Training on

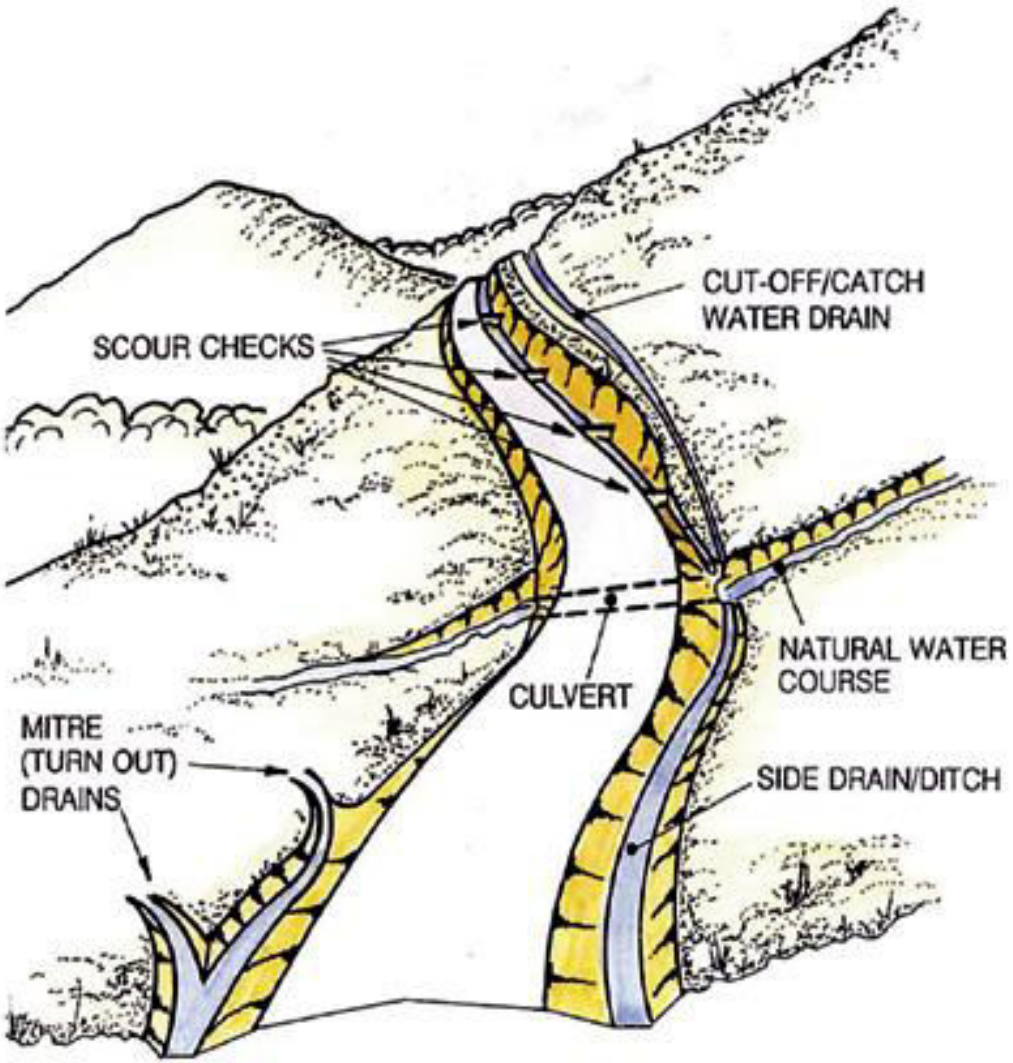
Roads for Water and Resilience

CULVERT AND CROSS DRAINAGE DESIGN

Culvert and cross drainage design

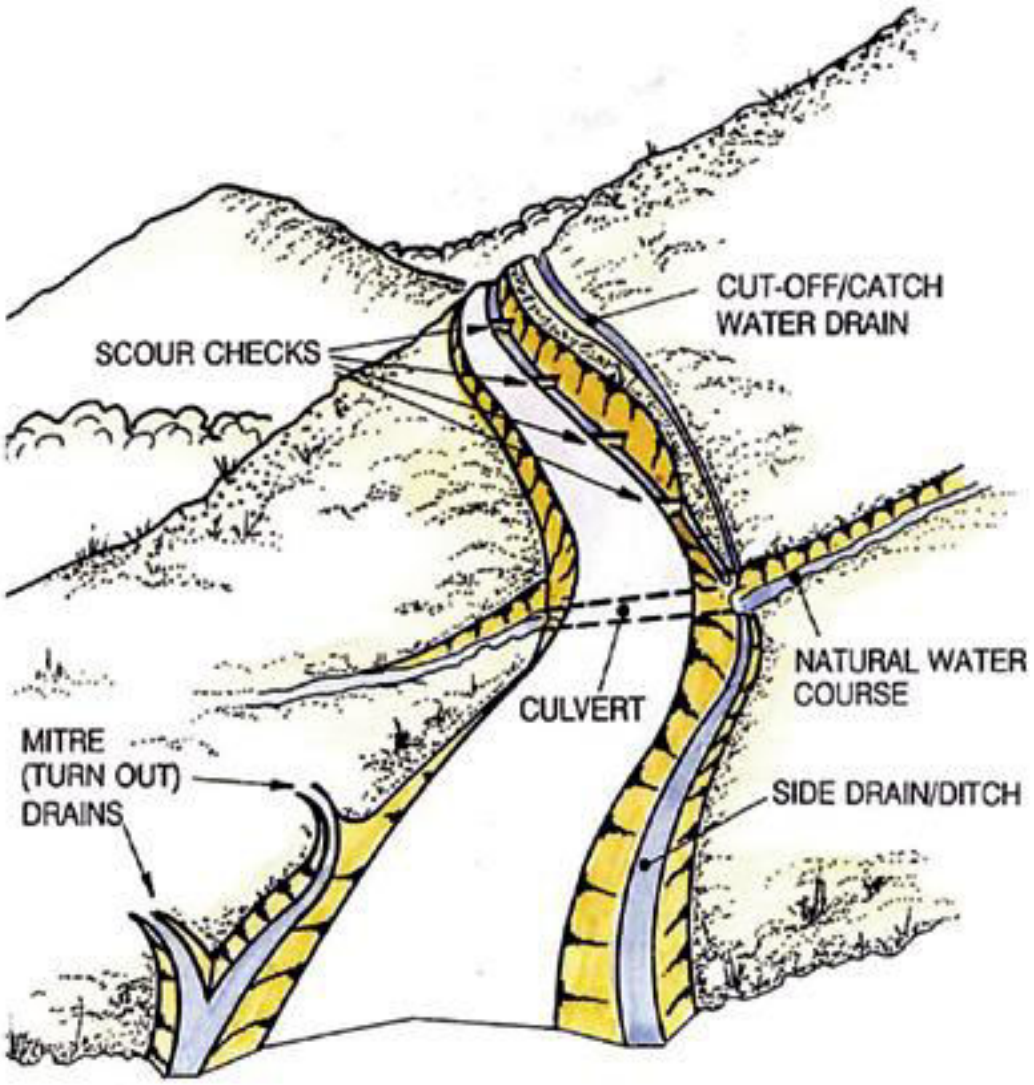
- Design parameters: climate, terrain, demographics and traffic
- Road alignment and impact on erosion and water flows
- Side drainage design and erosion problems
- Culvert design and erosion problems
- Problems into opportunities

