INTEGRATING CLIMATE CHANGE ADAPTATION AND WATER MANAGEMENT IN THE DESIGN AND CONSTRUCTION OF ROADS IN ZAMBIA

Status and Opportunities

WORLD BANK GROUP

Roads for Water

META META

RDA

Contents

Executive summary

Road construction often changes surface runoff patterns which, if unmanaged, can lead to water-related problems. The most common design approach in road development is to allow water to flow through hydraulic structures (roadside ditches, culverts, bridges) to ensure the safety of the structures. In many countries, water shortages are a common challenge. Research carried out in Ethiopia and other countries shows that water harvesting from roads has multiple benefits: it enhances soil moisture and groundwater recharge; it increases the availability of surface water for multiple uses; it reduces flooding and erosion at downstream areas; and it increases the resilience of local communities to droughts and rainfall variability. MetaMeta was given the assignment to assess and introduce the systematic use of roads for water management in Zambia.

MetaMeta undertook the following steps to assess the potential for water management in Zambia:

(a) Conducting preparatory and support activities, including communication with key stakeholders, identification of potential road corridors for surveys, and use of remote sensing information to assist the mission

(b) Reviewing strategic plan documents for Zambia, mainly considering road and water sectors

(c) Conducting a transect survey of representative roads (about 1,450 km) of different road types (feeder and highway), topography, and agro-ecology

(d) Facilitating discussions with government experts and decision-makers from the road and water sectors

(e) Facilitating discussions with community members (farmers) and contractors involved in road development

Results of the assessment show that the main water-related problems in Zambia are siltation/sedimentation of road hydraulic structures such us culverts; erosion downstream of road hydraulic structures, including scouring of bridge foundations; water logging and associated challenges; and water-related slope failures.

This study shows that there is high potential to use roads as instruments for water management in Zambia for several reasons:

(a) Integrating road water management in the design and construction of roads could provide additional livelihood opportunities and reduce maintenance costs.

(b) Shallow groundwater is a major source of water for small-scale irrigation and rural water supply in Zambia. Discussions with stakeholders reveal that there is a general decline in shallow groundwater levels; hence, water from roads can recharge groundwater.

(c) Zambia, under WARMA, is creating water resources development master plans for its major basins; road water management options could be integrated into these plans.

(d) The road sector in Zambia, under RDA, is developing a climate resilient strategy for roads. Road water management is a strategy that needs to be integrated to enhance benefits and ensure road safety.

1. Introduction

Road development is one of the largest investments in many countries of the developing world, but due to water-related issues challenges often present during and after the construction of roads. Road hydraulic structures (culverts, roadside ditches, bridges, and road embankments) act as conveyance systems for the concentrated flow of water. Unmanaged water from roads could lead to several problems, including downstream flooding; siltation/sedimentation; erosion of downstream areas; and damage to other infrastructure, including the roads themselves.

The beneficial management of road water, on the other hand, has considerable potential:

- To reduce damage to road infrastructure and provide a cost-effective approach to addressing the effects of climate change.
- To reduce damage to the surrounding areas (flooding, drainage congestion, erosion, sedimentation) triggered by roads.
- To create useful assets in terms of harvested water and increased flood protection using the roads.

Research carried out in Ethiopia and other countries reinforces the above arguments, where managing road water has resulted in multiple benefits: it enhances soil moisture and groundwater recharge; it increases the availability of surface water for multiple use; it reduces flooding and erosion at downstream areas; and it increases the resilience of local communities to droughts and rainfall variability. Road water management is a strategy that has great potential to safeguard roads from water-related damage and to foster the use of roads as instruments for climate change resilience.

MetaMeta was given the assignment to assess and introduce the systematic use of roads for water management in Mozambique, Bolivia, Zambia, and Tajikistan. This report[1] describes the results of the mission carried out in Zambia.

2. Approaches and Methods

The activities undertaken to make the assessment include the following:

- **Conducting preparatory and support activities**, including included communication with key stakeholders, identification of potential road corridors for surveys, and use of remote sensing information to assist the mission.
- **Reviewing strategic plan documents for Zambia**, including conducting a review of strategic documents for different sectors (road, water, agriculture, and environment) to obtain useful information for promoting road water management in Zambia.
- **Conducting a transect survey of representative roads** to survey the status of and potential for road water management. We surveyed 1,450 km of roads of different road types (feeder and highway), topography, and agro-ecology of Zambia (Figure 1) in Central, Lusaka, Southern, and Copper Belt Provinces. A comprehensive check-list was used during the transect survey.
- **Facilitating discussions with government experts and decision-makers** from the road and water sectors (local and national levels) in Zambia (Annex 3).
- **Facilitating discussions with community members**, particularly male and female farmers involved in small-holder farming (rainfed and irrigated).
- **Facilitating discussions with road contractors** to assess current construction approaches; the potential to promote road water management was discussed with the national contractors association.

[1] This assessment is undertaken by MetaMeta under the World Bank assignment "Integrating Climate Change Adaptation and Water Management in the Design and Construction of Roads". The Mission was undertaken by Kifle Woldearegay, Taye Alemayehu, and Sundie Silwimba from 14-27 July.

- **Hosting a workshop on 26 July 2017** with key stakeholders who play an important role in promoting road water management, including presentations (by stakeholders and consultants) and discussions on the status and opportunities for prompting road water management for resilience in Zambia. For the list of participant see Annex 3.

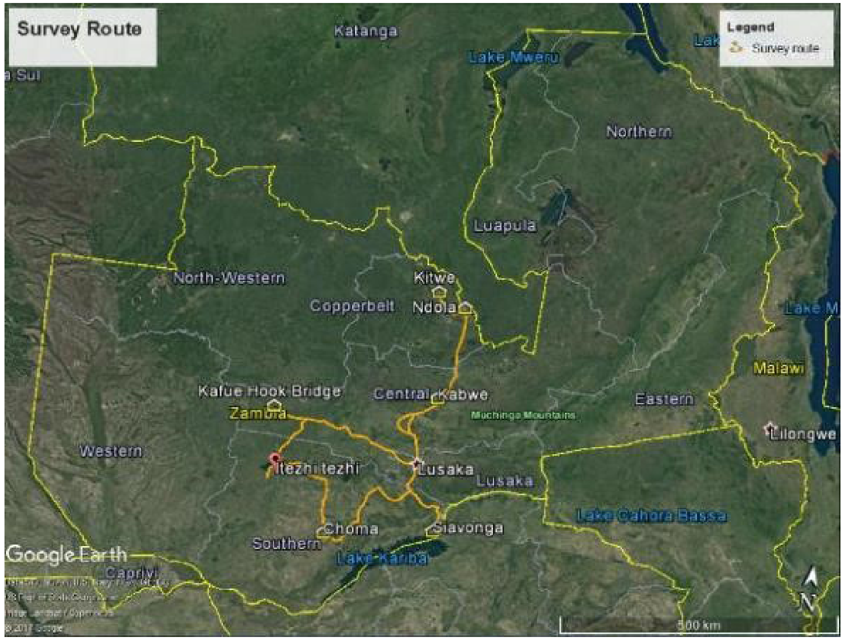


Figure 1: Route of the road transect survey in Zambia

3. General characteristics of Zambia

A landlocked country, Zambia is located on the plateau of Central Africa, between 1,000 and 1,600 m above sea level: the average altitude is about 1,200 m. Zambia's total land size is 752,614 km^2, and its population is about 16,212,000.

