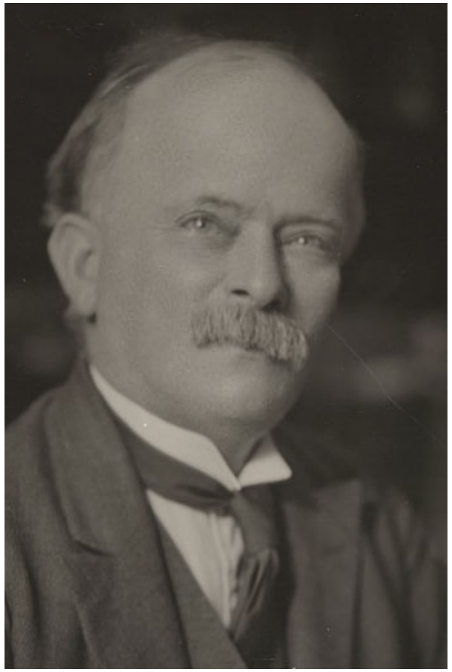
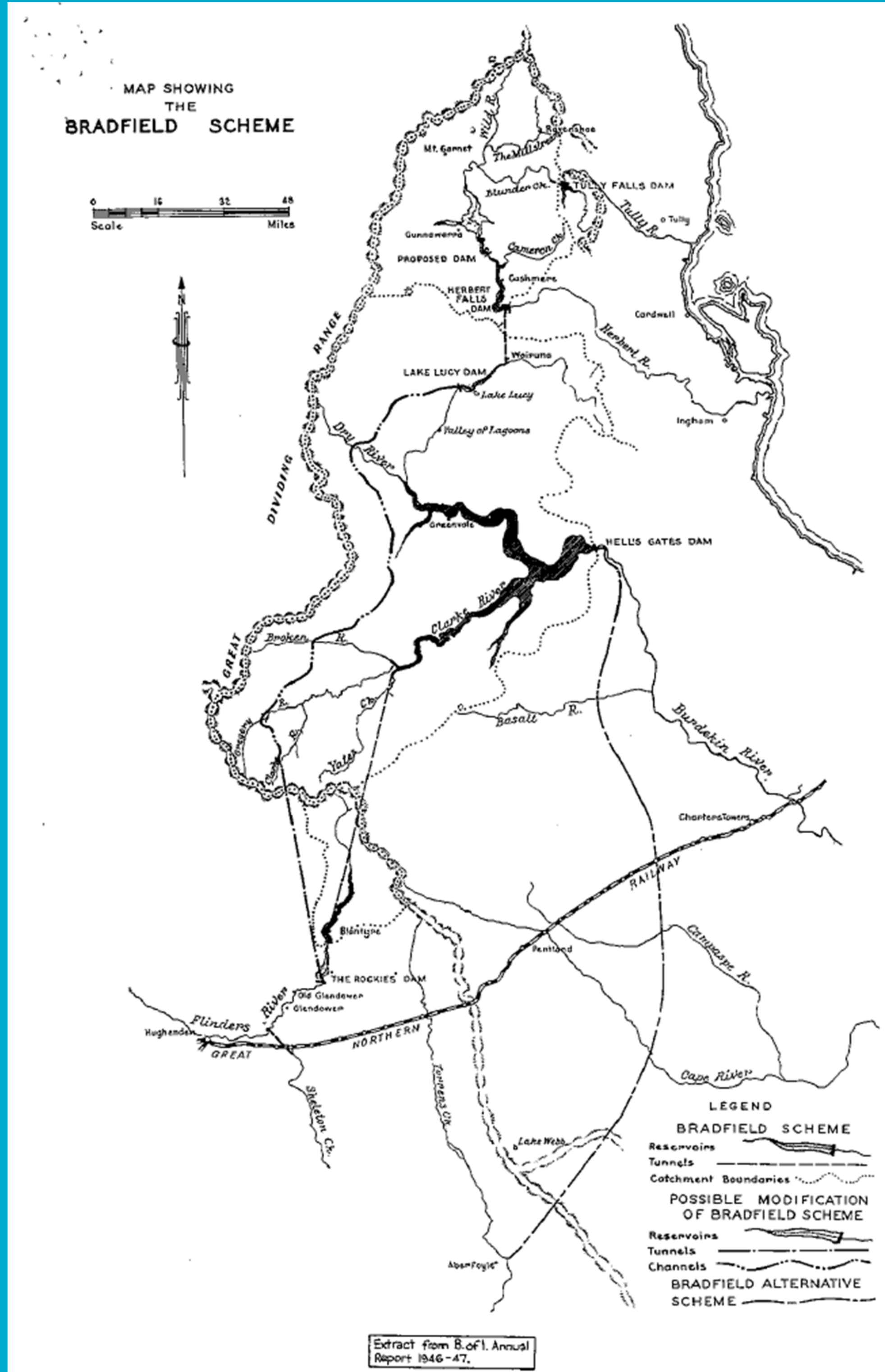
An assessment of the Bradfield Scheme and modern variants

(August 2020 to May 2021)

Cuan Petheram | 9 November 2022
Chris Stokes
Tom Vanderbyl
and many others



Dr John Bradfield
(1867 – 1943)
Australian engineer most famous for overseeing the design and construction of the Sydney Harbour Bridge



Overview slide

“In the development of Australia the wings of dawn are but beating at the break of day”

“We can hold the Commonwealth only by effective occupation”

Dr John Bradfield (1941)

Rebecca Bartley
Sediment runoff to GBR

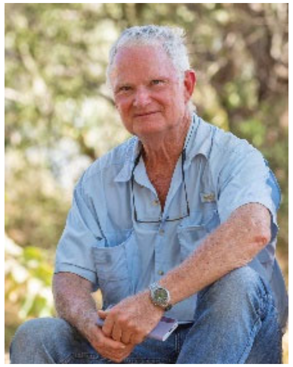
Arthur Read
Infrastructure modelling

Chris Chilcott
Project director

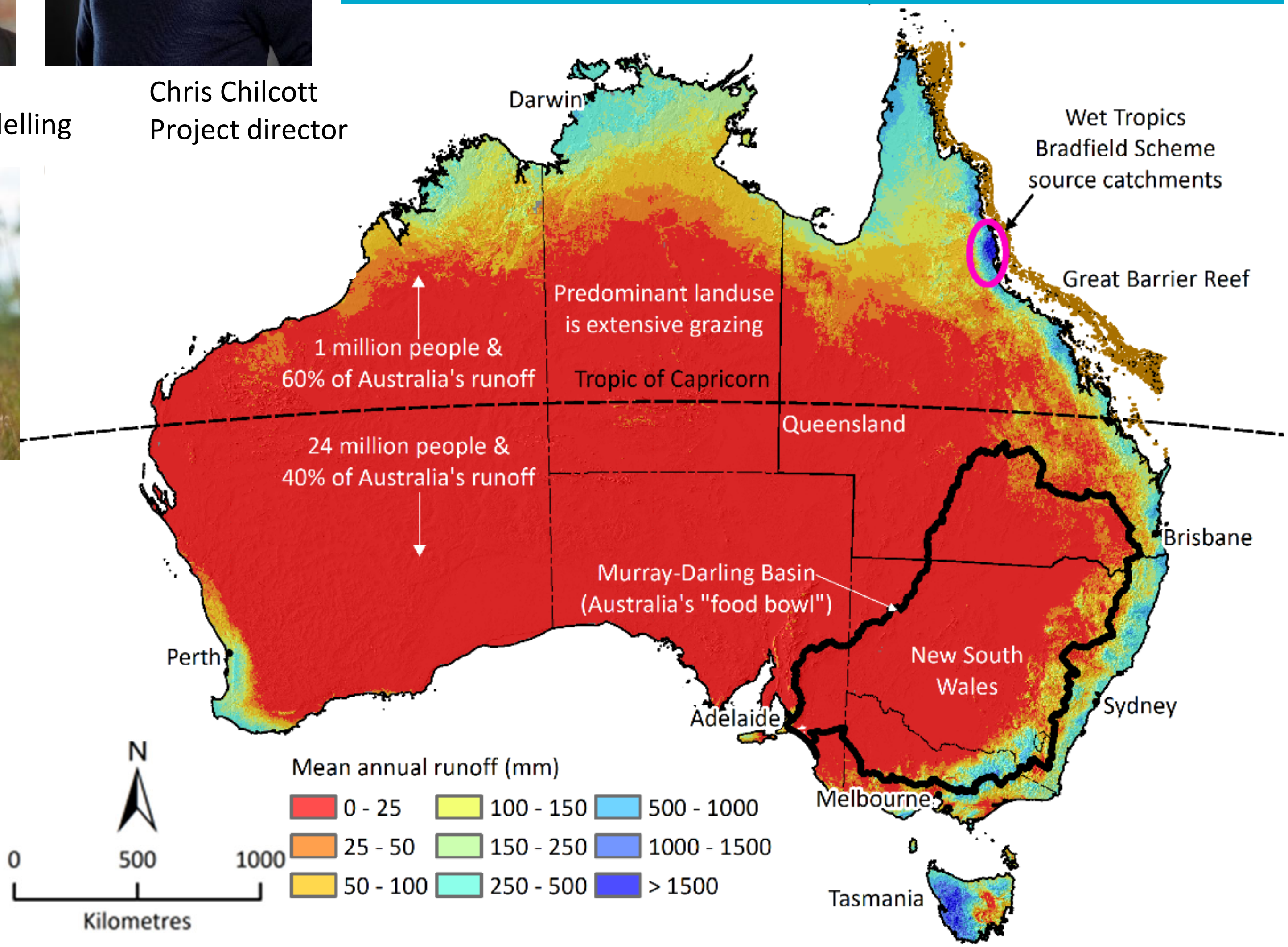
Justin Hughes
River modelling

Seonaid Philip
Soil scientist

Jenny Hayward
Energy and technology costs



Kev Devlin
Diversion and reticulation infrastructure advisor



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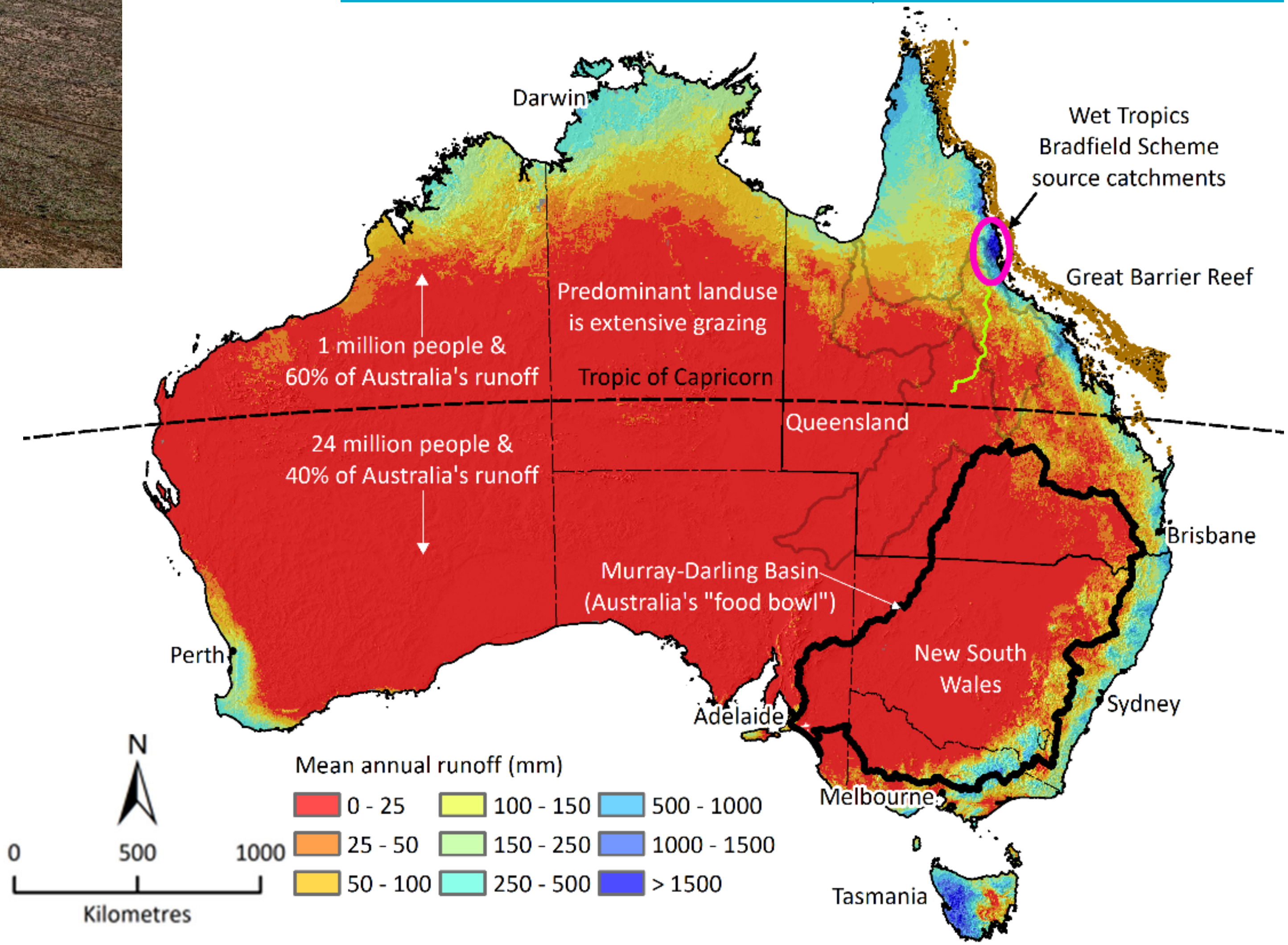

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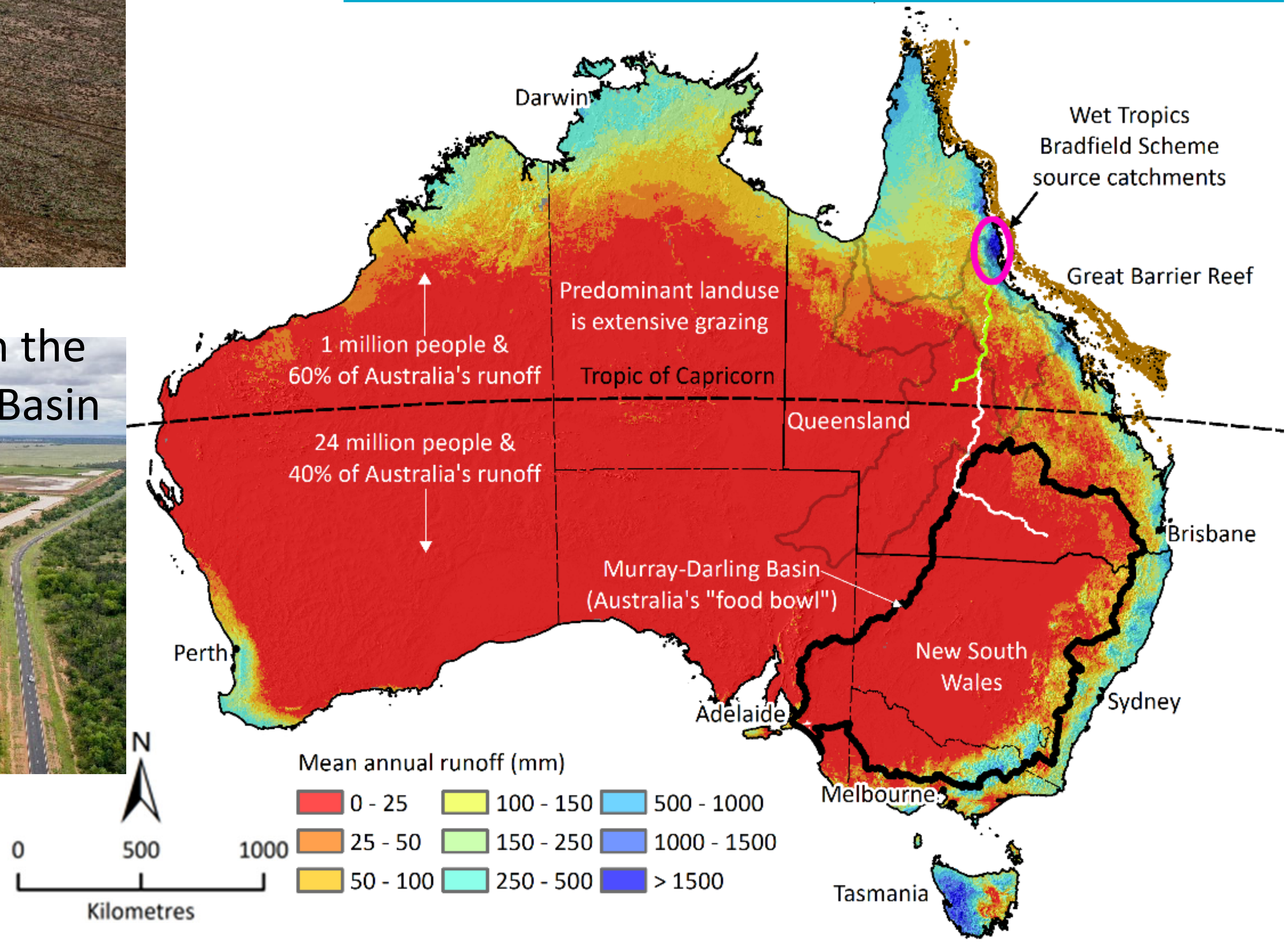


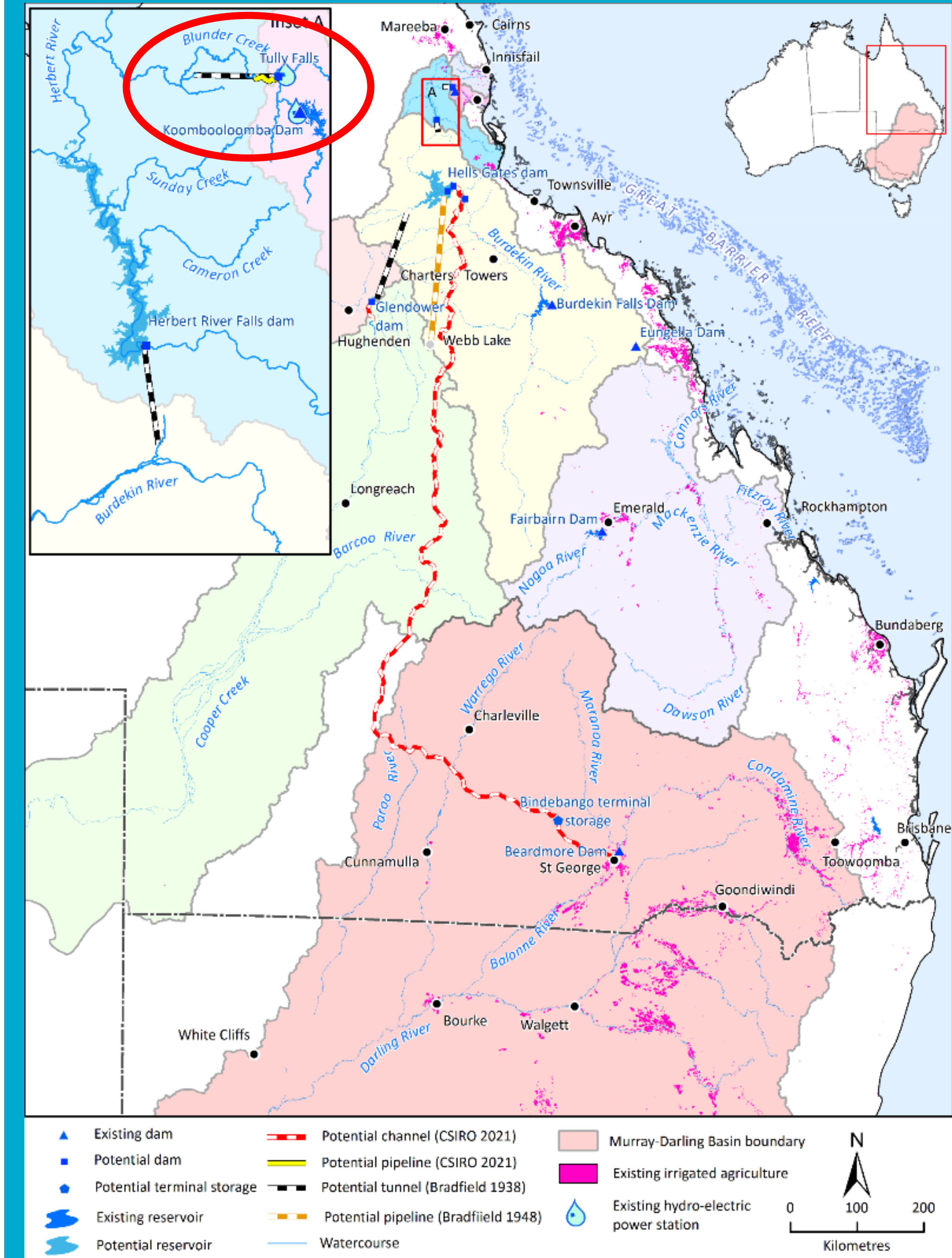
What is the Bradfield Scheme?

