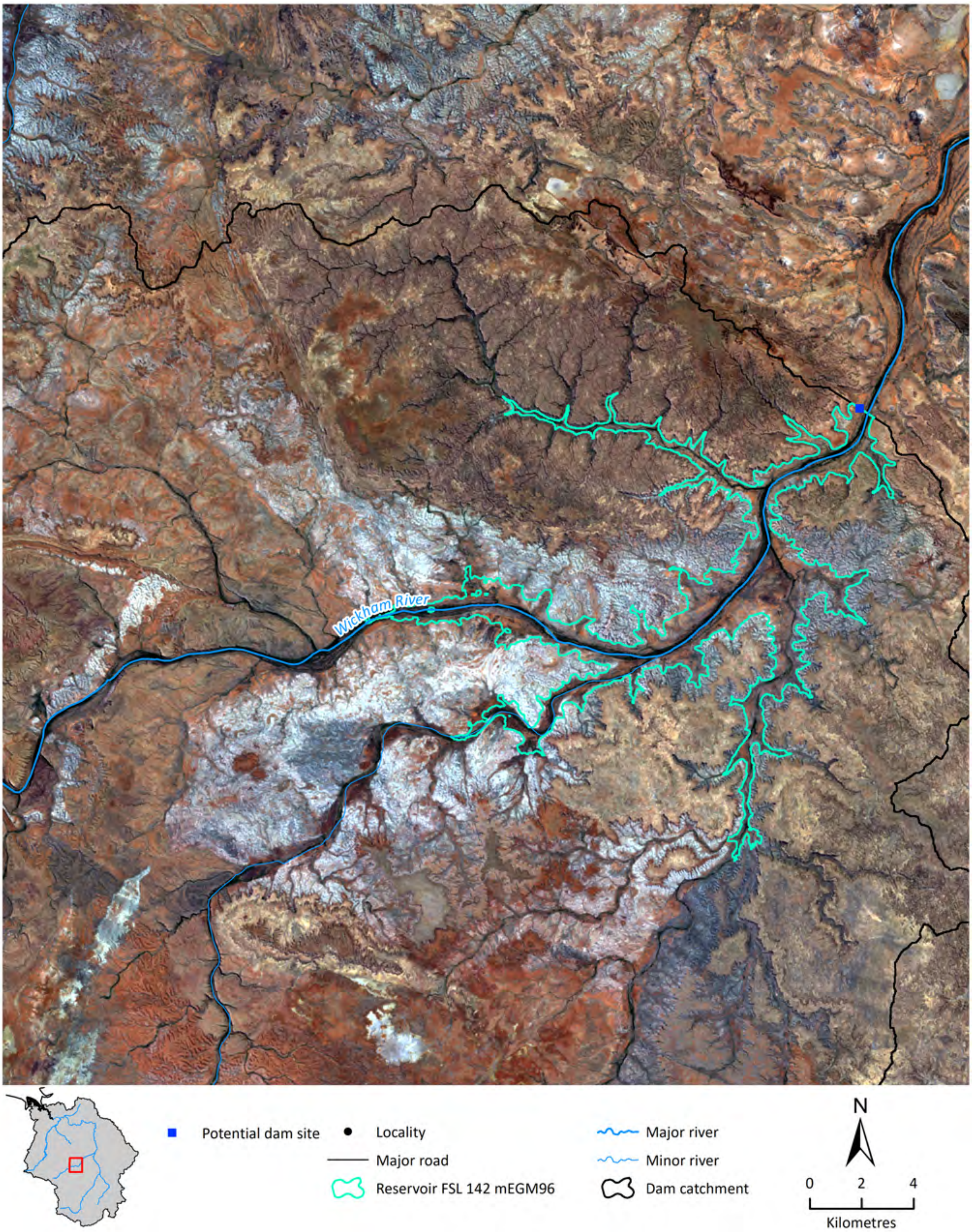
PARAMETER	DESCRIPTION
	In this potential dam site, there were ecology asset records for northern snapping turtle (*Elseya dentata*), spangled grunter (*Leiopotherapon unicolor*), western rainbow fish (*Melanotaenia australis*), eastern rainbow fish (*Melanotaenia splendida*), the fork-tailed catfish *(Neoarious graffei*) and mouth almighty (*Glossamia aprion*). The models predict that ~6% of the catchment (30,684 ha) has suitable habitat for at least 40% of the species. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively small, depending on the species, and ranges from 0.02% to 9.8% of their total potentially suitable habitat in the Victoria catchment. These species may have fragmented habitat and/or have movement impeded by a dam. The upstream catchment of this potential dam site includes part of the Judbarra National Park. Apx Figure B-14 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Wickham River (AMTD 63 km) site. **Ecological implications of inundation** Some listed species have been recorded in the catchment of this potential dam site. In the potential inundation area, there are records of the northern masked owl (*Tyto novaehollandiae kimberli*), listed as vulnerable at federal and territory level, the common brushtail possum (*Trichosurus vulpecula vulpecula*) and the yellow-spotted monitor (*Varanus panoptes*), listed as endangered and vulnerable, respectively, at territory level. The Gouldian finch (*Chloebia gouldiae*), listed as endangered (EPBC Act) and vulnerable (NT), occurs in the potential dam catchment. Waterbirds such as the royal spoonbill (*Platalea regia*), the endangered Australian painted snipe (*Rostratula australis*), cattle egret (*Bubulcus ibis*) and magpie goose (*Anseranas semipalmata*) also occur near this site. The potential inundated area at FSL for this site (142 mEGM96) may have an effect on these species. The inundation extent of this potential dam site overlaps with part of the Judbarra National Park. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 140 mEGM96 – estimated cost = $1518 million FSL of 142 mEGM96 – estimated cost = $1593 million FSL of 144 mEGM96 – estimated cost = $1668 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 140 mEGM96 – estimated cost/ML of supply = $7815 /ML FSL of 142 mEGM96 – estimated cost/ML of supply = $7603/ML FSL of 144 mEGM96 – estimated cost/ML of supply = $7530/ML
Summary comment	A hypothetical instream dam at this site has the potential to provide irrigation supplies downstream to riparian areas adjacent to the Wickham River. The foundations appeared possibly to be suitable for a RCC dam. Although one of the higher-yielding potential dam sites in the Victoria catchment, the site is also one of the more expensive and is very remote. The headwaters of the catchment of this site includes part of the Judbarra National Park. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.



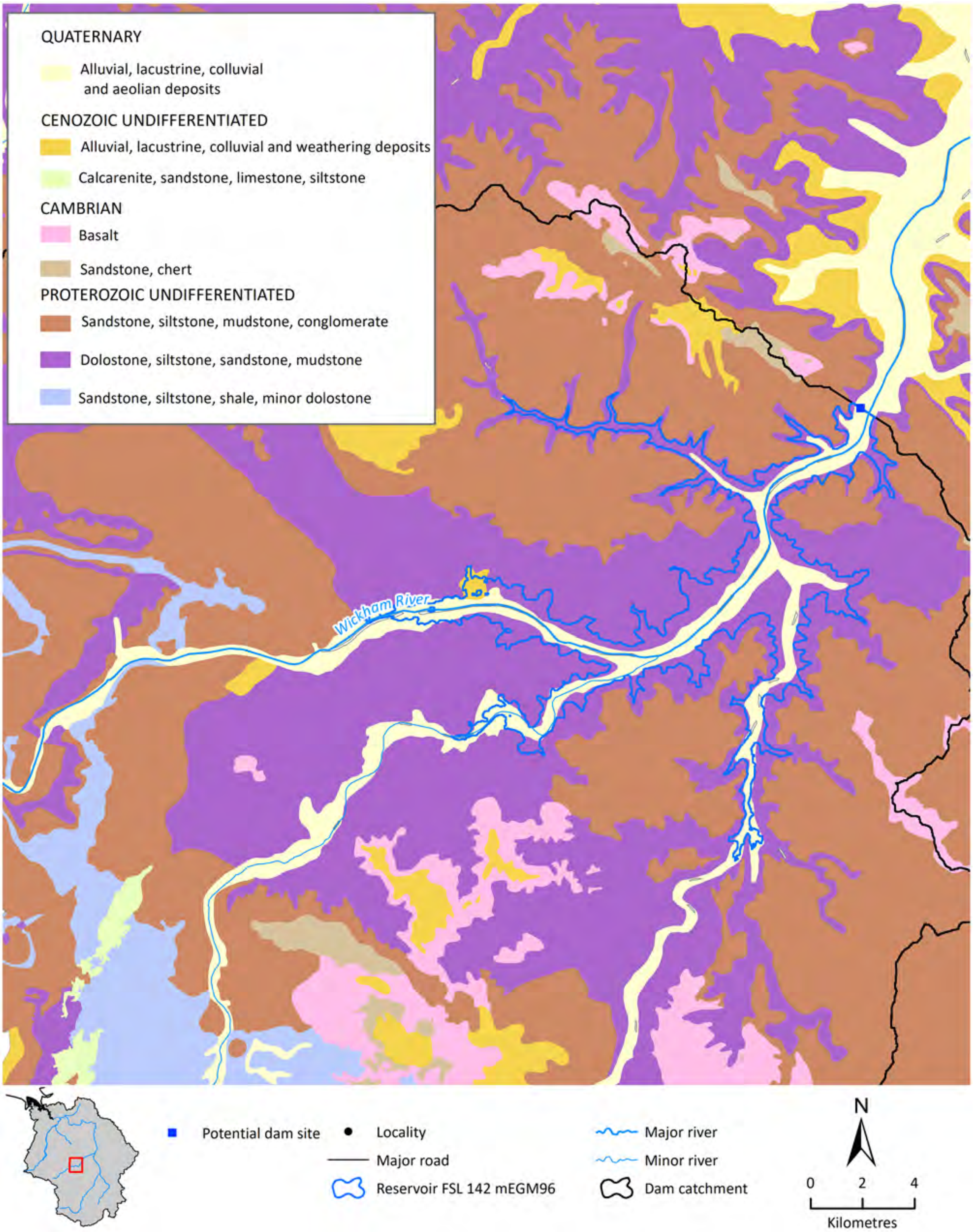
Apx Figure B-7 Location map of potential Wickham River dam site, reservoir extent and catchment area

AEP = annual exceedance probability.



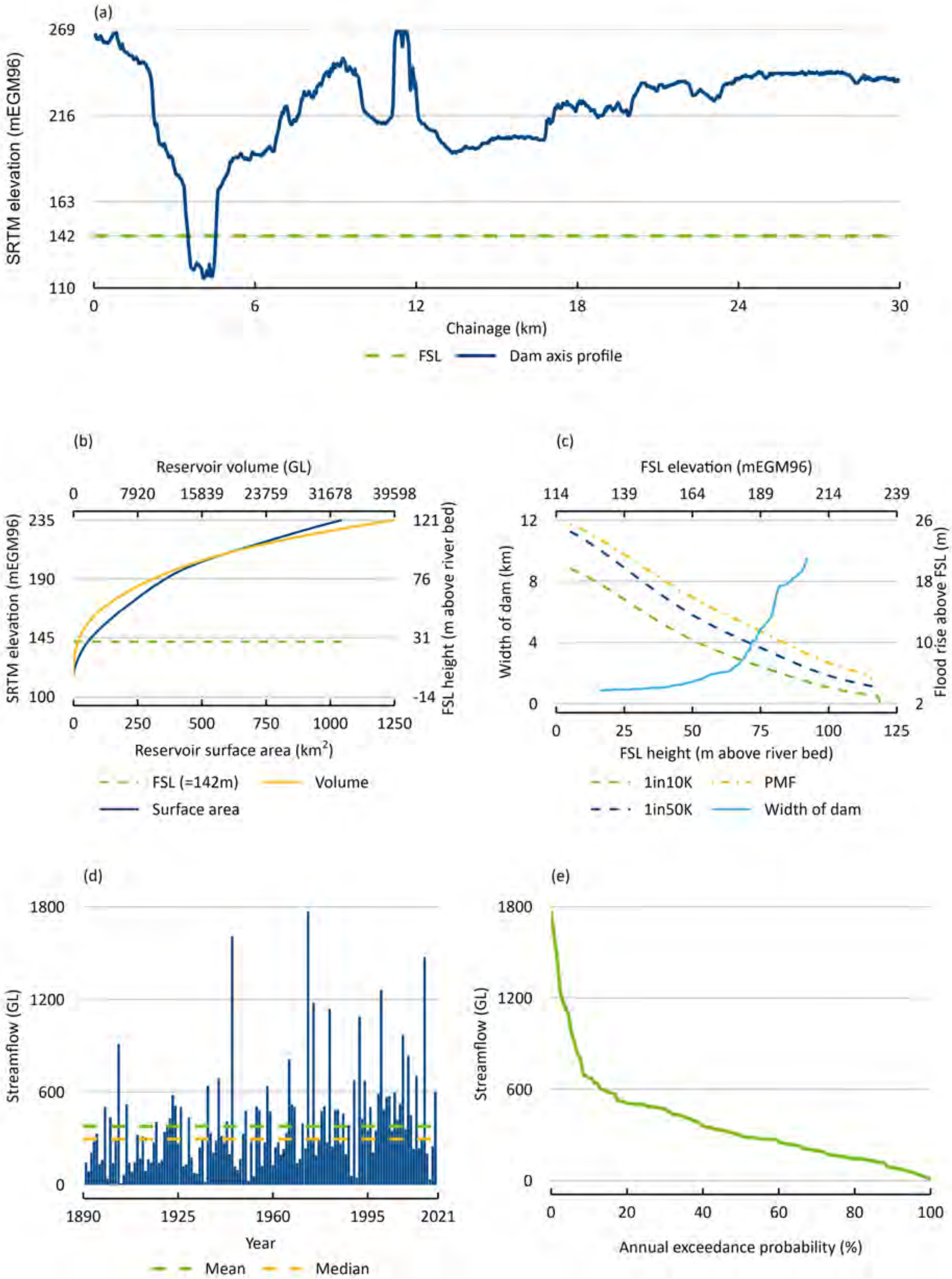
Apx Figure B-8 Potential Wickham River dam reservoir

AEP = annual exceedance probability.



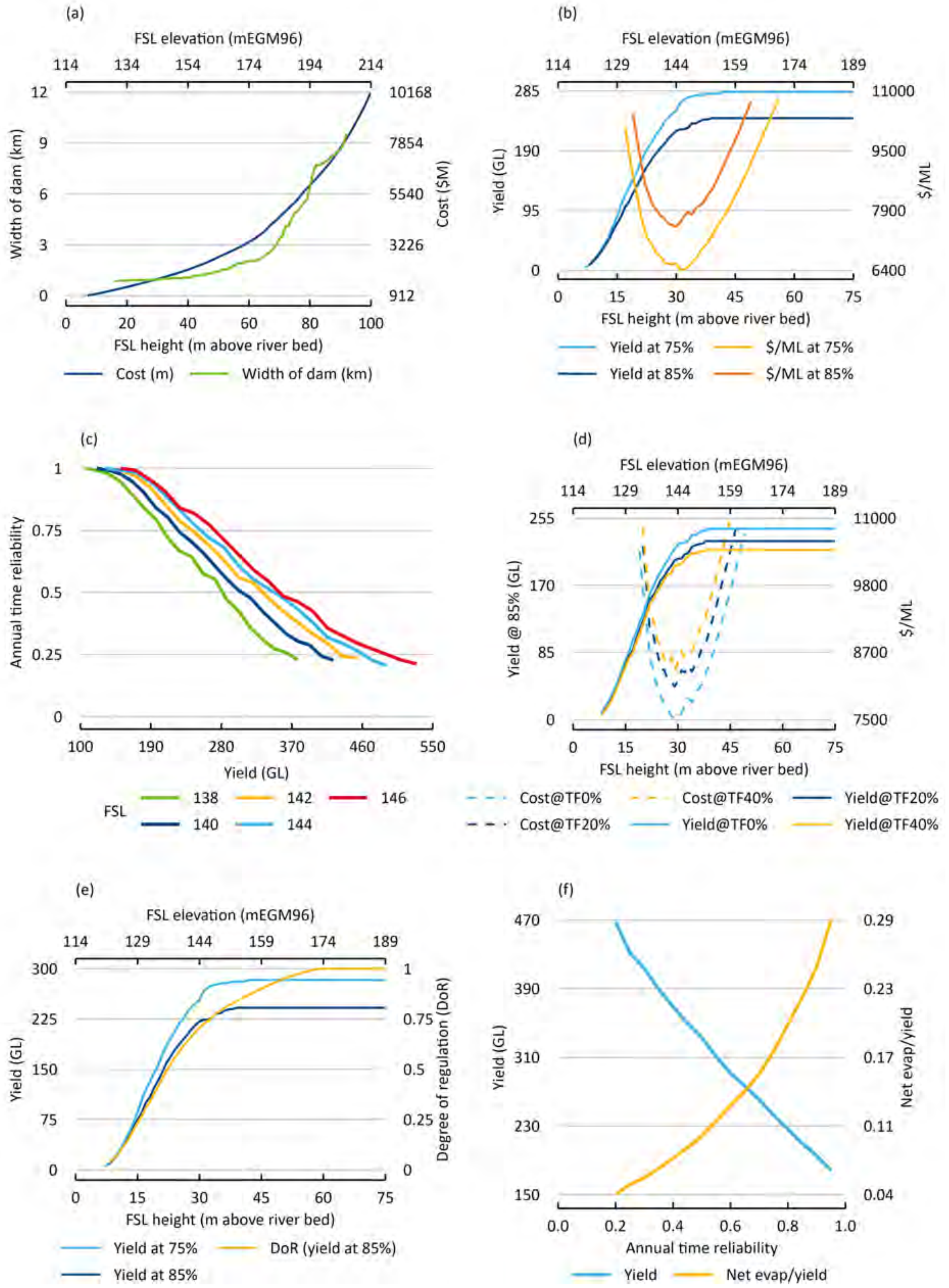
Apx Figure B-9 Geology underlying the potential Wickham River dam site and reservoir

AEP = annual exceedance probability.



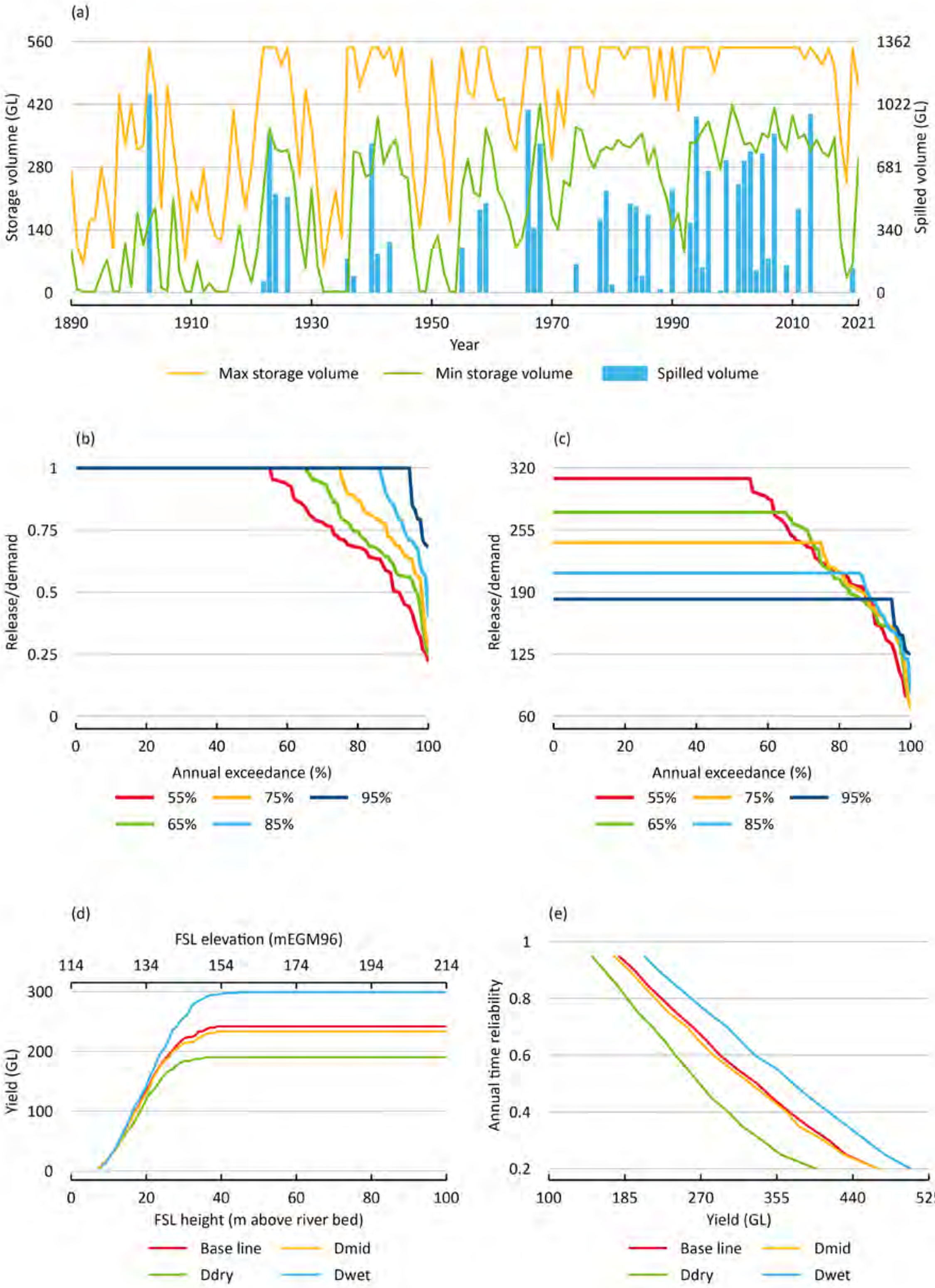
Apx Figure B-10 Wickham River potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



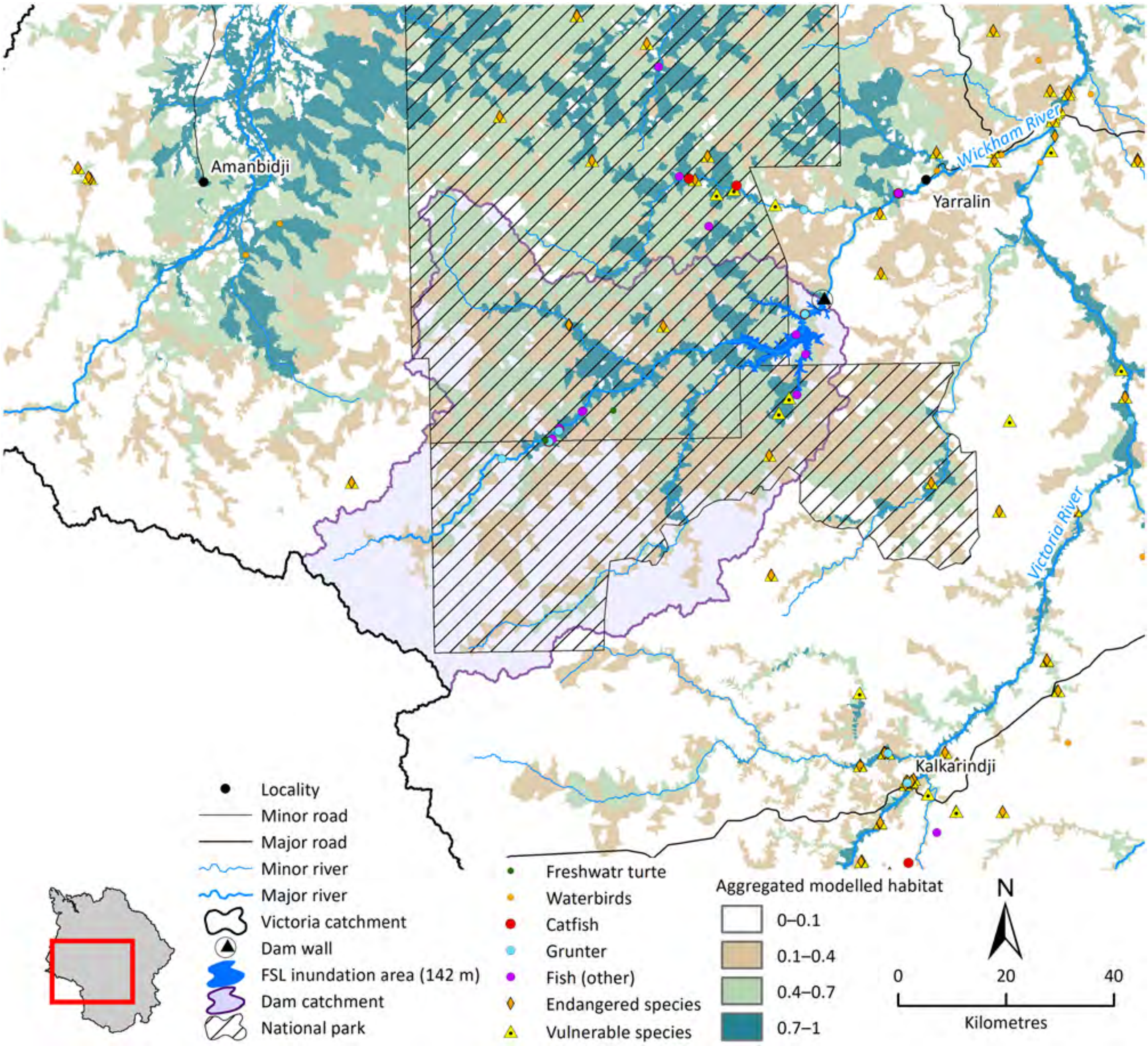
Apx Figure B-11 Wickham River potential dam site cost, water yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-12 Wickham River potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 142 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-13 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Wickham River dam site

FSL = full supply level.

B.1.3 Bullo River AMTD 57 km (Site 150) FSL 84 mEGM96

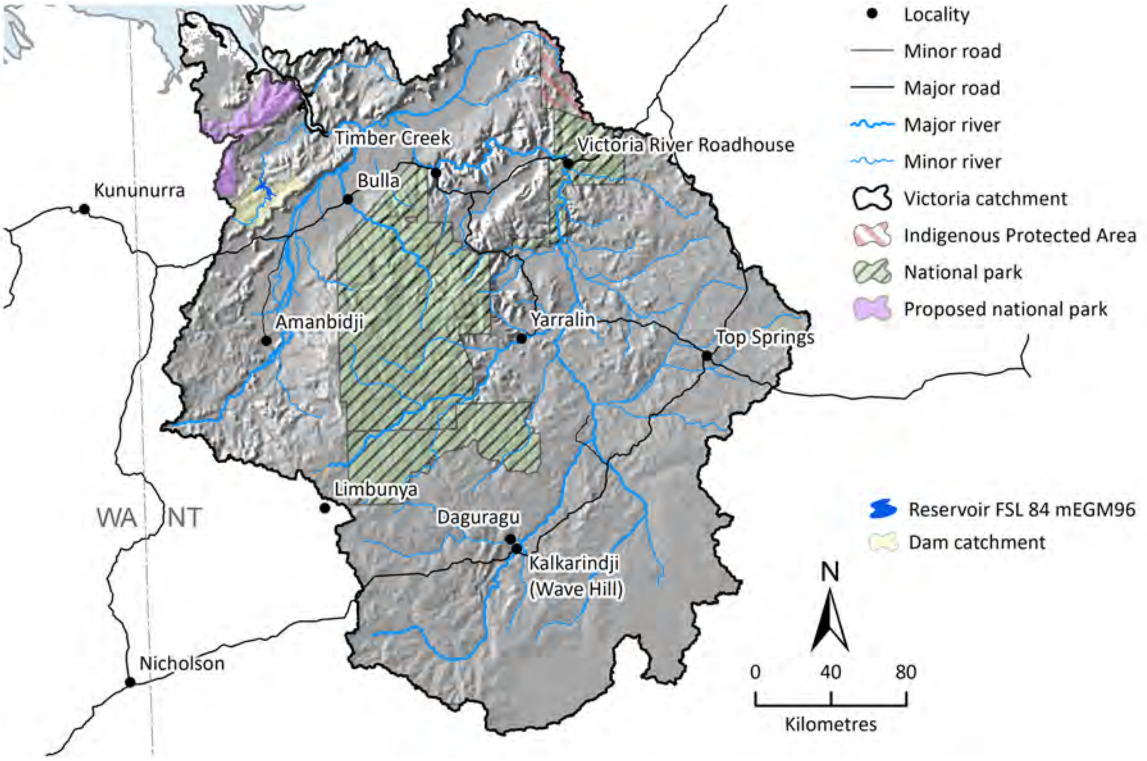
PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies in the Victoria River catchment were identified in web-based searches or searches of Northern Territory Government databases.
Description of potential dam	The hypothetical Bullo River AMTD 57 km dam site is an instream development with potential to provide irrigation supplies downstream. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 84 mEGM96. Apx Figure B-14 and Apx Figure B-15 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Victoria catchment has a generally flat to undulating topography that drains to the north-west into the Joseph Bonaparte Gulf. The oldest rocks are Proterozoic sediments, including potentially soluble dolostone units, which were folded, faulted, uplifted and then eroded to a level not far above that of the current topography. In the higher ground to the west and south-east, they are overlain by a Cambrian sequence of basalts with overlying potentially soluble limestones and dolomites of limited occurrence, mainly in the south-east part of the catchment. Cretaceous sediments occur on the south-east margins of the catchment. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma. This resulted in the formation of deep weathering profiles and associated iron-cemented cappings on the older rocks, and broad valleys infilled with alluvium.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Apx Figure B-16) and satellite imagery. The dam site is located on Proterozoic rocks of the Bullo River Sandstone (Pb), which consists of quartz sandstone and conglomerate. There appeared to be gently dipping outcrop on both of the abutments, and the river bed was ~70 m wide, with ponded water and bouldery alluvium. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 5–10 m of alluvium in the river bed and 5 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 50-m-wide central uncontrolled spillway. The abutments would be set at a 1:50,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the left abutment of the dam. A fish lift transfer facility would also be installed in the left abutment of the dam. Access to the site would be via a 50-km-long new road branching from Highway 1. The total distance to the site from Kununurra would be some 145 km.
Availability of construction materials	A quarry that could provide suitable and coarse aggregate might be found within 30 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 30 km of the dam site. For estimating purposes, assume a ratio of useful rock or gravel excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC or conventional concrete for the dam could probably be sourced from Kununurra.
Catchment area	605 km^2

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td>Modelled annual inflow data</td><td>
<table>
<tr><th>Parameter</th><th>Scenario A (GL/y)</th><th>Scenario Cdry (GL/y)</th><th>Scenario Cmid (GL/y)</th><th>Scenario Cwet (GL/y)</th></tr>
<tr><td>Max</td><td>358</td><td>298</td><td>340</td><td>467</td></tr>
<tr><td>Mean</td><td>77</td><td>63</td><td>75</td><td>92</td></tr>
<tr><td>Median</td><td>65</td><td>56</td><td>64</td><td>78</td></tr>
<tr><td>Min</td><td>16</td><td>13</td><td>15</td><td>17</td></tr>
</table>
</td></tr>
<tr><td>Reservoir characteristics</td><td>
Reservoirs with FSLs of selected heights are tabulated below.
<table>
<tr><th>FSL (mEGM96)</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>82</td><td>1157</td><td>102</td></tr>
<tr><td>84</td><td>1320</td><td>127</td></tr>
<tr><td>86</td><td>1476</td><td>155</td></tr>
</table>
</td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>
FSL of 82 mEGM96 – estimated yield at 85% annual time reliability = 52 GL
FSL of 84 mEGM96 – estimated yield at 85% annual time reliability = 55 GL
FSL of 86 mEGM96 – estimated yield at 85% annual time reliability = 57 GL
Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-17, Apx Figure B-18 and Apx Figure B-19.
</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at a FSL of 84 mEGM96</td><td>
<table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>0.6</td><td>0.8</td><td>0.9</td></tr>
<tr><td>100 years (%)</td><td>1.8</td><td>2.8</td><td>3.1</td></tr>
<tr><td>Years to fill</td><td>5439</td><td>3626</td><td>3263</td></tr>
</table>
</td></tr>
<tr><td>Potential use of supply</td><td>
The most versatile land for agriculture is the plains and pediments downstream of the potential dam site, formed from dolomite and limestone upstream of more recent alluvium closer to the Victoria River. The soils of the plain include sandy red and brown soils (SGG 6), loamy red and brown soils (SGG 4) and clayey wet soils that remain wet for at least 2 to 3 months of the year (SGG 3) adjacent to the Bullo River.