Terminology

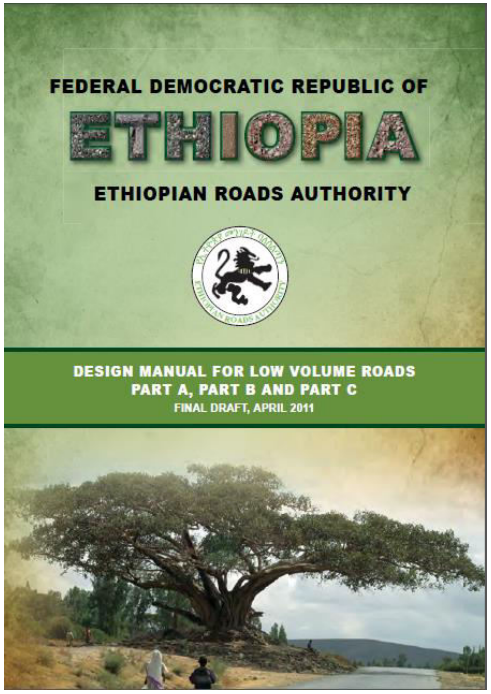


Factors influencing drainage design

- Slope of terrain
- Slope of drain
- Catchment area
- Runoff
- Frequency of culverts and mitre drains
- Straightness of road

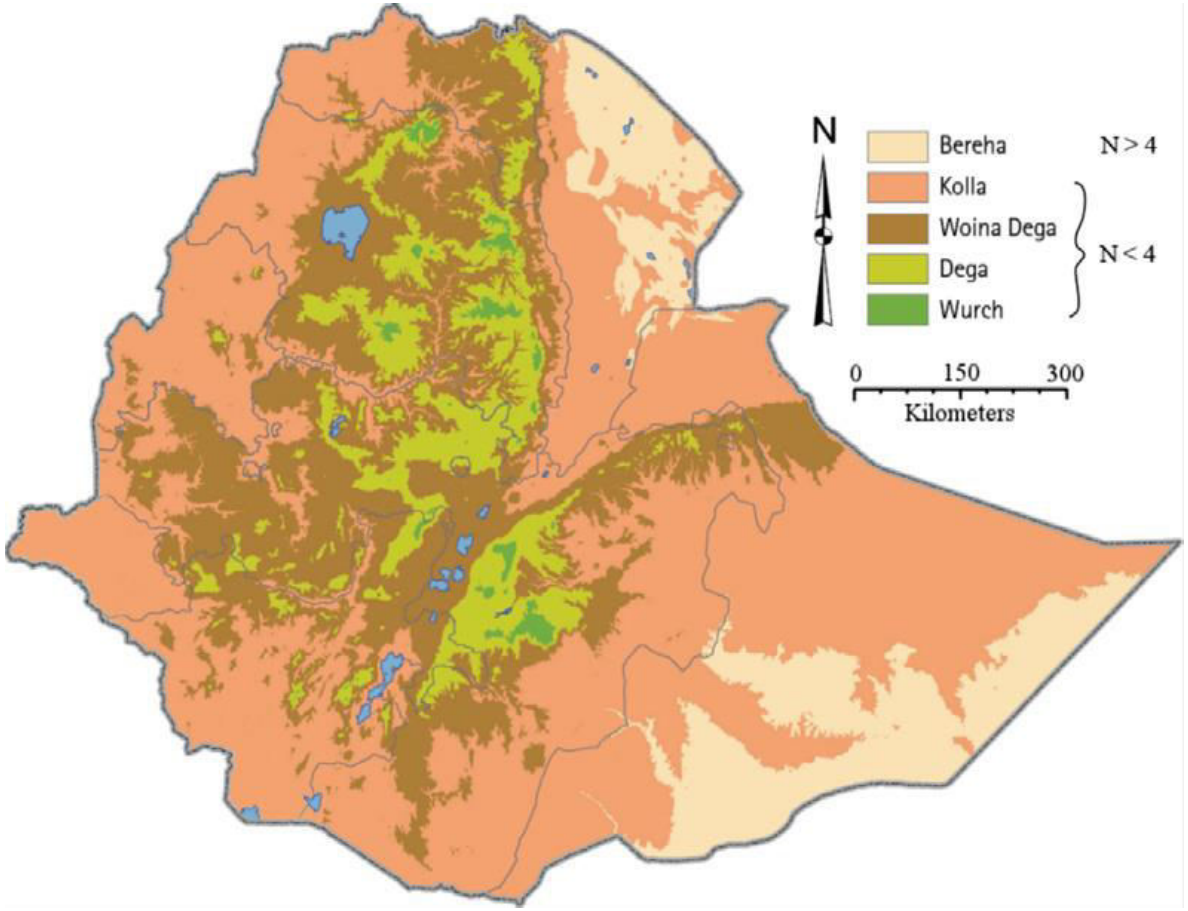


Similarities in road and water harvesting design parsmeters



Road design parameters	Erosion control and water harvesting design
Climate	Climate
Terrain	Terrain
Demographics	Demographics including livelihoods
Traffic	Water demands: people, livestock, crops, environment

