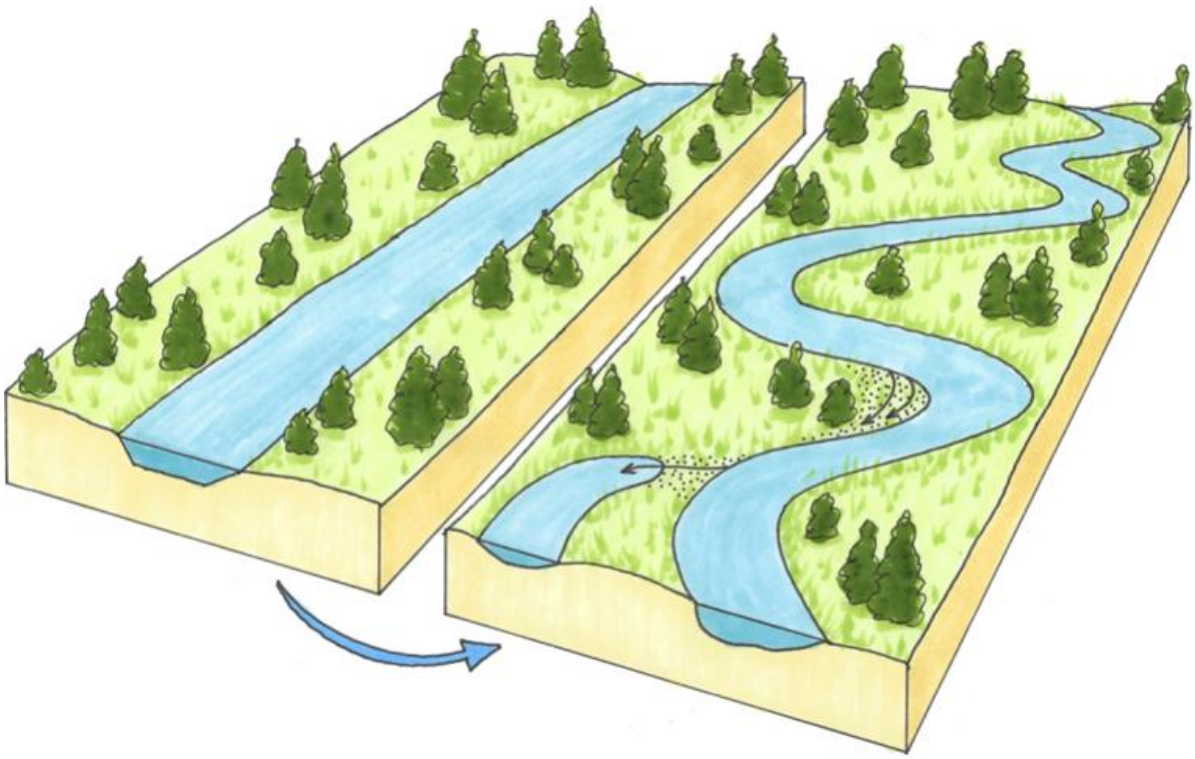
LARRATT AQUATIC

A Toolkit for Restoring Watershed Storage



Prepared for: City of West Kelowna
Supported by: Okanagan Basin Water Board
Letter of support from: Westbank First Nation
Submitted: Spring 2025

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Syilx Territory

This study's primary focus was within Westbank First Nation's core traditional territory. Staff members of Larratt Aquatic Consulting Ltd. are grateful to work in syilx traditional territory and to serve City of West Kelowna, Westbank First Nation, and the communities of the Okanagan Valley.