The climate of Zambia is tropical, modified by elevation. There are two main seasons: the rainy season (November to April) and the dry season (May/June to October/November). The average temperature in Zambia in the summer is 30°C, and in the winter it can get as low as 5°C.

The agro-ecology of Zambia is divided into three zones (Figure 2): region one, which receives less than 800 mm of annual rainfall; region II, which receives between 800 mm and 1,000 mm of annual rainfall; and region III, which receives more than 1,000 mm of annual rainfall.

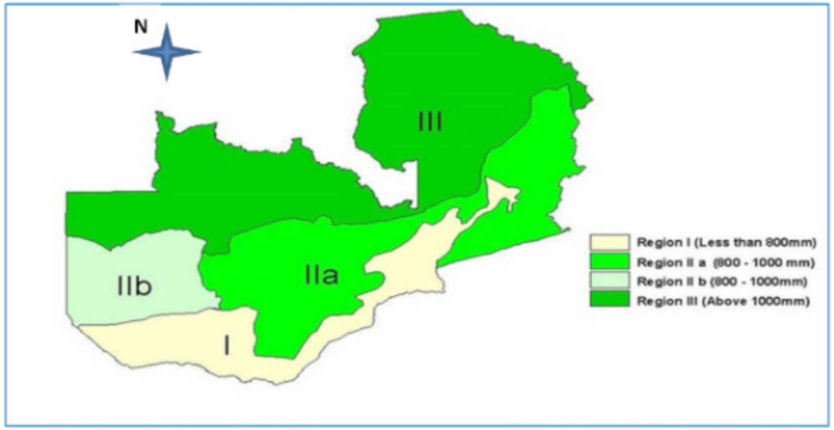
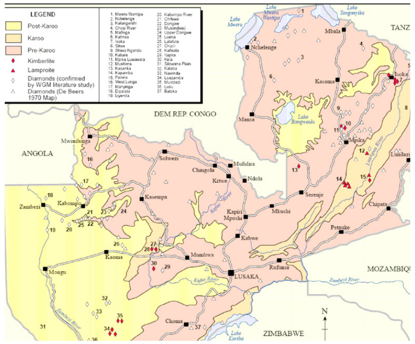
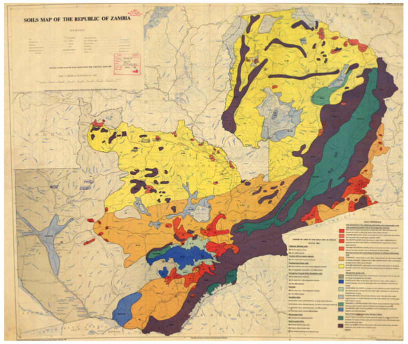


Figure 2: Agro-ecological zones of Zambia (Source: Zambia Meteorological Department)

The geology and soil types of Zambia create both an opportunity and a challenge for road water management. The geology is dominantly Precambrian basement (Figure 3a) with loamy, sandy soil types, found in most parts of the northern and central regions. Rock and rubble type soils dominate in the southern and northeastern regions (Figure 3b).

 *Figure 3a: Dominant soil types found in most parts of the northern and central regions*	 *Figure 3b: Dominant soil types in the southern and northeastern regions*

4. Climate Change in Zambia and the Need for Climate Change Resilient Roads

Historically, Zambia has been prone to extreme rainfall events resulting in widespread flooding. River flows in central and southern Zambia were generally below average from 1910 to 1950 and in the period after 1980. Zambia saw a wet period between 1951 and 1979. Hydrological droughts occurred in the Kafue and Zambezi river areas. During these hydrological extreme periods, impacts of the drought on the reservoir of Kariba were disastrous, affecting power generation and resulting in widespread crop failure, loss of livestock, and disruption of urban lifestyles due to water rationing (Gottschalk et al., 1999). A recent flooding event during the 2006-7 rainy season saw nearly 1.5 million people affected (GRZ, 2007). Typical impacts from a major flooding event include collapsed houses and buildings; destruction of infrastructure (roads, sanitation facilities); waterlogged agricultural fields; destruction of crops; contaminated water supplies; and an increase in human diseases (Ibid).

Climate forecasts and climate change projections for Zambia show that annual temperatures in Zambia have increased by 1.3°C since 1960 and are projected to increase above the 1970-1999 average by 1.2 to 3.4°C and 1.6 to 5.5°C by the 2060s and 2090s, respectively. Similarly, annual rainfall has decreased by an average of 1.9 mm per decade since 1960, and projections show an overall downward trend in precipitation. Most alarming is the increase in extreme events. Zambia has experienced an increase in the frequency and intensity of drought and flood events in recent decades. Climate models project an increase in the frequency and intensity of heavy rainfall events during the rainy season (GRZ, 2007; Leary, Kulkarni and Sept, 2007; USAID, 2013). Records of emergency events from 1980 to 2009 show an exponential increase in extreme events. Between 1980 and 1989, only three emergency events were recorded. These increased to four events between 1990 and 1999, and twelve events between 2000 and 2009. Eleven of the emergency events were droughts. Zambia is vulnerable to an increased frequency of drought and a shortening of the growing season. Key crops (sorghum, cassava, millet, and maize) cannot mature during this short growing season. Supplemental irrigation from road water harvesting ponds and extra soil moisture can help bridge the gap between dry-spells.

Agroecological zones I and II (Figure 2) are predicted to experience strong water deficits at critical periods of crop calendars, resulting in severe decreases in crop yields. Is in these areas, water harvesting will be critical for the livelihoods of the rural population (UNDP 2010)[2].

[2] Adaptation to the effects of drought and climate change in Agro-ecological Regions I and II in Zambia. 2010. UNDP. http://www.undp.org/content/dam/undp/documents/projects/ZMB/00058205_Adaptation%20ProDoc_FINAL_.pdf

As shown in Figure 4, Zambia's southern and eastern regions are more prone to erosion. In those areas, road erosion control measures (roadside revegetation, water bars – see section 7) should be implemented to protect roads and the surrounding areas. The northern region experiences more floods; therefore, road water management measures will be focused on the safe disposal of excess road run-off and the implementation of catchment management measures to increase water infiltration around the roads.

To combat these challenges, Zambia has developed a National Climate Change Response Strategy (NCCRS) to support and facilitate a coordinated response to key climate change issues in the country. The goal is aligned with the period of the Sixth National Development Plan; however, in the longer term the goal is to ensure climate change is mainstreamed in all sectors by 2030 (GRZ, 2010).

Climate predictions for Zambia show the importance of climate resilient roads. Such roads will sustain predicted extremes. Apart from protecting road structures and minimizing the cost of road maintenance, proper management of road water will help compensate for the lost moisture for crops, wildlife, livestock, and humans in dry years, and will minimize flood hazards in wet years.

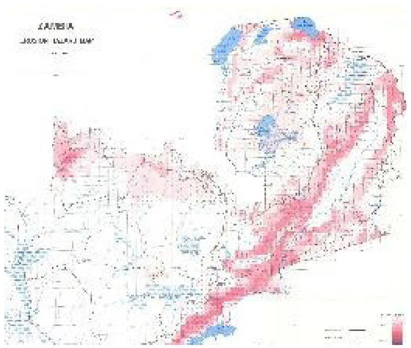


Figure 4. Zambia erosion hazard map – red areas are more prone to erosion (Source: European Soil Data Centre)

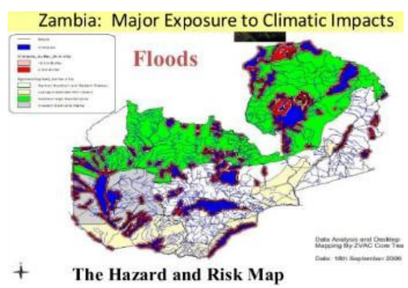


Figure 5. Areas in Zambia exposed to floods (blue and purple areas), excessive rainfall (green) and drought (light yellow)

5. Road development in Zambia: Status and water-related challenges

5.1 Road sector development in Zambia: Status and Plan

Zambia has a total Road Network of 67,671 km, and out of this the Core Road Network (CRN) is 40,454 km (Table 1).

