"Detainment Bunds[PS120] (DBs)"

What's a DB?

John Paterson

Southland / Otago:

- *Raised Southland 240 ha sheep farm, eeling and fishing the Waikaka, Mataura, Pomahaka rivers and walking in the Blue and Hokonui Mountains*
- *BSc. (Geology) Otago University; palaeontology, sedimentology, geomorphology*

Bay of Plenty:

Small Farm *– Kaharoa near Rotorua (Deer & Sheep - Wiltshire X Beltex)*

Current Work:

- *PMPInc Project Manager*
- *PMP partnership with Massey University – Catchment Solutions programme*
- *Consultancy – GIS LiDAR Scoping DB sites*

Phosphorus Mitigation Project Inc. (2016)

A farmer governance group leading **innovative** applied research on interception of storm water run-off with **Detainment Bunds**[PS120]

PMP Inc. has co-ordinated a collaboration of Government, Science institutions, Ag-Industries and Councils

Research results on DBs to date have transformational implications for improved rural water quality
and peak flow management

The key drivers of water quality

- *Nitrogen* *lost via leaching*

- *Phosphorus*
- *Sediment*
- *Pathogens*

} *lost mainly in runoff events*

Detainment Bunds^{PS120} *proven effective for Water Quality outcomes*

- *Mitigating contaminants in stormwater runoff from pasture*
- *55% to 65%* reduction (Clarke MSc 2013, Levine PhD 2020)*
- *Other multiple benefits*

A Detainment Bund^{PS120} (DB) at Rerewhakaaitu – superscript denotes a storage requirement of ≥ 120m^3 for each hectare of catchment

DBs occupy productive farm pasture

Pasture not taken out of production (max 3 day ponding)

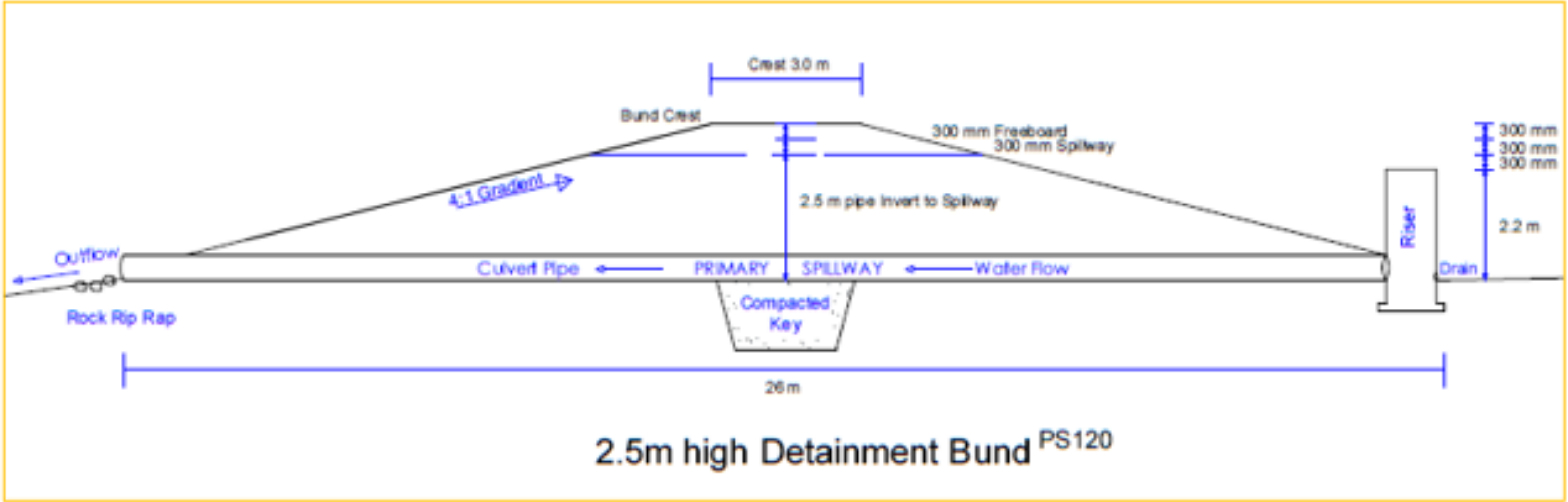
Temporary capture and holding of storm water runoff

Building DBs is a permitted activity

The target is sediment, phosphorus and E.coli

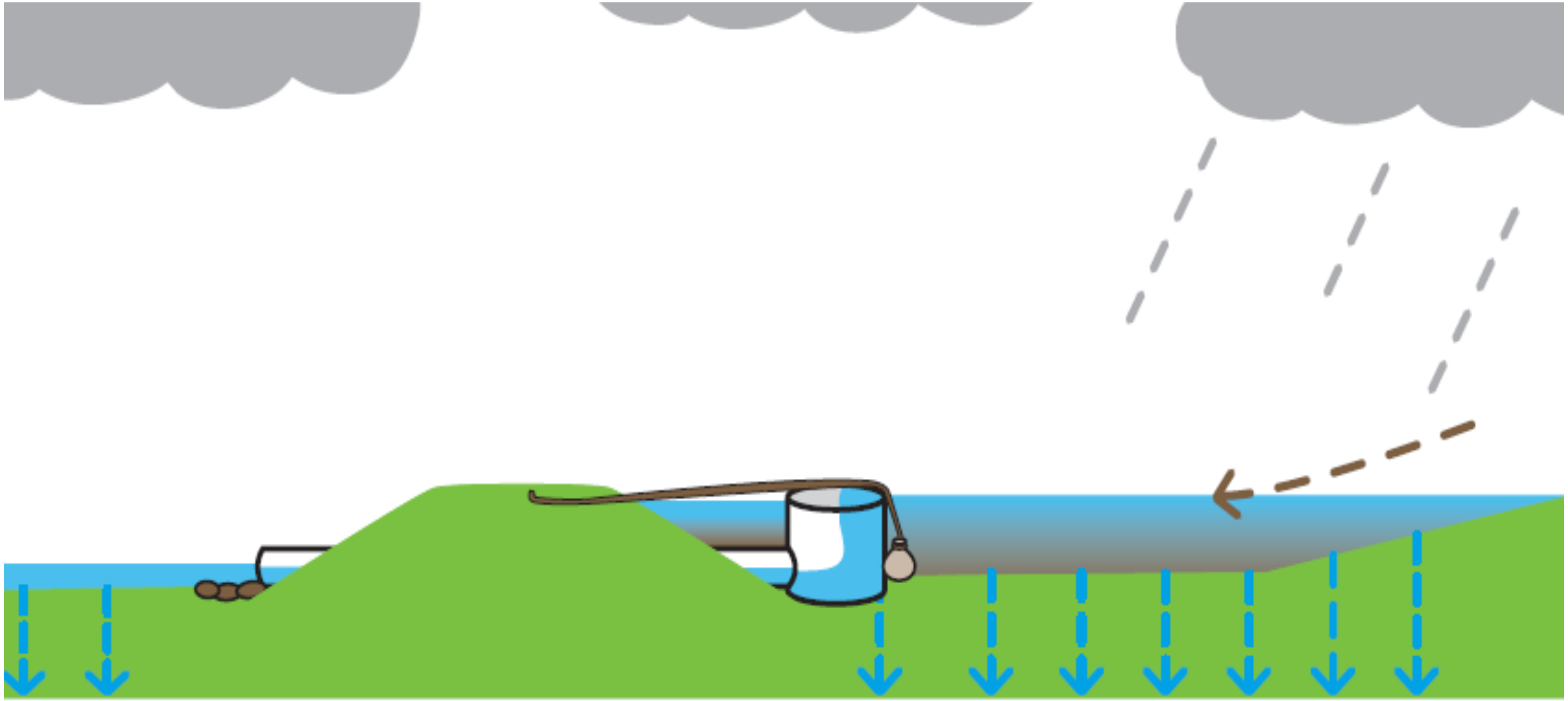
The scientific evidence of benefits is growing

