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ENHANCING RESILIENCE OF CRITICAL ROAD STRUCTURES UNDER NATURAL HAZARDS

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RESEARCHERS & END USERS

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Geoscience Australia

vicroads

Roads & Maritime

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Enhancing resilience of critical road structures: bridges, culverts and flood ways under natural hazards

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4 strands

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Attorney-General's Department

Structures:

- BRIDGES
- CULVERTS
- FLOOD-WAYS

Hazards:

- EARTHQUAKE
- FLOOD
- BUSHFIRE
- CLIMATE CHANGE

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Queensland Government
Department of Transport and Main Roads

Lockyer Valley REGIONAL COUNCIL

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RESILIENCE OF BRIDGES UNDER FLOOD LOADING

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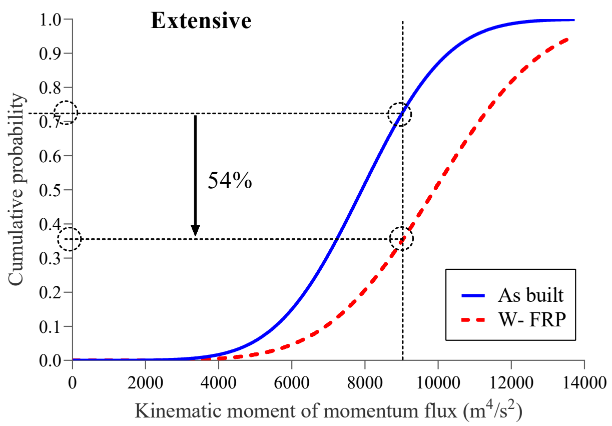
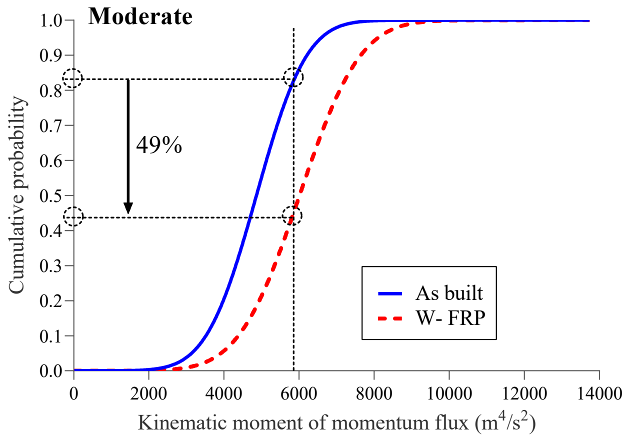
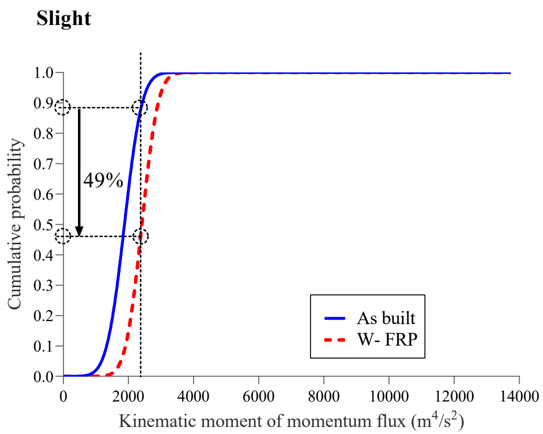
STRENGTHENING OF PIERS USING FRP WRAPS







The reduction in probability of failure using FRP wraps is more pronounced at the extensive damage state (i.e. drifts at peak in capacity curves)

FINDINGS

- **Girder bridge decks can be vulnerable under flood and log impact with high probabilities of failure for Queensland**

- **Bridge piers under flood**
  - Uniformly distributed load describes the flood impact reasonably well
  - Bridge pier cross section shape impacts on the load applied on the piers
  - An energy based damage index is suitable for bridge piers
  - The velocity has to be over 7 m/sec to apply significant damage with just flood loading
  - Log impact can be critical to the piers

- **Bridge superstructure and piers under flood – momentum flux**
  - Momentum flux (rate of change of horizontal momentum) can capture the effect of depth and velocity
  - Strengthening can reduce the failure probability

RESILIENCE OF BRIDGES UNDER FIRE

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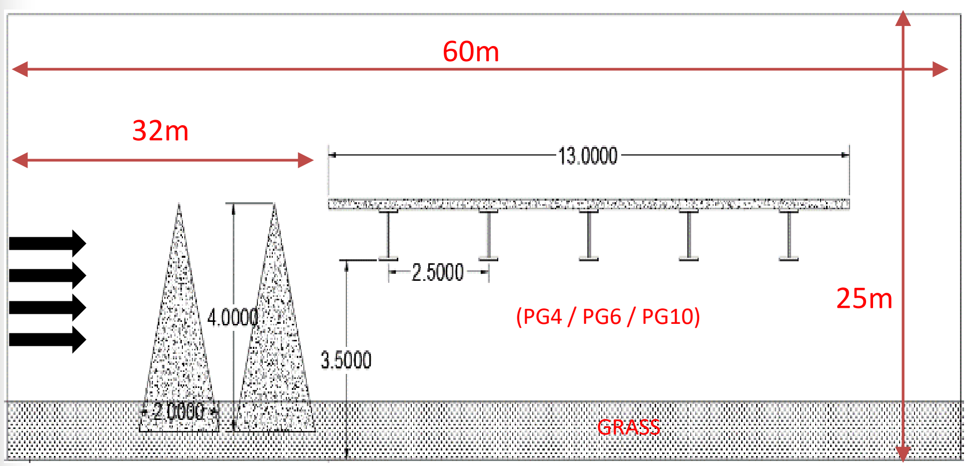
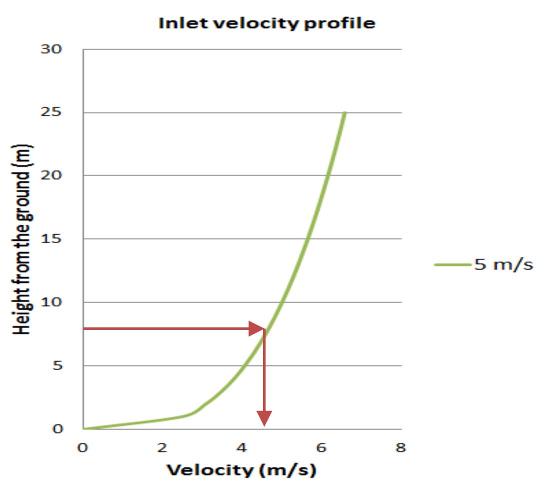
EFFECT OF FINE FUEL BASED WUI ON BRIDGES