Table 1. Classification of the Core Road Network (CRN)

Road Type	CRN (km)
Trunk (T)	3,116
Main (M)	3,701
District (D)	13,707
Urban	5,597
Primary Feeder (PF)	14,333
Total	**40,454**

The Road Development Agency (RDA) of Zambia oversees the design and construction of roads in Zambia, including maintenance. Road and bridge maintenance is currently coordinated by the Road Maintenance Directorate under RDA. The primary maintenance functions include:

- Routine maintenance: applied on roads/bridges in good and fair condition to preserve the road assets
- Periodic maintenance: typically carried out once in five years
- Emergencies: work carried out as a reaction to unplanned problems that occur on the road network arising, for instance, from wash-away on culverts, bridges, etc.

National program “Link Zambia 8000 Project”:

The Link Zambia 8000 Road Project (Figure 4), also known as the Accelerated National Roads Construction Program, is a five-year project that the Government of the Republic of Zambia initiated to accelerate road construction in the country through the Road Development Agency (RDA). The project aims to improve about 8,000 km of roads at an estimated cost of US$ 400 million over 10 years. The project was launched on 20 September 2012 and is expected to be completed in 2018. The Link Zambia 8000 Project seeks to achieve the following objectives:

- Transform Zambia into a truly land-linked country
- Create 24,000 jobs, especially for youth
- Promote the growth of the local contracting industry
- Contribute to the reduction of road user costs and transit times across Zambia
- Create economic growth poles and wealth in outlying areas (RDA, 2013)

Up to 2016, approximately 3,947 km of roads under Phase I of the Link Zambia 8000 Program were being implemented, out of which approximately 678 km have been surfaced and are open to traffic. In 2016, the project was approximately 30% complete[3], which means there is still a lot of potential to include beneficial road water management practices in upcoming road construction under the Link Zambia 8000 Program.

5.2 Road and water related challenges in Zambia

Compared to other countries in Sub-Saharan Africa, Zambia receives rainfall (typically above 800 mm) in a unimodal rainy season. Zambia is known for its extensive wetlands, lakes, and rivers. Unless improved design considerations are in place to reduce impacts of road construction on the hydrology, the increasing pace of road construction is expected to bring more negative impacts in the future. Though not yet visible, there impacts of different scales are happening to the hydrology because of roads crossing wetlands and water bodies in different part of the country (Figure 7).

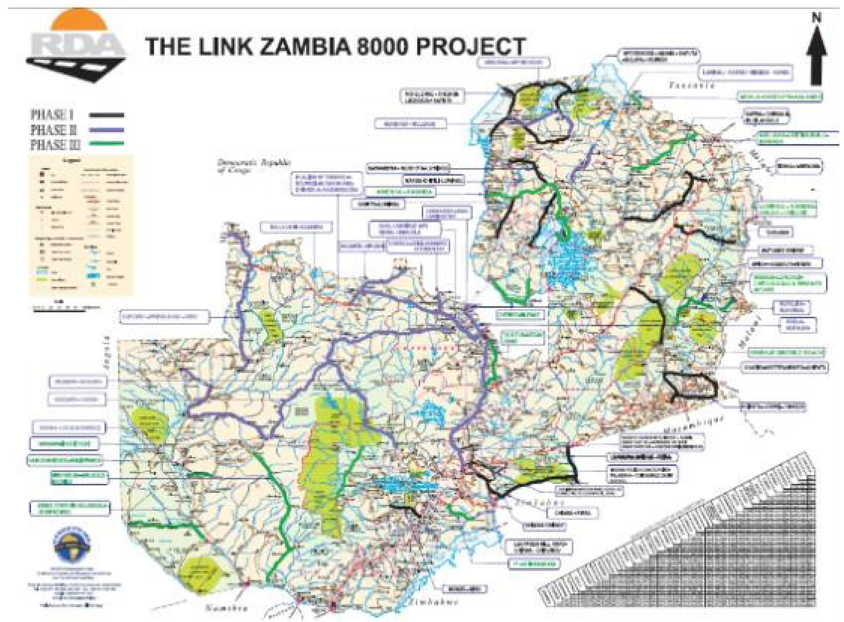


Figure 6. Map of the Link Zambia 8000 Project (RDA, 2012)

A field assessment and a report by RDA (2015) show that road water-related problems are common in Zambia, such as siltation/sedimentation of road hydraulic structures; erosion downstream of culverts; scouring of bridge pier foundations and retaining structures and road damage; water logging; and slope failures and associated road damage. These are discussed next.

[3] Link Zambia 2016 Updated. http://www.rda.org.zm/index.php/link-zambia-8000-project

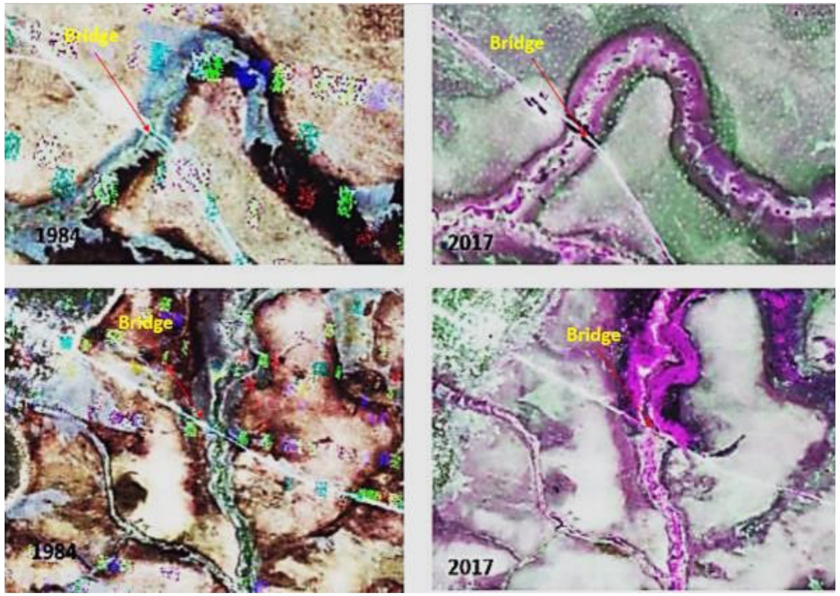


Figure 7. Emerging hydrological impacts of roads on steam flow patterns in Central Zambia as observed from Landsat images (1984 and 2017). Upstream of the bridges at both locations show expansion of the river banks and growing wetlands compared to 1984, where the bank width and the wetland conditions were similar on either side of the bridges

(a) Siltation/sedimentation of road hydraulic structures

The silting-up of culverts and roadside drains in many of the roads in Zambia is common (e.g., Figure 8 a and b). This leads to flooding of land in nearby areas and road deterioration, which results in additional maintenance costs.