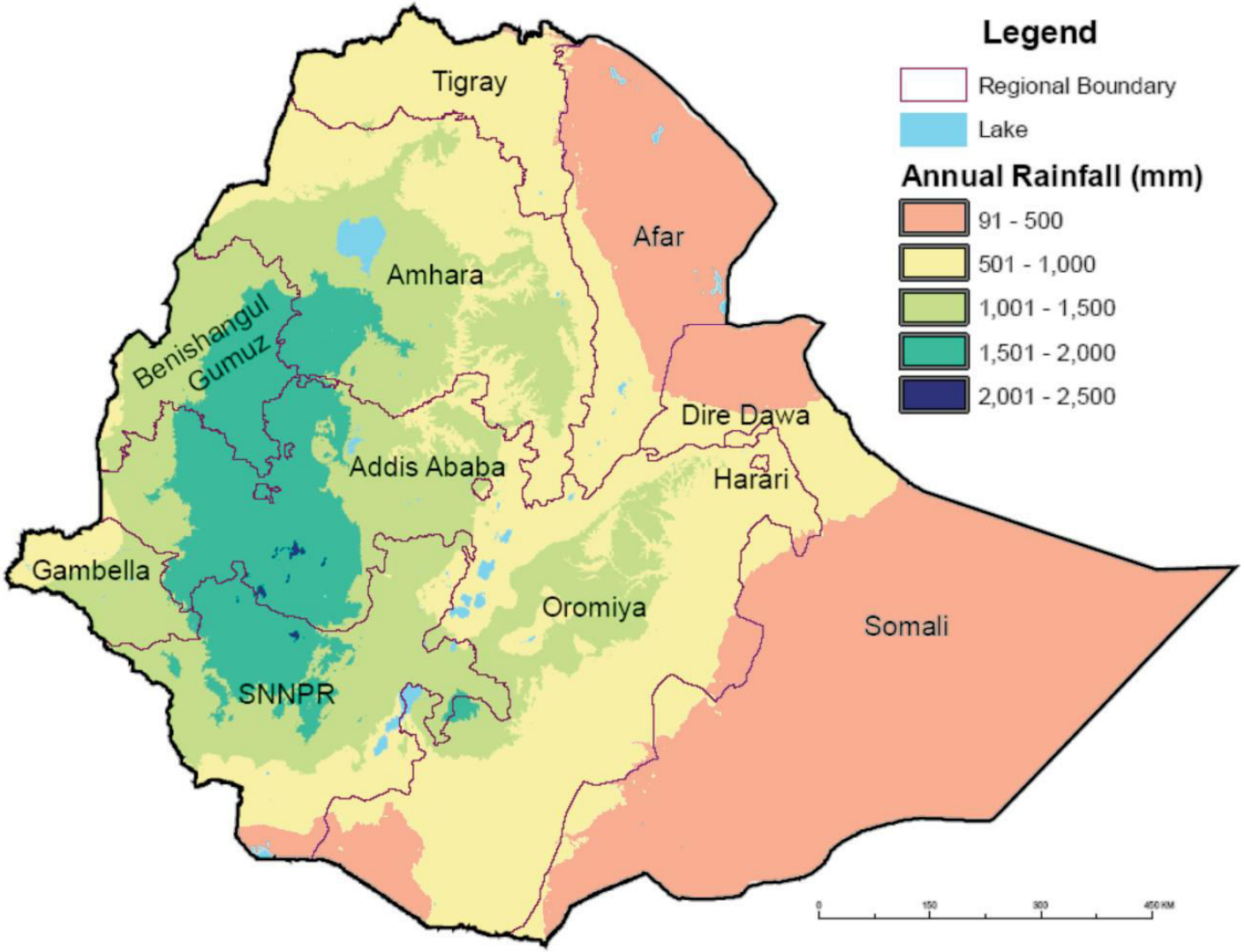
4 climate zones



N = 12.Ej/Pa where:

Ej = evaporation for the warmest month and Pa = total annual precipitation

Rainfall


Legend
Regional Boundary
Lake
Annual Rainfall (mm)
91 - 500
501 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 2,500
Tigray
Afar
Amhara
Benishangul Gumuz
Dire Dawa
Addis Ababa
Harari
Gambella
Oromiya
Somali
SNNPR
0
150
300
450 KM

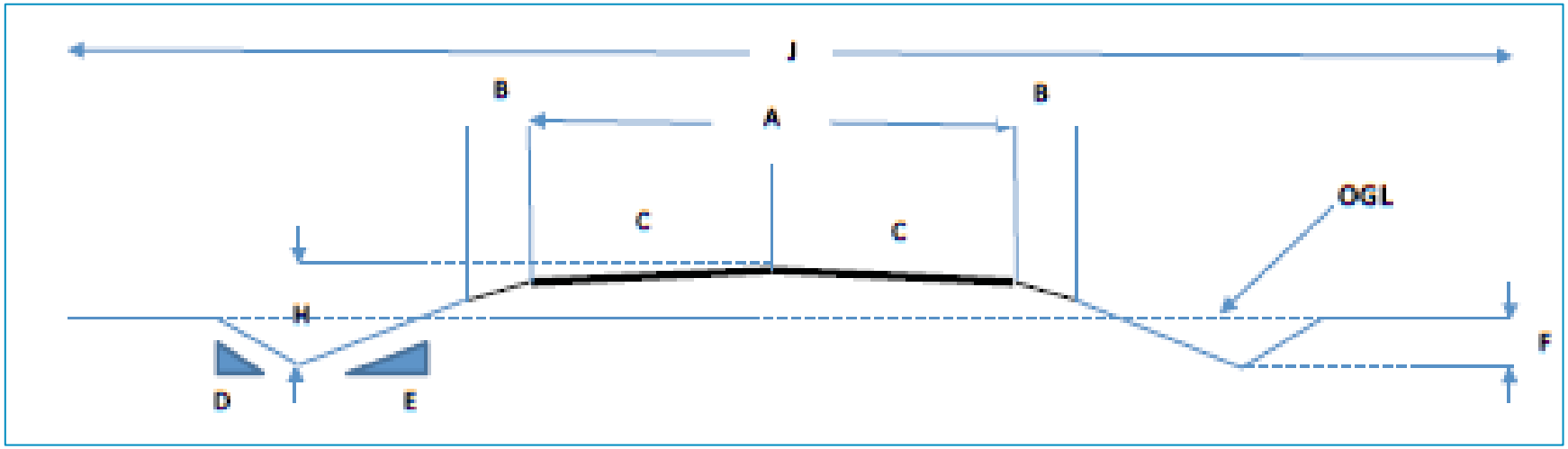
Terrain

Flat	0 to 10 five-metre contours per km. The natural ground slopes perpendicular to the ground contours are generally below 3%.
Rolling	11 to 25 five-metre contours per km. The natural ground slopes perpendicular to the ground contours are generally between 3 and 25%.
Mountainous	26 to 50 five-metre contours per km. The natural ground slopes perpendicular to the ground contours are generally above 25%.
Escarpment	Escarpments are geological features that require special geometric standards because of the engineering risks involved. Typical gradients are greater than those encountered in mountainous terrain.