10m WIDTH

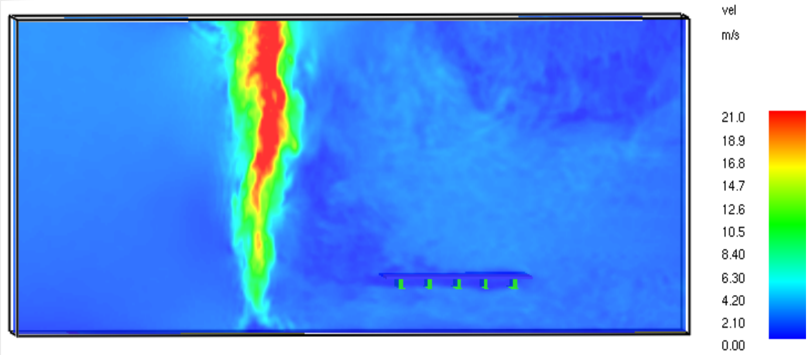


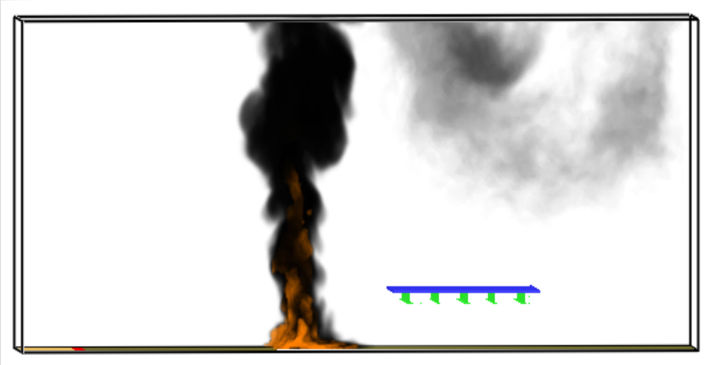
Inlet velocity profile

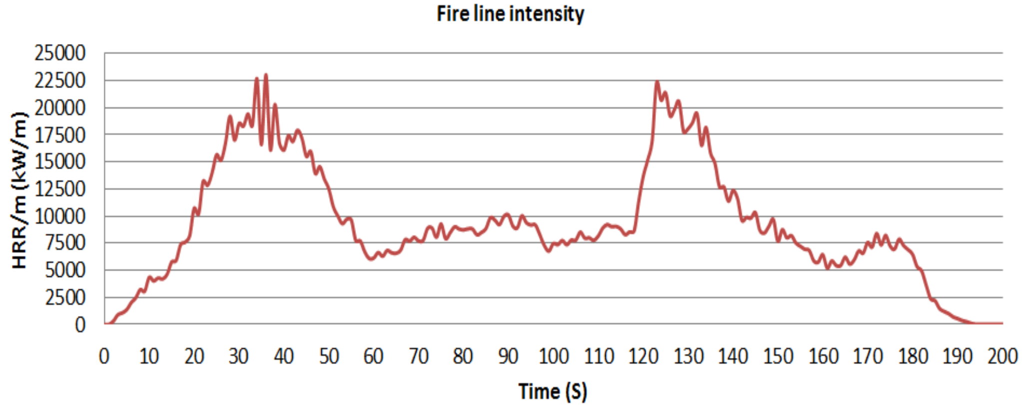
Measured 10 m above the ground

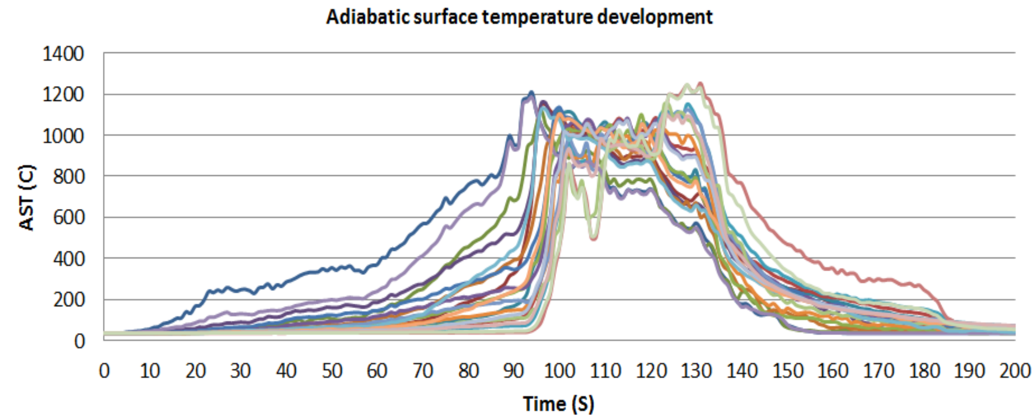
Case name	grass height	Bulk density grass	vegitation moiture	wind velocity
H0.5/B0.5/M0.063/W2	0.5	0.5	0.063	2
H1/B0.5/M0.063/W2	1	0.5	0.063	2
H0.5/B1/M0.063/W2	0.5	1	0.063	2
H1/B1/M0.063/W2	1	1	0.063	2
H0.5/B2.5/M0.063/W2	0.5	2.5	0.063	2
H1/B2.5/M0.063/W2	1	2.5	0.063	2
H0.5/B0.5/M0.1/W2	0.5	0.5	0.1	2
H1/B0.5/M0.1/W2	1	0.5	0.1	2
H0.5/B1/M0.1/W2	0.5	1	0.1	2
H1/B1/M0.1/W2	1	1	0.1	2
H0.5/B2.5/M0.1/W2	0.5	2.5	0.1	2
H1/B2.5/M0.1/W2	1	2.5	0.1	2
H0.5/B0.5/M0.15/W2	0.5	0.5	0.15	2
H1/B0.5/M0.15/W2	1	0.5	0.15	2
H0.5/B1/M0.15/W2	0.5	1	0.15	2
H1/B1/M0.15/W2	1	1	0.15	2
H0.5/B2.5/M0.15/W2	0.5	2.5	0.15	2
H1/B2.5/M0.15/W2	1	2.5	0.15	2
H0.5/B0.5/M0.063/W5	0.5	0.5	0.063	5
H1/B0.5/M0.063/W5	1	0.5	0.063	5
H0.5/B1/M0.063/W5	0.5	1	0.063	5
H1/B1/M0.063/W5	1	1	0.063	5
H0.5/B2.5/M0.063/W5	0.5	2.5	0.063	5
H1/B2.5/M0.063/W5	1	2.5	0.063	5
H0.5/B0.5/M0.1/W5	0.5	0.5	0.1	5
H1/B0.5/M0.1/W5	1	0.5	0.1	5
H0.5/B1/M0.1/W5	0.5	1	0.1	5
H1/B1/M0.1/W5	1	1	0.1	5
H0.5/B2.5/M0.1/W5	0.5	2.5	0.1	5
H1/B2.5/M0.1/W5	1	2.5	0.1	5
H0.5/B0.5/M0.15/W5	0.5	0.5	0.15	5
H1/B0.5/M0.15/W5	1	0.5	0.15	5
H0.5/B1/M0.15/W5	0.5	1	0.15	5
H1/B1/M0.15/W5	1	1	0.15	5
H0.5/B2.5/M0.15/W5	0.5	2.5	0.15	5
H1/B2.5/M0.15/W5	1	2.5	0.15	5
H1/B2.5/M0.063/W2 CANOPY)	1	2.5	0.063	2

RESULTS OF CASE STUDY – H1/B2.5/M0.63/W2

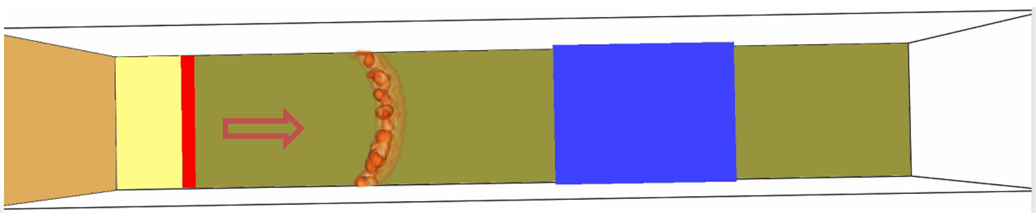








Description	Vaue
Domain size	60x10x25 m3
Mesh size	0.2x0.2x0.2m3
Wind velocity	2m/s
Grass height	1 m
Bulk density	2.5kg/m3
Moisture content	6.3%



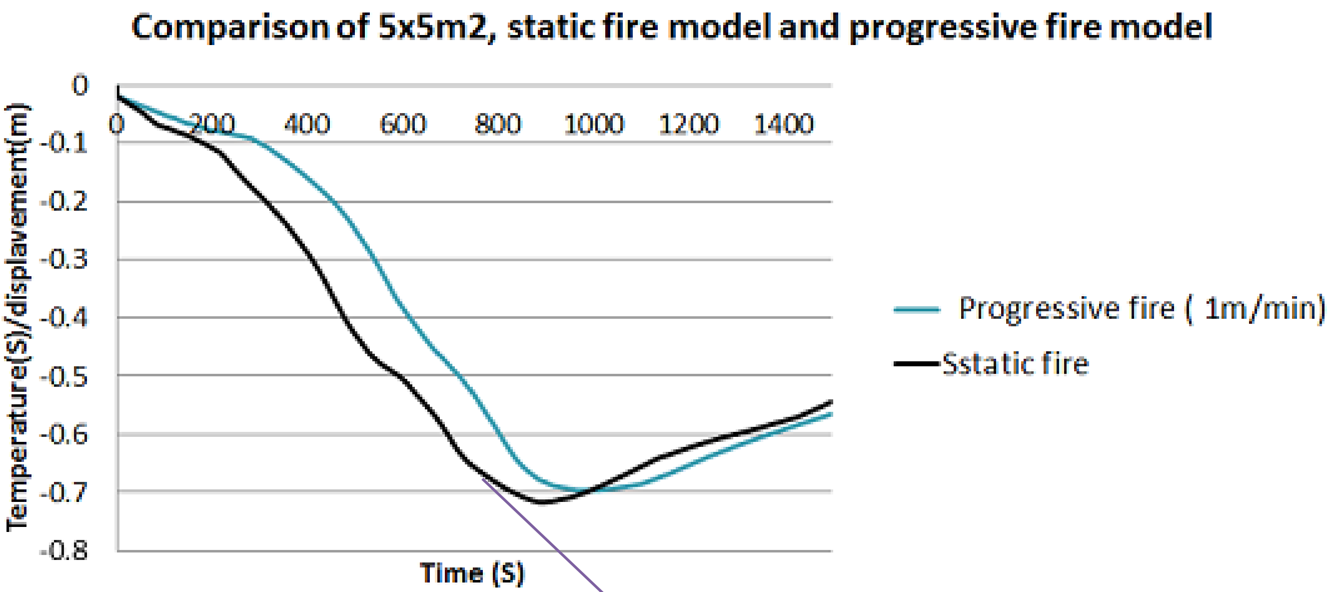
Top view of the domain

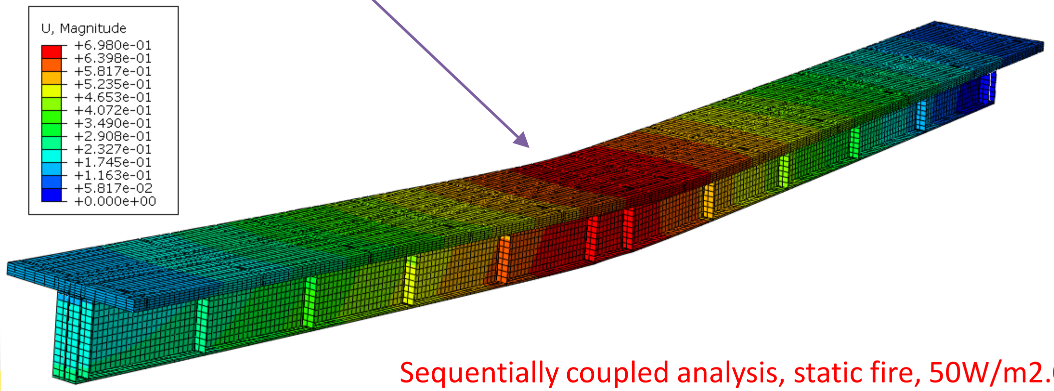
STATIC FIRE VS PROGRESSIVE FIRE (5X5M2 FIRE)

- Sequentially coupled TM analysis

  Convective heat transfer coefficient 50W/m2

- Midspan vertical displacement development





Sequentially coupled analysis, static fire, 50W/m2.C conv.ht.coef.

FINDINGS

- **Debris driven fires can cause a significant flexural response of the structure.**

- **Fine fuel based WUI can also cause a significant temperature development of the structure.**
  - This could effect the shear response of the structure.
  - Could effect on to the bridge retrofitting with CFRP/GFRP materials

- **Fire curve depends on vegetation and the modelling methodology has been developed**

- **Effect of aging can be significant**

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RESILIENCE OF BRIDGES UNDER EARTHQUAKE LOADING

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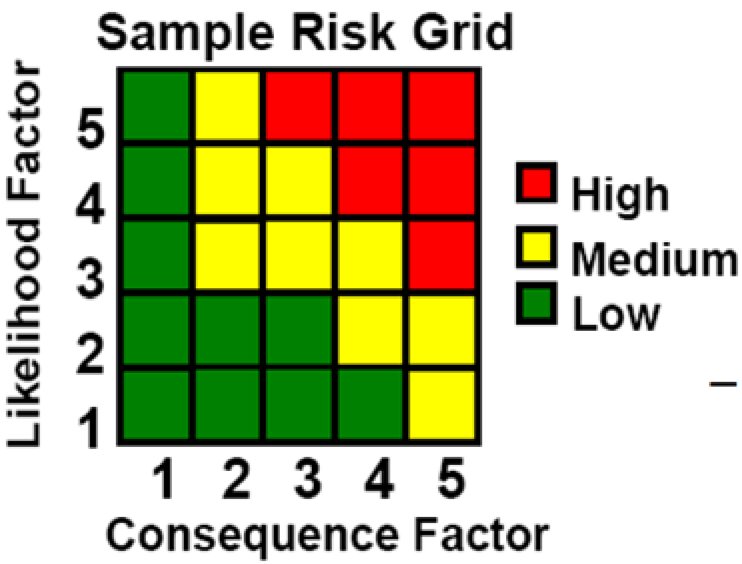
PRIORITISATION OF BRIDGE UNDER EARTHQUAKE LOADS



1 – Low
2 – Minor
3 – Moderate
4 – Significant
5 - High

- **Age of the bridge**
- **Traffic volume**

– Likelihood

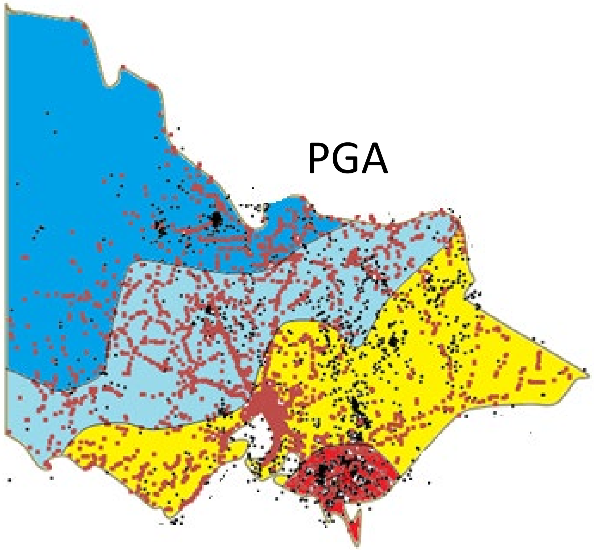
Level	Descriptor	Description
1	Low	The event may occur only in exceptional circumstances
2	Minor	The event could occur at some time
3	Moderate	The event should occur at some time
4	Significant	The event will probably occur in most circumstances
5	High	The event is expected to occur in most circumstances

