# Improved Pavement Design for Aggregate Surfaced Roads

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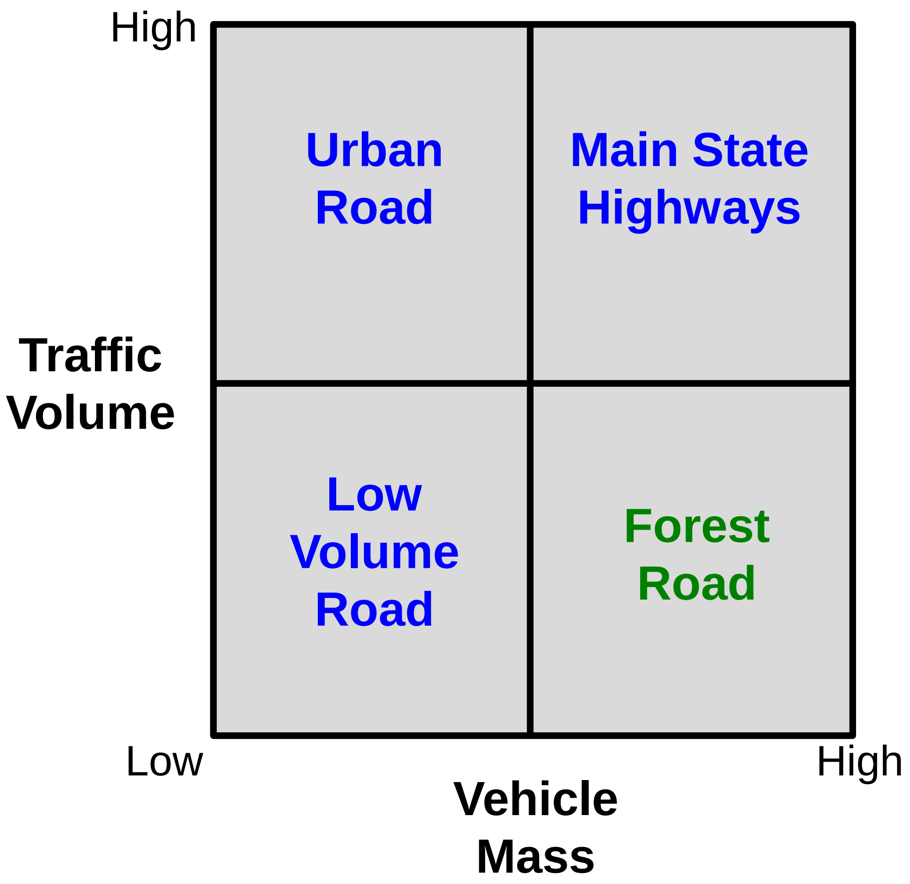
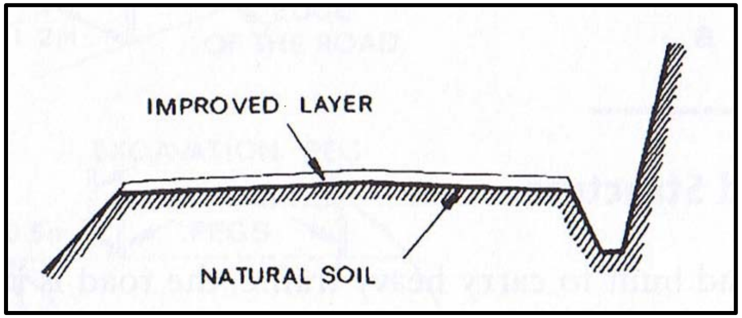
# Introduction to Forest Roads

- Aggregate surfaced roads are common-place in the forest industry
- New road construction estimate >2000km per year
- Construction budget ~$200 million/year
- Maintenance budget ~$50 million/year



# Design of Forest Road Pavements

- Forest roads are typically constructed using a single aggregate layer spread over a prepared subgrade soil
- Aggregate layer thickness needs to be sufficient to reduce stress to a level that can be borne by the underlying subgrade soil
- But … the aggregate layer needs to be as thin as possible, as it is the most expensive part of road construction (60-70% of total cost)
- Aggregate thickness currently determined by experience and 'feel'.




