# Risque de sédimentation des réservoirs et mesures d'atténuation en faveur de la durabilité en Tunisie Activity No.: N-W-TN-2

## Atelier de Consultation Nationale

18 Sep 2023, Hotel Golden Tulip El Mechtel, Tunis

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# Plan

1 - General scope and objectives of the Activity

2 - Proposed actions under the activity and Expected results

3 - Target beneficiaries and stakeholders involved

4 - Human resources implicated

5 - Action plan of the activity

# Sediment Deposition in Reservoirs

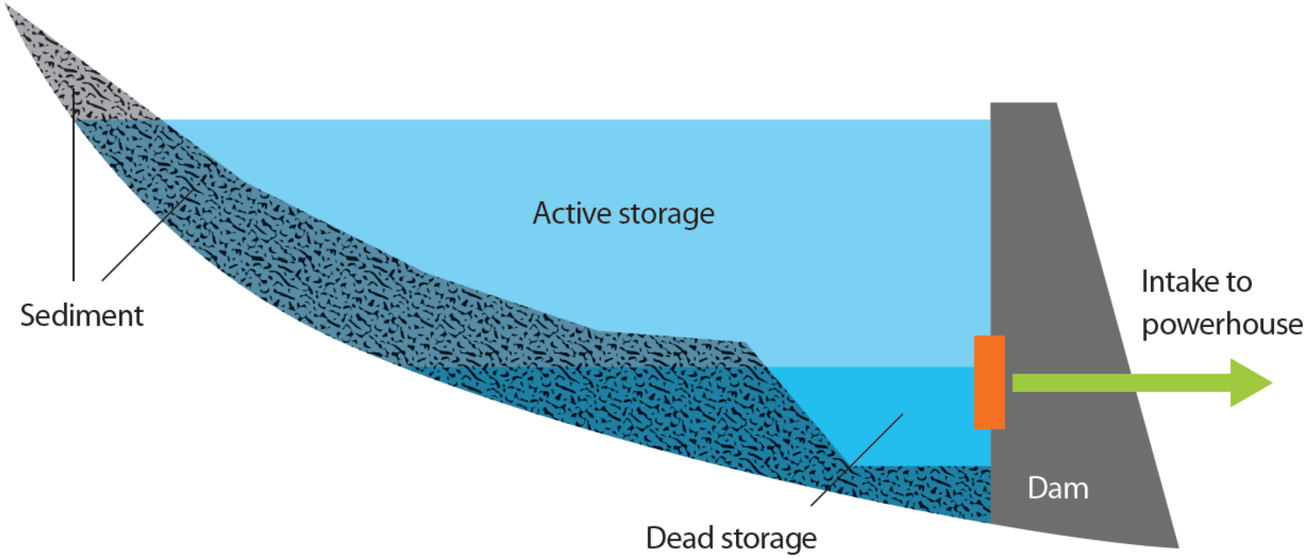
It is estimated that the annual loss in storage capacity of the world's reservoirs due to sediment deposition is around 0.5–1% [WCD (2000) Dams and development. A New Framework for Decision-Making. Earthscan Publications Ltd, London, 356 pp.]. For many reservoirs, however, annual depletion rates are much higher and can go up to 4% or 5%, such that they lose the majority of their capacity after only 25–30 years.

Three main concerns regarding sediment yield modeling and designing large scale hydraulic systems are:

(a) To reliably predict sediment yield at the catchment scale and understand which factors affect the sedimentation rate of reservoirs.

(b) To simulate the correct accumulation pattern in the reservoir in order to optimize the placement of the outlet works.

(c) To design measures for prevent ... ert or remove existing deposits from th



# General Objectives of the Activity

- ✓ Collection, processing and evaluation of available data for two pilot cases in Tunisia regarding reservoir sedimentation rates and sediment yield of the upstream catchments.
- ✓ Better understanding of reservoir sedimentation causes and origin of eroded sediment within the catchment (fingerprinting).
- ✓ Assessment of the actual sedimentation rate and loss of useful storage in the two pilot reservoirs and correspondence with erosion and sediment yield rates.
- ✓ Examining the applicability of possible Natural Water Retention Measures to combat sediment accumulation in reservoirs with priority given to green infrastructure.
- ✓ Review of economic incentives and regulation to support and amplify protective measures with priority given to green infrastructure.
- ✓ Circulation of outcomes to the scientific community and drafting a Guidance Principles Textbook on sustainable mitigation measures.

# Target beneficiaries and stakeholders involved

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## Main beneficiaries

- ✓ Direction Générale des Barrages et des Grands Travaux Hydrauliques (DGBGTH)

## Stakeholders involved

- ✓ Direction Générale de l’Aménagement et de la Conservation des Terres Agricoles (DGACTA)
- ✓ Direction Générale des Ressources en Eau (DGRE)
- ✓ Direction Générale du Génie Rural et Exploitation des Eaux (DGGREE)
- ✓ Commissariats Régionaux de Développement Agricole (CRDA)
- ✓ Les GDA tant en amont qu'en aval des deux réservoirs étudiés
- ✓ Les usagers de l’espace des bassins versants des ouvrages hydrauliques
- ✓ Other stakeholders to be presented by Emad Adly the stakeholders engagement expert


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# Proposed Actions & Expected Results

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## Task 1: Review of Current Knowledge relative to Erosion, Sediment Yield and Reservoir Sedimentation in two pilot reservoirs in Tunisia

All current knowledge including design studies, research projects, papers in international journals or proceedings in conferences (both national and international), postgraduate theses will be evaluated to provide a coherent and clear picture on the magnitude and severity of sediment accumulation in these two pilot reservoirs. Use shall be also made of available relevant documents at the General Direction of Dams and Large Hydraulic Works (DGBGTH - Direction Générale des Barrages et des Grands Travaux Hydrauliques).

## Results

- Collection of all relative information on reservoir sedimentation / sediment yield for these two pilot reservoirs in a single database. Analyses of all assumptions / computations that have been adopted in the design studies on reservoir sedimentation.
- NWRMs classified according to different scope of soil erosion prevention and areas of application focusing on arid and semi-arid climatic conditions.
- The **various stakeholders concerned are identified** and their role in the activity is agreed upon.

## Tools for deployment:

- Search for technical reports and data in local and international databases.
- Data collection, processing and storage in GIS database and timeseries databases.