- 4 categories based on number of 5m contours/km on a line drawn between 2 points and slope perpendicular to line
- Flat, rolling and mountainous are useful categories for understanding road erosion and water harvesting potential
- Google earth allows this to be quickly calculated

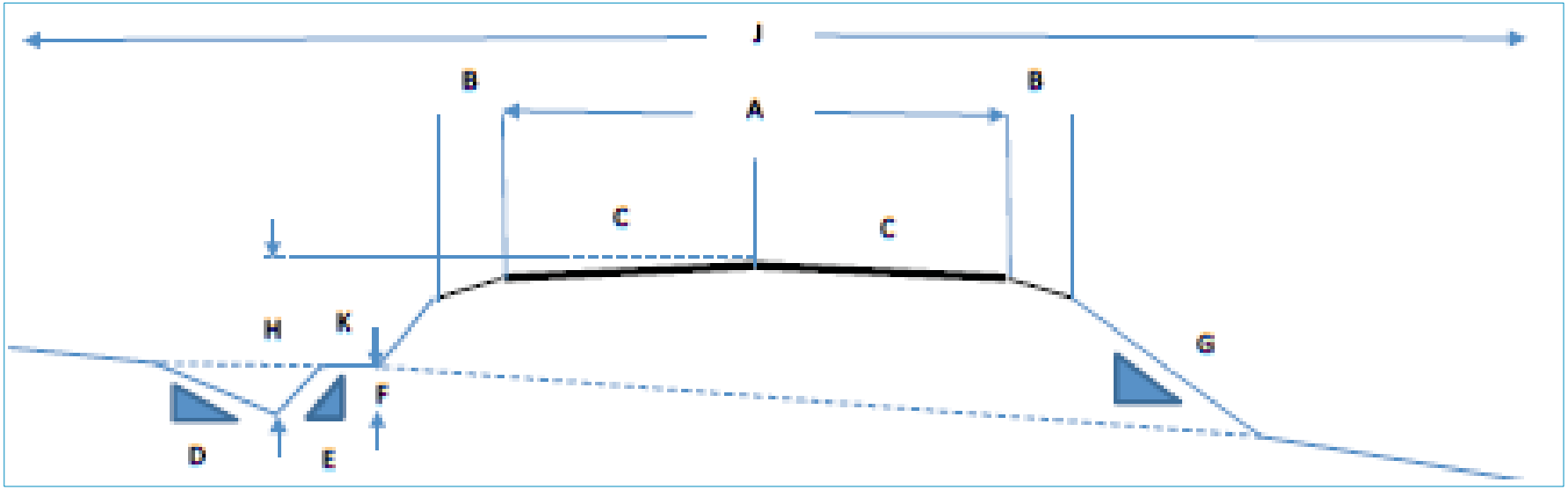
Culverts and drains in flat terrain

Design of side ditches and spacing of culverts varies with terrain and whether paved or unpaved road just as erosion control and water harvesting options vary with terrain



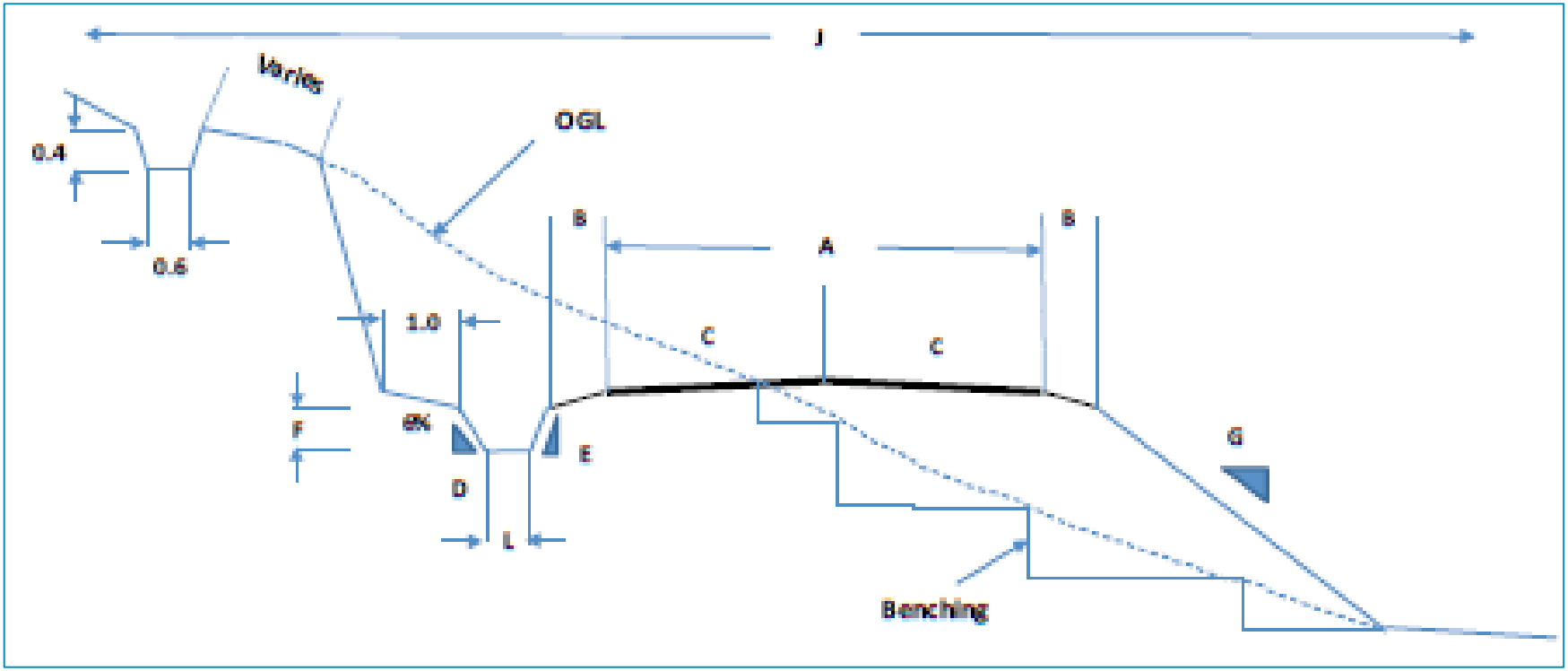
Few or no culverts on flat terrain. Roads more liable to flooding. Mitre drains divert water away