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Toolkit Purpose

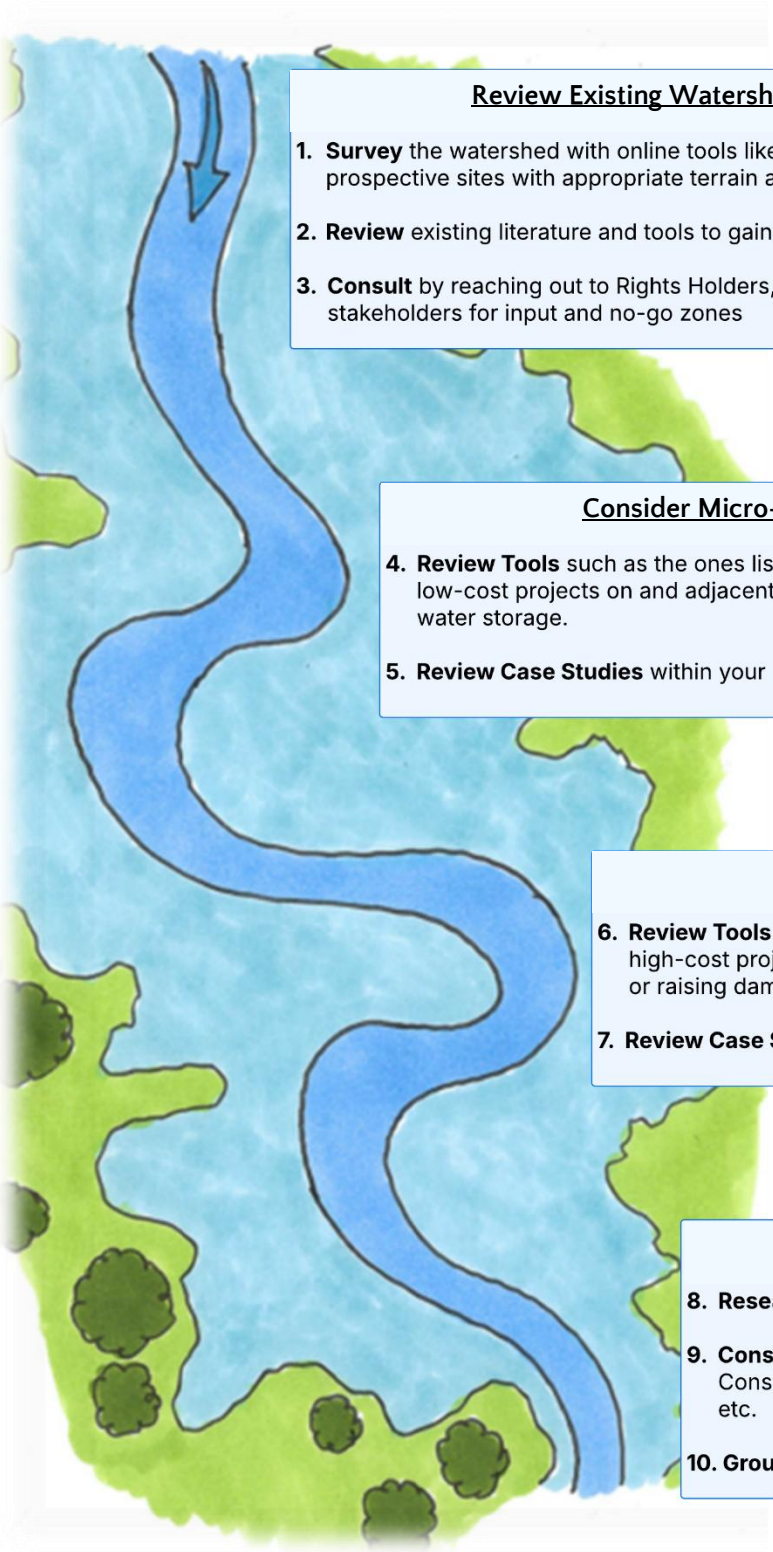
Unprecedented drought combined with reduced watershed resilience leads to intense freshet flows followed by low summer flows in the Okanagan Valley. Climate change is affecting Okanagan bodies of water, and noticeable changes in streamflow were apparent in recent decades. The spring freshet period is starting and finishing earlier, and late summer flows are becoming lower (AE 2020). This unfortunate combination reduces water quantity and water quality available for community and fishery needs.

Increased water storage can mitigate intense freshets and augment low summer flows every year. Increasing storage also increases water available during extended droughts. During wet years, increased storage can hold greater quantities of water and improve preparedness for extended droughts. Hydrology and engineering considerations of storage options are critical and need to be joined by biological, limnological, and ecological considerations in the water storage selection process.

This Project aimed to develop a toolkit of techniques that increase water storage. These techniques restore creek hydrographs to more natural conditions that can reduce the risks of abrupt spring freshets and very low summer flows. This Toolkit offers a thorough review of upland water storage options. It is broken down into micro-storage options that employ simple structures that are 1 m in height or less, and macro-storage options that employ conventional large dams. The Bear (Lambly) and Powers Creek watersheds were used in this project as case studies for both micro-storage and macro-storage options. The results of the case studies will contribute to CWK Water Use Master Plan (WUMP) 2025 Update.

Toolkit Roadmap

The following steps are linked to the toolkit sections that discuss them.