The loamy soils (SGG 4) are suitable, with minor limitation (Class 2), for trickle-irrigated intensive horticulture, spray-irrigated perennial grasses and pulse crops and small-seeded crops. These soils are also suitable, with moderate limitations (Class 3), for citrus. The sandy soils (SGG 6) are suitable, with moderate limitations (Class 3), for trickle-irrigated citrus, intensive horticulture and spray-irrigated root crops. The red sandy and loamy soils (SGG4.1 and 6.1) are suitable, with negligible limitations (Class 1), for trickle-irrigated tropical trees and sandalwood (Santalum spp.) plantations. The red soils are also suitable, with minor limitations (Class 2), for spray-irrigated perennial grasses. The brown sandy and loamy soils (SGG 4.2 and 6.2) are suitable, with minor limitations (Class 2), for trickle-irrigated tropical tree crops and sandalwood plantations. The red loamy soils (SGG 4.1) are suitable, with negligible limitations (Class 1), for spray-irrigated root crops. The brown loamy soils (SGG 4.2) are suitable, with minor limitations (Class 2), for spray-irrigated root crops. The red sandy soils (SGG 6.1) are suitable, with minor limitations (Class 2), for spray-irrigated pulse crops, and the brown sandy soils (SGG 6.2) are suitable, with moderate limitations (Class 3), for pulse crops.
</td></tr>
</table>

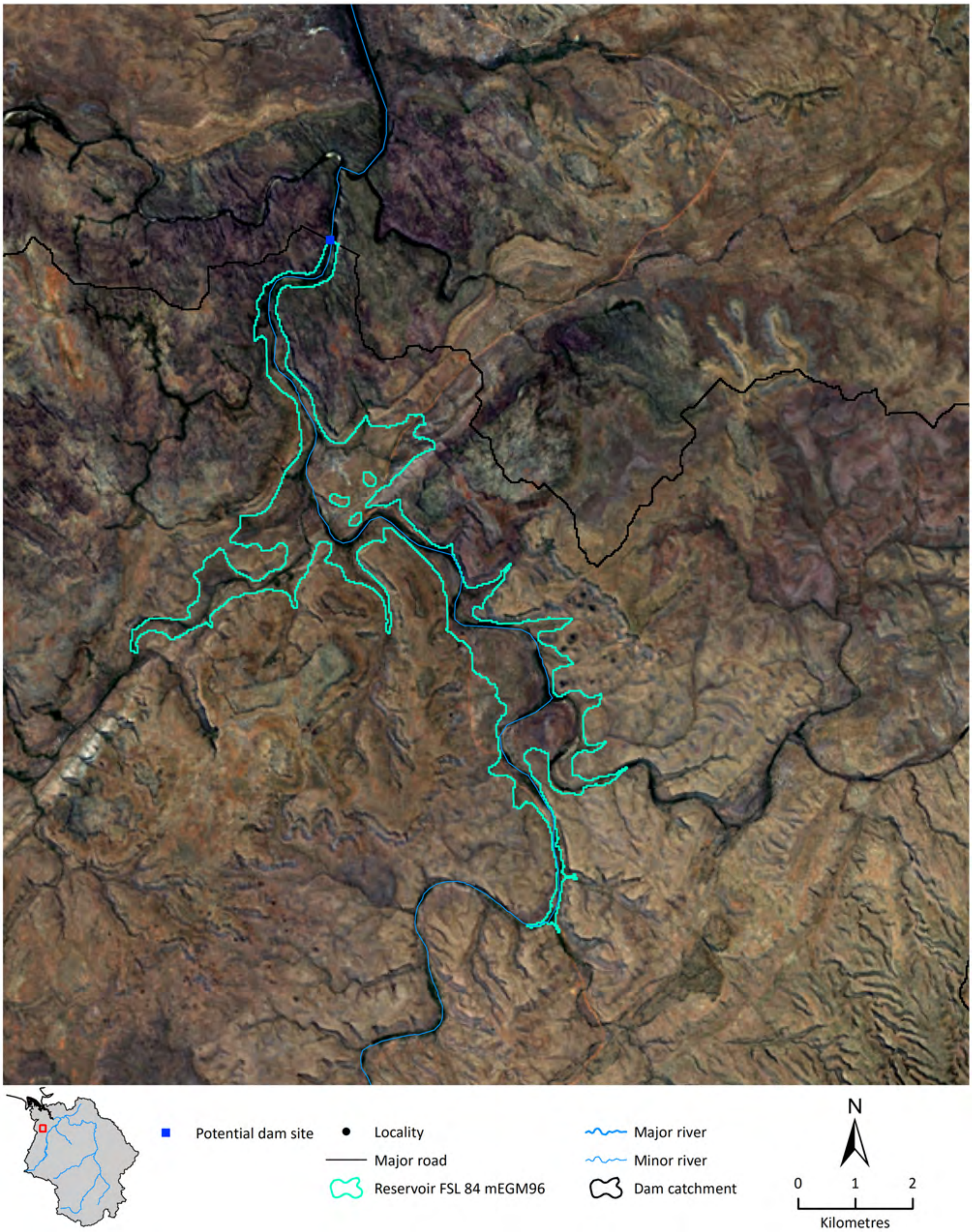
PARAMETER	DESCRIPTION
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** Records of western rainbow fish (*Melanotaenia australis*), eastern rainbow fish (*Melanotaenia splendida*) and mouth almighty (*Glossamia aprion*) were identified at this site. The models predict that ~1% of the catchment (793 ha) has suitable habitat, most of it for up to 40% of the species. Other fish species found in neighbouring streams are the spangled grunter (*Leiopotherapon unicolor*) and the fork-tailed catfish *(Neoarious graffei*). The modelled suitable habitat for these water-dependent species upstream of the potential dam site is small, depending on the species, and ranges from zero % to 1.3% of their total modelled suitable habitat in the Victoria catchment. These species may have fragmented habitat and/or have movement impeded by a dam. The catchment of this potential dam site occurs near the proposed Keep River National Park extension. Apx Figure B-20 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Bullo River (AMTD 57 km) site. **Ecological implications of inundation** Golden bandicoot (*Isoodon auratus*), listed as vulnerable (in the EPBC Act) and as endangered (in the NT), have been recorded downstream, in the inundated area of this potential dam site. Another listed species occurring near this potential dam site is the Gouldian finch (*Chloebia gouldiae*), listed as endangered (EPBC Act) and vulnerable (NT). Waterbirds such as the royal spoonbill (*Platalea regia*) and magpie goose (*Anseranas semipalmata*) also occur near this potential dam site. The potential inundated area at FSL for this site (84 mEGM96) may have an effect on these species. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 82 mEGM96 – estimated cost = $223 million FSL of 84 mEGM96 – estimated cost = $232 million FSL of 86 mEGM96 – estimated cost = $243 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 82 mEGM96 – estimated cost/ML of supply = $4280/ML FSL of 84 mEGM96 – estimated cost/ML of supply = $4199/ML FSL of 86 mEGM96 – estimated cost/ML of supply = $4288/ML
Summary comment	Although commanding the smallest catchment area of the short-listed potential dam sites, the yield of this site is comparable with that of other sites with larger catchment areas, due to the higher rainfall in the Bullo River catchment. With the lowest capital cost, it also has the lowest cost per megalitre released from the dam wall. However, the site is very remote and considerable additional capital expenditure would be required to develop this location. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.



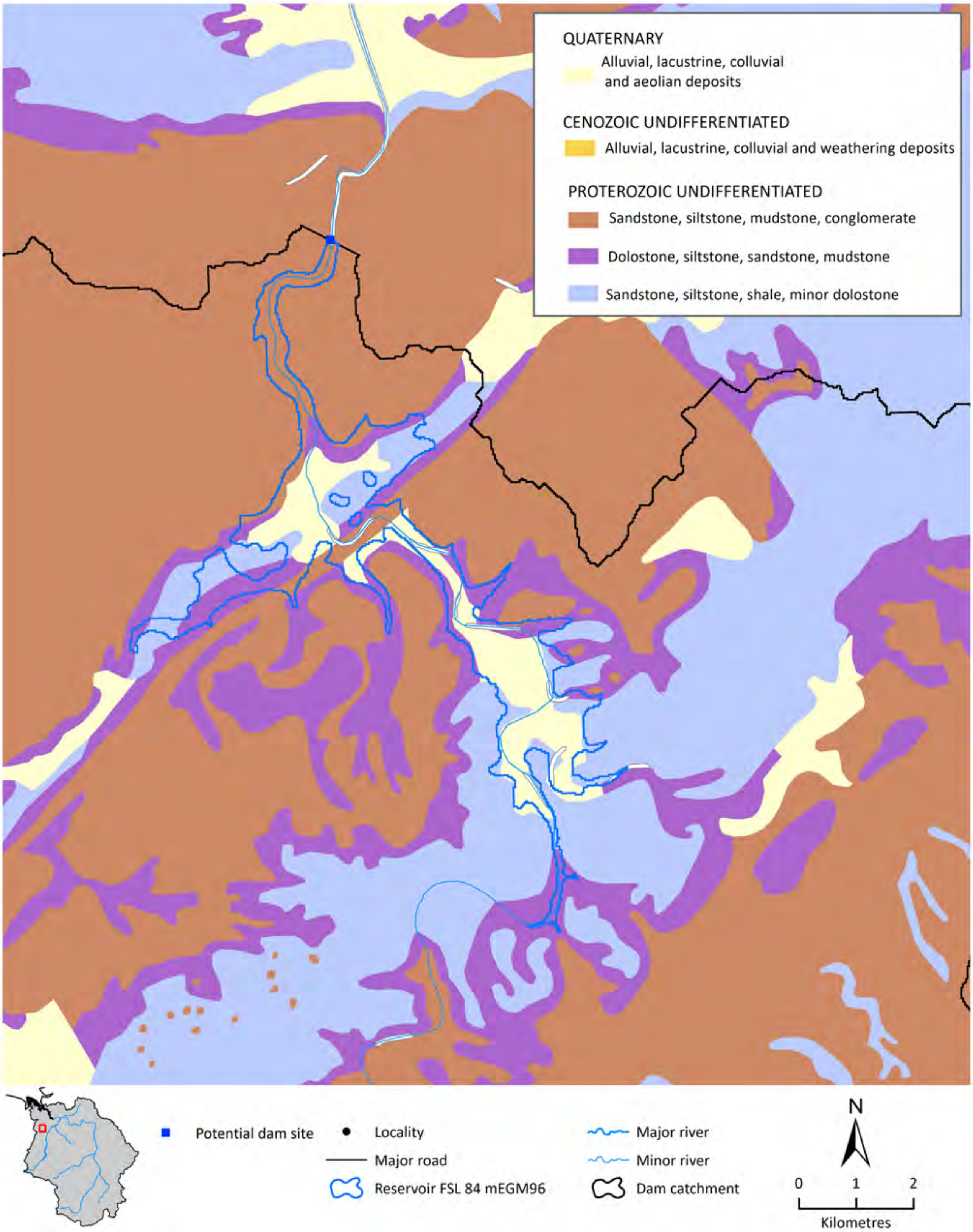
Apx Figure B-14 Location map of potential Bullo River dam site, reservoir extent and catchment area

AEP = annual exceedance probability.



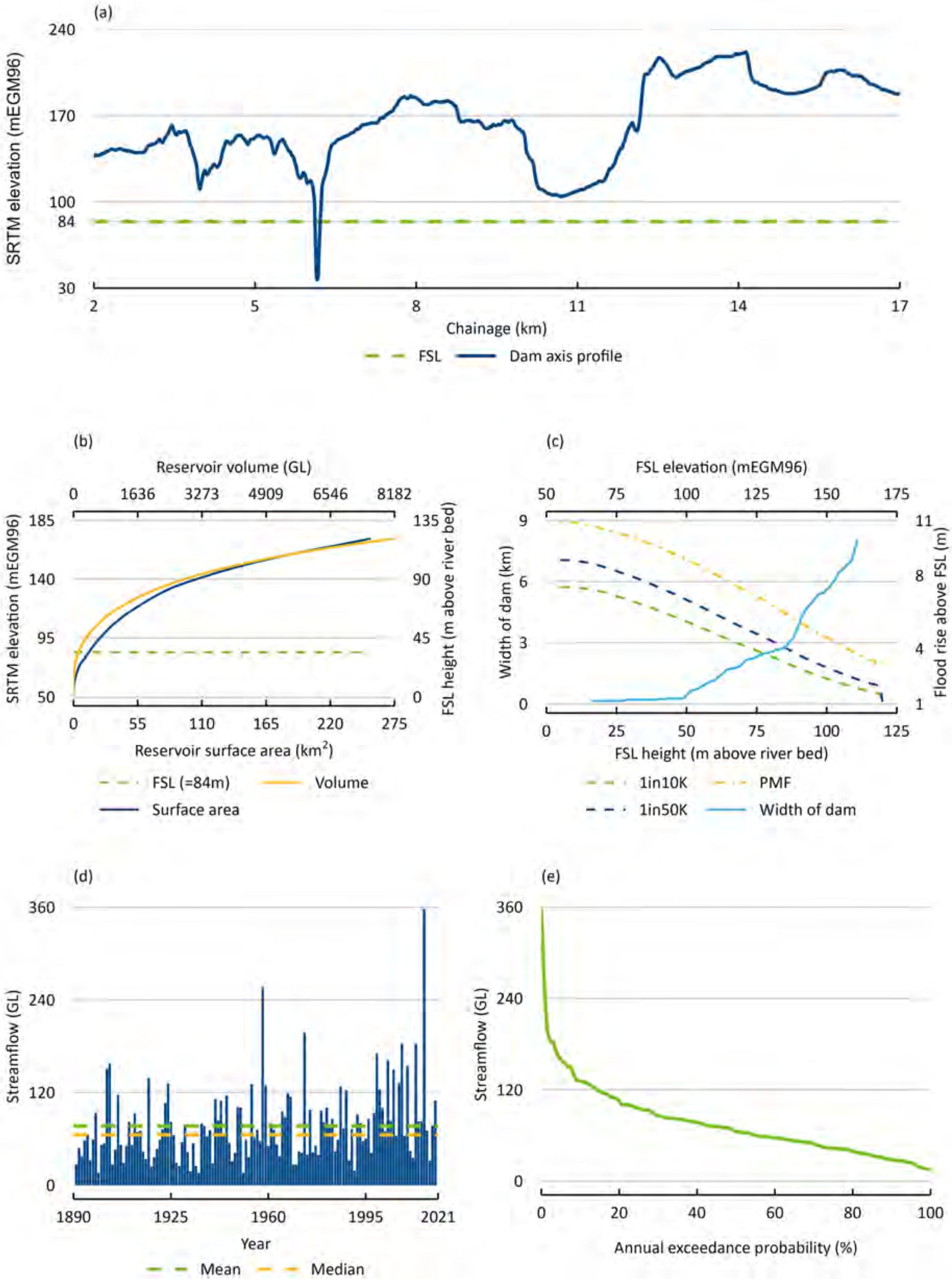
Apx Figure B-15 Potential Bullo River dam reservoir

AEP = annual exceedance probability.



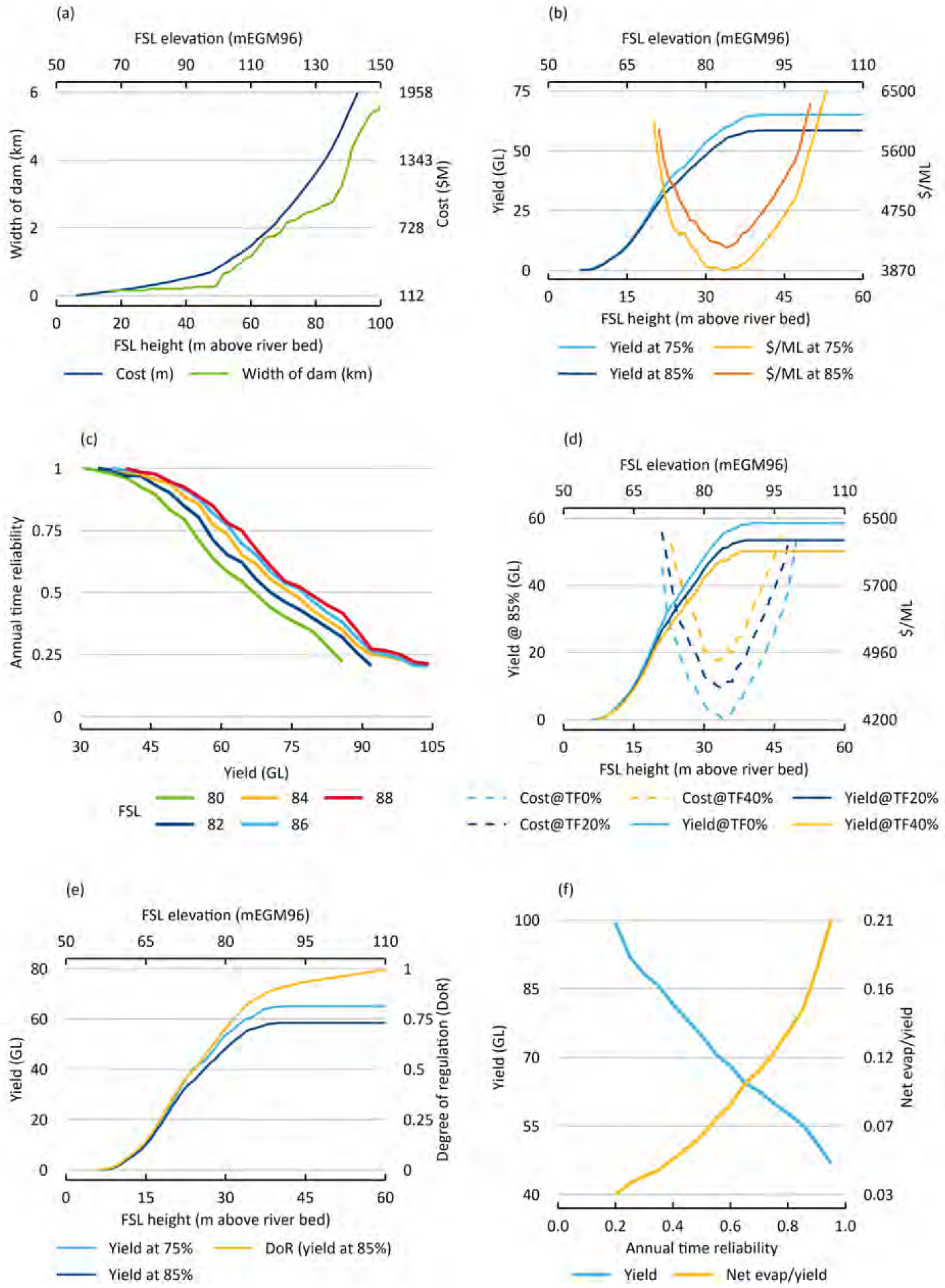
Apx Figure B-16 Geology underlying the potential Bullo River dam site and reservoir

AEP = annual exceedance probability.



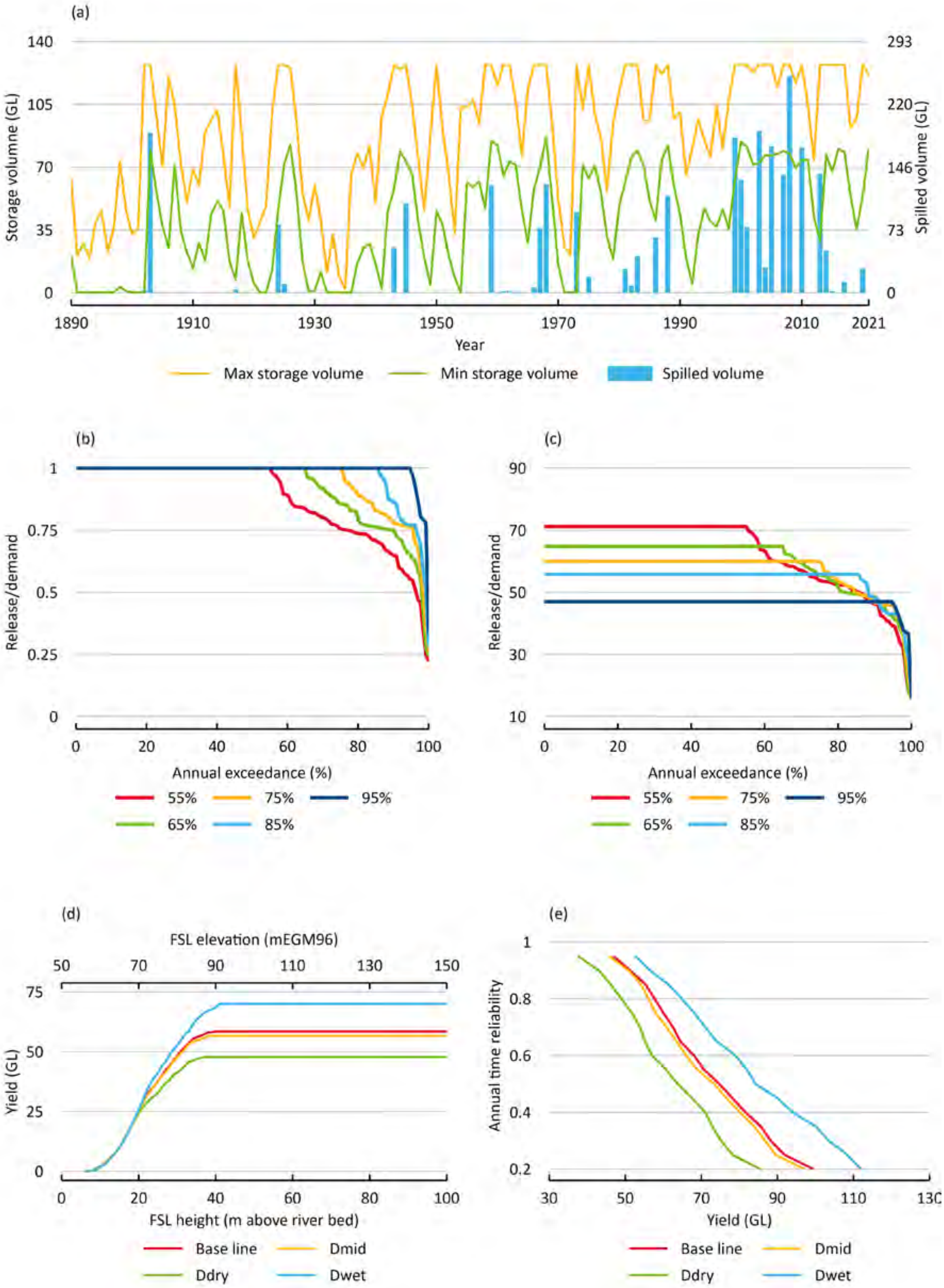
Apx Figure B-17 Bullo River potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



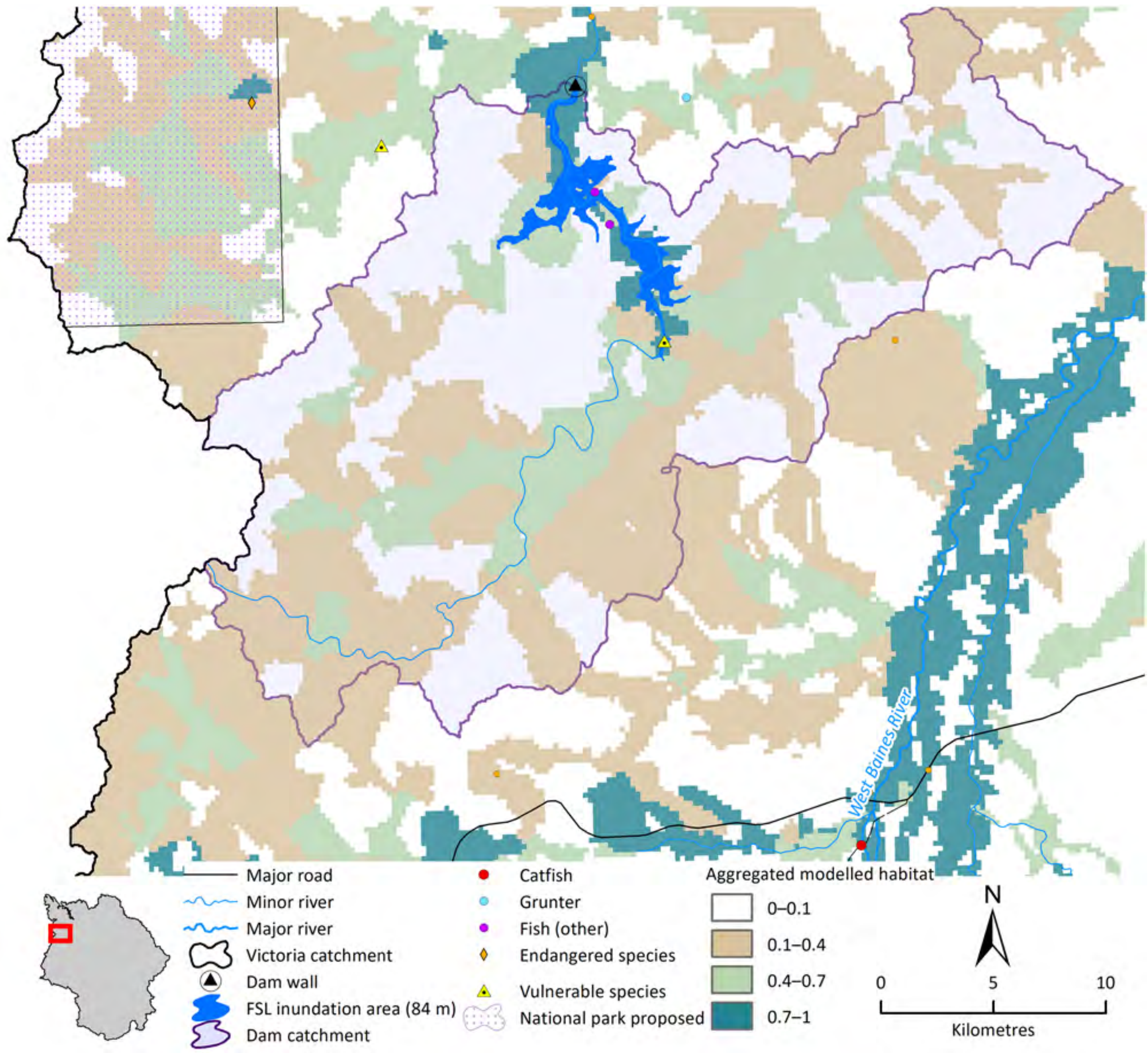
Apx Figure B-18 Bullo River potential dam site cost, water yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-19 Bullo River potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 84 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-20 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Bullo River dam site

FSL = full supply level.

B.1.4 Gipsy Creek AMTD 56 km (Site 230) FSL 86 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies in the Victoria River catchment were identified in web-based searches or searches of Northern Territory Government databases.
Description of potential dam	The hypothetical Gipsy Creek AMTD 56 km dam site is an instream development with potential to provide irrigation supplies downstream along the creek to land adjacent to the upper West Baines River. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 86 mEGM96. Apx Figure B-21 and Apx Figure B-22 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Victoria catchment has a generally flat to undulating topography that drains to the north-west into the Joseph Bonaparte Gulf. The oldest rocks are Proterozoic sediments, including potentially soluble dolostone units, which were folded, faulted, uplifted and then eroded to a level not far above that of the current topography. In the higher ground to the west and south-east, they are overlain by a Cambrian sequence of basalts with overlying potentially soluble limestones and dolomites of limited occurrence, mainly in the south-east part of the catchment. Cretaceous sediments occur on the south-east margins of the catchment. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma. This resulted in the formation of deep weathering profiles and associated iron-cemented cappings on the older rocks, and broad valleys infilled with alluvium.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (Apx Figure B-23) and satellite imagery. The dam site is located on Proterozoic rocks of the Jasper Gorge Sandstone (Paj), which consists of quartz sandstone. There appeared to be gently dipping outcrop on both abutments, and the river bed was ~50 m wide, with ponded water ~20 m wide. In the river bed there are possible rock bars, and the alluvium appears to be shallow. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 2–5 m of alluvium in the river bed and 5 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 130-m-wide central uncontrolled spillway. The abutments would be set at a 1:50,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the right abutment of the dam. A fish lift transfer facility would also be installed in the right abutment of the dam. Access to the right abutment at the site would be via a 30-km-long new road branching from Highway 1. The total distance to the site from Kununurra would be some 175 km.
Availability of construction materials	A quarry that could provide suitable and coarse aggregate might be found within 30 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 30 km of the dam site. For estimating purposes, assume a ratio of useful rock or gravel excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC or conventional concrete for the dam could probably be sourced from Kununurra.
Catchment area	645 km^2

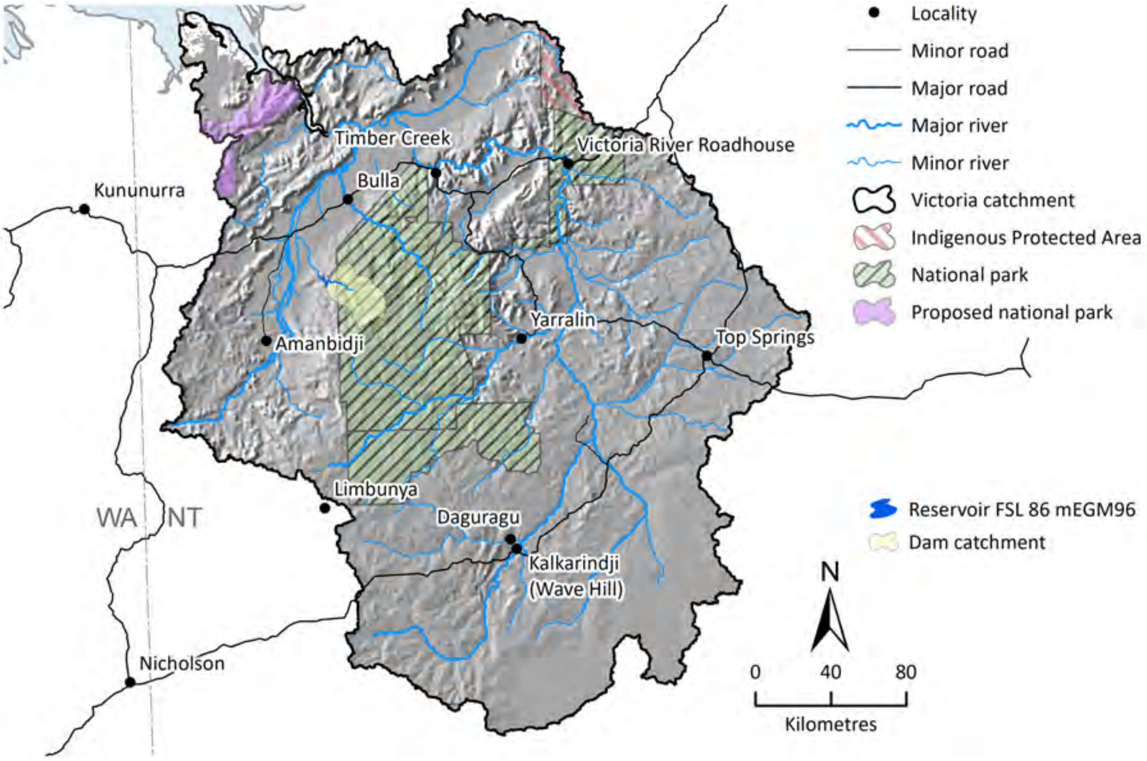
PARAMETER	DESCRIPTION				
Modelled annual inflow data	**Parameter**	**Scenario A (GL/y)**	**Scenario Cdry (GL/y)**	**Scenario Cmid (GL/y)**	**Scenario Cwet (GL/y)**
	Max	398	338	376	517
	Mean	77	61	74	96
	Median	62	50	62	71
	Min	13	12	13	14

PARAMETER	DESCRIPTION		
Reservoir characteristics	Reservoirs with FSLs of selected heights are tabulated below.		
	FSL (mEGM96)	Surface area (ha)	Capacity (GL)
	84	405	48
	86	444	56
	88	488	65
Reservoir yield assessment at dam wall	FSL of 84 mEGM96 – estimated yield at 85% annual time reliability = 40 GL FSL of 86 mEGM96 – estimated yield at 85% annual time reliability = 43 GL FSL of 88 mEGM96 – estimated yield at 85% annual time reliability = 65 GL Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-24, Apx Figure B25 and Apx Figure B-26.		