Culverts and drains in rolling terrain



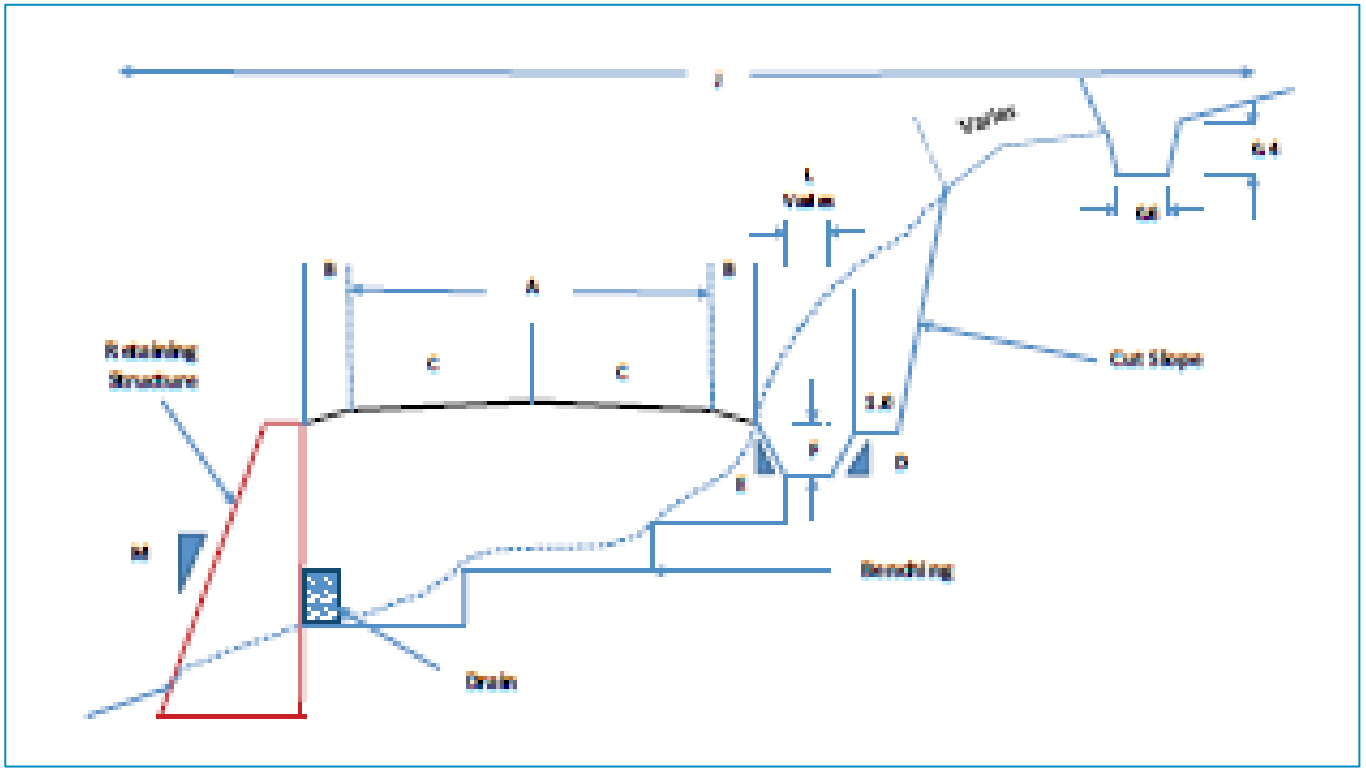
1-2 culverts / km on rolling terrain to carry water from the upside drain to the downslide of the road

Culverts and drains in mountainous terrain



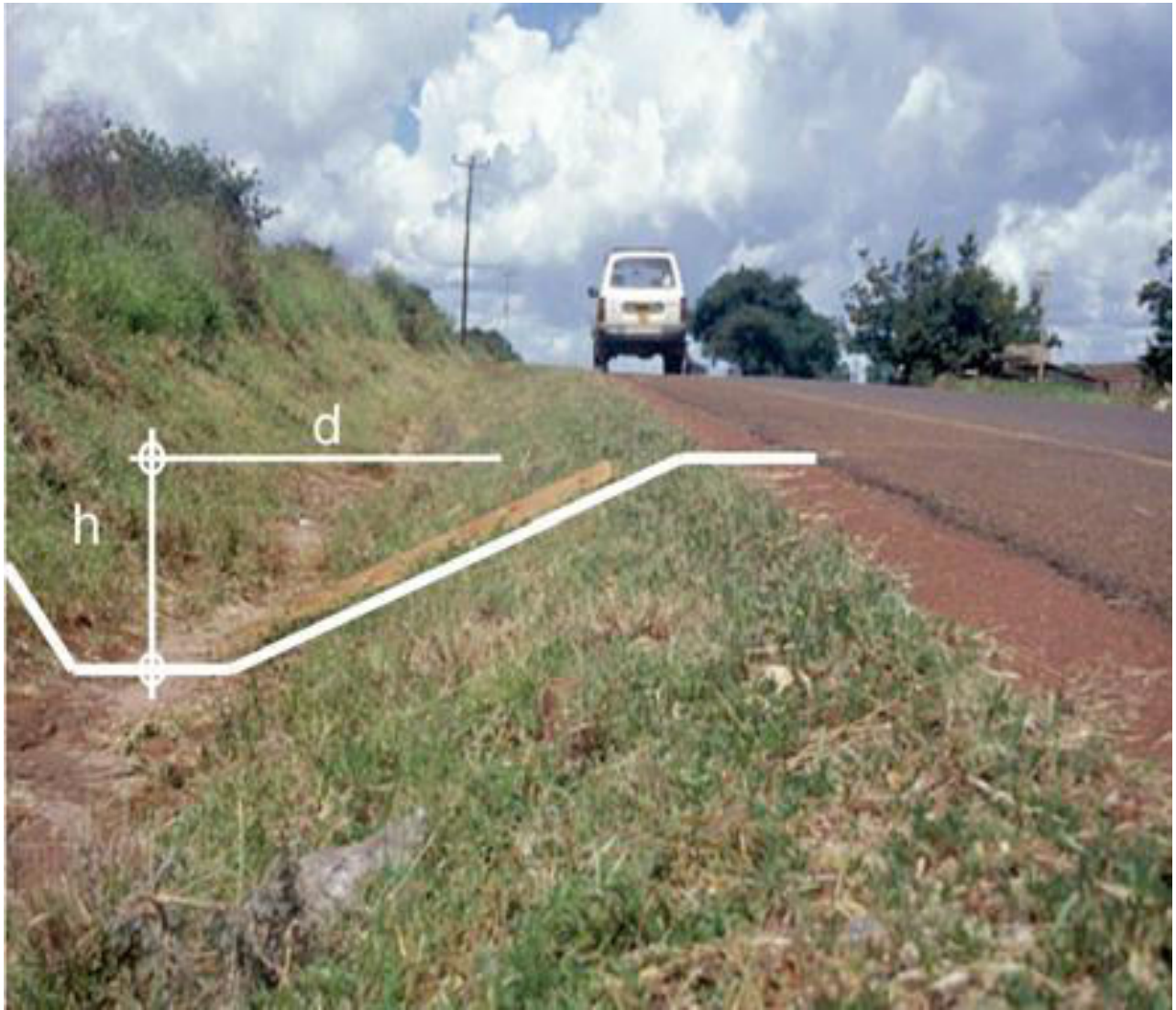
This rises to 5-6 culverts / km on mountainous terrain

Escarpment roads



Requires specialist surveys and engineering knowledge. Consider the risk of landslides