DB Design



Example – DB 2.5m high to spillway (can be less if site is very flat and catchment is small) Refer Pg. 56 PMP DB Manual
Primary spillway pipe sized according to catchment size – Refer Pg. 33 – pipe size look-up table – PMP DB Manual
Note: Compacted key

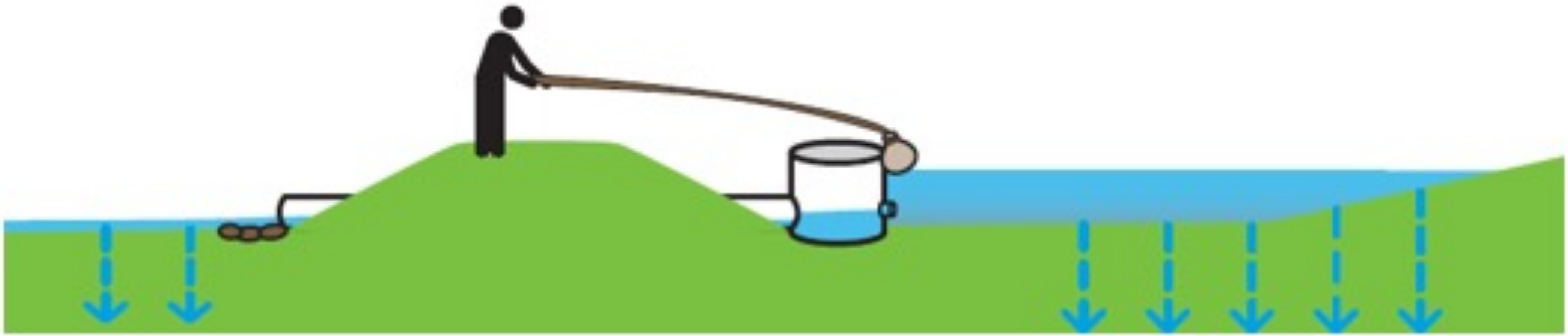
Detainment Bunds[PS120]



Detainment Bunds[PS120]

Significant infiltration with well-drained soils occurs over the 1 to 3 day ponding period

Detainment Bunds[PS120]

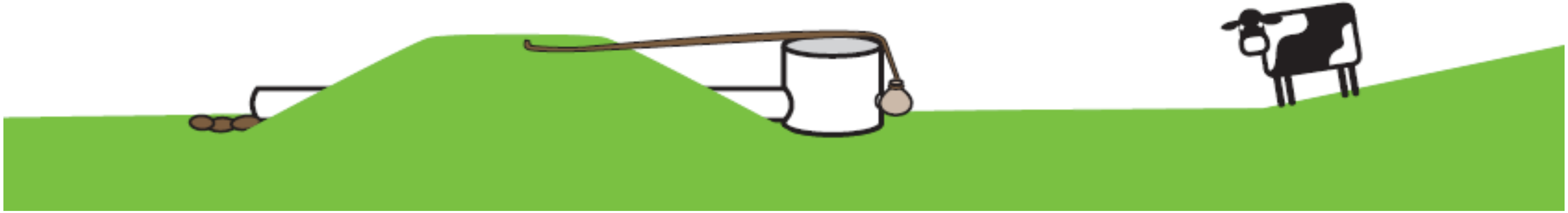


If any pond water remains after 3 days it is released

The 3 day maximum ponding period assures pasture health

Released discharge post storm will likely infiltrate soil

Detainment Bunds[PS120]



After an appropriate drying period the former ponding area is again available for grazing

Prioritising environmental mitigation actions

Primary *– 'most effective / best' things to do*

1 Good Management Practices (GMP's)

minimise contaminant release and mobilisation in first instance

Secondary *– 'next best' things to do*

2 Interception and mitigation of mobilised contaminants

"edge of field"

'Sedimentation' a natural process – needs stillness / time

Stillness:

- *'Stokes law' relates load bearing of water to its velocity*
- *Zero velocity needed to maximise settling out of fine particles*
- *Most 'sediment traps' – fail to achieve full potential*
- *Inadequate storage = inadequate 'stillness'*

Time:

- *What 'residency time' is needed? 3 days on pasture*
- *Adequate storage volume? to enable stillness*