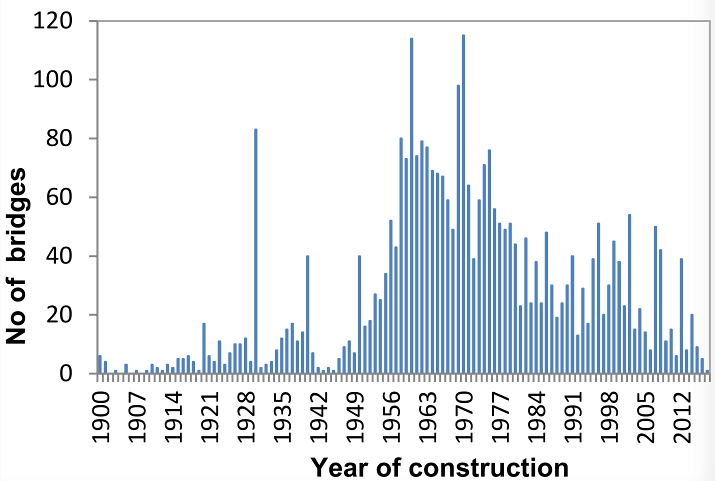
– Consequence

Level	Descriptor	Description
1	Low	No injuries, low financial loss
2	Minor	First aid treatment, medium financial loss
3	Moderate	Medical treatment required, high financial loss
4	Significant	Extensive injuries, loss of production capability, major financial loss
5	High	Death, huge financial loss

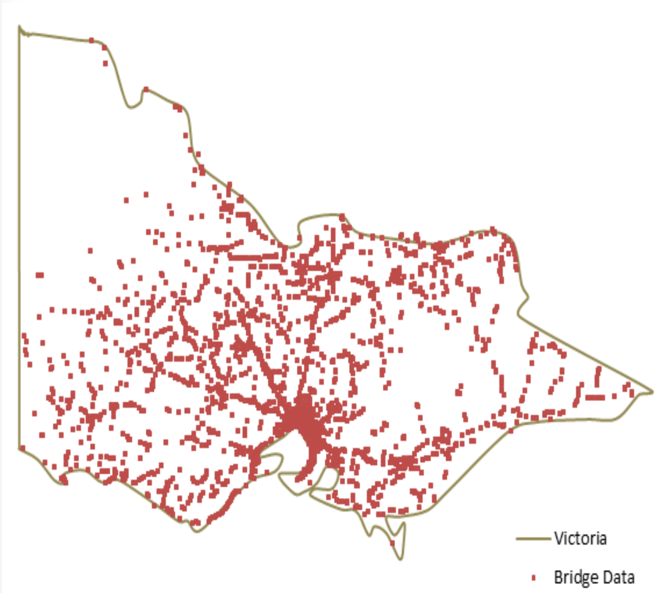
ANALYTICAL HIERARCHY PROCESS

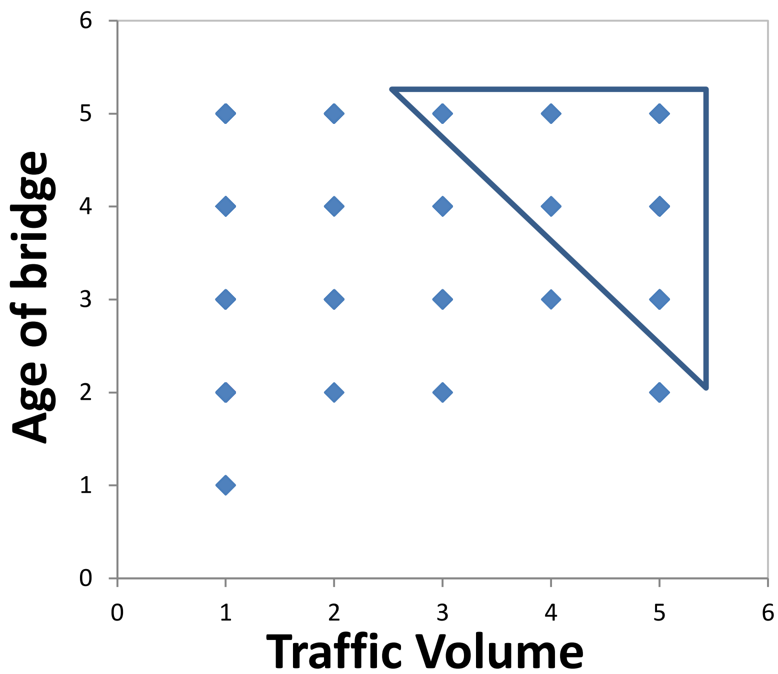
CRITERIA	WEIGHT
Seismic Hazard	0.32
Vulnerability	
Age of bridge	0.22
Total Length	0.05
Total Width	0.05
Impact	
Traffic volume	0.11
Emergency response	0.16
Road type	0.09

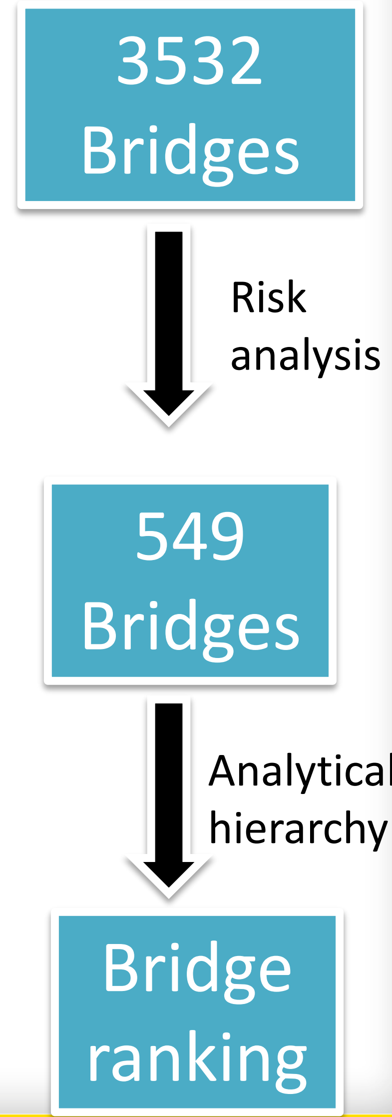




PRIORITISATION OF BRIDGES UNDER EARTHQUAKE LOADS







BRIDGE RANKING

Rank	Bridge
1	RAILWAY LINE OVER BURGUNDY
2	RAILWAY OVER WARRIGAL HWY
3	RAILWAY OVER BURWOOD HWY
4	WEST GATE BRIDGE

RESILIENCE OF FLOODWAYS

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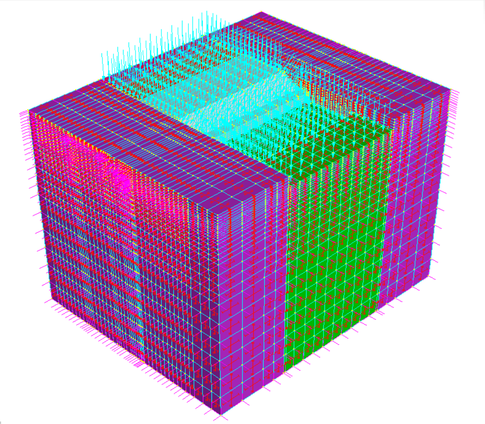
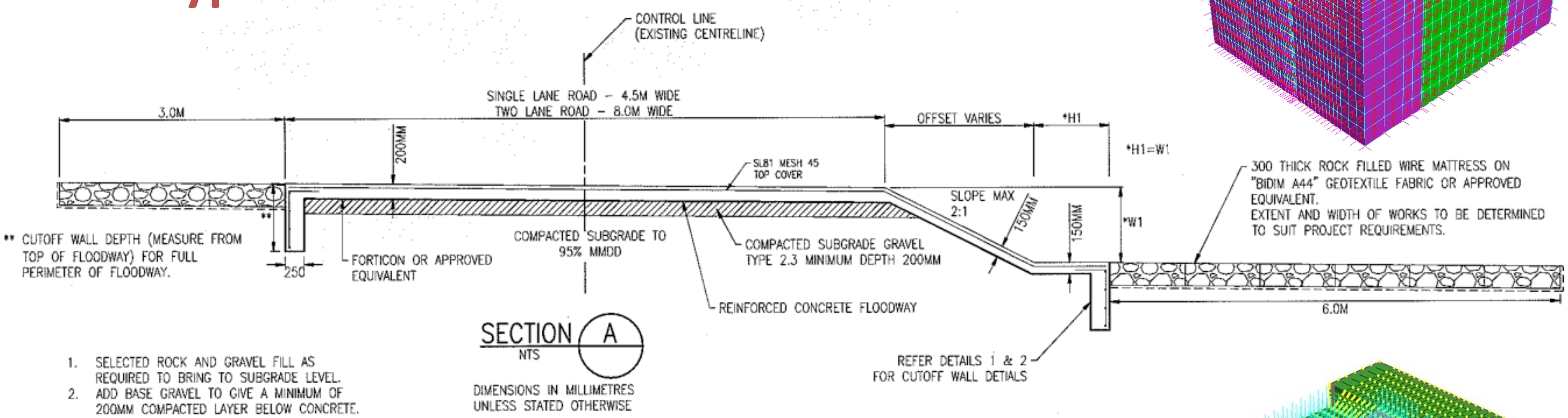
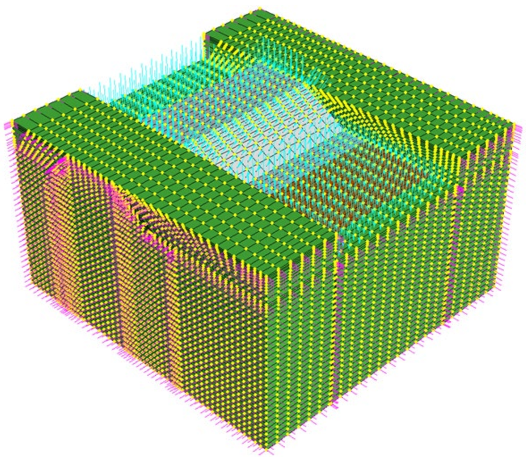
STRUCTURAL ANALYSIS (FEM)