# Pilot Reservoirs in Tunisia

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## A. Lebna Dam
Original Capacity: 29hm$^3$
Storage Depletion: 0.5hm$^3$/a


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# Lebna Dam & Reservoir

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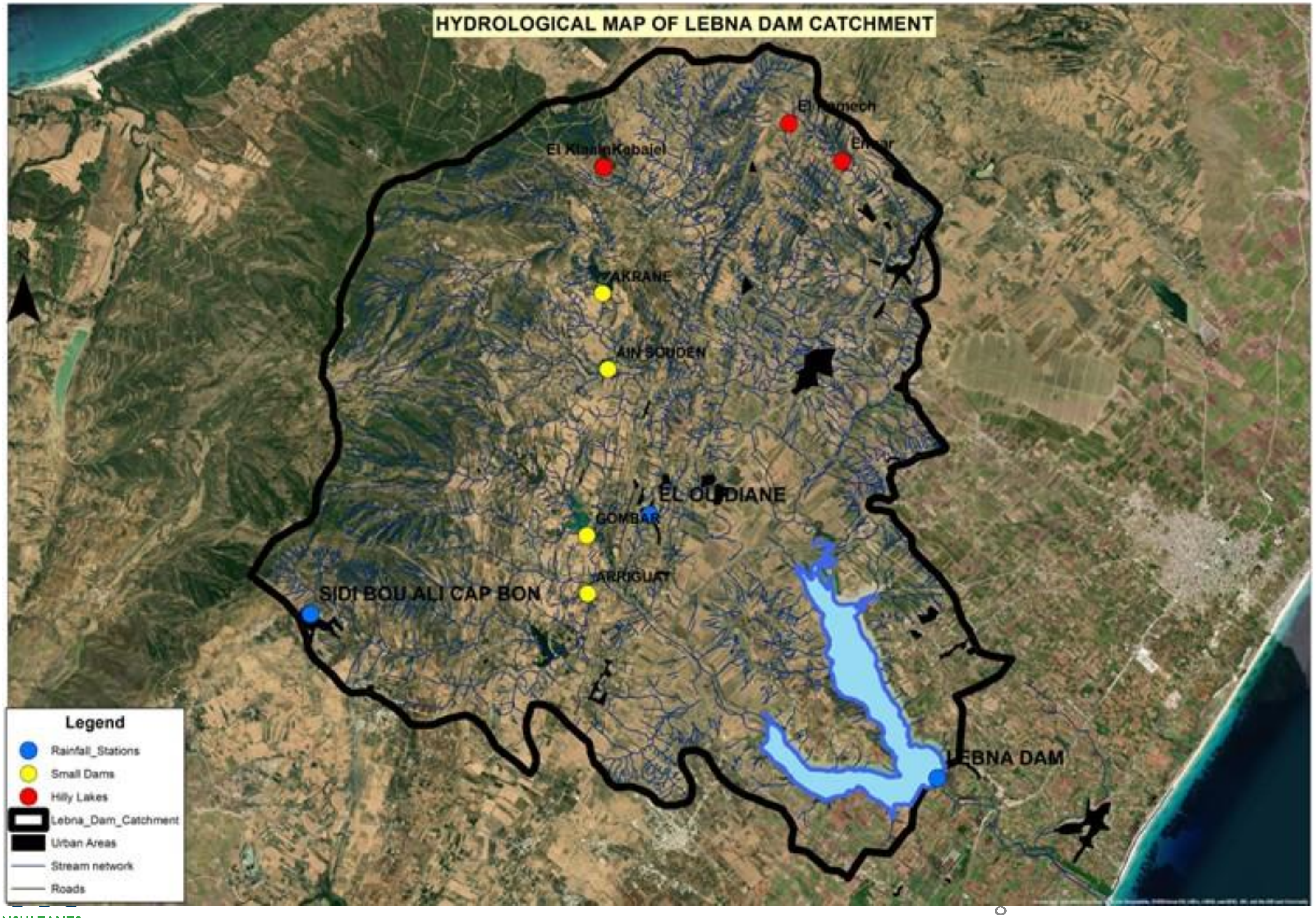
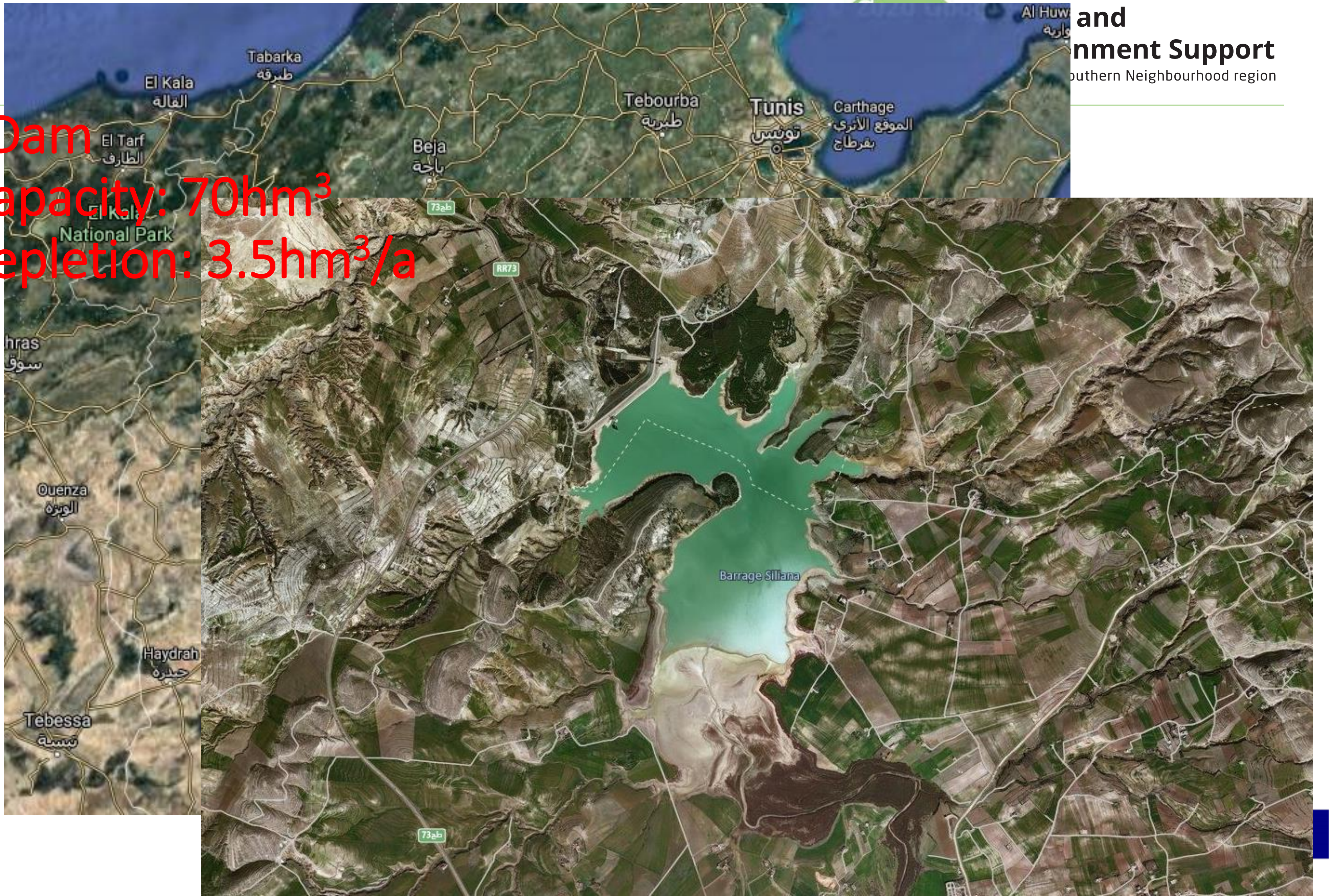