Review Existing Watershed Tools

1. **Survey** the watershed with online tools like GIS and LiDAR for prospective sites with appropriate terrain and access. Create maps.
2. **Review** existing literature and tools to gain context for project
3. **Consult** by reaching out to Rights Holders, Indigenous Nations, and stakeholders for input and no-go zones

Consider Micro-Storage Tools

4. **Review Tools** such as the ones listed in this toolkit. These are small low-cost projects on and adjacent to creeks that aim to provide water storage.
5. **Review Case Studies** within your region and this document

Consider Macro-Storage Tools

6. **Review Tools** such as the ones listed in this toolkit. These are large, high-cost projects that aim to provide water storage through developing or raising dams.
7. **Review Case Studies** within your region and this document

Research Selected Tools

8. **Research** the selected tools in detail beyond the introduction provided in this toolkit
9. **Consult Again** with Rights Holders and Indigenous Nations before proceeding. Consult environmental experts on construction timing, safety concerns, legislation, etc.
10. **Ground Truth** to confirm feasibility of the storage project with detailed studies

Existing Watershed Tools

Many tools exist for Okanagan watersheds and were consulted for this project:

Title	Link/Contact
Environmental & Hydrological Tools	
Environmental Flow Needs (EFN) Project	https://obwb.ca/efn/
Source Water Protection Toolkit	https://sourcewaterprotectiontoolkit.ca/
Okanagan Climate Indicators Dashboard	https://obwb.ca/indicators/
Okanagan Climate Guide	https://okanaganwater.ca/okcdg/
Okanagan Hydrologic Modelling Project	https://www.obwb.ca/docs/obwb_report_2020-okanagan-hydrologic-modelling.pdf
Okanagan Groundwater Monitoring Project	https://obwb.ca/projects/okanagan-groundwater-monitoring-project/
Hydrologic Connectivity Study	https://obwb.ca/projects/ohcm/
Lake Evaporation Study	https://obwb.ca/wsd-index/data/lake-evaporation/
Okanagan Water Quality Database	https://www.obwb.ca/wqdb
Okanagan Water Supply and Demand Project	https://obwb.ca/wsd-index/
Guidebook for Constructed Wetlands in the Okanagan	https://obwb.ca/guidebook-for-constructed-wetlands-in-the-okanagan/
Wetland Enhancement and Restoration	https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/best-management-practices/wetland_ways_ch_11_enhancement.pdf
Guidance & Legislative Tools	
Syilx Water Law/Declaration	https://www.obwb.ca/newsite/wp-content/uploads/terbasket_siwlkw_water_responsibility.pdf
Syilx Water Strategy	https://syilx.org/wp-content/uploads/2022/04/Syilx-Water-Strategy-2022-Edition.pdf
B.C. Water Sustainability Act (WSA) 2016	https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/water-sustainability-act
Wildlife Act	https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/96488_01
Dam Safety Regulations	https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/dam-safety-regulation
Fisheries Act	https://laws-lois.justice.gc.ca/eng/acts/f-14/
Canadian Environmental Assessment Act	https://laws-lois.justice.gc.ca/eng/acts/c-15.21/
BC Water Tool	https://www.bcwatertool.ca/
Analysis of Flood Policy and Planning Tools in the Okanagan Valley	Dr. Kh Md Nahiduzzaman

Note: this is a non-exhaustive list, and relevant tools differ by region and province

Micro-storage Tools

Micro-storage development projects require extensive planning and collaboration. Projects often involve biologists, engineers, and hydrologists. Micro-storage development works best when it is tailored to each site. Storage options have unique purposes and applications that may not be applicable to an entire area. At all times, extreme care must be taken to prevent invasive plant introductions (Appendix 1: Links for Invasive Plant Management).

Micro-storage refers to small scale water storage options and can take many forms. Its purpose is to supplement water availability to managed centralized sources. Micro-storage provides many benefits associated with detaining water on the landscape (Table 1).

By carefully considering concepts listed in Table 2, micro-storage development projects can contribute to sustainable and resilient resource management (Appendix 2: Additional Micro-Storage Details).