Figure 8. Silting-up/blockages of culverts in Zambia: (a) a pipe culvert blocked with sand and silt, and (b) a pipe culvert blocked with woody debris

(b) Erosion downstream of culverts

Roads are often associated with downstream erosion due to concentrated water flows. In areas with higher hydraulic gradients and erodible soils, it is common to observe erosion downstream of culverts (e.g., Figure 9).

Figure 9. Examples of erosion downstream of culverts in Zambia

(c) Scouring of bridge pier foundations and retaining structures

In some cases, scouring of bridge pier foundations and lateral erosion of retaining structures is observed (Figure 10). The bridge in Figure 10 is located on a meandering stream.

Figure 10. Water-related effects on bridges in Zambia: (a) damage to retaining walls, and (b) scouring of bridge pier foundations

(d) Water logging and associated issues

Water logging at road sides of raised embankments and downstream of culverts is a common issue in Zambia, as the topography of most roads is relatively flat (e.g., Figure 11 a, b). Water logging leads to losses of land for productive use. On the other hand, though not designed with purpose, some of the raised embankments act as water storage structures and are used for livestock and wildlife watering; this is an opportunity that needs to be tapped.

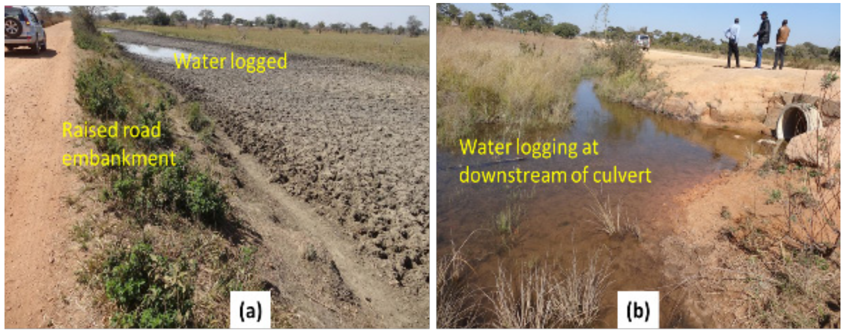


Figure 11. Water logging issues in Zambia: (a) beside raised road embankments, and (b) downstream of culverts and bridges

(e) Water-related slope failures

During heavy rainfalls, slope failures of different sizes are common (e.g., Figure 12 a and b) leading to damage on roads, blockages of drainage systems, and hampering of traffic.

Figure 12. Slope failures in Zambia: (a) debris slides that block roadside drains and result in frequent maintenance (photo: MetaMeta), and (b) road damage due to a large-scale slide (Photo: RDA: http://www.rda.org.zm/index.php/news/278-section-of-luangwa-feira-road-damaged)

(f) Other water-related problems on low volume roads

Low volume feeder roads are damaged due to a lack of proper structures to channel surface and subsurface flows (e.g., Figure 13) leading to blockages of drainage systems and muddy ground that blocks traffic during rainy months. Water runs alongside long stretches of the unpaved road, causing road erosion, puddling, and deterioration.

Figure 13. Loose road surface on a WB-funded, low-volume road; developed as a result of the absence proper drainage structures

6. Current Practices on Road Water Management in Zambia

Few current road designs adopt a systematic approach to maximizing the benefits of roads for climate resilience, with the exception of some roads that incorporate systems to channel water into borrow pits. Water from roadside drains (mitre drains), culverts, and bridges remains an unexploited resource for livelihood improvement.

From field observations during the transect road survey and discussions with various stakeholders, we learned that:

- Water from roads is considered an enemy rather than a resource to tap
- Road design is based on drainage and water discharge of into streams, not on beneficial water uses
- The various sectors (agriculture, water, roads), contractors, and communities have yet to make significant efforts to systematically use water from roads for climate resilience, despite water shortages during the dry periods and continuous lowering of groundwater levels, which could have been recharged with water from roads.
- There is no integration or joint planning arrangements among the key actors in the water, roads, and agricultural sectors.
- Similar to the road guidelines in other countries (e.g., Ethiopia, Kenya, and Uganda), the concept of beneficial road water management is missing in the RDA guidelines. There are also mandate and legal issues related to road water management, as water resources development is a mandate of the water sector rather than the road sector.

Though not done with proper designs or in a systematic manner, some road water harvesting practices are being implemented by the road sector for livestock wildlife watering and homestead vegetable cultivation. Techniques observed in the transect surveys are as follows:

(a) Use of ponds to store water from mitre drains

Mitre drains are common road hydraulic structures designed to discharge roadside runoff and minimize road damage. In some locations (e.g., Figure 14 a, b), it was observed that water from roadsides is being channeled into ponds through mitre drains for livestock and wildlife use. These ponds are also important for groundwater recharge, though maintenance, health, and safety issues are concerns.

Figure 14a. Borrow pits used to store road water using mitre drains in Zambia

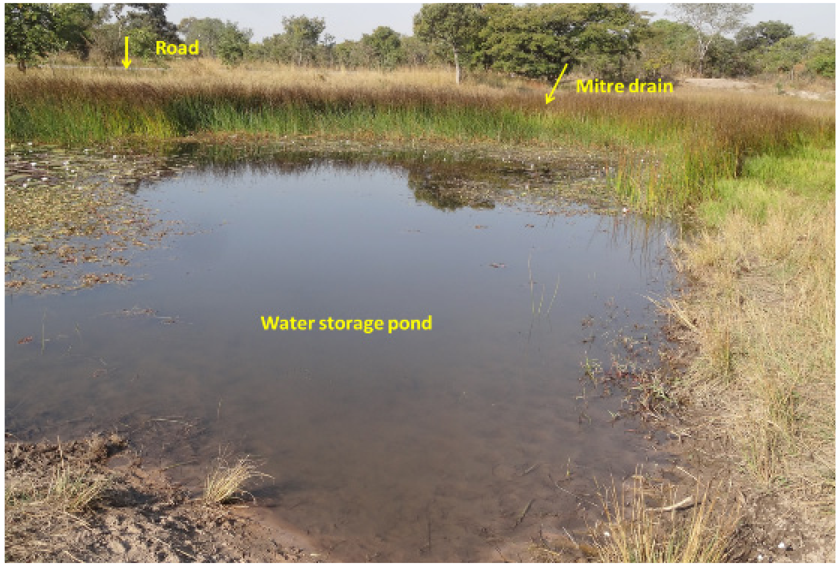


Figure 14b. Borrow pits used to store road water using mitre drains for livestock and wildlife in Zambia

(b) Use of ponds to store water from culverts

Road hydraulic structures, like culverts, often carry concentrated flows of water and can be instrumental for water harvesting if connected with storage structures like ponds. Though not systematically implemented, in some locations of Zambia water from culverts are being stored in ponds for livestock watering, small-scale irrigation, and to recharge the water supply of groundwater wells (Figure 15).

Figure 15. Use of borrow pits to store water from culverts for livestock and wildlife in Zambia

(c) Diverting water from roadsides and culverts to plantation farms

Although there are few cases like this one, some farmers are diverting water from roadsides to tree plantations (Figure 16).

Figure 16. Water from roadsides diverted to tree plantations in Zambia

In some cases, borrow pits are used for multiple purposes, including livestock, household use (washing), and small garden irrigation in Zambia.

7. Potential for promoting road water management in Zambia

The potential for road water management is related to a number of factors, including the availability of water/surface runoff; site characteristics (topography, geohydrology, etc.); water demand; scale/size of infrastructure development; etc.

In Zambia, there is good potential for promoting road water management for climate change resilience and livelihood improvement for the following explained reasons.