Dam on the Tully River at Tully Falls and a diversion tunnel to Blunder Creek

Koombooloomba Dam on the Tully River

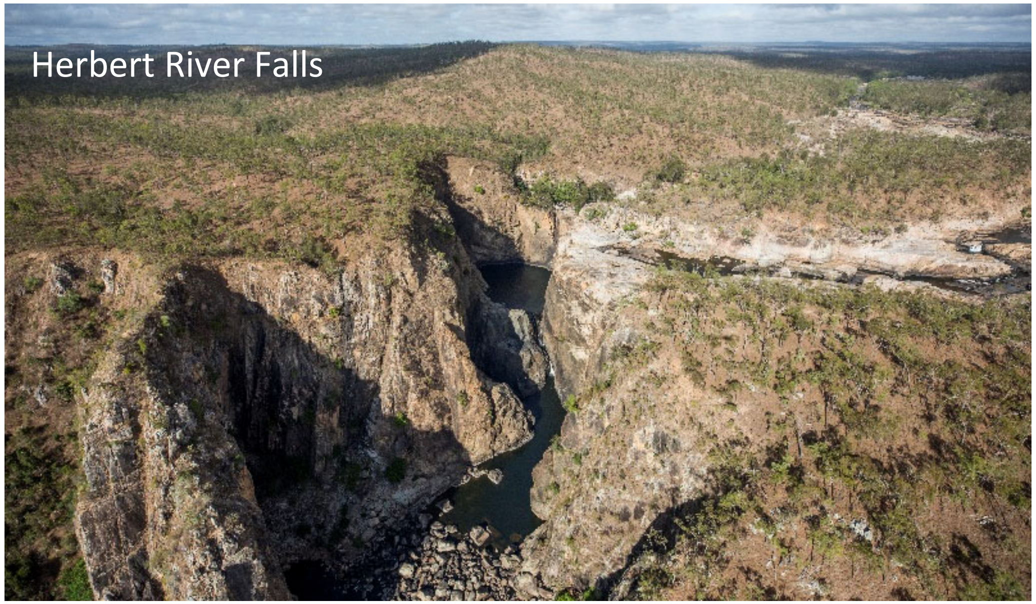
Weir at Tully Falls on Tully River

Original Bradfield Scheme

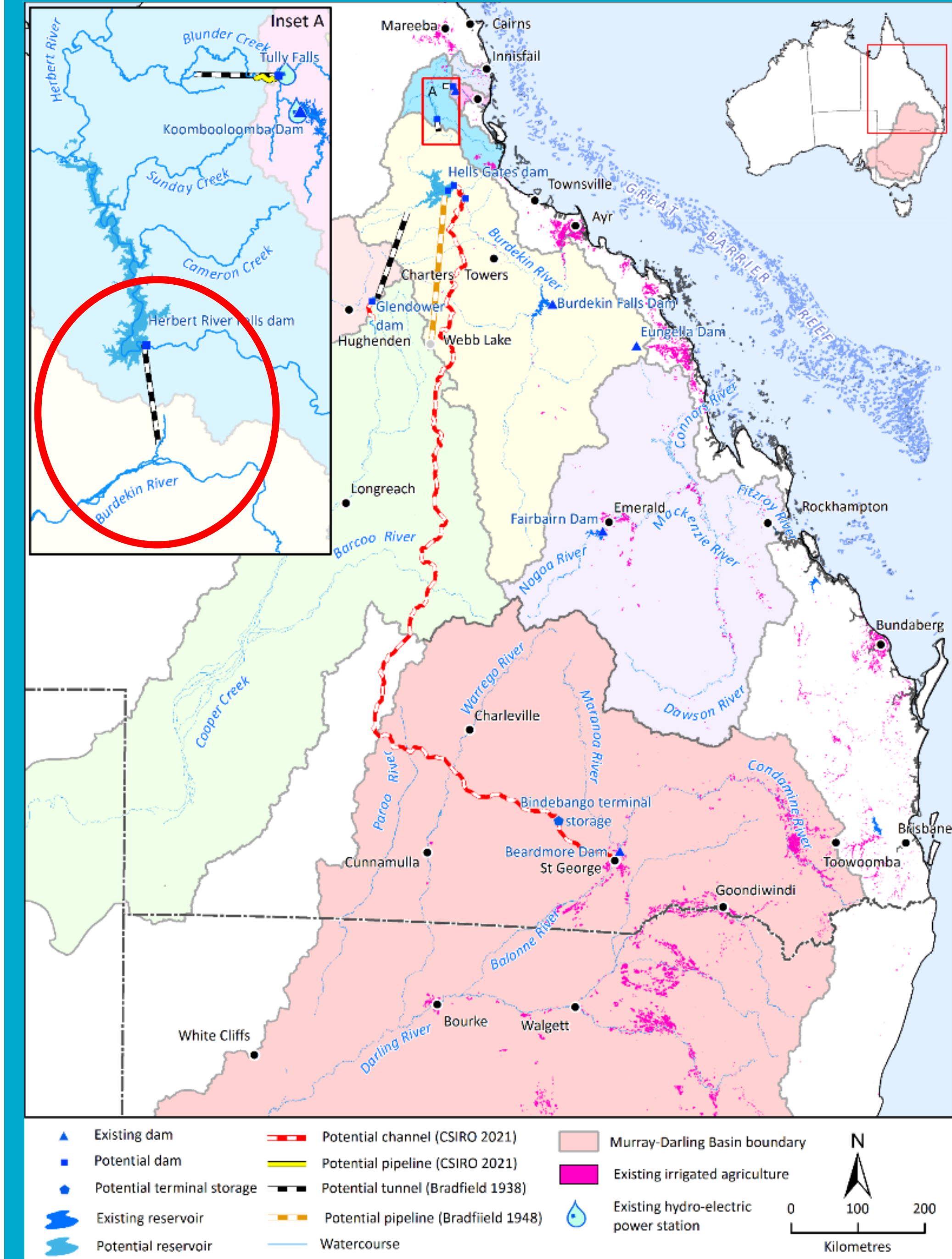


What is the Bradfield Scheme?

Dam on the Herbert River near Herbert River Falls Tully Falls and a diversion tunnel to the Burdekin River



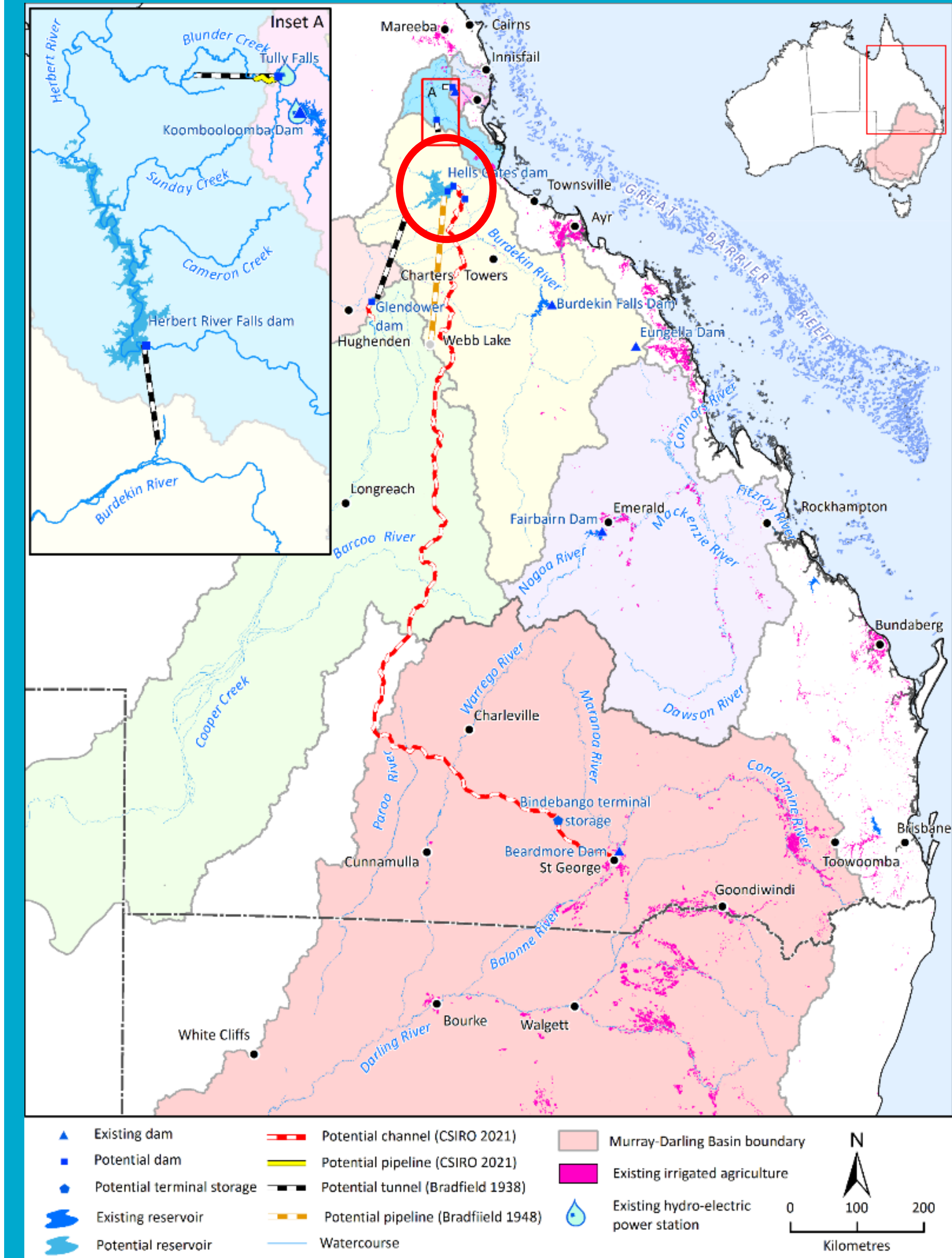
Original Bradfield Scheme



What is the Bradfield Scheme?

Dam at Hell's Gates on Burdekin River

Original Bradfield Scheme

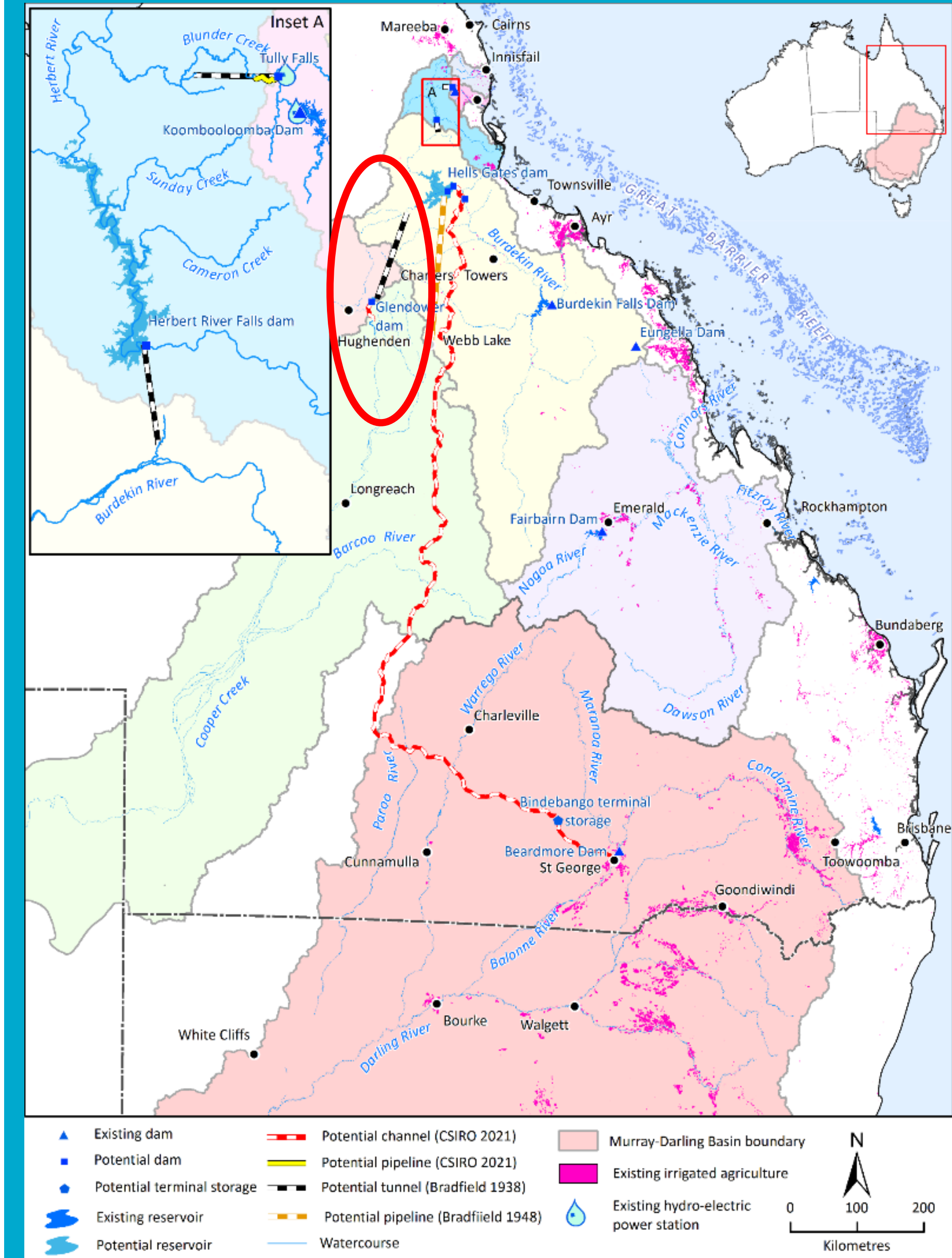


What is the Bradfield Scheme?

Bradfield (1938)

Diversion under the Great Divide to a dam/s on the Flinders River and open cut channel to Skeleton Creek

Original Bradfield Scheme



What is the Bradfield Scheme?

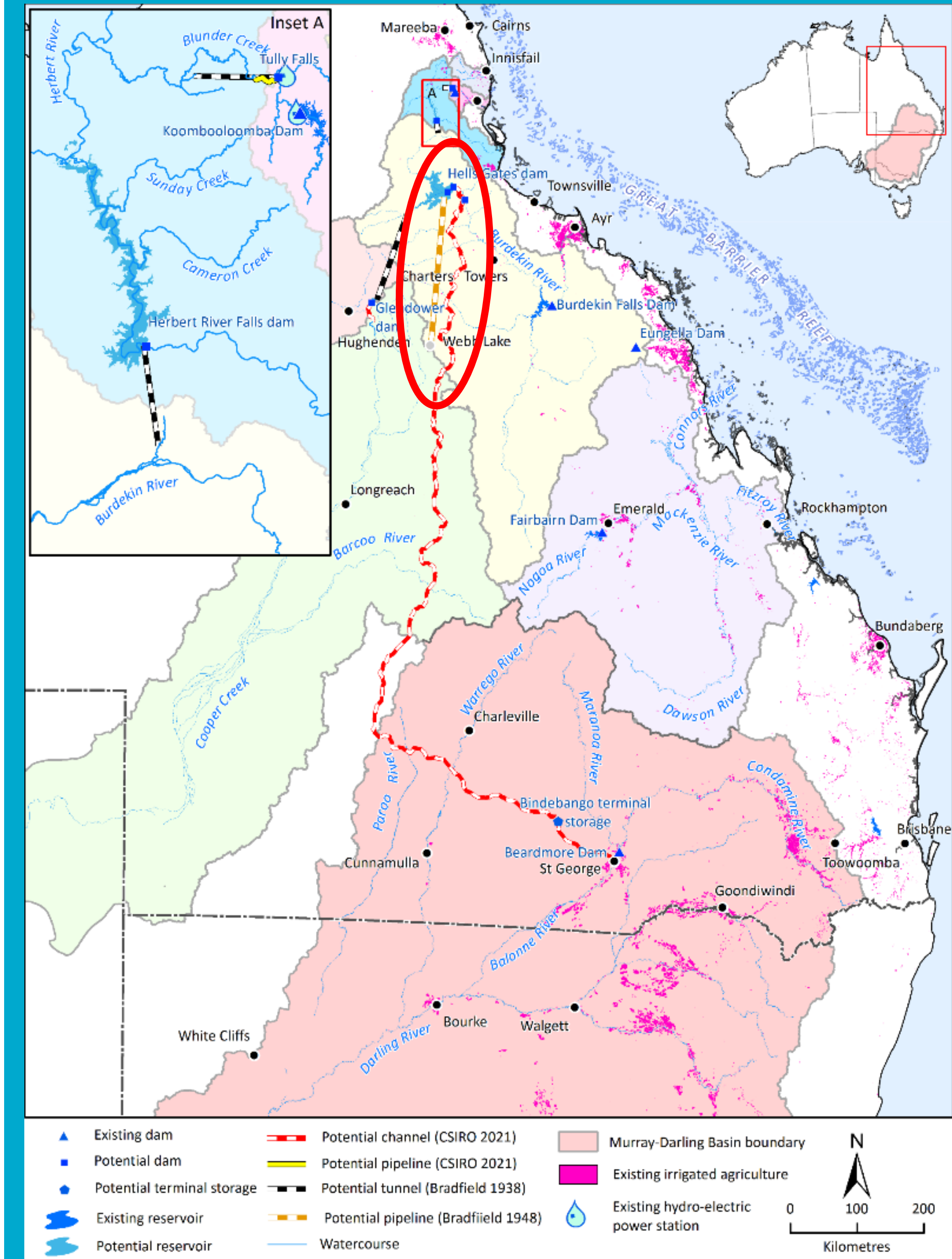
Bradfield (1938)

Diversion under the Great Divide to a dam/s on the Flinders River and open cut channel to Skeleton Creek

Bradfield (1942)

Pipeline/channel to Webb Lake/Lake Buchanan and diversion into Thomson

Original Bradfield Scheme



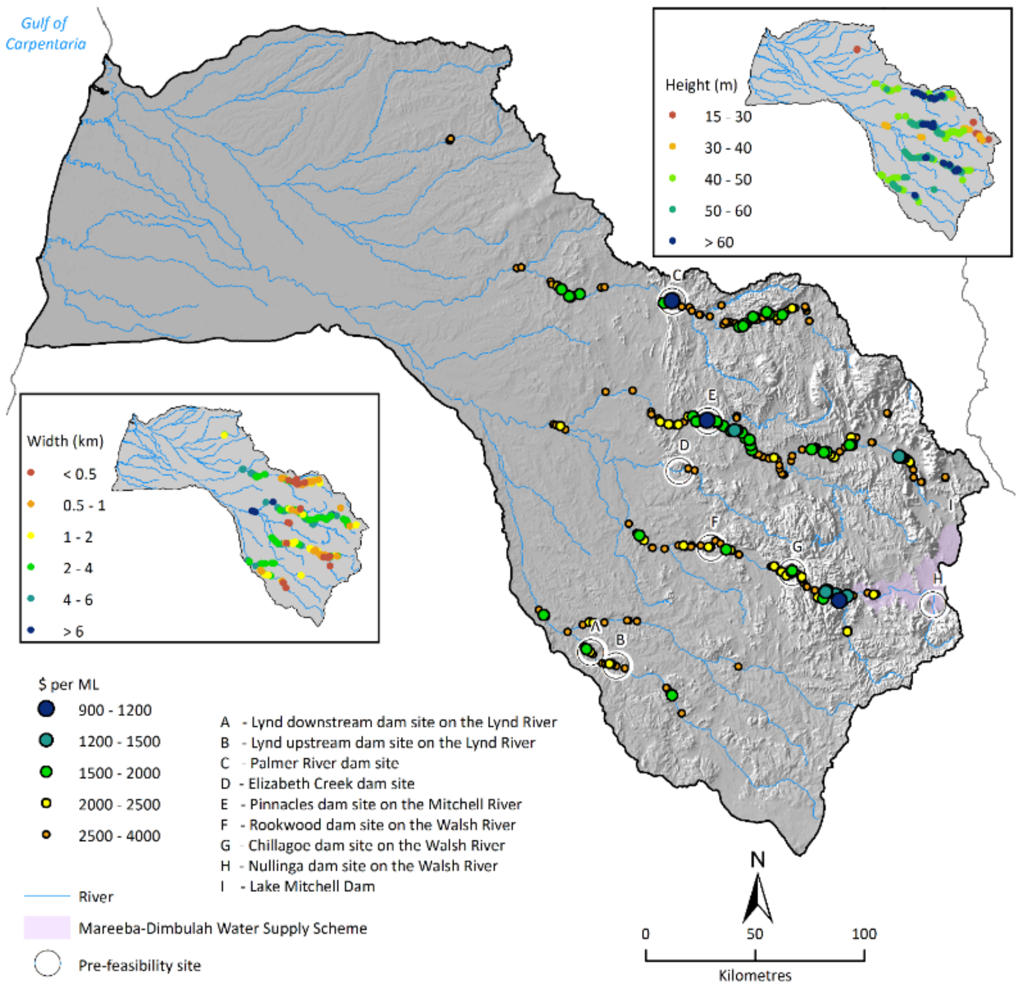
Hydrological modelling (River system models)

Water plan (WP) is a statutory document that defines the long-term availability of water for different purposes including environmental and consumptive water uses in a specific river basin or groundwater resource.