PARAMETER	DESCRIPTION			
Estimated rates of reservoir sedimentation at a FSL of 86 mEGM96		Best case	Expected	Worst case
	30 years (%)	1.3	2.0	2.2
	100 years (%)	4.4	6.6	7.4
	Years to fill	2260	1506	1356
Potential use of supply	The most versatile land for agriculture is the alluvial plain downstream of the potential dam site. The soils of the plain include friable clay loam soils (SGG 2), cracking clays (SGG 9), clayey wet soils that remain wet for at least 2 to 3 months of the year (SGG 3) and shallow and/or rocky soils on rises (SGG 7) in the river plain. The cracking clay soils on the alluvial plain are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated intensive horticulture, dry-season flood-irrigated rice (*Oryza* spp.) and dry-season furrow-irrigated lablab (*Lablab purpureus*). The friable clay loam soils (SGG 2) adjacent to the river and creeks are suitable, with minor limitations (Class 2), for dry-season trickle-irrigated intensive horticulture and spray-irrigated root crops.			

PARAMETER	DESCRIPTION
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** There were no ecology asset fish records at this site. However, the ecology asset models predict that ~24% of the catchment (15,446 ha) has suitable habitat for at least 40% of the species. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively small, depending on the species, and ranges from zero % to 3.4% of their total modelled suitable habitat in the Victoria catchment. These species may have fragmented habitat and/or have movement impeded by a dam. Most of this potential dam site is within the Judbarra National Park. Apx Figure B-27 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Gypsy Creek (AMTD 56 km) site. **Ecological implications of inundation** One listed species has been recorded in the catchment of potential dam site, the purple-crowned fairy-wren (western) (*Malurus coronatus coronatus*), listed as endangered (EPBC Act) and vulnerable (NT). The Gouldian finch (*Chloebia gouldiae*), also listed as endangered (EPBC Act) and vulnerable (NT), has been recorded in the vicinity of the potential catchment. The potential inundated area at FSL for this potential dam site (86 mEGM96) may have an effect on these species. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	No site-specific evaluation of cultural heritage considerations was possible, as pre-existing Indigenous cultural heritage site records were not made available to the Assessment. Land tenure and native title information were derived from regional land councils and the National Native Title Tribunal. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 84 mEGM96 – estimated cost = $360 million FSL of 86 mEGM96 – estimated cost = $384 million FSL of 88 mEGM96 – estimated cost = $410 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 84 mEGM96 – estimated cost/ML of supply = $9096/ML FSL of 86 mEGM96 – estimated cost/ML of supply = $8993/ML FSL of 88 mEGM96 – estimated cost/ML of supply = $8889/ML
Summary comment	This potential dam site commands a relatively small catchment. Consequently, it is relatively low yielding and has one of the higher costs per megalitre yield released from the dam wall of the short-listed sites in the Victoria catchment. The dam site has potential to provide irrigation supplies downstream along the creek to land adjacent to the upper West Baines River. The foundations appear to be suitable for a RCC dam. Although the site is located on a small headwater catchment, this catchment has the highest area of suitable habitat of the modelled water-dependent species expressed as a percentage of the catchment area (99%). There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; MSCL = mild steel cement lined; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.

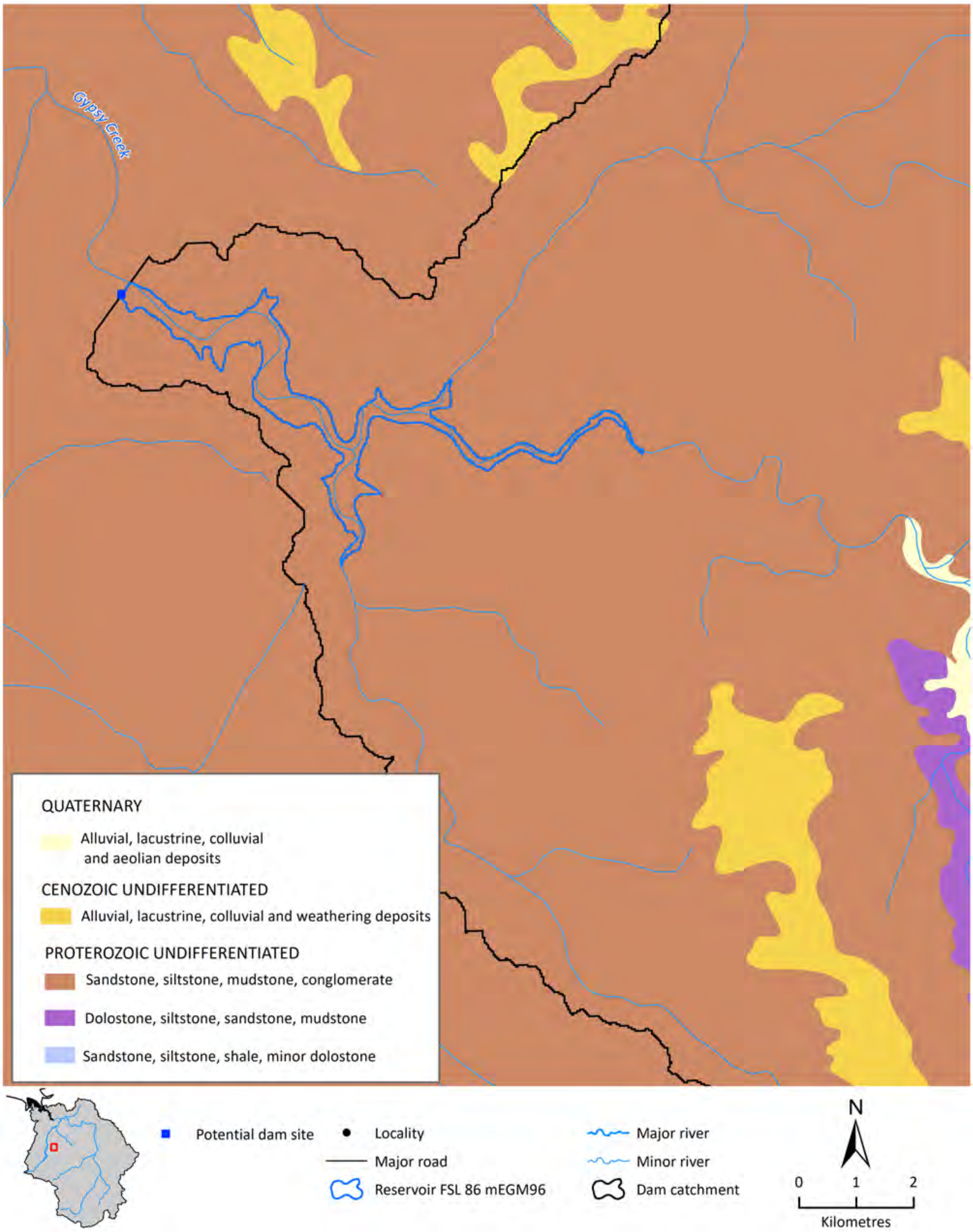


Apx Figure B-21 Location map of potential Gipsy Creek dam site, reservoir extent and catchment area

AEP = annual exceedance probability.

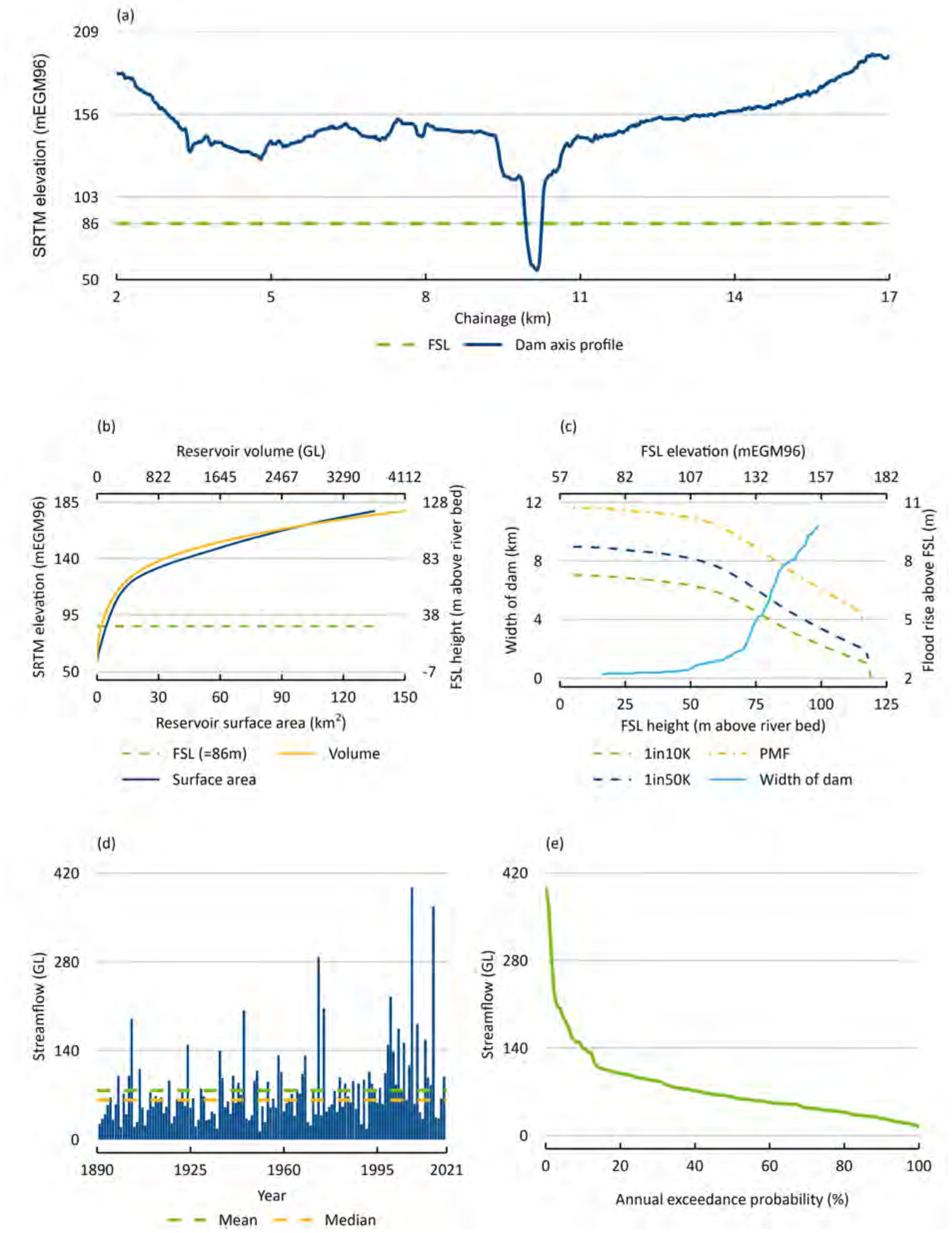
Apx Figure B-22 Potential Gipsy Creek dam reservoir

AEP = annual exceedance probability.



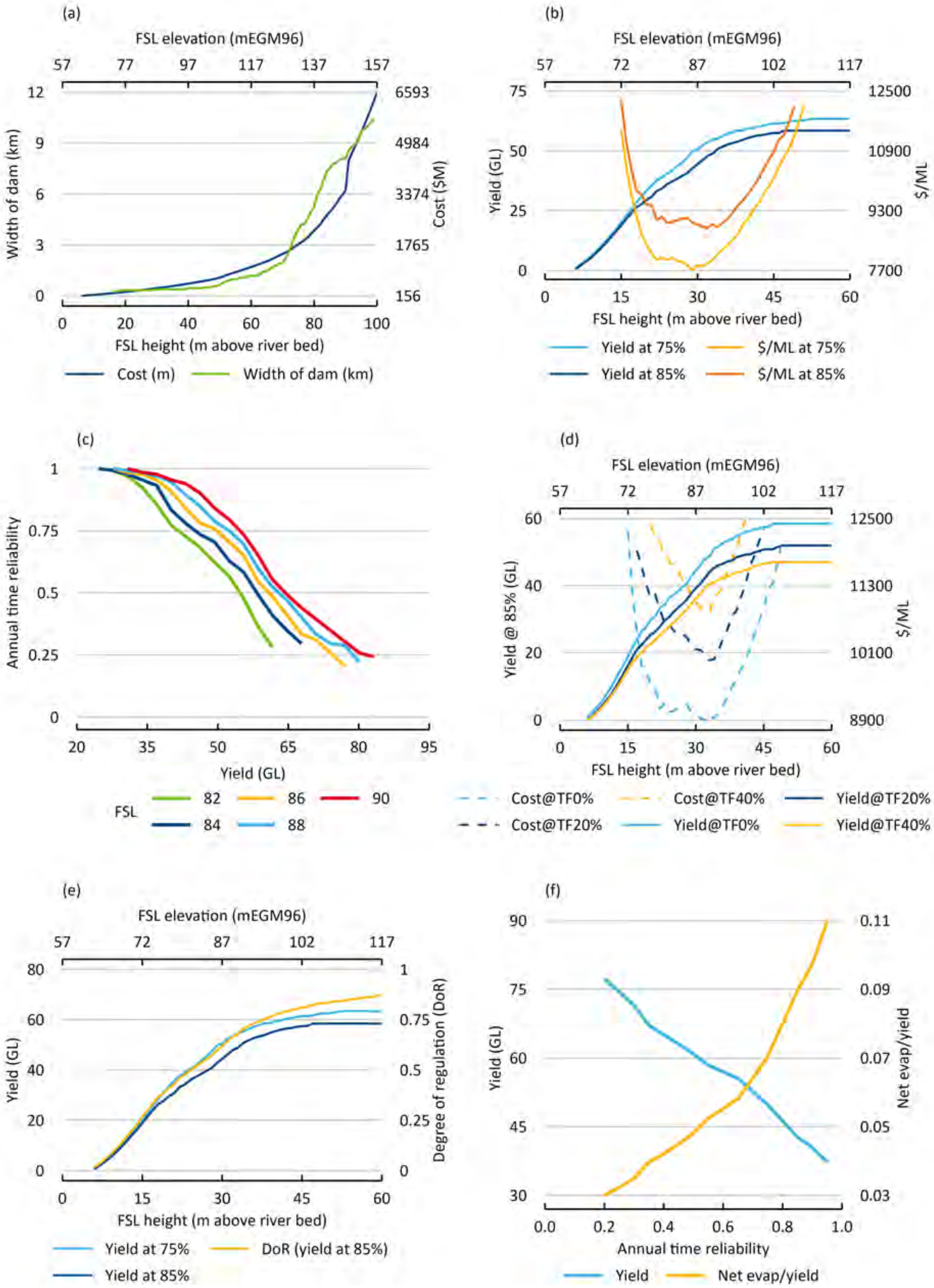
Apx Figure B-23 Geology underlying the potential Gipsy Creek dam site and reservoir

AEP = annual exceedance probability.



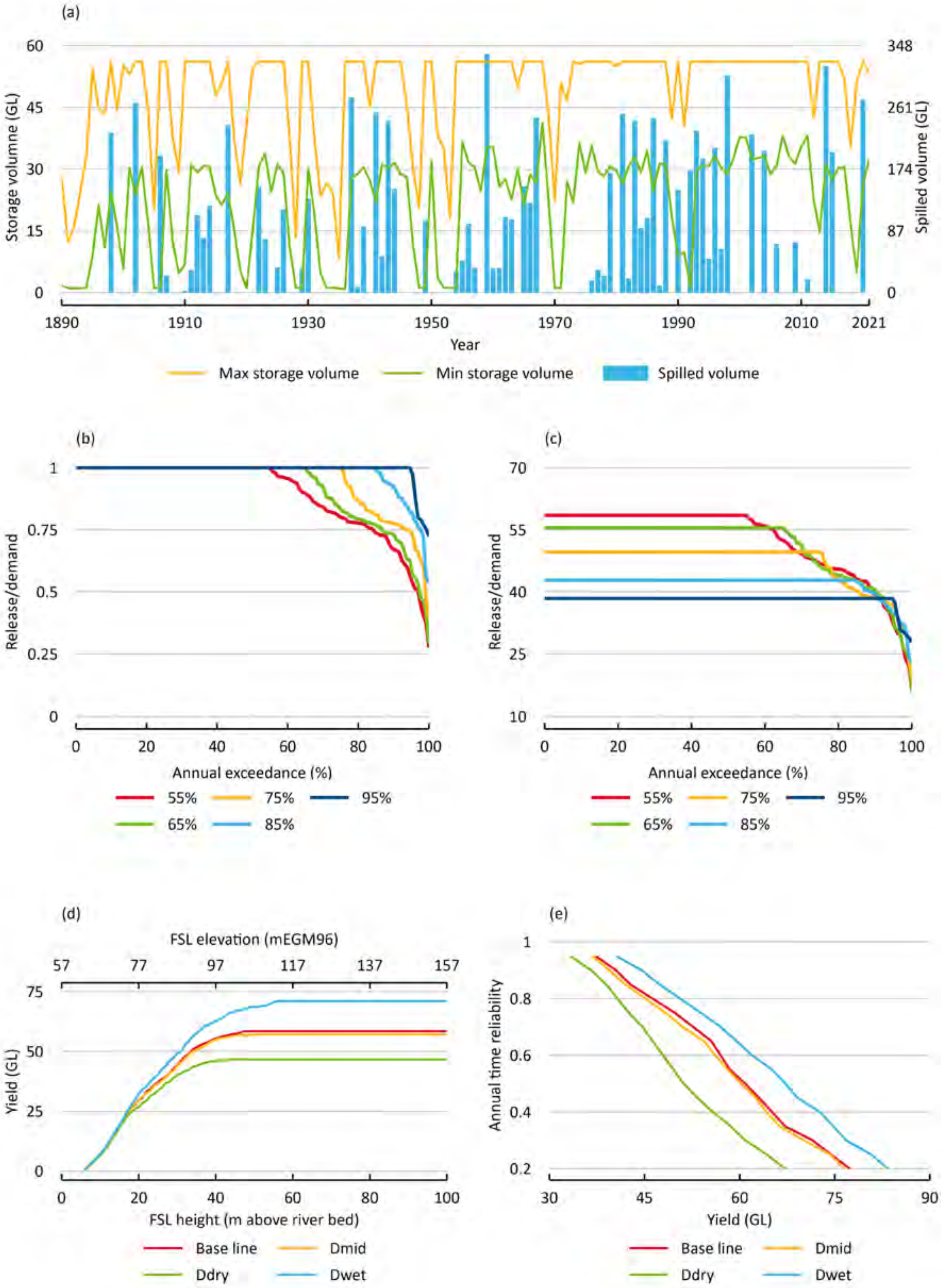
Apx Figure B-24 Gipsy Creek potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



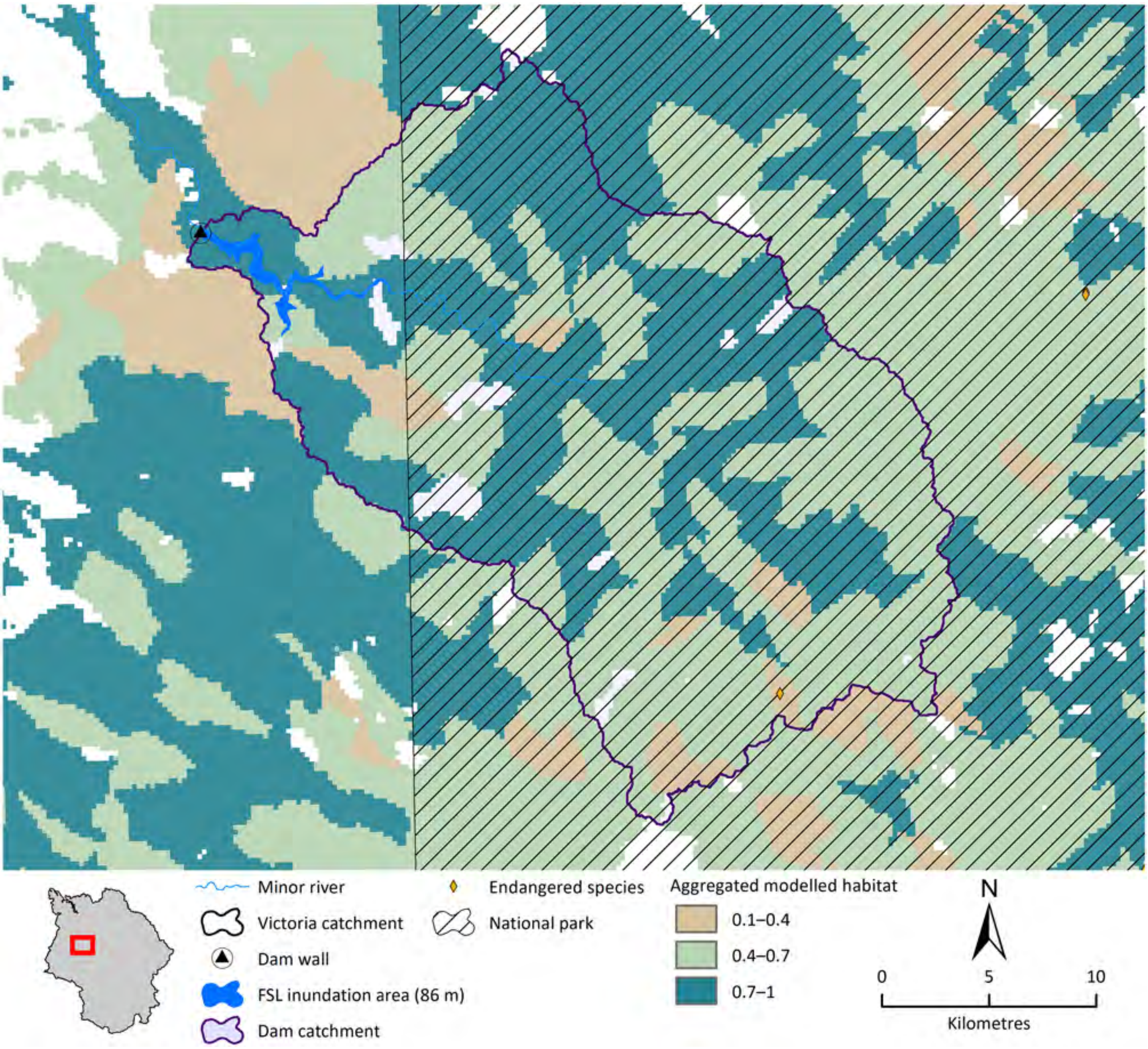
Apx Figure B-25 Gipsy Creek potential dam site cost, water yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-26 Gipsy Creek potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 86 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-27 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Gipsy Creek dam site

FSL = full supply level.

B.2 Southern Gulf catchments

B.2.1 Nicholson River AMTD 198 km (Site 3) FSL 108 mEGM96

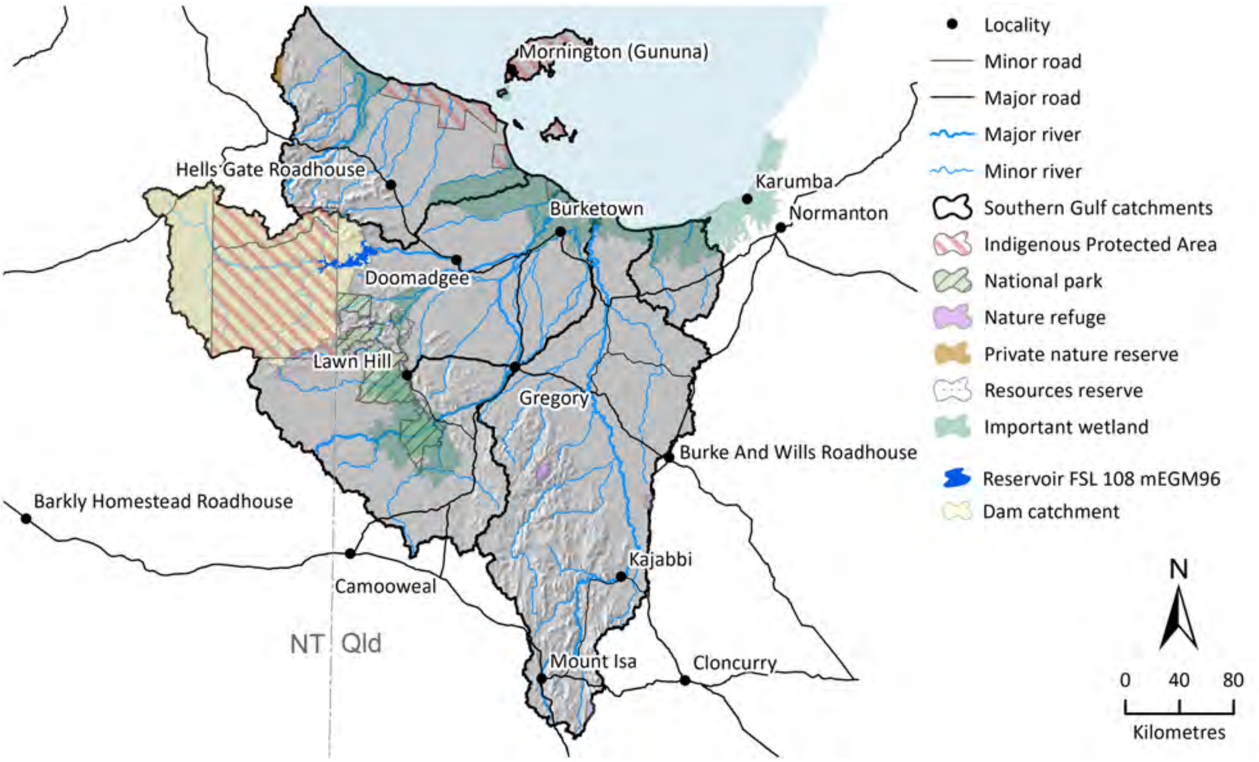
PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies at or near this site were identified in web-based searches or searches of Queensland Government databases.
Description of potential dam	The hypothetical Nicholson River AMTD 198 km dam site is an instream development with potential to release water for irrigation along the Nicholson River. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 108 mEGM96. Apx Figure B-28 and Apx Figure B-29 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, basalt were followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains and coastal deposits, where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (Apx Figure B-30) and satellite imagery. The dam site is located on Proterozoic rocks of the Constance Sandstone (Psa), which consists of white and reddish brown, medium quartz sandstone with scattered pebbles and cobble conglomerate lenses and appeared to be gently folded and outcropping extensively on both abutments. The shape of the upper slopes suggests a planation surface with structurally controlled erosion having removed the weathering profiles and produced well-defined fault lineaments. The river bed was 80-m wide, with ponded water and no alluvium visible. A swampy area occurs downstream. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 3–5 m of alluvium in the river bed and 3–5 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Storage appears stable and watertight but is underlain by the Fickling Group, which contains dolomites that could provide leakage paths to downstream. Nearby swampy areas could be groundwater inflows and/or outflows. May need to carefully consider regional groundwater conditions.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 110-m-wide central uncontrolled spillway. The abutments would be set at a PMF peak storage level, given the township of Doomadgee is downstream of the dam, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the left abutment of the dam. A fish lift transfer facility would also be installed in the left abutment of the dam.

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td></td><td>Access to the site from Doomadgee would require upgrading of some 70 km of tracks to the Kingfisher Camp area and a further 4 km of new road to the dam site. The total distance to the site from Mount Isa would be some 545 km.</td></tr>
<tr><td>Availability of construction materials</td><td>Assume coarse aggregate might be won and processed from a quarry or river bed within 20 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 20 km of the dam site. For estimating purposes, assume a ratio of useful aggregate excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Mount Isa.</td></tr>
<tr><td>Catchment area</td><td>13,870 km^2</td></tr>
<tr><td>Modelled annual inflow data</td><td>
<table>
<tr><th>Parameter</th><th>Scenario A (GL/y)</th><th>Scenario Cdry (GL/y)</th><th>Scenario Cmid (GL/y)</th><th>Scenario Cwet (GL/y)</th></tr>
<tr><td>Max</td><td>4565</td><td>2957</td><td>4112</td><td>5605</td></tr>
<tr><td>Mean</td><td>649</td><td>430</td><td>583</td><td>814</td></tr>
<tr><td>Median</td><td>267</td><td>149</td><td>240</td><td>390</td></tr>
<tr><td>Min</td><td>30</td><td>25</td><td>25</td><td>34</td></tr>
</table>
</td></tr>
<tr><td>Reservoir characteristics</td><td>Reservoirs with FSLs of selected heights are tabulated below.
<table>
<tr><th>FSL (mEGM96)</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>106</td><td>10,985</td><td>1,169</td></tr>
<tr><td>108</td><td>12,417</td><td>1,403</td></tr>
<tr><td>110</td><td>13,936</td><td>1,666</td></tr>
</table>
</td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>FSL of 106 mEGM96 – estimated yield at 85% annual time reliability = 272 GL
FSL of 108 mEGM96 – estimated yield at 85% annual time reliability = 289 GL
FSL of 110 mEGM96 – estimated yield at 85% annual time reliability = 303 GL
Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-31, Apx Figure B-32 and Apx Figure B-33.</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at a FSL of 108 mEGM96</td><td>
<table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>1.0</td><td>1.6</td><td>1.7</td></tr>
<tr><td>100 years (%)</td><td>3.5</td><td>5.2</td><td>5.8</td></tr>
<tr><td>Years to fill</td><td>2886</td><td>1924</td><td>1731</td></tr>
</table>
</td></tr>
<tr><td>Potential use of supply</td><td>The dam site is located on the Nicholson River upstream of the Doomadgee Plain and Doomadgee. These plains are made up of a deeply weathered Cenozoic land surface. Further downstream more recent alluvial sediments have accumulated on the Nicholson floodplain.
Cracking clay (SGG 9) and shallow (SGG 7) soils have formed on the Doomadgee Plain. Red sandy (SGG 6.1), red loamy (SGG 4.1) and cracking clay (SGG 9) soils have formed on the Nicholson floodplain.
All soils are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated sandalwood (Santalum spp.) plantations. The red sandy (SGG 6.1) and loamy (SGG 4.1) soils are suitable, with minor limitations (Class 2), for dry-season spray-irrigated perennial grasses and suitable, with moderate limitations (Class 3), for dry-season spray-irrigated annual grasses, small-seeded crops and root crops and dry-season trickle-irrigated tree crops, citrus, intensive horticulture and wet-season spray-irrigated oilseed crops.
The cracking clay (SGG 9) soils are suitable, with minor limitations (Class 2), for dry-season spray-irrigated annual grasses and root crops, dry-season trickle-irrigated tree crops, intensive horticulture and wet-season spray-irrigated oilseed. The cracking clay (SGG 9) soils are also suitable, with moderate limitations (Class 3), for dry-season spray-irrigated perennial grasses and dry-season furrow-irrigated pulse crops and leguminous hay or forage crops.</td></tr>
</table>

PARAMETER	DESCRIPTION
Impacts	
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** In this potential dam site there were records for spangled grunter (*Leiopotherapon unicolor*), sooty grunter (*Hephaestus fuliginosus*) and eastern rainbow fish (*Melanotaenia splendida*). In addition to these species, in the neighbouring streams there are records of mouth almighty (*Glossamia aprion*). The models predict that ~12% of the catchment (169,005 ha) has suitable habitat for at least 40% of the species. The modelled suitable habitat for these water-dependent species upstream of the potential dam site varies significatively, depending on the species, and ranges from zero % to 23% of their total modelled suitable habitat in the Southern Gulf catchments. These species may have fragmented habitat and/or have movement impeded by a dam. Some of the potential reservoir at the nominated FSL is within the Ganalanga-Mindibirrina Indigenous Protected Area. Boodjamulla (Lawn Hill) National Park and Lawn Hill (Stockyard Creek), Lawn Hill (Littles Range) and Lawn Hill (Arthur Creek) Resources reserves border the potential dam site to the south-east. Apx Figure B-34 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Nicholson River (AMTD 198 km) site. **Ecological implications of inundation** In the catchment of this potential dam site several listed species occur, for example, the northern quoll (*Dasyurus hallucatus*), listed as endangered in the EPBC Act and as critically endangered in the NT; the Carpentarian grasswren (*Amytornis dorotheae*), endangered at federal and territory level; and the northern brush-tailed phascogale (*Phascogale pirata*), vulnerable in the EPBC Act and endangered in the NT. Three species of monitors, listed as vulnerable in the NT have also been recorded in the potential dam site: Mertens' water monitor (*Varanus mertensi*), Mitchell's water monitor (*Varanus mitchelli*) and the yellow-spotted monitor (*Varanus panoptes*). Waterbirds such as the royal spoonbill (*Platalea regia*), the western cattle egret (*Bubulcus ibis*) and magpie goose (*Anseranas semipalmata*) occur downstream of the dam wall. The potential inundated area at FSL for this site (108 mEGM96) may have an effect on these species. The inundation extent of this potential dam site overlaps with parts of the Ganalanga-Mindibirrina Indigenous Protected Area. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 106 mEGM96 – estimated cost = $3082 million FSL of 108 mEGM96 – estimated cost = $3344 million FSL of 110 mEGM96 – estimated cost = $3668 million.
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 106 mEGM96 – estimated cost/ML of supply = $11,340/ML FSL of 108 mEGM96 – estimated cost/ML of supply = $11,569/ML FSL of 110 mEGM96 – estimated cost/ML of supply = $12,089/ML

PARAMETER	DESCRIPTION
Summary comment	This potential dam site is the most expensive of those on the short-list and is a considerable distance upstream of the soil potentially suitable for irrigated agriculture. Furthermore, the site is very remote and access would require considerable additional infrastructure. At the adopted FSL, the inundation extent of this potential dam site overlaps with parts of the Ganalanga-Mindibirrina Indigenous Protected Area. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. Asset models predicted that 46% of the catchment has habitat suitable for at least one of the ten modelled migratory species, which constitutes zero % to 6.4% of the total habitat modelled as suitable in the Southern Gulf catchments.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; PMF = probable maximum flood; RCC = roller compacted concrete.