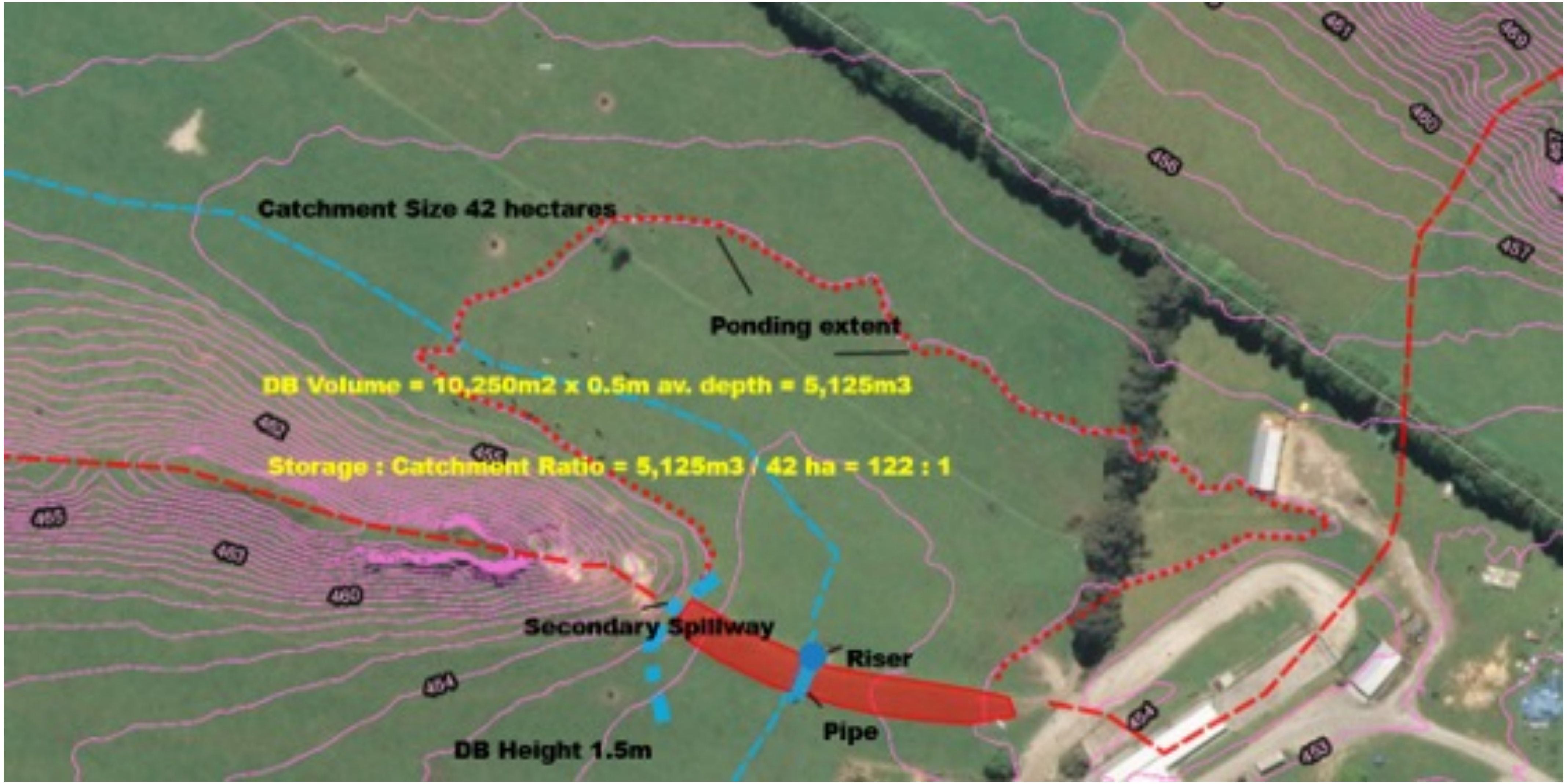
The 120:1 - ratio new science validated metric

- 120:1 - minimum standard to qualify as a DB
- A threshold for adequate storage relative to catchment size
- Detainment Bund^{PS120} (DB)
- $\geq$ 120m³ storm water run-off storage per hectare of catchment
- Accurately measure proposed DB pond volumes
- Accurately measure catchment sizes
- (cups demo)
- Endorsed by AgResearch (C. Smith 2023 - NZ Journal of Agricultural Research)

Where can we fit DBs into our catchments ?

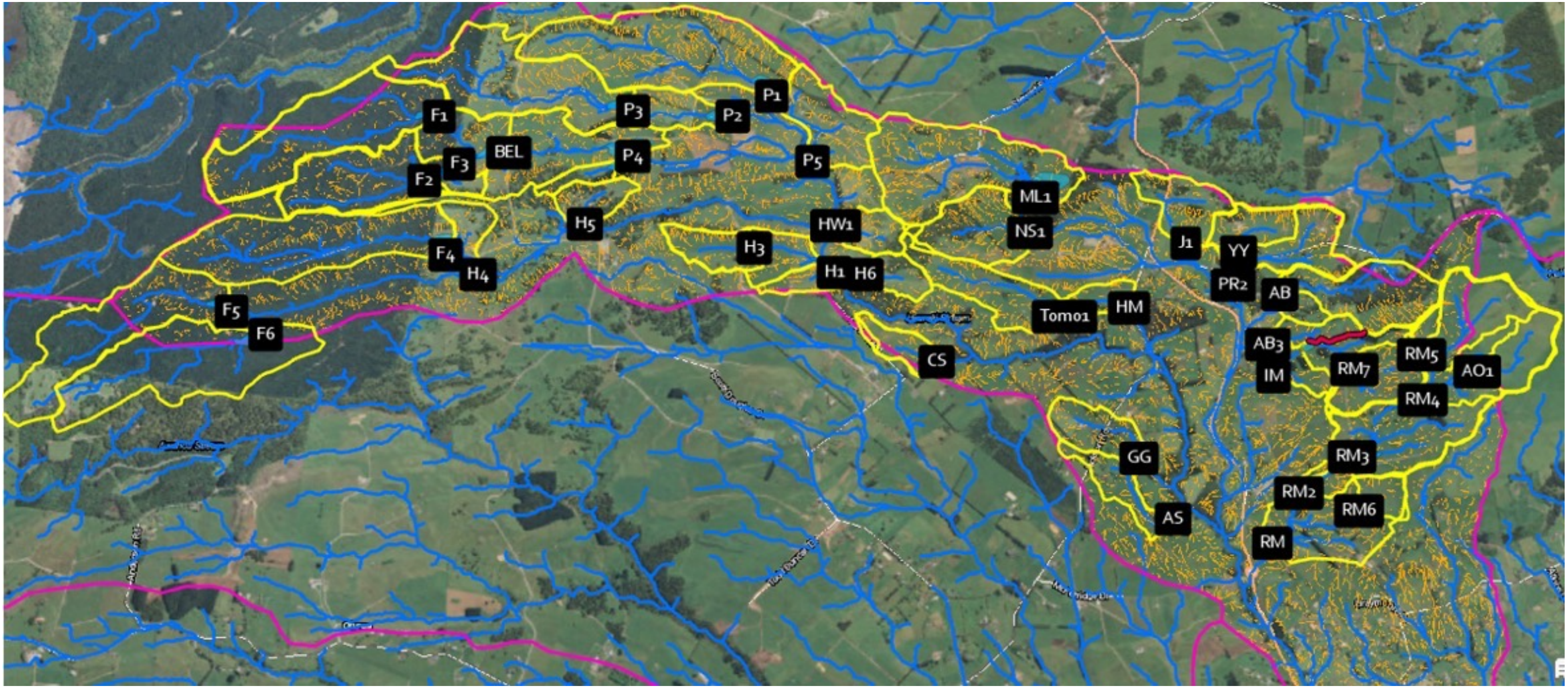
- *GIS based mapping with LiDAR data enables 1m contour mapping*
- *Likely sites occur along storm water flow paths*
- *In GIS - draw a **'mock-up'** DB wall (say 2.5m high)*
- *Draw the ponding extent and estimated ponding area (m^2)*
- *Calculate potential storage volume (m^3) and catchment size (ha)*
- ***Does the DB 'mock up' site achieve ≥120m^3 per ha ?***
- *A trial and error process – generally 2 of 3 fail to achieve ≥120:1*
- *How to?* *See pages 19 – 21 of PMP's DB Guideline*
- *Automation of this process is progressing (Fernando Avendano)*

DB Placement – example of GIS based DB 'mock up'



Hauraki sub-catchment (1200 ha) example – 70% DB applicability

Developing site optimisation tool - ArcPro 'DB arpx GIS package' - Requires high resolution LiDAR enabling 1m contour for DB 'mock ups'



Potential DB treatment - Hauraki sub-catchment of Lake Rotorua

- **Applicability rate ≈ 70% of the whole sub-catchment area.**
- **38 potential DBs found by GIS scoping process**
- **DBs catching ≈ 60% of phosphorus and sediment load**

Calculation of benefit:

DB applicability rate X DB % effect = Water quality outcome

Hauraki example (70% DB applicability):

0.7 X 60% ≈ 42% reduction (P & sediment)

120:1 serves water quality goals

What storage ratio would mitigate flooding?

