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Remedial Measures:

Construction Practice

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- 9.1 Spoil Management
- 9.2 Cut and Fill Slopes
- 9.3 Drainage
- 9.4 Wall Construction
- 9.5 Site Safety

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9.1 Spoil Management: Sources of Spoil During Road Operation

- From landslides onto the road or into the side drain
- From streams that discharge debris onto the road or block culverts
- From road improvement works, including road widening, slope improvement or wall reinstatement, where the excavated material is not re-used as fill

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- Many landslides below the road are triggered or made worse by spoil dumping

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Spoil Management: Preferred Spoil Dumping Locations:

Where should the material blocking the road or roadside drain be dumped?

Slip debris should only be dumped in locations where it will not cause more stability problems nor create land-use, environmental or safety issues. In decreasing order of preference, these are:

- on level ground;
- on the tops of spurs;
- at steeper locations protected by resistant bedrock; or
- at locations as far away from the edge of the road as possible.

However, in many mountain areas these locations are often uncommon

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Spoil Management: Where not to dump spoil

Where should the material NOT be dumped?

Slip debris should not be dumped:

- on the valley side of a "sinking" area; it should be taken away at least beyond the boundary of the sinking area;
- on top of existing watercourses, as this may create major erosion problems; or
- over retaining walls, unless it is obvious that the wall is founded on non-erodible material; in particular, dumping over gabion retaining walls is likely to prevent water escaping from the gabions and cause the foundations to soften or erode.

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Water seeping through these gabions is unable to drain away due to the uncleared debris dumped in front of the wall.

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Below road gabion retaining wall largely destroyed by spoil tipping

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Spoil Management: Constructing and Reinstating a spoil slope

- Remove existing vegetation
- Remove and stockpile topsoil
- Bench the slope to key the spoil wedge (if on sloping ground)
- Decide whether a toe wall or check dam is required to support spoil (if on sloping ground)
- Preferably compact the spoil in layers
- Compact the final surface layer to reduce erosion
- Spread topsoil and plant (bio-engineering Theme 10)
- Prevent road and other drainage from flowing over the slope

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9.2 Cut and Fill Slopes

Cut Slopes

- During the wet season, failures in cut slopes occur where slopes have been cut too steeply for the materials that form the slope as the water content in the slope increases
- They also occur where an external force or a factor becomes applied
  - Change in land use on the slope above
  - Change in drainage condition on the slope above
  - Erosion at the base of the cut in the side drain or on the slope itself
  - Excavation of the slope for widening or some other reason

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9.2 Cut and Fill Slopes

Fill Slopes

- During the wet season, failures in fill slopes occur where slopes have been formed too steeply for the fill material
- They also occur where the fill slope itself triggers movement in the underlying slope, or where there is a pre-existing landslide below
- They also occur where an external force or a factor becomes applied
  - Where road runoff is allowed to drain into the slope
  - Where they become surcharged by spoil during maintenance
  - Where toe erosion below leads to loss of support
  - Where the vegetation pattern on the fill slope changes

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Recommended practice for cut slope reinstatement

- Determine extent of failure, both along the road and upslope, does it:
  - Occupy the cut slope only, or
  - Extend upslope into the natural hillside
- Determine the approximate depth of the failure
- Confirm that it is confined to the slope above the road, and does not extend below the road
- Assess the likelihood of continuing slope failures and decide whether debris removal only is sufficient, or whether stabilisation works are required
- If the latter is the case, schedule and design the works:

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Typical options for cut slope reinstatement works

In increasing level of hazard from 1 to 7

1. Remove landslide material from the road and any remaining loose material from the slope itself
2. 1 plus drainage control above the slide area if there is a remaining source of water
3. 1 and 2 plus cutting back of any over-steep sections of slope above the failure that look as if they could fail in the future
4. 1 - 3 plus bio-engineering of the slope to protect it from erosion and shallow failure
5. 1 - 4 plus toe protection of any remaining slide debris
6. 1 - 4 plus a toe retaining structure to retain landslide debris or prevent further cut slope failure
7. 1-6 plus drainage of the slope itself to lower the water table, thereby increasing stability.

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- **Remember that a spoil management plan is required prior to embarking on remedial works.**

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Typical options for fill slope reinstatement works

1. Reinstate failed section of slope by re-excavation of fill and re-compaction, and replacement if fill is below specification
2. If the entire fill slope has failed consider the relative merits of:
    1. A toe wall to retain the fill
    2. A retaining wall at road level, founded into natural ground, thus avoiding the need for a fill slope
3. Control of surface water, especially road runoff, to prevent water from entering the fill slope
4. Ensure that the toe of the fill slope (or retaining wall) will not be exposed to erosion by an adjacent stream, river or road drainage discharge
5. Apply bio-engineering or other surface protection to the finished slope

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Construction & Reinstatement of Fill/Spoil Slope

Tidy up afterwards. Remove or reshape and compact unsightly heaps of debris on the side of the road. If appropriate, carry out bio-engineering to reduce the risk of erosion.

