ROAD INFRASTRUCTURE MANAGEMENT FORUM

GeoSolve Pavements Group

Traffic speed deflection data applied to network asset management

THE KAIKOURA BYPASS REALITY CHECK

GeoSolve

RIMS Roading Infrastructure Management Support

IDS Infrastructure Decision Support

NZ Utilities Advisory Group Inc

Introduction

- Traffic Speed Deflection Data:
  - 10 m centres
  - Accurate and repeatable
  - TSD “dynamic” bowls -> equivalent FWD “static” bowls
- 2015 TSD data has been used to produce two FWPs:
  - Empirical Drainage Study (William Gray / Elke Beca + NZTA)
  - Regional Calibrated Mechanistic Study (Martin Gribble, NZTA)
- NZTA’s Kaikoura Bypass project is a prime opportunity for a “reality check” to compare both methods on a 800 lane km “test track”.

Traditional Empirical Procedure

	Functional Evaluation (surface)
RCA Requirements →	Functional Levels of Service Rut, IRI (Skid)
RAMM High Speed Data Visual Condition →	Data QA, Historic Evaluation
	Preliminary Specified FWP from Visual Surveys
Traffic Data Geometry ONRC Maintenance Costs SNP →	dTIMS Surface Performance
	Coordinated Outputs: FWP for Resurfacings

Integration of Mechanistic Procedure

RCA Requirements

RAMM
High Speed Data
Visual Condition
FWD & TSD

Traffic Data
Geometry
ONRC
Maintenance Costs
Mechanistic Models

Functional Evaluation (surface)

Functional Levels of Service
Rut, IRI (Skid)

Data QA,
Historic Evaluation

Preliminary Specified FWP from
Visual Surveys

dTIMS Surface Performance +
Subsurface added from
Mechanistic- FWP

Coordinated Outputs:
FWP for Resurfacings &
Validated Specified M-FWP for
Renewals

Feedback loops
to optimise
Structural FWP

Structural Evaluation (sub-surface)

Structural Levels of Service
% Terminal Fatigue, % Excessive cost

Data QA, Validation of Terminal Sites
(RAPT), Regional Precedent
Performance for Fatigue Criteria

Loading (ESA)
Mechanistic Analyses
(Moduli, Stresses & Strains)
Remaining Structural Life

Additional Outputs:
Sub-surface Drainage Priorities
Quantified HPMV Route Impacts

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Traditional Analysis – Distress Modes

- Empirical or traditional mechanistic approaches: Consideration of only 1-2 criteria for pavement life prediction (e.g. SNP or subgrade strain)
- Through extensive data collection at high speed (incl. TSD): Mechanistic approach enables more criteria and multiple distress modes to be considered and calibrated to region or sub-region (using methodology of the Regional Precedent Performance (RPP) Study recently undertaken for NZTA on 5 of their regional networks).
- Recent developments now allow mechanistic analysis of TSD data to be carried out very rapidly at effectively project level analysis with a non-linear layered elastic model. Thus, enabling the 10m intervals to be used for more definitive examination and interpretation of the stresses and strains at every test interval, i.e. almost continuously along each lane.

Multiple Distress Criteria

- Andrew Dawson
- International workshop for the development of Mechanistic Design Methods for Unbound Pavements

Rutting → (mechanisms 1–6)

Roughness → (mechanisms 8–10)

Degradation → (mechanisms 11, 24)

Flexure → (mechanism 17)

Shear → (mechanism 19)

1	Excess resilience of pavement (see also Mechanisms 6 and 7)
2	Excess rutting from within granular layer due to granular material shear displacement
3	Excess rutting from within granular layer due to compaction by traffic loading
4	Excess rutting from within subgrade layer due to subgrade shear displacement
5	Excess rutting from within subgrade layer due to combined action of subgrade and granular layer(s)- due to complex stress interaction effects
6	Excess rutting from within subgrade layer due to combined action of subgrade and granular layer(s) when subgrade is too resilient
7	Pumping of subgrade into base course
8	Excess longitudinal roughness - uneven-ness
9	Excess longitudinal roughness - potholing
10	Excess longitudinal roughness - corrugations
11	Frost action on susceptible subgrades or granular materials
24	Breakdown of pavement aggregate due to repeated freeze-thaw cycling
25	Softening of the pavement at the time of Spring-thaw
12	Soil heave / shrinkage
13	Wear due to dust loss
14	Wear due to stone displacement by tyre ('gravel loss')
26	Wear due to stone 'loss' into soft subgrade ('gravel loss')
27	Wear due to erosion of surface metalling by water ('gravel loss')
15	Wear due to stone abrasion / attrition
16	Wear due to studded tyre action
17	Seal breakage due to traffic-induced flexure
18	Seal breakage due to environmentally-induced shrinkage (thermal cracking)
19	Seal breakage due to shoving / tearing / shearing
20	Inadequate surface condition- sealed surface too smooth due to aggregate texture loss
21	Inadequate surface condition- sealed surface too smooth due to excess bitumen rising to surface
22	Inadequate surface condition- unsealed surface too slippery due to excess fines on surface (wet weather)
23	Inadequate surface condition- unsealed surface too slippery due to loose gravel on surface

NB Shaded mechanisms largely set aside by workshop - see Section 3.1 and following

Very substantial progress in the last 3 years for New Zealand <u>Unbound Pavements</u>