Can DBs also modify flooding events?

120:1 Vs 252:1

PMP Inc. USA EPA

120:1 works for NZ water quality outcomes

Moderates most annual storm runoff events

252:1 is a USA EPA standard for Sediment Basins

252m^3 of ponding accounts for **1/3 of a net 75mm** runoff event

MANAWATŪ RIVER CATCHMENTS COLLECTIVE

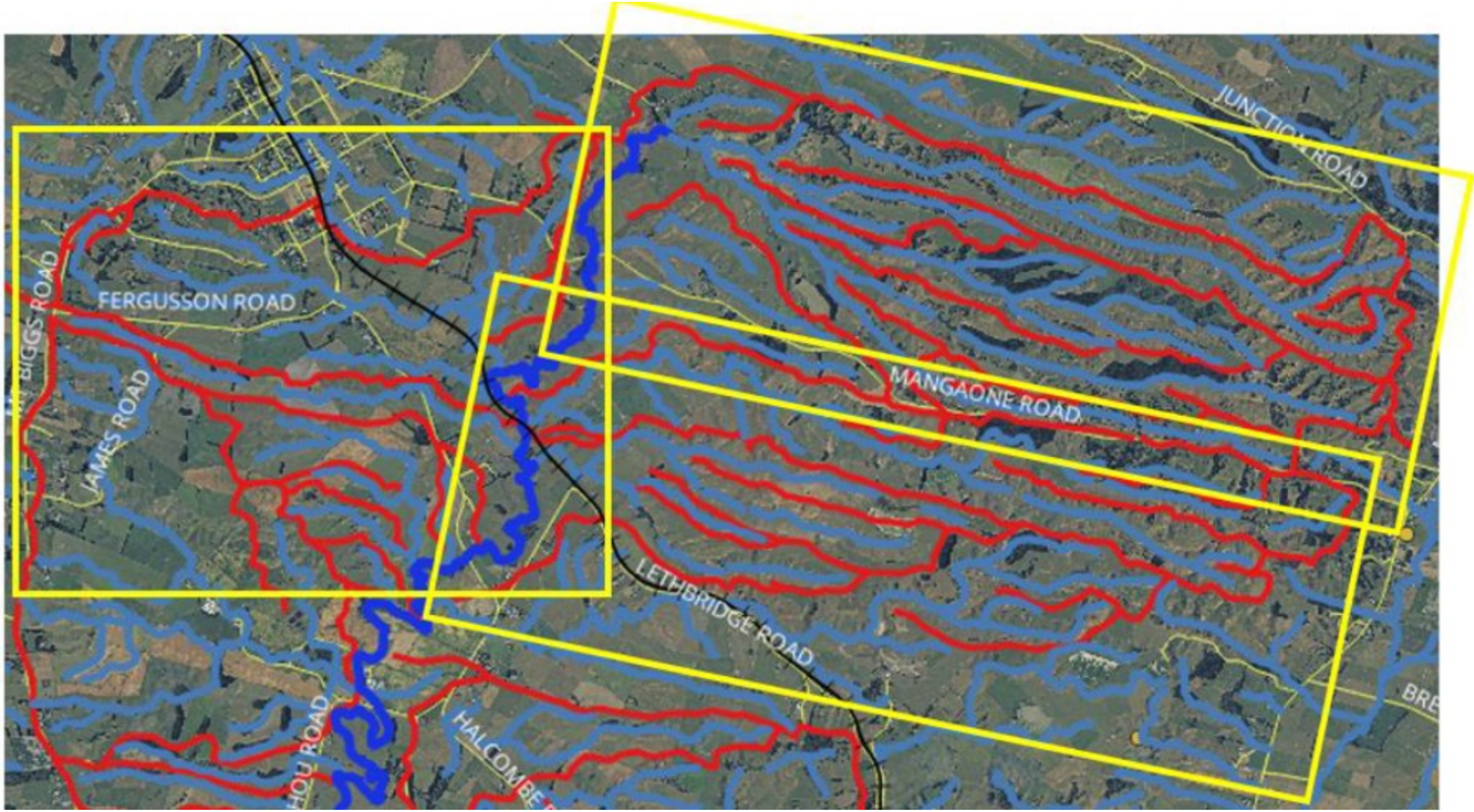
Mission:

1 – Improve our waterways and environmental footprint

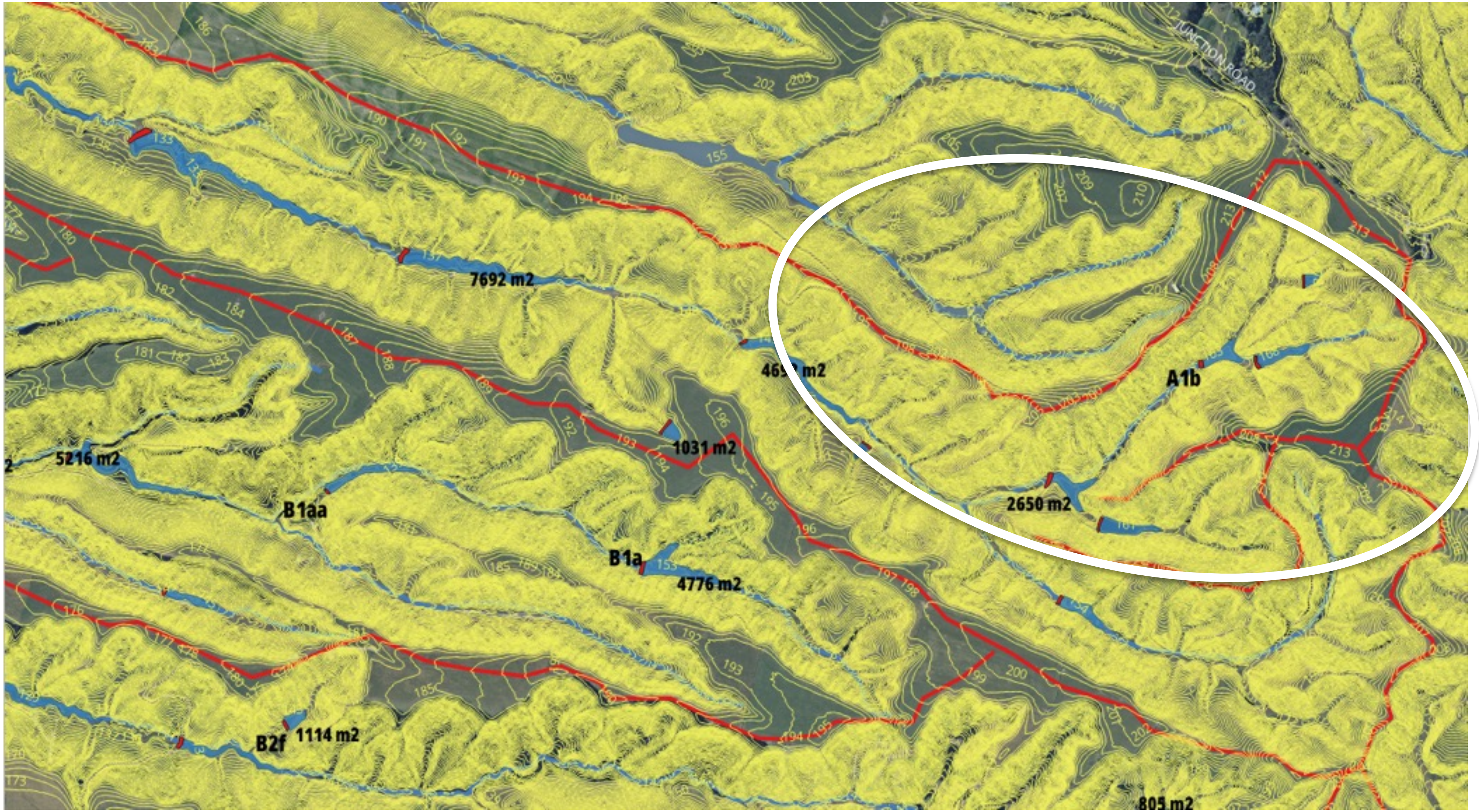
2 – Be custodians of the land for future use and generations

3 – Create thriving biodiversity free from pests and weeds

West Mangoane 3,000 ha – 3 Blocks: North-East, West and South [with permission MRCC – F. Burke]



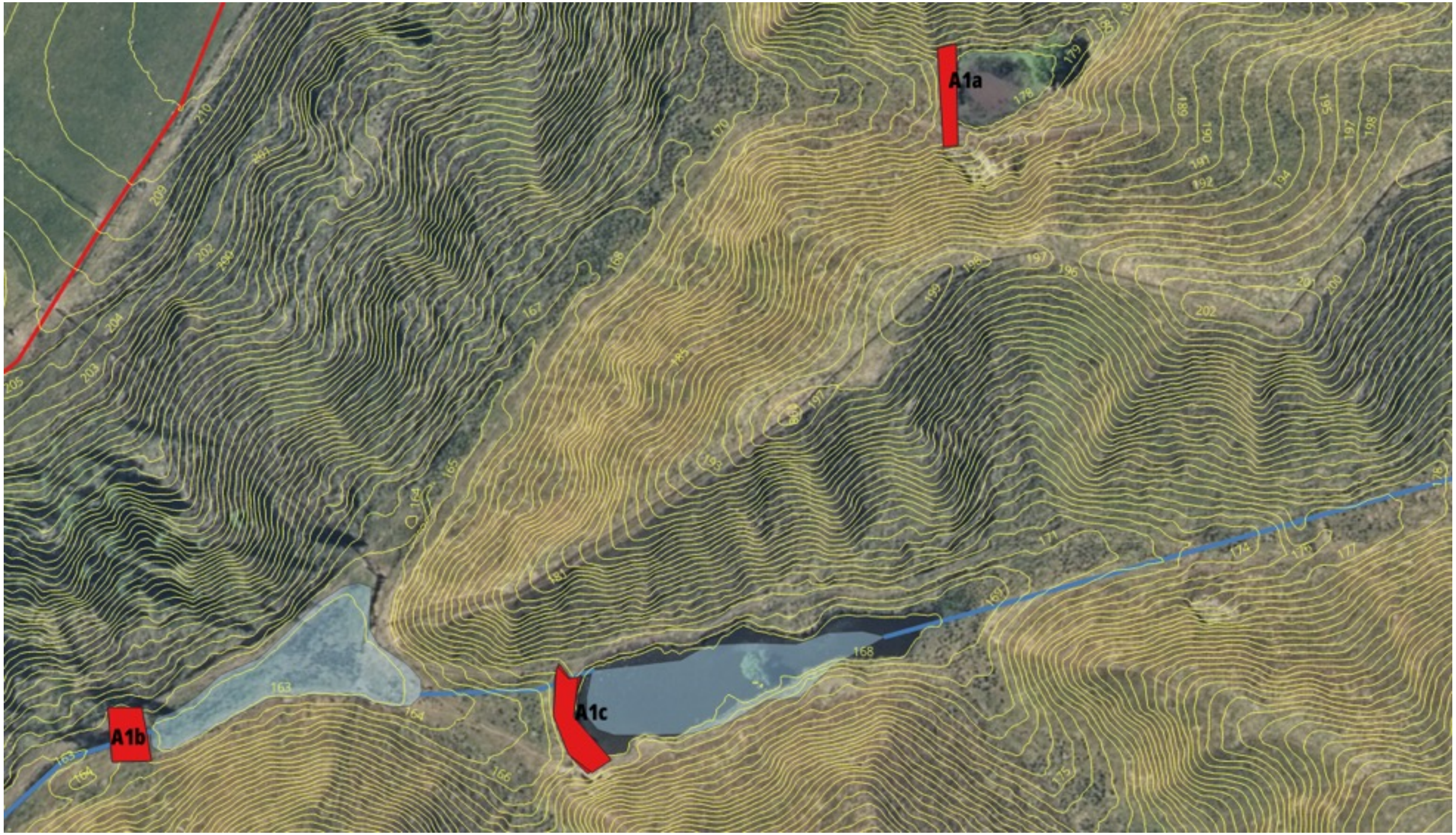
One example snap shot - *The 'A' flowpath with 1mDEM downloaded*