Table 1: Benefits of micro-storage

Benefit	Description
Increases water availability	Captures rainwater and run off that would otherwise be lost
Improves water distribution	Increases reliability of a water supply system
Regulates water flow	Naturalizes systems to stabilize water flows
Increases soil moisture	Promotes soil moisture retention by holding water in place
Creates wetlands	Promote the natural development of wetlands
Recharges groundwater	Replenishes groundwater aquifers
Provides wildlife protection	Increasing the floodplain increases areas protected from fire
Reduces erosion	Restores natural flow patterns that reduce water velocity and erosion
Supports natural environmental services	Supports biodiversity, protects water quality, provides flood control
Increases riparian habitats	Newly wetted soils support riparian habitats

Note: non-exhaustive list of benefits. Each storage option has unique advantages and disadvantages.

Table 2: Micro-storage Tools – a checklist of initial actions (non-exhaustive list)

Consideration:	Description
Collaboration	Engage with stakeholders, community members, and indigenous nations Collaboration is essential for project success
Understand existing site conditions	Micro-storage must be tailored to specific environmental, social and economic context. Conduct surveys to understand: 1) anthropogenic influences: - determine land use and community needs 2) topography and drainage: - determine elevation, slope, drainage, soil type and permeability 3) hydrological conditions - understand rainfall, run off, ground water and flood risks 4) existing natural conditions - identify existing vegetation and native flora (BEC zone) - assess impact on wildlife - identify and comply with all environmental regulations and permits 5) access and infrastructure - evaluate logistics of accessibility - determine utilities and infrastructures that may be influenced 6) risk assessment - identify and assess risks associated with micro-storage developments and determine mitigation strategies
Sustainability	Develop Invasive Plant Management Plan to protect native vegetation Prioritize long-term sustainability, consider climate change and resource availability Systems should be designed for future expansion and adaptation capacity
Economic viability	Must be economically viable Consider initial investment, operating costs and social credit while determining benefits of micro-storage
Long-term monitoring	Tracks system performance and identifies areas for improvement Monitor key indicators including water storage capacity, water quality, and environmental impact

Micro-storage Memos

The following 1-page descriptions of micro-storage options were developed to provide high level guidance. All storage types and applications must consider the concepts listed in Table 2. Storage options fall into in-stream, riparian, and adjacent micro-storage categories (Table 3; Figure 1). The riparian and adjacent micro-storage options can be used interchangeably, depending on the site.

Table 3: Micro-storage types

Application	Type
In-stream	Beaver dam analogues
	Bladder dams
	Conservation
	Cross vanes
	J-hook vane
	Reconnecting meanders
	Rock check dams
	Zuni bowl
Riparian (off-stream)	Artificial meanders
	Cistern analogues
	Floodplain waffle garden
	Lined detention basins
	Mulch basins
	Riparian Hügelkultur garden
	Storm rain garden/bioretention cell
	Unlined detention basins
Adjacent / (upland)	Boomerang berms
	Burnt slope stabilization
	Created wetlands
	Expanding riparian corridors
	Infiltration basin
	Off-side watering
	Swales