(a) Suitable topography and vegetation cover along road corridors for road water harvesting/management: The topography of Zambia is generally dominated by flat to gentle terrain. Water from roads follows a laminar flow and with little hydraulic gradient. There is generally good vegetation cover (grass) that helps to reduce sedimentation from roads, resulting in less siltation of water storage structures. A combination of low topographic gradient, good vegetation cover (see Figure 17), and excess runoff during rainy seasons makes it possible to systematically use roads to manage water for climate change resilience.

Figure 17. Examples of roadside drains with well managed grass in Zambia

(b) Suitable geohydrological conditions for shallow groundwater recharge with water from roads: The major rocks in Zambia are basement rocks. Most of the groundwater system is characterized by shallow aquifers, which is related to the weathered and fractured zone of these basements. Groundwater recharged using water from roads can easily be extracted using shallow groundwater wells with low-cost water lifting technologies, presenting an opportunity to promote groundwater recharge using roads.

(c) High demand for water (for livestock, groundwater recharge): Discussions with key stakeholders reveal that water demand across sectors (water supply, livestock, and wildlife) has been increasing. The high demand for water could help to promote road water harvesting/management.

(d) Increase in off-season, small-scale irrigation practices: Through field observations and discussions with stakeholders we learned that small-garden irrigation practices are emerging using water from various sources like shallow groundwater wells (Figure 18), ponds, and streams. Local communities reported the prevailing water shortage during the dry season and the lowering of groundwater levels despite the channeling of road water into nearby streams.

(a) (b)

Figure 18. Examples of home garden irrigation using shallow hand-dug wells in Zambia. (a) a single woman framer in Central Province uses four roadside, hand dug wells to irrigate her vegetable plots with a bucket; (b) a model farmer developed many roadside hand dug wells in the southern province

(e) Extensive road development that could incorporate road water management: Under the Link Zambia 8000 km project, the country plans to upgrade and/or construct 8,000km of road in the next few years. The ongoing and extensive road development is an opportunity to tap the multi-functionality of the roads and to integrate road water management. In addition to the planned projects, several roads are under construction where borrow pits could be converted into water storage ponds for livestock, wildlife, and groundwater recharge (e.g. Figure 19).

Figure 19. Examples of active borrow pits that could be converted into water storage systems for livestock, wildlife, and groundwater recharge in Zambia

(f) Several dam constructions are planned that require upstream-downstream water management: Zambia is planning to construct several dams for water storage to be used for irrigation and water supply in different parts of the country. There is, therefore, a need to link road development/road water management to dam construction and landscape management, both upstream and downstream of dams. Reducing erosion triggered by insensitive road development is otherwise likely to affect the lifetime of these dams. Studies in several countries show that unpaved road surfaces may contribute to 15% to 40% of sediment in a catchment. This amount is increased by road-triggered erosion.

(g) Presence of sandy rivers with potential to develop water buffering road crossings and controlled sand-mining: Several rivers are good candidates for controlled sand mining, sand dam construction, and the development of road crossings that buffer moisture (non-vented drifts) in Zambia (Figure 20).

Figure 20. Typical examples of sandy rivers with (a) and without (b) flowing water; high potential for controlled sand-mining, sand dam construction, and development of water buffering river crossings

(h) Ongoing soil and water conservation and land management practices that could be linked to road water management: The government is embarking on massive soil and water conservation and land management projects as part of its climate change adaptation plan. These efforts could be aligned with road development and linked with watershed management at scale. Linking road water management and soil/ water conservation can ensure the sustainability of infrastructure and water sources.

(i) Strong interest in road water management: Key stakeholders and decision-makers demonstrate a strong interest in integrating road water management into the design and construction of roads as well as in water resources development (including groundwater recharge) and environmental management.

(j) Dependence of large national wildlife parks on water sources, including roads (mainly using ponds): Systematically using roads to create water sources for wildlife could reduce the number of animals killed while crossing roads (e.g., Figure 21).

Figure 21. Wildlife, road, and water in Zambia: (a) wildlife in search of food and water endangered by traffic; (b) borrow pits converted into water storage structures for livestock and wildlife use

7.1 Retaining water in the upper catchment to reduce flood risks along roads

As explained in section 3, floods in Zambia are a recurrent hazard expected to worsen due to climate change. The technologies outlined below increase water infiltration in the upper catchment and thus reduce the amount of water reaching the road.

Eyebrow basins are small water harvesting systems designed to collect water from a small catchment area (Figure22a). Contour bunds are a physical measure to control erosion, enhance infiltration, and increase yields (Figure 22b). Bunds are constructed on hillsides along contours, dividing the slope into several smaller microcatchments. By slowing the speed of runoff, water is given time to infiltrate and soil moisture is augmented. There are many different bund designs, and they are used globally as a means of water harvesting and soil conservation. Soil bunds, stone bunds, tied ridges, and stone-faced bunds are examples of how the basic principles of contour bunds can be applied in many different ways.

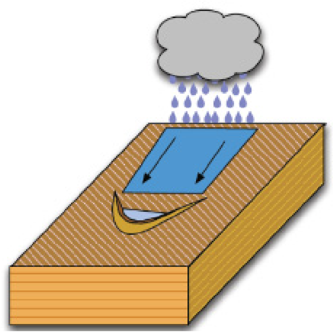


Figure 22a) Eyebrow basins

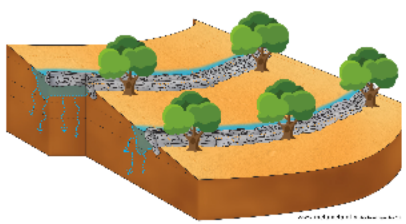


Figure 22b) Contour bunds

7.2 Water bars: Harvesting water from the road surface

Water can be harvested directly from the road surface. The amount of water generated from the road surface depends on the road grade or slope (Figure X) as well as the width and surface of the road and the runoff coefficient of the road surface. A well graded and compacted surface will generate most runoff. Runoff generated by the road surface can be diverted to recharge areas or storage ponds using drainage techniques. The most common road surface drainage methods are rolling dips, water bars, and lead-off ditches.

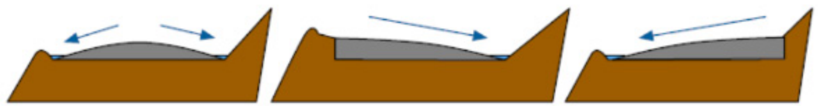


Figure 23. Three examples of how road grade influences road water drainage

Water bars

Water bars (See figure 1) are narrow structures akin to speed breakers. Their primary purpose is to divert water from the unpaved road surface, although in most cases they will also reduce traffic speed.

Here are the specifications for the implementation of water bars:

- The position of the water bar is at angle to the road direction – preferably between 45 o and 60o (outslope to daylight) (see figure 24).
- Water bars are prone to clogging if they are at less than a 45 o angle to the road
- Generally, water bars have a height of 75 mm to 150 mm and with a width of 0.3 m to 1 m (see figure 2).