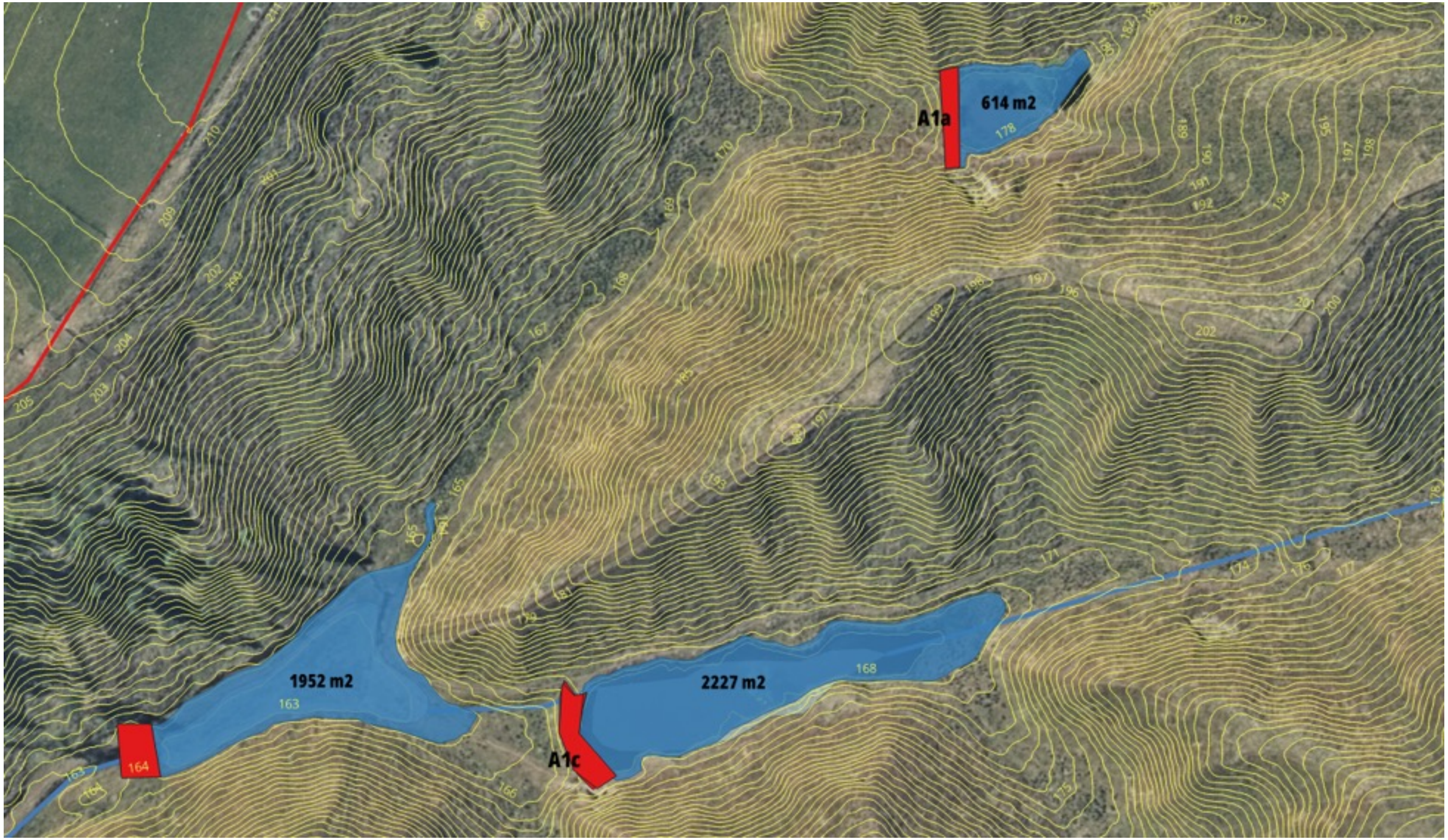
‘A’ flow path – a section of the headwater catchment

‘A’ flow path – 1mDEM layer

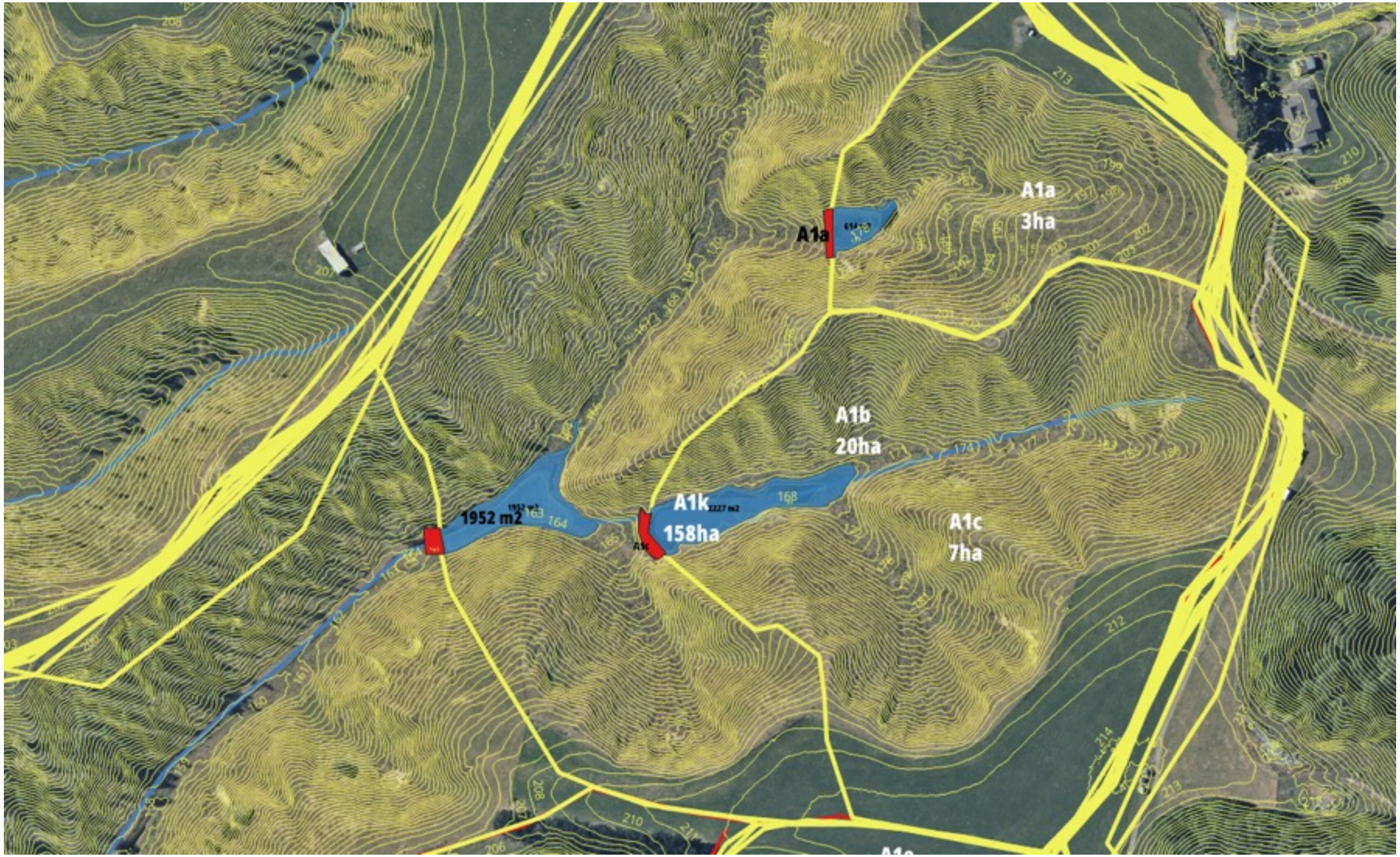
'A' flow path – 'mock up' DB walls drawn and labelled – A1a, A1b, A1c