If the slip is very minor, there may be no other further requirements. If it is obvious that further movements are going to occur, or water is continuing to seep into the failed area, or the road itself has partly fallen away, then additional measures will be required. These are likely to include:

- additional drainage;
- retaining wall construction; and
- bio-engineering.

Damage caused to a slope below a road by bad tipping practice.

Bio-engineering is covered in Theme 10

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9.3 Drainage

- Control of drainage is vital to the stability of road side slopes and structures
- It is also important if the impact of the environment is to be minimised
- As well as the control of drainage, slope and stream channels need to be protected against erosion

Some key points are

raised on the following slide:

Bituminous upstand to wall for drainage control

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Temporary/emergency drainage measures

Why are temporary drainage measures required?

If the failure is located below the road, immediate steps should be taken to prevent water from the road surface or drainage system from entering the crest of the failure and creating further instability. It may be necessary to dig catchpit bypass channels to prevent roadside drainage water from entering a culvert. The upstream roadside drain may need to be blocked and water directed across the road away from the failure by an earth bund to a more suitable temporary discharge point.

If the failure is located above the road with debris blocking the roadside drain, then immediate measures should be taken to prevent the water from crossing the road and discharging at random down the valley slope.

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- If side drains are not regularly maintained then they become blocked and water can then flow across the road causing serious damage
- The road geometry can cause road drainage to cross the road and discharge into unprotected slopes and channels. This hazard should be anticipated and monitored and drainage diversion/protection measures taken accordingly
- Water ingress into fill slopes and behind retaining walls can significantly reduce stability
- The pro-active drainage of landslides, cut slopes and fill slopes is also an important measure to be undertaken from the stability perspective, as has been covered in previous Themes.

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9.4 Retaining Walls

As has been covered in previous Themes, the following are vital to the satisfactory construction and functioning of retaining walls:

- **Ensure the wall is fit for purpose**
- **Ensure that the foundation is adequate and stable**
- **Ensure that it is constructed and maintained according to specification**

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Fit for Purpose

- **The wall must be scheduled and designed to cater for the landslide size and depth, and be able to withstand the forces that will act upon it.**

Wall Selection

Type	Advantages	Disadvantages
Composite masonry	Fairly cheap.	No flexibility.
	Dry stone panels very permeable	Not as strong as full mortared masonry.
Mortared masonry	Very durable.	Expensive.
		No flexibility – should always be constructed on good foundations.
		Limited permeability, weep holes should always be provided.
Gabion	Flexible – good where founding conditions are variable.	May be too flexible for road supporting retaining walls.
	Very permeable	Usually requires geotextile on back face to reduce fines seeping through wall.
	Cheaper than cemented masonry	Foundation may be softened by water percolating through wall.
		Less durable than mortared masonry.
		Difficult to construct if foundation uneven, although this can be overcome by using a mortared masonry layer at the base.
		More difficult to construct in curves in plan.
Reinforced Concrete	Very durable if good quality construction	Most expensive option
		No flexibility – should always be constructed on good foundations.
		No permeability, weep holes should always be provided

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Adequate foundation

- If the bearing capacity of the soil (or rock) in the foundation is not adequate, or the foundation slope itself is unstable then the wall will fail. Field mapping and investigations will be required to ensure or maximise stability

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Attention to detail during construction: Masonry

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The mix for this mortared masonry wall is much too dry and being applied too sparingly. The exposed face of the wall needs to be properly finished and smoothed.

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Good and not-so-good gabion wall construction

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Compaction of free-draining fill behind a masonry retaining wall using a vibrating plate compactor.

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9.5 Site Safety

Who requires protection?

- Safety to workforce (hard hats, harnesses, safety briefings and audits etc)
- Safety to road users (falling debris, falling into excavations, collisions etc)
- Safety to pedestrians and local residents (falling debris, falling into excavations, collisions etc)

From what?

- Rock fall/debris fall and landslides
- Excavations in slopes
- Excavations in roadway for road repairs and retaining walls
- General plant operations
- Spoil disposal

Develop a Safety Plan that contains Physical and Operational provision for Safety and ensure workforce and public are fully briefed in its implementation.