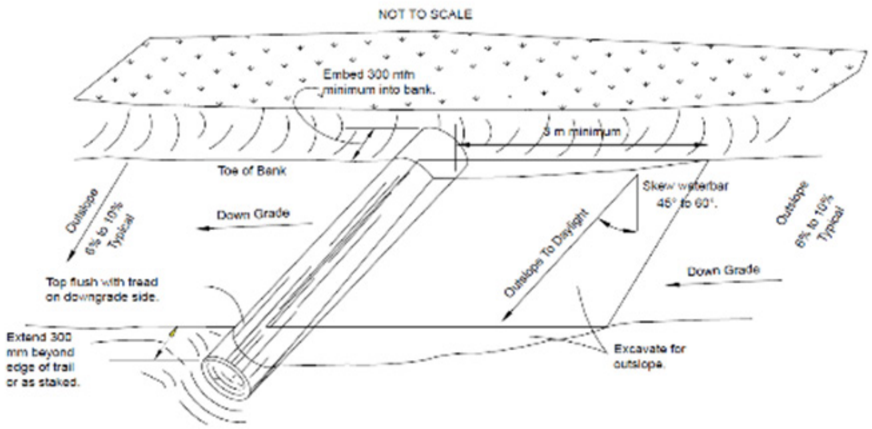


Figure 24. Rock water bar specifications (Source: United States Forest Service, 2017)

7.3 Spreading water from side drains and road surfaces over land

Runoff water spreading can start from either roadside drains or culverts. The key element here is the construction of ditches and bunds with different sloping angles.

First, the water is brought to the target area using simple diversion structures from culverts and roadside drains (Figure 25). The simplest diversion structures are loose stone barriers that slow the runoff and divert it laterally in direction of the fields. A good example of this is mitre drains. Downstream of culverts, when the waterway reaches flat areas (0-5%), flood spreading weirs can be used.

Next, the water can be directed to the fields/grazing area with small ditches with a very gentle side slope to avoid erosion. The ditch gradient should be kept to 3%. Once the slope reaches the field, there are many ways to apply the water. Typical methods include:

a) Levelled ditches at the top of the field to homogenously spill water onto the downstream field. The field needs to have a very even and continuous gentle slope to avoid erosion and waterlogging.

b) The field is divided in the sub-basin (Figure X). Water is allowed in the uppermost basin. Once filled, its retaining bund is breached to allow water to enter the field downslope.

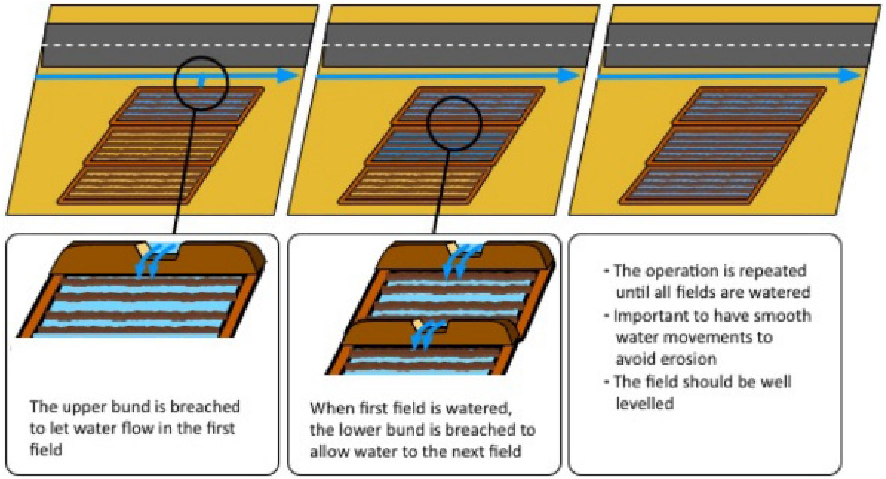


Figure 25. Flood irrigation sequence

c) Water is directed to planting pits that are connected to each other by ditches (Figure 26). Once a pit is filled, water continues to the connecting pit. This system is typically used to grow high value trees. In some areas, the same principle is applied with long trenches.

In grazing areas, there is less concern about the management of water. If there is permanent vegetation cover and the area is flat, the water can be directly spread over the area without additional structures and/or earthwork. Alternatively, water can be spread in a controlled manner using low earthen or stone bunds along the contour or vetiver grasses.

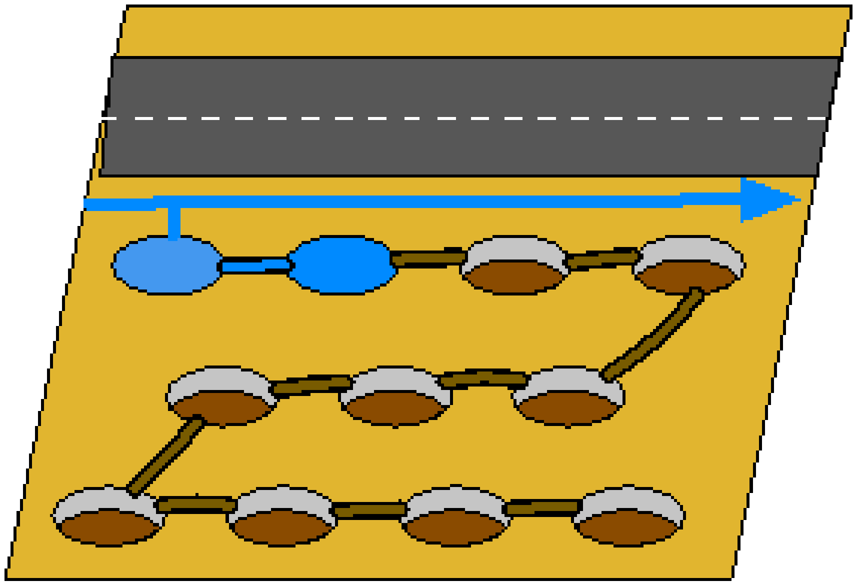


Figure 26. Road runoff is directed to interconnected soaking pits

7.4 Harvesting water from culverts, side drains, and depressions

Road drainage structures can be used, not only for cross drainage, but also to feed borrow pits and storage ponds or for enhanced recharge areas such as infiltration ponds, swales, and infiltrations pits.

7.4.1 Using roadside borrow pits as water ponds

Borrow pits are the result of excavations made to extract materials for road construction. Borrow pits are often left open and are located near roads, which offers¬ an opportunity for water harvesting (Figure 15). They can be used as storage reservoirs for rainwater by, for instance, connecting them with culverts and other cross-drainage structures through a canal. However, some measures are needed to improve the design to ensure safety and accessibility. These measures include technical considerations such as improving the geometry to facilitate access and increase capacity, compressing the base and sides to reduce permeability, and constructing a well for water extraction to allow filtration and improve water quality.

7.4.2 Creating storage ponds supplied by road water

Runoff can also be channelled for storage in small reservoirs. This water can be used by roadside communities for small-scale irrigation purposes and livestock watering. There are two main types of ponds that can be built: embankment ponds and excavated ponds. Embankment ponds are built by constructing an embankment or dam across a waterway where the land is depressed enough to allow for water storage. Excavated ponds are built by digging a pit or dugout in an almost flat area. Since they require more labour and machinery, excavated ponds are most often used where only a small water supply is needed. Dugouts are particularly useful in dry areas where evaporation losses are high and water is scarce, since they can be built to expose a minimum water surface. A combination of both types of ponds can be built in gently to moderately sloping areas where the capacity is achieved both by excavating and by building a dam or embankment.

Infiltration ponds (Figure 27 a, b) are designed to capture and retain runoff, letting it infiltrate for groundwater recharge. They are advantageous in places where runoff might be polluted (such as next to highways) and where shallow wells and hand-pumps are viable. The first step to designing infiltration ponds is estimating the volume of runoff that must be infiltrated. Second, a trial geometry must be defined. The third step is to estimate the infiltration rate by multiplying the gradient by the hydraulic conductivity. Finally, post design-evaluations should be conducted.