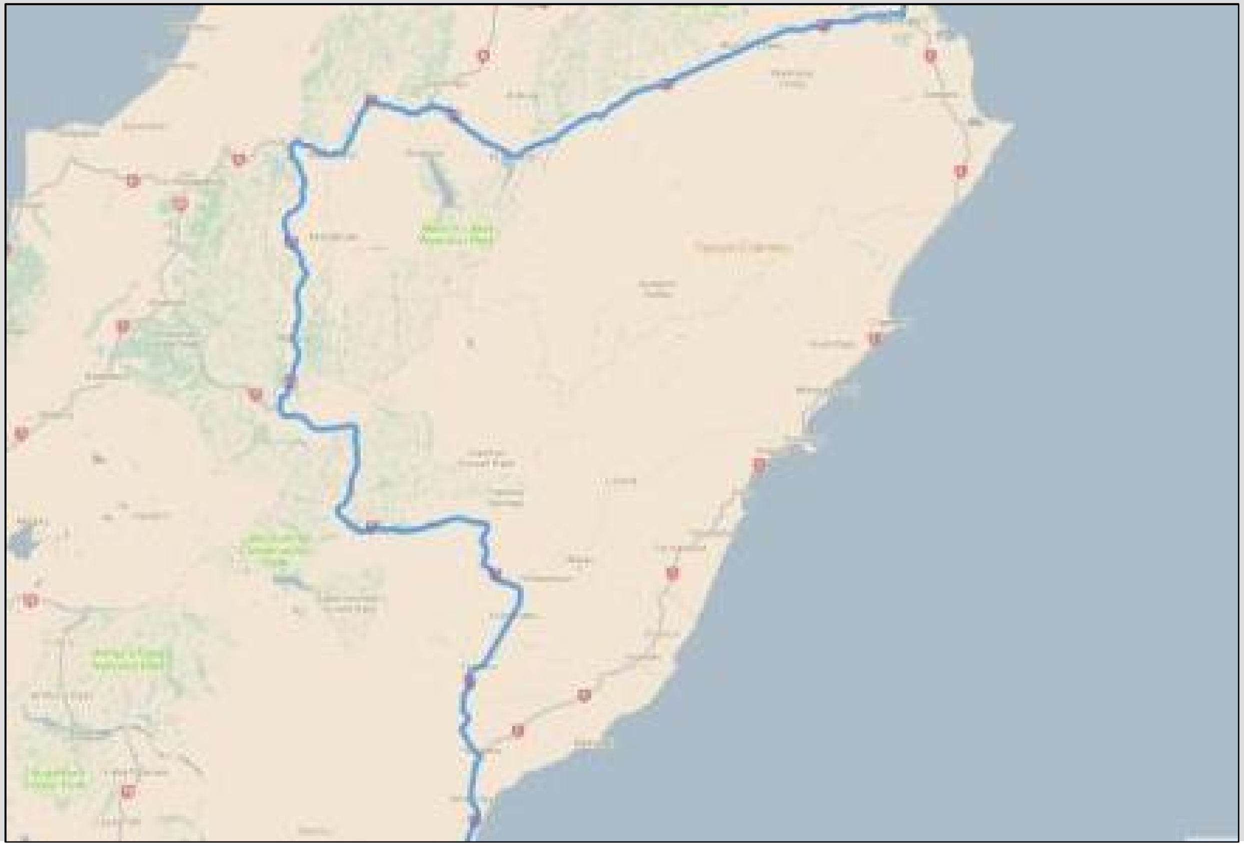
Andrew Dawson, 2002

Kaikoura Bypass Case History

Background

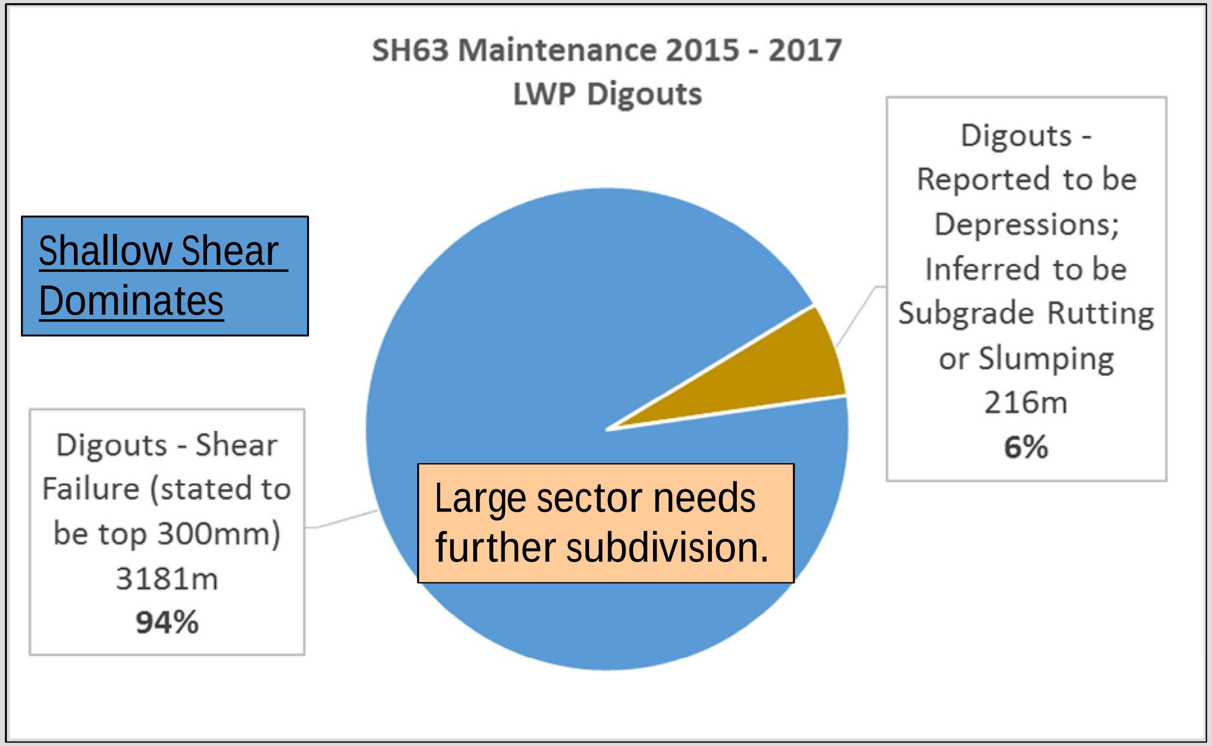
- Kaikoura earthquake
- Inundation of parts of SH1
- Need for bypass route
- Original 25-Year Traffic will be experienced by mid next year
- The ultimate "Reality Check" of life prediction models: Real traffic on real roads with a range of real environments.
- TSD data collected in 2015

→ Impacts and Distress modes?



Mechanistic Analysis – Distress Modes

Observed Distress Modes from Kaikoura Bypass Maintenance



Mechanistic Analysis – Distress Modes

Distress Modes from NZ Data Mining

Structural distress modes

1 Shallow Shear – Low Strength (shoving)
2 Shallow Shear – Spreading (strong but inadequate support)
3 Shallow Shear – Heave (in loose or low broken faces BC)
4 Shallow Shear – Hybrid (from above)
5 Aggregate Instability (pumping >75%S, potholing, heave)
6 Aggregate Rutting (VSD in basecourse or subbase)
7* Aggregate Weathering (mineralogical changes in fines)
8 Aggregate Degradation (physical generation of fines)
9 Cracking (conventional, bottom up) of bound layers
10 Flexure (top down cracking) of bound layers
11* Binder Curing/Hardening (aging)
12* Bond loss (cement bound reverting to unbound)
13 Subgrade Rutting (vertical deformation)
14 Subgrade Shear (lateral and vertical deformation)
15 Accumulated Deformation (multiple layers contributing)
16 Slumping/Edge Break (lack of shoulder support)
17 Roughness Progression
18 Shrinkage Cracking (viz FBS with curing/ thermal)

Surfacing distress modes

19 Seal Deformation (more likely as multiple seal layers accumulate)
20 Flexure (top down cracking in seal or thin AC)
21 Reflection Cracking
22* Seal Flushing
23 Scabbing/Ravelling

Economic Triggers

24 Excessive Maintenance costs for the surfacing (seal, thin AC)
25 Excessive Maintenance costs for structural layer(s)

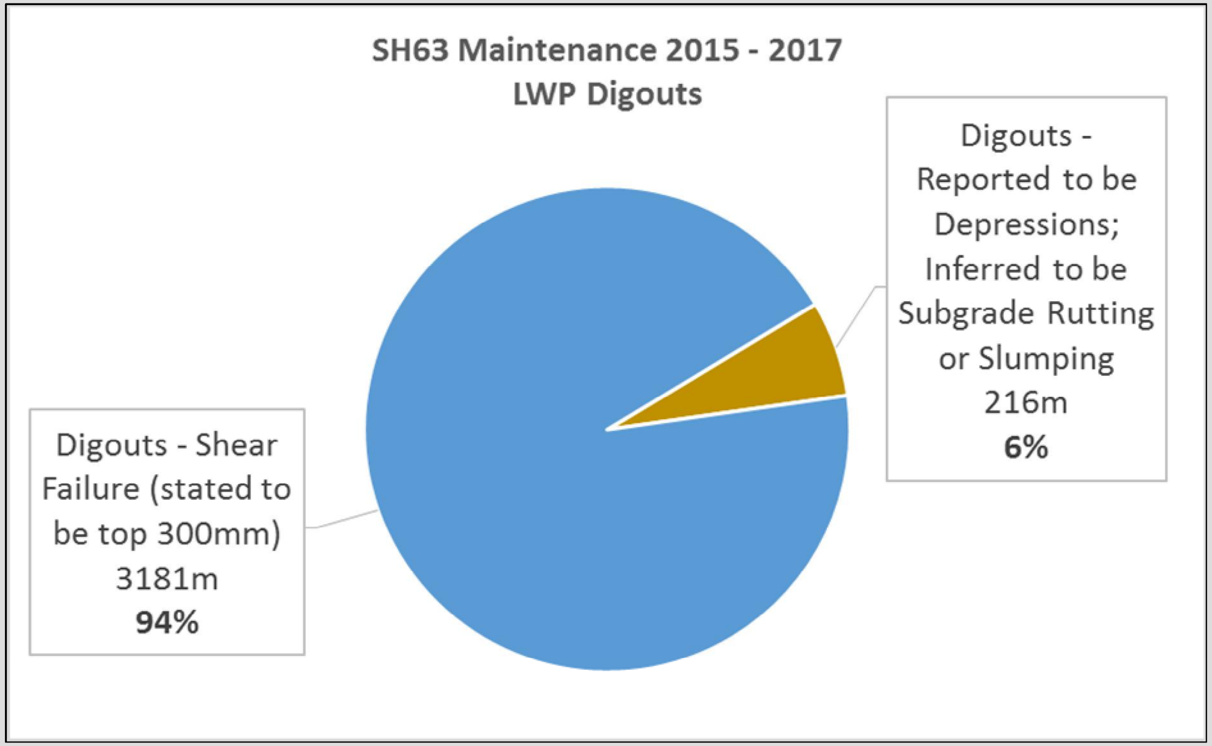
Other characteristics or causes that affect timing of triggers include:

26* Loading frequency effects on inter-particle bonds
27* Cement curing
28* Bitumen embrittlement (environmental ageing)
29* Subgrade –subbase intrusion
30* Frost heave
31* Particle breakdown in freeze-thaw cycles
32 Foundation subsidence (vertical depression)
33 Foundation slumping (lateral deformation)

*7, 11, 12, 22 & 26-31 Not explicitly included in current modelling
Vehicle speed and temperature included for individual modes