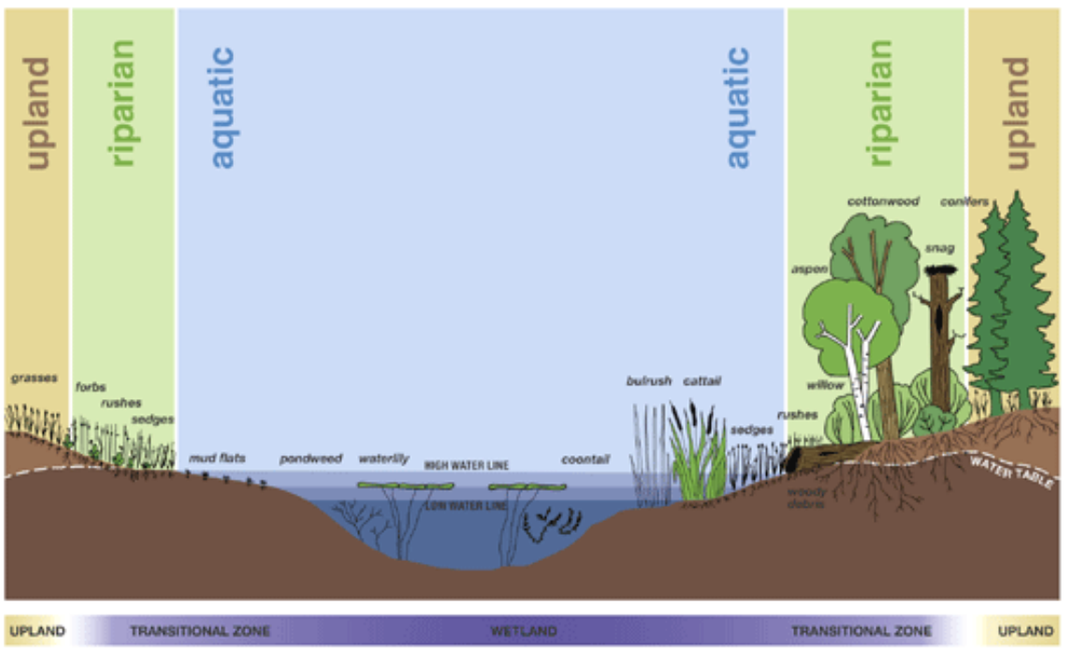


Figure 1: A typical wetland demonstrating the aquatic (wetland), forest riparian buffer, grass riparian buffer, and upland zones (State of Delaware, n.d.)

In-stream micro-storage

Micro-storage implemented within natural water ways aim to enhance ecological services and provide water quantity solutions (Figure 2). In-stream micro-storage structures can restore degraded stream channels, promote natural water retention and reduce sediment transportation. When thoughtfully designed, in-stream applications can be used to enhance aquatic environments, promote wetland development, and benefit overall biodiversity. They also retain moisture over a larger floodplain area, making it more resilient to wildfire.



Figure 2: Cross-Vane structure
Source: River Reach Foundation, 2021

Beaver Dam Analogues

Purpose

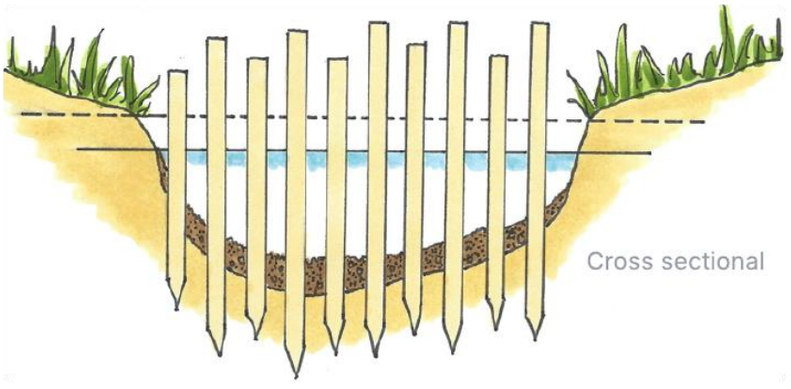
1) Regulates water flow: mimics natural hydrological and ecological functions of beaver dams
2) Restoration: used to stabilize water courses, increase water storage and restore wetlands
3) Increases ecological function: re-establishes wetlands and increases wetted footprint around streams
4) Increases soil moisture: allows water to infiltrate soil, recharges ground water, supports vegetation
5) Wildlife: promotes beavers, fish, amphibian, and benthic invertebrate habitats
6) Sediment control: structures trap sediment and prevent downstream movement

Basic Design

- Requires careful design and monitoring
- Can be made with or without vertical posting (untreated wood posts)
- Can be placed anywhere in a stream and is not limited to bars and riffles
- Materials include, wooden stakes, mud, bed materials, branches and turf from remediation area
- Crest dam should be perfectly level without preferial flow or weir
- Dam is permeable and allows flow through
- If using vertical posting, posts should be evenly seperated to allow weaving

