Course content

1 Introduction
2 Performance
3 Design
4 Construction
5 Maintenance
6 Management
7 Investigation & maintenance measure selection
8 Safety aspects
9 Rehab, improvement and upgrading

3 DESIGN

3.1 Geometric design
3.2 Cross drainage
3.3 Pavement thickness design
3.4 Wearing course thickness design
3.5 Material selection

Gerrie Van Zyl

What are we designing for?

- Accessibility

	Required standards
Level of Serviceability	Impassability
5 4 3 2 1	Frequently < 5 days/yr Never Never Never

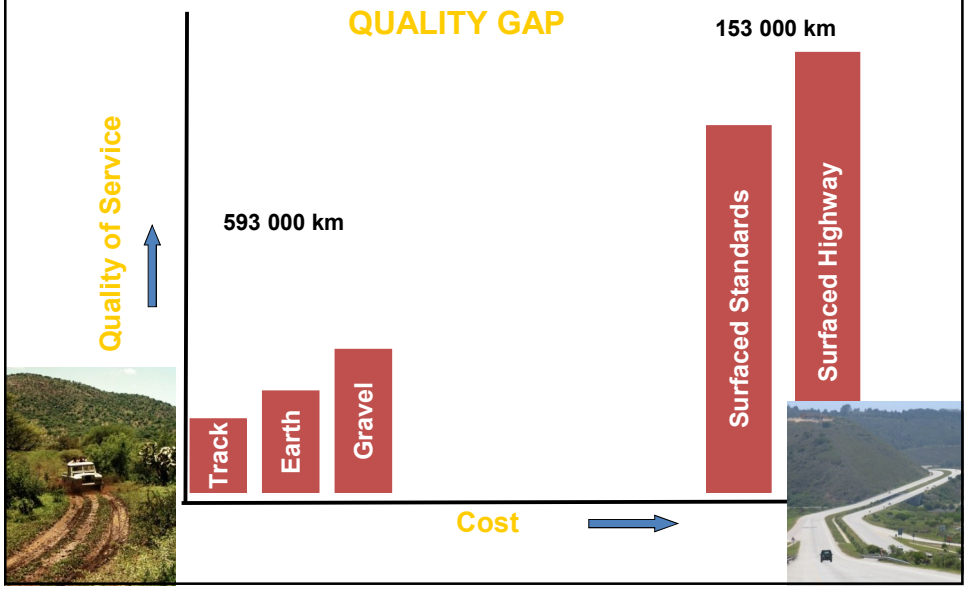
Design for what ?

- Safety

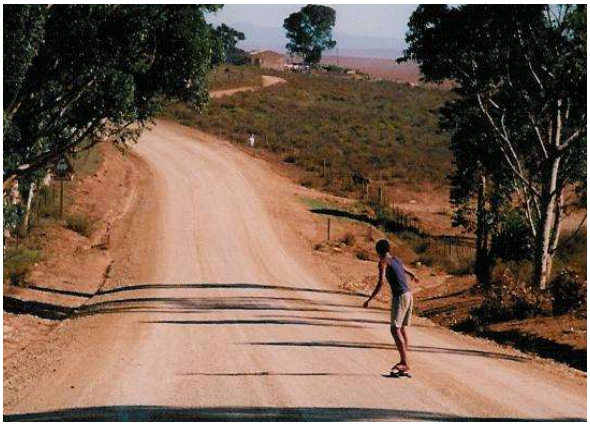
Design Aspects

- Geometric design issues
- Cross drainage
- Pavement thickness
- Wearing course thickness