WP require that decisions about the allocation & management of water in a river basin are consistent with the Environmental Flow Objectives (EFO) and Water Allocation Security Objectives (WASO) stated in the plans.

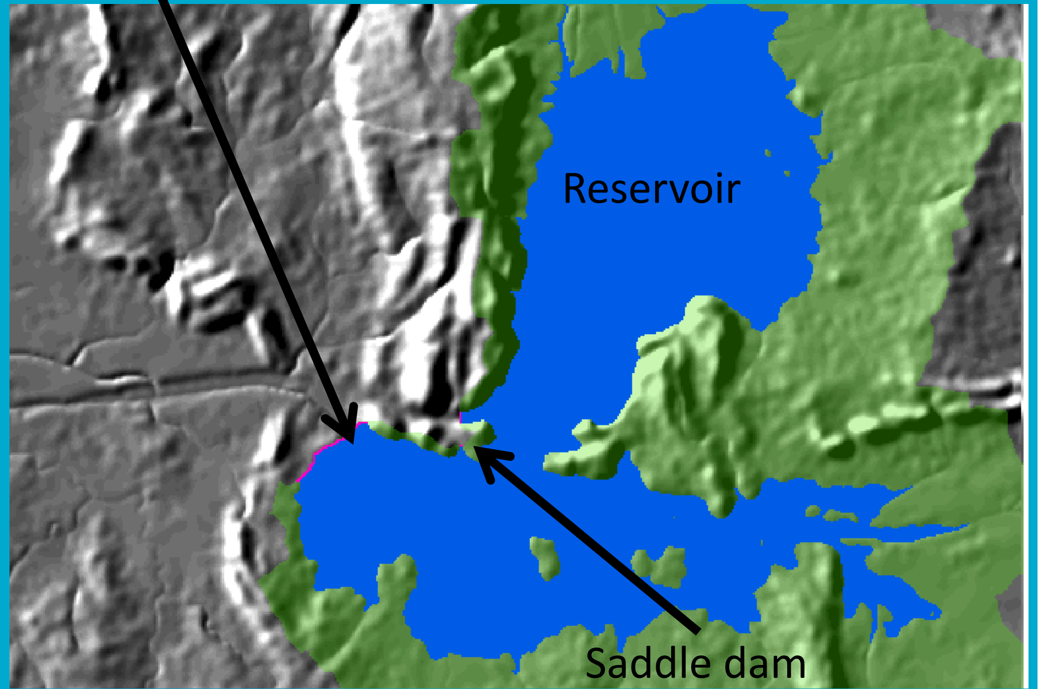
Herbert River above Herbert River Falls

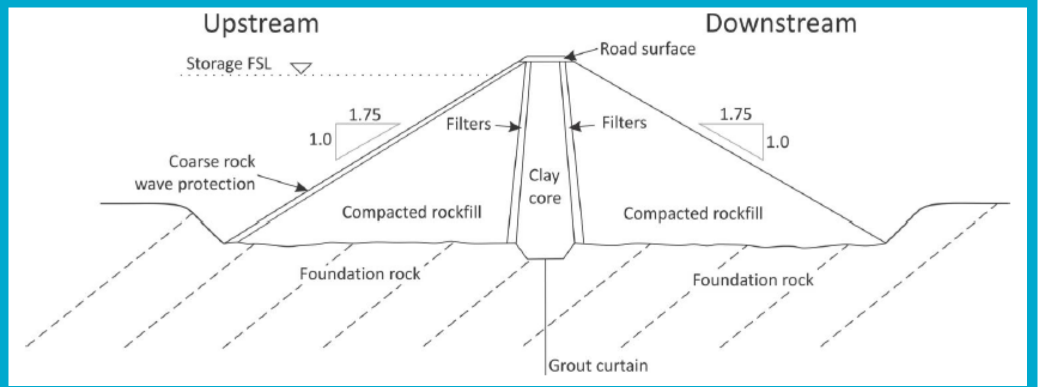
Modelling dam cost (DamSite model)



Yield = controlled release of water from a dam

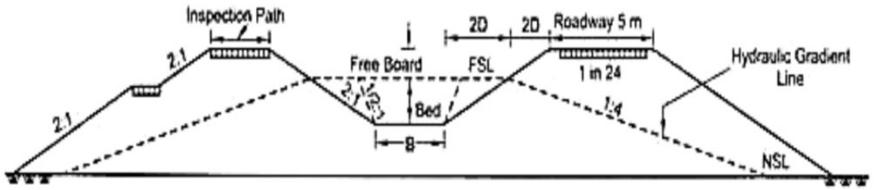
Main dam wall

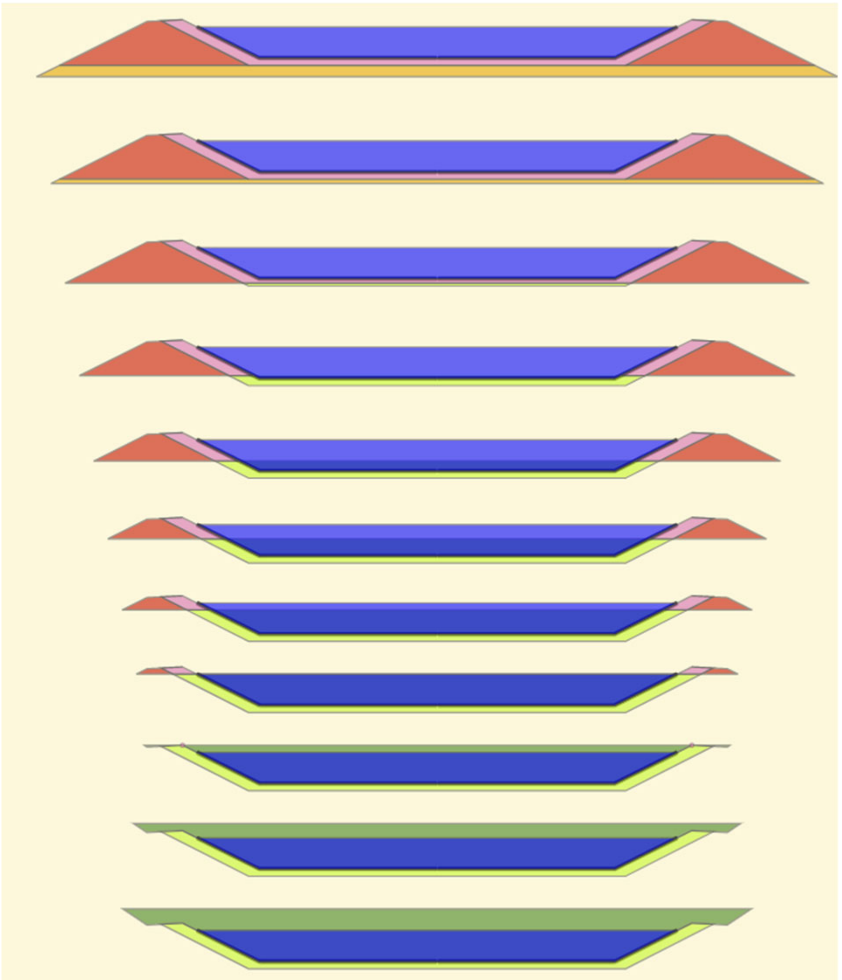


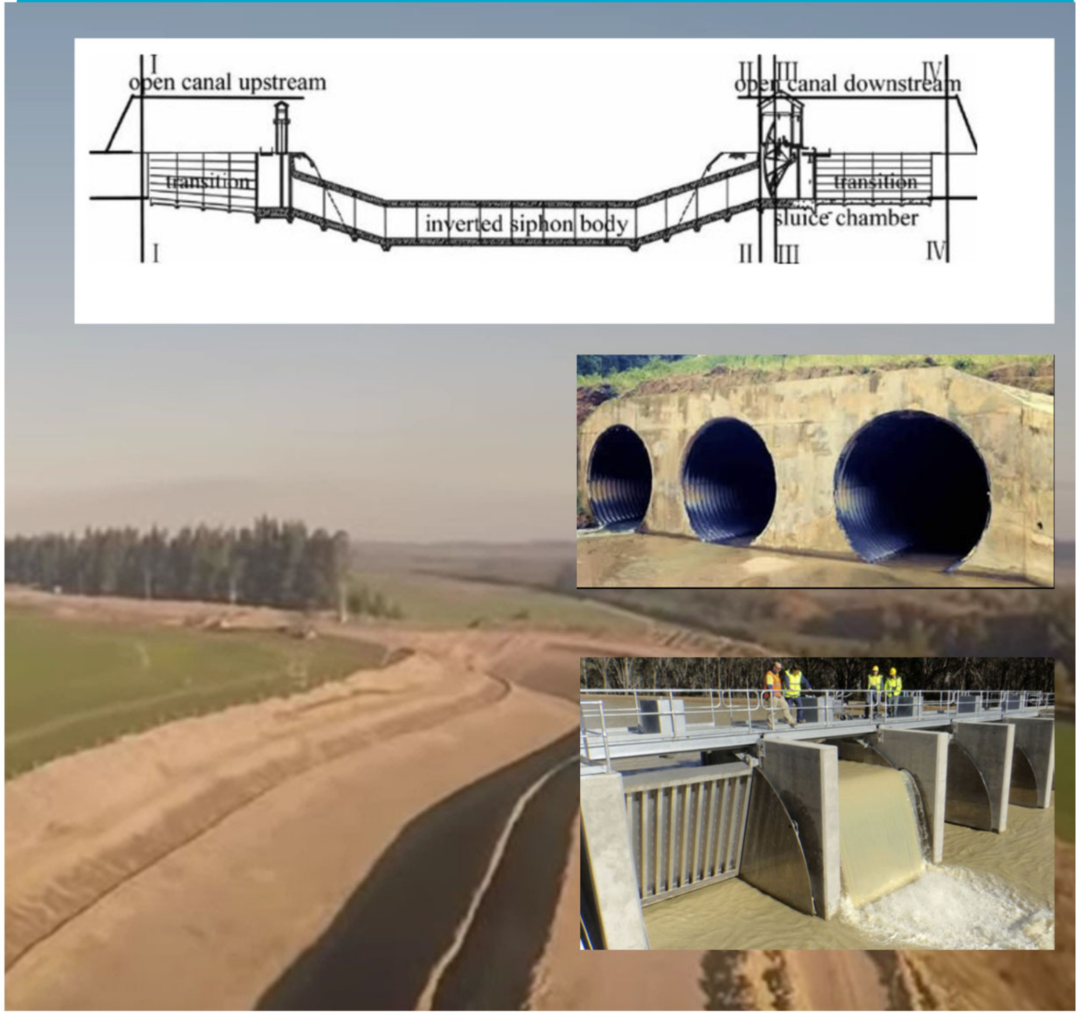


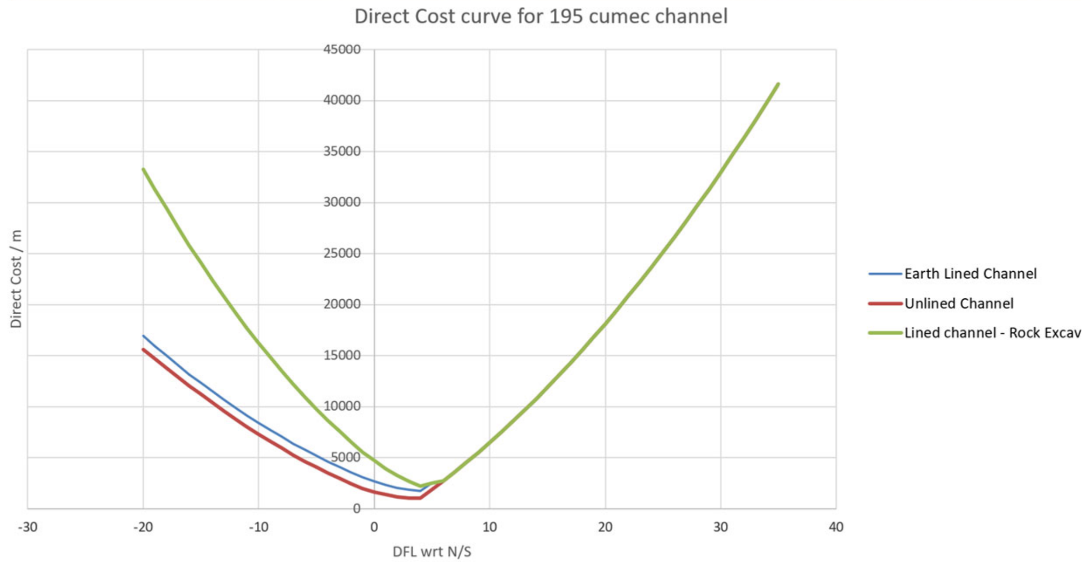
Dam cost calculated by calculating volume of each material required multiplied by (non-linear) unit cost models

Modelling diversion channel cost (WaterRoute model)







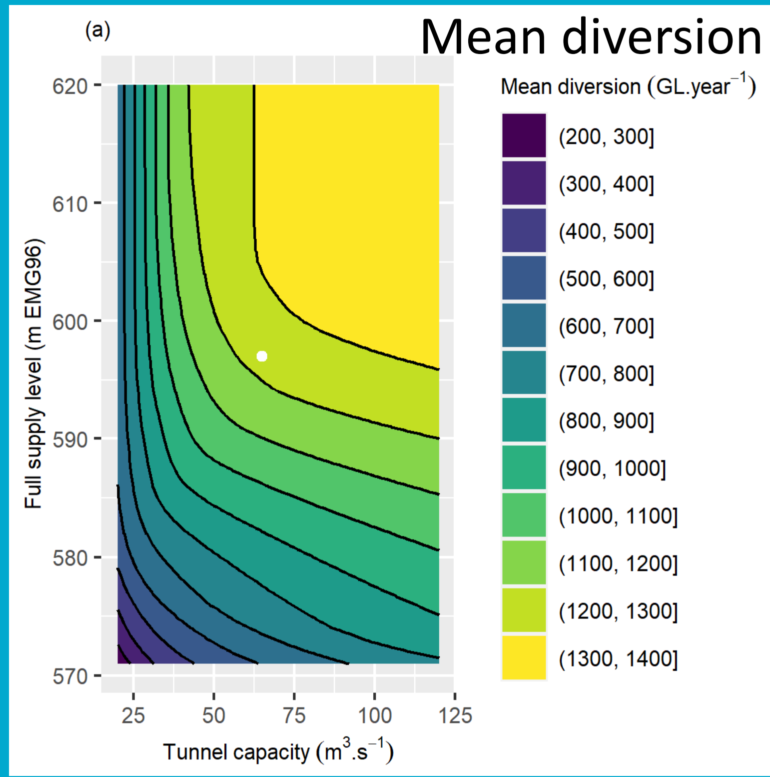


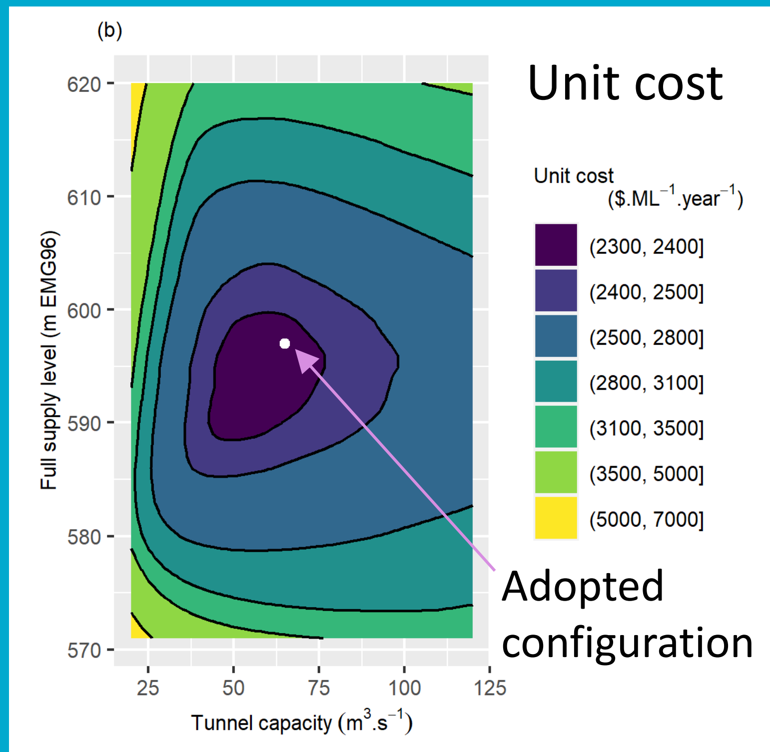
Screening vs scoping level costs

Screening-level cost
Modelled cost with no input from engineer.