*Typical design of a forest road*
*(Sessions, 2007)*

# Problem with 'Design by Feel'

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- Designing by 'feel' often results in:
  - Pavement design that is risk averse – resulting in conservative (expensive) pavement design
  - Road failures that are too prevalent – with resulting high maintenance costs
  - Poor wet weather performance
  - Affordability being an ongoing issue for both forest companies and local councils

# The 'NZ Design Method' for Unsealed Roads

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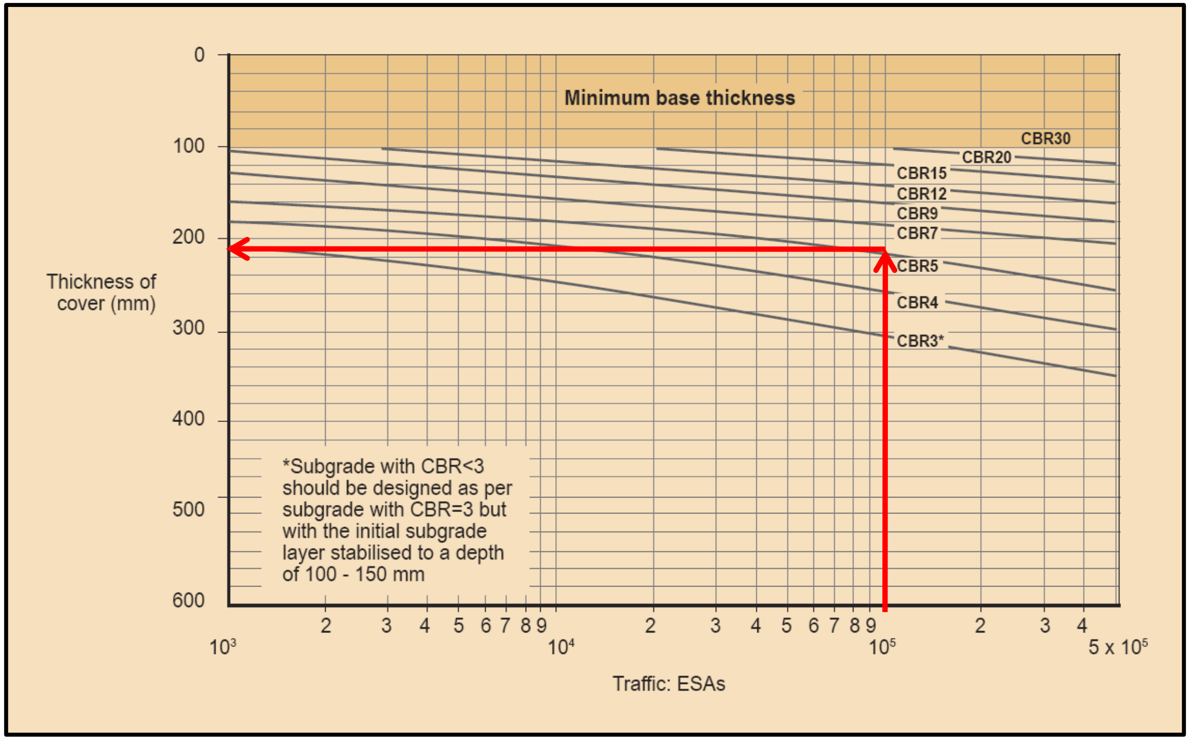
- APRG 21 (ARRB 1998) is currently the accepted design method for unsealed roads in NZ




*Subgrade CBR = 5*

*DESA = 100,000*

*Need 220mm thick aggregate layer*

*Top 100mm compliant base course*

*Bottom 120mm CBR>20*

*A guide to the design of new pavements for light traffic. APRG Report 21 (ARRB 1998)*