The Lebna dam was constructed in 1987 at the confluence of the El Oudiane and Boudokhane rivers. It is situated 3 km from the sea at the catchment outlet. With a 30 $hm^3$ original capacity, it is the biggest dam on the CapBon peninsula.

# Pilot Reservoirs in Tunisia



## B. Siliana Dam
## Original Capacity: 70$hm^3$
## Storage Depletion: 3.5$hm^3$/a



# Siliana Dam & Reservoir

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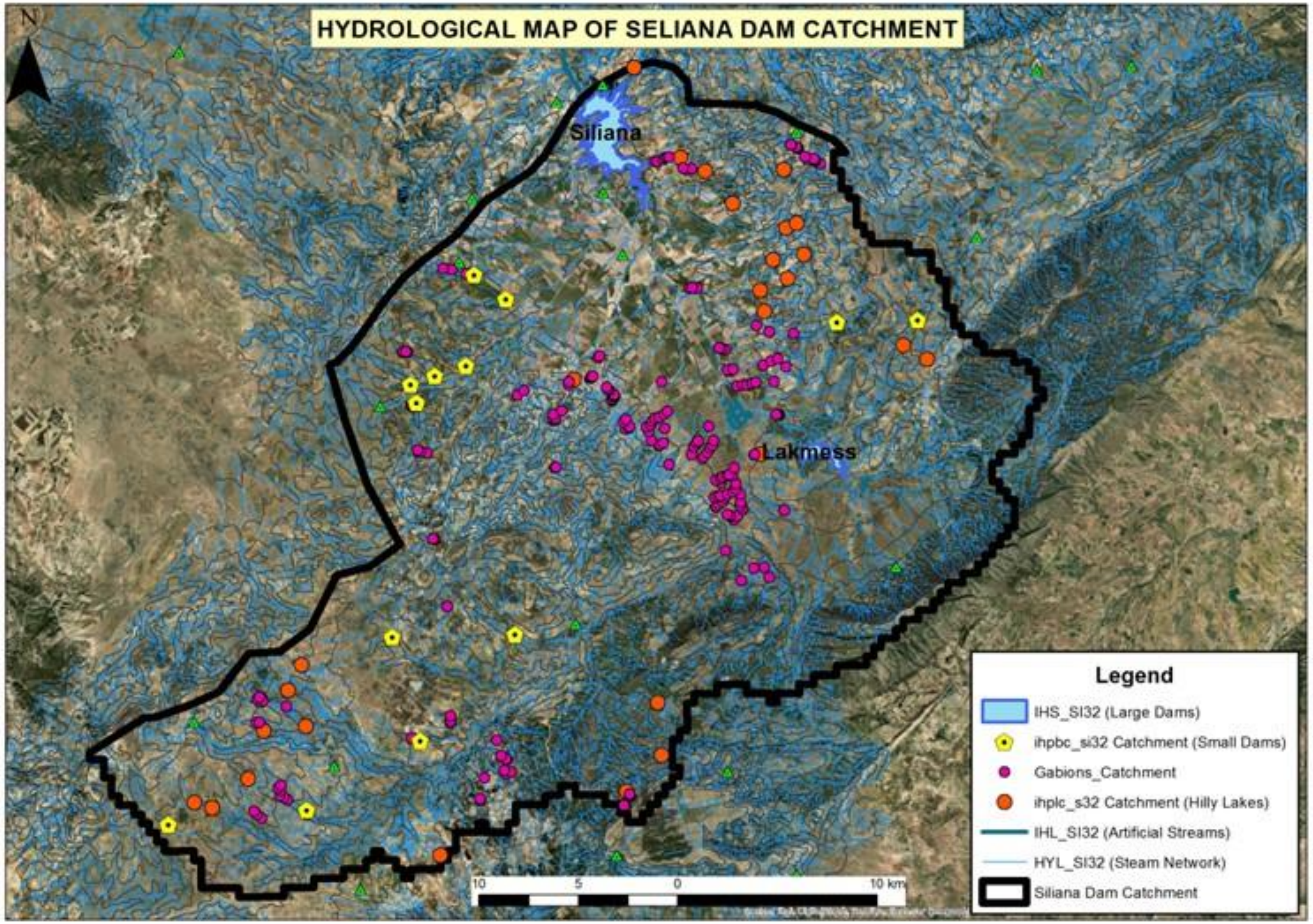


The 1028 km$^2$ Siliana catchment is located in the northwest of Tunisia. With an average annual precipitation of 580 mm with most of it falling between October and April, the climate is Mediterranean. The dry season, which lasts from May to September, can reach temperatures of more than 28 °C.

