Roads in flood plains (1)

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Costs and benefits of floods

- Costs: damage to infrastructure and houses, lost lives and crops
- Benefits: sedimentation provides fertile lands, flushing of stagnant water and pollutants and opportunities for flood based farming

Goal: to adapt to the constrains that floods impose and take advantage of their benefits

Interactions between roads and floods

- Roads fragment habitats and interrupt the flow of water, sediments, nutrients and aquatic life
- Roads can act for instance as ‘reservoir dam’ to keep water for irrigation in the dry season
- Floods cause damage to infrastructure increasing maintenance costs
- Flooding on one side of the road and drying out on the other, altering vegetation and associated species

Roads in floodplains

Construction-Maintenance	Drainage characteristics	Erosion susceptibility	Water Harvesting potential
Elevated subgrades and embankments can increase costs as construction material in floodplains can be scarce.	Laminar flows through floodplains require wide drainage systems, flood control mechanisms such as flap gates or surface drainage outlets.	Waterlogging on buffer areas between road embankments and floodplain. Flood interception – less moisture (sediments) on downstream areas. This can have major impact on flood plain agriculture	Shallow groundwater – hand dug wells and manual drilled boreholes as well as dugout ponds and borrow pits

Roads as flood control mechanisms

- Roads subgrades and embankments act as dikes, many roads in the Netherlands are laid on the top of dikes.
- In areas prone to periodical floods – roads may serve as flood regulators.
- Roads laid in floodplains often block flood flow fronts diminishing flood areas.
- This scenario could be reverted if road design principles are modified.
- Road may be open to flood flows enabling "flood corridors" including bridges and long culverts, flap gates and fusing sluice gates.
- Thus roads can act as flood regulators, controlling flood and drainage patterns.

Road design in flood plains

- Planning and design should take into account the local flood flow patterns
- Assess the existing hydraulic behaviour of drainage paths, waterways and floodplains, with particular reference to known and potential flood levels in the vicinity of the road alternatives.
- Identify and assess the potential short- and long-term impacts of construction and operation on the quantity and quality of surface runoff, floodplain inundation and waterway water quality.

Damage to rural road by flood

Important questions to be addressed during planning phase

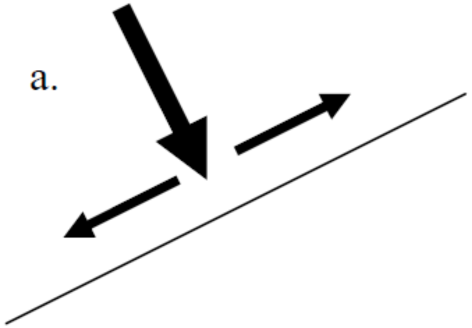
- Will the project affect an existing water course or floodplain?
- Will the project change either the road drainage or natural land drainage catchments?
- Will the project change the number or type of junctions?
- Will earthworks result in sediment being carried to watercourses?
- Will the project allow drainage discharges to the ground?

Road embankment geometry

- The recommended crest level for National and Provincial roads is the highest recorded flood level plus 0.5 meters. For regional roads the crest level should correspond with a minimum height of the water level of floods with a recurrence of 10 years plus 0.25 meters.
- For road embankments up to 4 meters high a slope gradient of 1:3 provides sufficient safety protection against the macro-instability mechanism during the rise and fall of the water level.
- Investigate the geotechnical characteristics of the top soils and take adequate measures in road design, for example removal of inappropriate top soils.

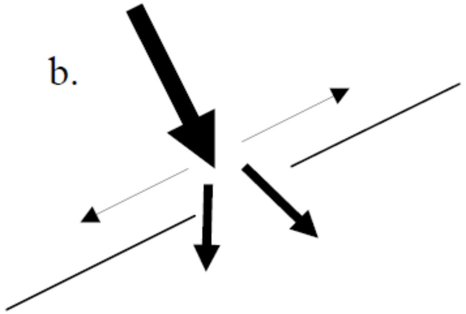
Resistance vs resilience strategies

- *Resistance strategy:* embankments and roads are constructed to protect r extract areas from the influence of floods
- Disadvantages:
  - pressure on the structure can cause **damage** and high maintenance costs
  - floodplain hydraulics are **disrupted**, which negatively impacts on the floodplain ecosystem
  - water **quality problems** because dirt and polluted water are no longer removed by the flood waters