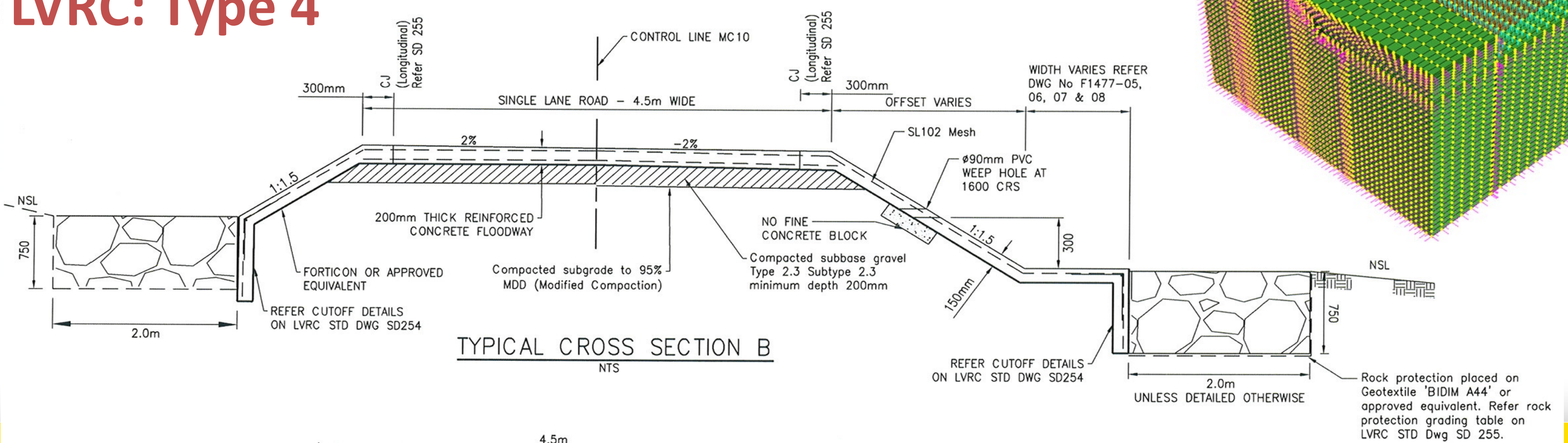


LVRC: Type 2



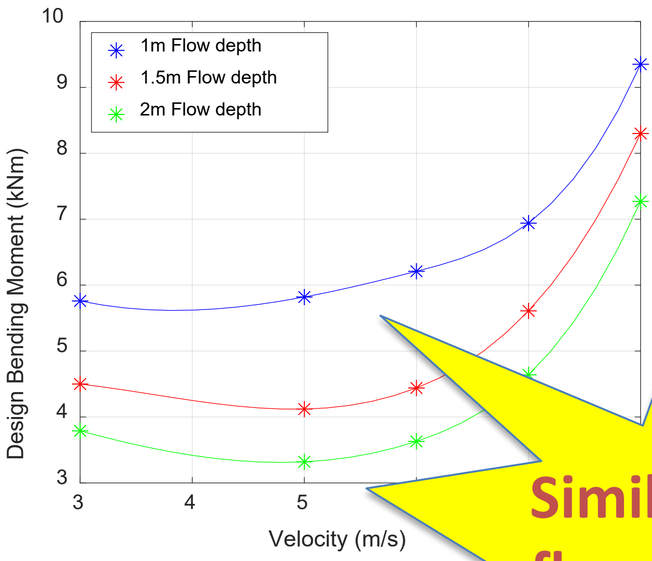


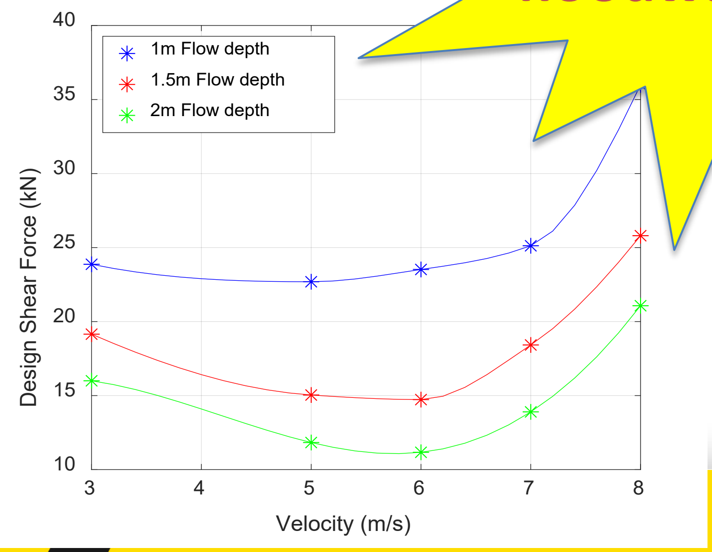
LVRC: Type 4



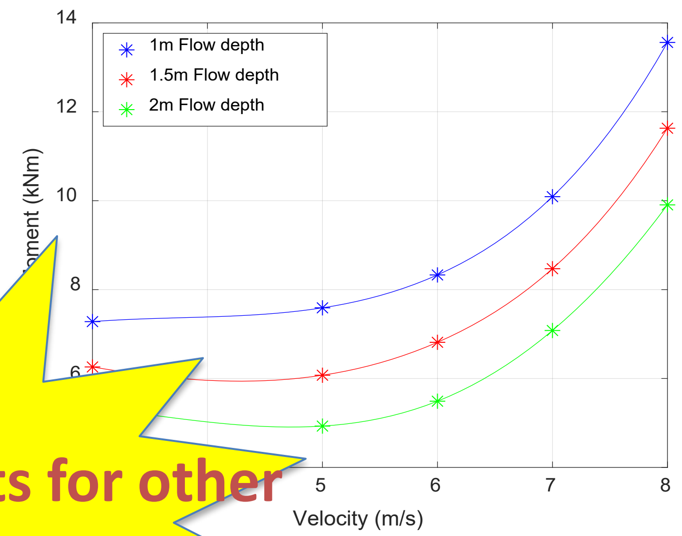
DESIGN CHARTS

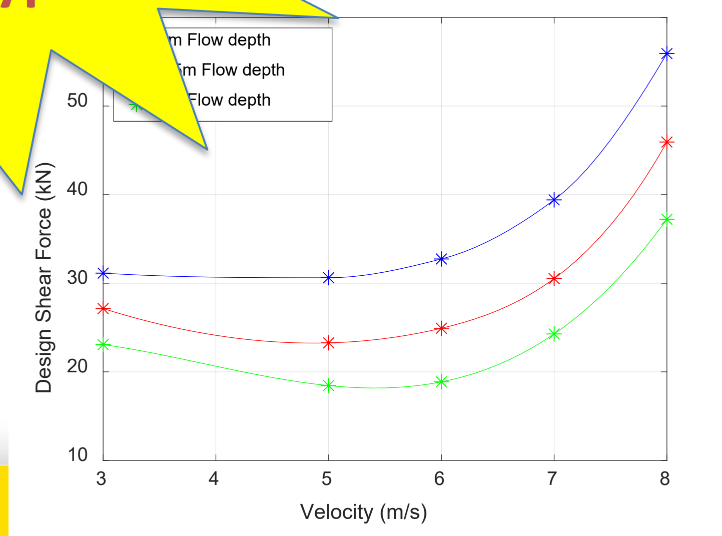
Sandy soil





Clay soil



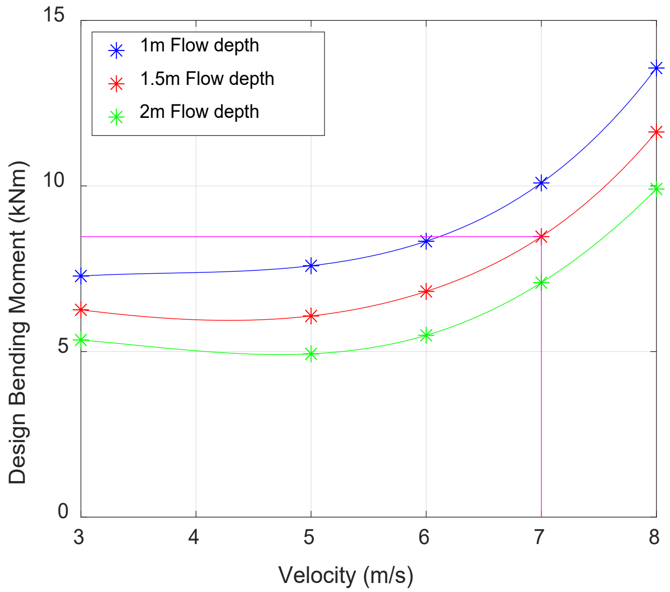


Similar charts for other floodways types

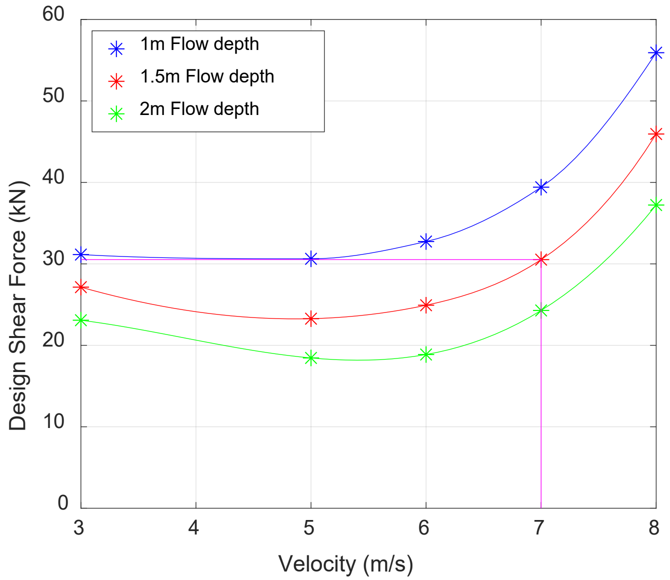
DESIGN EXAMPLE

Step 1 – Determine Design Parameters:

- Location: LVRC LGA (temperate environment);
- Clay soil;
- 7 m/s maximum flow velocity; and 1.5m maximum flow depth;
- Initially assume SL81; and
- Determine design M* and V* as follows:



M* = 8.47 kNm



V* = 30.52 kN

DESIGN OUTCOMES
(TYPE 2 FLOODWAY)

Application of AS5100.2 (Bridge Design) loadings produced results consistent with the failures experienced by Lockyer Valley Council.

Strength in Compression

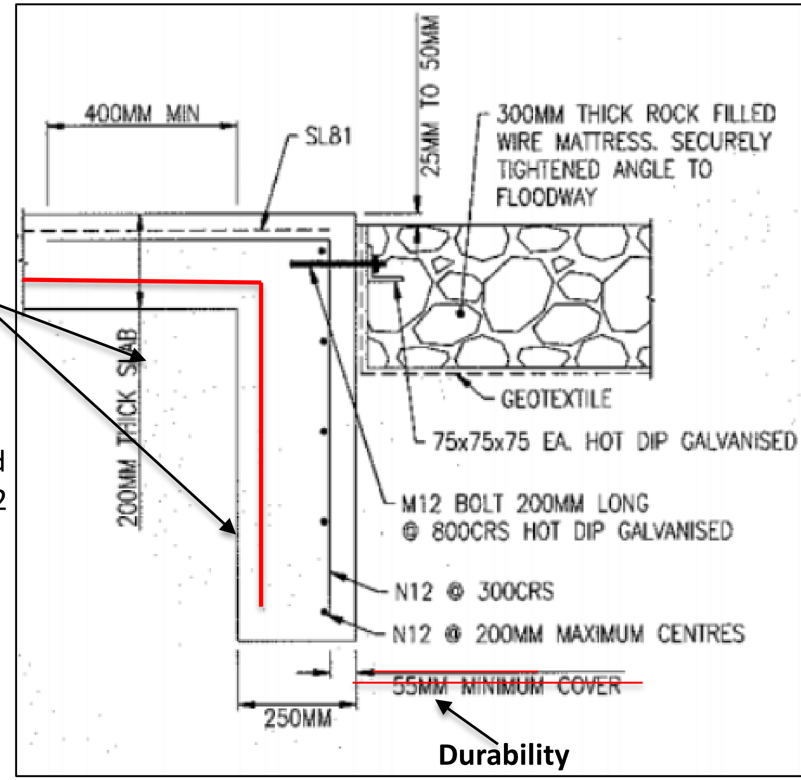
✓ Stress resultant = 4.51 MPa, only 14.1% of f'c = 32 MPa

Strength in Bending

✗ Both positive and negative M* exist, therefore reinforcement is required at both the inner and outer faces.