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| | SILIANA Dam (Completed in 1987) | LEBNA Dam (Completed in 1988) |
|---|---|---|
| **A - location:** | | |
| **Watercourse:** | Wadi siliana | Wadi lebna |
| **Governorate:** | Siliana | Nabeul |
| **Closest city** | Siliana | Menzel Temime |
| **Main and secondary destinations of the dam:** | irrigation of the plains of gafour and laroussa (4,400 ha) | irrigation, drinking water |
| **B - Hydrological characteristics:** | | |
| **Watershed area:** | 1,040 km² | 189 km² |
| **Average annual precipitation** | between 500 and 600 mm | 550 mm |
| **Average annual inflow from the river** | 57.98 hm³ | 9.69 hm³ |
| **C - main characteristics of the retention:** | | |
| **Normal Retention grade (NRG)** | 388.50 | 18.05 |
| **Normal area of reservoir** | 600 ha | 650 ha |
| **Capacity of the normal reservoir** | 70 hm³ | 30.2 hm³ |
| **D - main characteristics of the dam:** | | |
| **type:** | compacted earth dam | earth dam with core and refills |
| **Dam height:** | 53 m | 22 m |
| **Crest length:** | 1,200 m | 500m |
| **Crest width:** | 8 m | 6.5 m |
| **Volume of the dam body:** | 2,600,000 m³ | 860,000 m³ |
| **concrete volume** | | 10,000 m³ |
| **E - Related works:** | | |
| **1) Spillway Structures** | | |
| **number:** | two (one main and one auxiliary) | 1 free surface spillway with three independent passes on the dike |
| **type:** | free surface weir and tulip | free on backfill |
| **type of valves:** | none | none |
| **maximum flow:** | 2,500 m³ / s for the main evacuator and 700 m³ / s for the auxiliary evacuator | 300 m³ / s |
| **2) Outlet works** | | |
| **type:** | two wagon-type irrigation water intakes | 1 water intake |
| **maximum flow:** | 3 m³ / s (1 m x 1.5 m) | 0.8 m³ / s |
| **3) Drainage works** | | |
| **Type** | wagon valve (two) | hollow jets |
| **maximum flow:** | 180 m³ / s at a rate of 90 m³ / s each | 8 m³ / s |

## General situation of reservoir sedimentation in Tunisia

At the end of 2017, Tunisia had 37 dams with a total storage capacity of 2,285 $hm^3$, 257 small dams with a total capacity of 365 $hm^3$ and 909 lakes with a total capacity of 58 $hm^3$ (the volume of silt is deducted for large dams).

The hydraulic situation of 30 out of the 37 dams indicates that as of August 31, 2017, a total loss of 25% of the initial capacity is noted. According to several sources, the reservoirs of Tunisian dams annually lose 0.86% of their capacity by sedimentation. The risk is that by 2030, the loss of storage capacity of dams in operation could reach 43% of their initial capacity .

# Catchment Management to Mitigate Deposition & Storage Loss

Management of surface runoff in areas designated as source erosion areas has in recent years been seen as an important planning goal for achieving three main objectives:

1. To prevent the loss of surface soil material by reducing runoff peak rates either by enhancing infiltration and vegetation interception or delaying / attenuating runoff peak conditions.

2. To reduce the storm water flows in natural drainage systems (i.e. streams and rivers), thereby creating an opportunity to reduce the total flood peaks and volumes.

3. To reduce pollution in streams, and coastal and marine pollution from the urban runoff's dissolved and suspended pollutants and solid waste (mainly plastics).

# Reservoir Management to Mitigate Deposition & Storage Loss

Management of reservoir operation has been seen as an important planning goal for achieving three main objectives:

1. To divert sediment upstream of the reservoir and transfer it downstream of the reservoir especially during flood events where the majority of sediment is transported.

2. To develop operation rules in such a way that at the beginning of the rainy season the reservoir should be empty so that sediment can reach the base of the dam and be flushed from the evacuation gate (if such one exists according to dam type).

3. To effectively dredge sediment form the reservoir's invert with normal equipment without using floating installations and pumps that is extremely costly.

# Definitio

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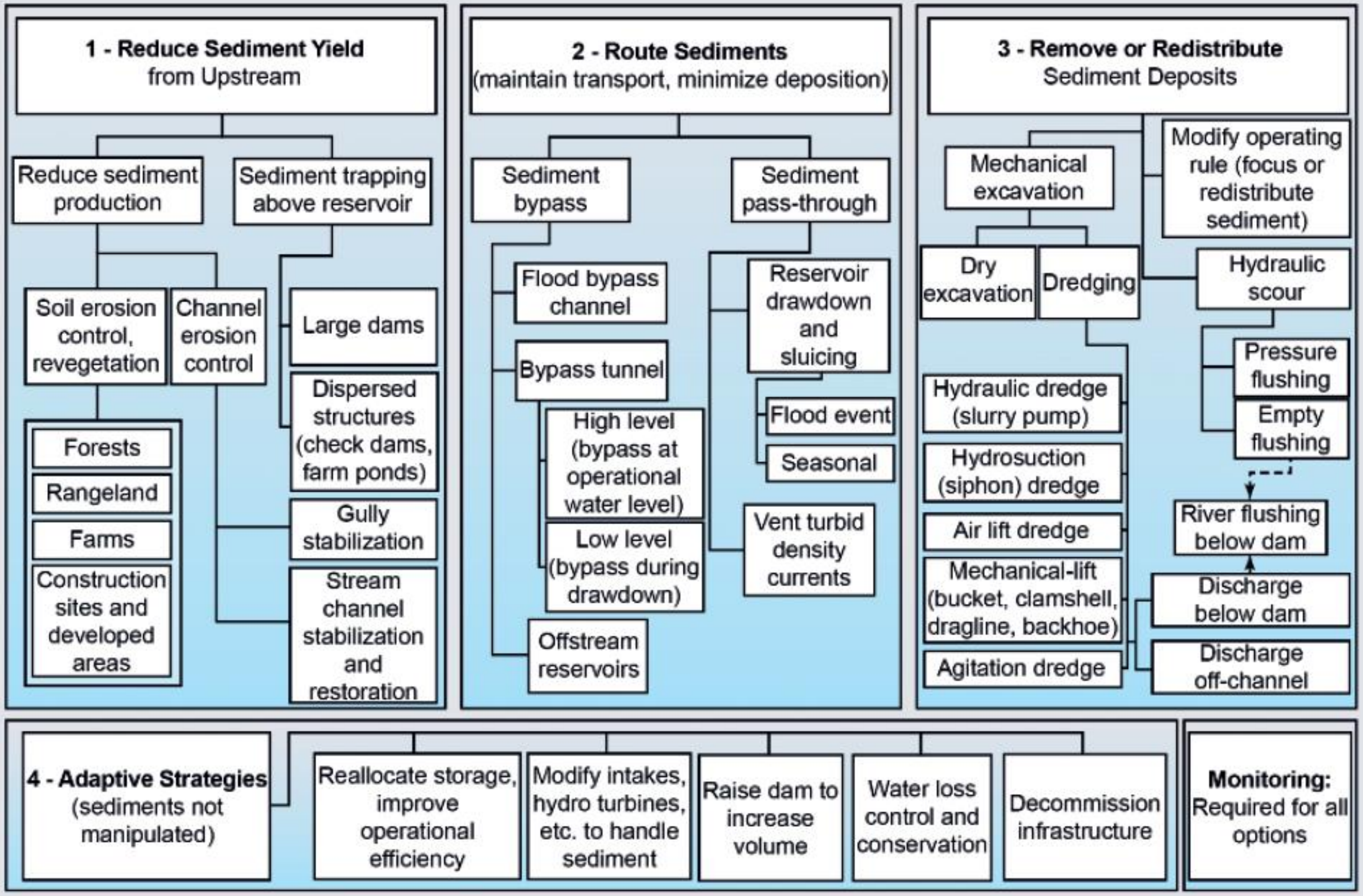