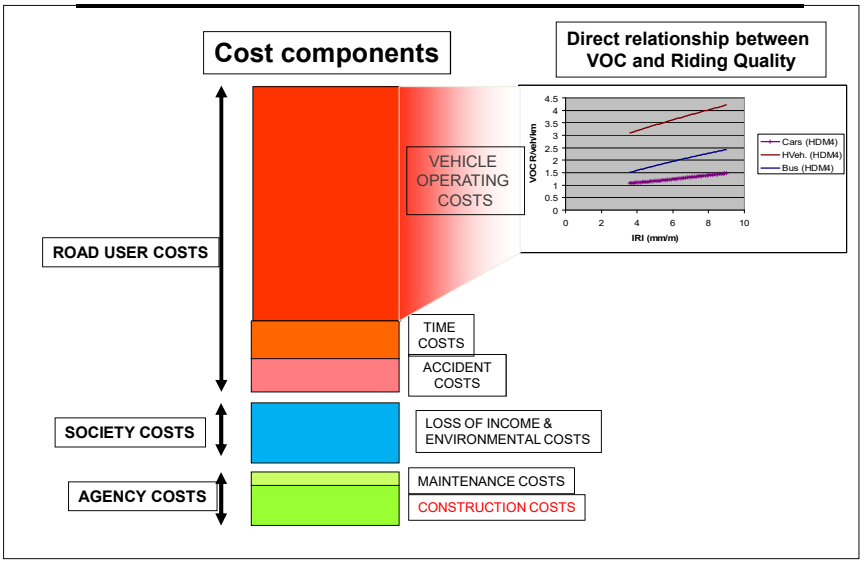
Road Standards



Safe/ Economic/ Appropriate



Road User Costs



Geometric design issues

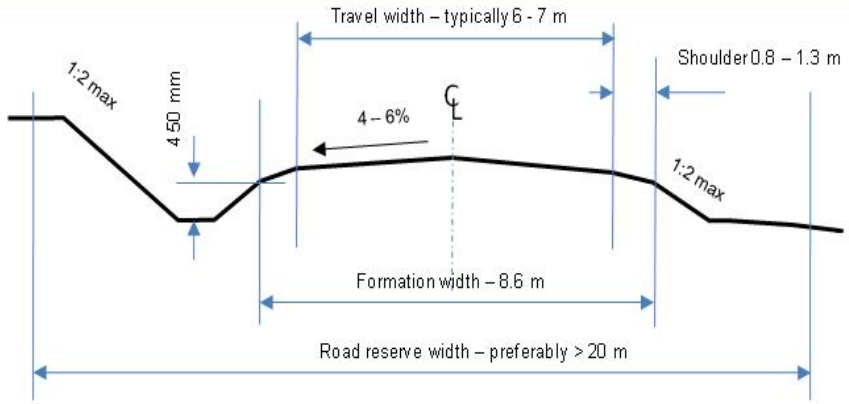
- Document focus – not on geometric design
- Refer to "AASHTO Guidelines for geometric design of very low-volume local roads" (AASHTO, 2002)
- Some guidelines
- Alignment –
  - Adapt to traffic, climate, topography
  - Risks
  - Costs

Minimum Radius

Table 2 Minimum recommended radii of horizontal curvature without super elevation

Material type		Gravel compacted (Dry)						
		Gravel compacted (Wet)						
		Gravel loose (Dry)						
		Gravel loose (Wet)						
		Earth (Dry)						
		Earth (Wet)						
		Clay (Wet)						
Design Speed (km/h)	Traction coefficient	0.8	0.7	0.6	0.5	0.4	0.3	0.2
20	Minimum Radius (m)		15	15	15	20	35	
30			15	20	25	40	75	
40			30	35	45	65	130	
50			40	50	70	100	200	
60			60	75	95	145	285	
70			80	100	130	195	385	

Typical cross section



Super-elevation

- Max 5% recommended

Recommended road widths

Terrain	Existing traffic (vpd)	Minor roads and tracks	Formed minor roads	Divisional roads	Main roads	Trunk roads
Flat and rolling	< 20	3 m (Note 1)	4 m (Note 1)	6 m	6 m	8,6 m
	20 – 50	5 m	5 m			
	50 – 200		6 m	7 m	7 m	
	> 200		6 m	8.6 m	8.6 m	
Mountainous		4 m (Note 2)	4 m (Note 2)	5 m (Note 2)	6 m (Note 2)	7 m (Note 2)
Surfacing			Formation 8.6 m Surface 6.8 m	Formation 8.6 m Surface 6.8 m	Formation 8.6 m Surface 6.8 m	Formation 8.6 m Surface 6.8 m

Notes

1 Clearances (turnouts) to be provided at regular intervals to allow vehicles to pass. Widening at crests should be considered.