Strength in Shear

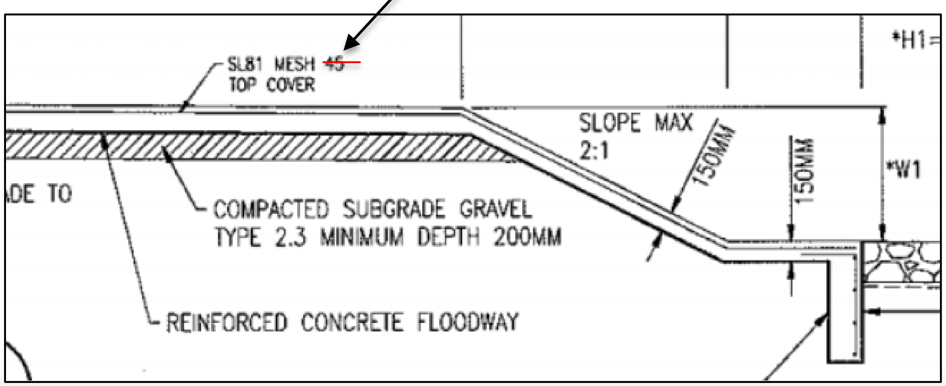
✓ $0.5\phi V_{uc} > V^*$, Shear reinforcement is not required as the shear strength of f'c 32 MPa concrete alone satisfies shear force requirements



Durability

✗ Revise to 40mm cover to increase distance from neutral axis i.e. greater ability to resist tensile stresses.

Revise to 40mm



FLOODWAY INSPECTION AND MAINTENANCE FRAMEWORK

- Defining condition states for each element (eg rock protection-US)

ASSESSMENT OF THE OVERALL CONDITION OF A FLOODWAY- CASE STUDY

- Use the developed framework

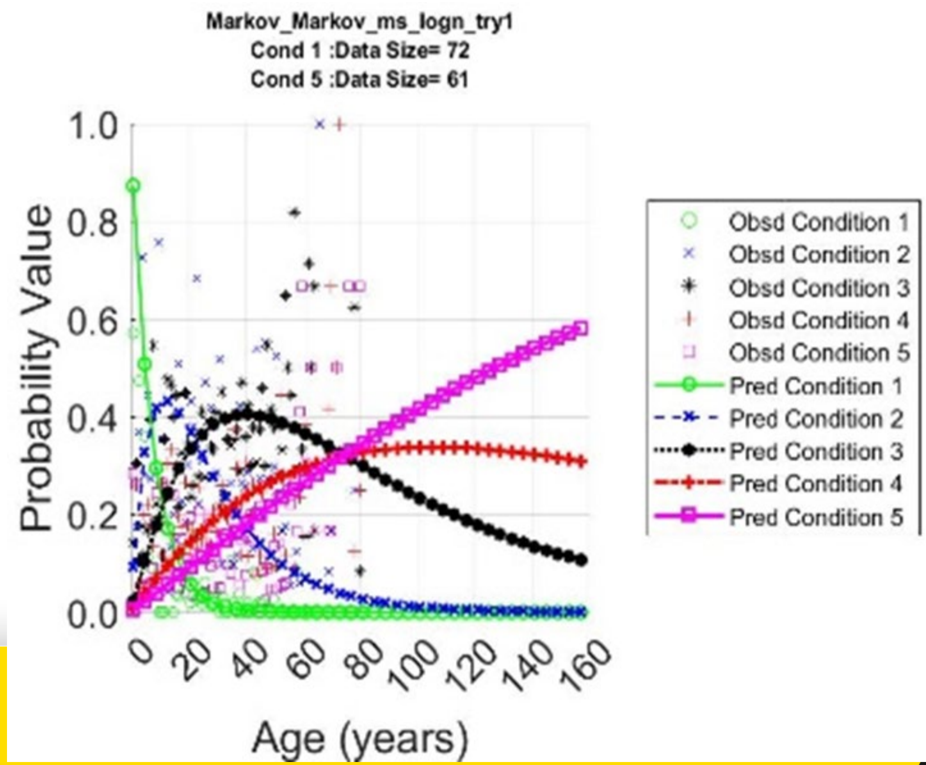
Damage index			
Repair Proceedure	Repair needed as a fraction	Factor	Adjusted Contributi
Temporary Access	0.5	0.05	0.025
Demolishing of existing structure	0	0.1	0
Reconstruction of culvert	29.65	0.5	14.825
Reconstruction of roadway	0	0.25	0
Replacing geo-textile	100	0.01	1
Reconstruction of riprap	100	0.05	5
Replacing sign posts	0	0.02	0
Cleaning and debris removal	20	0.02	0.4
DI = Σ Adjusted Contribution Factors	MUST EQUAL 1	1	21.25

Level of Damage	Complet e	Extreme	Major	Moderate
Damage Index	1	0.8 - 1	0.5 - 0.8	0.1 - 0.5
Recommendations based on the damage index	Replace the structure	Perform a detailed analysis considering the design life	Critically assess compon e nts subject to	Repair activities should perform quickly as possible
Other recommendations	Mowing of downstream not required with geotextile placement			
Asset ID	Withheld			
Date of Inspection	10-Sep-18			
Prepared by				
Name				
Id				
Signature				
Date				

FLOODWAY/CULVERT MAINTENANCE

- Floodways are inspected infrequently or only after a major natural disaster
- Data available from 2005
- Data is sorted based on each structure
- Linking the condition state with available photos
- Deterioration modelling

	A	C	E	F	H	K	L	M	N	T	U	V
1	Asset_ID	RoadName	FloodwayDeckM	PipeMaterial	PipeSize	SlabLength_m	SlabWidth_m	Cells	CellLength_m	Condition	ConditionDate	ConstructionDate
2	FS006970	Heise Road	CONCRETE	RCP	300	0	6.8	1	7.32	2	13/10/15	01/01/70
3	FS007657	Minton Road	CONCRETE	RCBC	450X300	0	4	1	4.88	2	13/10/15	01/01/87
4	FS008790	Woolshed Creel	CONCRETE	NA	NA	0	4.3	0	0	3	13/10/15	01/01/66
5	FS007025	Hill Road	CONCRETE	RCP	375	0	4	4	7.5	3	17/08/16	01/01/87
6	FS006165	Becky Road	CONCRETE	NA	NA	0	3.8	0	0	4	16/08/16	01/01/91
7	FS006579	Douglas McInne	CONCRETE	RCBC	2400X900	0	5.7	6	7.7	2	15/08/16	02/01/00
8	FS006153	Beames Drive	CONCRETE	NA	NA	22.3	4.9	0	0	3	26/08/16	01/01/75
9	FS007677	Moonlight Parad	CONCRETE	RCBC	600X225	0	7.9	1	9.76	2	30/08/16	01/01/87
10	FS006284	Boland Lane	CONCRETE	NA	NA	0	3.6	0	0	3	31/08/16	01/01/87
11	FS007448	Lester Lane We	CONCRETE	RCP	225	0	3.5	1	7.32	3	31/08/16	01/01/87
12	FS000001	Red Gap Road	CONCRETE	NA	NA	0	2.8	0	0	2	31/08/16	02/01/00
13	FS000002	Taylor Road	CONCRETE	NA	NA	0	3.7	0	0	1	28/09/16	28/09/13
14	FS000003	Stoney Creek R	GRAVEL	RCP	300	0	0	1	5	2	11/10/16	02/01/00
15	FS006553	Dippel Road	CONCRETE	RCBC	1200X600	0	3.7	7	9.76	3	07/10/16	01/01/83
16	FS006561	Watkins drive	CONCRETE	TBD	1200X450	0	5	6	4.88	2	07/10/16	01/01/83
17	FS000004	Main Camp Cre	CONCRETE	RCBC	1200X600	0	4.8	8	5.3	2	07/10/16	02/01/00
18	FS008906	Main Camp Cre	CONCRETE	NA	NA	0	4.6	0	0	1	07/10/16	02/01/00
19	FS008538	Thornton Schoo	CONCRETE	NA	NA	0	4	0	0	3	05/10/16	01/01/73
20	FS008537	Thornton Schoo	CONCRETE	NA	NA	0	3.9	0	0	3	05/10/16	01/01/73
21	FS007280	Kowaltzke Road	SEAL	NA	NA	0	3.7	0	0	TBD	30/06/14	01/01/83
22	FS007945	Peters Road	CONCRETE	NA	NA	0	3.9	0	0	2	29/09/16	01/01/87
23	FS000005	Peters Road	CONCRETE	NA	NA	0	3.3	0	0	2	29/09/16	02/01/00
24	FS007723	Mount Berryman	CONCRETE	RCBC	1200X600	50	5	1	7.32	4	06/12/17	01/01/89
25	FS006525	Dalton Road	CONCRETE	RCP	375	14	3.5	2	4.5	1	06/12/17	01/01/65
26	FS007710	Mount Berryman	CONCRETE	RCP	450	30	3	1	4	4	06/12/17	01/01/89
27	FS007709	Mount Berryman	CONCRETE	RCBC	375X225	17	3.5	2	7.4	4	30/06/14	01/01/89
28	FS007705	Mount Berryman	CONCRETE	RCP	450	24.5	3	1	10	4	07/12/17	01/01/89
29	FS007704	Mount Berryman	CONCRETE	RCBC	1200X450	15.9	4.6	1	7.2	1	07/12/17	01/01/89
30	FS007703	Mount Berryman	CONCRETE	RCP	600	42.3	3.6	3	6	3	07/12/17	01/01/89
31	FS007701	Mount Berryman	CONCRETE	RCBC	1200X450	18	4.6	1	7.3	1	07/12/17	07/12/12
32	FS007744	Mount Berryman	CONCRETE	RCBC	1200X600	36.5	4.4	3	8.8	3	07/12/17	01/01/89
33	FS007743	Mount Berryman	CONCRETE	RCBC	1200X450	15	4.6	1	6.2	1	07/12/17	07/12/12
34	FS000006	Ropeley Rocksi	CONCRETE	RCP	375	6	4	1	4	4	11/12/17	02/01/00
35	FS008147	Ropeley Rocksi	CONCRETE	RCP	375	15.4	4	1	4.88	3	11/12/17	06/06/86
36	FS008145	Ropeley Rocksi	CONCRETE	TBD	375	9	4	1	4.88	2	11/12/17	01/01/58