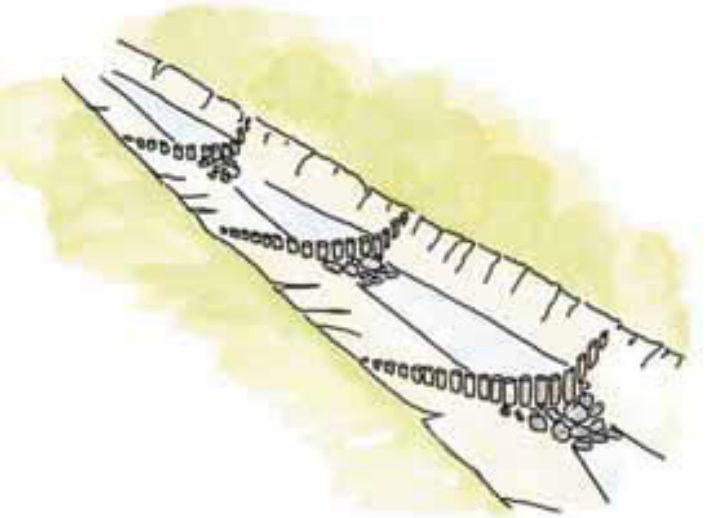
Side drainage as it should be

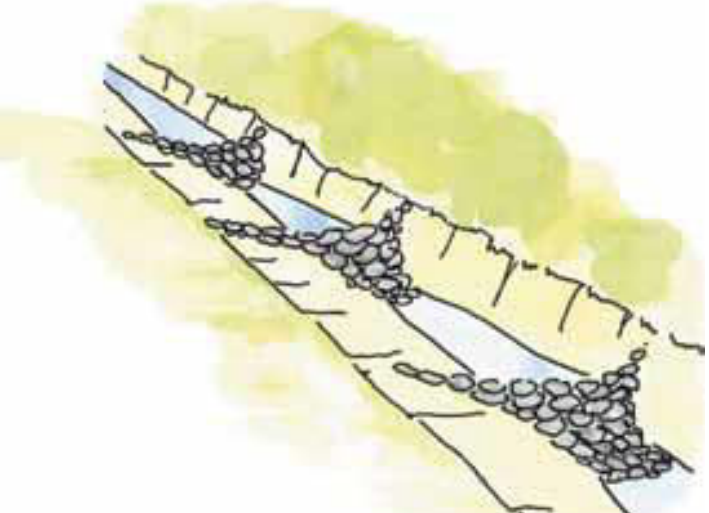


Upslope side drain as shouldn't be

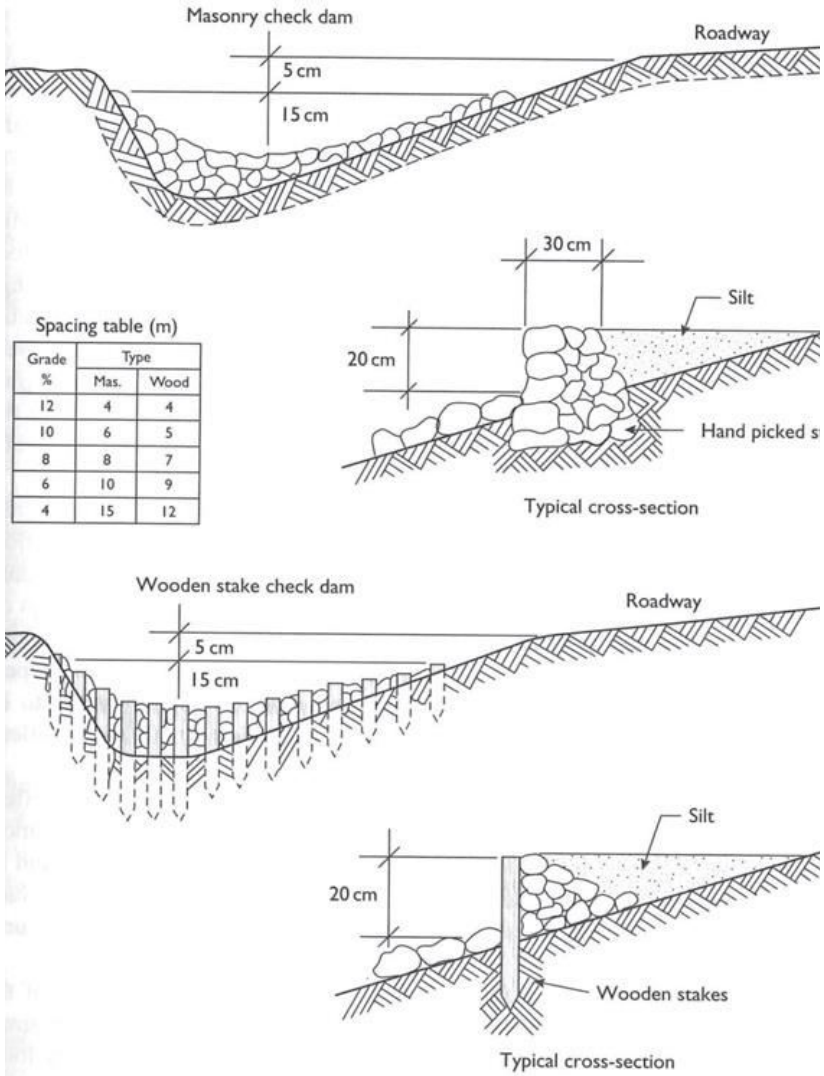
Threatens land and road

Scour checks control erosion





Types and spacing of scour checks



Spacing table (m)

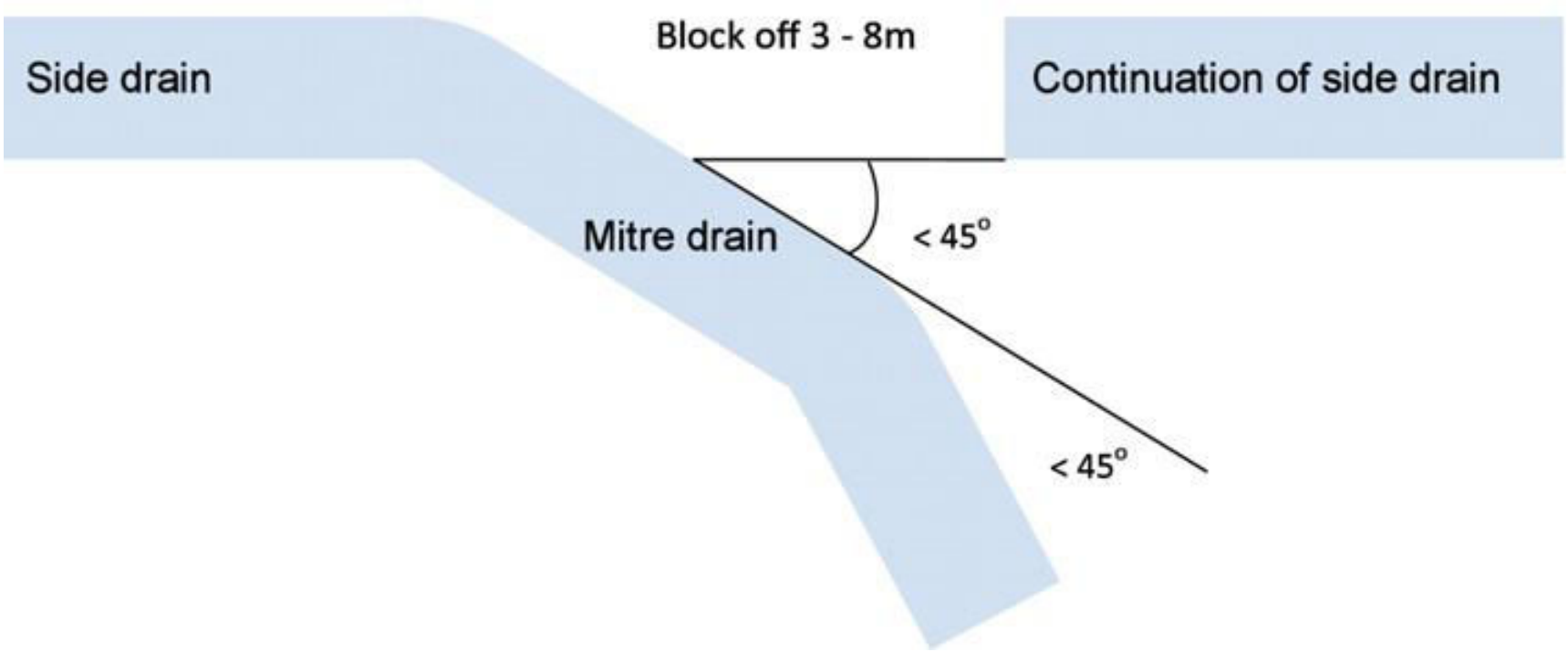
Grade %	Type	
	Mas.	Wood
12	4	4
10	6	5
8	8	7
6	10	9
4	15	12