Scoping-level cost
‘Traditional method’ where costs are calculated by engineer/s undertaking manual calculations

All costs in $AUD and indexed to December 2020 (pre-COVID)





Screening vs scoping level costs

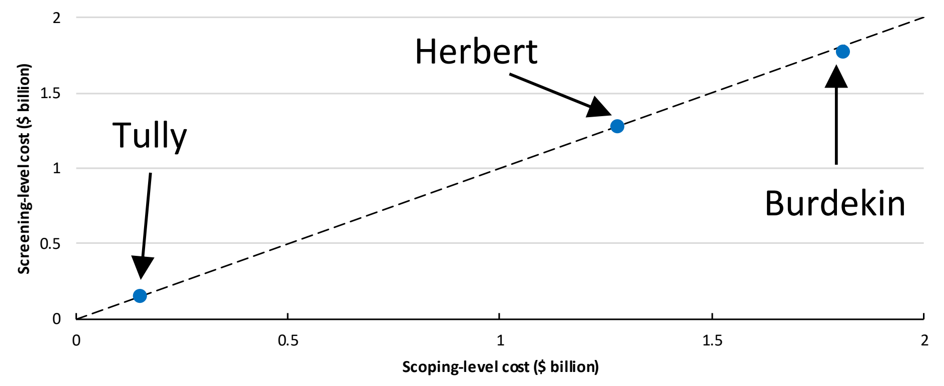
<u>Screening-level cost</u>
Modelled cost with
little to no input from engineer.

<u>Scoping-level cost</u>
Cost calculated by engineer/s undertaking manual calculations

All costs in $AUD and indexed to December 2020

Dam cost comparison

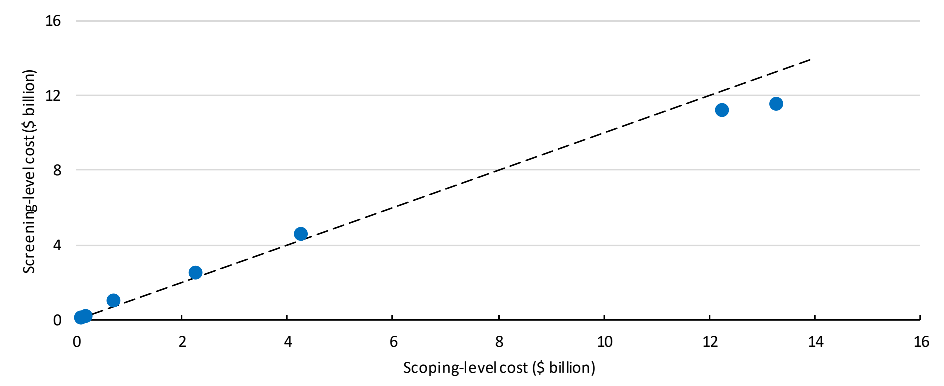
Screening-level costs ($b)



Scoping-level costs ($b)
(Lee Rogers – Appendix C)

Tunnel cost comparison

Screening-level costs ($b)



Scoping-level costs ($b)
(SMEC – Appendix E)

Tunnel screening-level costs estimated using non-linear empirical relationships from actual tunnel costs found in literature

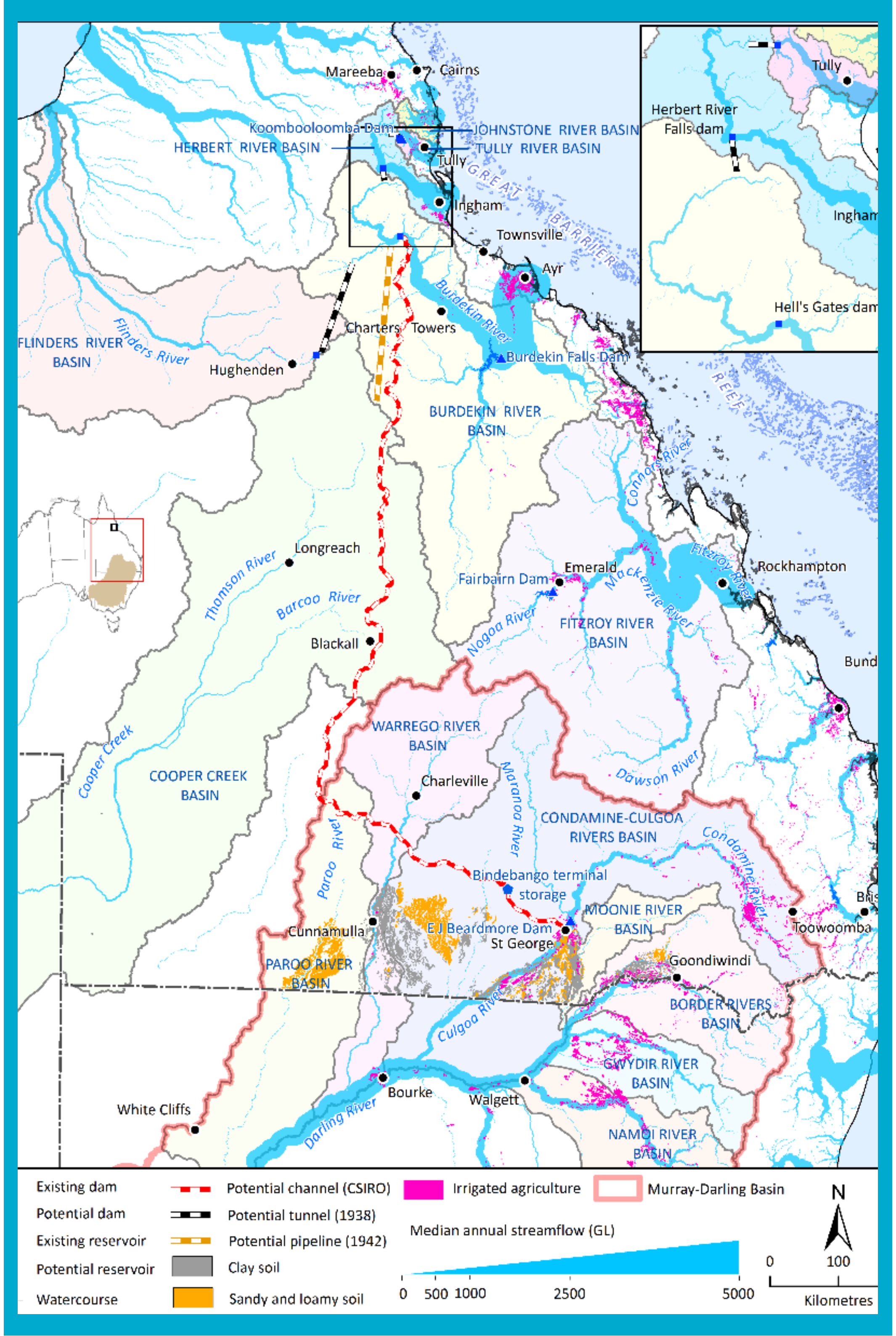
Is Bradfield's scheme feasible?

Technically feasible with some minor modifications

However, there are issues…..

Mean streamflow

LOCATION	BRADFIELD (GL/YEAR)	CSIRO 2020 (GL/YEAR)
Tully River at Tully Falls	562	506†
Herbert River at Herbert River Falls	2677	1090‡
Upper Burdekin River at Hell's Gates	3678	1603§
Flinders River at Glendower	275	107††
Total	7192	3306



Thickness of blue lines indicates median annual streamflow

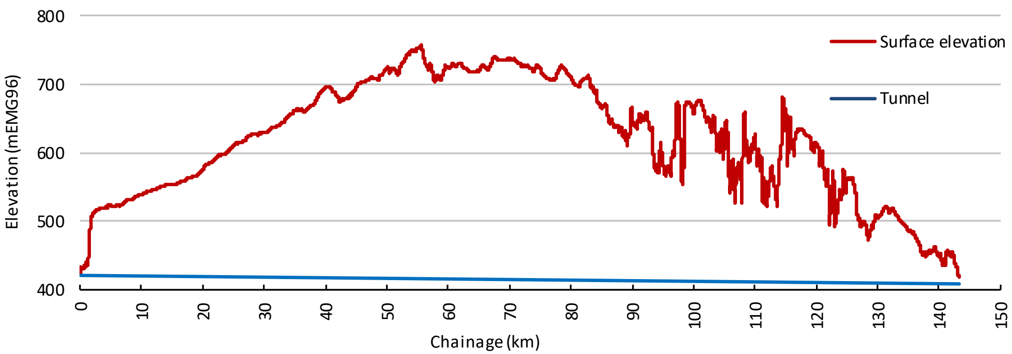
Generated using locally calibrated landscape model (AWRA-L).

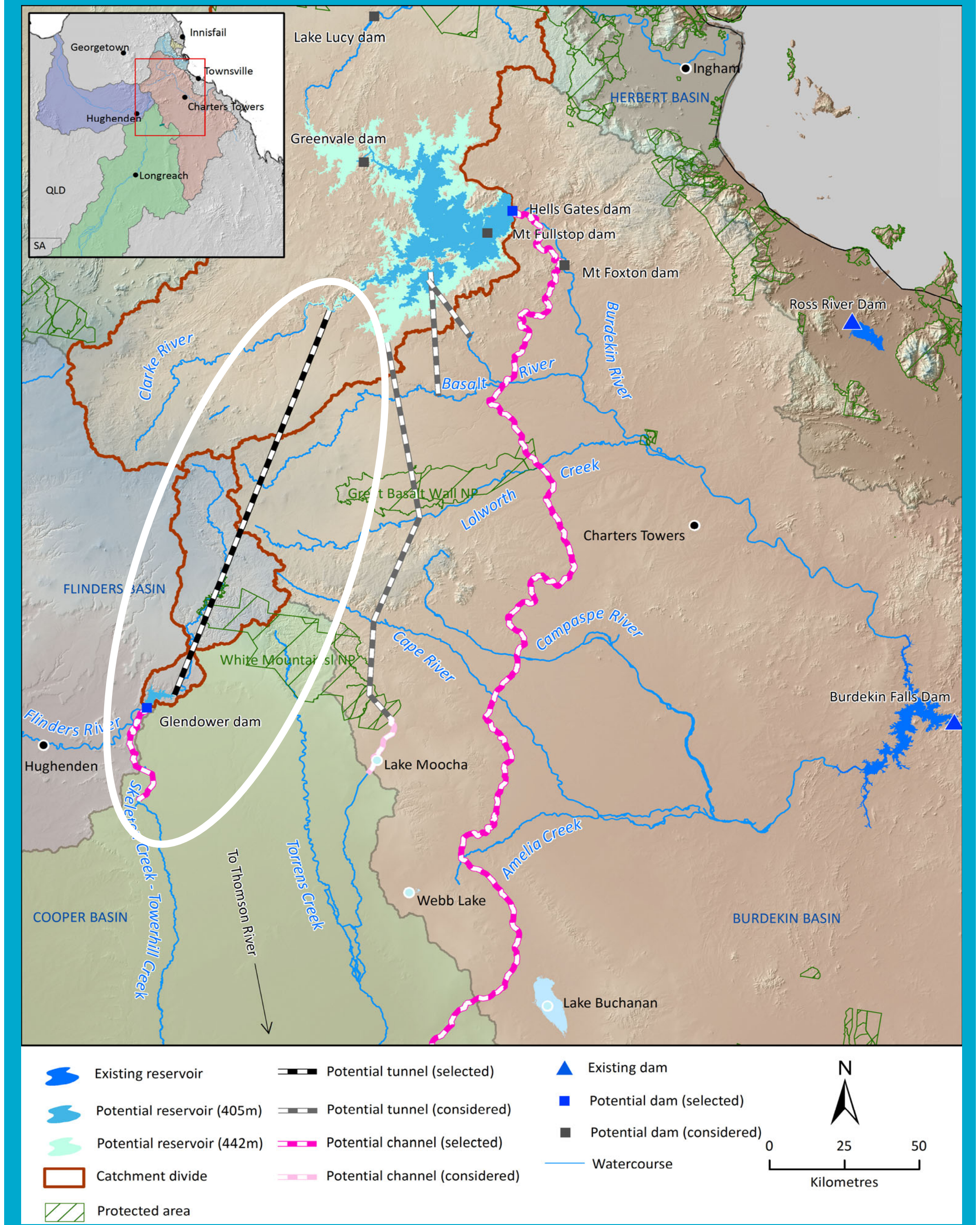
Bradfield's original (1938) proposal

- Limitations of high tunnel offtake
  - High net evaporation
  - Take on average 19 years for water to start spilling into diversion tunnel

  - It may be possible for 7 boring machines operating simultaneously to complete tunnel in ~10 years
  - Considerable logistics challenges – overburden up to 300 m thick.

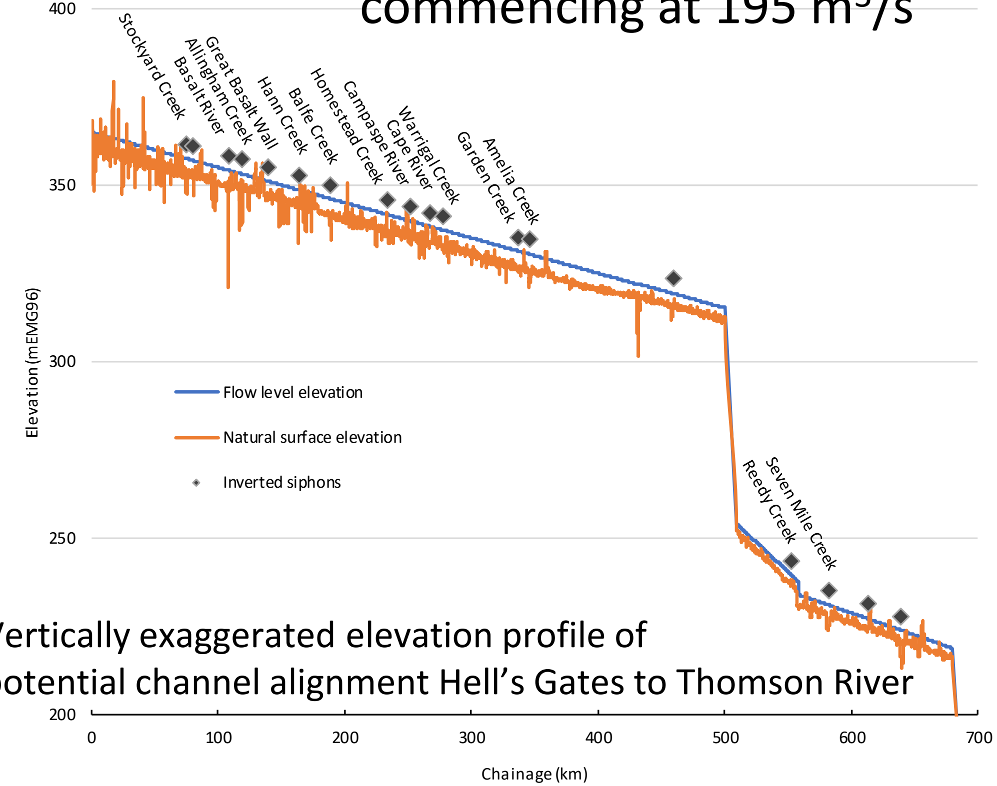
Hell's Gates to Flinders River tunnel profile



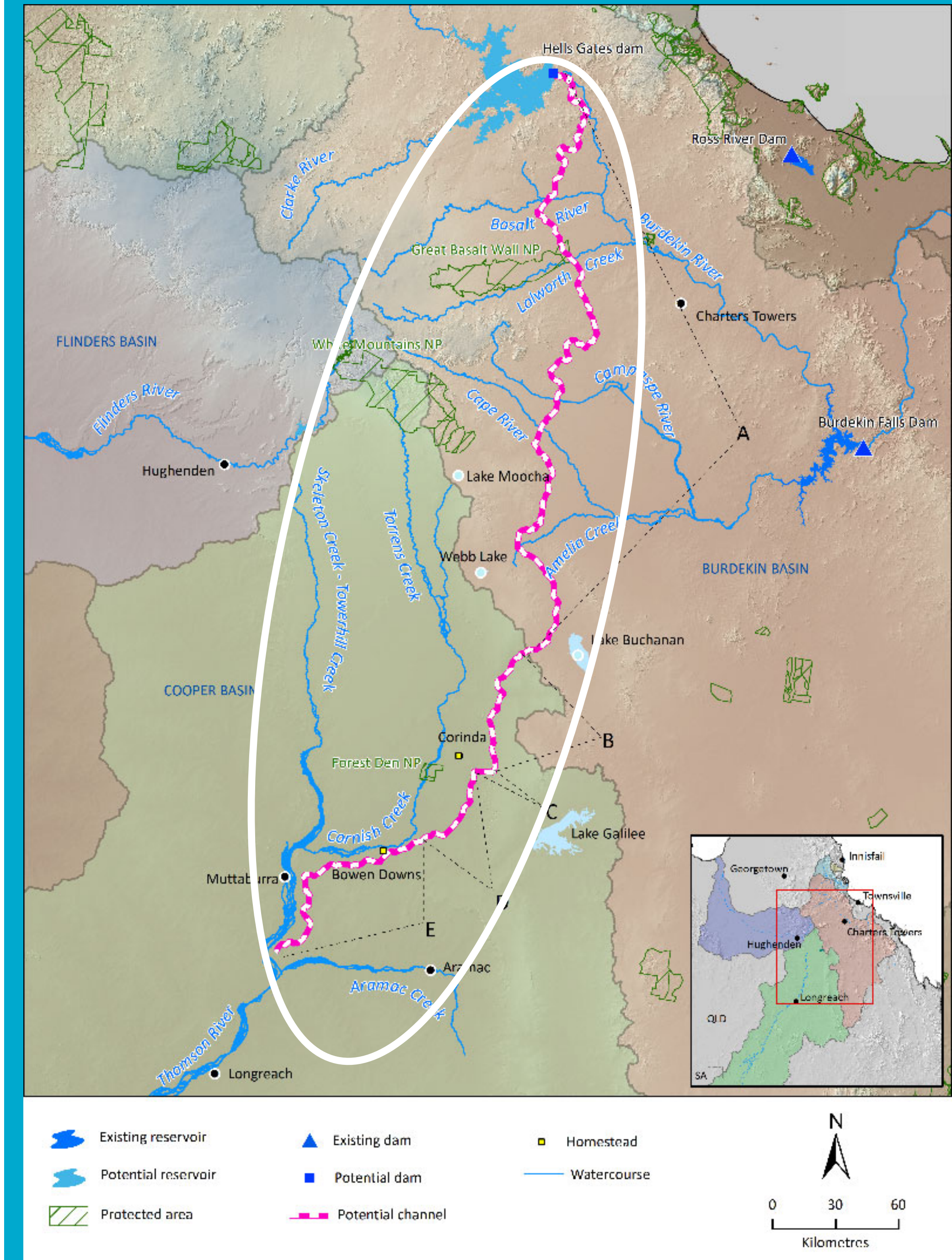


Bradfield's variation (1942)

- Adopted gravity channel and 97.5m high dam at Hell's Gates
- Yield > 2000 GL in 75% of years, considerably higher than previous studies but half of what Bradfield estimated.
- 670-km channel estimated.
- Channel designed for peak flow commencing at 195 m^3/s