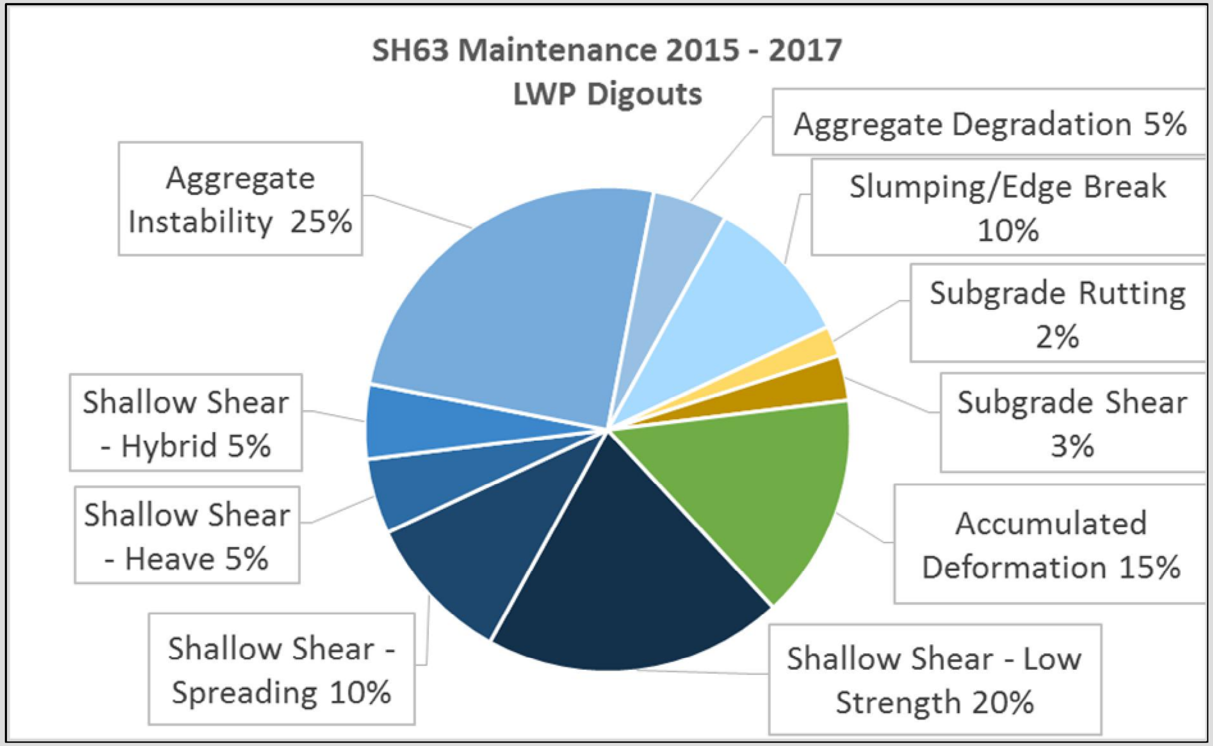
Mechanistic Analysis – Distress Modes

Distress Modes from Kaikoura Bypass Maintenance



Mechanistic Analysis – Distress Modes

Distress Modes from Mechanistic Analysis



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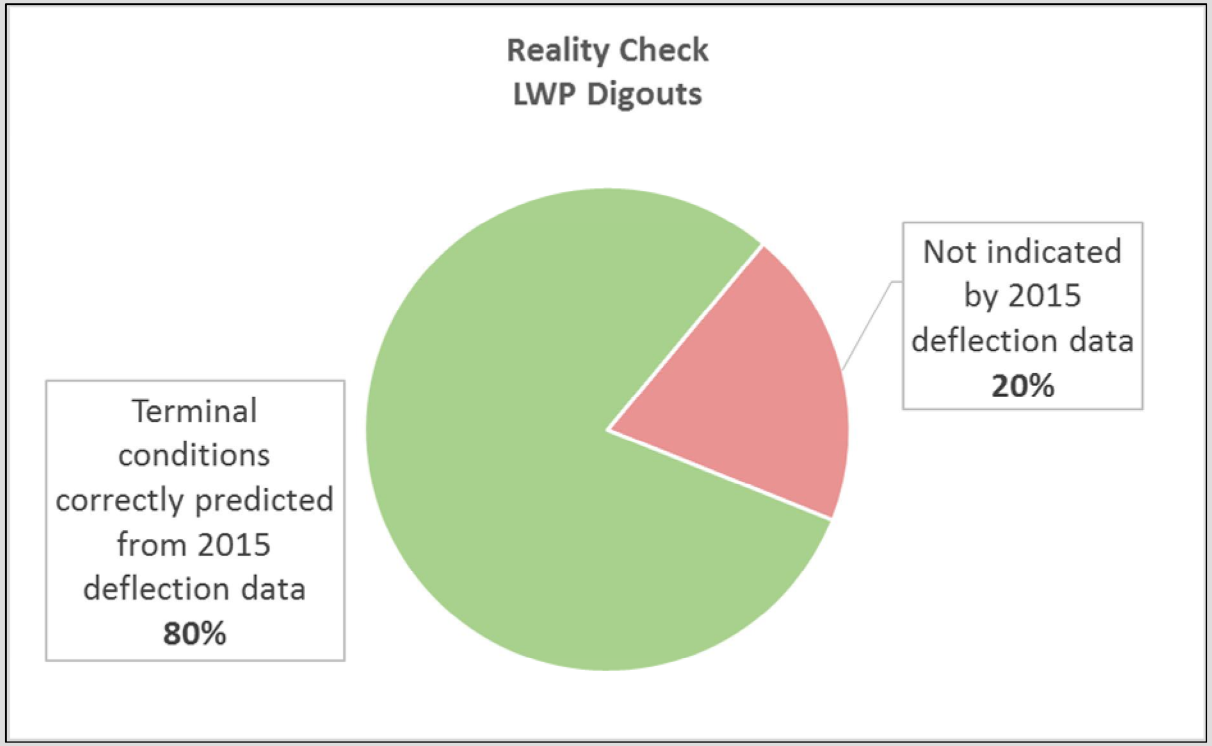
Mechanistic Analysis – Distress Modes

Kaikoura Bypass Maintenance – Reality Check (Preliminary Calibration)



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Mechanistic Analysis – Distress Modes

Kaikoura Bypass Maintenance – Reality Check (Preliminary Calibration)

Reasons for not predicting distress:

- Only network calibration, not site-specific
- TSD test data averaged over 10m spacings; shallow shear often initiates for only 1-2m length

→ "Dilution" of signal of distressed portion

Finer subdivision than 10m is now being explored.

Reasonable expectations: 90% reliability of predictions

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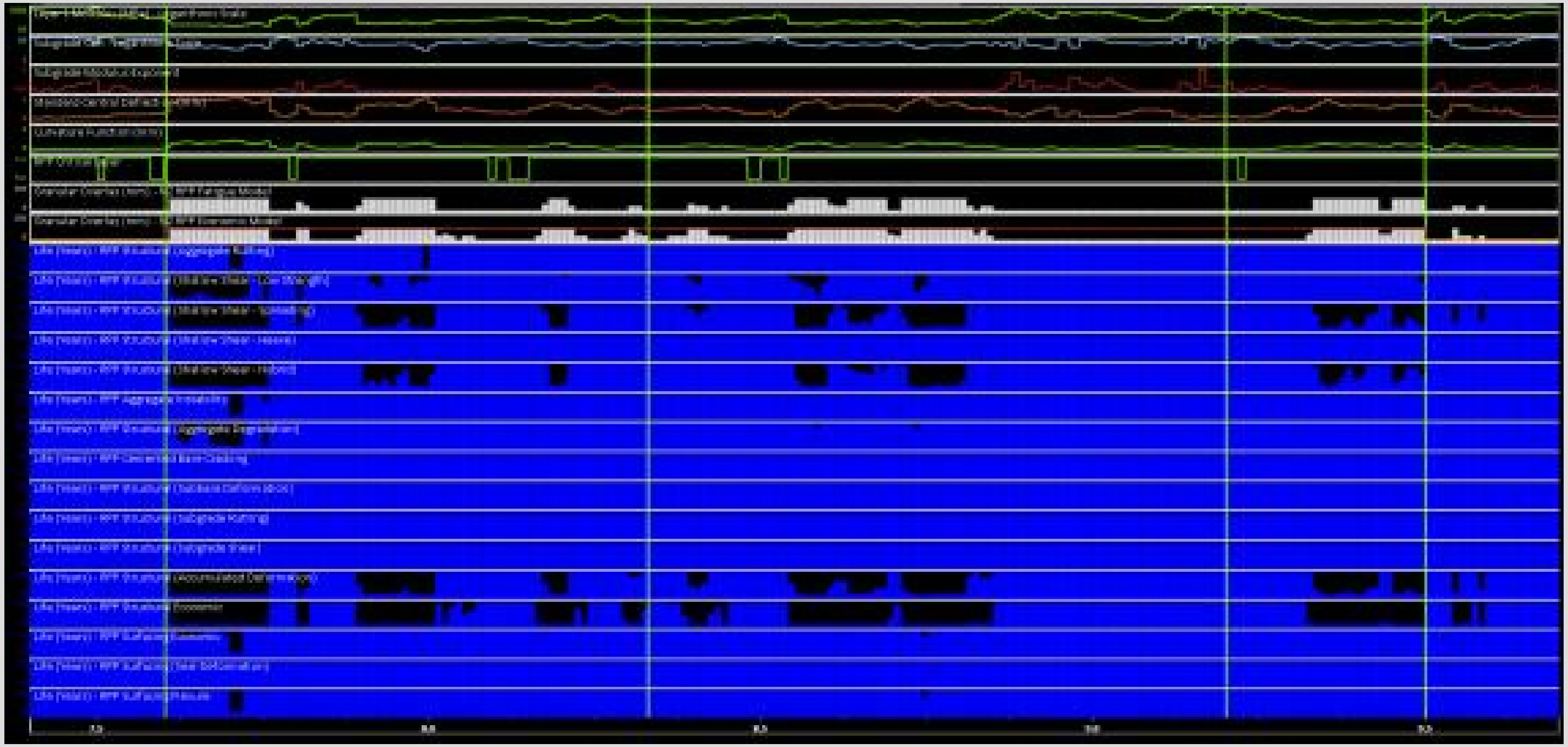
Structural Treatment Length

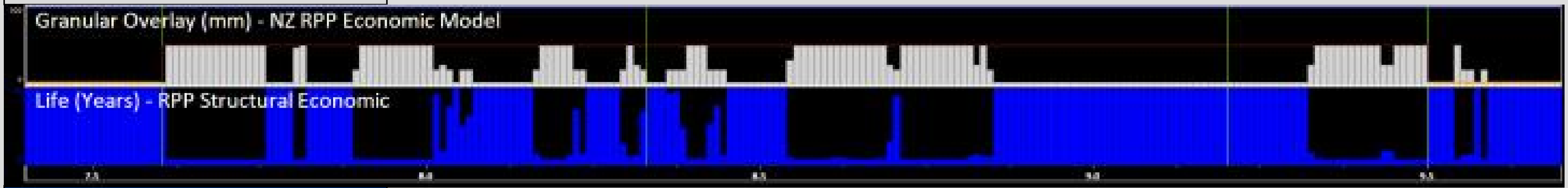
PE-Grapher Output



Structural Treatment Length

PE-Grapher Output

Overlay (0-300 mm)