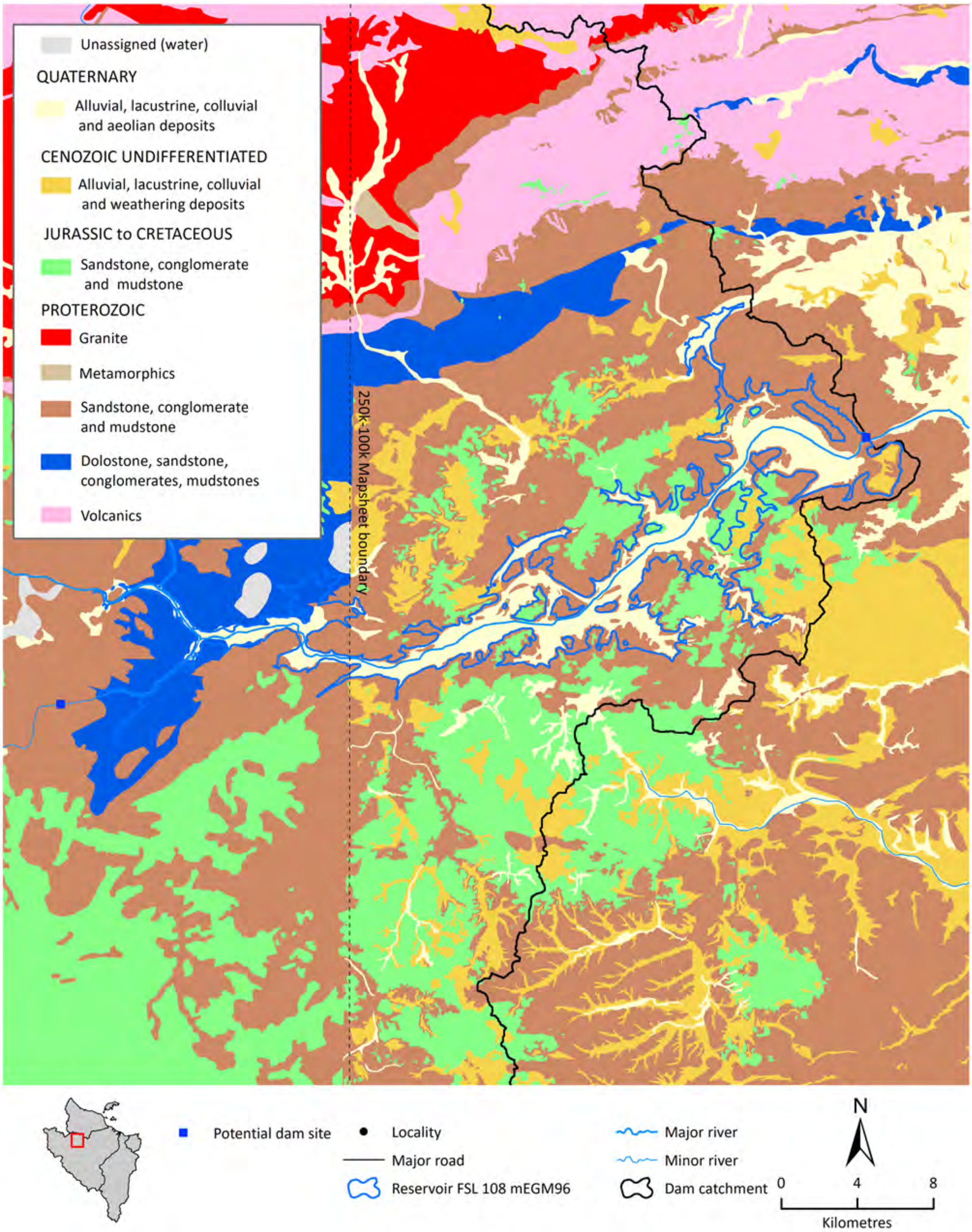


Apx Figure B-28 Location map of potential Nicholson River dam site, reservoir extent and catchment area

AEP = annual exceedance probability.

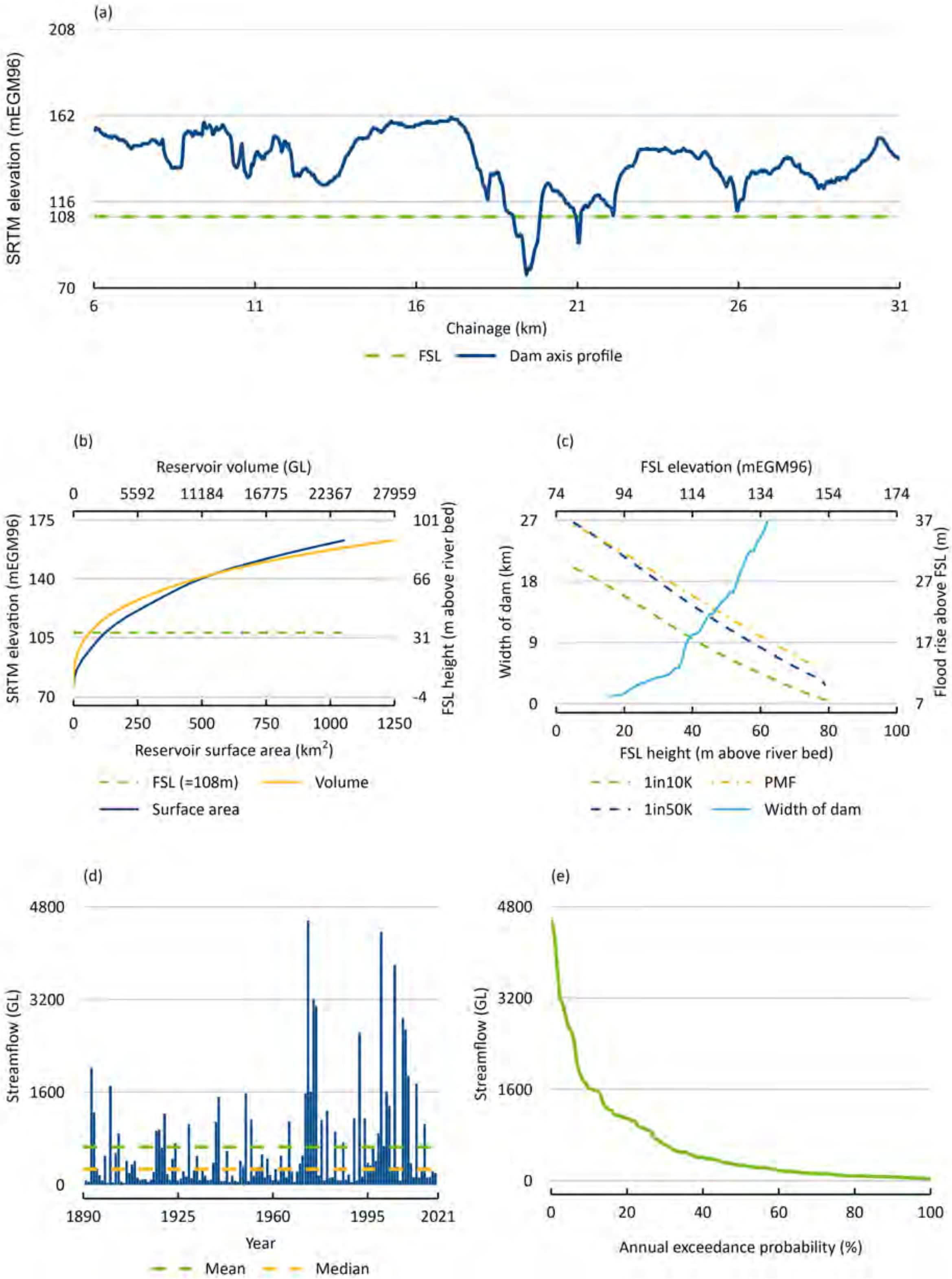
Apx Figure B-29 Potential Nicholson River dam reservoir

AEP = annual exceedance probability.



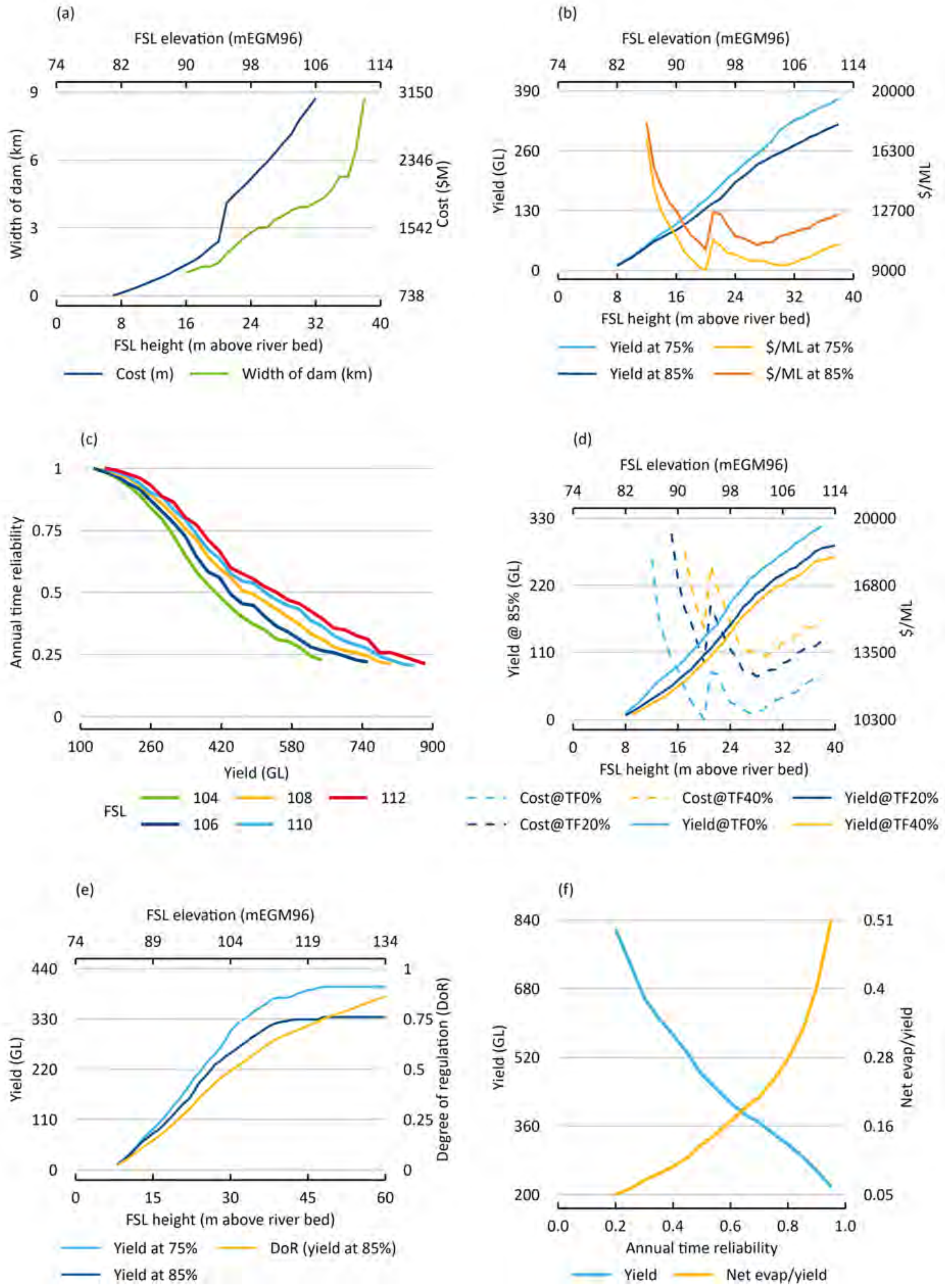
Apx Figure B-30 Geology underlying the potential Nicholson River dam site and reservoir

AEP = annual exceedance probability.



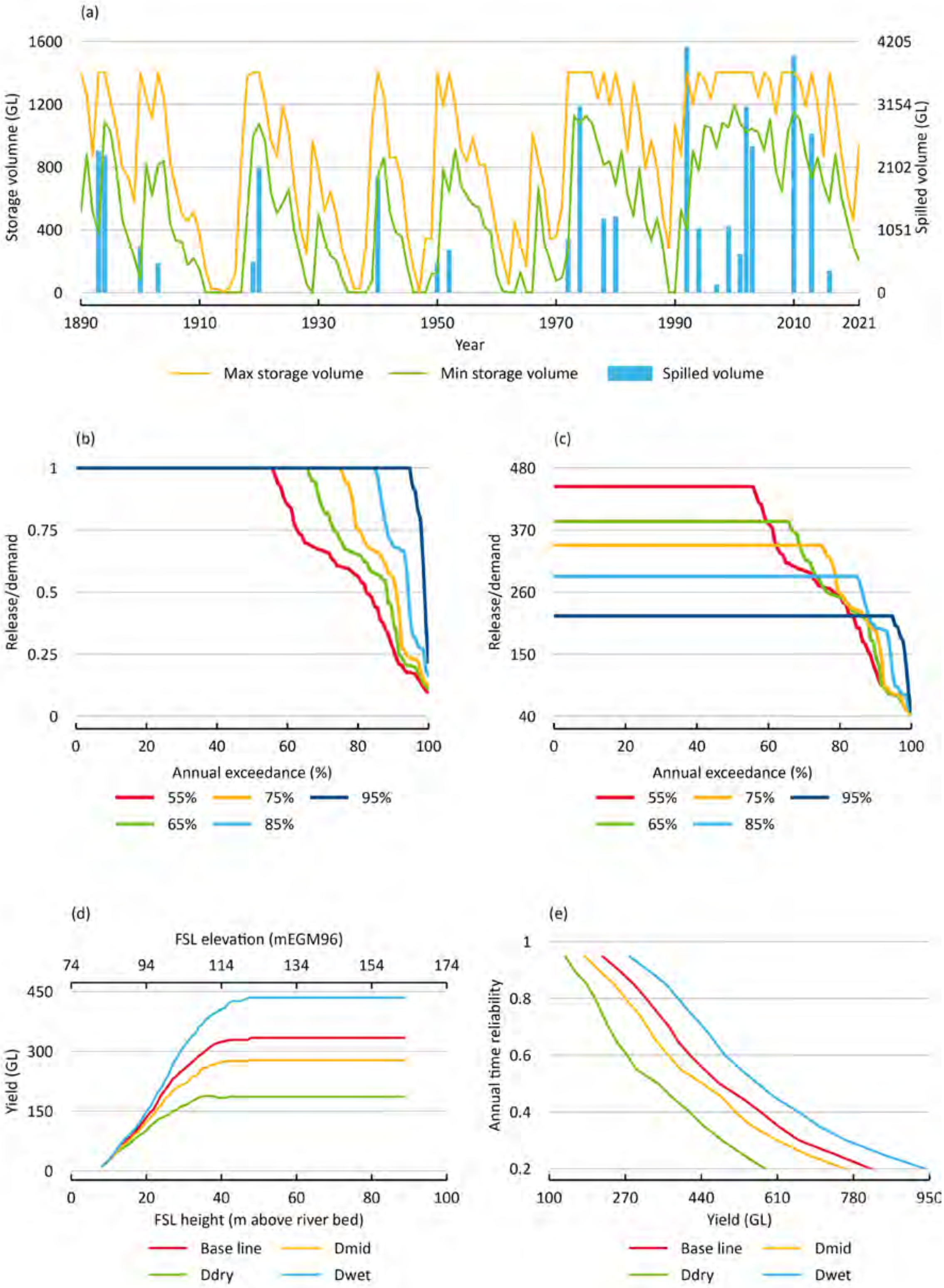
Apx Figure B-31 Nicholson River dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



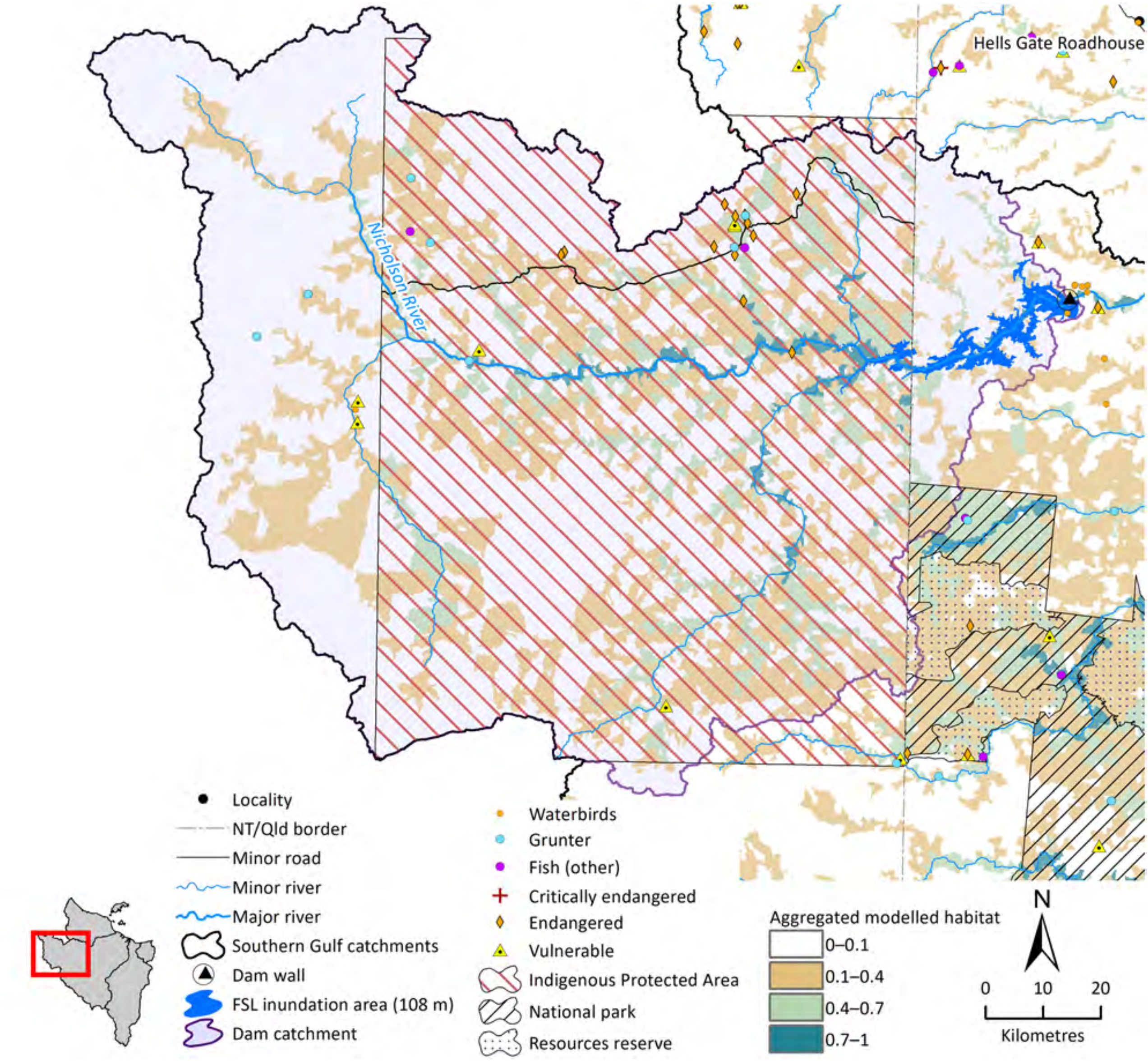
Apx Figure B-32 Nicholson River potential dam site cost, yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-33 Nicholson River potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 108 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-34 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Nicholson River dam site

FSL = full supply level.

B.2.2 South Nicholson River AMTD 9 km (Site 290) FSL 162 mMG96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies at or near this site were identified in web-based searches or searches of Queensland Government databases.
Description of potential dam	The hypothetical South Nicholson River AMTD 9 km dam site is an instream development with potential to provide irrigation supplies for riparian pumping along the Nicholson River. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 162 mEGM96. Apx Figure B-35 and Apx Figure B-36 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, basalt was followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains, and coastal deposits where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Apx Figure B-37) and satellite imagery. The dam site is located on Proterozoic rocks of the Burangoo Sandstone Member (Psc_u), which consists of white to pale yellow, silicified to friable, fine- to coarse-grained, quartzose to sublithic sandstone, with minor scattered granules and rare small pebbles of quartz. It appeared to be gently folded and outcropping on both abutments. There is a pronounced fault offset downstream of the dam site. The shape of the upper slopes suggests a planation surface, with structurally controlled erosion having removed the weathering profiles and produced extensive outcrop with well-defined fault lineaments and ablation/weathering hollows. The river bed was 50-m wide, with ponded water and possible rock bars. No alluvium was visible, and a swampy area occurs downstream. The foundations appeared to be suitable for a rRCC dam. For estimating purposes, assume 2–3 m of alluvium in the river bed and 3–5 m of stripping on the abutments.
Reservoir rim stability and leakage potential	Storage appears stable and watertight but is underlain by the Fickling Group, which contains dolomites that could provide leakage paths to downstream. Nearby swampy areas could be groundwater inflows and/or outflows. May need to carefully consider regional groundwater conditions.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 40-m-wide central uncontrolled spillway. The abutments would be set at a 1:50,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows.

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td></td><td>Releases downstream of the dam would be made via pipework installed in a diversion channel located in the left abutment of the dam. A fish lift transfer facility would also be installed in the left abutment of the dam.

The dam site is very remote and best access to it requires further studies. One option to access the site would involve access from Doomadgee, which would require upgrading of some 70 km of tracks to the Kingfisher Camp area and a further 54 km of new road to the dam site. The total distance to the site from Mount Isa via this route would be some 595 km.</td></tr>
<tr><td>Availability of construction materials</td><td>Assume coarse aggregate might be won and processed from a quarry or river bed within 20 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 20 km of the dam site. For estimating purposes, assume a ratio of useful aggregate excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Mount Isa.</td></tr>
<tr><td>Catchment area</td><td>3113 km^2</td></tr>
<tr><td>Modelled annual inflow data</td><td>
<table>
<tr><th>Parameter</th><th>Scenario A (GL/y)</th><th>Scenario Cdry (GL/y)</th><th>Scenario Cmid (GL/y)</th><th>Scenario Cwet (GL/y)</th></tr>
<tr><td>Max</td><td>1022</td><td>645</td><td>923</td><td>1255</td></tr>
<tr><td>Mean</td><td>116</td><td>75</td><td>104</td><td>147</td></tr>
<tr><td>Median</td><td>44</td><td>16</td><td>29</td><td>68</td></tr>
<tr><td>Min</td><td>6</td><td>5</td><td>5</td><td>7</td></tr>
</table>
</td></tr>
<tr><td>Reservoir characteristics</td><td>Storages with full supply levels (FSLs) of selected heights are tabulated below.
<table>
<tr><th>FSL</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>160</td><td>4277</td><td>290</td></tr>
<tr><td>162</td><td>4923</td><td>382</td></tr>
<tr><td>164</td><td>5562</td><td>487</td></tr>
</table>
</td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>FSL of 160 mEGM96 – estimated yield at 85% annual time reliability = 38 GL
FSL of 162 mEGM96 – estimated yield at 85% annual time reliability = 42 GL
FSL of 164 mEGM96 – estimated yield at 85% annual time reliability = 42 GL
Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-38, Apx Figure B-39 and Apx Figure B-40.</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at a FSL of 162 mEGM96</td><td>
<table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>0.9</td><td>1.3</td><td>1.5</td></tr>
<tr><td>100 years (%)</td><td>3.0</td><td>4.5</td><td>5.0</td></tr>
<tr><td>Years to fill</td><td>3347</td><td>2231</td><td>2008</td></tr>
</table>
</td></tr>
<tr><td>Potential use of supply</td><td>The dam site is located on South Nicholson Creek, a tributary of the Nicholson River. The Nicholson River emerges onto the Carpentaria plains upstream of Doomadgee on the Doomadgee Plain. These plains are made up of a deeply weathered Cenozoic land surface. Further downstream, more recent alluvial sediments have accumulated on the Nicholson floodplain.

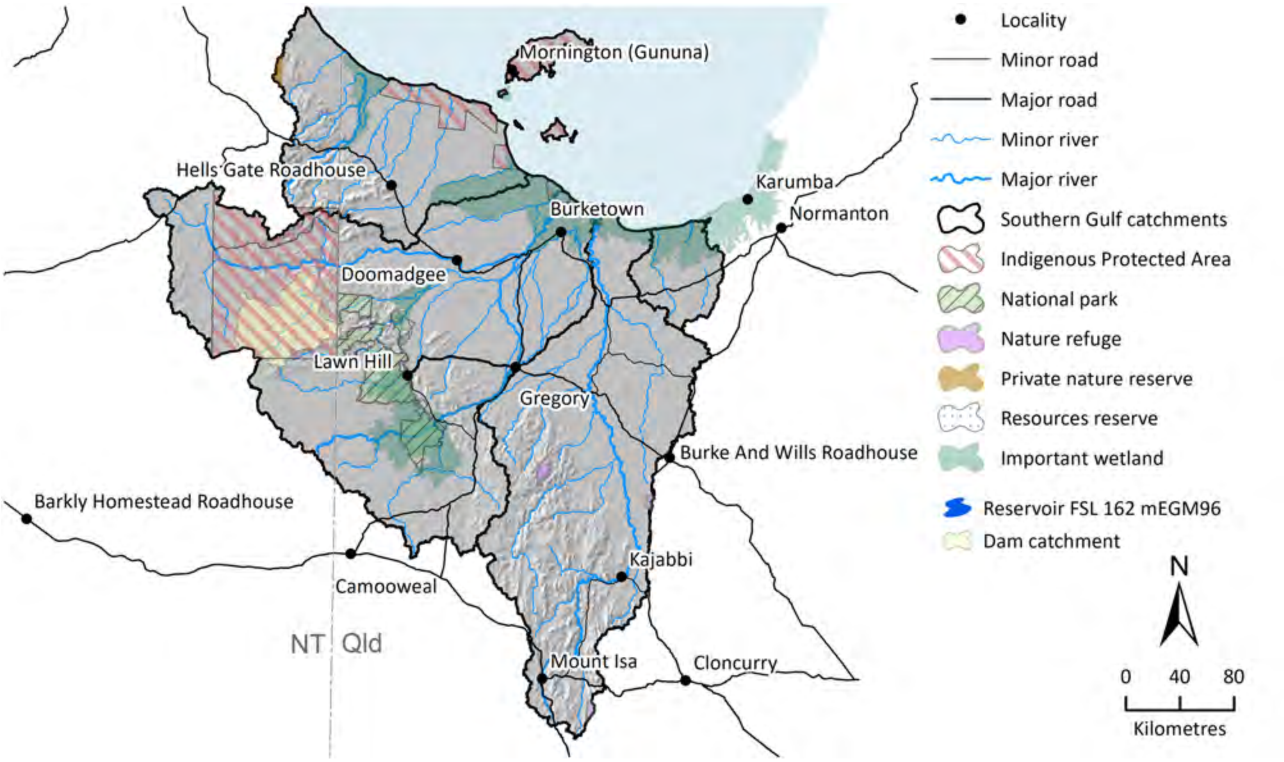
Cracking clay soils (SGG 9) and shallow soils (SGG 7) have formed on the Doomadgee Plain. Red sandy (SGG 6.1), red loamy (SGG 4.1) and cracking clay (SGG 9) soils have formed on the Nicholson floodplain.