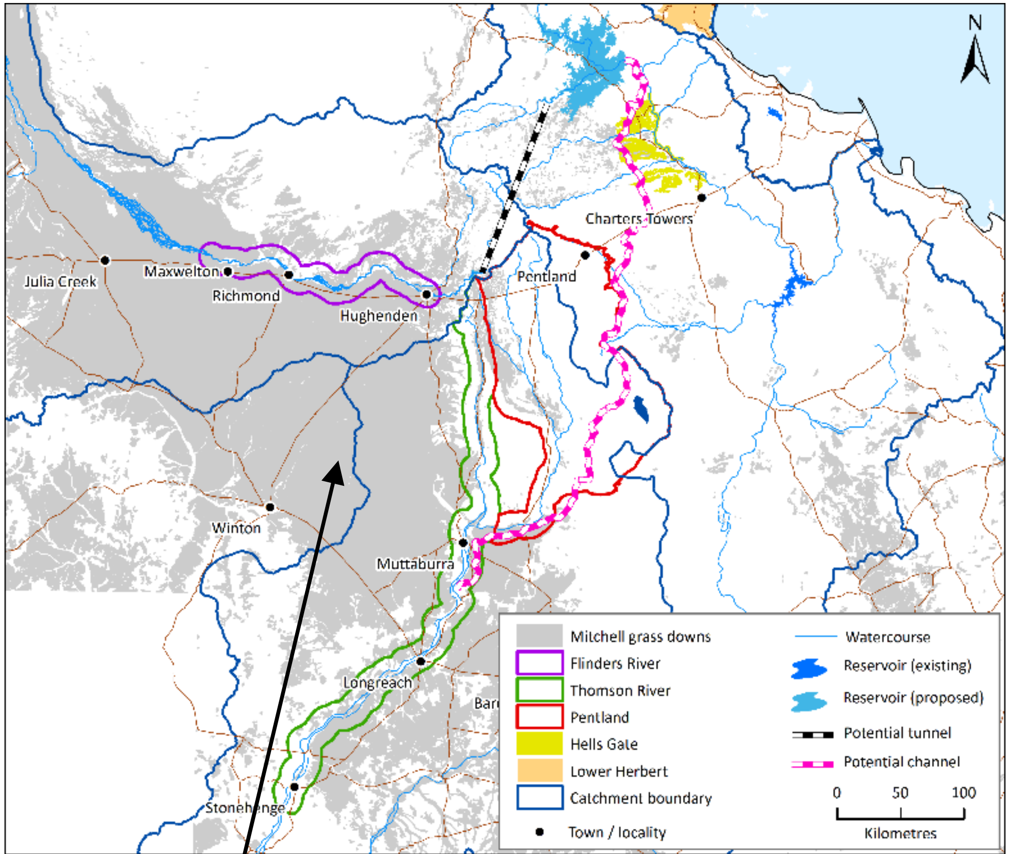


Vertically exaggerated elevation profile of potential channel alignment Hell's Gates to Thomson River



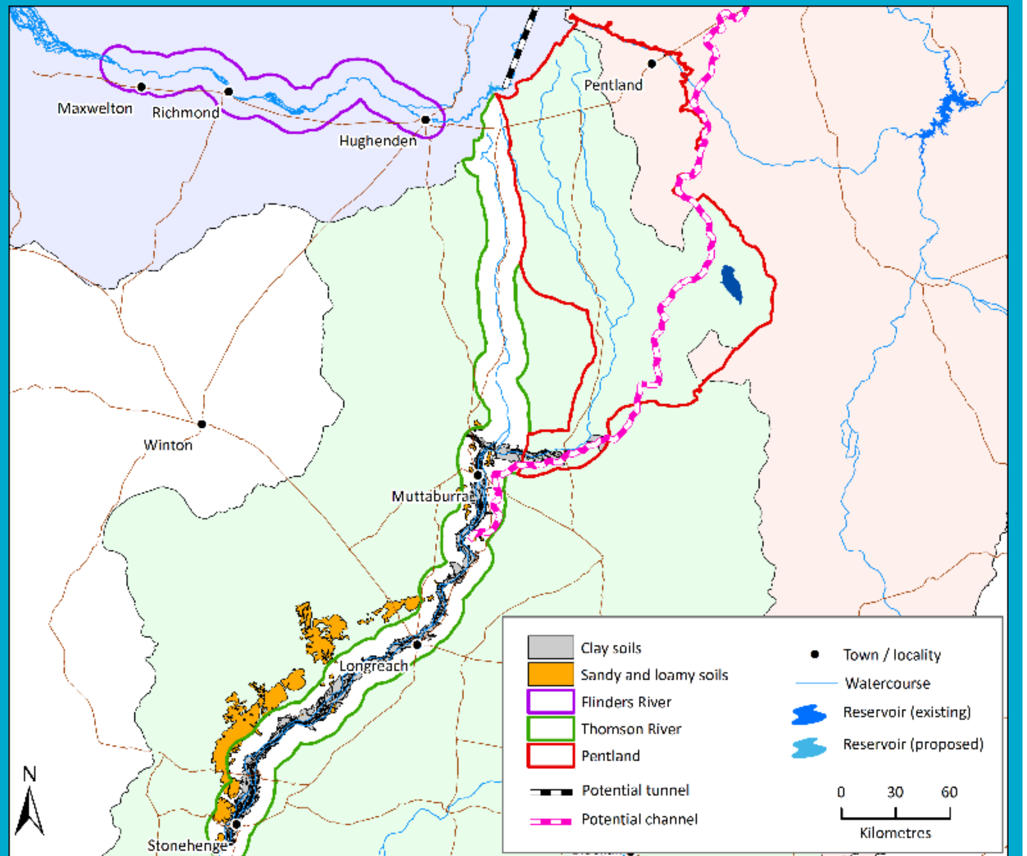
There is more water than there is suitable soil to irrigate

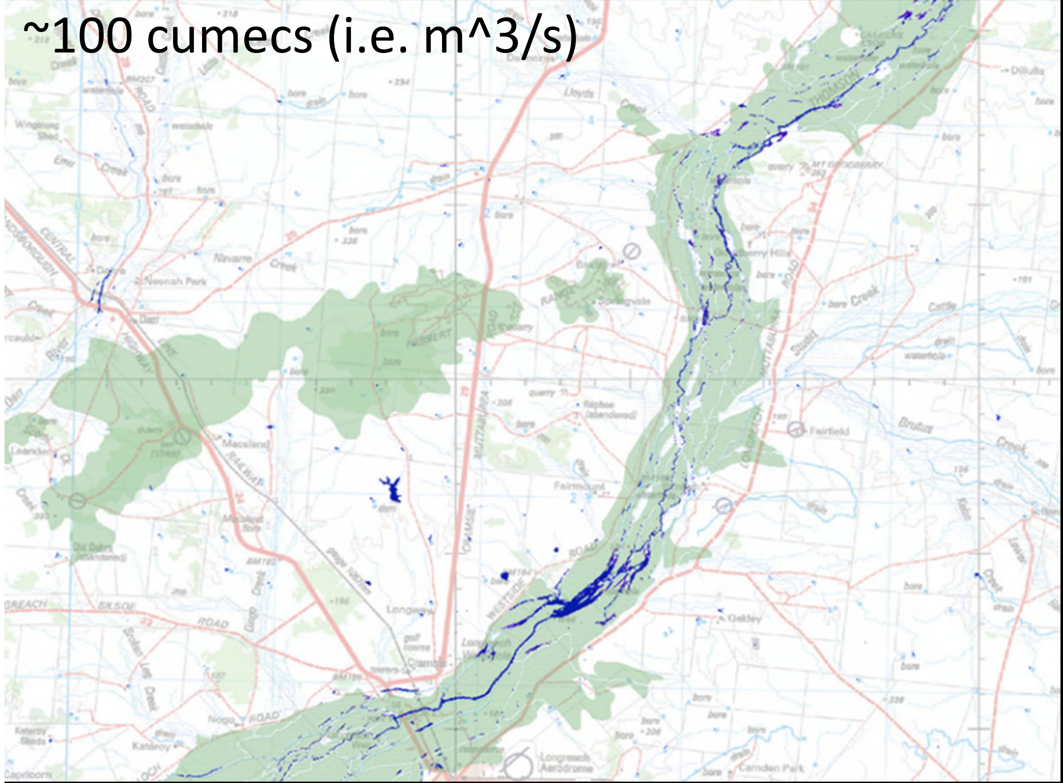
“4000 sq miles of the best agricultural land in the State” Bradfield (1938)

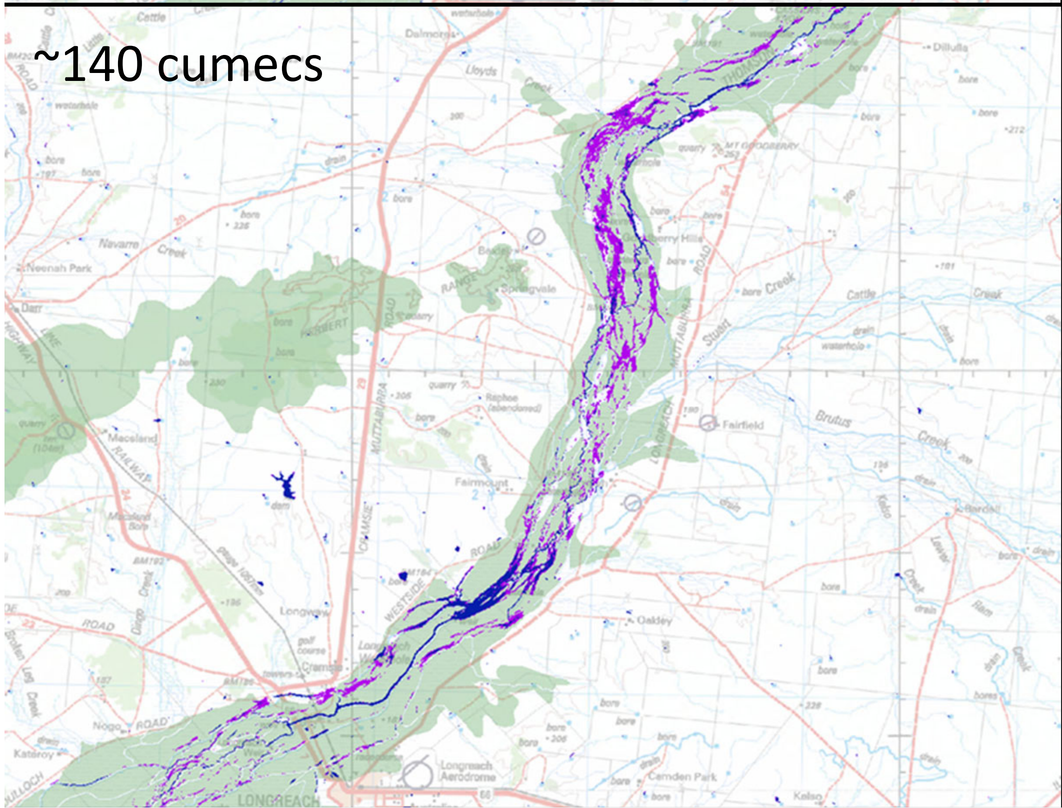


Mitchell grass downs country

Mitchell grass downs support productive pastures but tend to have high levels of salt in their subsurface




~100 cumecs (i.e. m^3/s)


~140 cumecs

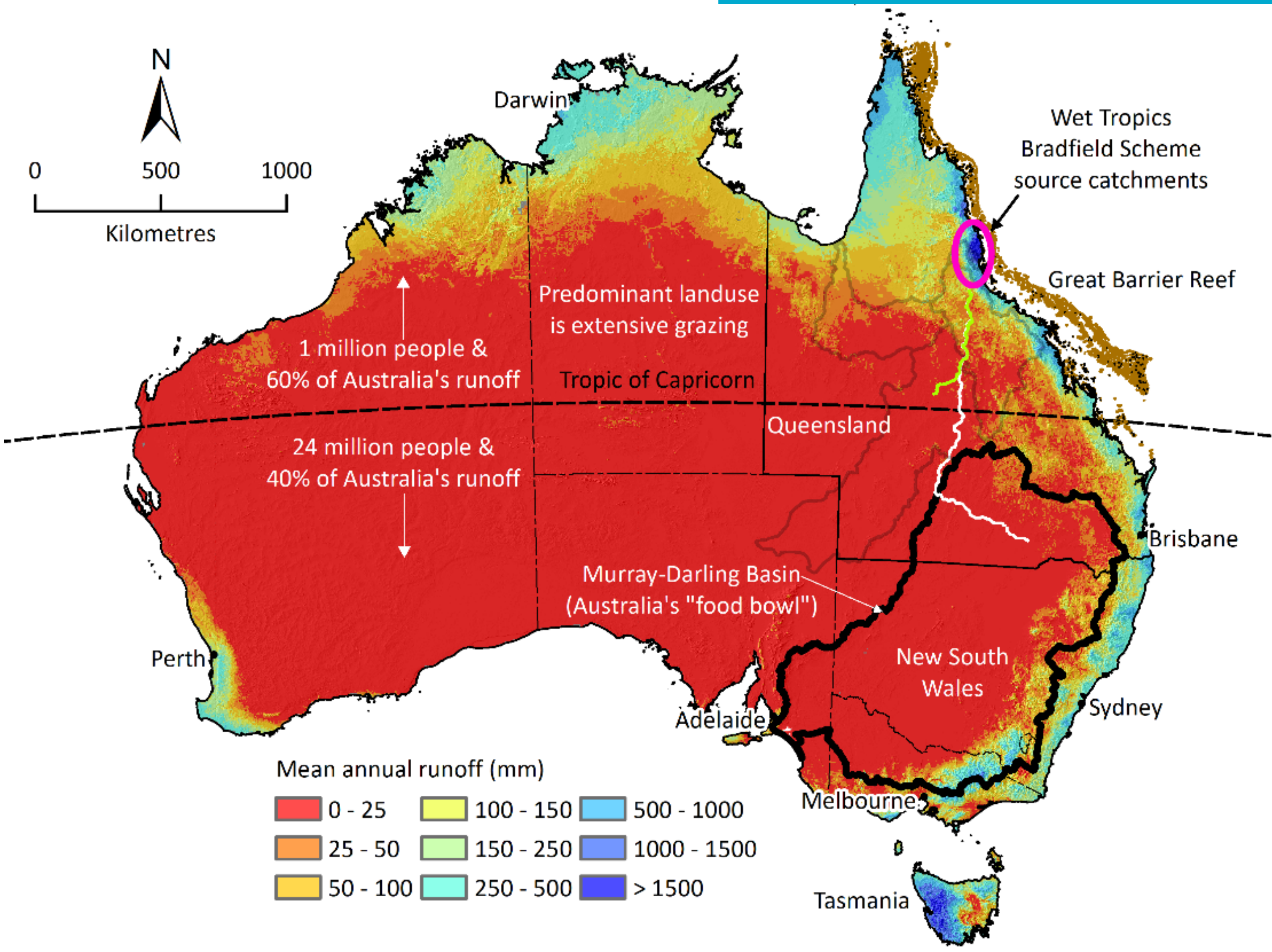

Thomson River and distributary channels

Bradfield's Scheme

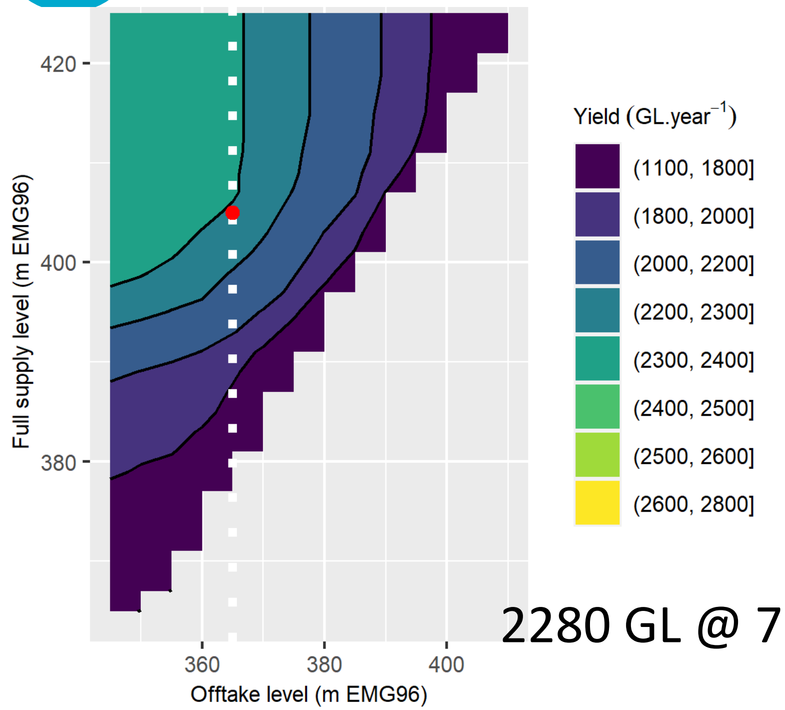
- Diverting water at great cost
- Incurring water losses en-route
- To irrigate an area where:
  - Water can be used less efficiently
  - Remote - higher input costs
  - Produce has to be transported back to coast (from where water originated)

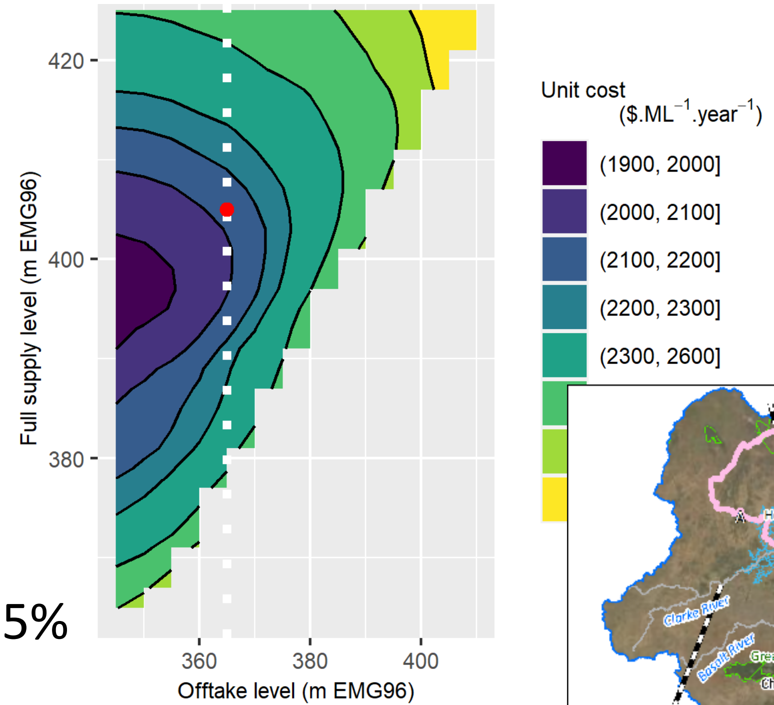

Longreach on Thomson River
Western Queensland after rain

Analysis of contemporary Bradfield Schemes (Stage 2)