Table D.5.6: Spacing between scour checks

Road gradient (%)	Scour check interval (metres)
3	Not required
4	17
5	13
6	10
7	8
8	7
9	6
10	5
12	4

Mitre drains

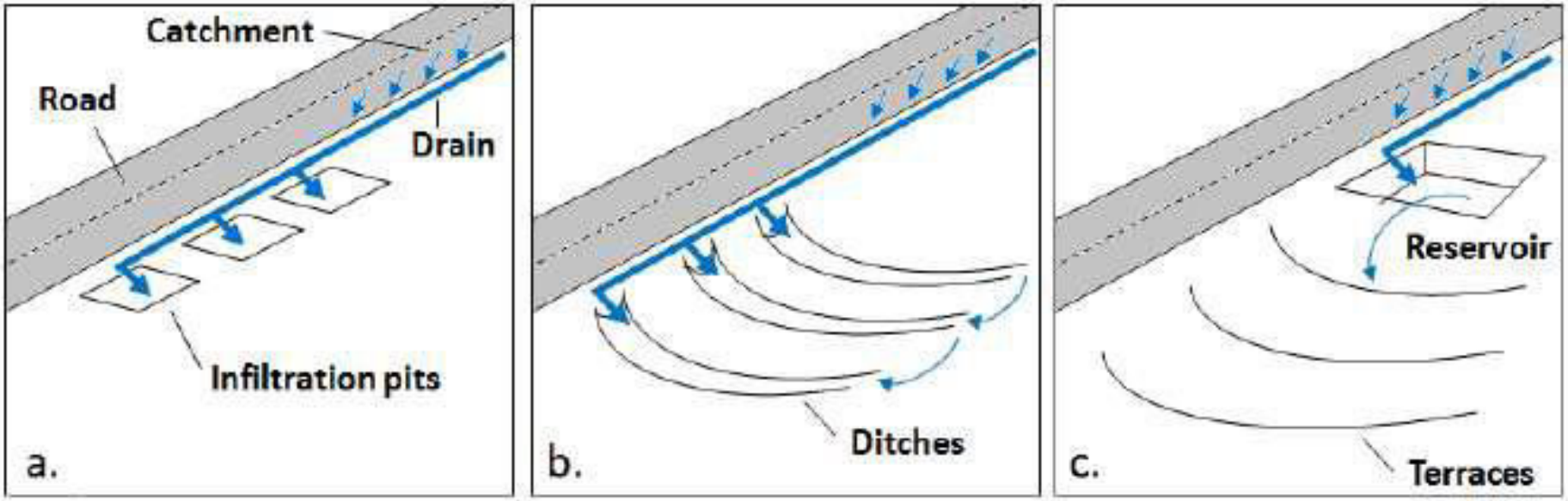
Mitre drains



Angle rises in flatter terrain

Embankment erosion

Problem into opportunity: pits, ponds, ditches and terraces



Infiltration ponds, downside drain, mountainous terrain

Ponding of water from downside drain, Tigray, Ethiopia

A hand-dug well which is recharged from ponding of water along road.

Culvert outlet as it should be

Culverts: pros and cons

Advantages	Disadvantages
▪ Culverts provide a relatively cheap and efficient way of transferring water across a road ▪ Can be constructed and maintained primarily with local labour and local materials ▪ Culverts allow vehicle and foot passage at all times ▪ Culverts do not require traffic to slow down when they are crossed ▪ Culverts allow water to cross the road at various angles to the road direction for a relatively small increase in costs	▪ Regular maintenance is often required to prevent the culvert silting up, or to remove debris blockage ▪ Culverts act as a channel, forcing water flow to be concentrated, so there is a greater potential for downstream erosion compared with drifts ▪ Culverts are not suited to occasional high volume flows

Culvert problems: siltation

Culvert problems: blockage

Culverts not suited to occasional high volumes

Culvert problems: concentrating flow and erosion

Minor erosion in watercourse upstream from culvert

Serious erosion downstream from the same culvert due to concentration of flow and lack of appropriate protection measures