Figure 3. Classification of reservoir sedimentation management techniques[4]

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# Discussion – Requirements & Challenges



## General

- Mobility of local experts
- Remote work
- Timely provision of information
- Stakeholder engagement in the activity
- Agree during the final workshop on the implementation of the selected actions recommended by the activity in order to ensure the development of the impact of the activity
- Facilitation of contact with local representatives of the pilot areas
- Facilitate the implementation of the communication plan

## Data availability and quality :

- Background maps [raster-vector] (e.g.: Digital Terrain Model, topographic maps, soil / geologic maps)
- Existing water harvesting and storage works [dams, lakes, etc.]
- Land use information with water demand of different water uses with map.
- Timeseries data on different scales (hourly for floods, daily for general water budget) including rainfall, runoff, evapotranspiration.

# Discussion – Requirements & Challenges

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During the site visits it was evident that the mechanism of the sediment yield in both catchments is the **gully (interrill)** erosion with impressive development of a dense network of constantly incised gullies which are propagating upstream. Therefore, the selection of the mathematical model to simulation the sediment yield transport must be capable to simulate mostly the ephemeral gully process and to a lesser extent sheet and rill erosion processes that are described with the USLE-type models (RUSLE, SWAT, etc.).

If the combined force of rainfall and overland flow is greater than the soil's ability to resist separation, soil erosion by water will result. The process of soil erosion can be thought of as occurring on a continuum of scales, ranging from interrill and rill to gully, though not always continuously. The disappearance of a somewhat uniform layer of soil by splashing from raindrop impact and sheet flow is known as interrill erosion. Both gully erosion and rill erosion are caused by concentrated overland flow or subsurface flow of water during and immediately after heavy rainfall.

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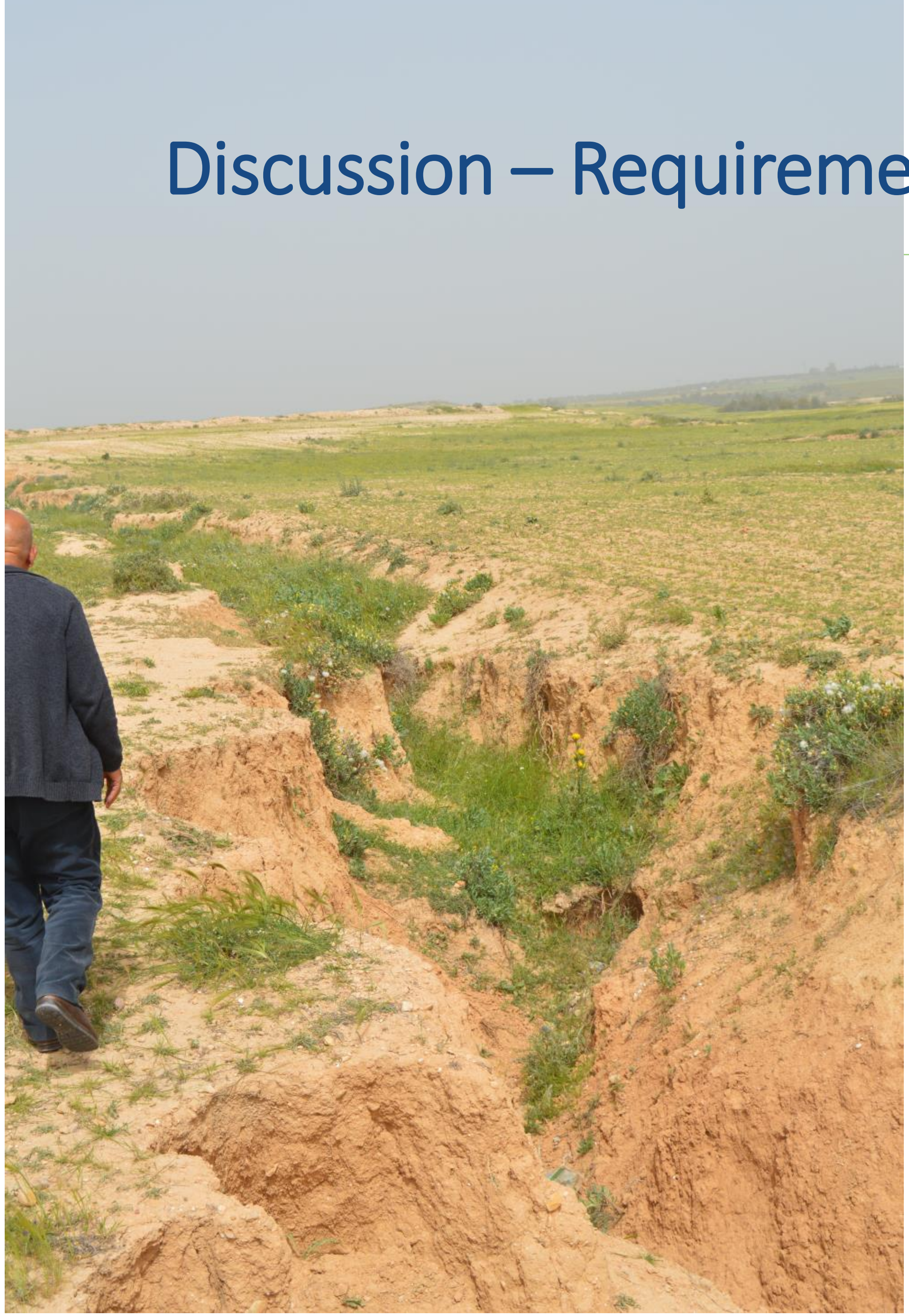
# Discussion – Requirements & Challenges



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The most noticeable mechanisms of headward gully erosion brought on by surface runoff are those linked to waterfalls; similar mechanisms but on a much smaller scale. The force of the water's impact on the soil causes the soil particles to be broken loose and carried away. The waterfall hitting a seat or slope has the greatest impact in this action. If the waterfall clears the headwall, its energy is used to create turbulence inside the pool and to dig the plunge pool. The plunge pool tends to be farther away from the headwall in general the higher the flow. Ephemeral gully waterfalls are often very small-scale features. However, because a plunge pool forms in contact with the toe and undermines the headwall, plunge pool turbulence is a significant process of erosion in ephemeral gullies. If the falling water is redirected back up against the headwall, undercutting will happen. Water flowing over the gully head, in contact with the headwall, produces erosion in the early and late phases of overland flow events because water is driven into the soil preferentially, separating the wet material from the drier material beneath.