# Limitations of APRG 21

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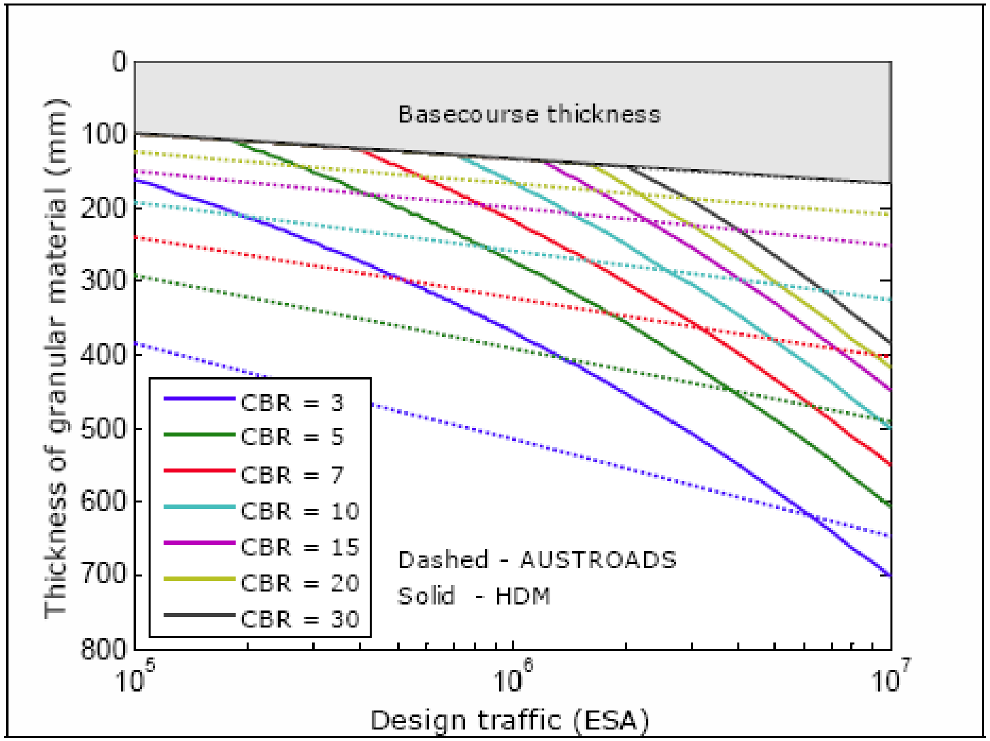
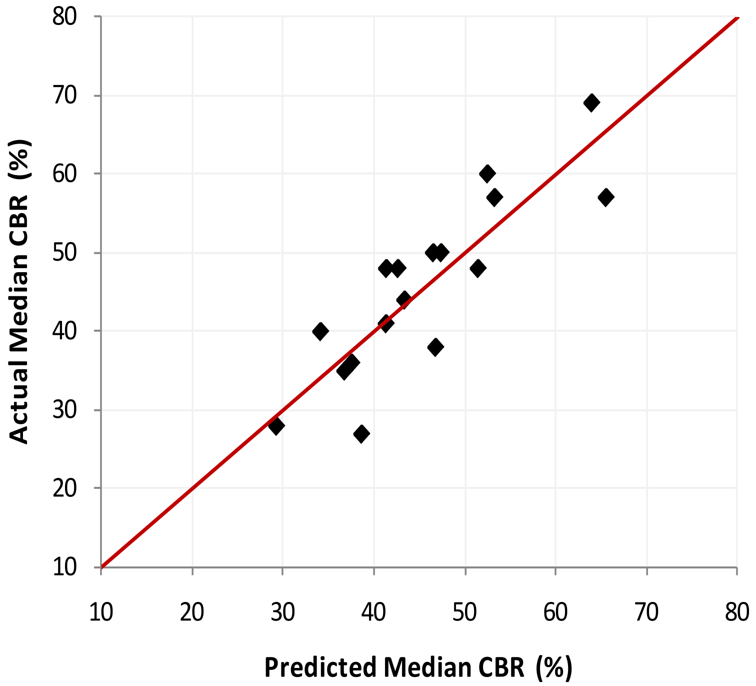
- APRG 21 is based on the AUSTROADS ‘Fig 8.4’ method – a design method developed for thin surfaced roads
- APRG 21 is based on a number of assumptions that are not particularly valid for forest roads:
  - Base course layer strength CBR > 80
  - Truck tyre pressure 550kPa
  - ESA best method to approximate traffic
  - Terminal failure is rut depth > 20mm
  - Rut development is via subgrade deformation only
- APRG21 is not validated – though experience suggests it produces conservative designs, particularly when number of vehicle passes is low (Bailey 2004, Gribble & Patrick 2008).

**APRG 21 requires excessive pavement depths when number of vehicle passes is low**

**Aggregate layer strength CBR > 80**




**Gribble, M. and Patrick, J. (2008)**

**Fairbrother, S. (2011)**

# A Forest Road Design Method

- Forest roads differ from other unsealed roads:
  - Finite and predictable design life
  - Traffic is log trucks with known loads and axle configuration
  - Traffic (log trucks) may use variable tyre pressure
  - They are typically constructed using a single layer approach
  - Variable strength aggregates used in construction
  - Terminal failure limits more relaxed than for public LVR
- A design method that incorporates these factors is required

# Alternative Design Methods

- Few quantitative unsealed pavement design methods are available:
  - Many forest roading manuals advise the designer to use an ‘appropriate’ aggregate layer thickness – no guidance is given to determine what is ‘appropriate’
  - Adequacy of design is often assessed *in situ* by observing the degree of deformation beneath the tyres of loaded trucks
- The majority of quantitative thickness design methods are developed in the Unites States by the USFS, USACE, FHWA and AASHTO