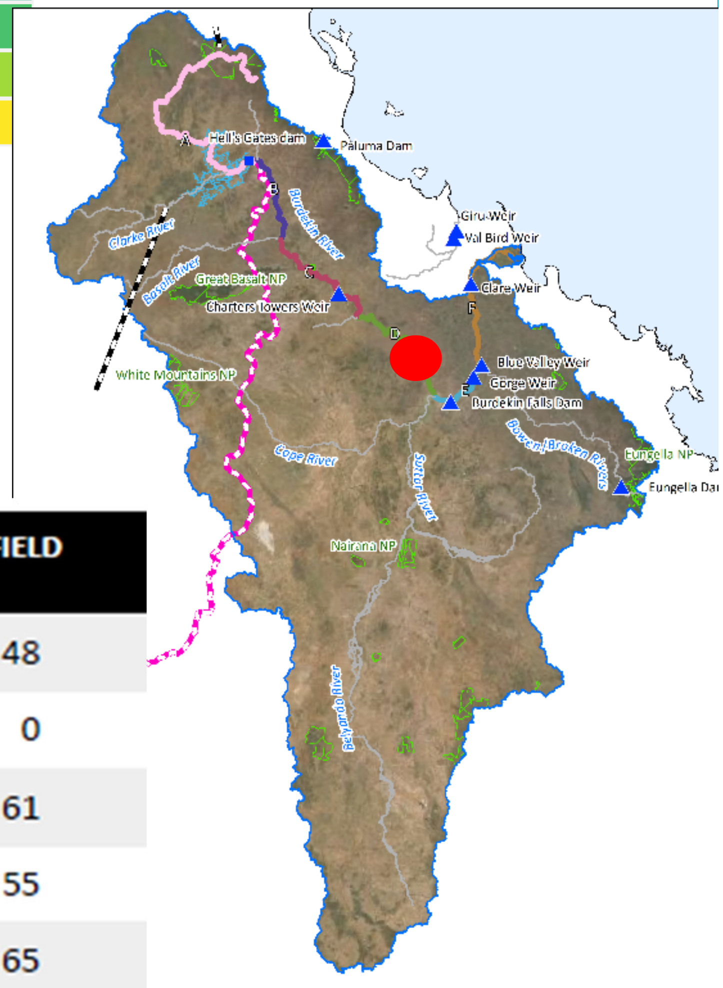


Yield at Hell's Gates and EFO metrics relative to plan limits





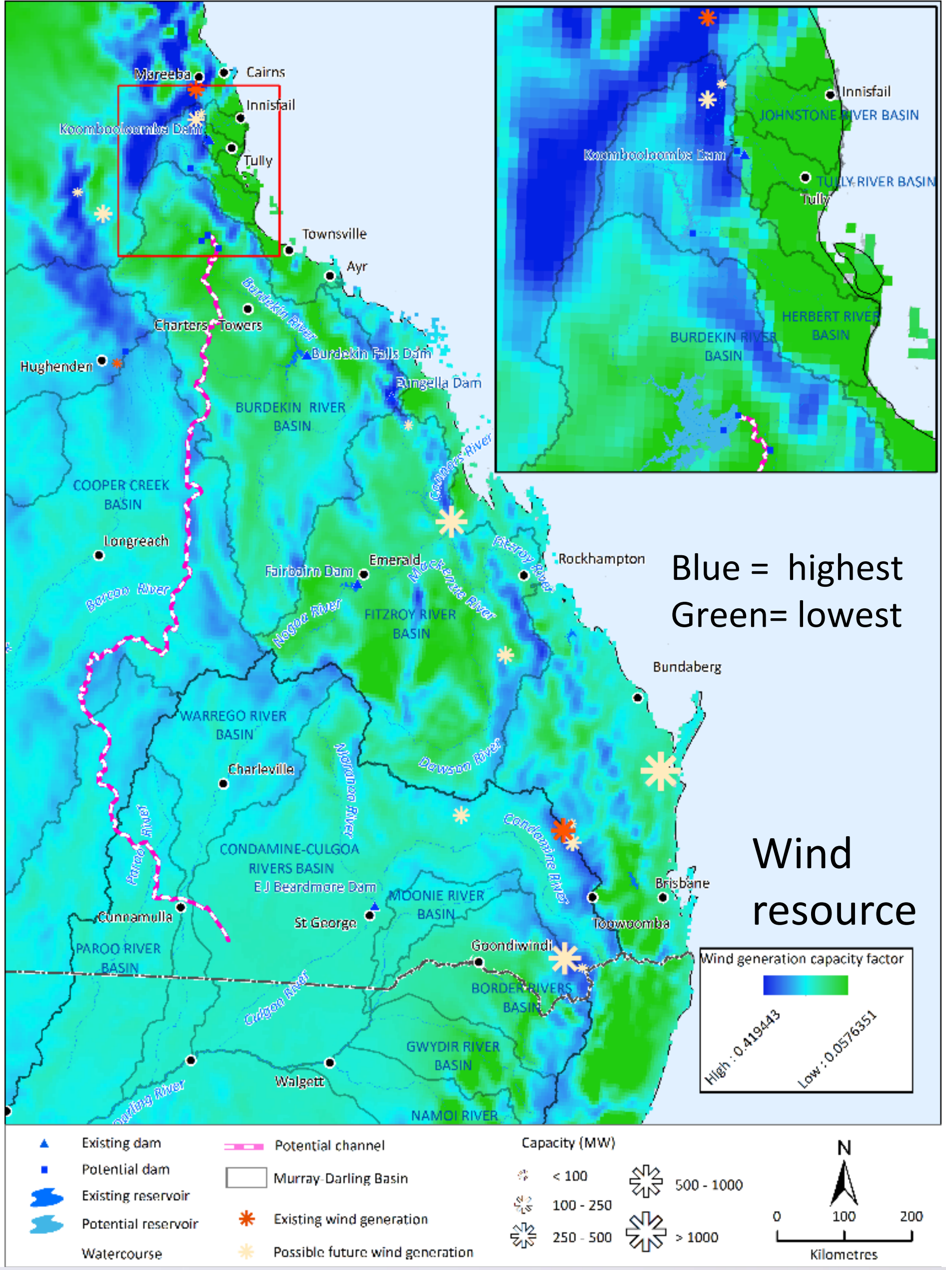
2280 GL @ 75%



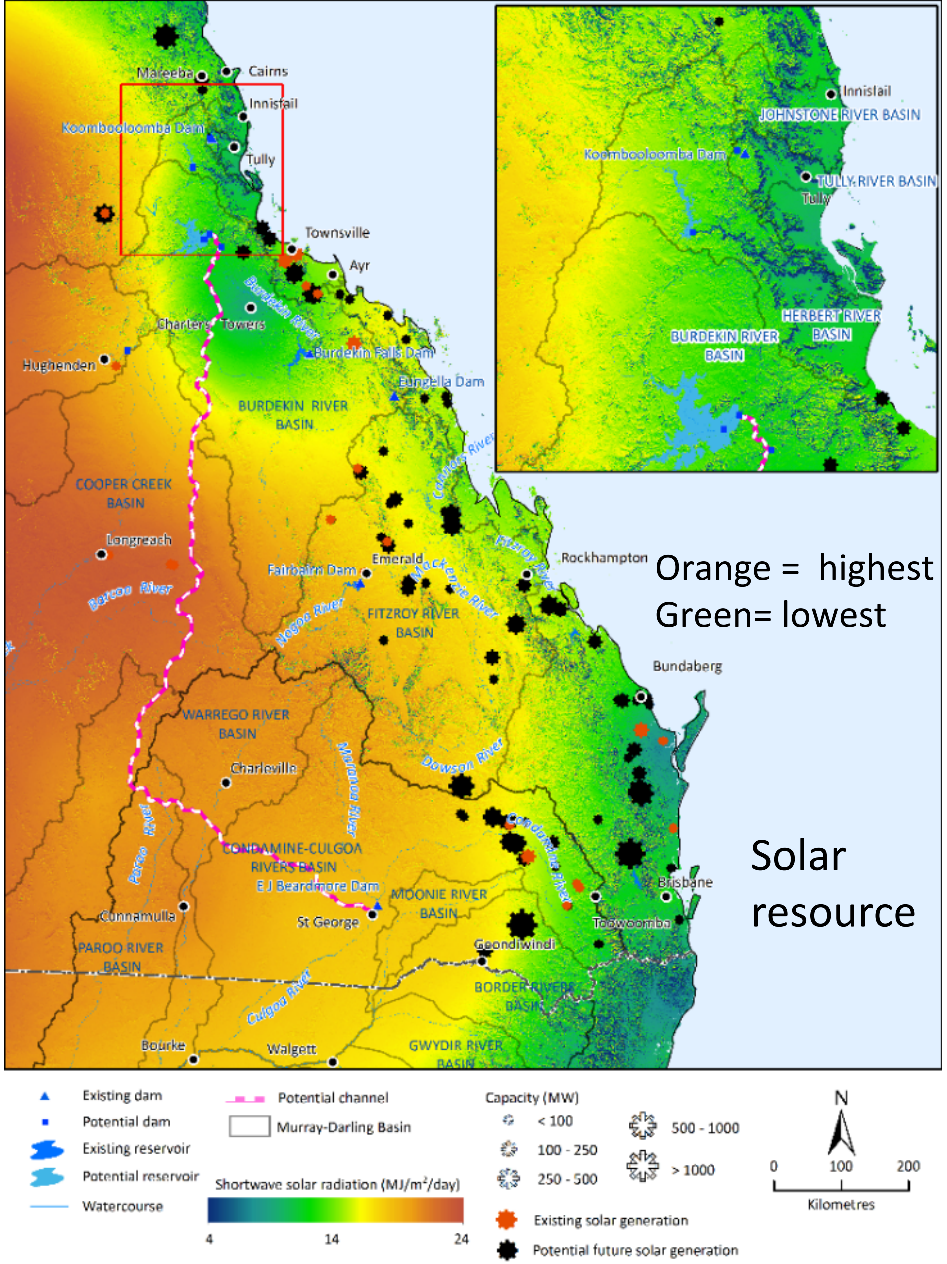
IQQM Node 196

METRIC 1 JULY 1890 TO 30 JUNE 2004	PRE-DEVELOPMENT	PLAN LIMIT (%)	IQQM BRADFIELD (%)
Occurrence 1–6 month no flow	0	57	48
Occurrence >6 month no flow	0	1	0
Mean annual flow (GL/y)	4,035	97	61
Median annual flow (GL/y)	2,665	96	55
1.5-year daily flow (%)	115,473	99	65

CSIRO



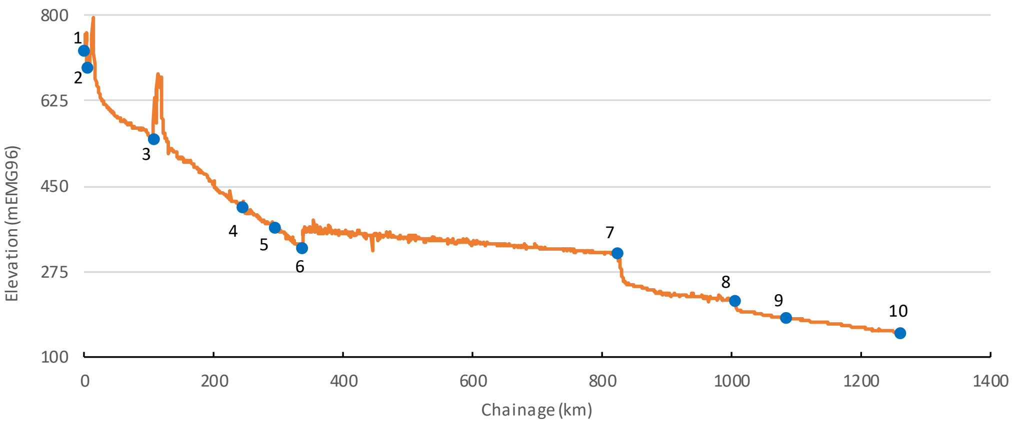
Blue = highest
Green= lowest
Wind resource
Wind generation capacity factor
High : 0.419443
Low : 0.0576351
Mareeba
Cairns
Innisfail
Koombooloomba Dam
Tully
Townsville
Ayr
Charters Towers
Hughenden
Burdekin River
Burdekin Falls Dam
Eungella Dam
BURDEKIN RIVER BASIN
COOPER CREEK BASIN
Longreach
Emerald
Fairbairn Dam
Rockhampton
FITZROY RIVER BASIN
Bundaberg
WARREGO RIVER BASIN
Charleville
CONDAMINE-CULGOA RIVERS BASIN
E J Beardmore Dam
MOONIE RIVER BASIN
St George
Cunnamulla
PAROO RIVER BASIN
Brisbane
Toowoomba
Goondiwindi
BORDER RIVERS BASIN
GWYDIR RIVER BASIN
Walgett
NAMOI RIVER
JOHNSTONE RIVER BASIN
TULLY RIVER BASIN
HERBERT RIVER BASIN
Existing dam
Potential dam
Existing reservoir
Potential reservoir
Watercourse
Potential channel
Murray Darling Basin
Existing wind generation
Possible future wind generation
Capacity (MW)
< 100
100 - 250
250 - 500
500 - 1000
> 1000
N
0
100
200
Kilometres

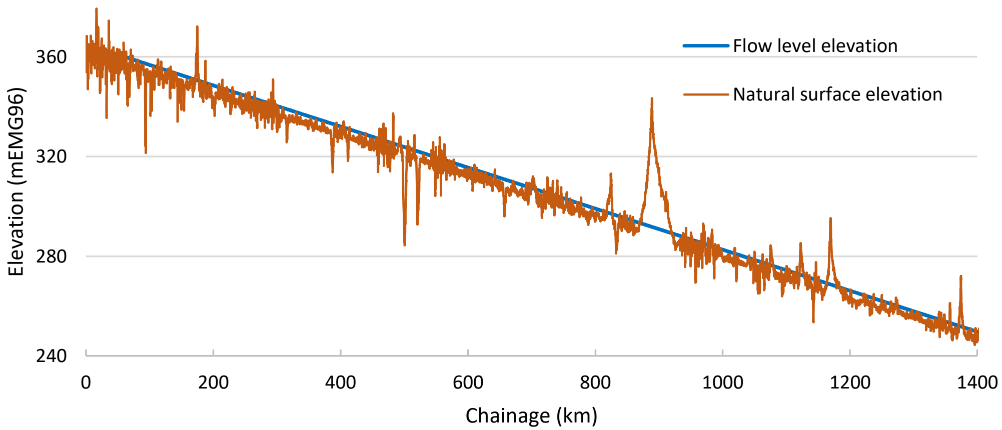


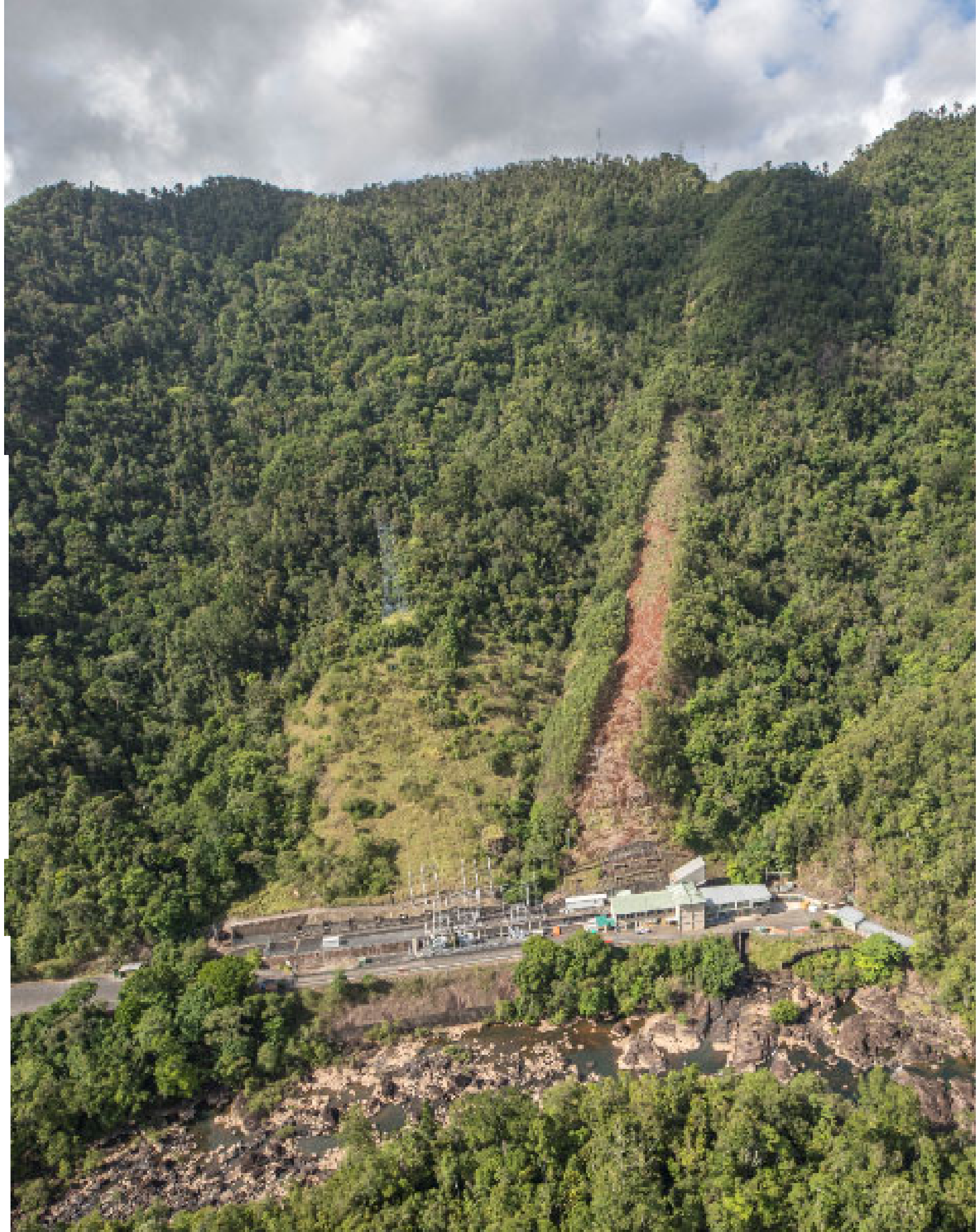
Orange = highest
Green= lowest
Solar resource
Mareeba
Cairns
Innisfail
Koombooloomba Dam
Tully
Townsville
Ayr
Charters Towers
Hughenden
Burdekin Falls Dam
Eungella Dam
BURDEKIN RIVER BASIN
COOPER CREEK BASIN
Longreach
Emerald
Fairbairn Dam
Rockhampton
FITZROY RIVER BASIN
Bundaberg
WARREGO RIVER BASIN
Charleville
CONDAMINE-CULGOA RIVERS BASIN
E J Beardmore Dam
MOONIE RIVER BASIN
St George
Cunnamulla
PAROO RIVER BASIN
Brisbane
Toowoomba
Goondiwindi
BORDER RIVERS BASIN
GWYDIR RIVER BASIN
Bourke
Walgett
JOHNSTONE RIVER BASIN
TULLY RIVER BASIN
HERBERT RIVER BASIN
Existing dam
Potential dam
Existing reservoir
Potential reservoir
Watercourse
Potential channel
Murray-Darling Basin
Shortwave solar radiation (MJ/m²/day)
4
14
24
Capacity (MW)
< 100
100 - 250
250 - 500
500 - 1000
> 1000
Existing solar generation
Potential future solar generation
N
0
100
200
Kilometres

Windy Hill (Upper Herbert)

Potential for in-line hydro power generation







The diversion of water from above Tully Falls Weir would severely reduce flow through the Kareeya hydro-electric power station on the Tully River

Potential to mitigate flooding in Tully, Herbert and Burdekin and reduce harmful runoff to reef