'A' flow path – Ponding areas (m^2)



'A' flow path – Extent of catcments (A1a - 3 ha, A1b - 20 ha, A1c - 7 ha)



Example – 3 DBs in series - Accumulated benefit

ID	Height m	ponding m^2	DB Volume m^3	DB Catchment ha	Ratio	Type
A1a	1.8	614	368	3	123:1	existing dam
A1b	1.8	1952	1,171	20	59:1	existing dam (failed)
A1c	1.8	2227	1,336	7	191:1	existing dam

'In-series' accumulated benefit: 2,876 m^3 20 ha 144:1 m^3 / ha

Types of DB opportunity in the West Mangoane New and ready made?

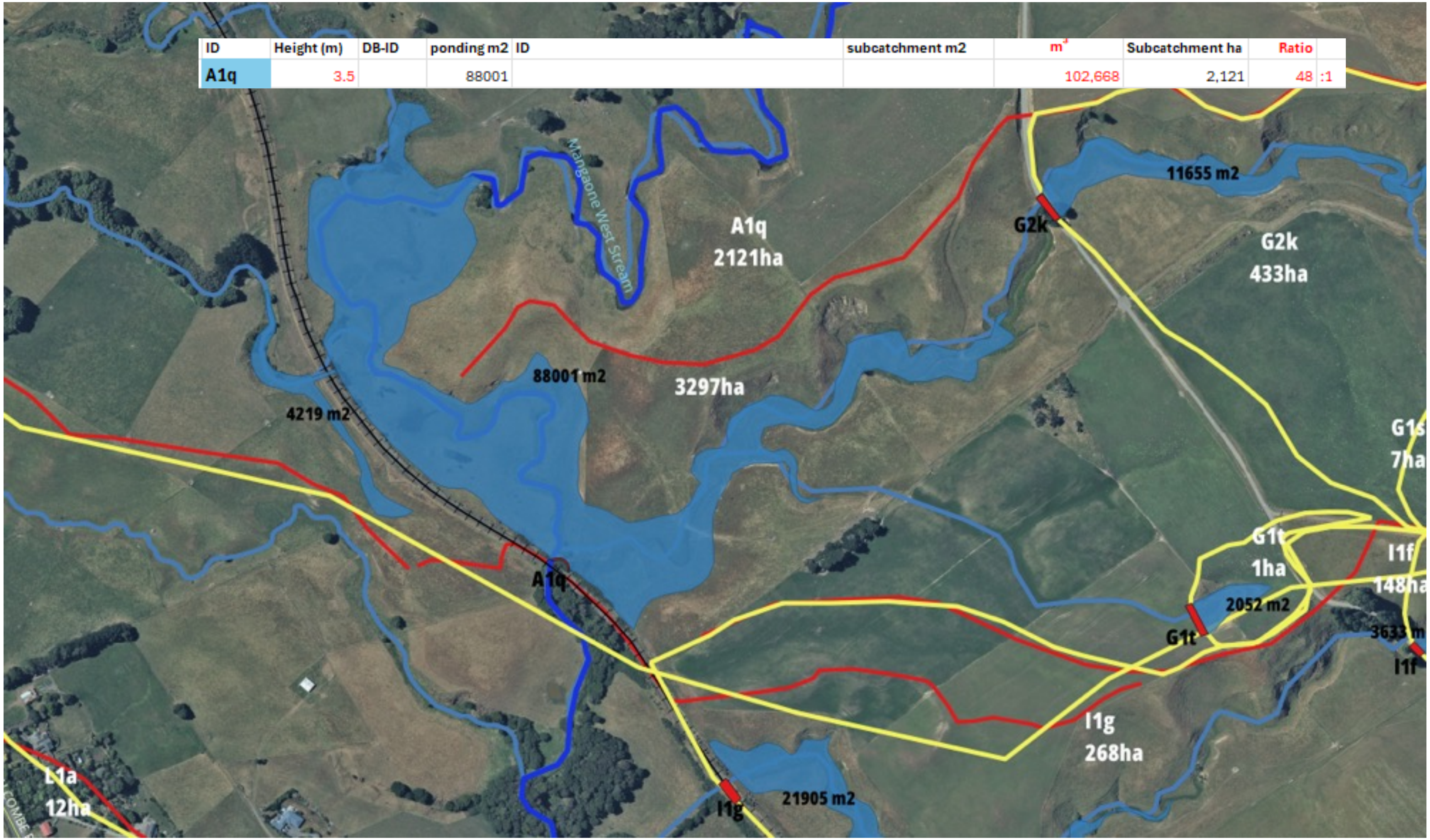
	Type of DB opportunity:	Nos.	% by No.
1	On-farm - New DB structures	38	24.7%
2	On-farm - Existing Dam retrofits	112	43.2%
3	Off-farm - DBs using public road embankments	8	4.9%
4	Off-farm - DB using railway line embankments	4	2.5%
	Total DB Nos.	**162**	100.0%

Cumulative effect of whole catchment DB application

K2e	2.5		2843			2,369	74	32 :1	147	28	new
K2fa	1.5		522			261	2	131 :1	148		existing pond
K2fb	1.2		1335			534	5	107 :1	149		existing pond
K2fc	2.5		1255			1,046	15	70 :1	150		new
K2f	2.5		1785			1,488	27	55 :1	151		new
K2ga	1.8		2179			1,307	7	187 :1	152		existing pond
K2g	3.5		24,090			28,105	526	53 :1	153	31	new
ID	Height (m)	DB-ID	ponding m2	ID	subcatchment m2	m^3	Subcatchment ha	Ratio			
L1a	2.5		2681			2,234	12	186 :1			new
M1a	2.5		2280			1,900	9	211 :1			new
M1b	2.5		1924			1,603	22	73 :1		34	new
M1c	2.5		6177			5,148	59	87 :1	157		existing - repair failed dam
M2a	2.1		761				6	0			
M2c	2.1		831			582	4	145 :1			existing pond
M2d	2.5		2091			1,743	18	97 :1			new
M3a	0.9		487				2	0			
M3b	2.5		3246			2,705	23	118 :1	160		new
M3c	2.5		3695			3,079	30	103 :1			new
M4a	2.5		3480			2,900	17	171 :1	**162**	**38**	new
									All	New	
DBs capacity for all upper West Mangoaene catchments (both on farms and public infrastructure)						**709,901**	**3,131**	**227 :1**			