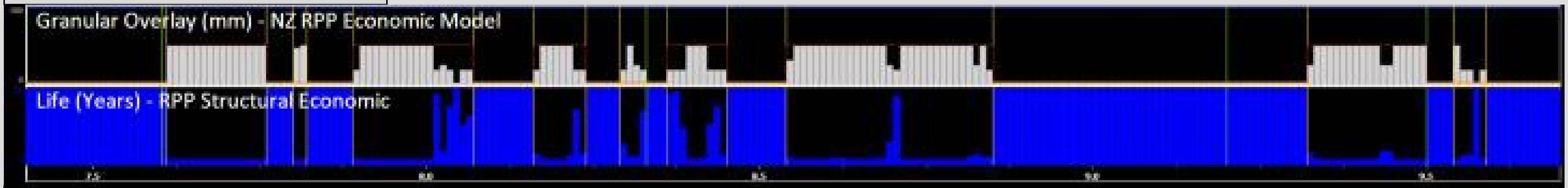
Remaining Life (0-25 Years)

Test Location (km)

Structural Treatment Length

PE-Grapher Output

Overlay (0-300 mm)



Remaining Life (0-25 Years)

Test Location (km)

Structural Treatment Length Table

STL file

								Rehabilitation Priority, Remaining Life and Governing Distress Mode													
Road ID	File Name	Start (km)	End (km)	Length (km)	Risk of Damage from HPMVs	Life (Years) - RPP Surfacing Fatigue (Governin	Life (Years) - RPP Surfacing Economic	Priority Ranking for Rehab (10th-%ile)	Life (Years) - RPP Structural Economic (50th-%ile)	Life (Years) - RPP Structural Fatigue (Governing, 10th-%ile)	Life (Years) - RPP Aggregate Instability (10th-%ile)	Life (Years) - IAL (Governing, 10th-%ile)	Priority Ranking for Rehab (50th-%ile)	Life (Years) - RPP Structural Economic (90th-%ile)	Life (Years) - RPP Structural Fatigue (Governing, 50th-%ile)	Life (Years) - RPP Aggregate Instability (50th-%ile)	Life (Years) - IAL (Governing, 50th-%ile)	Life (Years) - User Weighted Mechanistic	Life (Years) - FWP Specified	Life (Years) - FWP	RPP Distress Mode
503	063-0017 L1	2.810	3.000	0.190	Medium	32	32	2.2	1	2	46	2	0.5	85	6	87	8	-6	-1	199	Shallow Shear - Spreading
505	063-0046 R1	9.890	10.060	0.170	Medium	171	153	1.2	2	2	76	5	0.2	90	22	137	23	-6	-1	199	Shallow Shear - Spreading
508	063-0074 L1	4.500	4.600	0.100	Medium	3	3	3.5	1	1	17	1	0.3	56	16	126	15	-5	-1	199	Subgrade Rutting
505	063-0046 R1	9.630	9.740	0.110	Medium	99	99	1.0	2	4	82	7	0.2	63	22	106	15	-5	-1	199	Shallow Shear - Spreading
2648	063-0084 L1	0.630	0.760	0.130	Medium	49	49	0.6	5	4	116	11	0.1	86	28	138	25	-5	-1	199	Shallow Shear - Spreading
501	063-0000 L1	6.480	6.699	0.219	Medium	33	33	2.6	1	2	40	3	0.4	60	3	65	22	-5	0	199	Shallow Shear - Spreading
504	063-0029 R1	6.360	6.550	0.190	Medium	23	23	3.1	1	1	3	2	0.2	78	16	87	19	-5	1	199	Shallow Shear - Low Strength
505	063-0046 R1	2.500	2.620	0.120	Medium	44	44	2.7	1	1	58	2	0.4	78	11	99	10	-5	2	199	Shallow Shear - Spreading
508	063-0074 L1	2.460	2.630	0.170	Medium	44	44	2.9	1	1	61	2	0.7	65	3	99	8	-5	199	199	Shallow Shear - Spreading
535	063-0092 L1	7.270	7.500	0.230	Medium	137	100	1.5	1	1	96	2	1.2	56	1	105	3	-5	199	199	Shallow Shear - Subsidiary
501	063-0000 L1	1.140	1.270	0.130	Medium	159	158	0.2	1	1	135	72	0.1	61	12	141	82	-5	199	199	Shallow Shear - Spreading
505	063-0046 R1	11.750	11.880	0.130	Medium	61	61	1.9	2	2	84	3	0.1	67	23	125	44	-5	199	199	Shallow Shear - Spreading
506	063-0059 R1	11.590	11.690	0.100	Medium	77	77	0.6	2	10	101	10	0.2	72	23	141	26	-5	199	199	Shallow Shear - Spreading
503	063-0017 L1	2.670	2.800	0.130	Medium	25	25	2.4	1	1	61	2	1.3	39	2	76	3	-4	-1	199	Shallow Shear - Spreading
508	063-0074 L1	5.260	5.410	0.150	Medium	40	40	3.2	1	1	66	2	1.4	46	2	91	3	-4	-1	199	Shallow Shear - Subsidiary
503	063-0017 R1	3.390	3.550	0.160	Medium	35	35	1.1	1	2	44	6	0.2	44	11	81	24	-4	-1	199	Shallow Shear - Spreading
2648	063-0084 L1	3.720	3.831	0.111	Medium	44	44	2.4	1	1	78	2	0.3	39	11	108	14	-4	-1	199	Shallow Shear - Spreading
508	063-0074 R1	5.080	5.400	0.320	Medium	78	78	2.1	1	2	71	3	0.3	41	15	100	12	-4	-1	199	Shallow Shear - Spreading
506	063-0059 R1	13.440	13.580	0.140	Medium	88	84	0.5	2	10	95	13	0.2	42	24	125	21	-4	-1	199	Shallow Shear - Spreading
503	063-0017 R1	8.340	8.680	0.340	Medium	41	41	2.2	1	1	31	2	0.3	40	3	77	16	-4	0	199	Shallow Shear - Spreading
504	063-0029 R1	14.370	14.510	0.140	Medium	129	129	0.4	1	1	56	28	0.1	37	12	100	41	-4	0	199	Shallow Shear - Low Strength
506	063-0059 R1	3.510	3.700	0.190	Medium	65	63	2.2	1	2	86	3	0.3	43	10	132	20	-4	0	199	Shallow Shear - Spreading
506	063-0059 L1	1.210	1.320	0.110	Medium	159	146	0.7	1	2	73	12	0.1	46	17	110	54	-4	0	199	Shallow Shear - Low Strength
504	063-0029 L1	14.550	14.700	0.150	Medium	117	117	1.3	2	2	66	5	0.2	47	23	92	19	-4	0	199	Shallow Shear - Low Strength
506	063-0059 R1	3.110	3.320	0.210	Medium	49	49	1.8	3	2	57	3	0.2	47	26	110	21	-4	0	199	Shallow Shear - Spreading
504	063-0029 L1	8.690	9.000	0.310	Medium	137	128	3.3	1	1	25	2	0.2	36	7	97	32	-4	2	199	Shallow Shear - Low Strength
504	063-0029 R1	8.110	8.280	0.170	Medium	147	143	2.3	1	1	44	3	0.2	36	12	80	39	-4	2	199	Shallow Shear - Low Strength
505	063-0046 L1	2.490	2.620	0.130	Medium	36	36	2.4	1	2	44	2	0.4	39	12	88	10	-4	2	199	Shallow Shear - Spreading
501	063-0000 R1	0.970	1.131	0.161	Medium	137	137	3.0	1	1	59	2	0.1	47	1	137	51	-4	199	199	Shallow Shear - Spreading
506	063-0059 R1	4.530	4.720	0.190	Medium	9	9	2.8	1	1	55	2	1.7	41	2	62	3	-4	199	199	Shallow Shear - Spreading
505	063-0046 R1	5.790	6.020	0.230	Medium	19	19	2.1	1	2	66	3	0.7	37	4	92	7	-4	199	199	Shallow Shear - Spreading
505	063-0046 R1	7.340	7.630	0.290	Medium	47	47	2.1	1	2	56	3	0.6	45	6	74	8	-4	199	199	Shallow Shear - Spreading
506	063-0059 R1	4.090	4.230	0.140	Medium	161	142	0.9	1	2	61	9	0.2	39	12	86	26	-4	199	199	Shallow Shear - Low Strength
2648	063-0084 R1	5.230	5.410	0.180	Medium	2	2	1.6	1	5	95	2	0.3	48	17	120	15	-4	199	199	Shallow Shear - Spreading
494	006-0000 L1	2.000	2.260	0.260	Medium	131	131	0.9	1	1	146	37	0.4	42	14	159	42	-4	199	199	Shallow Shear - Spreading
508	063-0074 L1	2.360	2.460	0.100	Medium	43	43	2.2	1	2	92	3	0.3	37	17	120	15	-4	199	199	Shallow Shear - Spreading
508	063-0074 R1	7.790	8.140	0.350	Medium	141	140	0.3	1	1	152	34	0.1	37	19	166	55	-4	199	199	Shallow Shear - Spreading
2648	063-0084 L1	7.650	7.750	0.100	Medium	170	150	1.2	2	2	106	7	0.2	40	15	136	22	-4	199	199	Shallow Shear - Spreading
505	063-0046 L1	11.850	12.000	0.150	Medium	53	53	2.2	2	1	77	2	0.2	48	21	122	16	-4	199	199	Shallow Shear - Spreading
501	063-0000 L1	9.140	9.280	0.140	Medium	169	149	0.2	2	8	49	49	0.1	38	22	67	66	-4	199	199	Shallow Shear - Low Strength
501	063-0000 R1	13.740	13.870	0.130	Medium	10	10	0.9	2	3	109	10	0.2	38	23	120	14	-4	199	199	Shallow Shear - Spreading
503	063-0017 R1	1.530	1.691	0.161	Medium	92	92	0.5	2	7	80	11	0.2	38	21	93	18	-4	199	199	Shallow Shear - Spreading
506	063-0059 L1	9.375	9.490	0.115	Medium	172	148	0.2	2	3	41	41	0.1	45	22	61	61	-4	199	199	Shallow Shear - Low Strength