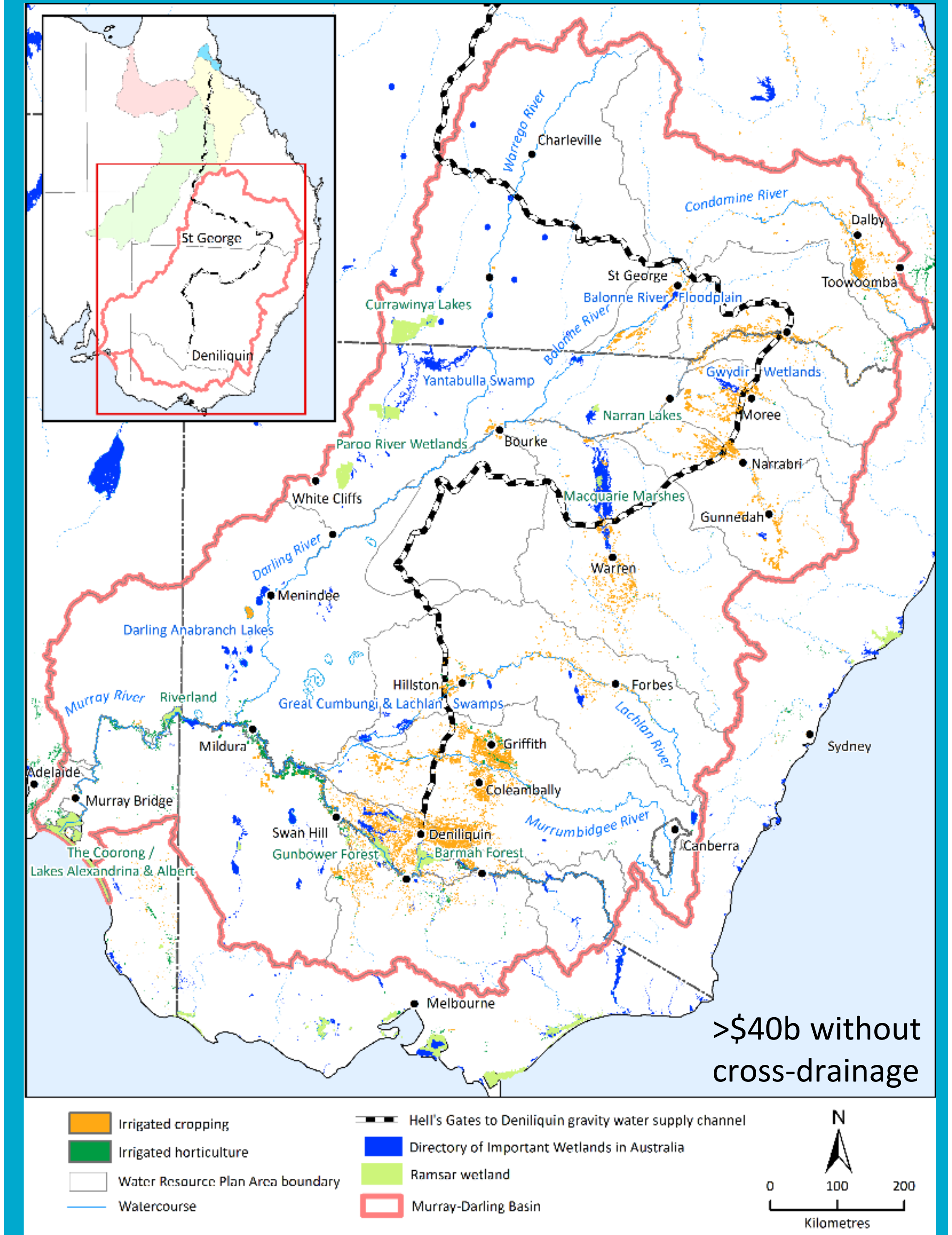
- Flood mitigation potential
  - Potential to reduce flood occurrence by 3%, 21% and 8% in Tully, Herbert and Burdekin respectively.
  - <10% annual operating costs of scheme
- Potential to mitigate harmful runoff to reef
  - Modelled reduction in TSS and PN anthropogenic load of ~10% from source catchments

Flood plume extending into Great Barrier Reef

Irrigated agriculture in the MDB

Beardmore Dam near St George

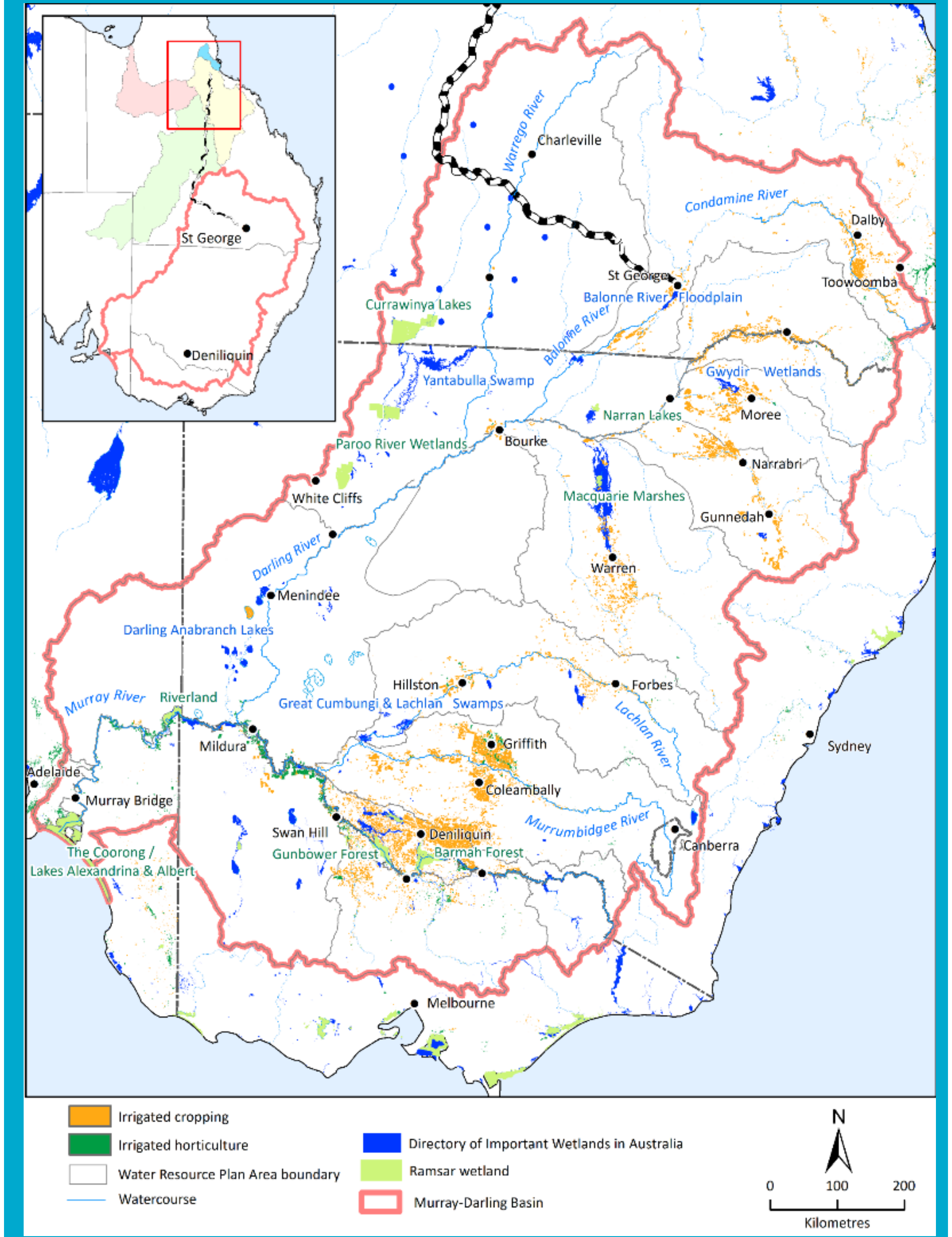
Cotton near St George (Murray-Darling Basin)



>$40b without cross-drainage

Taking water to St George

- Channel length ~1600-km
- Capital cost of backbone and reticulation infrastructure ~$21b
- Annual operating and maintenance $155m
- Annual pumping $29m
- Annual revenue -$1m
- Mean annual diversion ~1880 GL



Thank you

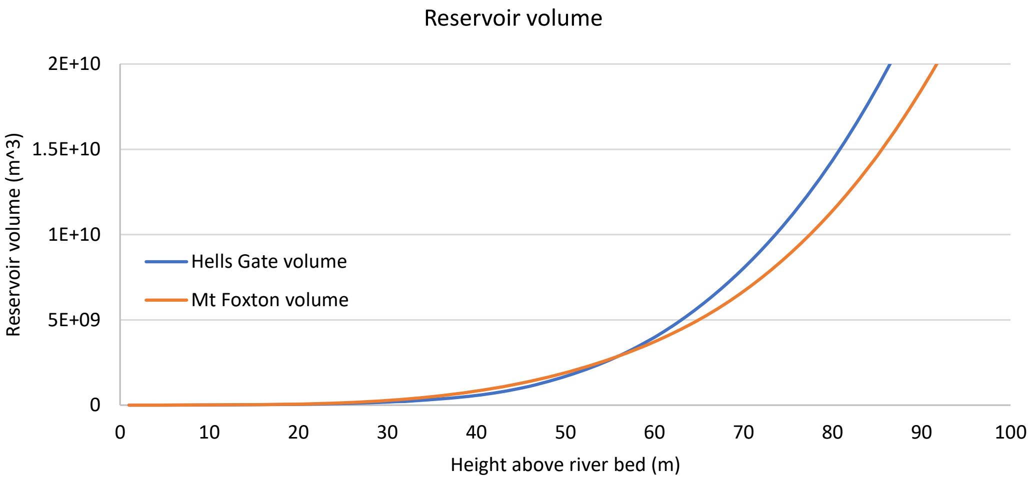
Petheram C, Read A, Hughes J, Stokes C, Marvanek S, Kim S, Philip S, Peake A, Podger G[1], Devlin K[2], Hayward J, Bartley R, Vanderbyl T[3], Rogers L, Wilson P, Pena Arancibia J, Stratford D, Baynes F[4], Yang A, Watson I, Austin J, Tredger R[5], Synergies, Potter N, McJannet D, Barber M,, Macintosh A[6], Ibrahimi T, Kuhnert P, Wang B, Ng S, Jarvis D[7], Cousins A, and Chilcott C

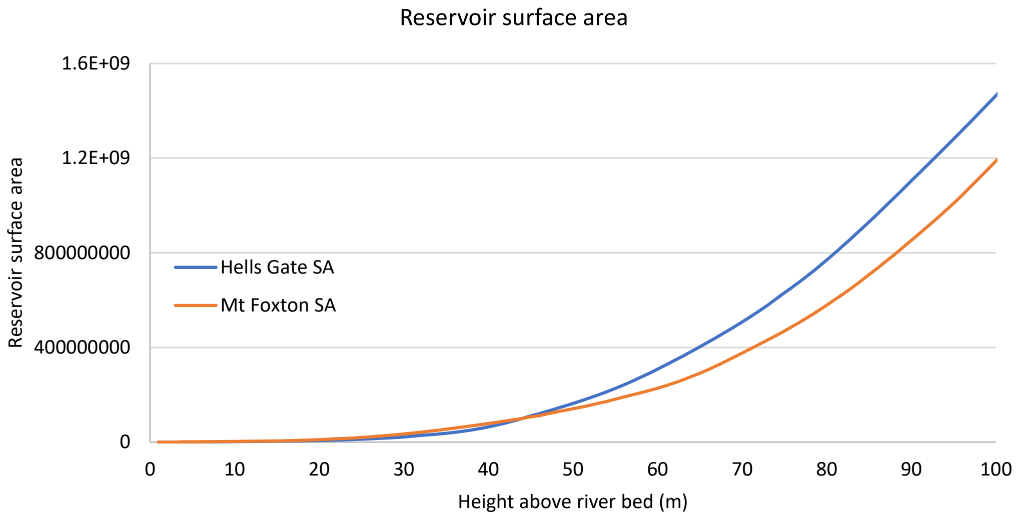
CSIRO unless specified.

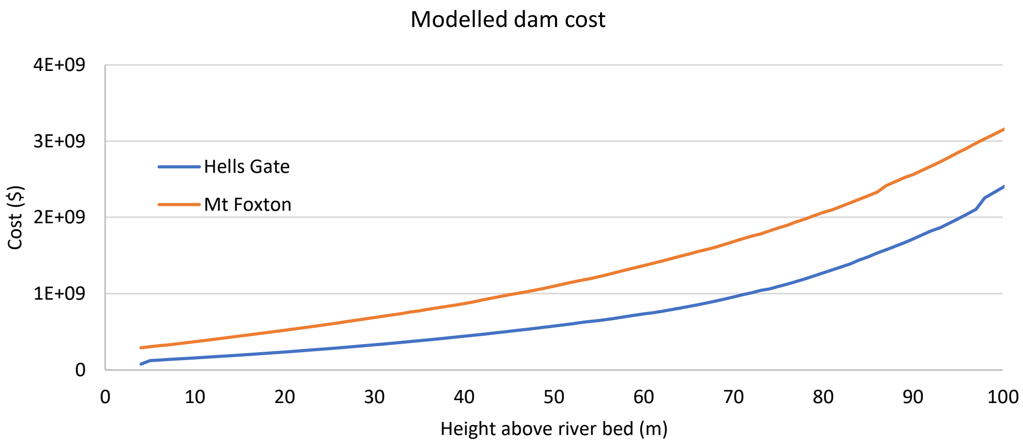
1. Water Bublu
2. Independent consultant
3. Badu Advisory
4. Baynes Geologic
5. SMEC
6. Australian National University
7. James Cook University

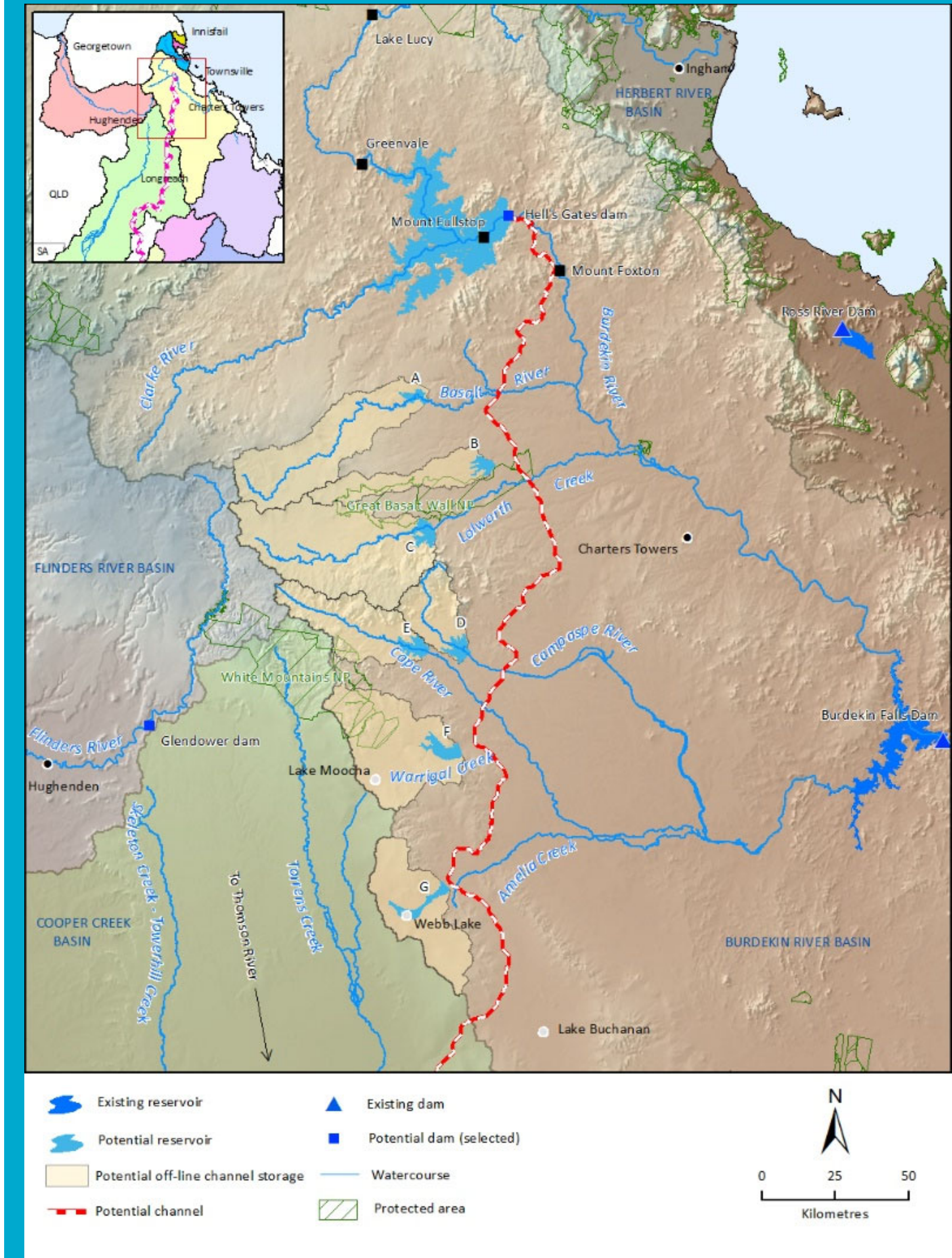
Reports can be found by searching “CSIRO” and “Bradfield”

Diverting water from the South Johnstone catchment


Reservoir volume
Reservoir volume (m^3)
2E+10
1.5E+10
1E+10
5E+09
0
0 10 20 30 40 50 60 70 80 90 100
Height above river bed (m)
Hells Gate volume
Mt Foxton volume


Reservoir surface area
Reservoir surface area
1.6E+09
1.2E+09
800000000
400000000
0
0 10 20 30 40 50 60 70 80 90 100
Height above river bed (m)
Hells Gate SA
Mt Foxton SA


Modelled dam cost
Cost ($)
4E+09
3E+09
2E+09
1E+09
0
0 10 20 30 40 50 60 70 80 90 100
Height above river bed (m)
Hells Gate
Mt Foxton

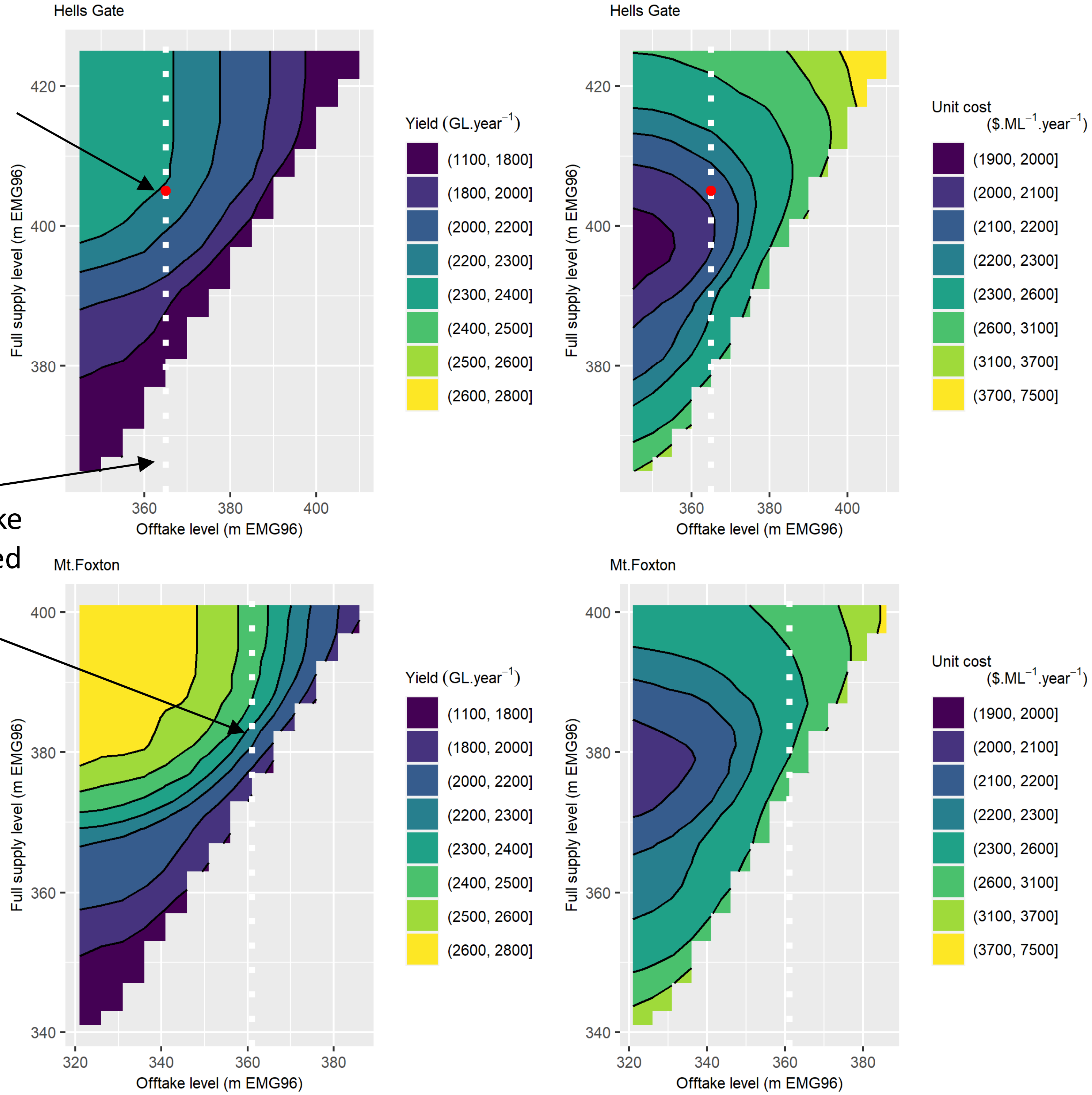

Georgetown
Innisfail
Townsville
Charters Towers
Hughenden
Longreach
QLD
SA
Lake Lucy
Ingham
HERBERT RIVER BASIN
Greenvale
Mount Fullstop
Hell's Gates dam
Mount Foxton
Ross River Dam
Burdekin River
Clarke River
Basalt River
Great Basalt Wall NP
Lolworth Creek
Charters Towers
FLINDERS RIVER BASIN
White Mountains NP
Cape River
Campaspe River
Burdekin Falls Dam
Flinders River
Glendower dam
Hughenden
Lake Moocha
Warrigal Creek
Amelia Creek
Webb Lake
COOPER CREEK BASIN
Skeleton Creek - Towerhill Creek
To Thomson River
Torrens Creek
BURDEKIN RIVER BASIN
Lake Buchanan
A
B
C
D
E
F
G
Existing reservoir
Potential reservoir
Potential off-line channel storage
Potential channel
Existing dam
Potential dam (selected)
Watercourse
Protected area
N
0 25 50
Kilometres