# Evaluation of Design Methods

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- Yapp et al (1991) identified the US ACE 1978 method to be best suited for forest roads

| ATTRIBUTES | COE - 1988 TM 5-822-3 *(7)* | FHWA (C) COE - 1970 (Hammitt) *(6)* | Region 4 COE - 1978 (Barber et al.) *(5)* | R - 8 ARMS | SDMS - Manual AASHTO - 1986 FHWA (A) *(8)* | SDMS Computer | USFS Chap. 50 *(1)* | Region 1 Willamette | FHWA (B) (AASHTO 1972) *(10)* |
|---|---|---|---|---|---|---|---|---|---|
| 1a. Validity for Aggregate Roads | + | - | + | 0 | 0 | - | - | - | - |
| 1b. Validity For Earth-Roads | - | + | + | - | - | - | - | - | - |
| 2. Inputs Make Sense | + | + | + | 0 | 0 | - | + | + | + |
| 3. Standard Traffic Units | - | - | - | + | + | + | + | + | + |
| 4. Varying Tire Pressure | + | + | + | + | - | - | - | - | - |
| 5. Material Characterization | + | + | + | + | + | - | 0 | 0 | + |
| 6. Risk/Reliability | - | - | - | - | - | + | - | - | - |
| 7. Change failure criteria | - | - | + | + | + | + | - | - | - |
| 8. Seasonal Haul | - | - | - | - | - | + | - | + | - |
| 9. Field Experience | - | - | - | + | 0 | - | + | + | - |
| SCORE | -2 | -2 | +2 | +2 | -1 | -2 | -3 | -1 | -4 |

# US ACE 1978 Method



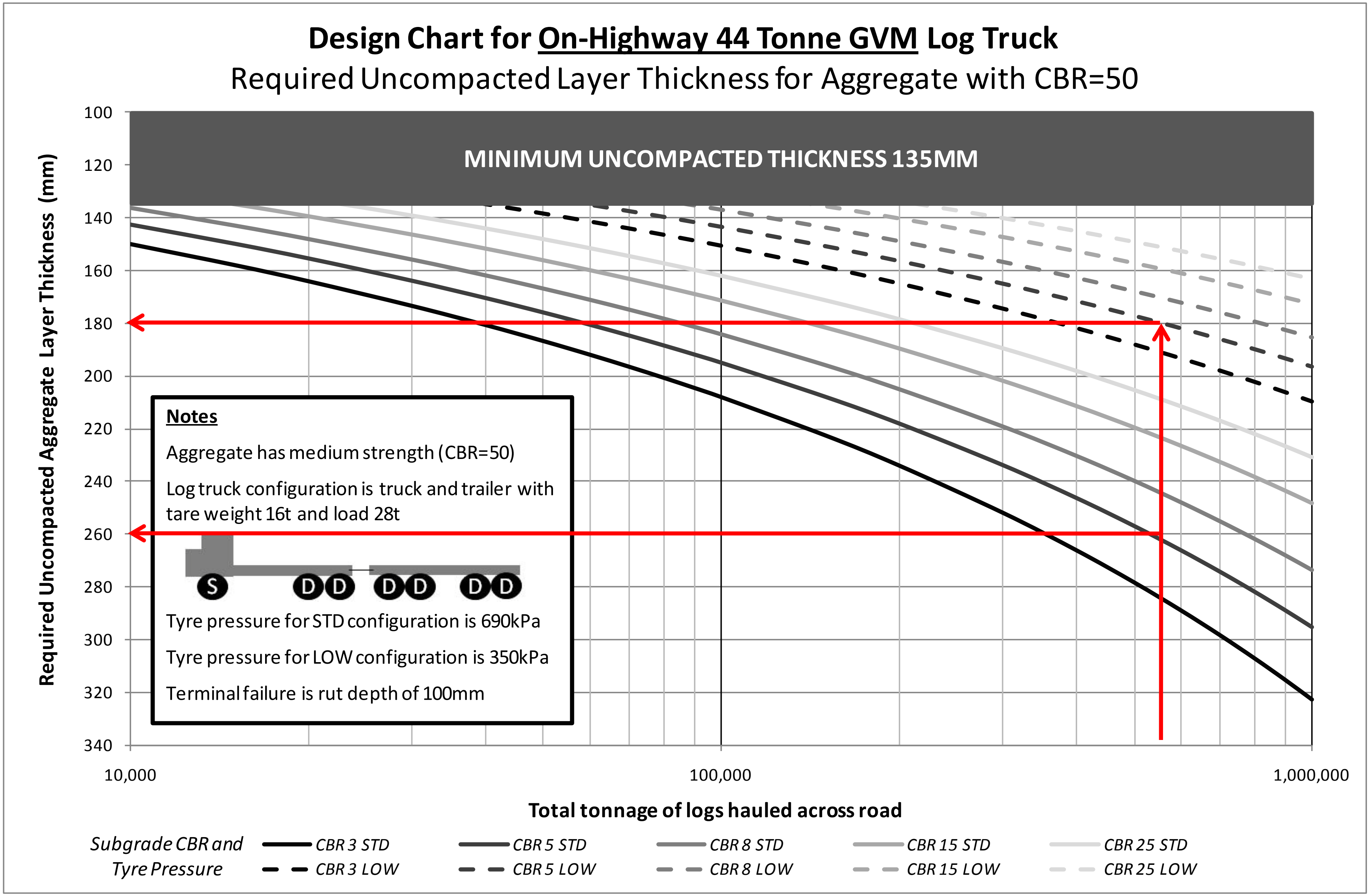
- The US ACE 1978 method was developed by Barber et al (1978) and further refined by Greenfield (1993) following the Variable Tyre Pressure trials