All soils are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated sandalwood (Santalum spp.) plantations. The red sandy (SGG 6.1) and loamy (SGG 4.1) soils are suitable, with minor limitations (Class 2), for dry-season spray-irrigated perennial grasses and suitable, with moderate limitations (Class 3), for dry-season spray-irrigated annual grasses, small-seeded crops and root crops and dry-season trickle-irrigated tree crops, citrus, intensive horticulture and wet-season spray-irrigated oilseed crops.</td></tr>
</table>

PARAMETER	DESCRIPTION
	The cracking clay (SGG 9) soils are suitable, with minor limitations (Class 2), for dry-season spray-irrigated annual grasses and root crops, dry-season trickle-irrigated tree crops, intensive horticulture and wet-season spray-irrigated oilseed. The cracking clay (SGG 9) soils are also suitable, with moderate limitations (Class 3), for dry-season spray-irrigated perennial grasses and dry-season furrow-irrigated pulse crops and leguminous hay or forage crops.
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** There were no records for ecology assets at this site. However, the asset models predict that ~14% of the catchment (43,749 ha) has suitable habitat for at least 40% of the species, some of which are found in neighbouring streams, including the Gulf snapping turtle (*Elseya lavarackorum*), the spangled grunter (*Leiopotherapon unicolor*), sooty grunter (*Hephaestus fuliginosus*), western rainbow fish (*Melanotaenia australis*) and mouth almighty (*Glossamia aprion*). The modelled suitable habitat for these water-dependent species upstream of the potential dam site is relatively small, depending on the species, and ranges from zero % to 6.4% of their total modelled suitable habitat in the Southern Gulf catchments. These species may have fragmented habitat and/or have movement impeded by a dam. Most of this potential dam site is within the Ganalanga-Mindibirrina Indigenous Protected Area. Boodjamulla (Lawn Hill) National Park and Lawn Hill (Stockyard Creek) and Lawn Hill (Littles Range) Resources reserves border the potential dam site to the east. Apx Figure B-41 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential South Nicholson River (AMTD 9 km) site. **Ecological implications of inundation** One listed species has been recorded upstream of the catchment of this potential dam site, the Mitchell's water monitor (*Varanus mitchelli*), listed as vulnerable in the NT. Other listed species occurring in the vicinity of this potential dam site are: the northern quoll (*Dasyurus hallucatus*), listed as endangered in the EPBC Act and as critically endangered in the NT; the grey falcon (*Falco hypoleucos*), red goshawk (*Erythrotriorchis radiatus*) and painted honeyeater (*Grantiella picta*), all listed as vulnerable (EPBC Act and NT); the Carpentarian grasswren (*Amytornis dorotheae*), endangered at federal and territory level; the Carpentarian rock-rat (*Zyzomys palatalis*), listed as endangered (EPBC Act); and the northern brush-tailed phascogale (*Phascogale pirata*) and the Gouldian finch (*Chloebia gouldiae*), both listed as endangered (EPBC Act) and vulnerable (NT); Mertens' water monitor (*Varanus mertensi*) and the yellow-spotted monitor (*Varanus panoptes*). Waterbirds such as the royal spoonbill (*Platalea regia*), the western egret (*Bubulcus ibis*) and the magpie goose (*Anseranas semipalmata*) also occur near this site. The potential inundated area at FSL for this site (162 mEGM96) may have an effect on these species. The inundation extent of this potential dam site overlaps with parts of the Ganalanga–Mindibirrina Indigenous Protected Area. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 160 mEGM96 – estimated cost = $1025 million FSL of 162 mEGM96 – estimated cost = $1089 million FSL of 164 mEGM96 – estimated cost = $1155 million.
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows:

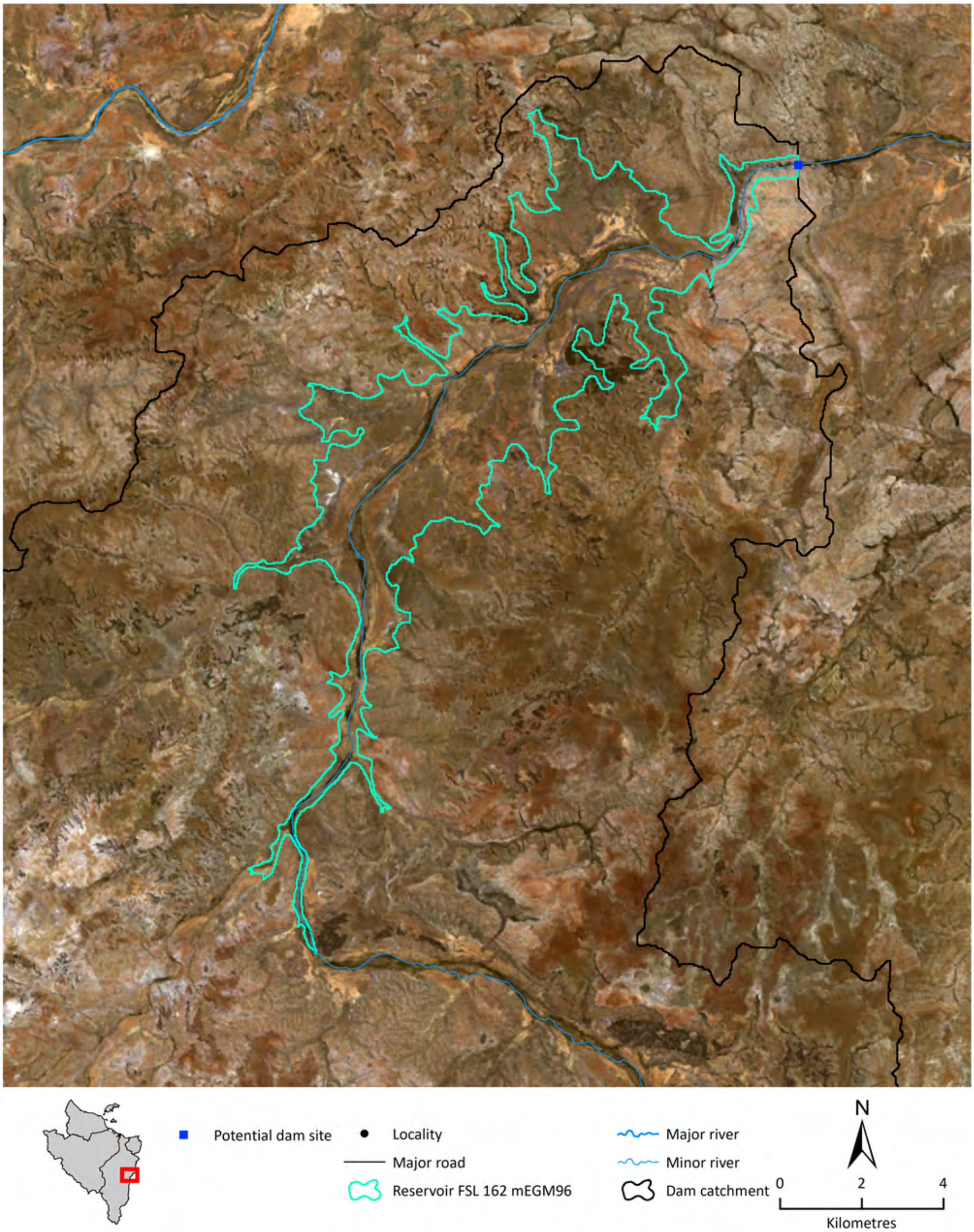
PARAMETER	DESCRIPTION
	FSL of 160 mEGM96 – estimated cost/ML of supply = $26,864/ML FSL of 162 mEGM96 – estimated cost/ML of supply = $26,199/ML FSL of 164 mEGM96 – estimated cost/ML of supply = $27,747/ML
Summary comment	This potential instream development has the potential to release water for irrigation along the Nicholson River to the Doomadgee and Armraynald Plains and Doomadgee. The foundations appeared to be suitable for a RCC dam. Nonetheless, the site is very remote and is one of the more expensive potential dam sites examined in the Southern Gulf catchments. At the adopted FSL, the inundation extent of this potential dam site overlaps with parts of the Ganalanga-Mindibirrina IPA. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.



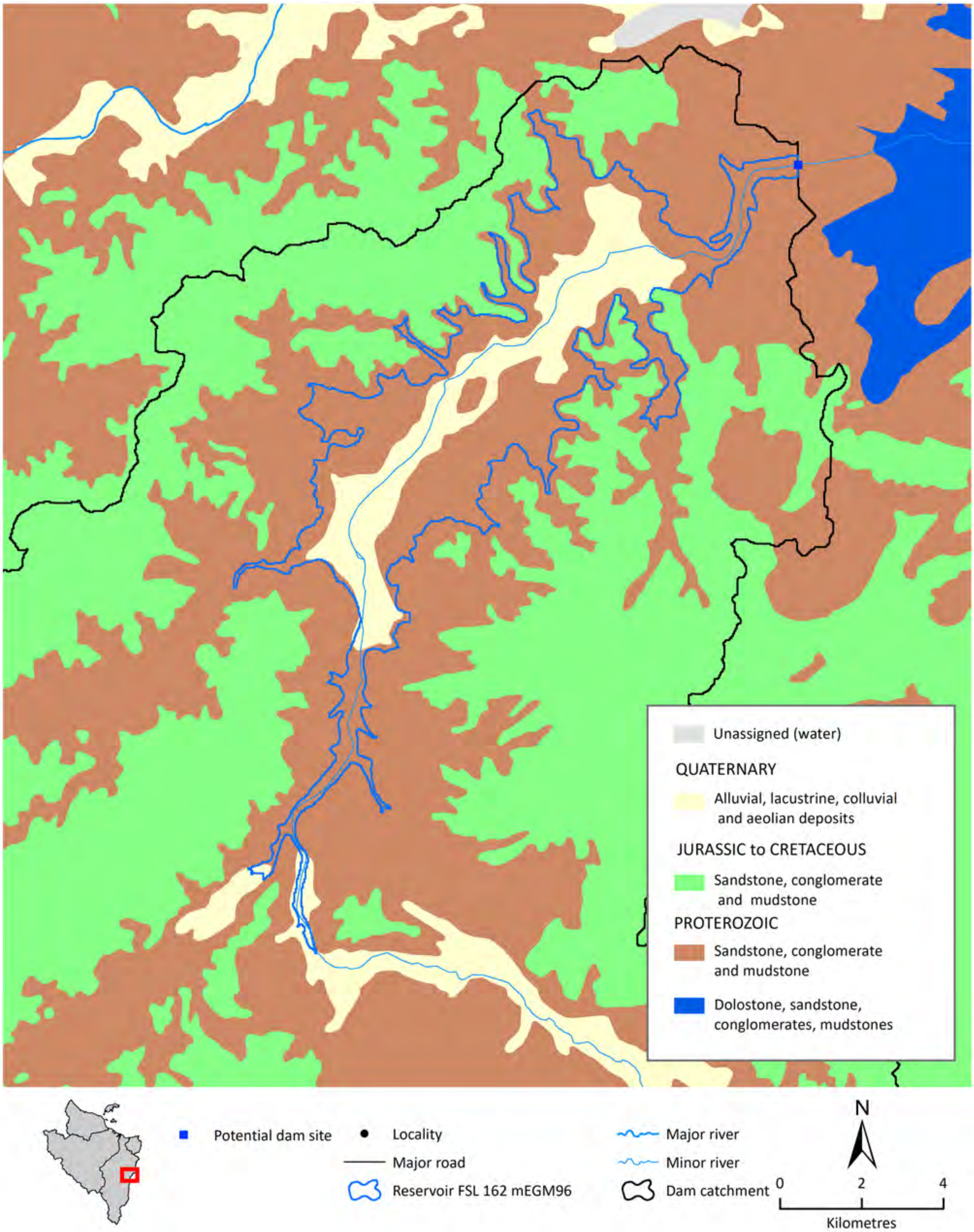
Apx Figure B-35 Location map of potential South Nicholson dam site, reservoir extent and catchment area

AEP = annual exceedance probability.



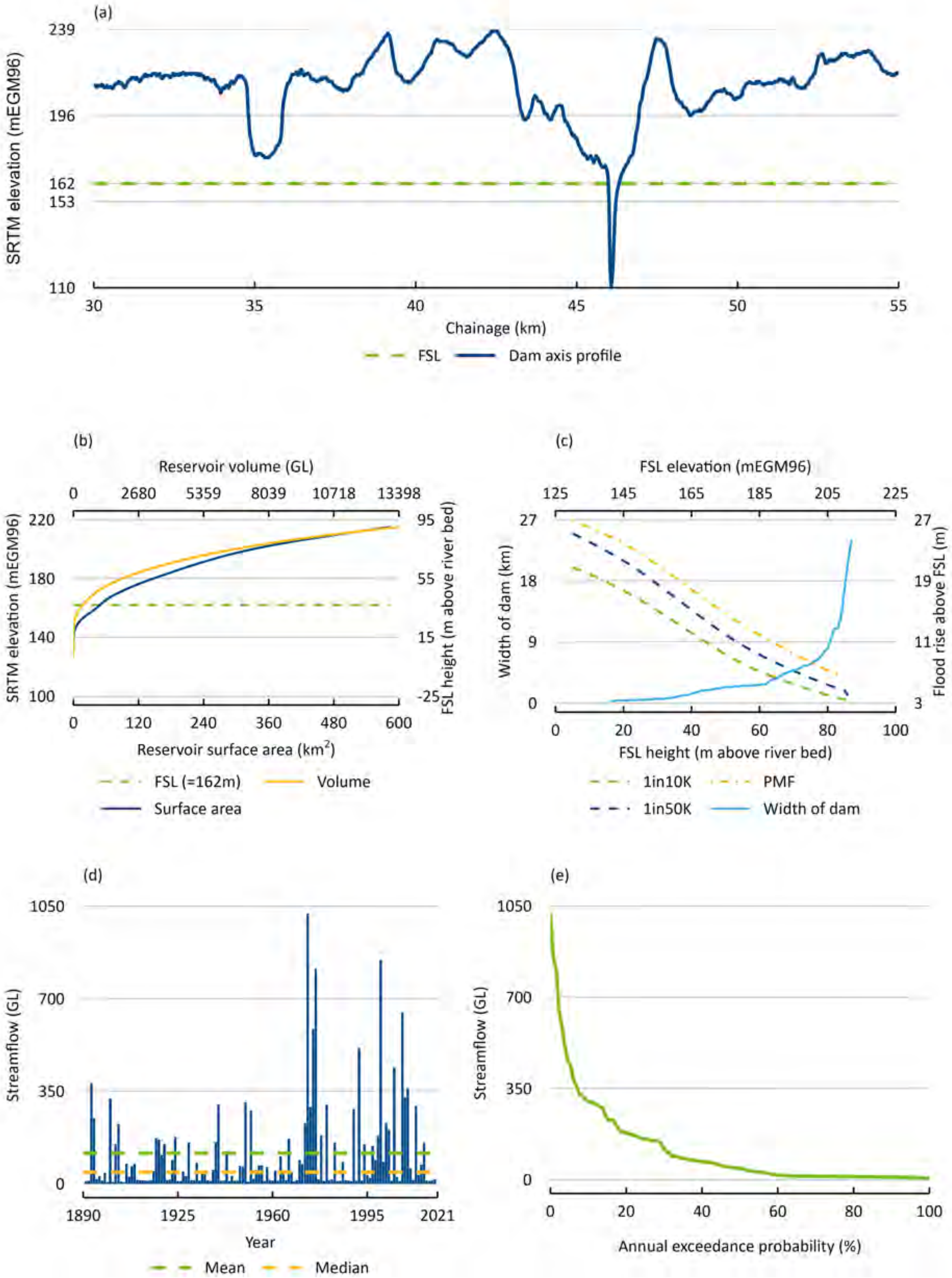
Apx Figure B-36 Potential South Nicholson dam reservoir

AEP = annual exceedance probability.



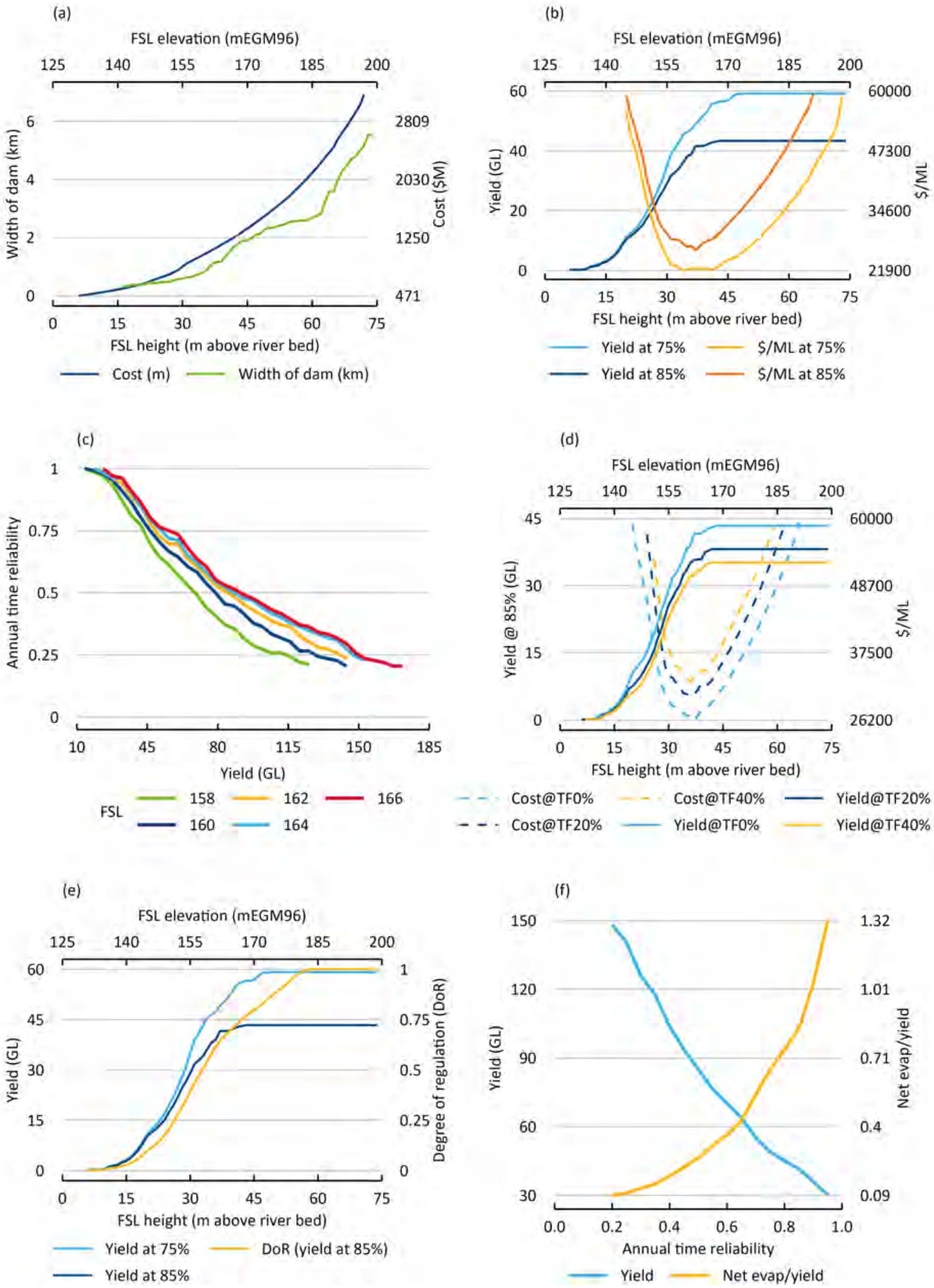
Apx Figure B-37 Geology underlying the potential South Nicholson dam site and reservoir

AEP = annual exceedance probability.



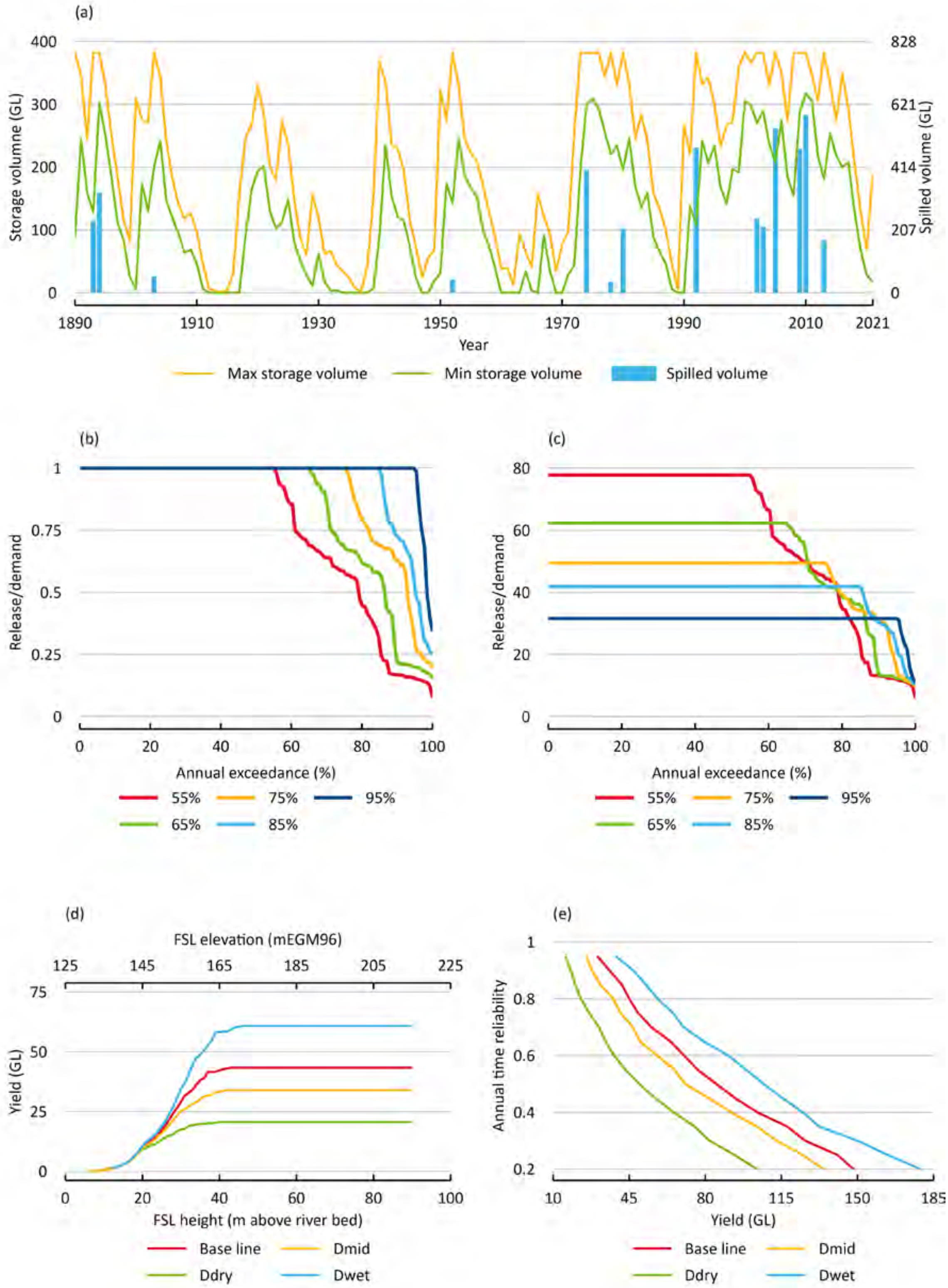
Apx Figure B-38 South Nicholson potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



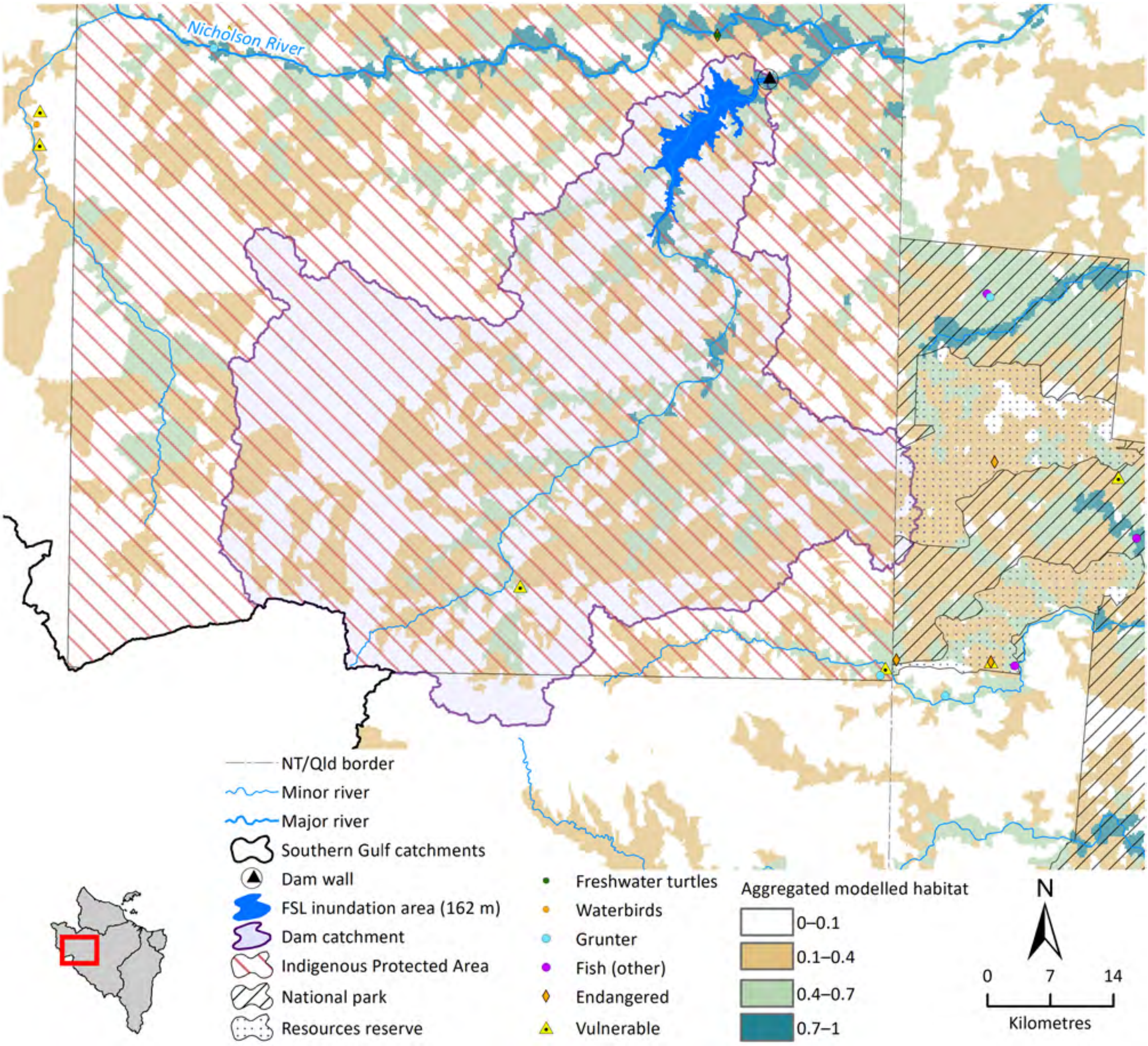
Apx Figure B-39 South Nicholson potential dam site cost, water yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-40 South Nicholson potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 162 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-41 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential South Nicholson dam site

FSL = full supply level.

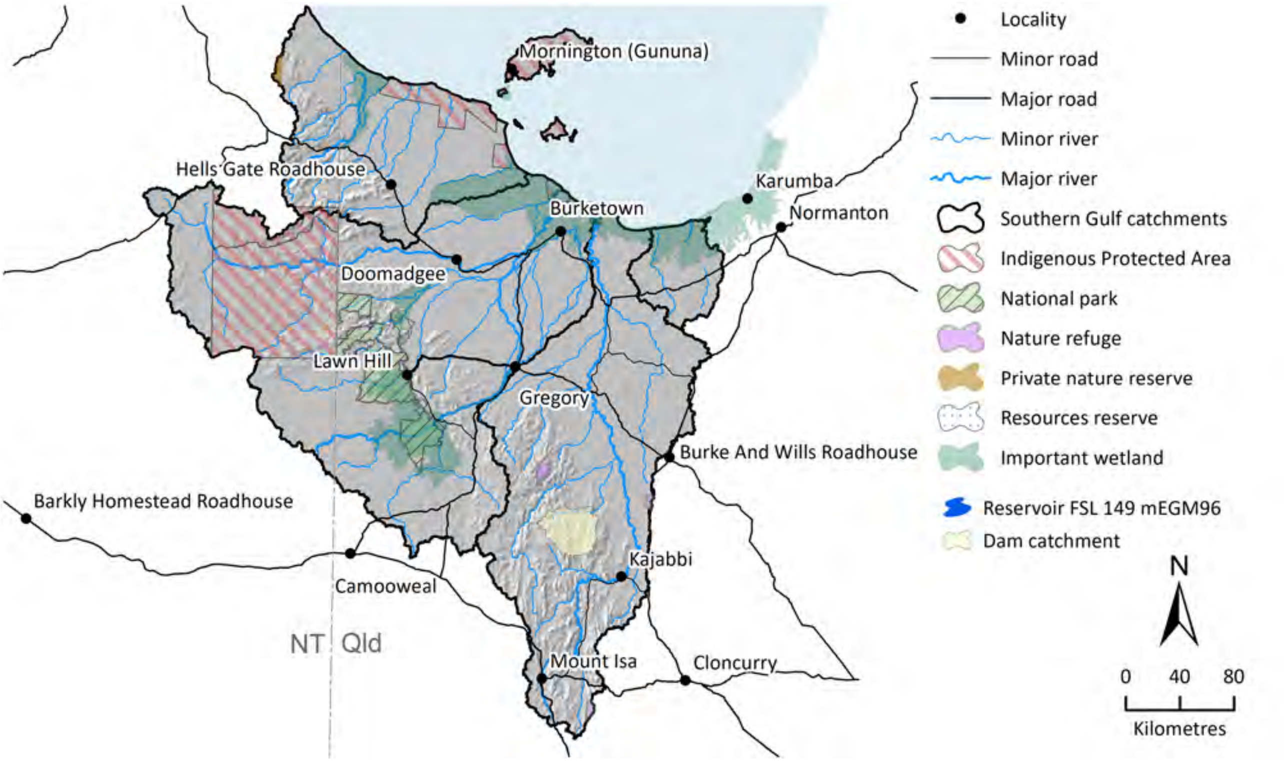
B.2.3 Mistake Creek AMTD 60 km (Site 165) FSL 149 mMG96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies at or near this site were identified in web-based searches or searches of Queensland Government databases.
Description of potential dam	The hypothetical Mistake Creek AMTD 60 km dam site is an instream development. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 149 mEGM96. Apx Figure B-42 and Apx Figure B-43 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, basalt was followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains, and coastal deposits where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Apx Figure B-44) and satellite imagery. The dam site is located on Proterozoic rocks of the Surprise Creek Beds (Plu), which consists of siltstone, sandstone and dolomite, with steeply dipping rocks outcropping extensively on both abutments. The shape of the upper slopes suggests a planation surface with structurally controlled erosion having removed the weathering profiles. The river bed is 20-m wide and has shallow ponded water and rock bars. The foundations appear to be suitable for a RCC dam. For estimating purposes, assume 2–3 m of alluvium in the river bed and 3–5 m of stripping on the abutments. The amount of dolomite rock in the foundation requires consideration, to establish whether it represents a problem due to cavities within dolomite strata.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam would be proposed. The dam would have a 50-m-wide central uncontrolled spillway. The abutments would be set at a 1:10,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the right abutment of the dam. A fish lift transfer facility would also be installed in the right abutment of the dam. Access to the site would require the construction of 45 km of new road, including a bridge across the Leichhardt River branching from the Cloncurry–Normanton Road some 174 km north of Cloncurry. The total distance from the site to Mount Isa would be some 340 km.