Culvert problems: concentrating flow and erosion

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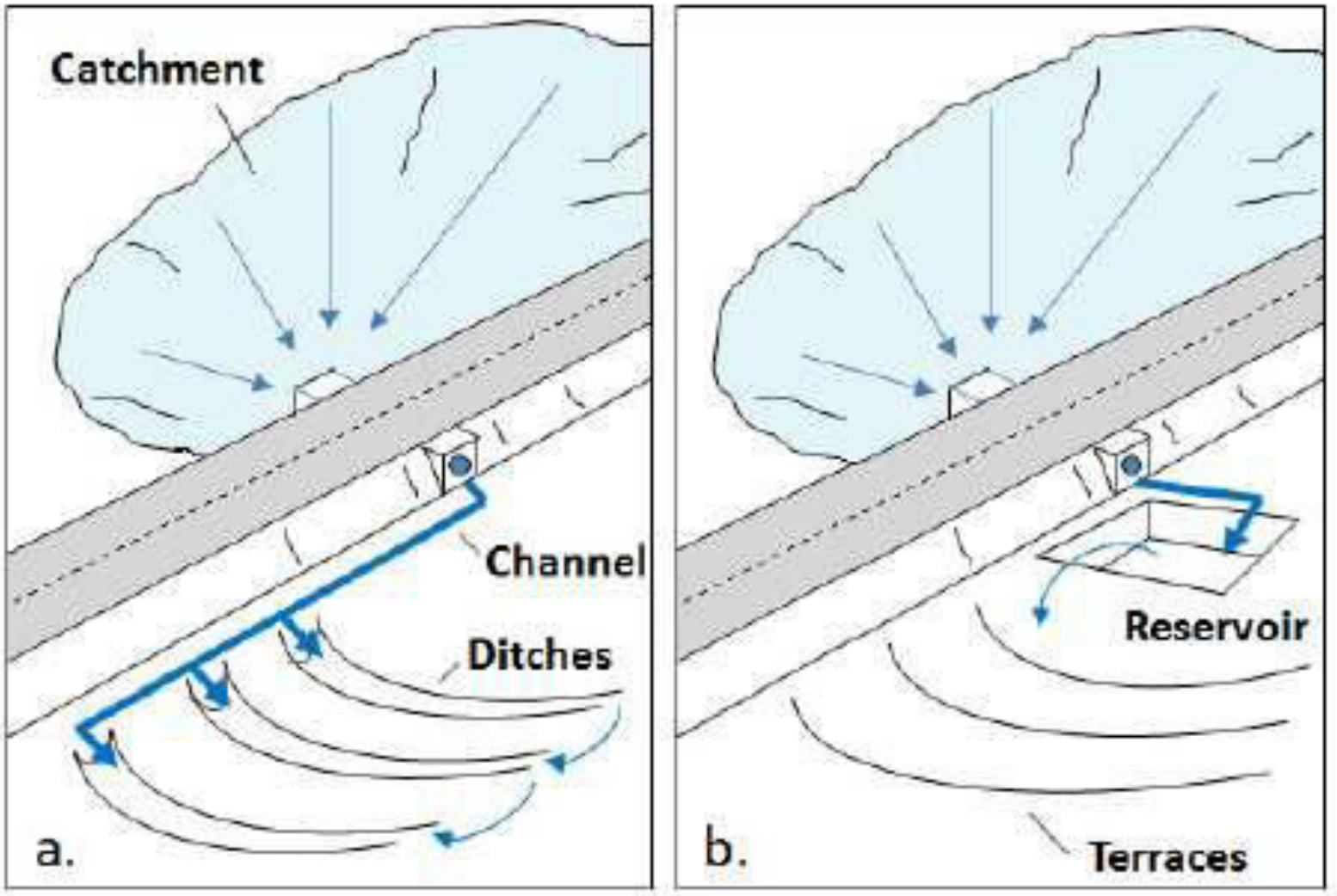
Culvert problems: concentrating flow and erosion

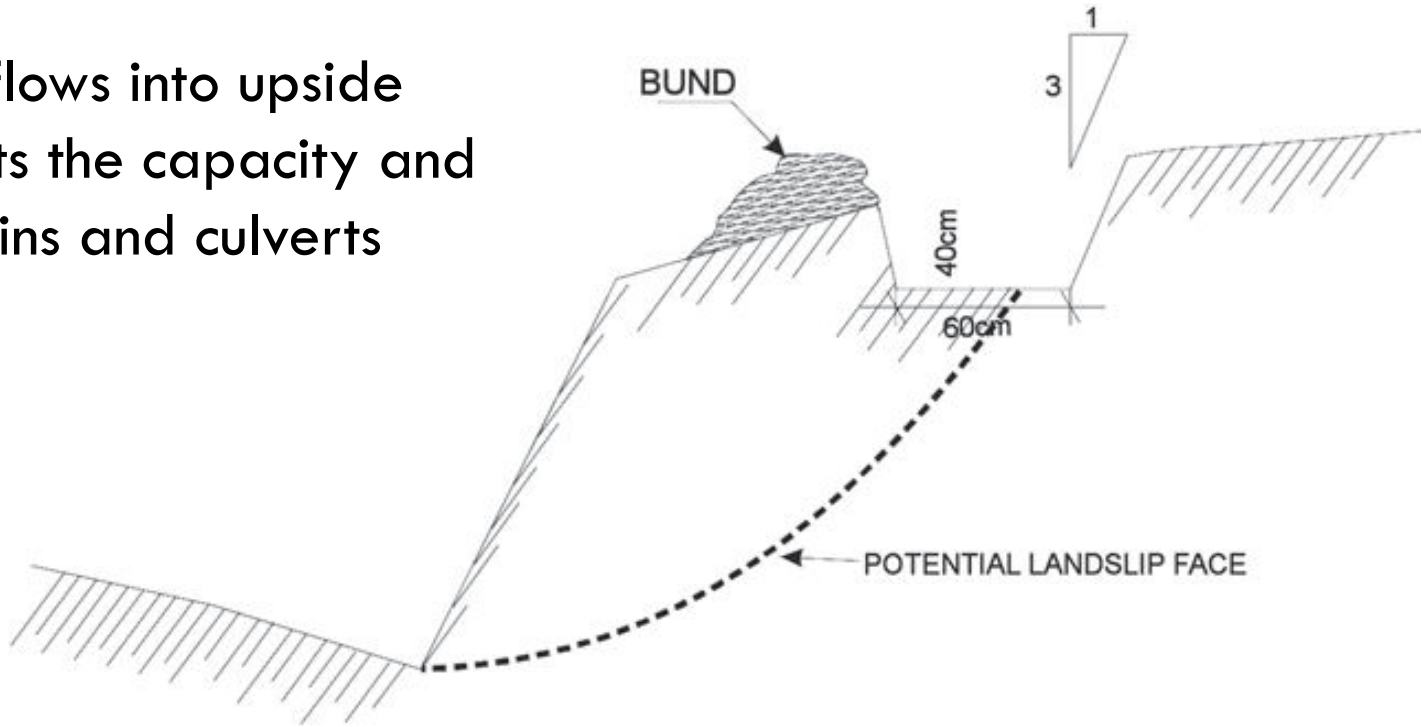
Problem into an opportunity



Problem into an opportunity
fanja juu terracing

Terracing land above upside drain boosts yields and reduces erosion

It also reduces flows into upside drain and so cuts the capacity and cost of side drains and culverts required



CATCH WATER DRAINS

Ponding water on upside of culvert using sluice gates

SE Mali,
flat terrain

Roadside pond on downside of culvert Yemen, in flat terrain

Ponding water on downside of culvert Ethiopia, in flat terrain

Photo: Sept. 01, 2013

Photo: Sept. 23, 2013

Sedimentation and erosion control: gabions, check dams, gulley reclamation

- Screens to prevent blockage
- Use drifts on river crossings unless significant flow
- Scour checks reduce and harvest sediment
- Correct inlet, gradient and outlet design to be self scouring
- Gabions, rip-rap, masonry protection on outlets
- Check dams and environmental protection measures

Examples of gabion protection

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