2 Each situation should be assessed for selection of an appropriate solution

Constraints: Road reserve width

Other aspects to consider

- Avoid surprises
- Space for reaction

Other aspects to consider

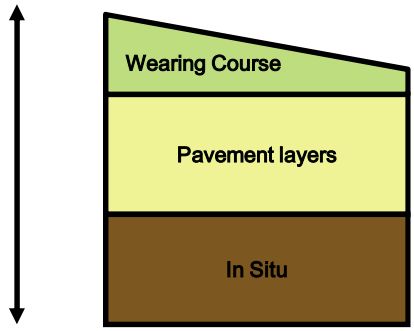
- Design traffic (<4m, 4-6m, >6m)
- Cost of maintenance
- Extra width for maintenance material
- Crossfall
  - 3% Narrow, slippery, winding
  - 5% Wide & straight
  - 1% lost soon after construction
- Superelevation
  - Max 5% (erosion)

3.3 Pavement Design

Pavement design

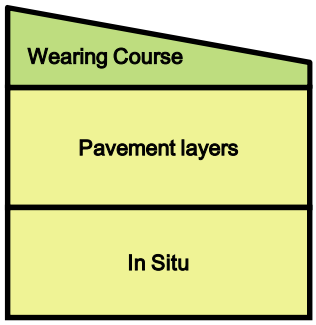
- Structure must carry the load
- Considerations
  - Different to sealed roads
  - Design life (Life-cycle strategy)
  - Terminal condition/ design reliability
  - Maintenance impact
- Catalogue
  - Conservative
  - Wearing course not structural

Pavement Structure

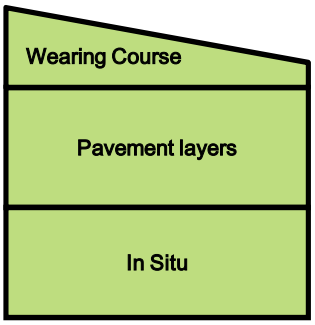


Typical SA Situations

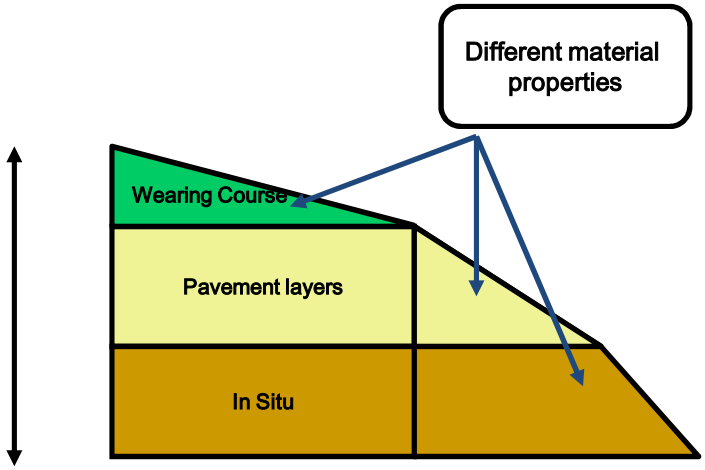
In-situ material strong enough
• no imported pavement layers required



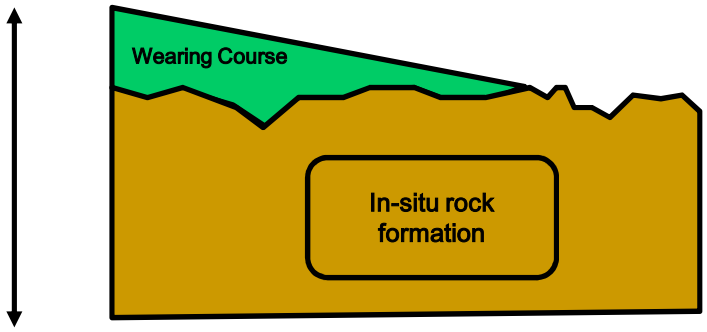
In-situ material strong enough and suitable as a wearing course
• no imported pavement layers required
• no imported wearing course required