<table>
<tr><th>PARAMETER</th><th>DESCRIPTION</th></tr>
<tr><td>Availability of construction materials</td><td>Assume coarse aggregate might be won and processed from a quarry or river bed within 20 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 20 km of the dam site. For estimating purposes, assume a ratio of useful aggregate excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Mount Isa.</td></tr>
<tr><td>Catchment area</td><td>1161 km^2</td></tr>
<tr><td>Modelled annual inflow data</td><td><table>
<tr><th>Parameter</th><th>Scenario A (GL/y)</th><th>Scenario Cdry (GL/y)</th><th>Scenario Cmid (GL/y)</th><th>Scenario Cwet (GL/y)</th></tr>
<tr><td>Max</td><td>700</td><td>555</td><td>686</td><td>792</td></tr>
<tr><td>Mean</td><td>81</td><td>59</td><td>74</td><td>98</td></tr>
<tr><td>Median</td><td>50</td><td>37</td><td>45</td><td>59</td></tr>
<tr><td>Min</td><td>2</td><td>1</td><td>2</td><td>3</td></tr>
</table></td></tr>
<tr><td>Reservoir characteristics</td><td>Storages with FSLs of selected heights are tabulated below.<table>
<tr><th>FSL</th><th>Surface area (ha)</th><th>Capacity (GL)</th></tr>
<tr><td>147</td><td>1841</td><td>116</td></tr>
<tr><td>149</td><td>2320</td><td>158</td></tr>
<tr><td>151</td><td>2900</td><td>210</td></tr>
</table></td></tr>
<tr><td>Reservoir yield assessment at dam wall</td><td>FSL of 147 mEGM96 – estimated yield at 85% annual time reliability = 38 GL
FSL of 149 mEGM96 – estimated yield at 85% annual time reliability = 40 GL
FSL of 151 mEGM96 – estimated yield at 85% annual time reliability = 41 GL
Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-45, Apx Figure B-46 and Apx Figure B-47.</td></tr>
<tr><td>Estimated rates of reservoir sedimentation at a FSL of 149 mEGM96</td><td><table>
<tr><th></th><th>Best case</th><th>Expected</th><th>Worst case</th></tr>
<tr><td>30 years (%)</td><td>0.9</td><td>1.3</td><td>1.4</td></tr>
<tr><td>100 years (%)</td><td>2.8</td><td>4.2</td><td>4.5</td></tr>
<tr><td>Years to fill</td><td>3591</td><td>2394</td><td>2155</td></tr>
</table></td></tr>
<tr><td>Potential use of supply</td><td>Downstream of the potential dam site, the creek emerges onto the Carpentaria Plains; the creek has cut through the Cretaceous Cloncurry plains leaving pediments of colluvial sediments either side of more recent sediments. Near the junction of Gunpowder Creek and the Leichhardt River, a large plain of recent alluvium has formed. Friable non-cracking clay or clay loam soils (SGG 2) and sand to loam over relatively friable red clay subsoils (SGG 1.1) have formed on the recent alluvial floodplain. Brown cracking clay soils (SGG 9) occur on the older Cloncurry plains.
The friable (SGG 2) and cracking clays (SGG 9) and sand to loam over red clay subsoils (SGG 1.1) are suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated tree crops, intensive horticulture, and sandalwood (Santalum spp.) plantations, dry-season spray-irrigated annual grasses, small-seeded crops and root crops, and wet-season spray-irrigated oilseed crops.
The friable non-cracking clays (SGG 2) and the sand to loam over red clay subsoils (SGG 1.1) are suitable, with minor limitations (Class 2), for dry-season spray-irrigated perennial grasses, and suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated citrus.
The cracking clay (SGG 9) soils are suitable, with moderate limitations (Class 3), for dry-season furrow-irrigated grain and fibre crops, pulse crops and leguminous hay and forage crops.</td></tr>
</table>

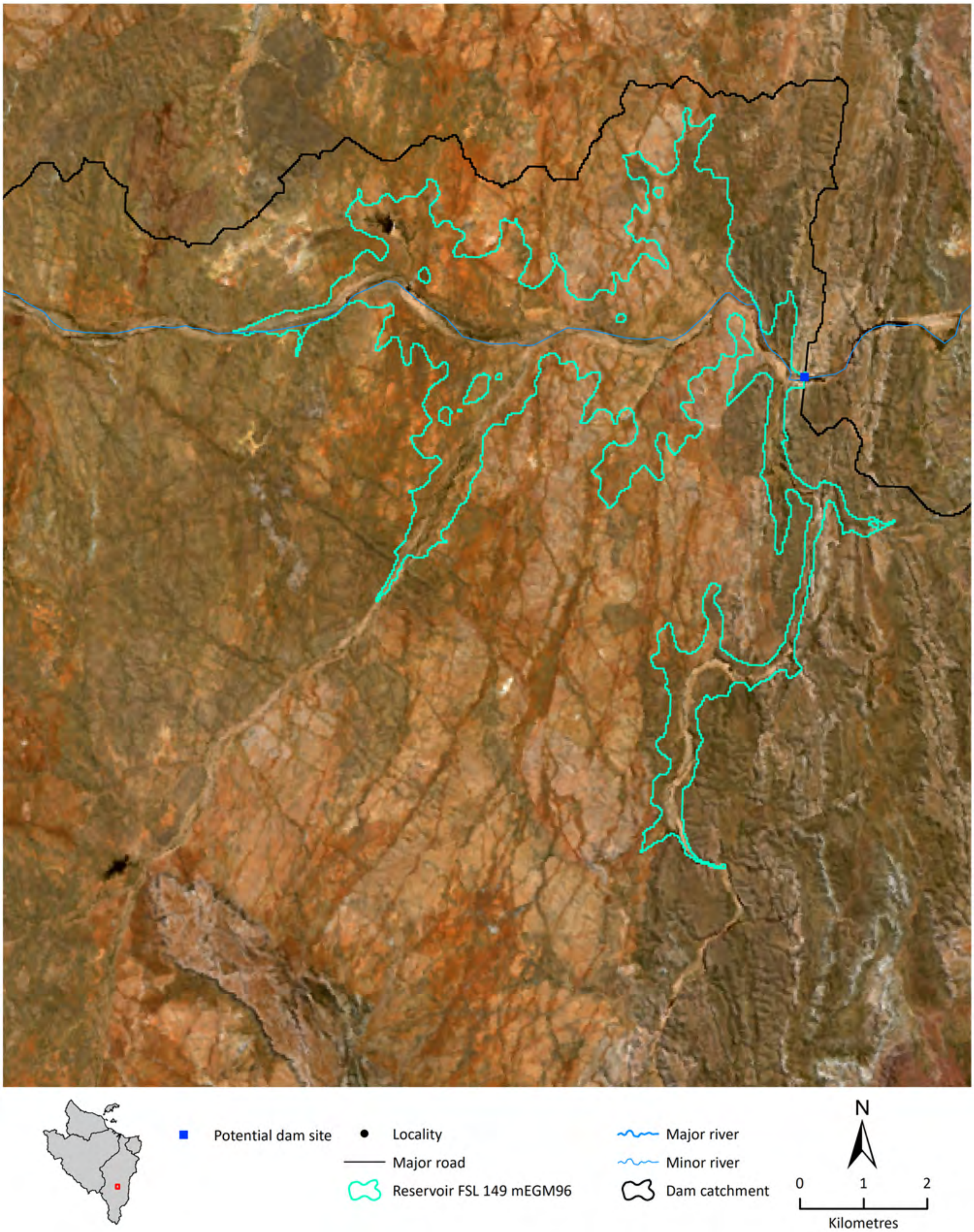
PARAMETER	DESCRIPTION
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** There were no ecology asset fish records at this site. However, the models predict that ~9% of the catchment (10,399 ha) has suitable habitat for at least 40% of the species. The modelled suitable habitat for these water-dependent species upstream of the potential dam site encompasses a small area; for most species it is less than 1% of their total area of modelled suitable habitat in the Southern Gulf catchments. The impact may be large, however, because these species may have fragmented habitat and/or have their movement impeded by a dam. There are no listings for DIWA sites or protected areas within the upstream catchment. Apx Figure B-48 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Mistake Creek (AMTD 60 km) site. **Ecological implications of inundation** No listed species have been recorded at this potential dam site, and only one waterbird, the western cattle egret (*Bubulcus ibis*), has records within the catchment. However, in the areas surrounding the potential catchment, the purple-necked rock-wallaby (*Petrogale purpureicollis*), listed as vulnerable (Queensland *Nature Conservation Act 1992*; NCA), has been recorded. The potential inundated area at FSL for this site (149 mEGM96) may have an effect on these species. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 147 mEGM96 – estimated cost = $582 million FSL of 149 mEGM96 – estimated cost = $659 million FSL of 151 mEGM96 – estimated cost = $749 million.
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 147 mEGM96 – estimated cost/ML of supply = $15,336/ML FSL of 149 mEGM96 – estimated cost/ML of supply = $16,545/ML FSL of 151 mEGM96 – estimated cost/ML of supply = $18,204/ML
Summary comment	This potential dam site would supply water to large areas of contiguous soils suitable for irrigated agriculture on the Carpentaria Plains. Being a relatively small tributary of the Leichhardt River, the site has a low yield, and it has the highest cost per megalitre released from the dam wall of all the short-listed sites examined in the Southern Gulf catchments. There is a high likelihood of unrecorded sites of cultural significance in the inundation area. For the migratory species modelled as part of the Assessment, the catchment of a dam at this potential site would constitute less than 1% of the total potentially suitable habitat modelled in the Southern Gulf catchments.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; DIWA = Directory of Important Wetlands in Australia; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; FSL = full supply level; RCC = roller compacted concrete.



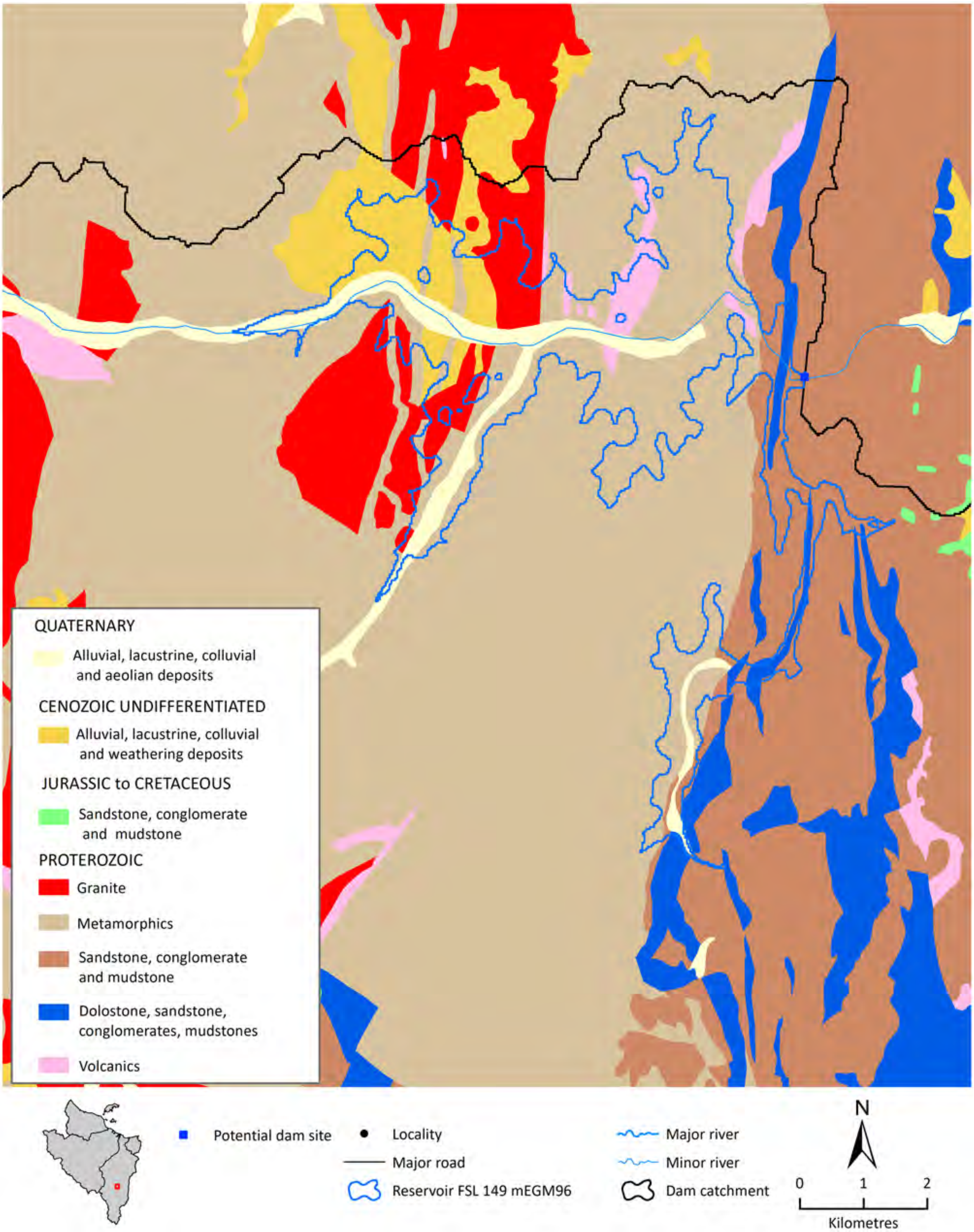
Apx Figure B-42 Location map of potential Mistake Creek dam site, reservoir extent and catchment area

AEP = annual exceedance probability.



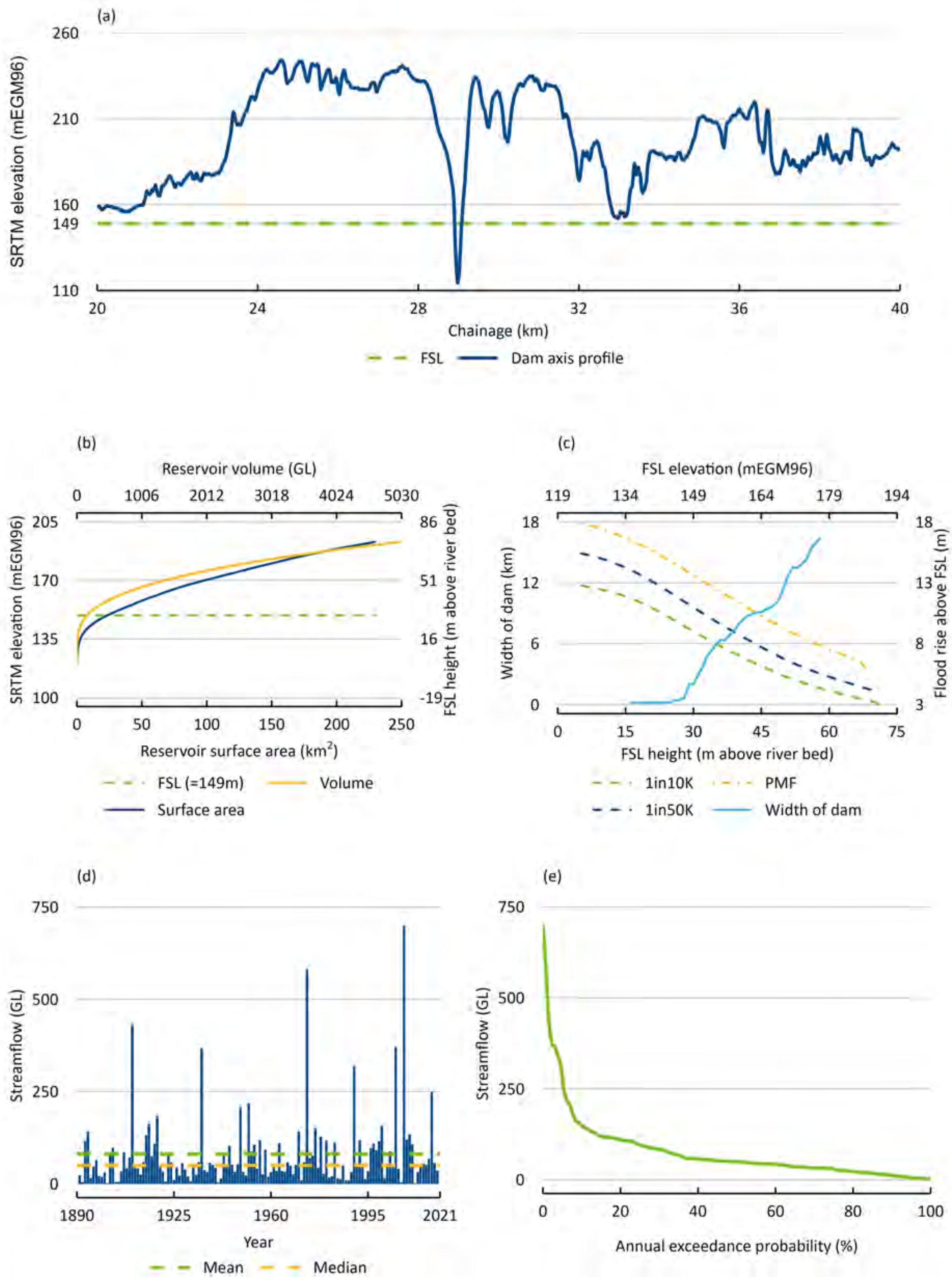
Apx Figure B-43 Potential Mistake Creek dam reservoir

AEP = annual exceedance probability.



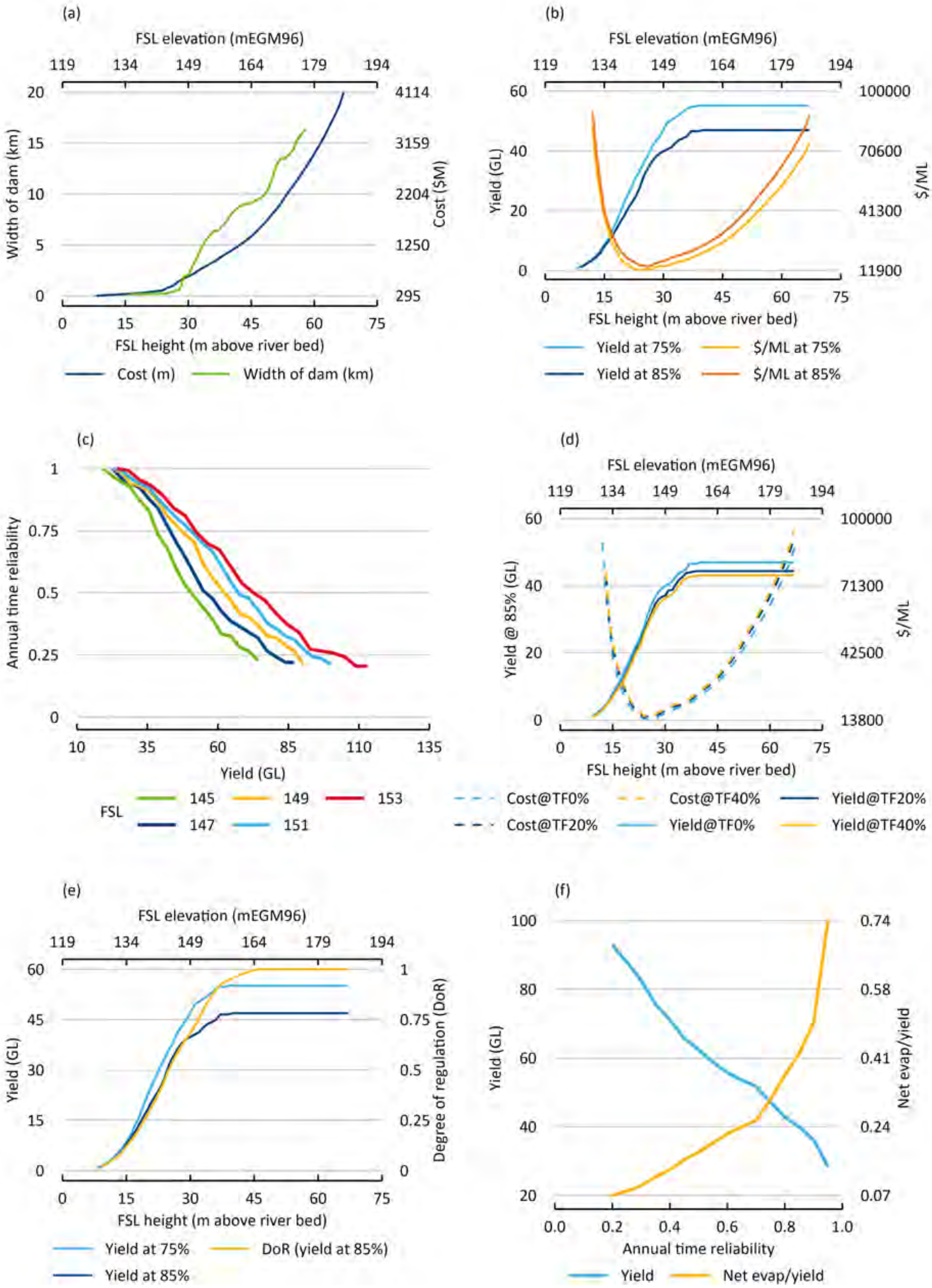
Apx Figure B-44 Geology underlying the potential Mistake Creek dam site and reservoir

AEP = annual exceedance probability.



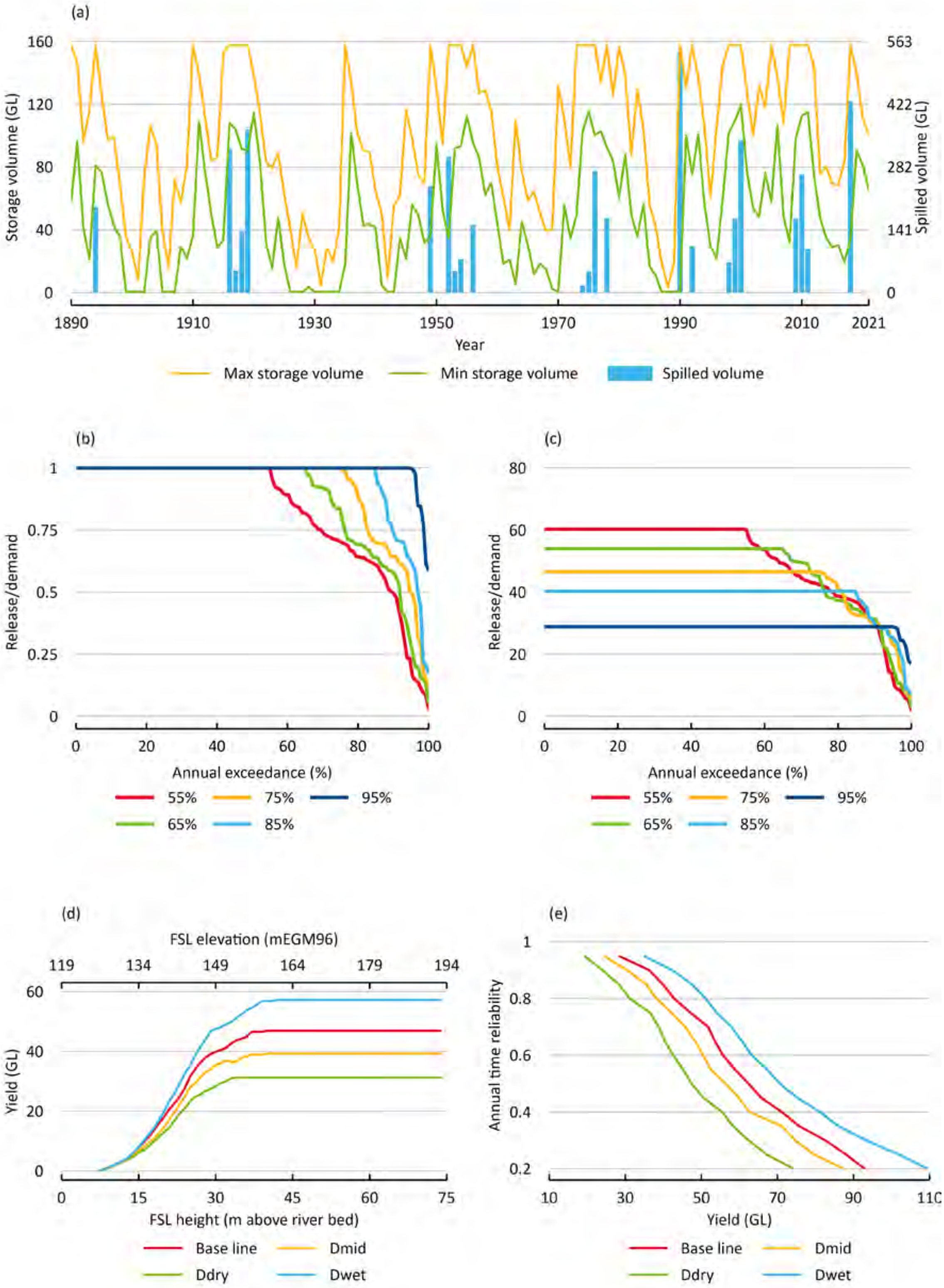
Apx Figure B-45 Mistake Creek potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



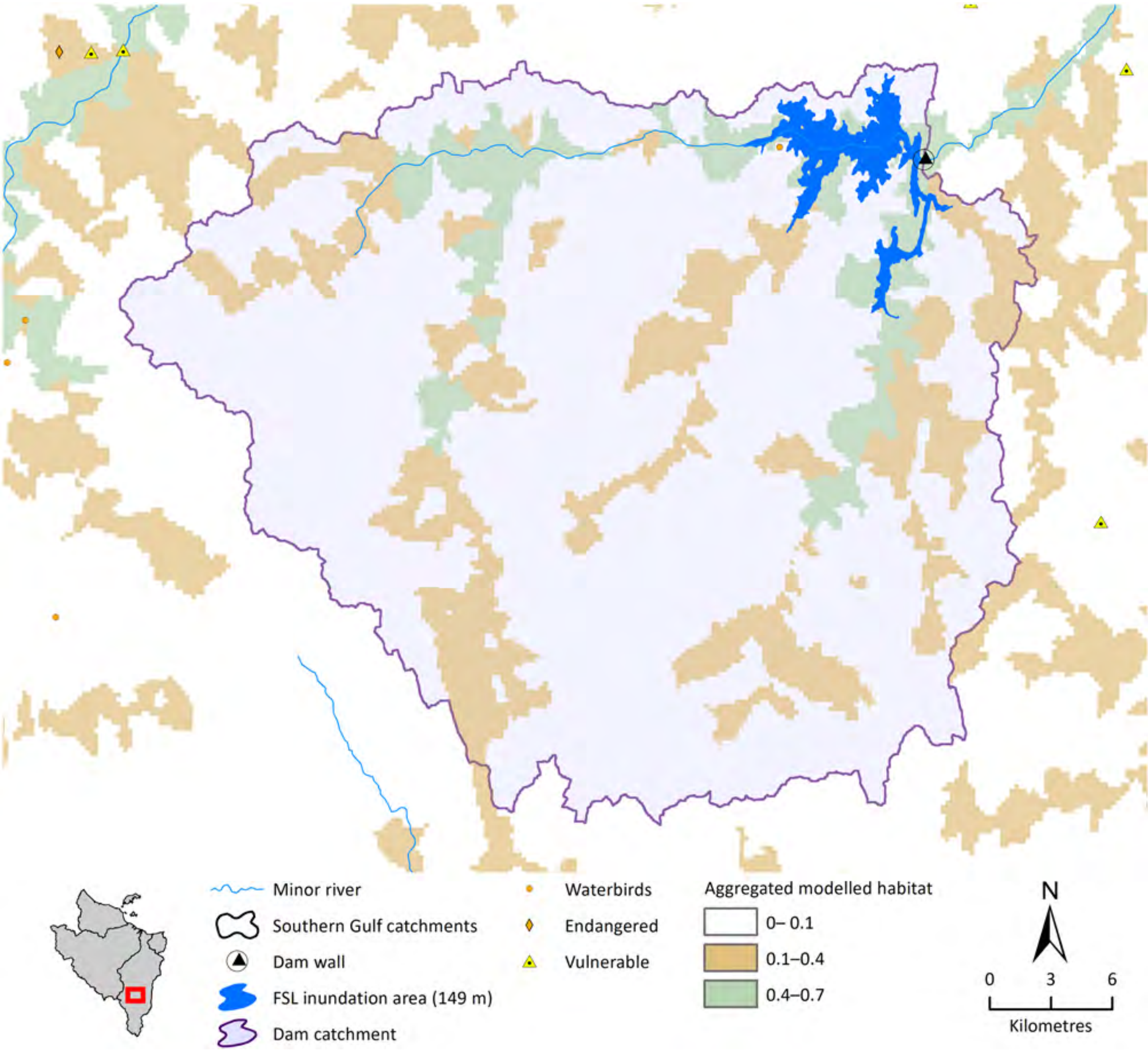
Apx Figure B-46 Mistake Creek potential dam site cost, water yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-47 Mistake Creek potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 149 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-48 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Mistake Creek dam site

FSL = full supply level.

B.2.4 Ewen Creek AMTD 6 km (Site 275) FSL 217 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies at or near this site were identified in web-based searches or searches of Queensland Government databases.
Description of potential dam	The hypothetical Ewen Creek AMTD 6 km dam site is an instream development in the upper Leichhardt catchment that could potential supply water for riparian irrigation in the mid-to-upper reaches of the Leichhardt River. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 217 mEGM96. Apx Figure B-49 and Apx Figure B-50 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, basalt were followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains, and coastal deposits where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (Apx Figure B-51) and satellite imagery. The dam site is located on Proterozoic rocks of the Bigie Formation/Surprise Creek Formation (Pfy/Pra), which consists of purple ferruginous feldspathic sandstone, conglomerate, tuffaceous sandstone, quartzite, marl, dolomite /conglomeratic sandstone, feldspathic quartzite and minor siltstone. Gently folded strata are locally outcropping lower down on both abutments but mainly covered with a weathering profile. The shape of the upper slopes suggests a planation surface with structurally controlled erosion having partially removed the weathering profiles. The river bed was 140-m wide, with active braided alluvium suggesting significant flood events. The foundations appeared to be suitable for a RCC dam. For estimating purposes, assume 3–5 m of alluvium in the river bed and 3–5 m of stripping on the abutments. The amount of dolomite rock in the foundation requires consideration to establish whether it represents a problem due to cavities within dolomite strata.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 100-m-wide central uncontrolled spillway. The abutments would be set at a 1:10,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the right abutment of the dam. A fish lift transfer facility would also be installed in the right abutment of the dam.

PARAMETER	DESCRIPTION
	Access to the site would require an 8-km-long connection to the existing Mount Isa to Julius Dam road. A bridge across the Leichhardt River would be required. The total distance from the site to Mount Isa would be some 80 km.
Catchment area	706 km^2

Modelled annual inflow data

Parameter	Scenario A (GL/y)	Scenario Cdry (GL/y)	Scenario Cmid (GL/y)	Scenario Cwet (GL/y)
Max	523	429	521	582
Mean	52	38	48	63
Median	31	22	29	37
Min	1	0.4	1	1

Reservoir characteristics

Storages with FSLs of selected heights are tabulated below.

FSL	Surface area (ha)	Capacity (GL)
215	2145	199
217	2515	245
219	2957	300

Reservoir yield assessment at dam wall

FSL of 215 mEGM96 – estimated yield at 85% annual time reliability = 27 GL

FSL of 217 mEGM96 – estimated yield at 85% annual time reliability = 29 GL

FSL of 219 mEGM96 – estimated yield at 85% annual time reliability = 30 GL

Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-52, Apx Figure B-53 and Apx Figure B-54.

Estimated rates of reservoir sedimentation at a FSL of 217 mEGM96

	Best case	Expected	Worst case
30 years (%)	0.3	0.5	0.6
100 years (%)	1.1	1.7	1.8
Years to fill	9050	6034	5430

Potential use of supply

The Three Rivers area is the most agriculturally versatile area nearest to the potential dam site and consists mainly of Quaternary alluvium deposited by the Leichhardt River and Cabbage Tree Creek. Three soils have developed in this alluvium, the most common being a sand to loam over relatively friable red clay subsoils (SGG 1.1), a red loamy soil (SGG 4.1) and a friable non-cracking clay or clay loam soil (SGG 2).

The soils are suitable, with minor limitations (Class 2), for dry-season spray-irrigated perennial grasses. The soils are also suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated tree crops, intensive horticulture and sandalwood (*Santalum* spp.) plantations, dry-season spray-irrigated annual grasses, small-seeded crops and root crops and wet-season spray-irrigated oilseed crops.

Environmental impacts

Habitat fragmentation and barrier to movement of aquatic species

There were no ecology asset fish records at this site. However, the models predict that ~4% of the catchment (2794 ha) has suitable habitat for at least 40% of the species. The modelled suitable habitat for these water-dependent species upstream of the potential dam site is small, depending on the species, and ranges from zero % to 0.5% of their total modelled suitable habitat in the Southern Gulf catchments. These species may have fragmented habitat and/or have movement impeded by a dam.