Infiltration trenches protect fields from runoff and let the water infiltrate in the soil. They increase the soil moisture of the adjacent farmlands, which in turn has a positive impact on yields.

Figure 27a) Roadside percolation trenches

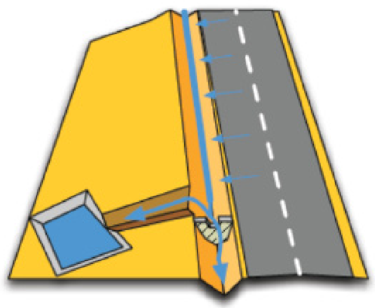


Figure 27b) Diversion from roadside drain to storage structure

7.5 Having non-vented drifts such as road crossings and sand dams

Non-vented drifts provide a low-cost road crossing constructed on a dry riverbed. In seasonal rivers in arid and semi-arid areas, they can act both as low volume traffic road conduits and as water retaining structures. They are important structures that will help capture and store flood water and retain it for use during the dry seasons.

Unlike vented drifts, non-vented drifts are not equipped with culverts. Non-vented drifts provide good opportunities to retain sand and water from ephemeral rivers, as they can act as 'sand dams'. Sand dams are structures that reinforce what sandy rivers are already doing: storing water inside the sand. A retaining wall across the riverbed enables the accumulation of sand upstream. Creating increased sand storage capacity increases water retention.

Because of the absence of culverts in the drift, coarse sand and gravel will ideally be halted and accumulated in the riverbed upstream of the drift. This creates a small aquifer of sand and water. A non-vented drift therefore builds upon the natural capacity of a sandy riverbed. The newly deposited material will store floodwater, making it available for use during the dry season. The water retained in the river bed will also connect to and feed the aquifers on the banks of the river. The extent of this effect depends on local topography and geology. If there is no use of water alongside the perceived structure, landscaping along the banks can be developed while constructing the road crossing. Vegetation also helps to safeguard the structures that are put in place.

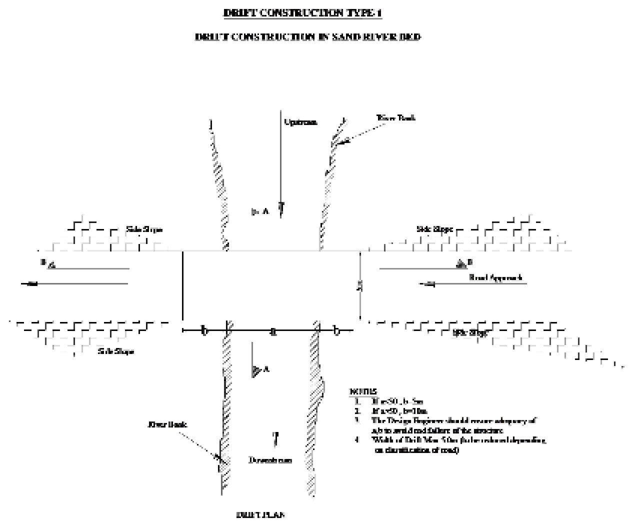


Figure 28. Sketch of a drift acting as sand dam

7.6 Special measures to manage wildlife water around roads

Given the geography of Zambia, roads cross many wildlife areas. At present, the crossing of wildlife is a road safety issue and also the reason for many wildlife kills. Although this cannot be avoided, measures can be taken to reduce the number of incidents. Moreover, water harvesting with road bodies and the development of water pans along such roads can serve wildlife populations and even guide their movement, because access to water – in addition to vegetation and salt licks – is a main determinant of animal movement.

As mentioned, roads have a major impact on hydrological flows in different areas, including the savannah lands and floodplains where much wildlife is encountered. The water that is blocked or guided by road bodies can be used to fill ponds or natural depressions more than we observe today. Roads can be used as an instrument in wildlife management if the following steps are taken:

- Planning and management of competing land and water uses
- Creation of water points at safe and well-considered locations
- Consideration of the design of wildlife ponds

7.7. Roadside planting

Roadside vegetation has the capacity to alleviate the social and environmental damage caused by roads. Trees, shrubs, and grasses established by the roadside contribute to soil formation by shedding dead leaves, improving water quality by reducing sediment flow, reducing erosion, breaking the wind, and providing important pollinator habitats while improving people's health and protecting crops. Well-designed vegetation barriers can improve local air quality by trapping near-road dust. In addition, the establishment of roadside vegetation is a labour intensive activity, resulting in added value through job creation.

The ability of a plantation to trap dust depends on a combination of tree and shrub species characteristics such as height, density, and longevity. Height will influence the size of the protected area, with taller plantations protecting larger areas. Density influences the extent of downwind protection. As trees mature, density near the ground will have to be provided by thick-growing shrub species. Spacing recommendations between trees, as well as between rows, varies depending on the species planted and the mature crown-size. When planning a plantation next to farmland using an ox-plough, consideration should be given to leaving enough space for ploughing maneuvers.

Table 2. Road safety mitigation measures

Speed zone	Road safety mitigation method
40 km/h	The impact force is unlikely to exceed human tolerance, so no specific mitigation is needed.
50 km/h	A minimum lateral distance from the road edge of 1 m should be maintained to reduce incidental interaction between vehicles and trees.
60 km/h	• Intersections: at least 10 m beyond intersection on the approach and departure side
	• Driveways: at least 3 m between driveway and tree
	• Lane merge locations : 3.6 m lateral distance from road edge
	• Curves: 3.6 m lateral distance from road edge for gentle curves; barrier for moderate/tight curves
70 – 100 km/h	The impact force is highly likely to exceed human tolerance Safety barriers are the most appropriate mitigation (wire rope safety barrier, guard rail, or other approved safety barrier that is suitable in high speed environments)

Source: VicRoads Tree Planting Policy, 2015

8. Findings and recommendations

8.1 Main findings

The main findings of the assessment were discussed with major stakeholders (including farmers and contractors) at the National Workshop on 26 July 2017.

Participants reviewed road and water issues and came up with a number of ideas/recommendations for promoting road water management in Zambia as an approach for climate change adaptation.

1) Water remains among the major factors causing damage to roads, leading to high maintenance costs. Water is considered a disaster to the road; hence, managing water from roads would not only provide additional livelihood opportunities but would also reduce maintenance costs.

2) In many parts of Zambia, the groundwater level is reported to be declining, especially in areas where major groundwater extraction is ongoing. In areas with relatively low rainfall rates, water shortages during the dry season is critical. Hence, there is a need to integrate road water management with other options of watershed management and to implement water harvesting to foster climate change resilience. Groundwater recharge using water from roads is an important solution, according to representatives from the road sector.

3) Zambia, under WARMA, is currently involved in developing the National Water Resources Development Plan, and the water sector has stressed the need to embed road water management concepts/principles into the plan. This is an important opportunity for the inclusion of road water management in water resources development in Zambia and other countries.

4) Zambia is developing massive catchment management in six catchments. The catchment management plan is being developed, creating an opportunity to integrate road water management in catchment management planning and development as a model for the region.

5) Zambia, under RDA, is developing a climate resilience strategy for roads, creating an opportunity to integrate road water management in this strategy.

6) Zambia is developing a National Transport and Communication Master plan, which includes roads, railroads, etc. Road water management could be considered an important aspect to include in the master plan to create climate resilient infrastructure.

7) Workshop participants stressed the need for cross-sector collaboration to promote the concepts of road water management for climate resilience.