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UTILISATION OF FLOODWAY ANALYSIS

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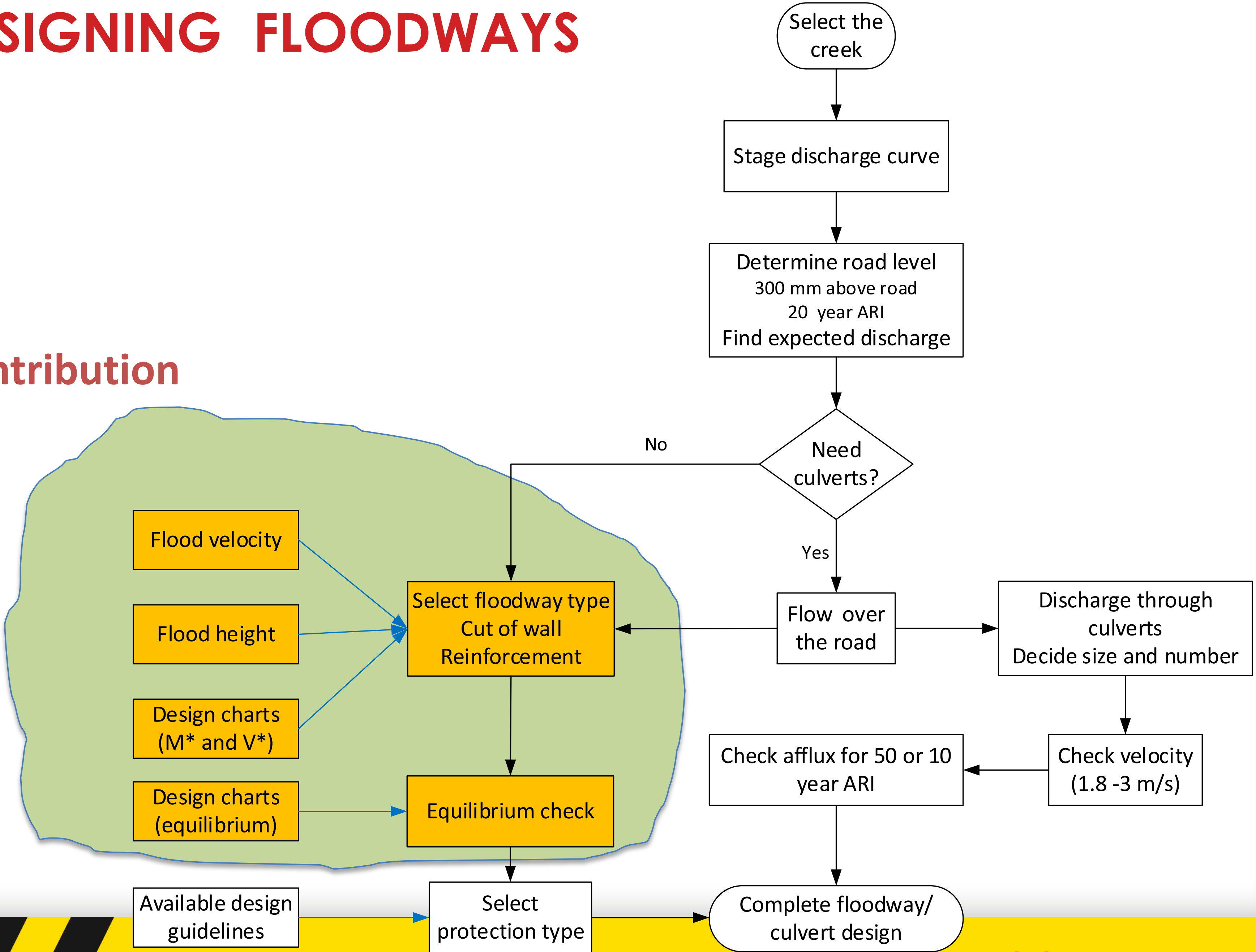
DESIGNING FLOODWAYS

Contribution



MAINTAINING FLOODWAYS

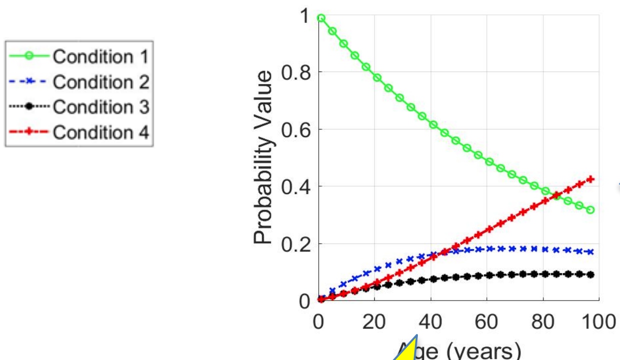
Consists of four main components:

A. Basic information

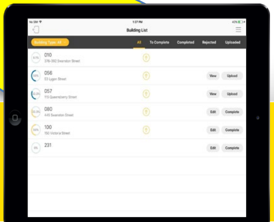
B. Notes from previous inspection, repair or maintenance work

C. Basic details of current inspection

D. Inspection records



Integrate with Central Asset Management System - CAMS



Inspection framework

Condition assessment

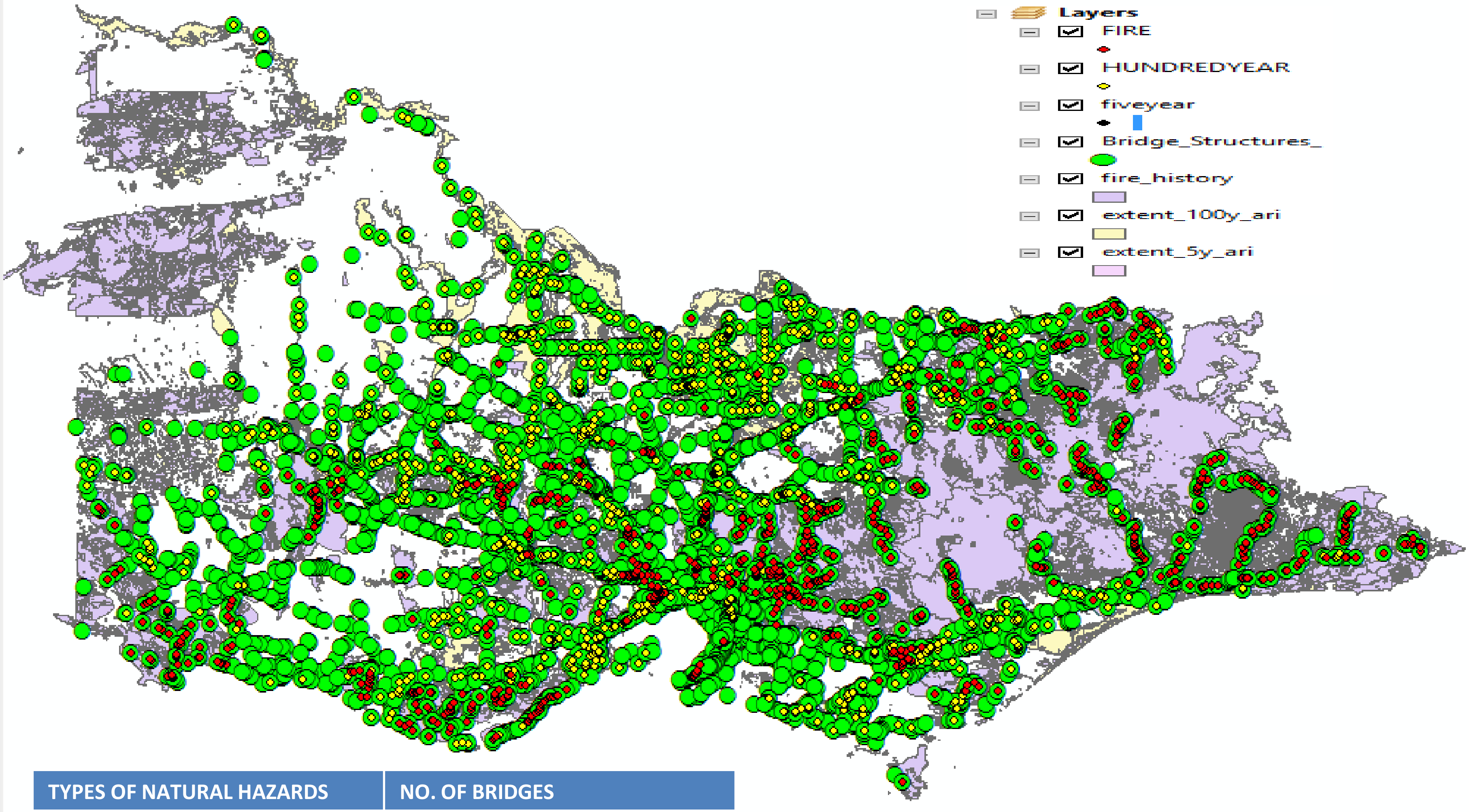
Deterioration modelling

Structure prioritisation

Link with photos

UTILISATION OF BRIDGE VULNERABILITY MODELLING

COMBINED GIS LAYER FOR FLOOD AND BUSHFIRE HAZARDS



TYPES OF NATURAL HAZARDS	NO. OF BRIDGES
FIRE HAZARD	1019
5 YEAR FLOOD HAZARD	58
100 YEAR FLOOD HAZARD	1460

BRIDGES VULNERABLE FOR FIRE HAZARD IN VICTORIA

ID_STRUCTU	ROAD NAME	FEATURES CROSSED	YEAR_CONST	LAT	LONGIT
SN6889	UN-NAMED WATERCOURSE	UN-NAMED WATERCOURSE	19400630	-39.02592	146.3324
SN7127	GREAT OCEAN RD	MILFORD CREEK	19600630	-3	
SN3901	GREAT OCEAN RD	WILD DOG CREEK	19530630	-3	
SN3900	GREAT OCEAN RD	STONY CREEK	19600630	-3	
SN7133	GELLIBRAND RIVER FLO	GELLIBRAND RIVER FLOODPLAI	19570630	-3	
SN7134	GELLIBRAND RIVER	GELLIBRAND RIVER	19580630	-3	
SN7120		STOCK UNDERPASS (WEST GELLIBRAND RIVER)	19570630	-3	
SN9692		STOCK UNDERPASS	19980101	-3	
SN3909	GREAT OCEAN RD	LATROBE CREEK	19920101	-3	
SN9110		STOCK UNDERPASS	19860101	-3	
SN9596		PED UNDERPASS APOSTLES CENTRE	20010101	-38	
SN9498		LATROBE CREEK	19700101	-3	
SN9004		SKINNER CREEK	19980422	-3	
SN7135	GREAT OCEAN RD	SHERBROOKE RIVER	19750630	-3	
SN0348		UN-NAMED WATERCOURSE	19700101	-3	
SN8097	COLAC-BEECH FOREST R	UN-NAMED STOCK CROSSING	19850630	-3	
SN3888	GREAT OCEAN RD	WYE RIVER	19540630	-3	
SN9001	SHIRELY JACKSON	WYE RIVER	19980501	-3	
SN3887	GREAT OCEAN RD	SEPARATION CREEK	20161026	-3	
SN1879		Seperation Creek		-3	
SN9365		GELLIBRAND RIVER	19991223	-3	
SN4004	CHAPPLE CREEK	CHAPPLE CREEK	19350601	-3	
SN3886	BOGGALEY CREEK	BOGGALEY CREEK	19710630	-3	
SN3885	GODFREY CREEK	GODFREY CREEK	19650630	-3	
SN3884	GREAT OCEAN RD	JAMIESON CREEK	19620630	-3	
SN9570		STOCK UNDERPASS	20010101	-3	