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# Proposed actions & Expected Results

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**Task 2: Assessment of the sedimentation rate and the sediment yield of the reservoirs in the two pilot cases.**

During this task, the two pilot cases in Tunisia will be comprehensively analysed, for the estimation of sediment yield and reservoir sedimentation rates by utilizing all possible source of information such as:

1. Sediment discharge measurements in rivers.
2. Hydrographic measurements in reservoirs.
3. Sediment yield modelling with empirical, conceptual or physically based mathematical models.

**Results**

- On-site expedition was about to take place for - on the spot- evaluation of site conditions.
- Technical Report on the estimation of sediment yield and reservoir sedimentation rates in two selected dams / reservoirs in Tunisia. Provided with all appendices and computations.

**Tools for deployment:**

- Data manipulation and processing with Excel.
- Mathematical modelling with the AGNPS mathematical model.

# Proposed actions & Expected Results

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## Task 3: Conceptual design of mitigation measures in the selected pilot cases.

For the selected pilot cases, the conceptual design of the selected mitigation measures with priority given to NWRMs will take place by means of (a) hydrologic modelling and (b) hydraulic design. The conceptual design will estimate how much of the mean annual soil erosion can be retained in natural or artificial storages on the site of the eroded material.

Apart from mitigation measures in the upstream catchments, the report will assess ways to combat reservoir sedimentation in each dam itself by proposing alternative structures for sediment wash-out downstream or management rules to allow sediment to be routed near the evacuation valve of the dams (if that exists and is fully functionable).

## Results

- **Hydrologic Report** presenting all the relative assumptions, computations and limitations that will conclude the balance between soil eroded / water inflow, soil/water stored and soil / water outflow. In each pilot area, the report will illustrate the percentage of the total eroded soil that will be retained in natural and artificial storages.
- **Hydraulic Report** presenting (at a feasibility level) the necessary infrastructure that will undertake the purpose of water/soil storage and sediment washout.
- Expedition to the country during design of NWRMs to further collaborate with local stakeholders.

## Tools for deployment:

- Hydrologic Modelling with AGNPS model.
- Sediment yield and discharge modelling.

# Proposed actions & Expected Results

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## Task 4: Review of economic incentives and regulation regarding mitigation measures.

A cost – benefit analyses will be performed for the selected NWRMs, comparing the economic and environmental benefits of the water/soil retained in natural and/or artificial storages (economically by the associated usage (irrigation, water supply, etc.), the flood defence and environmentally by the water quality of the recipients) with the costs of applying the NWRMs and the profits associated with each unit of volume of reservoir's useful storage not associated with sediment.

Specific attention would be drawn to dredging of sediments from reservoirs. The cost-benefit analysis of dredging compared to the proactive NWRMs will be carried out comparatively to NWRMs including environmental benefit from keeping sediment within the catchment.

## Results

- 1. Cost – benefit analyses of NWRMs comparing the costs (cost of construction, flood, pollution, etc.) with the benefits per m3 soil retained in the catchment and not stored in the reservoir.
- 2. Cost – benefit of dredging as a conventional practice to reclaim useful storage in reservoirs.
- 3. Assessment of funding options according to the nature of soil /water retention (groundwater, surface water) and purpose of soil / water use.
- 4. Economic incentives for the application of NWRMs.
- 5. Basic structure of regulation manual regarding application of NWRMs in Tunisia.



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# Proposed actions & Expected Results

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## Task 5: Closing Workshop, Presentation to Donors and Training Sessions

A **closing workshop** is expected to be organized involving relevant national and local stakeholders in order to present the outcomes of the sediment yield / reservoir sedimentation outcomes and further promote the sustainability of NWRMs in Tunisia to combat erosion and desertification. The results of the activity including those from both pilot cases will be presented alongside the cost – benefit analyses to illustrate the viability for the general application of NRWMs in the country for preventing soil loss.

Report on guidelines/criteria for the reservoir management and operation to reclaim useful storage that previously occupied by sediments is also to be issued.

## Results

- The results of the activity are presented to the beneficiaries (in a one-day national consultation workshop) and evaluated and priorities of NWRM options are selected.
- Report mentioning the guidelines and criteria for selecting appropriate sites for the implementation of natural water retention measures.
- Summary report of the workshop and presentation to the group of donors in accordance with the standard report recommended under the WES project.
- Training documents, exercises, questions, etc.

## Tools for deployment:

- Presentations with Q&A.
- Training Sessions.
- Consultation among stakeholders on the applicability of the NWRMs in Tunisia.

# Available data

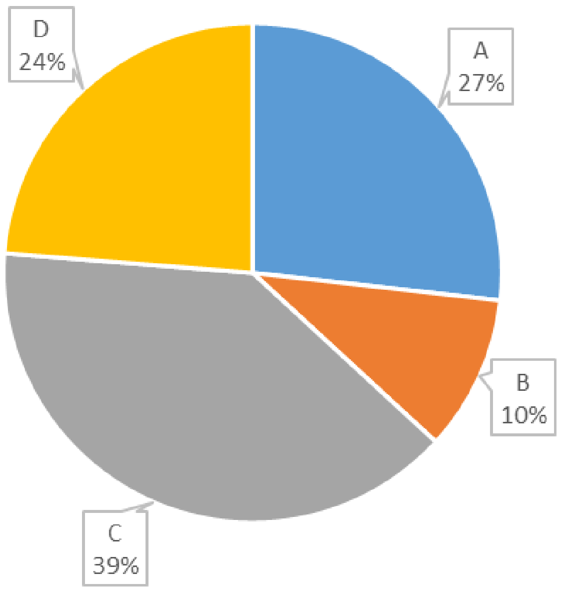
The data used for the model were.