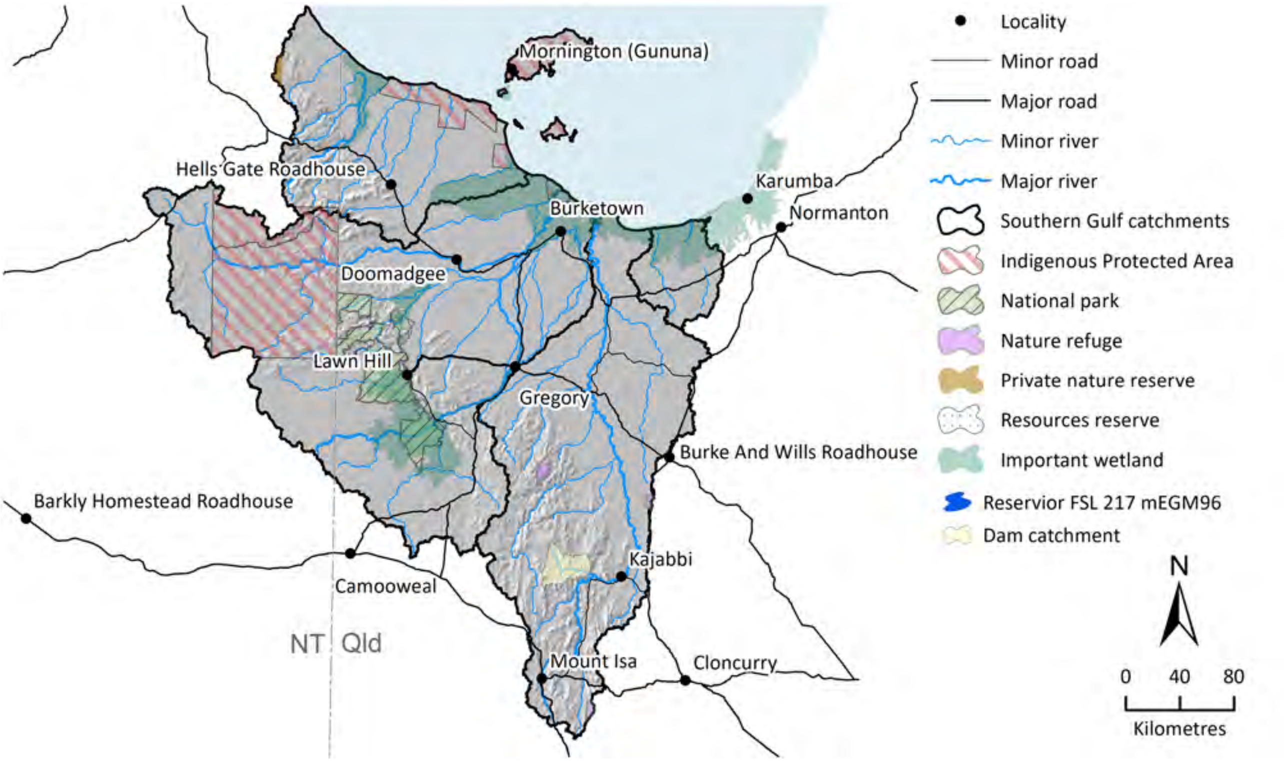
There are no listings for DIWA sites or protected areas within the upstream catchment.

Apx Figure B-55 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Ewen Creek (AMTD 275 km) site.

Ecological implications of inundation

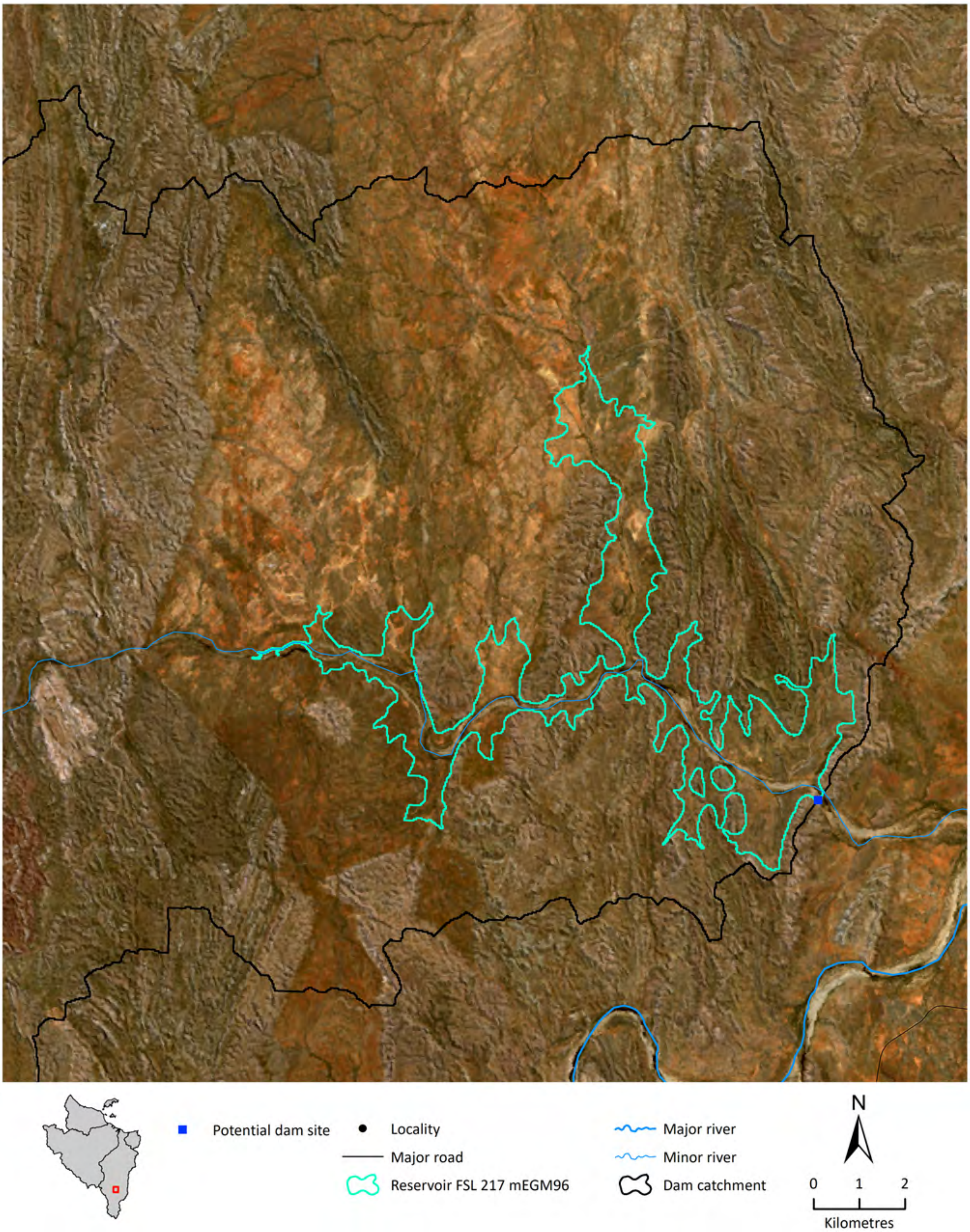
PARAMETER	DESCRIPTION
	Near this potential catchment only one listed species has been recorded: the ghost bat (*Macroderma gigas*), listed as vulnerable in the EPBC Act and as endangered (NT). One species of waterbirds has also been recorded near this catchment, the western cattle egret (*Bubulcus ibis*). The potential inundated area at FSL for this site (217 mEGM96) may have an effect on these species. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024).
Indigenous land tenure, native title and cultural heritage considerations	There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC-type dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 215 mEGM96 – estimated cost = $442 million FSL of 217 mEGM96 – estimated cost = $466 million FSL of 219 mEGM96 – estimated cost = $490 million.
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 215 mEGM96 – estimated cost/ML of supply = $16,341/ML FSL of 217 mEGM96 – estimated cost/ML of supply = $16,158/ML FSL of 219 mEGM96 – estimated cost/ML of supply = $16,500/ML
Summary comment	A low-yielding and relatively expensive potential dam site, on the tributary that joins the Leichhardt River downstream of Lake Julius. The foundations appeared to be suitable for a RCC dam, though the amount of dolomite rock in the foundation requires consideration to establish whether it represents a problem due to cavities within dolomite strata. Given the small catchment area and modest percentage of habitat suitable for migratory species upstream of the potential dam (22% for at least one species), a potential dam at this location would have an effect on zero % to 0.5% of the total potentially suitable habitat modelled in the Southern Gulf catchments. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; BHA = behaviour analysis; FSL = full supply level; MSCL = mild steel cement lined; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; PMF = probable maximum flood; RCC = roller compacted concrete.



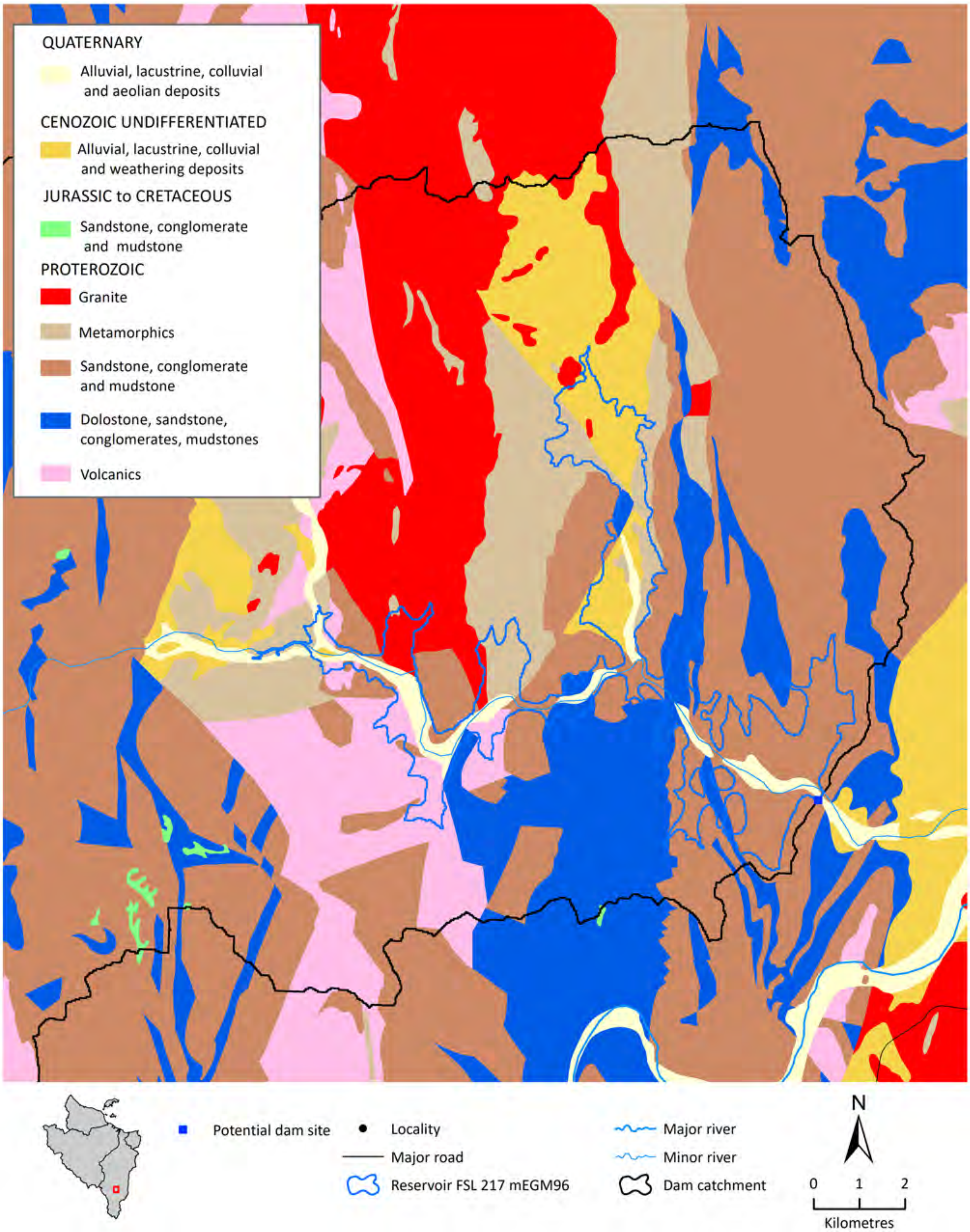
Apx Figure B-49 Location map of potential Ewen Creek dam site, reservoir extent and catchment area

AEP = annual exceedance probability.



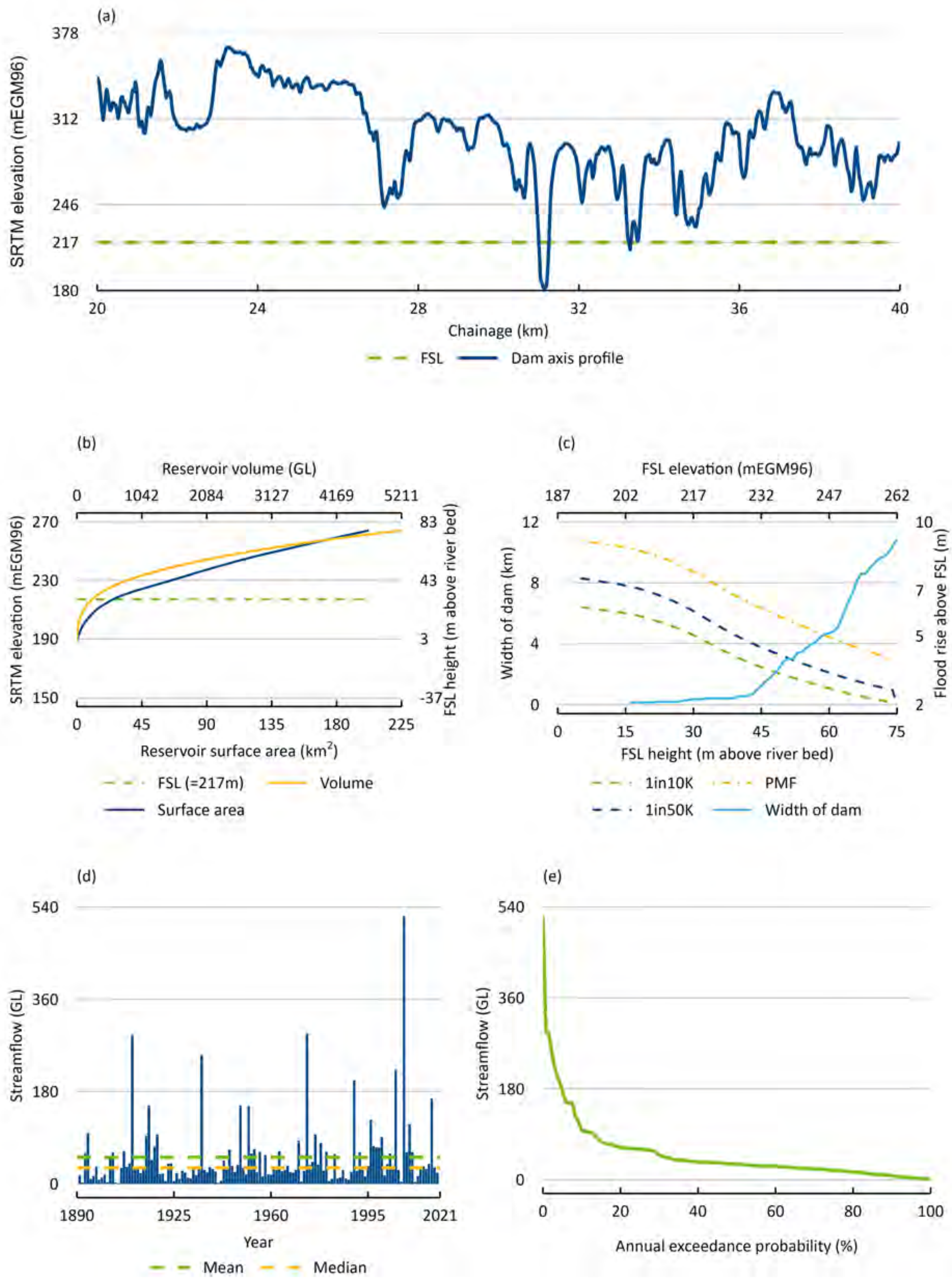
Apx Figure B-50 Potential Ewen Creek dam reservoir

AEP = annual exceedance probability.



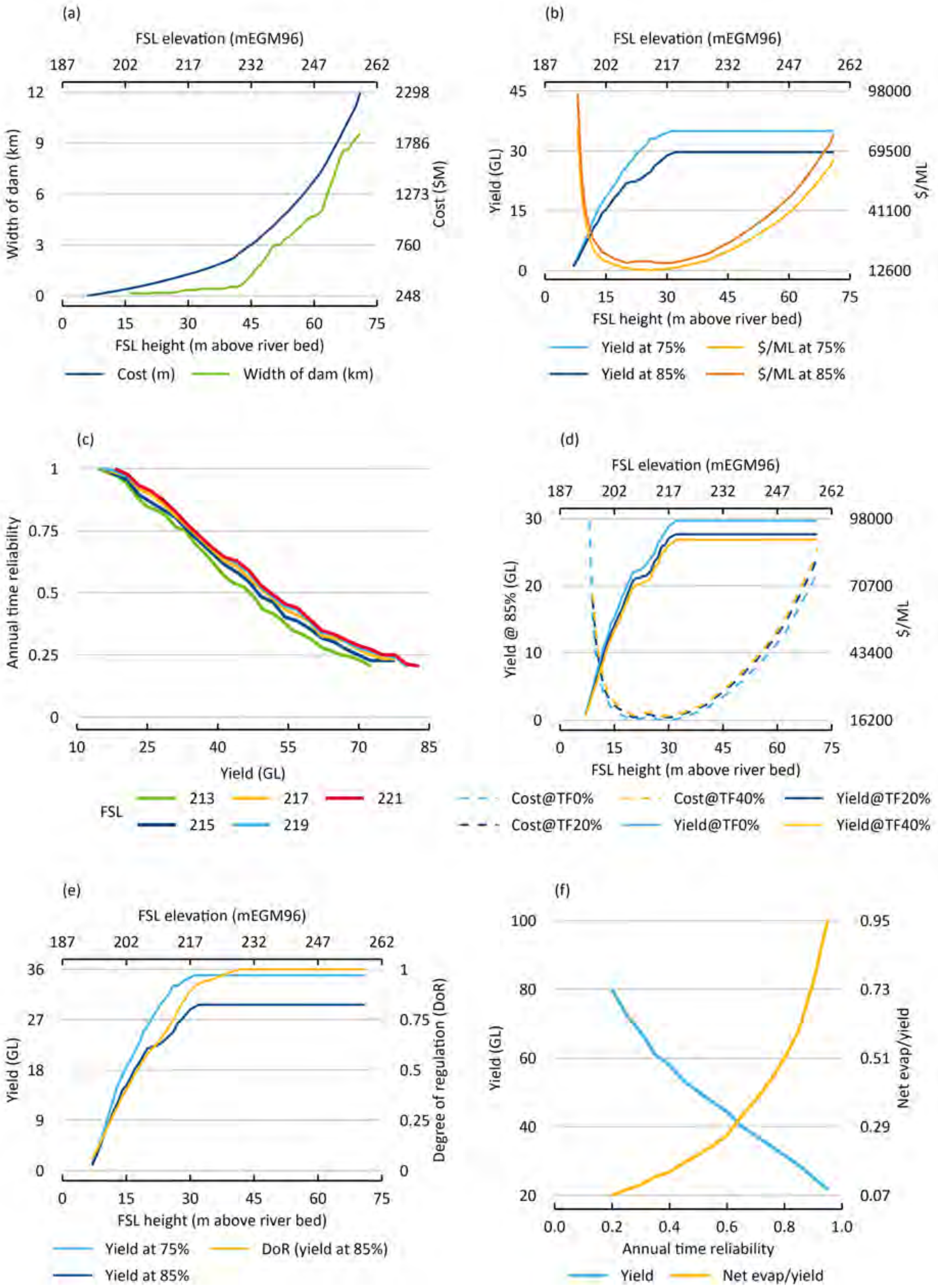
Apx Figure B-51 Geology underlying the potential Ewen Creek dam site and reservoir

AEP = annual exceedance probability.



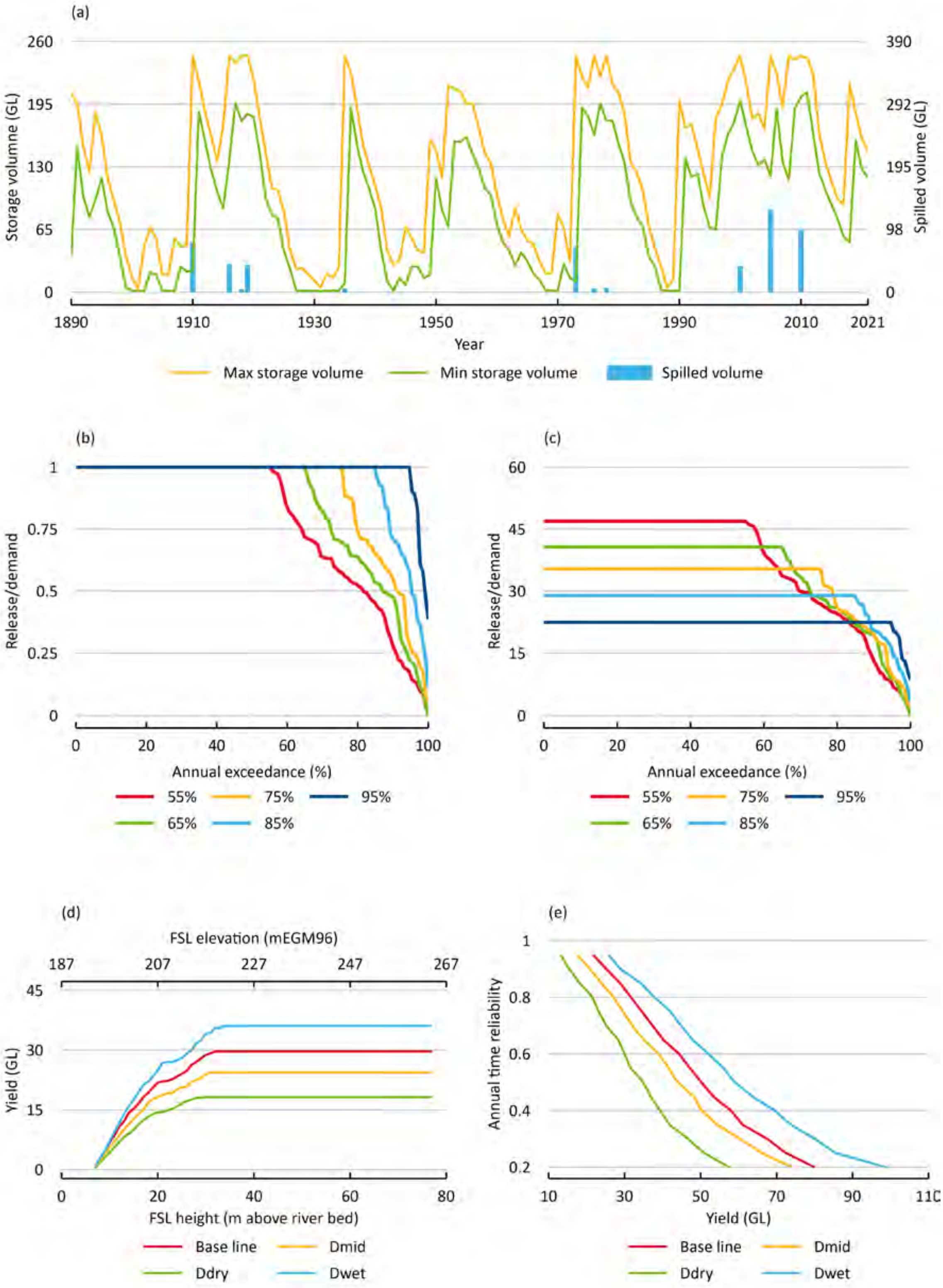
Apx Figure B-52 Ewen Creek potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



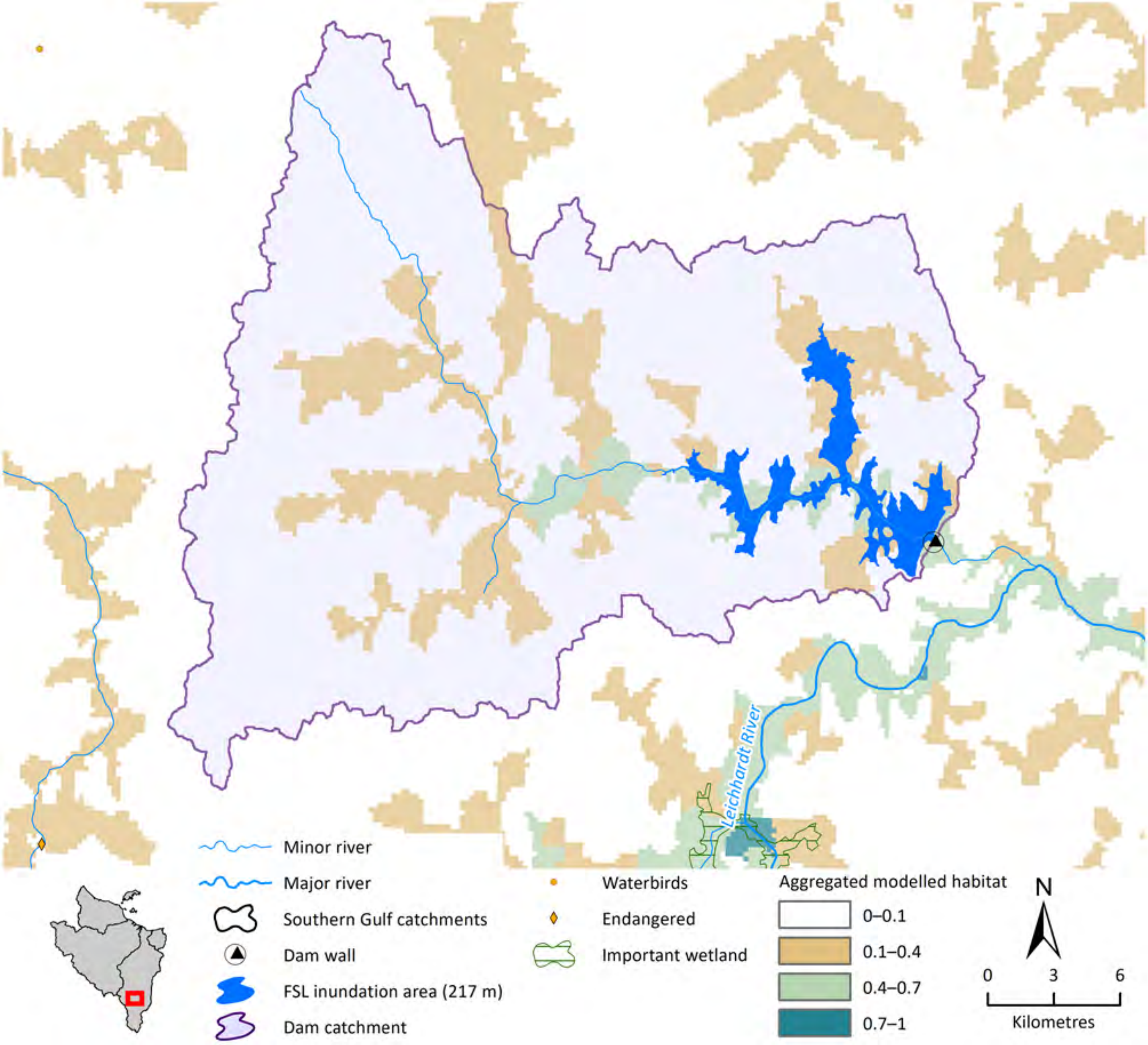
Apx Figure B-53 Ewen Creek potential dam site cost, water yield at the dam wall and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-54 Ewen Creek potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 217 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-55 Location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Ewen Creek dam site

FSL = full supply level.

B.2.5 Gold Creek AMTD 58 km (Site 206) FSL 84 mEGM96

PARAMETER	DESCRIPTION
Previous investigations	No literature on past dam studies at or near this site were identified in web-based searches or searches of Queensland Government databases.
Description of potential dam	The hypothetical Gold Creek AMTD 58 km dam site is a small instream development in the Settlement Creek AWRC river basin. The site was identified from a CSIRO DamSite model run undertaken as part of the Assessment, and this analysis is predominantly based on an assumed FSL of 84 mEGM96. Apx Figure B-56 and Apx Figure B-57 show the location of the site, the extent of the reservoir area and the nearest streamflow gauging station.
Regional geology	The Southern Gulf catchments drain from the higher ground to the south-west and south towards the north-east, where the river systems cross a broad depositional plain several tens of kilometres wide before emptying into the Gulf of Carpentaria. The oldest rocks in the area are Proterozoic sediments, volcanics and intrusives, which were folded, metamorphosed and eroded. During the Cambrian, basalt was followed by a sequence of limestones and dolomites and another cycle of erosion. During the late Jurassic and into the Cretaceous, a thick succession of sediments was deposited in the geological Carpentaria Basin, which underlies the broad depositional plain that extends down to the coastline and into the Gulf of Carpentaria; thinner Cretaceous sediments deposited across the eroded surface of the older formations are now only locally preserved. The present landscape has been produced by warping and dissection of a series of erosion surfaces formed during several cycles of erosion that started about 70 Ma and are associated with deep weathering profiles and iron-cemented cappings. An area of karst limestone and dolomite forms the higher ground to the south-west. Continued erosion has led to the development of incised valley systems on the weathered rocks and extensive floodplains, and coastal deposits where the modern drainage systems flow out onto the broad plain running down to the coastline.
Site geology	There were no field studies of this site or general region, so the following comments are based only on viewing geological maps (e.g. Apx Figure B-58) and satellite imagery. The dam site is located on Proterozoic rocks of the Bigie Formation / Surprise Creek Formation (Pth/Ptg), which consists of pink porphyritic, massive to spherulitic rhyolite / grey to red, vesicular to massive basalt; dolomitic sandstone, mudstone and peperite, with flat-lying or gently dipping strata with a deep weathering profile developed and little or no outcrop. The shape of the upper slopes suggests a planation surface with structurally controlled erosion and deep weathering profiles. The river bed was 180 m wide with active braided alluvium and a channel of standing water. Some outcrop occurs in the river downstream of the dam site. The foundations appeared to be suitable for a roller compacted concrete dam. For estimating purposes, assume 5–7 m of alluvium in the river bed and 5–10 m of stripping on the abutments. The amount of dolomite rock in the foundation requires consideration to establish if it represents a problem due to cavities within dolomite strata.
Reservoir rim stability and leakage potential	Storage appears stable and watertight.
Potential structural arrangement	Given the potential for significant flooding during construction and the spillway capacity required, a RCC gravity dam is proposed. The dam would have a 150-m-wide central uncontrolled spillway. The abutments would be set at a 1:10,000 AEP peak storage level, although this should be reviewed if this proposal is to be considered further. A hydraulic jump-type dissipator apron would be provided to protect the river bed against erosion during spillway overflows. Releases downstream of the dam would be made via pipework installed in a diversion channel located in the left abutment of the dam. A fish lift transfer facility would also be installed in the left abutment of the dam.

PARAMETER	DESCRIPTION
	The dam site is exceedingly remote and access to it requires further studies. One option to access the site would involve 210 km of new and upgraded road branching from the Daly Waters to Borroloola road. The total distance from the site to Daly Waters would be some 470 km.
Availability of construction materials	Assume coarse aggregate might be won and processed from a quarry or river bed within 20 km of the dam site. Assume fine aggregate might be won and processed from a river bed or terrace deposit within 20 km of the dam site. For estimating purposes, assume a ratio of useful aggregate excavated to total volume excavated of 0.5. Higher-quality aggregate for constructing an outer layer of RCC for the dam could probably be sourced from Mount Isa
Catchment area	422 km^2
Modelled annual inflow data	(see table below)

Parameter	Scenario A (GL/y)	Scenario Cdry (GL/y)	Scenario Cmid (GL/y)	Scenario Cwet (GL/y)
Max	439	338	409	520
Mean	57	39	52	71
Median	31	19	27	40
Min	1	1	1	1

Reservoir characteristics

Reservoirs with FSLs of selected heights are tabulated below.

FSL (mEGM96)	Surface area (ha)	Capacity (GL)
82	710	105
84	756	119
86	809	135

Reservoir yield assessment at dam wall	FSL of 82 mEGM96 Estimated yield at 85% annual time reliability = 23 GL FSL of 84 mEGM96 Estimated yield at 85% annual time reliability = 24 GL FSL of 86 mEGM96 Estimated yield at 85% annual time reliability = 25 GL Reservoir characteristics and yields under current and projected future climates are shown in Apx Figure B-59, Apx Figure B-60 and Apx Figure B-61.