BRIDGES VULNERABLE FOR 5 YEAR ARI FLOOD HAZARD IN VICTORIA

ID_STRUCTURE	ROAD NAME	FEATURES CROSSED	YEAR_CONST	LAT	LONGIT
SN7889	WERRIBEE MAIN RD	WERRIBEE RIVER	19920630	-37.9039	144.65457
SN0869		UN-NAMED WATERCOURSE	19700101	-37.0662	143.09615
SN0872		UN-NAMED WATERCOURSE	19651201	-36.9568	143.0966
SN0437		BANDIANA LINK ENTRY RAMP OVER WODONGA CK	20070304	-36.1092	146.89962
SN0438		FLANAGANS CREEK	20070304	-36.1068	146.90362
SN7543	DING DONG CREEK	DING DONG CREEK	19280630	-37.4437	143.37932
SN0448	SPIRIT OF PROGRESS	MURRAY RIVER	20070304	-36.0999	146.910261
SN0453		DISUSED RAILWAY/BANDIANA LINK RD/WODONGA CK	20070304	-36.1087	146.90186
SN0466	SPIRIT OF PROGRESS	MURRAY RIVER REV	20070304	-36.1	146.910402
SN7166	ARARAT-ST ARNAUD RD	UN-NAMED WATERCOURSE	19340101	-37.0567	143.09821
SN7168	ARARAT-ST ARNAUD RD	UN-NAMED WATERCOURSE	19400630	-36.898	143.11343
SN8141	BACCHUS MARSH-WERRIB	UN-NAMED WATERCOURSE	19750630	-37.8935	144.63188
SN0579		JACK IN THE BOX CREEK	20061002	-36.1096	146.89651
SN0581		JACK IN THE BOX CREEK FLOODWAY	20061002	-36.1104	146.89902
SN8779	LOCAL SIGNIFICANCE	MURRAY RIVER AT HEYWOODS	19870101	-36.0996	147.022365
SN8780	ISLAND BRIDGE	MURRAY RIVER AT TRABANTS -ISLAND BRIDGE	19410101	-36.0785	146.956255
SN9212		PINKERTONS CREEK	19520101	-37.1955	143.05696
SN9540		IRRIGATION CHANNEL	19700101	-37.9671	146.890984
SN3660	HAMILTON HWY	UN-NAMED WATERCOURSE	19750630	-37.751	142.05015
SN4586	SEVEN MILE CREEK	SEVEN MILE CREEK	19580630	-36.9641	142.89311
SN4587	STAWELL-AVOCA RD	WIMMERA RIVER	19780630	-36.9536	142.92125
	STAWELL-AVOCA RD	UN-NAMED WATERCOURSE	19580630	-36.922	142.98961
	DOOLEYS BRIDGE	HEIFER STATION CREEK	19590630	-36.9214	142.99124
	BATCOCKS SCOUR	BATCOCKS SCOUR	19300601	-36.9064	143.03177
	STAWELL-AVOCA RD	UN-NAMED WATERCOURSE	19670630	-36.9003	143.103
	STAWELL-AVOCA RD	WATTLE CREEK	19610630	-36.9749	143.19243
	STAWELL-AVOCA RD	UN-NAMED WATERCOURSE	19570630	-36.9587	143.17293
	ARARAT-ST ARNAUD RD	DOG ROCK CREEK	19230630	-37.1895	143.08199
	BENALLA-TATONG RD	HOLLANDS BRANCH	19340701	-36.5642	145.99393
	ARARAT-ST ARNAUD RD	MT COLE CREEK	19690630	-37.1654	143.09447
	ARARAT-ST ARNAUD RD	GRENDHU CREEK	19390101	-37.0981	143.1008
	ARARAT-ST ARNAUD RD	UN-NAMED WATERCOURSE	19380101	-37.0554	143.09925

BRIDGES VULNERABLE FOR 100 YEAR ARI FLOOD HAZARD IN VICTORIA

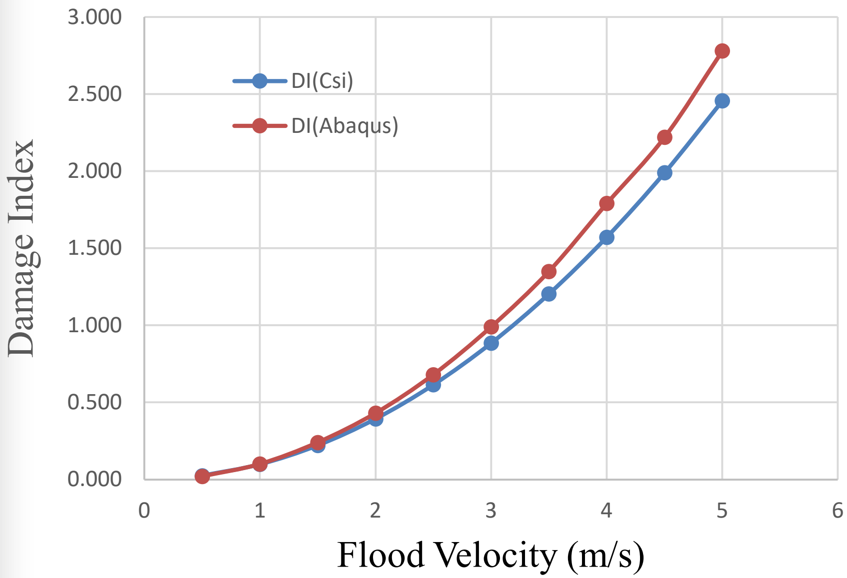
ID_STRUCTURE	ROAD NAME	FEATURES CROSSED	YEAR_CONST	LAT	LONGIT
SN3908	FORD RIVER	FORD RIVER	19560630	-38.77688	143.43258
SN3905	CALDER RIVER	CALDER RIVER	19560630	-38.77307	143.50905
SN7132	GREAT OCEAN RD	UN-NAMED WATERCOURSE	19800630	-38.76396	143.47314
SN3907	AIRE RIVER	AIRE RIVER	19650630	-38.76385	143.47453
SN7127	GREAT OCEAN RD	MILFORD CREEK	19600630	-38.74858	143.67057
SN7120		STOCK UNDERPASS (WEST GELLIBRAND RIVER)	19570630	-38.72724	143.25051
SN3899	GREAT OCEAN RD	SKENES CREEK	19790815	-38.72434	143.71118
SN5884	INVERLOCH-VENUS BAY	TARWIN RIVER	19620101	-38.69443	145.87759
SN5697	FISH CREEK	FISH CREEK	19870630	-38.69435	146.07729
SN3909	GREAT OCEAN RD	LATROBE CREEK	19920101	-38.69332	143.15273
SN3159	AGNES RIVER	AGNES RIVER	19470601	-38.6709	146.38812
SN3889	GREAT OCEAN RD	KENNETT RIVER	19640630	-38.66647	143.86245
SN3157	FRANKLIN RIVER	FRANKLIN RIVER	19630630	-38.65226	146.29722
SN9004		SKINNER CREEK	19980422	-38.64046	143.30774
SN0348		UN-NAMED WATERCOURSE	19700101	-38.64011	143.30938
SN5869	CASHINS SWAMP	CASHINS SWAMP	19640630	-38.63252	145.77959
SN9365		GELLIBRAND RIVER	19991223	-38.62603	143.2722
SN4004	CHAPPLE CREEK	CHAPPLE CREEK	19350601	-38.62506	143.27844
SN3169	ALBERT RIVER	ALBERT RIVER	19540630	-38.62226	146.66435
SN3910	CAMPBELLS CREEK	CAMPBELLS CREEK	19720630	-38.61212	142.99962
SN3911	CURDIES RIVER	CURDIES RIVER	19860630	-38.60615	142.88298
SN7436	MEENIYAN-PROMONTORY	STONY CREEK FLOODPLAIN	19660630	-38.60245	146.01889
SN3152	SOUTH GIPPSLAND HWY/	STONY CREEK	19610630	-38.59034	146.06915
SN4025	COBDEN-PORT CAMPBELL	EASTERN CREEK	19580630	-38.58135	143.01306
SN3883	CUMBERLAND RIVER	CUMBERLAND RIVER	19580630	-38.57523	143.94948
SN7576	KORUMBURRA-WONTHAGGI	POWLETT RIVER FLOODPLAIN	19770630	-38.57484	145.631
SN7575	KORUMBURRA-WONTHAGGI	POWLETT RIVER FLOODPLAIN	19610630	-38.57453	145.63078
SN7573	KORUMBURRA-WONTHAGGI	POWLETT RIVER	19850630	-38.57265	145.63075
SN7574	KORUMBURRA-WONTHAGGI	POWLETT RIVER FLOODPLAIN	19770630	-38.57163	145.63115
SN7572	KORUMBURRA-WONTHAGGI	UN-NAMED WATERCOURSE	19770630	-38.5697	145.63215
SN3460	BASS HWY	UN-NAMED WATERCOURSE	19830630	-38.56754	145.56262
SN3459	BASS HWY	POWLETT RIVER	19590630	-38.56649	145.56097

COMPARISON OF VULNERABILITY CURVES

ABAQUS VS CSI BRIDGE

$$DI = \frac{M^*}{\phi M_u}$$

Vulnerbaility curves for Tenthill Creek Bridge



Flood velocity(m/s)	Flood load(kN/m)	M*(kNm)	DI(Csi)	DI(Abaqus)	%Error
0.5	0.38	11.78	0.025	0.020	19%
1	1.51	47.15	0.098	0.100	-2%
1.5	3.40	106.09	0.221	0.240	-9%
2	6.04	188.61	0.393	0.430	-9%
2.5	9.43	294.70	0.614	0.680	-11%
3	13.58	424.36	0.884	0.990	-12%
3.5	18.49	577.61	1.203	1.350	-12%
4	24.15	754.43	1.572	1.790	-14%
4.5	30.56	954.83	1.989	2.220	-12%
5	37.73	1178.79	2.456	2.780	-13%

- Running time for ABAQUS is 45-50min. whereas CSiBridge takes about 1-2 min.
- Results vary between 1-15% most of the time and give reasonably accurate result as shown in the above graph.
- Flood prone bridges have been short listed and CSiBridge software could be easily deployed to analyse these bridge stocks to generate necessary vulnerability and fragility curves.