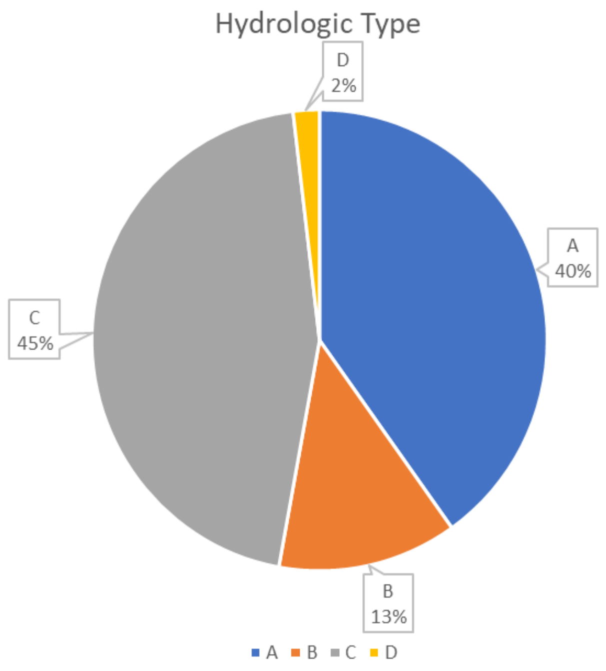
- Topographic mapping (Digital Terrain Models)
- Geological, Soil and Land Use data on GIS platform.
- Current data on infrastructures (check dams, etc.)
- Weather Data (Precipitation, Temperature etc.). When weather data was unavailable the time series were filled or stochastically generated.
- Sediment Volume calculation data for sediment discharge calibration.
- Water Budget of the reservoirs for the river inflows calculation for the runoff calibration.

# Discussion – Requirements & Challenges

| a/a | Required data | Time Step | Date From | Date To | Measurements Frequency |
|---|---|---|---|---|---|
| 1 | Stream discharge measurements | AT LEAST DAILY DISCHARGES | | | |
| 2 | Rainfall | AT LEAST DAILY RAINFALL | | | |
| 3 | Sediment Discharge Measurements | SPORADIC BUT WITH SUFFICIENT FREQUENCY FOR THE CALCULATION OF SEDIMENT DISCHARGE RATING CURVES | | | |
| 4 | Reservoir Water Budget (Overflow, Seepage, Evaporation, Abstractions) | MONTHLY DATA | | | |
| 5 | Catchment Digital Terrain Model | | | | |
| 6 | Soil Map | | | | |
| 7 | Geological Map | | | | |
| 8 | Landuse Map | | | | |
| 9 | Map with Existing Hydraulic Works | | | | |

# Soil Structure




Soil Hydrologic Type for Siliana Catchment

Soil Hydrologic Type for Lebna Catchment

# Land Use Data

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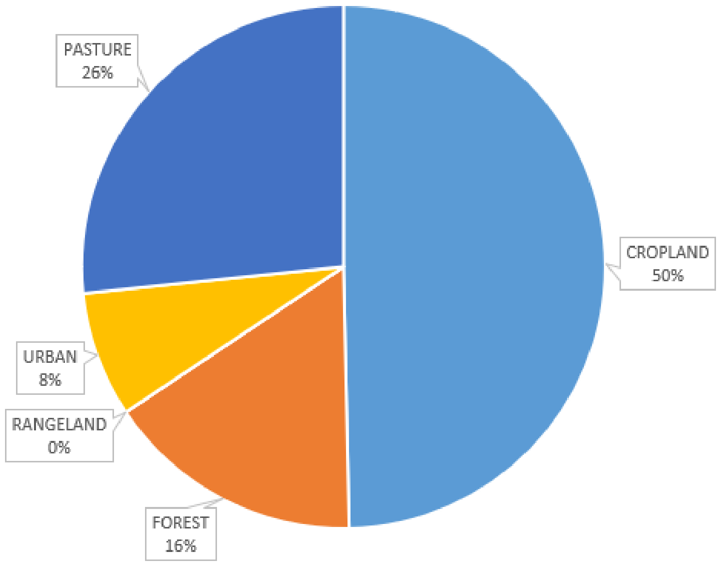
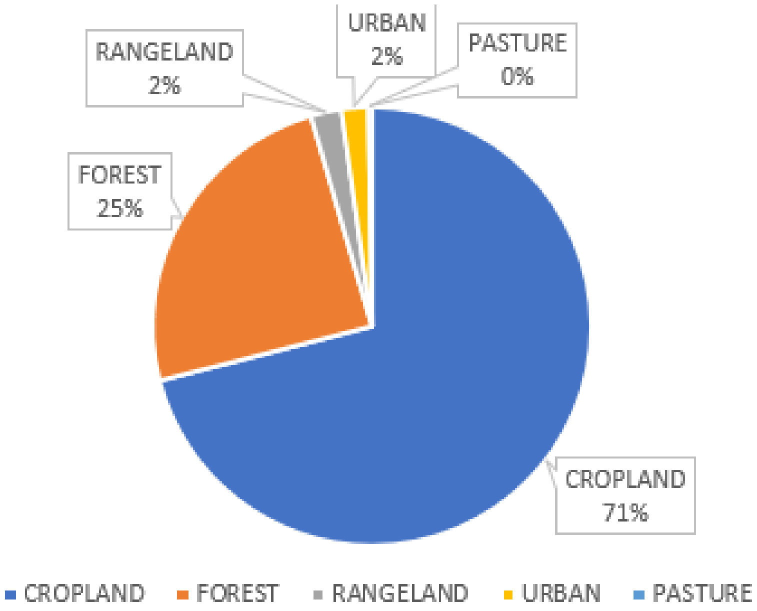
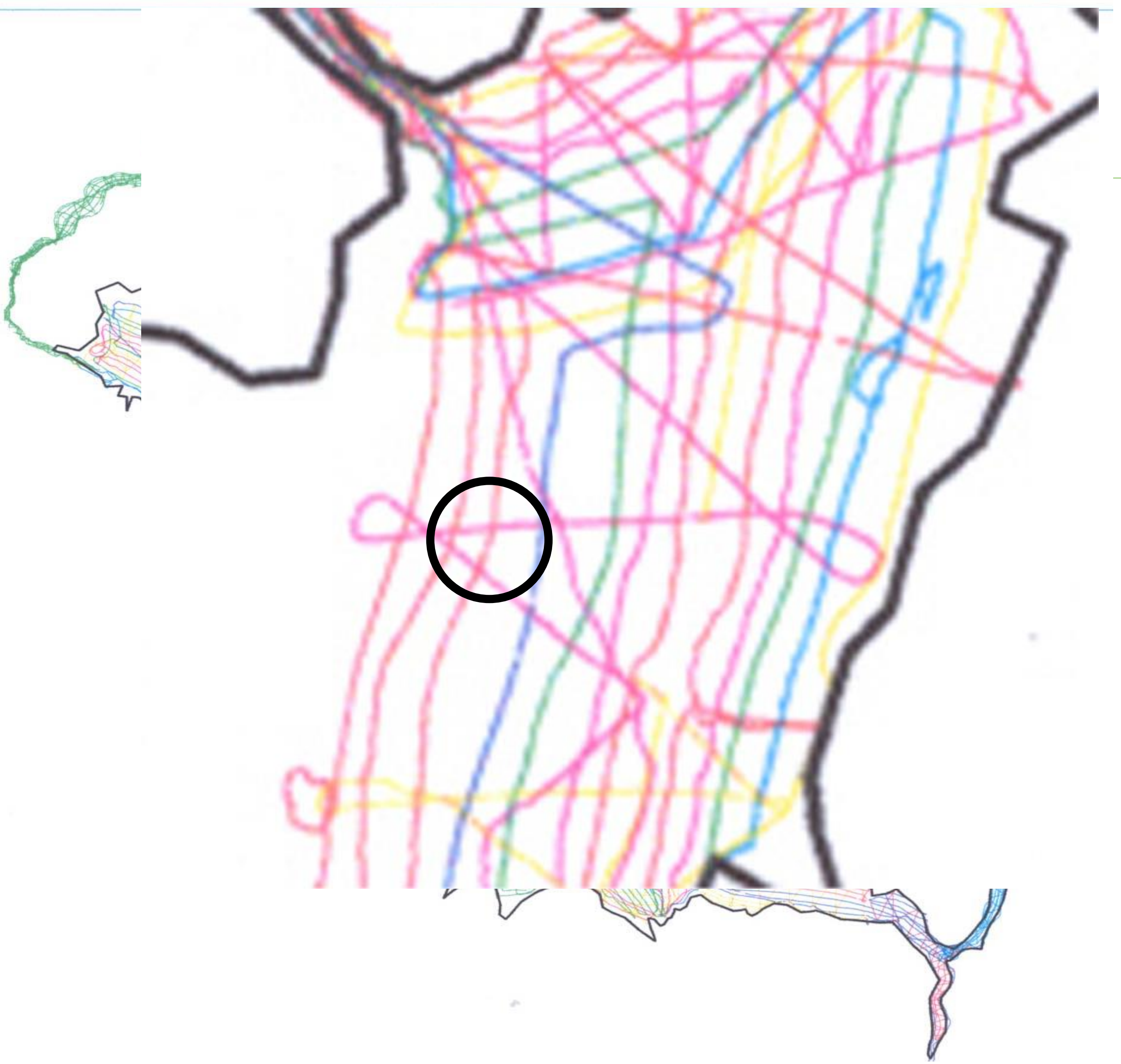