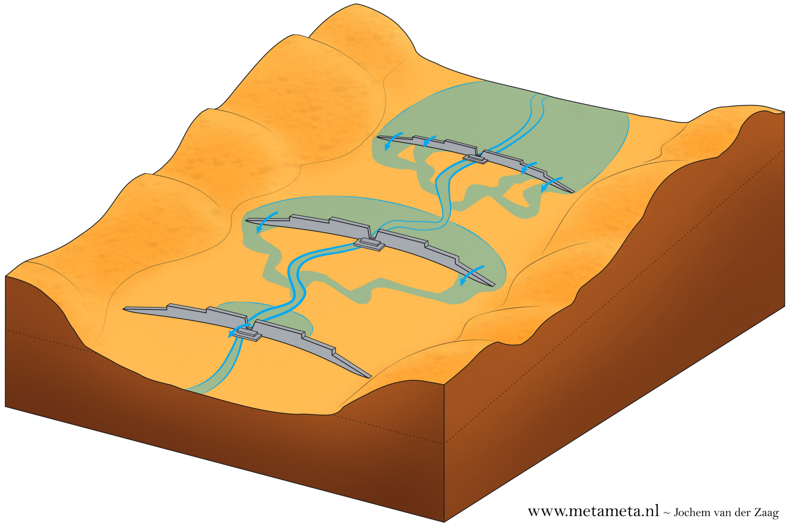
Resistance vs resilience strategies

- **Resilience strategy:** minimizing the consequences of floods, but at the same maintain the natural floodplain dynamics as much as possible.
- Might require higher initial investment, but **longer term costs** in terms of road damage and ecological impacts will be **lower**.
- Important to locate bridges and culverts at the best possible locations and recommend solutions that have only small additional construction costs.



Water spreading weirs

- Example of resilience strategy
- Temporary floods are routed out of the dry river beds so as to inundate the surrounding area
- The river crossings as well as embanked roads leading to them act as flood spreaders
- Drop structures and cross drainage is provided so as to ensure their stability



Example of resilience approach: Room for the River in the Netherlands

- Creates safety against extreme river floods by widening river cross sections to lower flood levels.
- Situating the dikes further away from the river, or lowering the river forelands, to reduce velocities and water levels by providing space for the watercourse.
- Requires properly designed flow-through structures that can withstand the high flow velocities.

Approach	Pros	Cons
Resistance strategy	• Better protection against floods • Reduction damage in high density • areas	• Fragmentation of floodplains and hydraulic changes and impact on flood-related functions • Downstream impacts • More expensive to protect roads against damage
Resilience strategy	• Less fragmentation floodplains and hydraulic changes • Less damage to roads • Long-term benefits to both financial investment in development and biodiversity conservation • Increased awareness of dangers of floodplain living	• More costly due to construction through-flow structures • Reduced access (lower roads) • More need for integrated planning and management

Integrated approach

- Flood mitigation measures upstream such as protection dikes, drainage from protected areas (irrigation schemes, cities, towns) or flushing of flood water from reservoirs will affect flood conditions downstream.
- Land-use development and construction of roads and through-flow structures change the natural flood flow patterns and increase flood risks to adjacent areas as well.

Conclusions

- Road developments in a floodplain system, require a **different approach to planning and technical design**, compared to road developments in areas that are not (regularly) inundated
- Need for **harmonisation of standards and guidelines** and inclusion of the specifics of developing roads in a dynamic floodplain system
- Search for a **win-win solution** where robust technical designs lead to benefits for various construction cost, infrastructure maintenance, ecology, natural resources and vulnerability of population.

Design recommendations

1. Tailor alignment and design solutions to the specific floodplain hydraulic and ecological situation
2. The number and dimensions of flow through openings (bridges and culverts) should be such that interference with the natural hydraulics of the floodplain in terms of extent and duration is minimal
3. Scour protection near bridges and other flow-through openings in order to prevent damage to the abutments and eventually the structure itself

Recommendations for technical design guidelines

1. Update and review the design standards and guidelines so road designers have better guidance and best-practice examples of how to develop flood proofed and environmentally friendly roads
2. Incorporate a hydraulic analysis or determination of the flood hydraulics and loads on road structures
3. Make costs analysis for the different options of slope protection, costs of flow through structures (bridges and culverts etc) and quantify the options in the integrated approach

Research and capacity building

- Improve knowledge of the floodplain system in terms of interactions between floodplain hydraulics and basin developments, functions of the system, critical thresholds to maintain these functions and values of the functions.
- Invest in education, training and technical support to introduce and / or strengthen practice of integrated planning of road development and rehabilitation.

General recommendations

- Apply an **integrated planning approach** that considers the consequences of the development throughout the system including environmental and social impacts.
- Apply a floodplain system's approach in which not only local impacts of roads but also regional and cumulative impacts are considered.
- Provide sufficient coordination between road development and rehabilitation planning and other sector planning.
- Assess possible transboundary (provincial, national, international) impacts of road development and rehabilitation