Adopted configuration

Hells Gate

Minimum channel offtake for gravity flow calculated using WaterRoute model

Mt Foxton



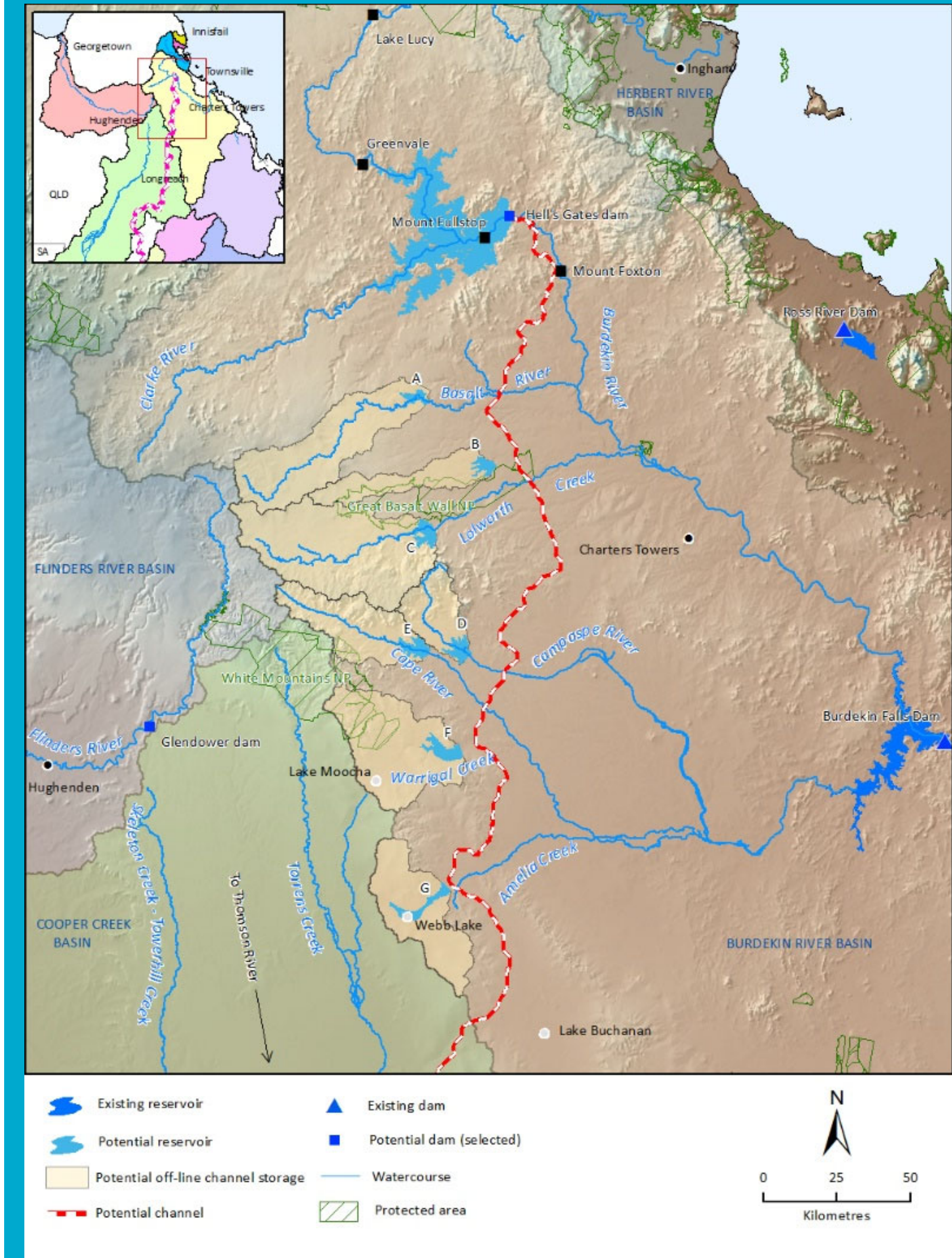
In-line and off-channel water storages

In-line (open bank) channel storages

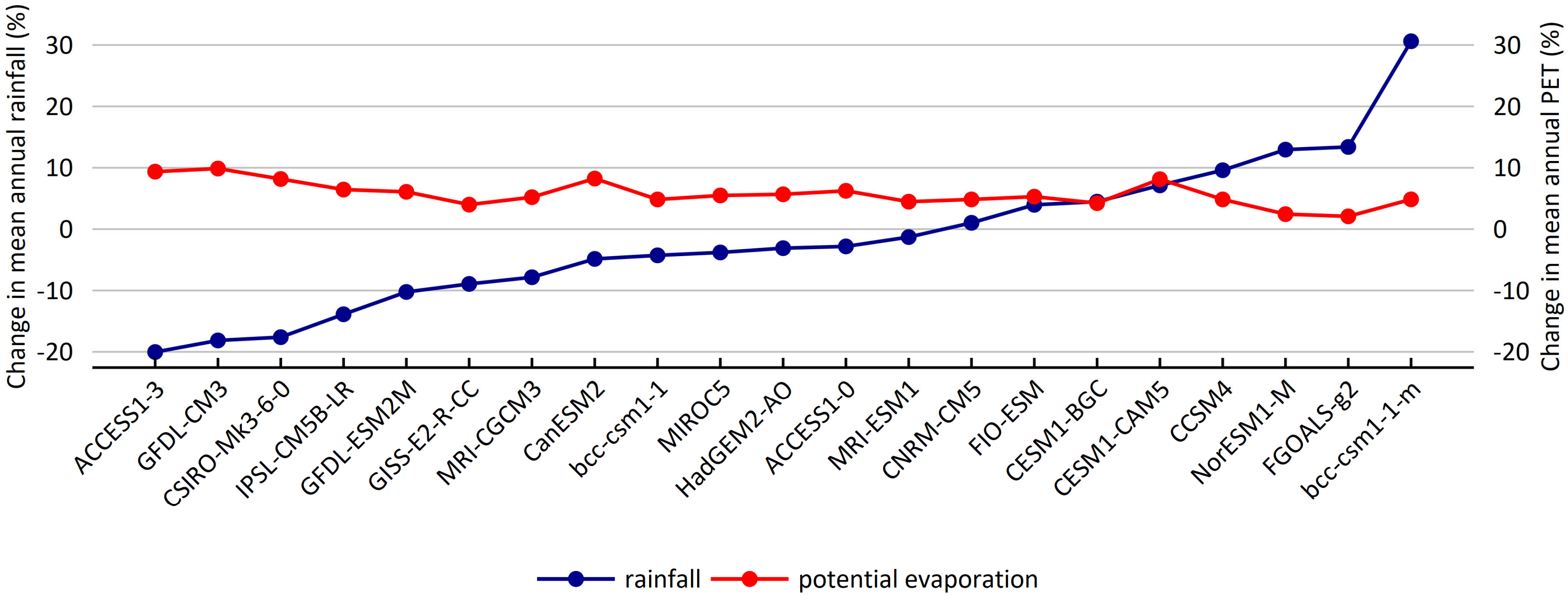
- Limited to capturing water from relatively small catchments
- Present considerable challenges
  - Increased evaporation
  - Sedimentation
  - Challenges controlling flow along channel

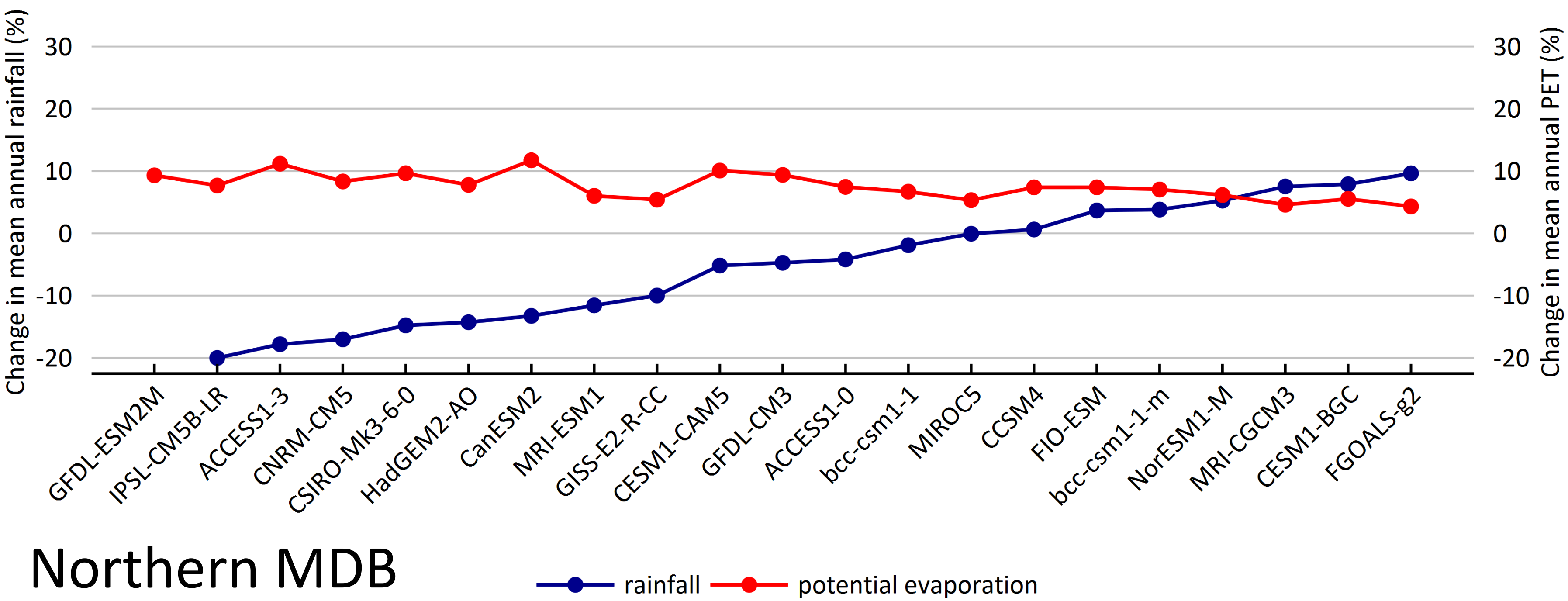
Off-channel water storages/dams more realistic

- 334 GL in 75% years @ $9.2b



Bradfield source catchments



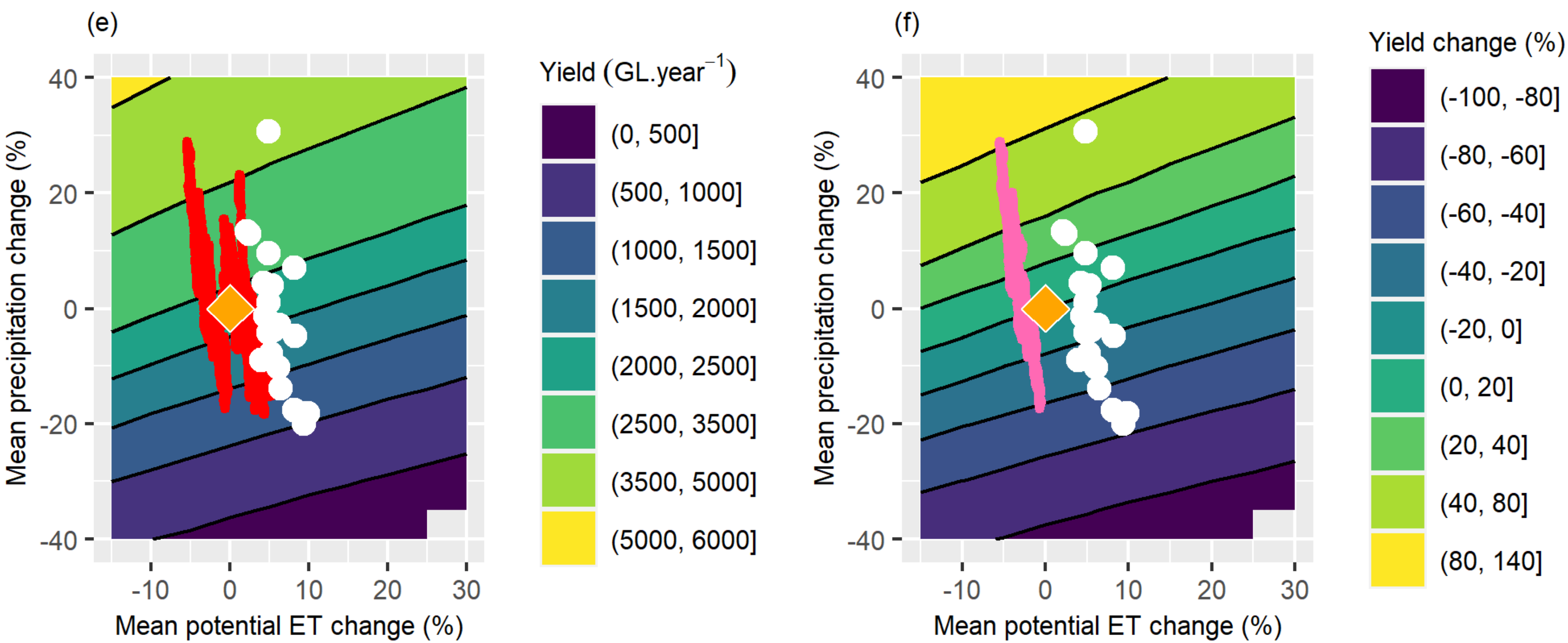


Northern MDB

Modelled yield under alternative future climates

- 2280 GL in 75% years
- ±12.5% alternate baselines

- 1150 (-50%) to 3000 (+30%)
- Median (-10%)



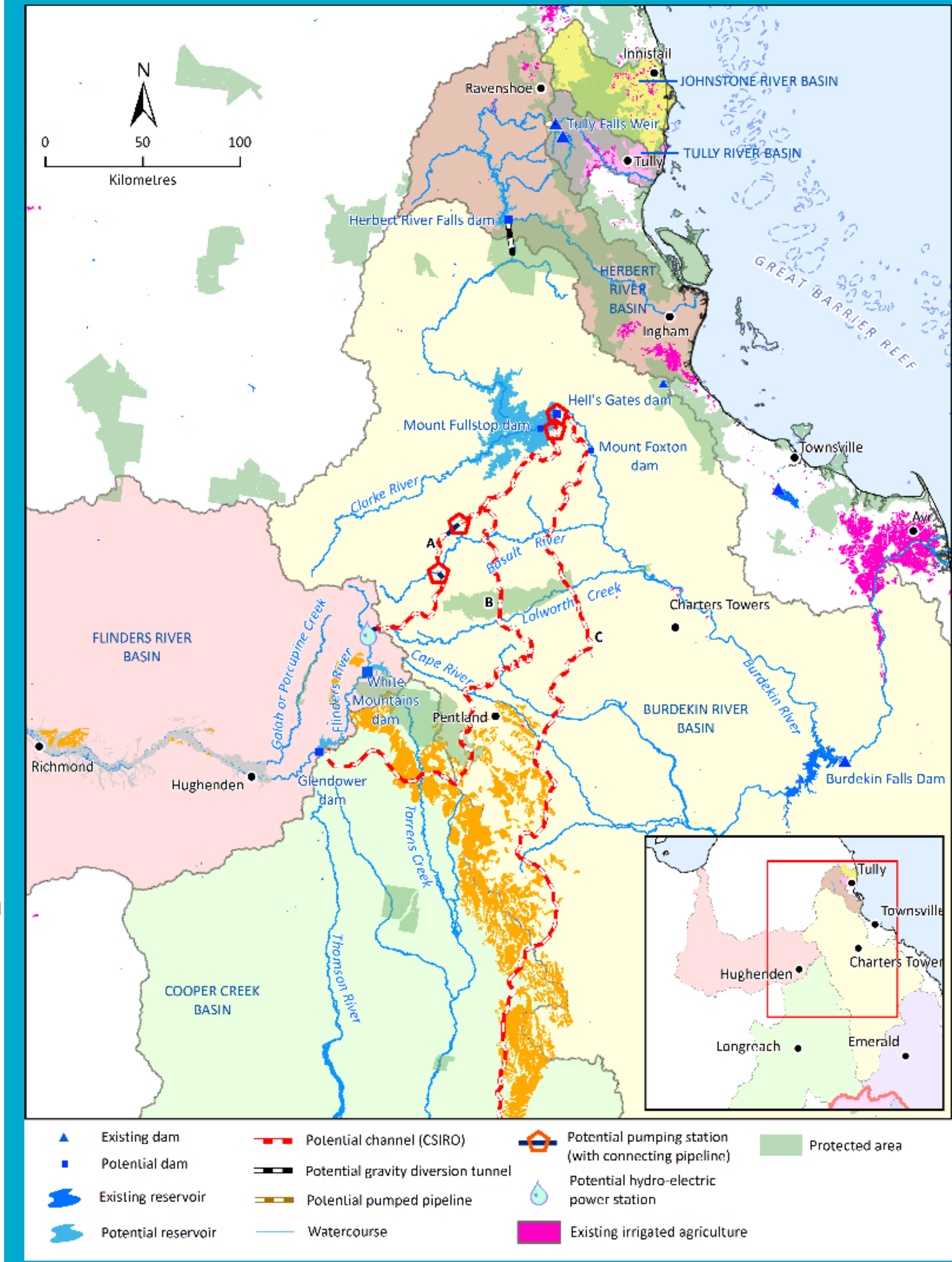
Pumped pipeline and channel configuration to Flinders catchment

CSIRO 'optimal' high alignment

- 4 pump stations, 20 km pipeline & 190 km channel (and 1 hydro-electric power station & 2 large terminal storages)
- $6b & $190m/yr

CSIRO 'optimal' low alignment

- 2 pump stations, 1.3 km pipeline, 10 km tunnel & 420 km open channel.
- $6.9b & $100m/yr > total project cost $12b
- 30,000 ha horticulture & 105,000 ha dry season cotton
- Dry-season cotton – 7 ML/ha (before losses)
- Wet-season cotton – 4.7 ML/ha (before losses)



Potential to supply other industries on route

- Mining
- Regional centres
- Grazing

Coal wash station in central Queensland