8.2 Specific recommendations

From the field assessments and from the discussions with stakeholders, the following specific recommendations are forwarded to systematically introduce and upscale road water management in Zambia:

- Zambia is undertaking extensive road development programs and road maintenance/rehabilitation under RDA. It is necessary to include road water management options in these programs, including the use of borrow pits as water storage structures with water from culverts, roadside ditches, and bridges, and the use of water from roads for groundwater recharge.
- There is a need for a comprehensive assessment of borrow pits to evaluate their potential for use as water storage structures. There is considerable potential to use borrow pits for water storage for wildlife, livestock, irrigation, as well as groundwater recharge.
- Road embankments could be used for water storage. Since the majority of Zambia is relatively flat, there is a need to explore options for using road embankments as water storage structures.
- Many of the slope failures in Zambia are debris/earth slides. It is advisable to promote bioengineering measures coupled with drainage-based water harvesting.

- Sensitization and capacity building programs are important components for the systematic introduction of road water management. Such programs should include all stakeholders including farmers, experts, and decision-makers.
- To facilitate the systematic implementation of road water management in Zambia, it is necessary to develop country-specific technical specifications.

Acknowledgement

The following organizations are acknowledged with gratitude: RDA, WARMA, World Bank, the offices of Roads and Water in the provinces, and the local community members interviewed. Special thanks to Eng. Derick Chizu and Eng. Danny Chaswala from Axle Load Control of RDA for their great hospitality and for making the overnight stay across the amazingly wonderful Itezhi-Tezhi river/bridge so memorable. Special thanks also to Mr. Tewodros Tena from GReSP for his insights and assistance.

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Annex 1 Mission Program

Assessment and introduction of road water management in Zambia

The aim of the mission is to assess and introduce the systematic use of roads for water management in Zambia. It is a potent strategy to address climate change – both to safeguard the roads and to use roads as instruments for climate change resilience. The assignment includes a reconnaissance visit to six road sections where a systematic transect survey assessing all the road-water interactions will be conducted and an interaction and discussion with the main stakeholders will be hosted.

Road water management in Zambia considerable potential:

- To reduce damage to road infrastructure and provide a cost-effective approach to addressing the effects of climate change;
- To reduce damage to the surrounding areas (flooding, drainage congestion, erosion, sedimentation) triggered by roads;
- To create useful assets (harvested water) and to increase flood protection;
- To assess the possible amenable connection between roads, wetland management, and flood protection.

Opportunities are wide-ranging and include the systematic use of borrow pits, using road drifts as sand dams, reconsidering lower road embankments, harvesting water from road drainage systems, and systematically using water bars and erosion control measures along feeder roads.

As part of the assignment, material will be prepared and customized to the situation in Zambia. Our work will be based on previous efforts in Ethiopia and work that has started in Uganda, Kenya, and Bangladesh. We will make use of material developed by the Road Water Alliance, available to a large extent at www.roadsforwater.org, particularly training material and input for guidelines and visual materials.

The activities will consist of:

Team: Kefle Woldearegay, Taye Alemayehu, Joseph Chibwe, and Sundie Silwimba

Activities	Date	
Arrival, kick-off briefing	14 July	Meet Zambia Team, program briefing, logistical arrangements
Transect road visit in seven different areas (each visiting feeder road and highway) to make first assessment and to document opportunities for road water harvesting/ management for resilience.	15-20 July	Visit to: Day 1: Visit to Western Province (M009, 598 km) – spend night in a town close to Kafuwe bridge Day 2: Drive to Mongu, visit the road along the flood plains, host discussion with provincial actors at Mongu- spend night at Mongu Day 3: Visit to Southern province (55km gravel road) (Kalomo Dumdumwezi) - spend night at Ithezi Thezi Day 4: Visit to the road to Kariba Road Central province - spend night in Siavonga Days 5 & 6: • Travel to Kabwe – Host discussion with provincial actors • Visit Luapula/Northern province - spend night in Mansa or Kasama Joseph, the focal person from RDA, to join
Discussion with stakeholders at national level and at regional level (the latter combined with transect road visits) to explore issues and opportunities and identify ongoing programs in which better integration of roads and water management can be promoted	21-25 July	Suggested names/organizations to visit: - Ministry of Water Development, Sanitation, and Environmental Protection - Water Resources Development Authority - Wildlife Protection Authority - Ministry of Transport and Communication - Ministry of Agriculture - Ministry of Lands and Natural Resources - Disaster Risk Reduction - World Bank office - Department in control of sand mining Visit to road affected by landslide

Daylong workshop with main stakeholders to discuss and agree upon the opportunities for road water management in Zambia	26 July	Venue: Radisson BLU Hotel, Lusaka Persons to invite (two or more people from each institution) - RDA (different sections including rural road section) - Ministry of Water Development, Sanitation, and Environmental Protection - Water Resources Management Authority - Ministry of Transport and Communication - Ministry of Agriculture - Ministry of Lands and Natural Resources - Disaster risk reduction (if exists) - World Bank - Wildlife Protection Authority - NGOs (two key NGOs working in the water sector) - GREST-BGR Objective of workshop - present field assessment - explore scope for beneficial road water use for resilience - ideas on guidelines
	27 July	Wrapping up and departure
Reporting and preparation of guidance note as contribution to Road Guidelines and World Bank investment programs	Draft prepared by 7 August	

Annex 2 Program - National Workshop 26 July 2017. Radisson BLU Hotel, Lusaka.

Time	Activity	Responsible
09:00-09:30	Registration/ welcome	Welcome by: Senior Manager – Planning Department Roads Development Authority (RDA)
09:30-10:00	Introduction to the Program Getting to know each other	Joseph Chibwe (RDA)
10:00-10:45	Roads for Water: International Experience	Taye Alemeyehu (MM)
10:45 to11: 00	**Coffee break**	
11:00-11:30	Developing and Maintaining the Road Network in Zambia: Status and Challenges	Sundie Silwimba and Senior Manager from Road Maintenance
11:30-12:30	Climate Change in Zambia: Challenges and Opportunities	Mr. Levy Museteka- Water Resources Management Authority (WARMA)
	Public Private Partnership possibilities and challenges in RWM	Danny Sinumba, NAMSSC
	Farmers' experience to bring resilience	Farmers invited from Southern Province
12:30 to 13:30	**Lunch break**	
13:30-14:15	Roads for Water – Roads as Instruments for Resilience: Opportunities in Zambia	Kifle Woldearegay
14:15- 14:30	Reflection from RDA and WRDA provinces	Heads of RDA and WRDA from Central Province
14:15-15:30	Facilitated Plenary Discussion - what are best opportunities - how do we take it further	Kifl/Levy/Joseph
15:30 to 15:45	**Coffee break**	
15:45-16:30	Follow up discussion and way forward	Kifl/Levy/Joseph
16:30-17:00	Closing	Senior Manager- WARMA

Annex 3 List of workshop participants and persons met

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23	Taye Alemayehu	MetaMeta	taye@metameta.nl		

Annex 4 People with whom discussion was held on BRWM in Zambia

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5	Lemmy Namayanga	Director General, Water Resources Management Authority	inamayanga@warma.org.zm
	Managers of the different departments of WARMA		info@warma.org.zm
6	Teodros Tena	Water Resources Engineer, GReSP	Teodros.gresp@gmail.com
7	Danny Sinumra	General Secretary, National Association for Medium and Small Scale contractors	danny_simumba@yahoo.com
8	Farmers in Southern and central provinces (I, Elina, Judit Maang Abe & Chongo)	Two men lead/model farmers and two single women farmers	


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