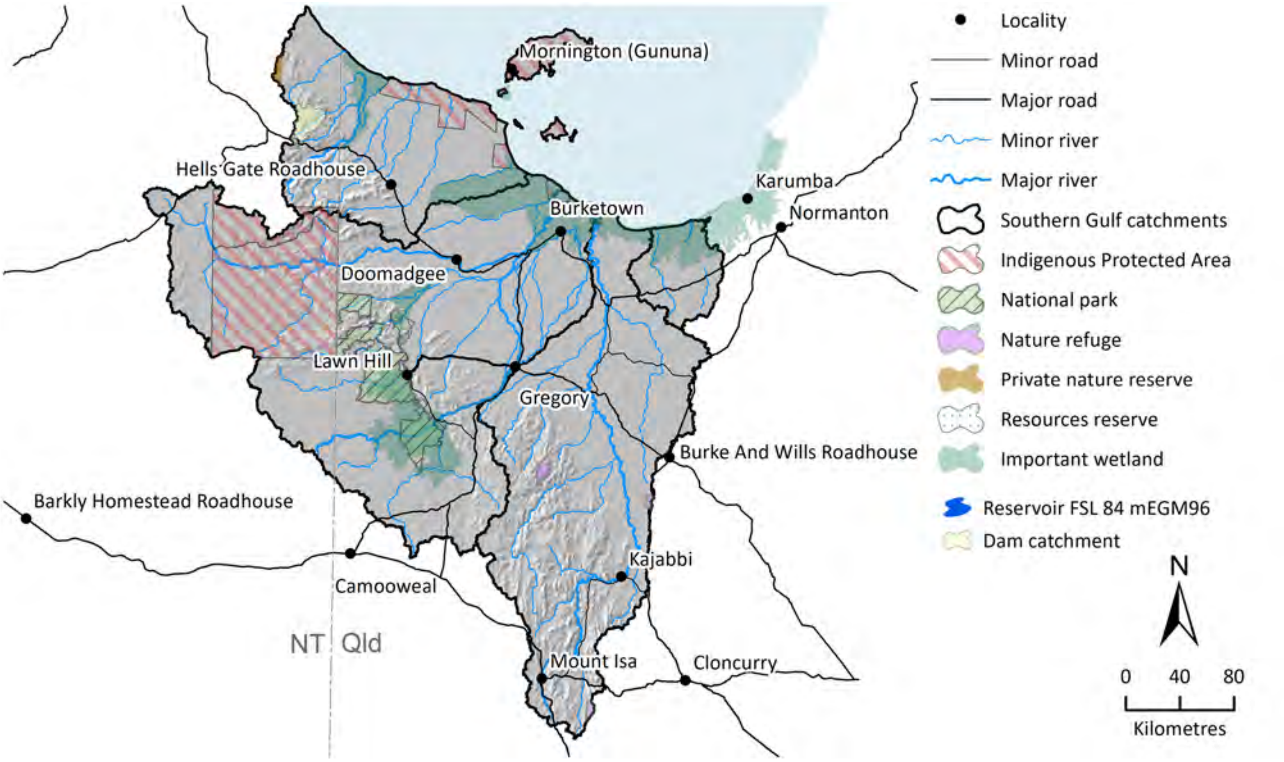
Estimated rates of reservoir sedimentation at a FSL of 84 mEGM96

	Best case	Expected	Worst case
30 years (%)	0.4	0.6	0.7
100 years (%)	1.4	2.1	2.3
Years to fill	7240	4826	4344

Potential use of supply	The potential dam site is located upstream of the Doomadgee Plain. These plains are made up of a deeply weathered Cenozoic land surface with sandy sediments deposited over the top. Along the creek there is recent alluvium. Brown, yellow or grey sandy (SGG 6.2) and brown, yellow or grey loamy (SGG 4.2) soils have formed on the Doomadgee Plain, with friable non-cracking clay loam to clay (SGG 2) soils along the creek. All soils are modelled suitable, with minor limitations (Class 2), for dry-season spray-irrigated perennial grasses. All soils are also potentially suitable, with moderate limitations (Class 3), for dry-season trickle-irrigated tree crops, citrus, intensive horticulture and sandalwood (*Santalum* spp.) plantations, dry-season spray-irrigated annual grasses, small-seeded crops, root crops and wet-season spray-irrigated oilseed crops.

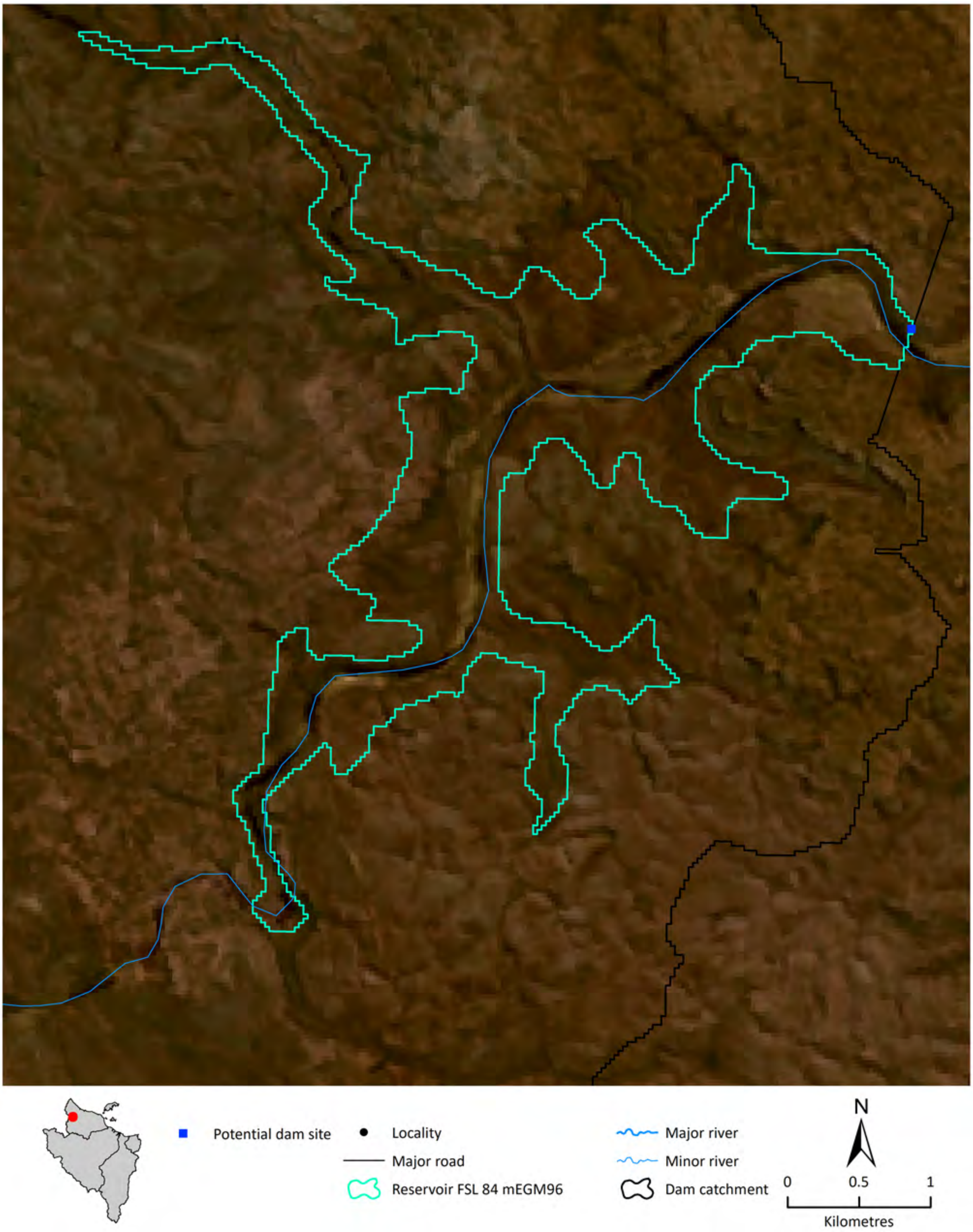
PARAMETER	DESCRIPTION
Environmental impacts	**Habitat fragmentation and barrier to movement of aquatic species** There were no ecology asset fish records at this site. However, the models predict that ~4% of the catchment (1469 ha) has suitable habitat for at least 40% of the species for which their movement could be impeded by a dam. Species found in neighbouring streams are the eastern rainbow fish (*Melanotaenia splendida*) and the sooty grunter (*Hephaestus fuliginosus*). The modelled suitable habitat for these water-dependent species upstream of the potential dam site is small, depending on the species, and ranges from zero % to 0.8% of their total modelled suitable habitat in the Southern Gulf catchments. These species may have fragmented habitat and/or have movement impeded by a dam. There are no listings for DIWA sites or protected areas within the upstream catchment. Apx Figure B-62 shows the location of listed species, water-dependent assets and aggregated modelled habitat in the vicinity of the potential Gold Creek (AMTD 58 km) site. **Ecological implications of inundation** One listed species has been recorded within the catchment of this potential dam site, upstream from the dam wall, the ghost bat (*Macroderma gigas*), listed as vulnerable in the EPBC Act and as endangered (NT). Other listed species, such as the gouldian finch (*Chloebia gouldiae*), listed as endangered (EPBC Act) and vulnerable (NT) and the Carpentarian rock-rat (*Zyzomys palatalis*), listed as endangered (EPBC Act) have records in areas surrounding the potential catchment. The potential inundated area at FSL for this site (84 mEGM96) may have an effect on species in this catchment. The potential for ecological change as a result of changes to the downstream flow regime is examined in the companion technical report on ecology (Stratford et al., 2024b).
Indigenous land tenure, native title and cultural heritage considerations	There is a high likelihood of unrecorded sites of cultural significance in the inundation area.
Estimated cost	To enable a like-for-like comparison with the sites that are not short-listed, dam costs were calculated using CSIRO's generalised dam-costing algorithm, which takes into account major cost elements for RCC dams with central overflow spillways. These are reported for a selection of FSLs below. FSL of 82 mEGM96 – estimated cost = $345 million FSL of 84 mEGM96 – estimated cost = $367 million FSL of 86 mEGM96 – estimated cost = $391 million
Estimated cost/ML of supply	Based on the yields estimated by CSIRO BHA modelling and the costs derived from the CSIRO generalised costing algorithm, the estimated cost/ML of supply at the following storage levels are as follows: FSL of 82 mEGM96 – estimated cost/ML of supply = $15,020/ML FSL of 84 mEGM96 – estimated cost/ML of supply = $15,154/ML FSL of 86 mEGM96 – estimated cost/ML of supply = $15,753/ML
Summary comment	This small potential instream dam site on a small catchment in Settlement Creek AWRC river basin has a low yield and high cost per megalitre released from the dam wall. Downstream of the site, water could be used to potentially supply water to soils moderately suitable for irrigated agriculture, with minor limitation. Approximately 11% of the catchment was estimated as having habitat suitable for 40% or more of the 11 migratory species modelled. There is a high likelihood of unrecorded sites of cultural significance in the inundation area.

AEP = annual exceedance probability; AMTD = adopted middle thread distance; AWRC = Australian Water Resources Council; BHA = behaviour analysis; DIWA Directory of Important Wetlands in Australia; FSL = full supply level; mEGM96 = Earth Gravitational Model 1996 geoid height in metres; RCC = roller compacted concrete.



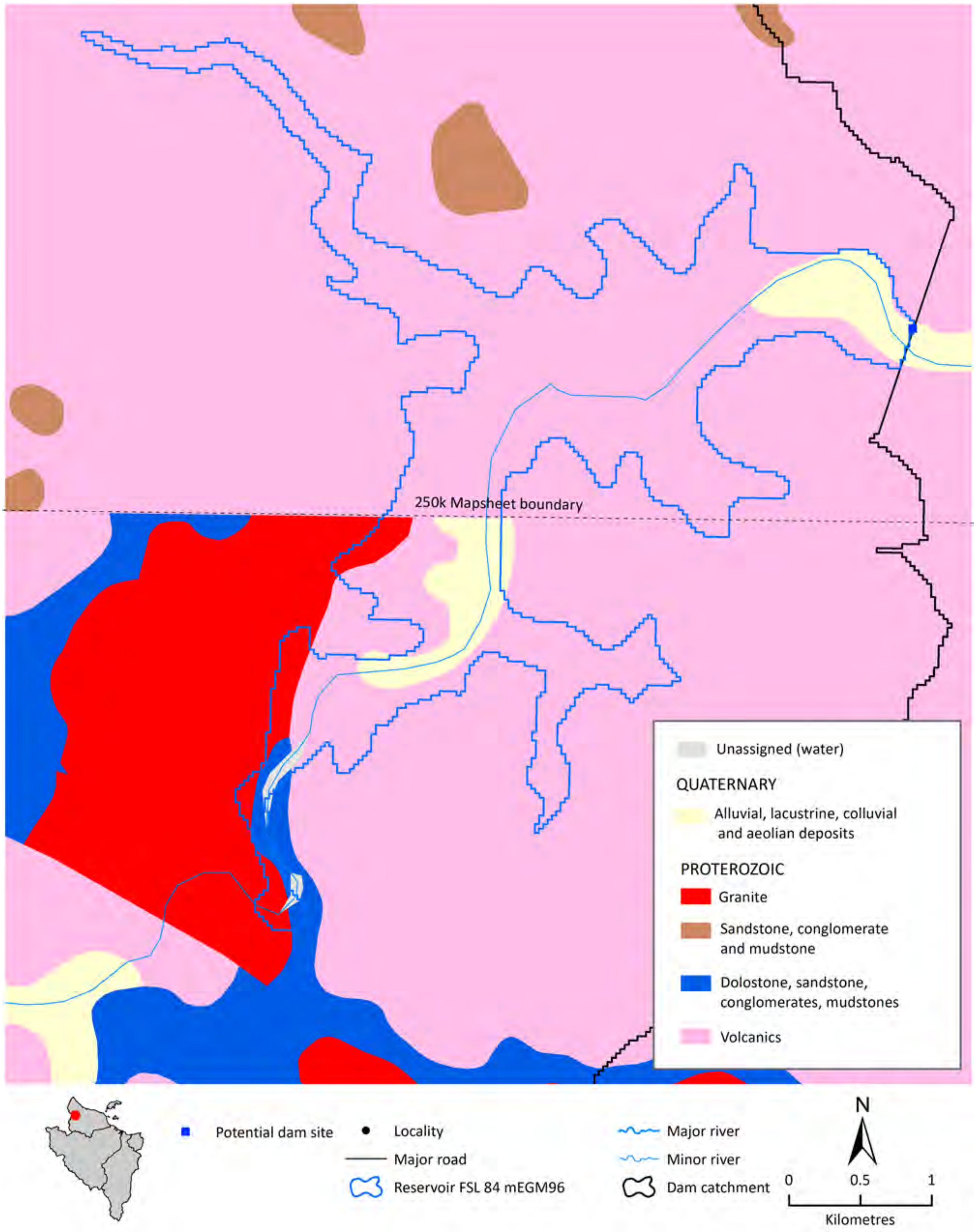
Apx Figure B-56 Location map of potential Gold Creek dam site, reservoir extent and catchment area

AEP = annual exceedance probability.



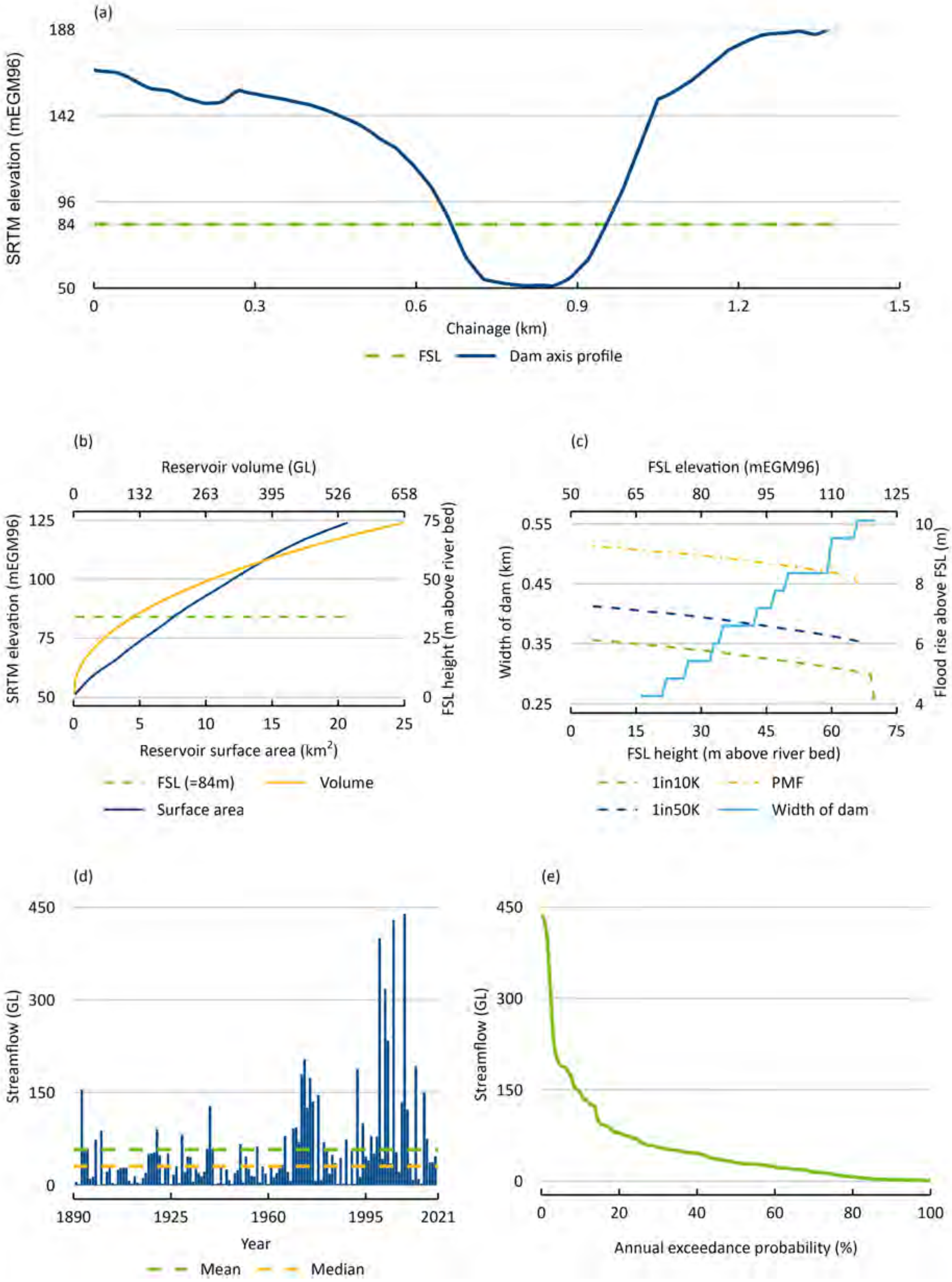
Apx Figure B-57 Potential Gold Creek dam reservoir

AEP = annual exceedance probability.



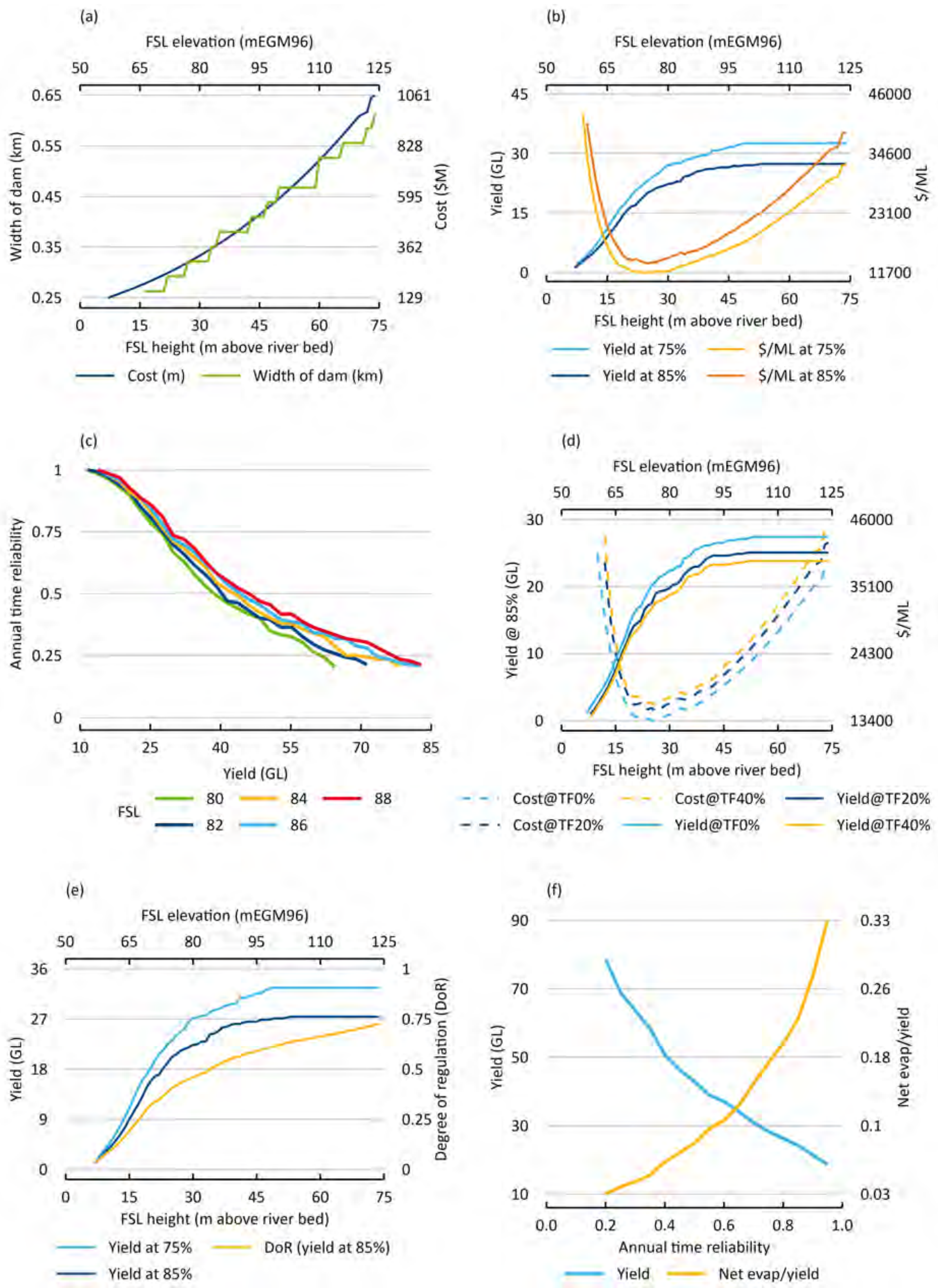
Apx Figure B-58 Geology underlying the potential Gold Creek dam site and reservoir

AEP = annual exceedance probability.



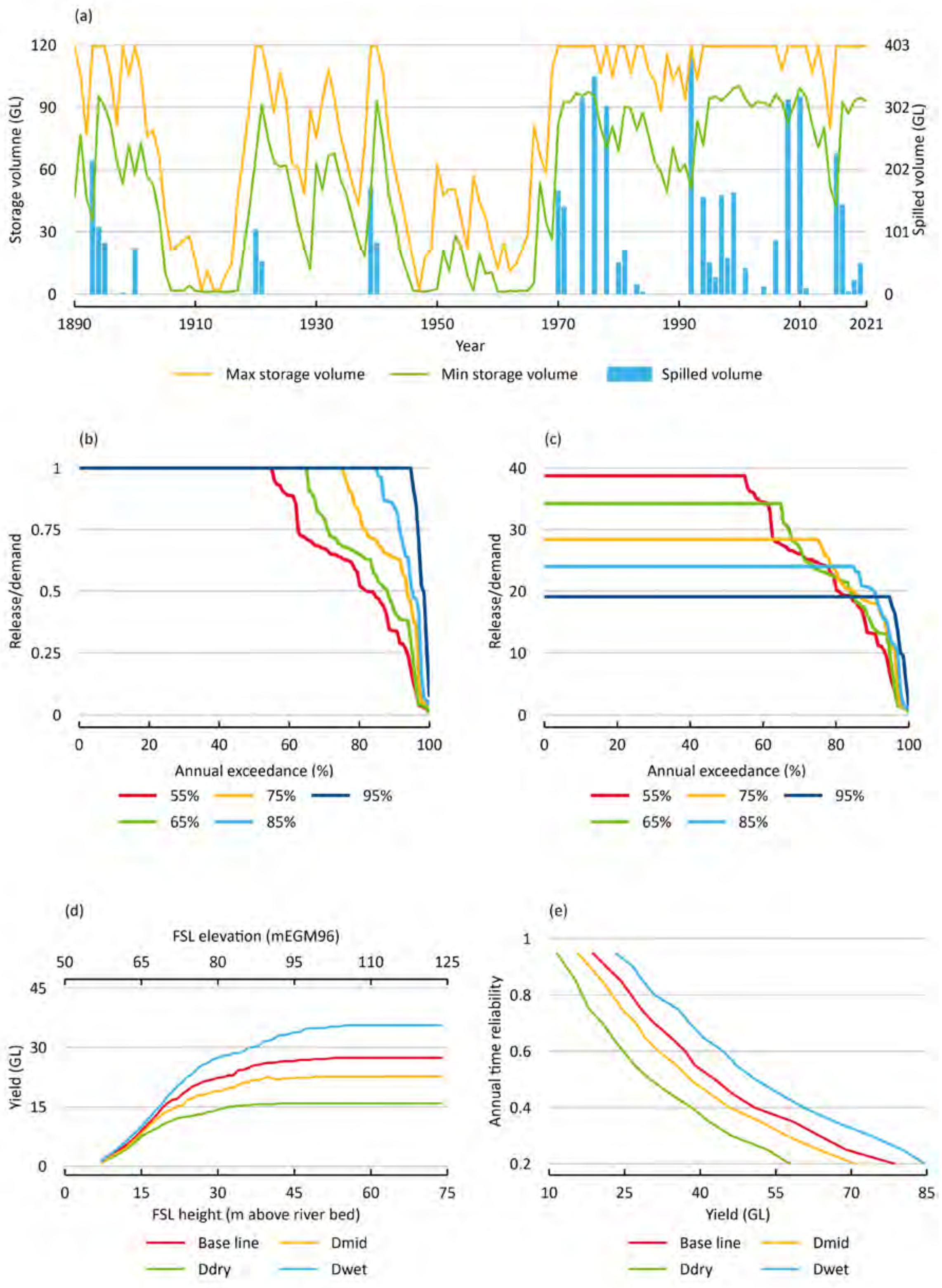
Apx Figure B-59 Gold Creek potential dam site topographic dimensions and inflow hydrology

(a) Elevation profile along dam axis (Shuttle Radar Topographic Mission, SRTM); (b) reservoir volume, surface area and height relationship; (c) dam wall height versus dam width and flood rise for 1:10,000 and 1:50,000 annual exceedance probability (AEP) and probable maximum flood (PMF) events plotted against full supply level (FSL); (d) annual streamflow; (e) annual flow exceedance.



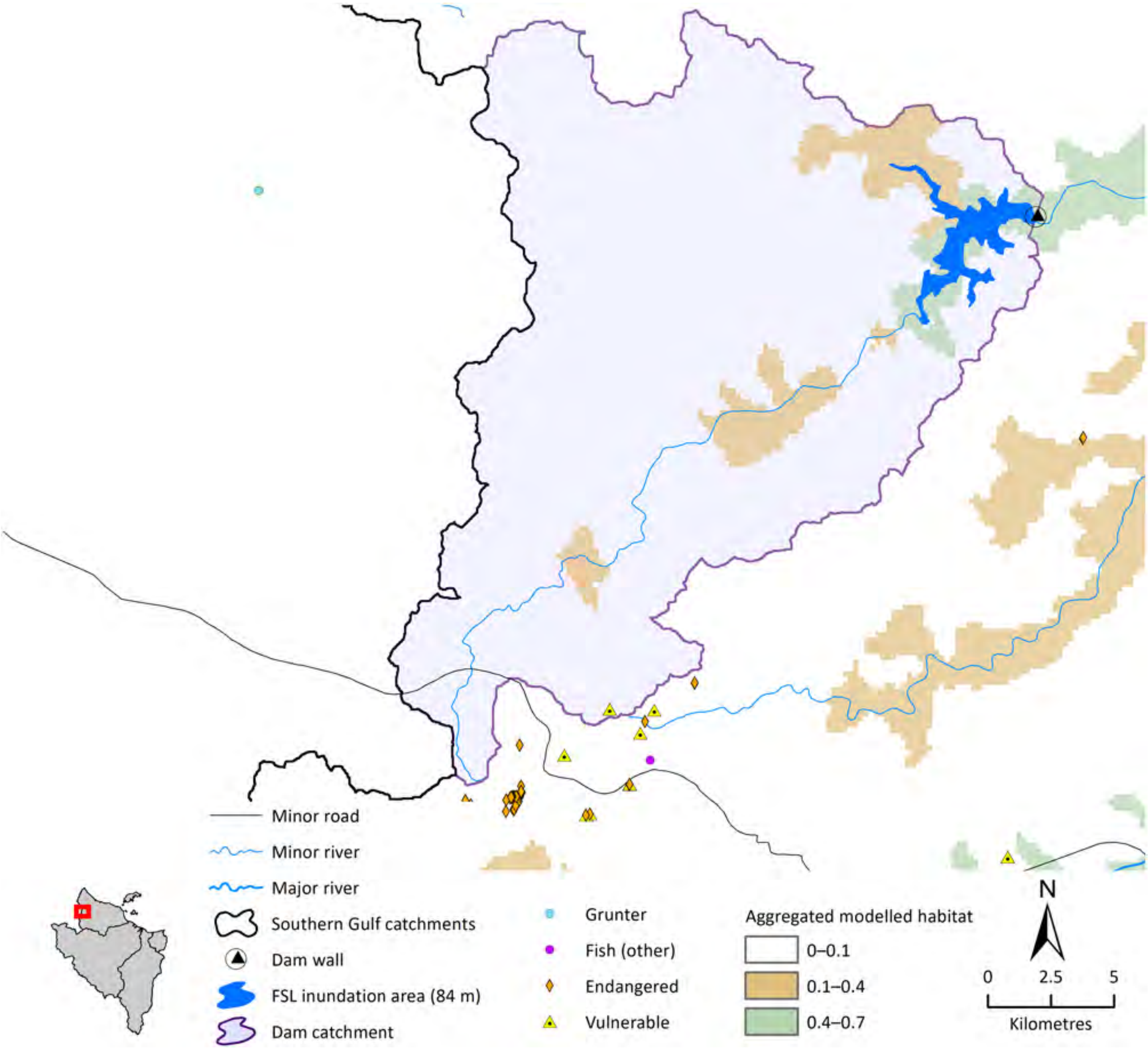
Apx Figure B-60 Gold Creek potential dam site cost, water yield at the dam wall, and evaporation

(a) Dam length and dam cost versus full supply level (FSL); (b) dam yield at 75% and 85% annual time reliability and yield per million dollars at 75% and 85% annual time reliability; (c) annual time reliability plotted against yield for selected FSLs; (d) volumetric reliability plotted against yield for selected FSLs; (e) dam yield at 75% and 85% annual time reliability and degree of regulation (ratio of total controlled releases to total reservoir inflows) plotted against FSL; (f) dam yield and net evaporation (evaporation minus rainfall) divided by yield plotted against annual time reliability.



Apx Figure B-61 Gold Creek potential dam site, storage levels and water yield

(a) Maximum and minimum annual storage trace at the selected full supply level (FSL) and annual spilled volume (i.e. uncontrolled releases); (b) annual exceedance of ratio of annual quantity of water released to annual demand (i.e. yield) under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (c) annual exceedance plot of released volume under conditions where the reservoir was operated to supply the full demand (yield) in 55% to 95% of years at the selected FSL; (d) annual yield at 85% annual time reliability plotted against FSL under Scenario A (baseline) and Scenario D; (e) annual time reliability versus yield for FSL 84 mEGM96 under Scenario A (baseline) and Scenario D.



Apx Figure B-62 Location of listed species, water-dependent assets, and aggregated modelled habitat in the vicinity of the potential Gold Creek dam site

FSL = full supply level.

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