Structural Treatment Length Table

STL file

Cost of Structural Treatments			
Type	*Rate*	*Unit*	*Description*
OVLA	$ 540	/ m³	Asphaltic concrete overlay
OVLG	$ 133	/ m³	Granular overlay plus chipseal surface
STAB	$ 170	/ m³	Stabilised granular overlay plus chipseal surface
FBS	$ 398	/ m³	Foamed bitumen stabilisation
RCN	$ 133	/ m³	Granular reconstruction
SMRA	$ 648	/ m³	Structural Mill and Replace Asphalt
STR	$ 160	/ m³	Stabilise and Reconstruct
CS	$ 6	/ m²	Spray Seal

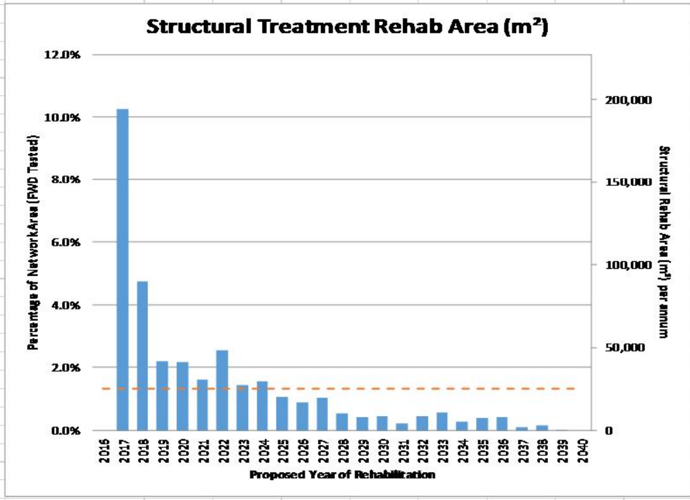
Rehabilitation Priority Weightings		
DF1	1	Negligible
DF2	1.1	Minor
DF3	1.2	Moderate
DF4	1.3	High
DT	1	Design Traffic

Distress Mode Weightings		
LRG	1	Functional Distress
LRE	1	Structural Economic
LRI	1	Aggregate Instability
LSF	0.5	Surfacing Fatigue
LSE	0.5	Surfacing Economic
LDO	0	dTIMS Optimal (Unlimited)
LDS	0	RCA Specified
SC	0	RCA Specified Duration (years)
SF	1	Fatigue Calibration

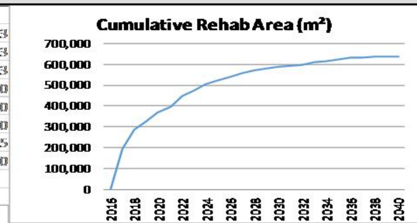
Update

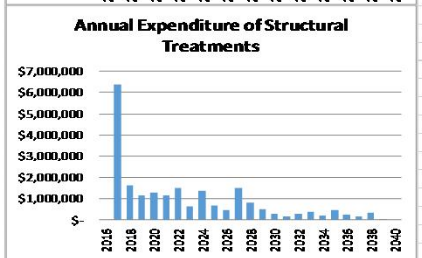
Export to KML

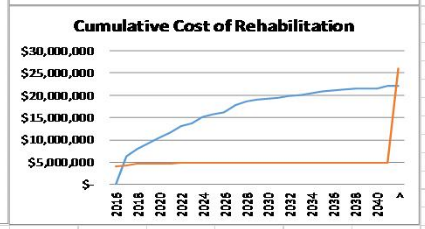
ONRC	R/U Facto	LOS(sur)	LOS(str)	COST				
High Volume	0.8	33	40	50		10	20	33
National	0.8	33	40	50		10	20	33
Regional	0.8	36	40	50		15	20	33
Arterial	1	40	40	63		20	20	50
Primary Collector	1	44	44	63		25	25	50
Secondary Collector	1	48	48	63		30	30	50
Access	1	51	51	66		35	35	55
Low Volume	1	63	63	78		50	50	70
					5			



Number of years included in the FWP: 25







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LRE	1	Structural Economic
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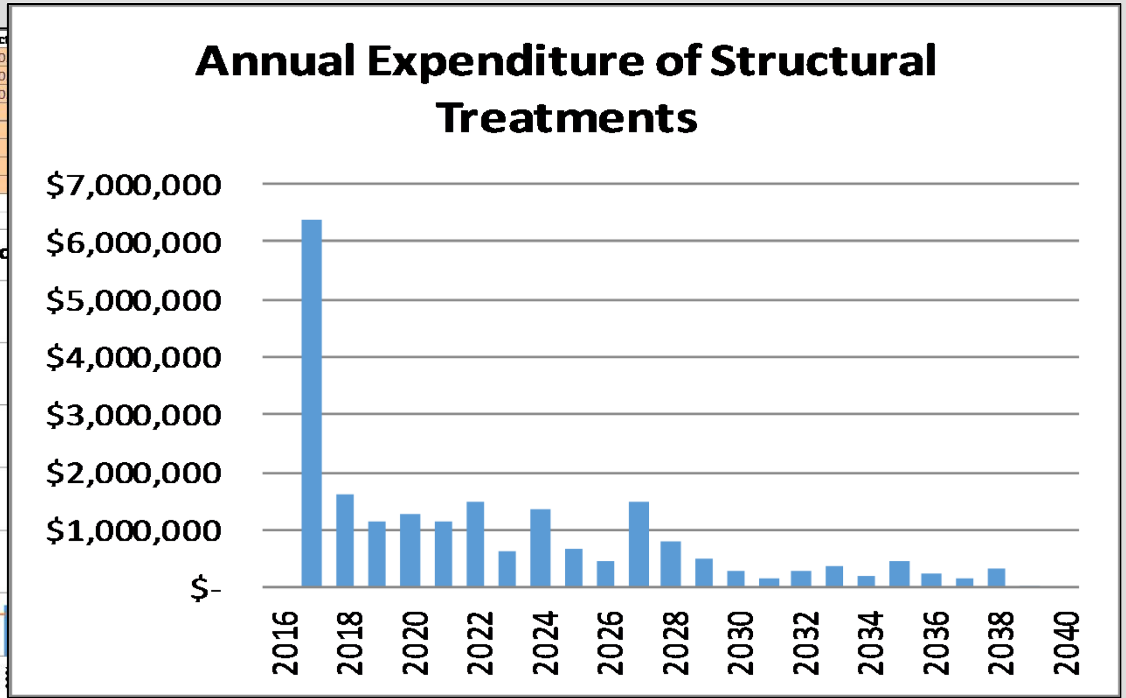
LSE	0.5	Surfacing Economic
LDO	0	dTIMS Optimal (Unlimited)
LDS	0	RCA Specified
SC	0	RCA Specified Duration (years)
SF	1	Fatigue Calibration

Update

Export to KML

ONRC	R/U Fac
High Volume	0
National	0
Regional	0
Arterial	
Primary Collector	
Secondary Collector	
Access	
Low Volume	