Implications



Implications



Design Catalogue

- Existing (Draft 2009)

Table 5 Simplified design catalogue for gravel roads

Existing moisture condition	In situ CBR from DCP (top 300 mm) (%)				
Dry	< 15	16 – 25	26 – 45	46 – 80	> 80
Moist	< 10	11 – 15	16 – 25	26 – 45	> 45
Wet	< 5	6 – 10	11 – 15	16 – 25	> 25
Pavement class	**Additional structure required (depth in mm)**				
ES 0.003	WC, 200 G7	WC. 150 G7	WC, 100 G7	WC	WC
ES 0.01	WC, 250 G7	WC, 200 G7	WC, 150 G7	WC	WC
ES 0.03	WC, 275 G7	WC, 225 G7	WC, 175 G7	WC	WC
ES 0.1	WC, 150 G6, 150 G7	WC, 125 G6, 125 G7	WC, 100 G6, 100 G7	WC, 100 G6	WC
ES 0.3	WC, 150 G5, 150 G7	WC, 125 G5, 125 G7	WC, 100 G5, 100 G7	WC, 100 G5	WC

Class	CBR (%)
G4	80
G5	45
G6	25
G7	15
G8	10
G9	7
G10	3

Existing Catalogue

- Concerns raised
  - Too conservative (Wearing course must contribute)
  - Only one material available
  - Provision also for G5 and G6
- Design traffic guidelines
  - E80/ heavy
  - Road width impact
  - Design period

Revision

Table 5 Simplified design catalogue for gravel roads

Existing moisture condition	In situ CBR from DCP (top 300 mm) (%)				
Dry	< 15	16 – 25	26 – 45	46 – 80	> 80
Moist	< 10	11 – 15	16 – 25	26 – 45	> 45
Wet	< 5	6 – 10	11 – 15	16 – 25	> 25
Pavement class	**Additional structure required (depth in mm)**				
ES 0.003	WC, 200 G7	WC. 150 G7	WC, 100 G7	WC	WC
ES 0.01	WC, 250 G7	WC, 200 G7	WC, 150 G7	WC	WC
ES 0.03	WC, 275 G7	WC, 225 G7	WC, 175 G7	WC	WC
ES 0.1	WC, 150 G6, 150 G7	WC, 125 G6, 125 G7	WC, 100 G6, 100 G7	WC, 100 G6	WC
ES 0.3	WC, 150 G5, 150 G7	WC, 125 G5, 125 G7	WC, 100 G5, 100 G7	WC, 100 G5	WC

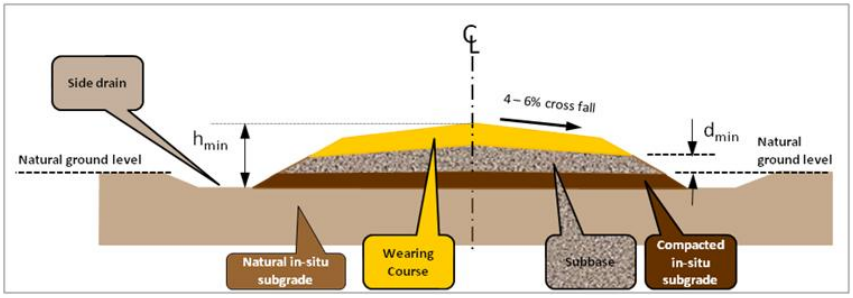
Existing	G9	G8	G7	G6
Pavement class	**Min**	**Min**	**Min**	**Min**
ES 0.003	200 G7 or 175 G6* or 150 G5*	150 G7 or 125 G6 or 110 G5	100 G7**	100 G6**
ES 0.01	250 G7 or 210 G6* or 180 G5*	200 G7 or 170 G6 or 145 G5	125 G7**	100 G6**
ES 0.03	275 G7 or 240 G6* or 200 G5*	225 G7 or 190 G6 or 165 G5	150 G7**	125 G6**
ES 0.1	325 G7 or 275 G6* or 230 G5*	270 G7 or 225 G6* or 200 G5	175 G7** 150 G6* or 125 G5*	125 G6**
ES 0.3	365 G7 or 310 G6* or 260 G5*	320 G7 or 265 G6* or 230 G5*	215 G7** 180 G6* or 150 G5*	125 G6**
ES 1.0	430 G7 or 365 G6* or 300 G5*	375 G7 or 320 G6* or 265 G5	300 G7** 250 G6* or 220 G5*	185 G6**