Public road areas not otherwise treated		420	
Railway embankment areas not otherwise treated		299	
DBs capacity with Public road and Railway DB embankment site opportunities deducted	**447,586**	**2,412**	**186 :1**
	m^3	ha	Ratio

Use of existing off-farm embankments 8 on roads, 4 on rail



ID	Height (m)	DB-ID	ponding m2	ID	subcatchment m2	m³	Subcatchment ha	Ratio	
A1q	3.5		88001			102,668	2,121	48	:1

Conclusions for West Mangoane

Existing old dams - excellent opportunity for retrofitting to DBs

Applicability rate across the whole 3,000 ha area is high

The minimum storage ratio for water quality (≥ 120:1 over) is achievable

With a whole community buy-in (including NZ Transport Agency and NZ railways) and some modest increase in on-farm DB storage
252:1 is not an unrealistic target

252m^{3} **of stormwater ponding accounts for:**

- **1/3 of a net 75mm runoff event**
- **1/4 of a net 100mm runoff event**

DB rollout to entire farmed catchments ?

- *Want to learn the skills for this rolling out DBs?*

- *Massey University (& PMP Inc. collaboration)*
  1st 'Master Class' – August/September 2024

- *Establish what proportion of your catchment could be treated with qualifying DBs? i.e. DBs achieving ≥ 120:1*

- *DB performance is related to soil drainage properties*
- *PMP's results for DBs on clay soils due 2026*

Questions?

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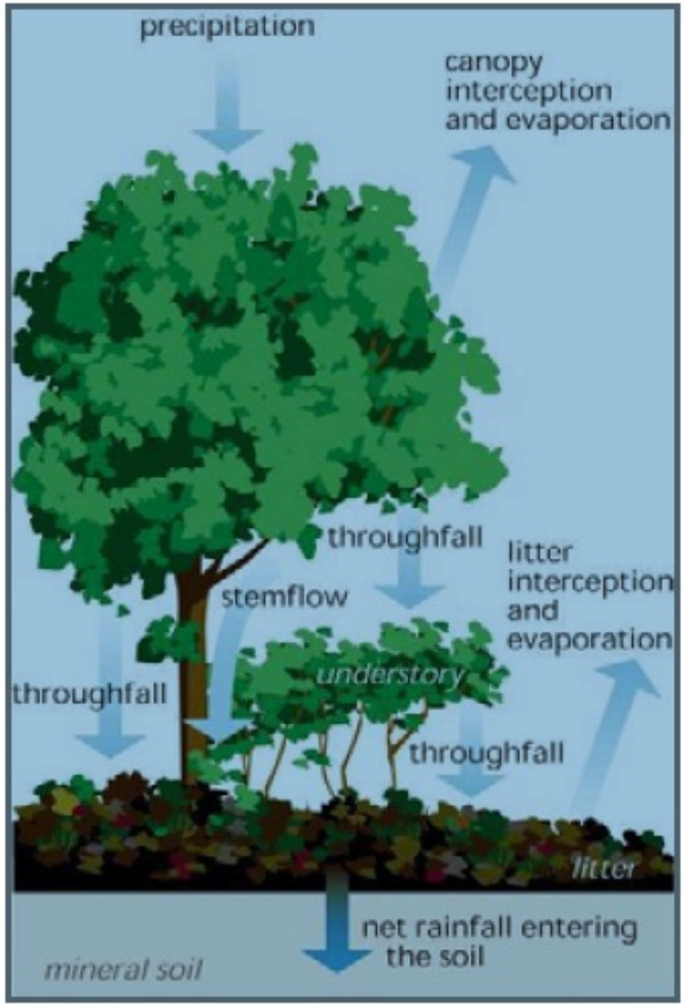
Reference: 'DB Manual'
https://atlas.boprc.govt.nz/api/v1/edms/document/A3539038/content

A DB safely intercepting storm water run-off where it first starts to flow, on a farm
We need thousands of these built over the next 10 years

Paleohydrology – NZ's lost forests



Forests:

- 75% NZ's original forest cover destroyed over last 1,000 years
- Canopy - an enormous sponge. Interception 10 – 40% (av. 25%)
- Enhanced evaporation – from canopy and litter
- Enhanced evapotranspiration – water moved from ground through the tree and leaves evaporating back into the air.
- Soil infiltration in forest can be 3x greater than pasture

Forests to Pasture effects:

At least 25% increase to the runoff volume and peak flow effects

- Faster storm water delivery - more 'peaked' hydrograph
- Greater flash flood effects – higher flood water levels
- More erosive flows and increased sedimentation
- Plus …………….

Paleohydrology - Returning farm waterways to pristine status Is it possible ?

	Issue (cause)	DB Benefits	DBs result in	Validated by
1	**Water quality** (phosphorus)	Phosphorus (P), in farm run-off captured in DBs.	Proven[1] 47% to 68% reduction of P load in storm water run-off	[1]Completed research (Levine PhD 2020 and Clarke MSc 2013).
2	**Water quality** (sediment)	Sediment captured in DBs.	Proven[2] 51% to 59% reduction of sediment in storm water run-off	[2]Completed research (Levine PhD 2020 and Clarke MSc 2013).
3	**Human health** (E. coli)[3]	Possible pathogens capture, reducing risk to potable water and downstream "Swimmability".	[3]Validation trials 2020 –2022. Likely similar to TP and SS results i.e. >50% reduction. Result pending.	Known association of Escherichia coli (*E.coli*) with sediment in run-off. [3] Pending applied research project.
4	**Erosion** (sediment)	Moderation of erosive peak flows by DBs.	Limiting downstream erosion (banks, head wall gullying).	100+ historic Detainment Dams (DDs) built 1980 – 2000 in BOP.
5	**Flood** (safety)	Moderation of peak flows by DBs during floods.	Limiting injury and loss of life from flooding induced road accidents.	Some DB works funded for peak flow risk reduction to public roads.
6	**Flood** (destruction)	Less downstream infrastructure maintenance cost.	Limiting damage to housing, bridges, culverts, roads, pasture and water supply.	As above. Works funded for this reason.
7	**Aquifer** **Depletion** (ground water)	'Aquifer recharge' through run-off residency in DB ponding area.	Proven[4] 43% to 63% infiltration through up to 72 hour DB ponding residency time.	[4]Completed research (Levine PhD 2020 and Clarke MSc 2013).

The Pristine hydrology goal – possible?

- *27% reduction rainstorm effects (achieved by 45% DB application rate)*
- *Will this return pristine state ≈ predevelopment hydrology ?*

Development = Pasture and regular soil exposure