Land Use for Siliana Catchment




Land Use for Lebna Catchment

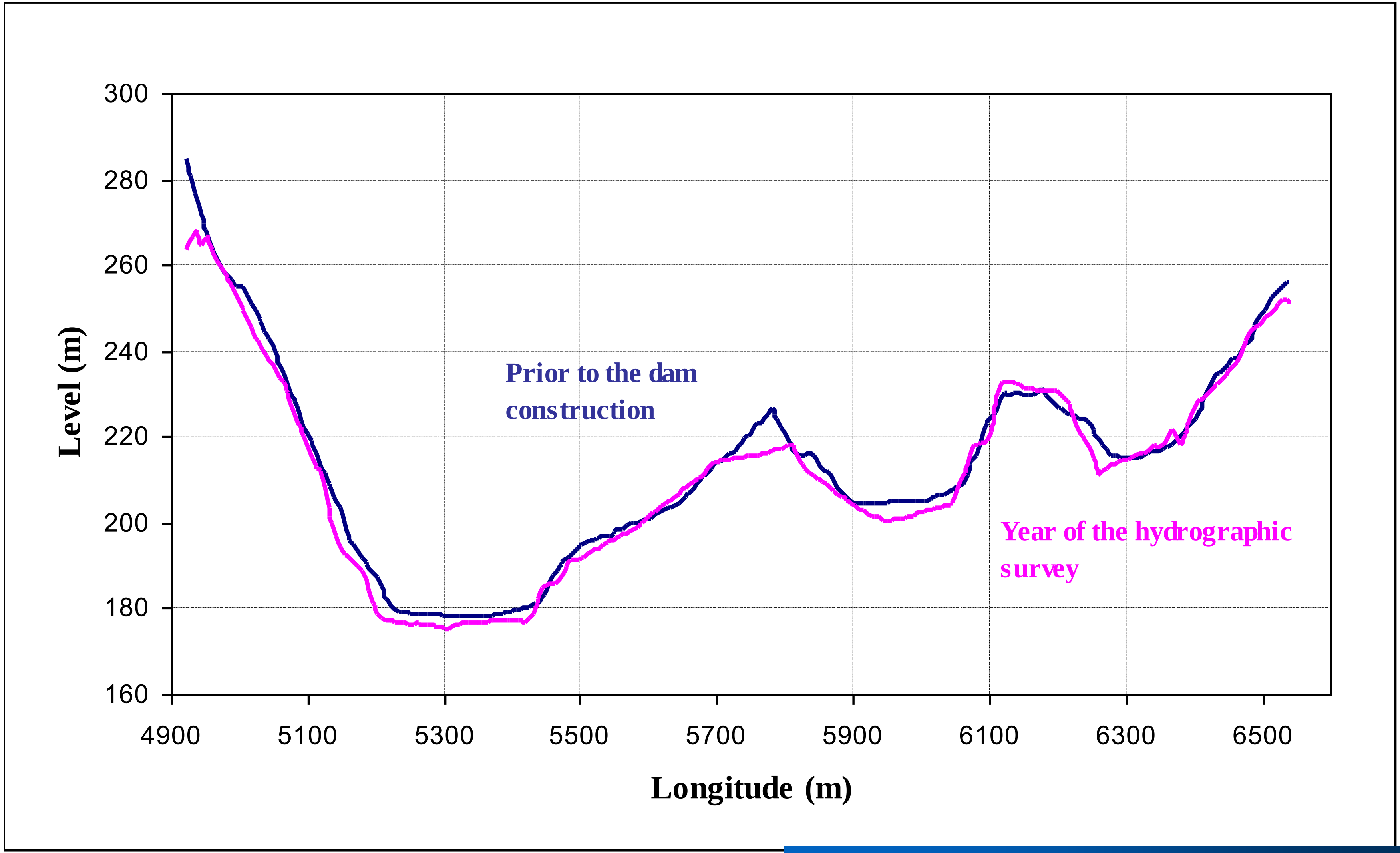
# Hydrographic routes for reservoir scanning



# Indicative profile of fluvial sediment deposits (a)


Section near the reservoir delta at Acheloos R. branch

# Indicative profile of fluvial sediment deposits (b)




Section at the inner part of the reservoir

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# Thank you for your attention!