Additional Notes to Catalogue

- DCP Pavement balance numbers of 60 to 12.5 have been used to create this catalogue, also taking into account:
  - Improved side drainage with more imported layers and cover thickness
  - Lower moisture conditions higher up in the pavement structure as a result of increased cover thickness
- Values represent total cover – compacted (Min 95% MAASHTO)
- It is assumed that:
  - The road bed will be properly shaped and compacted (at least 150 mm)
  - h_{min} achieved
- * G5 and G6 material types are sensitive to traffic abrasion
- ** In-situ material available (additional 150 mm to be compacted)

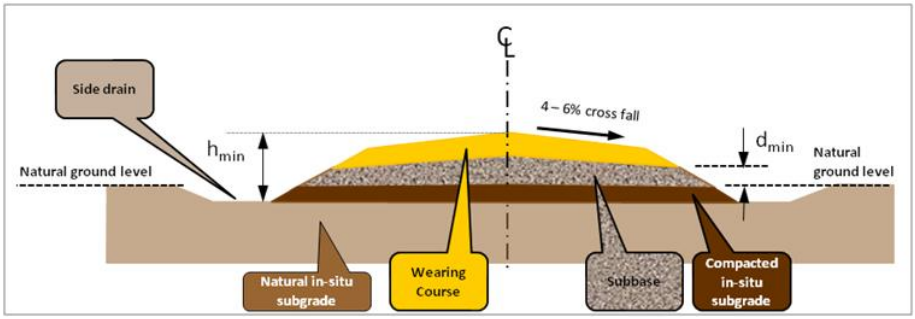
Final road level

- Cover to protect sub-grade
- Maximum moisture content of pavement layers
- Drainage
  - Cross drainage (Pipe cover – min 250mm)
  - Side drainage



- d_{min} = 150 mm

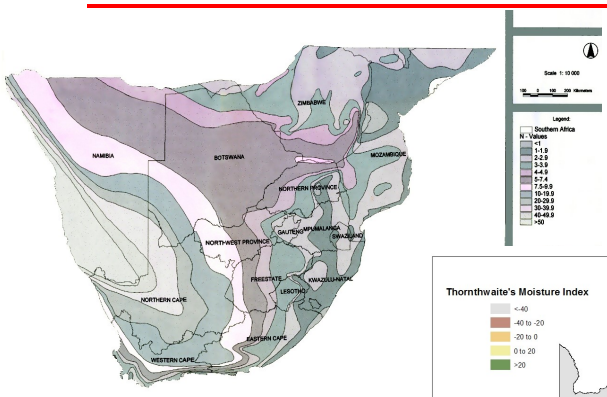
h_{min}

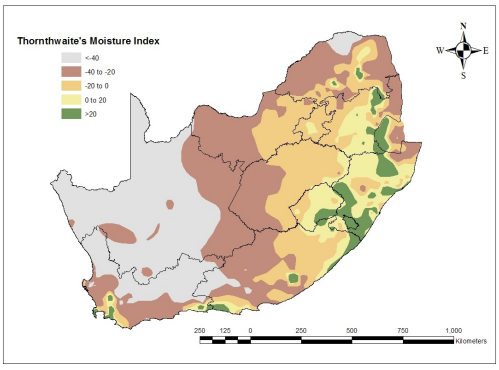


Traffic Class grouping	h_{min}		
	Dry Climate (Weinert N>5)	Moderate Climate Weinert N (2-5)	Wet Climate Weinert N <2
ES 0.003 – ES 0.01	250mm	300mm	350mm
ES 0.03	350mm	400mm	450mm
ES 0.1 – ES 0.30	450mm	500mm	550 mm