Number of years included in the FWP: 25



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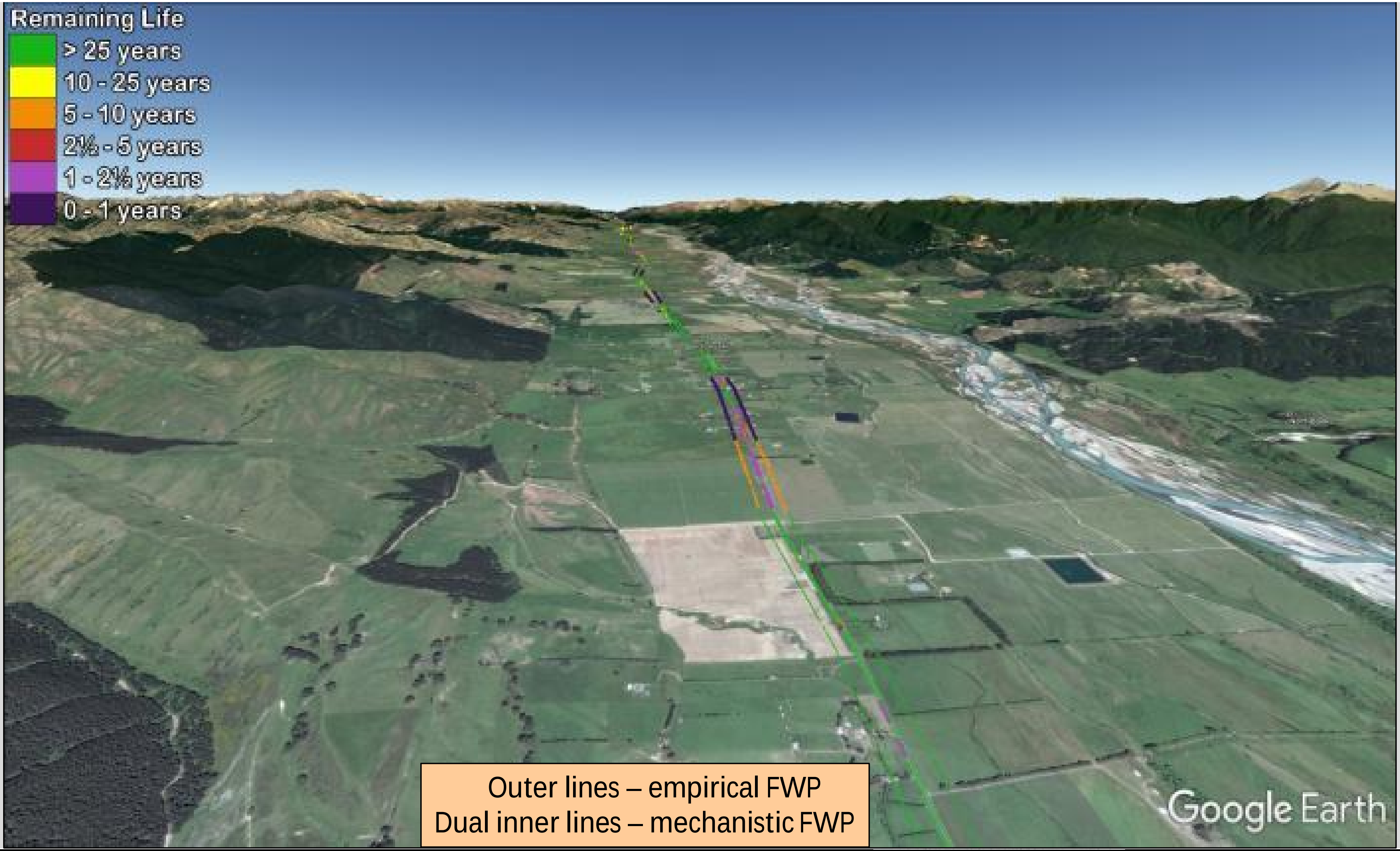
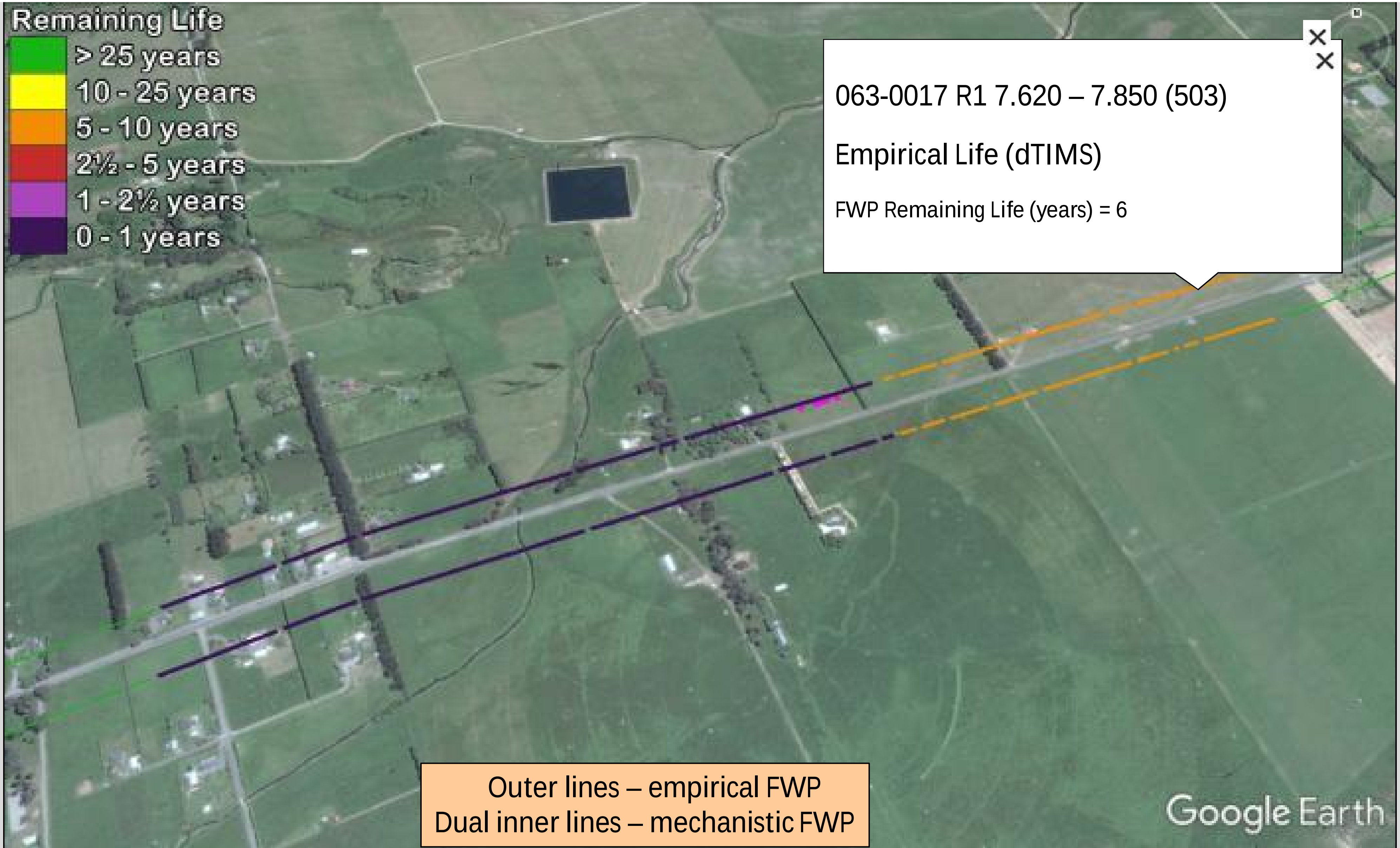
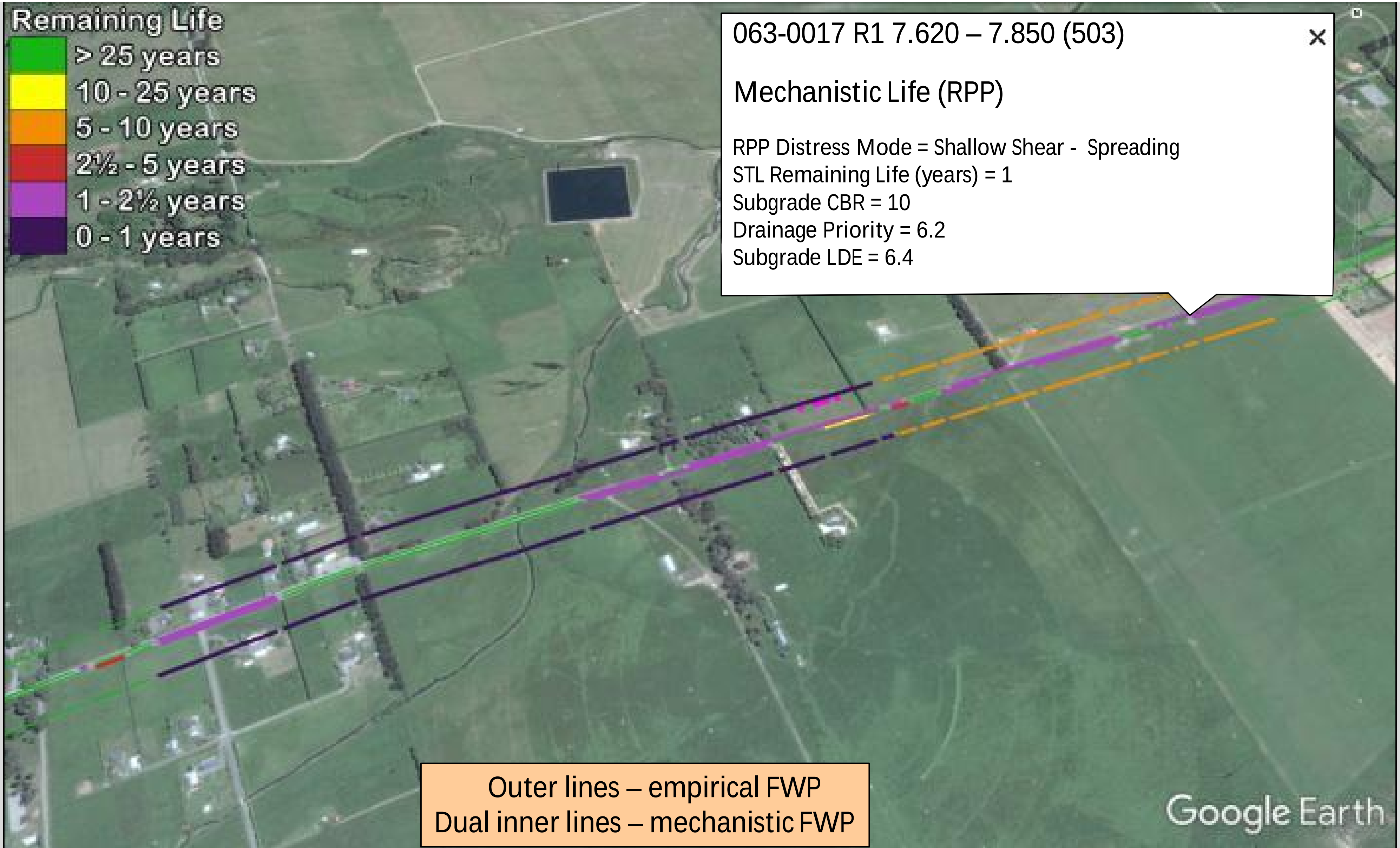
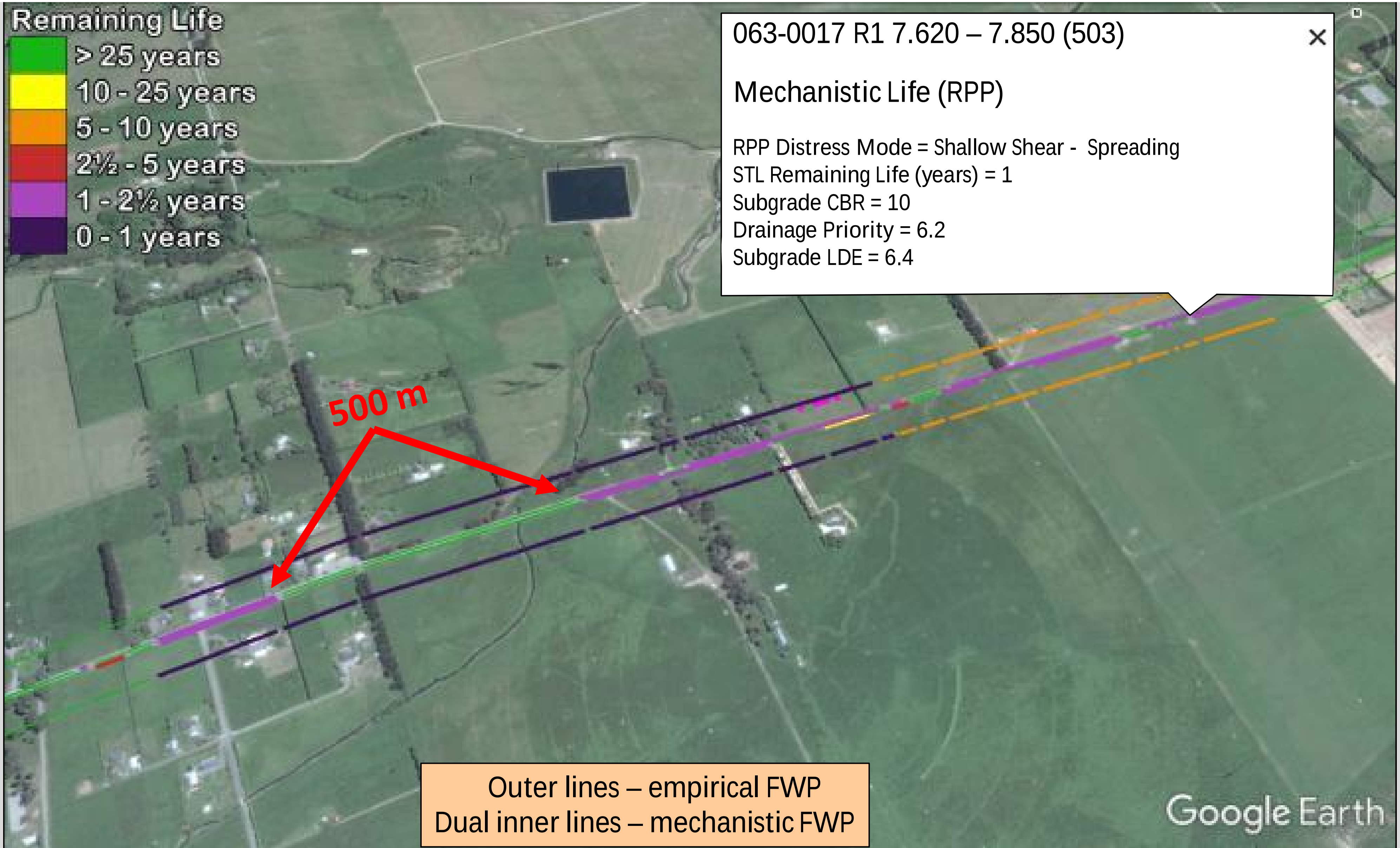
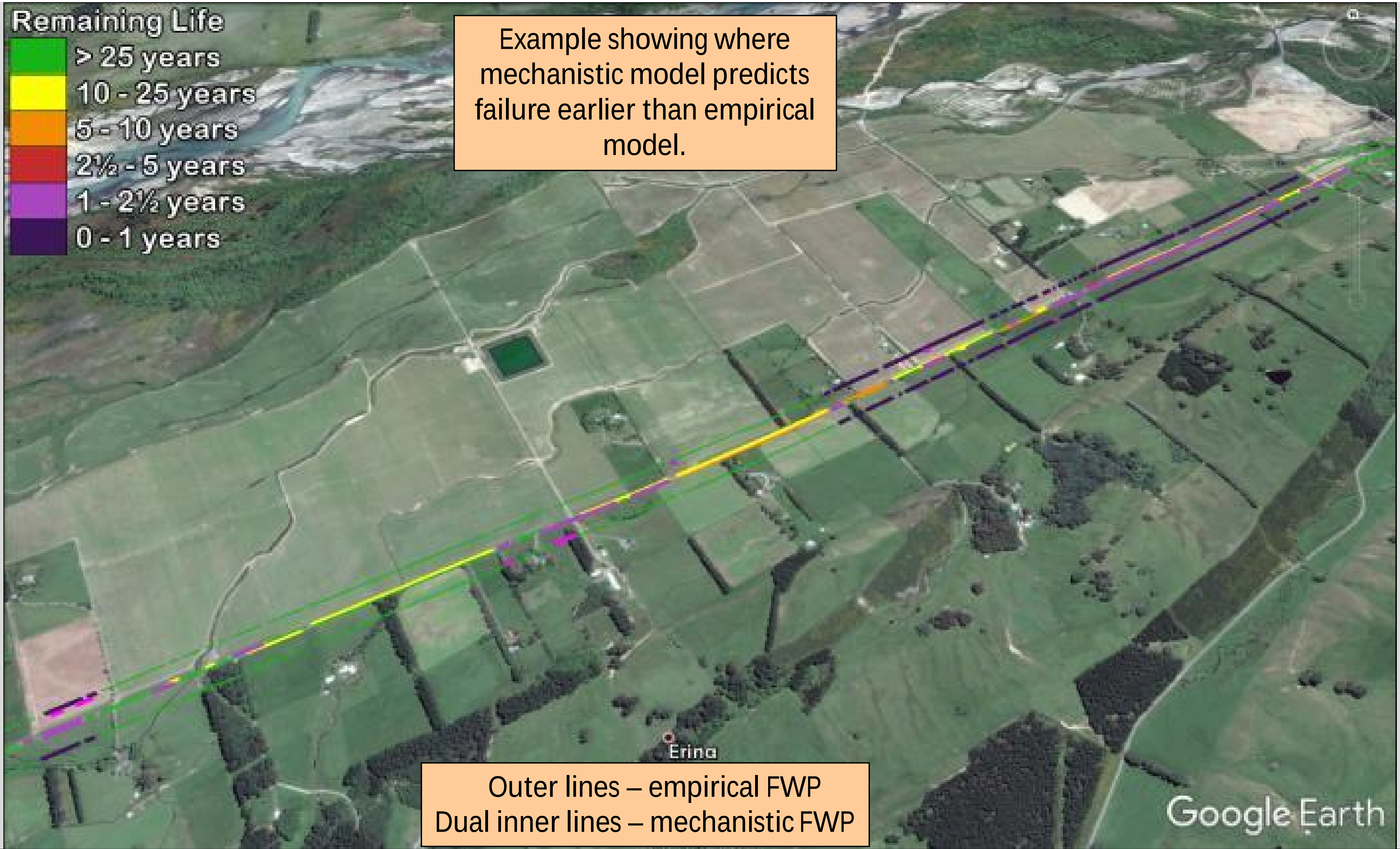