- The method predicts pavement thickness (t) using Equivalent Standard Wheel Load($P_k$), tyre pressure ($t_p$), load repetitions (R), terminal rut depth (RD), and subgrade ($C_2$) and aggregate ($C_1$) bearing strengths as variables.

$$\log(t) = 1.53 + 0.27 \frac{P_k^{0.2016} t_p^{0.2481} R^{0.0474}}{RD^{0.2128} C_1^{0.2414} C_2^{0.0596}}$$

# Simplifying the Method

- The USACE 1978 Method incorporates all of the factors identified as necessary for forest roads
- However… this makes the design algorithm particularly complex
- Assumptions need to be made to simplify the algorithm:
  - The major benefit of APRG21 is its simplicity
  - A similar graphical approach for the USACE 1978 method is desirable



Design Chart for On-Highway 44 Tonne GVM Log Truck
Required Uncompacted Layer Thickness for Aggregate with CBR=50
MINIMUM UNCOMPACTED THICKNESS 135MM
Required Uncompacted Aggregate Layer Thickness (mm)
100
120
140
160
180
200
220
240
260
280
300
320
340
Notes
Aggregate has medium strength (CBR=50)
Log truck configuration is truck and trailer with tare weight 16t and load 28t
S
D D
D D
D D
Tyre pressure for STD configuration is 690kPa
Tyre pressure for LOW configuration is 350kPa
Terminal failure is rut depth of 100mm
10,000
100,000
1,000,000
Total tonnage of logs hauled across road
Subgrade CBR and Tyre Pressure
CBR 3 STD
CBR 5 STD
CBR 8 STD
CBR 15 STD
CBR 25 STD
CBR 3 LOW
CBR 5 LOW
CBR 8 LOW
CBR 15 LOW
CBR 25 LOW

# Benefits of this approach

- Encourages Forest Road Engineers to:
  - Use a more quantitative design approach
  - Spend more effort on subgrade preparation
  - Make better value judgments when purchasing aggregate
  - Promote the use of CTIS on forest roads

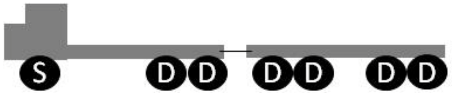
# Challenges

- The USACE 1978 method:
  - Uses ESWL to quantify traffic
  - The simplified graph is only valid for the given assumptions
  - Has been developed using a limited dataset
  - Is not validated

**Notes**

Aggregate has medium strength (CBR=50)

Log truck configuration is truck and trailer with tare weight 16t and load 28t




Tyre pressure for STD configuration is 690kPa

Tyre pressure for LOW configuration is 350kPa

Terminal failure is rut depth of 100mm

# Summary

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- Current forest road construction relies on experience and ‘feel’ for aggregate thickness design
- The APRG 21 method is the accepted design approach for unsealed roads in NZ, but has significant limitations
- The USACE 1978 method:
  - is better suited to meet the needs of forest road design
  - but is not validated or field tested in NZ

# Effective research can help turn this…

# ... into this!

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# QUESTIONS?

Thanks for your attention ☺

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