Note: h_{min} also dependent on volume of water expected

Macro Climatic Areas





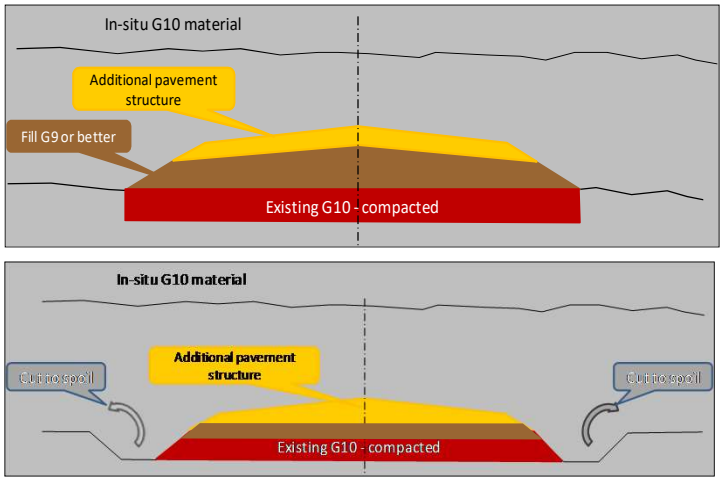
New unsurfaced roads

- Do visual assessment
- Identify uniform sections (DCP)
- Check moisture condition, drainage etc.
- Sampling and testing
- Design traffic calculation
- Material quality available ?
- Select thickness
- Treat outliers differently e.g. very poor isolated

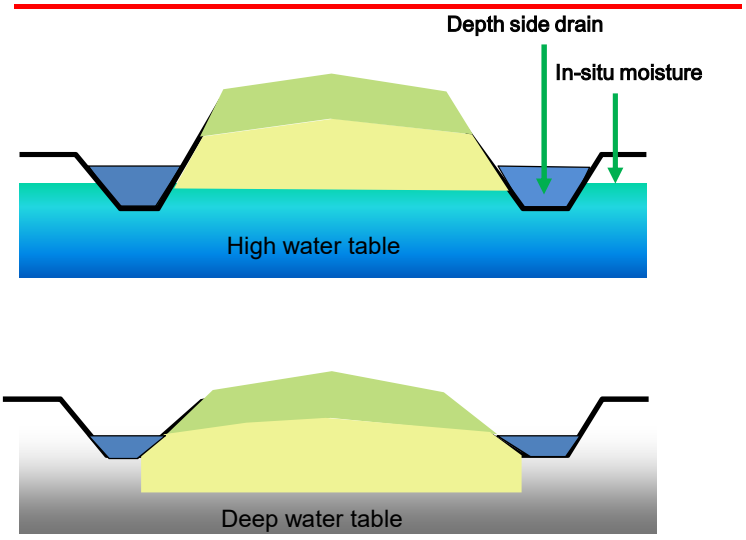
Weak sub-grades

Wet sub-grades

Very poor in-situ material



NB Drainage !!!



Expansive soil (< G10)

- CBR < 1%
- Keep as dry as possible – side drains

Sub-grade preparation

- Additional material ?
- Pioneer layer
- Geotextile
- Other

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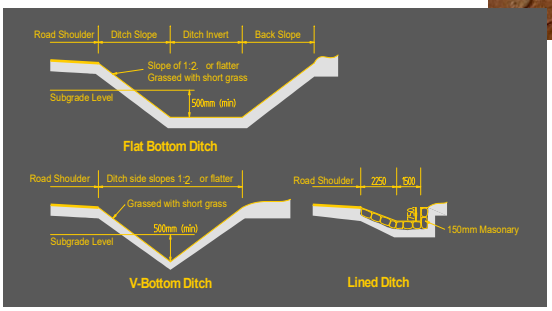
Pipe coverage