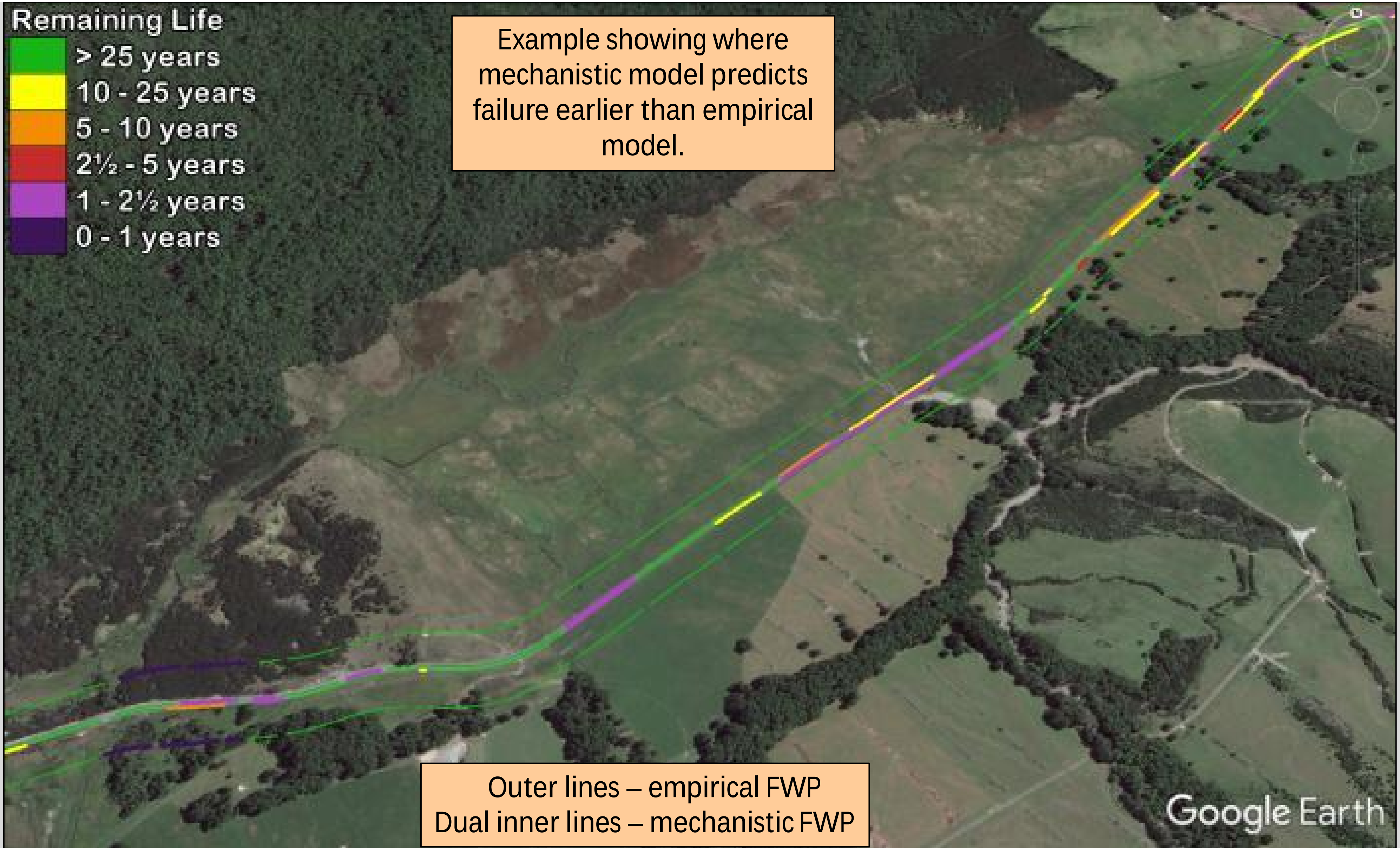
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP

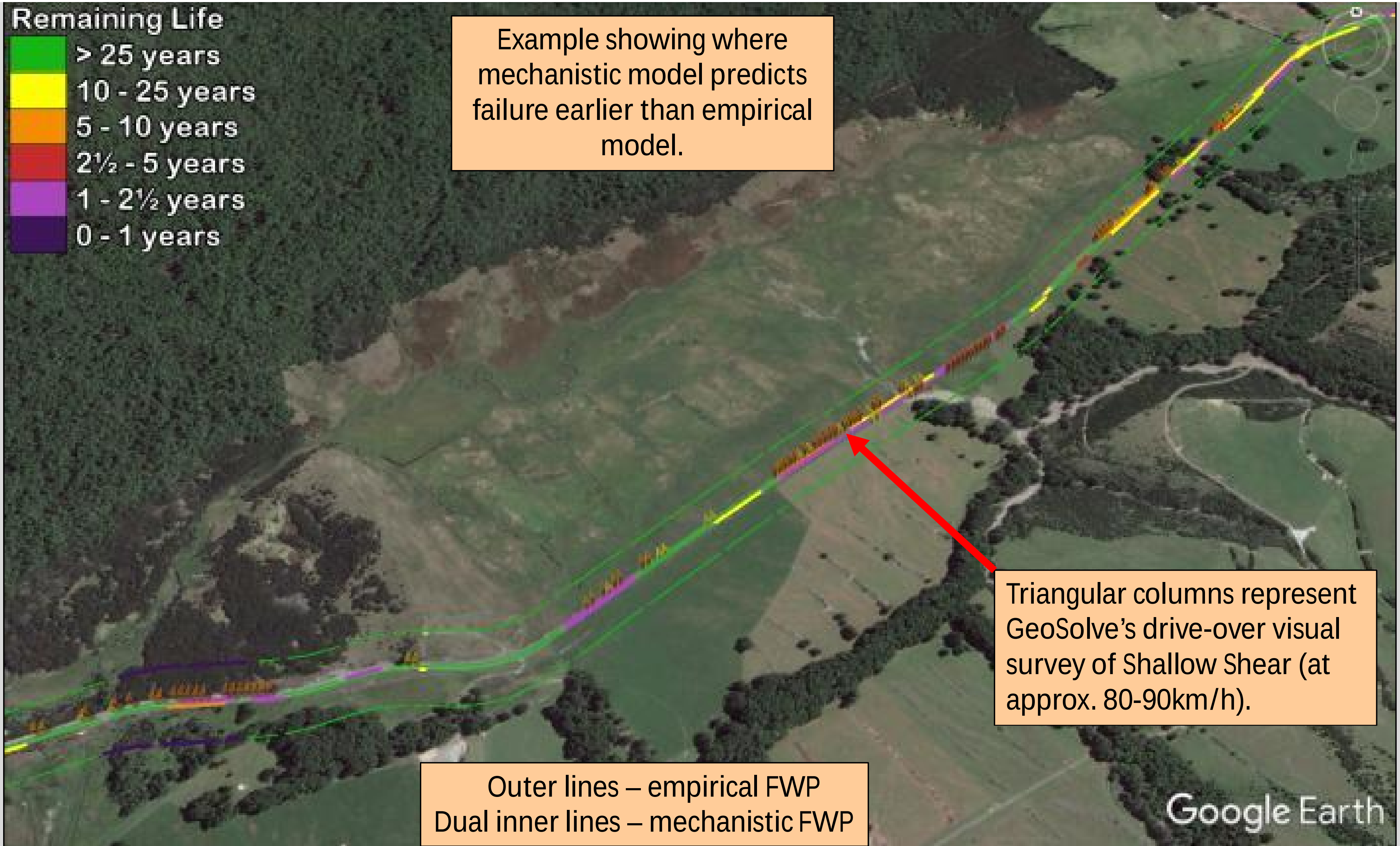

Remaining Life
> 25 years
10 - 25 years
5 - 10 years
2½ - 5 years
1 - 2½ years
0 - 1 years
063-0017 R1 7.620 – 7.850 (503)
Empirical Life (dTIMS)
FWP Remaining Life (years) = 6
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP
Google Earth


Remaining Life
> 25 years
10 - 25 years
5 - 10 years
2½ - 5 years
1 - 2½ years
0 - 1 years
063-0017 R1 7.620 – 7.850 (503)
Mechanistic Life (RPP)
RPP Distress Mode = Shallow Shear - Spreading
STL Remaining Life (years) = 1
Subgrade CBR = 10
Drainage Priority = 6.2
Subgrade LDE = 6.4
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP
Google Earth


Remaining Life
> 25 years
10 - 25 years
5 - 10 years
2½ - 5 years
1 - 2½ years
0 - 1 years
063-0017 R1 7.620 – 7.850 (503)
Mechanistic Life (RPP)
RPP Distress Mode = Shallow Shear - Spreading
STL Remaining Life (years) = 1
Subgrade CBR = 10
Drainage Priority = 6.2
Subgrade LDE = 6.4
500 m
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP
Google Earth


Remaining Life
> 25 years
10 - 25 years
5 - 10 years
2½ - 5 years
1 - 2½ years
0 - 1 years
Example showing where mechanistic model predicts failure earlier than empirical model.
Erina
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP
Google Earth


Remaining Life
> 25 years
10 - 25 years
5 - 10 years
2½ - 5 years
1 - 2½ years
0 - 1 years
Example showing where mechanistic model predicts failure earlier than empirical model.
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP
Google Earth


Remaining Life
> 25 years
10 - 25 years
5 - 10 years
2½ - 5 years
1 - 2½ years
0 - 1 years
Example showing where mechanistic model predicts failure earlier than empirical model.
Triangular columns represent GeoSolve's drive-over visual survey of Shallow Shear (at approx. 80-90km/h).
Outer lines – empirical FWP
Dual inner lines – mechanistic FWP
Google Earth

Mechanistic-Empirical Analysis

Mechanistic	Empirical
• Subsurface moduli, stresses and strains • Based on network precedent performance • Calibrated to region or sub-region evaluating pavements on the same basis throughout the country	• Surface analysis and simplified subsurface parameter • Visual evaluation based on staff familiar with the network

For you to take away

Mechanistic approach now allows us to analyse pavements better than in the past:

- 12+ distress modes
- More meaningful sub-sectioning with lanes differentiated
- Optimised Forward Work Programming

All of this incorporated into the Empirical FWP leads to more informed decision-making.

Update: The team has now acquired TSD data for a sizeable network of thick structural asphaltic pavements In the US and the current reality check is being extended (using the same mechanistic approach to assess remaining life and FWP, then compared with the empirical approach). There are now multiple interested parties involved in the study hence if others would like to follow or partake, please email TSD@pavementanalysis.com

Where to from here?

- 800 lane km test track – the ultimate reality check
- Highest real benefit/cost research ever for NZTA?
- Significant finding after only 3 months
- Ideal database leading to betterment of existing models
- Additional inputs:
  - Accurate dates of each digout or AWT
  - Definitive terminal distress mechanism
- Joint research with University of Queensland & TMR
- Strong commitment within NPTG

Link: Conversion of TSD to equivalent FWD bowl spreadsheet

Link: Report on Conversion of TSD

The Google Earth (kmz) file containing the detailed results of this reality check can be downloaded from here (requires Google Earth): http://www.pavementanalysis.com/KMZ/KaikouraBypass.kmz

GEOSOLVE Pavements Group

The End