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SOCIAL ENVIRONMENTAL AND ECONOMIC IMPACTS OF ROAD STRUCTURE FAILURE

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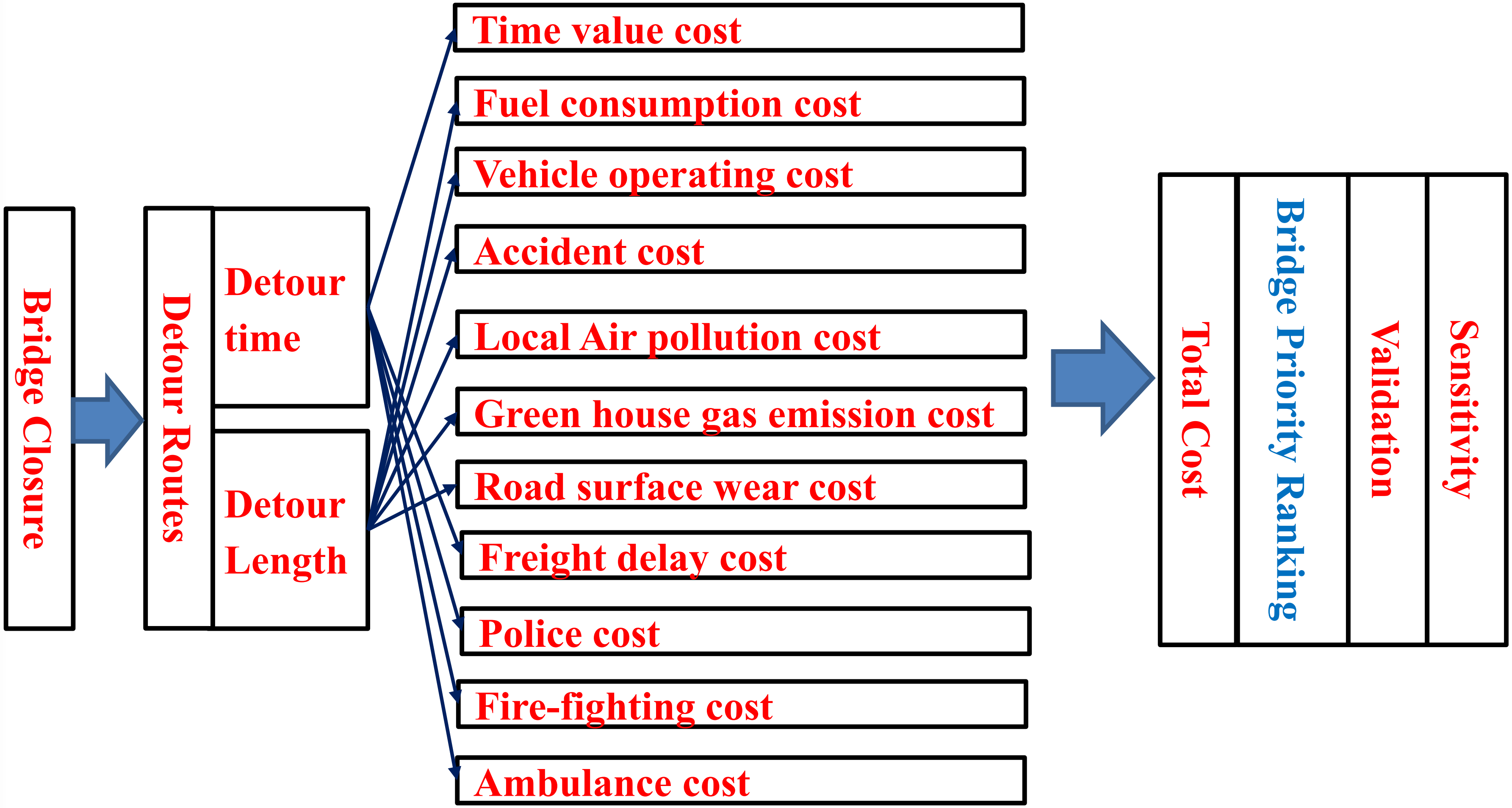
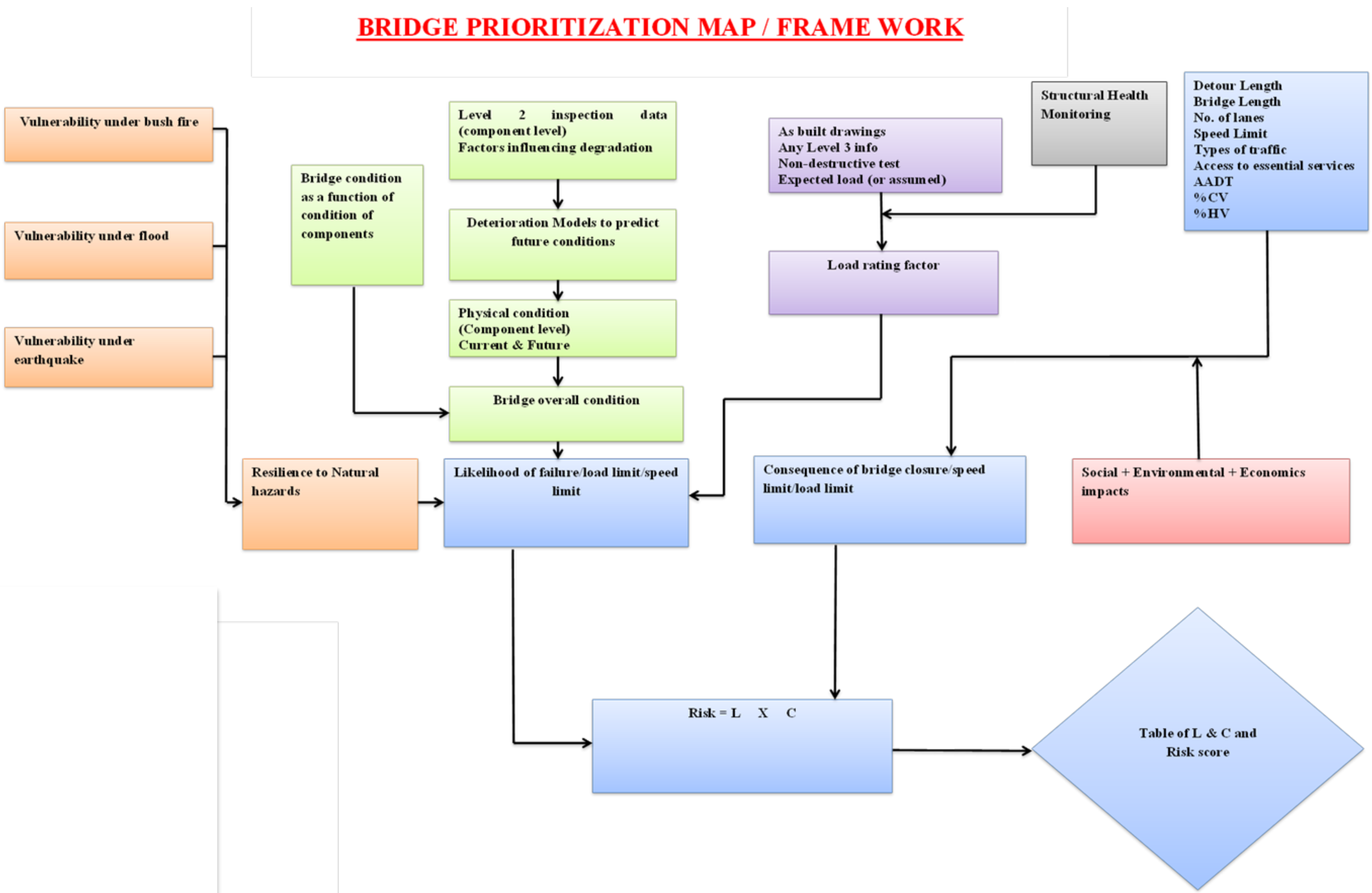
METHODOLOGY FLOWCHART



Noise, soil pollution, water pollution, vibration are ignored due to difficulty to measure in short term impact.

TYPICAL BRIDGE PRIORITY RANKING FOR 20 BRIDGES

ID_STRUCTURE	ROAD NAME	AADT	Length (m)	Time(min)	Det.Length (m)	Det.Time (min)	Time value cost	vehicle operatinmg cost	Freight Delay cost($)	Environmental cost	Total Cost($)	Rank
SN6520	WEST GATE FWY	92576	7130	6	15000	25	676786	130235	49954	42074	1706069	1
SN6225	WEST GATE FWY	90385	7900	10	11730	25	535439	62586	44921	45651	1286622	2
SN8846	METROPOLITAN RING RD	38025	5760	5	16600	26	277916	72125	17009	25986	743076	3
SN2583	WEST GATE FWY	77419	3750	4	5880	12	247750	29981	21987	21106	598555	4
SN2586	WEST GATE FWY	69685	3730	3	6010	11	223000	28887	19791	19616	543180	7
SN8845	METROPOLITAN RING RD	38201	2900	5	14500	16	148384	77991	9945	26416	489112	8
SN9633	5901 DONCASTER-ELTHAM RD	27431	3160	5	14680	28	220311	54231	7466	14663	571212	6
SN7961	5826 SUNBURY RD	16061	3580	5	43800	34	162644	110857	5512	28524	581038	5
SN6199	5901 DONCASTER-ELTHAM RD	27431	3310	6	14650	23	162839	53383	5518	14500	452462	9
SN1051	2550 HUME HWY	16489	11230	8	22000	19	83615	34461	11590	27945	275689	12
SN7937	5606 COOPER ST	19178	3500	5	13160	22	133729	34061	13117	15403	364099	10
SN0599	2510 PRINCES HWY EAST	30108	7360	5	10705	12	78706	18136	6983	13751	214418	13
SN0600	2510 PRINCES HWY EAST	30108	7360	5	10705	12	78706	18136	6983	13751	214418	13
SN2544	2600 MORNINGTON PENINSULA FWY	25244	5160	7	12090	14	58807	30076	2509	9796	190070	18
SN1081	2996 EASTLINK TOLLWAY FWY	38849	1180	1	3200	10	127018	13972	9930	5864	297774	11
SN2809	PRINCES HWY EAST	36538	800	2	2090	10	94305	8007	2767	2215	209606	16
SN1147	5164 THOMPSON RD	10478	3940	3	19800	20	65822	29197	3794	9452	203282	17
SN2672	PRINCES HWY WEST	17970	2010	2	4610	17	94125	8018	3190	2450	209926	15
SN1501	2570 MURRAY VALLEY HWY	1798	56320	41	100550	72	22231	14727	2506	10418	86841	20
SN6814	2400 STATE (BELL/SPRINGVALE) HWY	18540	2110	2	6930	11	58267	15336	1975	4323	153502	19


BRIDGE PRIORITIZATION MAP / FRAME WORK
Vulnerability under bush fire
Vulnerability under flood
Vulnerability under earthquake
Bridge condition as a function of condition of components
Level 2 inspection data (component level) Factors influencing degradation
Deterioration Models to predict future conditions
Physical condition (Component level) Current & Future
Bridge overall condition
As built drawings Any Level 3 info Non-destructive test Expected load (or assumed)
Structural Health Monitoring
Detour Length Bridge Length No. of lanes Speed Limit Types of traffic Access to essential services AADT %CV %HV
Load rating factor
Resilience to Natural hazards
Likelihood of failure/load limit/speed limit
Consequence of bridge closure/speed limit/load limit
Social + Environmental + Economics impacts
Risk = L X C
Table of L & C and Risk score

Thank You