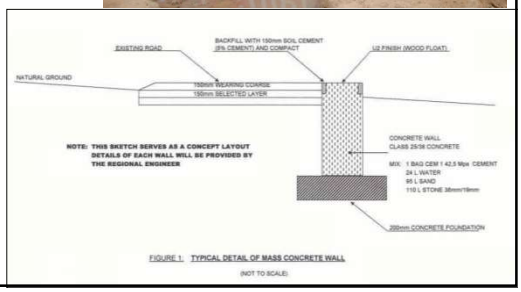
Drainage

- Side drainage



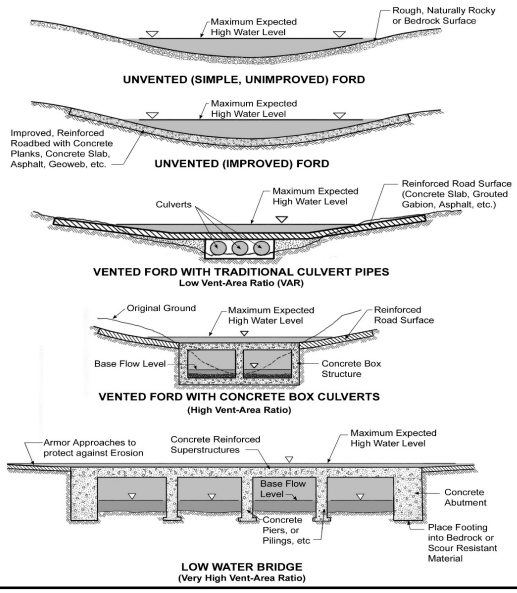
Cross Drainage

- Accessibility (Level of Service)
- No water flow across unless
  - Low level structure provided
  - Easy to repair
  - Alternative routes/ Accessibility
  - Protection walls



Low level structures

Low Water Crossings



Gordon Keller

Cut-off walls

Cross drainage

- Bridges
- Culverts
  - Min size 450mm (ideal 600mm)
  - Minimum cross fall 1.5% (ideal 2%)
  - Cover Supplier
    - Pipes 300mm
    - Culverts 150 mm

Head- & Wing walls ?

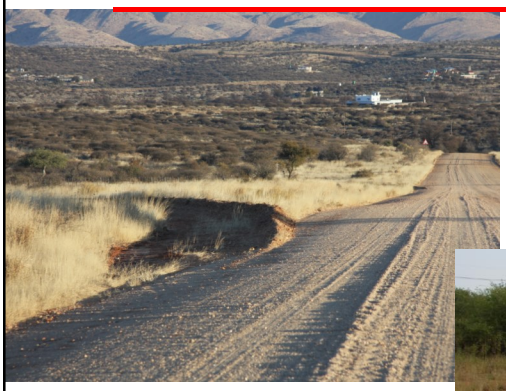
Drainage

Signage

Side drainage

Side drainage (Mitre drains)

Side drainage (Mitre drains)



Mitre drains

- Each site is different
- Monitor and increase

Typical minimum and maximum distances between mitre drains (m)

Gradient (%)	2	4	6	8	10	12	14
Erodible material (min)	50	40	30	20	10	10	10
Clayey material (max)	300	150	100	75	60	50	40

Wearing Course Thickness design

- Appropriate regravelling frequency
- Expected gravel loss (5 – 10 years)
  - Factors influencing (traffic, material, climate, geometry)
  - Curves, grades
  - Buffer thickness (depend on subgrade strength)
- Typically 100 – 150 mm
- Sensitivity of sub-grade
- Maintenance capability of RA
- Optimisation of in-situ material

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Performance Models Available

- World Bank HDM4
- South Africa TRH20
- Others

- Performance in terms of:
  - Gravel Loss
  - Roughness deterioration (only as a result of the wearing course)

SA MODELS

Gravel loss

AGL = 3.65[ADT(0.059+0.0027N-0.0006P26) – 0.367N-0.0014PF+0.0474P26]

Roughness

LnR = D[-13.8+0.00022PF+0.064S1+0.137P26 + 0.0003.N.ADT +GM(6.42-0.063P26)

LRA = 1.07 + 0.699LRB+0.0004ADT-0.13DR + 0.0019LABMAX

Design with maintenance in mind

- Road width + 1-2 m shoulder
  - Flat areas – 1m
  - Steep/ curves – 1m either side if possible
- Maintenance material
- Buffer thickness
  - Support
  - Traffic load