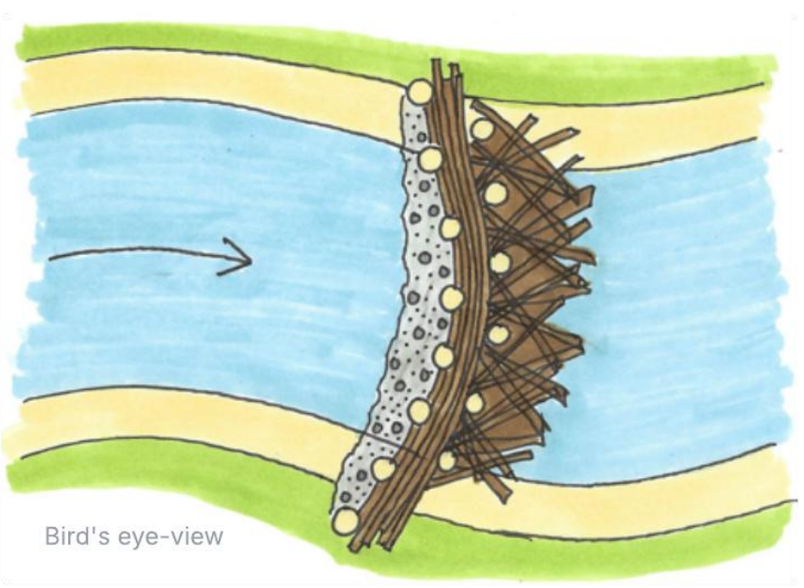
Advantages

Facilitates wetland formation
Improves water filtration
Restores natural ecosystem functions
Increases biodiversity
Provides flood protection
Can conform to channel shapes
Cost-effective



Disadvantages

Risk of damage during high flows
Suitable for small scale streams
Can cause unintended ecosystem changes
Limited life span
May require regular maintenance
Can negatively impact infrastructure
Risk of debris-based-blockages



Bladder Dams

Purpose

1) Flood management: can be deployed quickly to redirect water
2) Water storage: creates an impermeable barrier condusive to water storage
3) Increases soil moisture: allows water to infiltrate soil, recharges ground water, promotes vegetation
4) Restoration: supports water storage and facilitates release at variable heights during dry periods

Basic Design

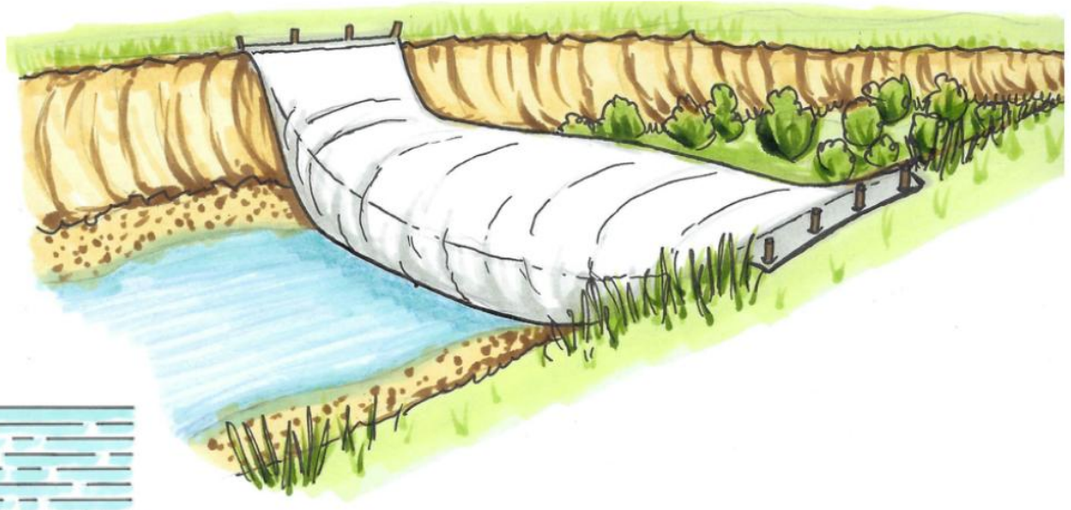
- Inflatable barrier
- Can be inflated with water or air depending on type
- Acts as a barrier to divert water flow
- Can be used in flowing or still water areas

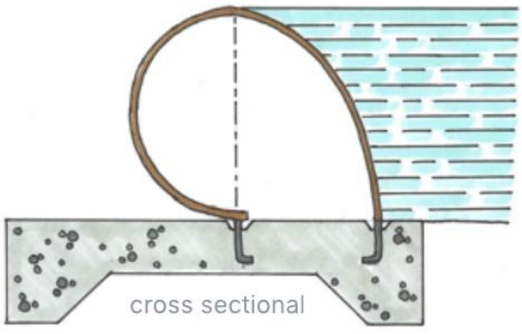
Advantages

Quick to set up
Provides water storage
Variable height possible
Flexible for variable terrain
Removable and reusable

Disadvantages

Unnatural appearance
May require anchoring
Requires inner baffles to prevent rolling
Not suitable for long-term storage
Vulnerable to damange





Conservation

Purpose

1) Protects natural flow: allows natural meandering and water movement over a landscape
2) Regulates water flow: maintains natural water movement and captures runoff
3) Reduces erosion: natural flow patterns reduce water velocity and erosion
4) Promotes soil moisture: maintains wetted area footprint and contributes to ground water recharge
5) Supports ecosystem services: maintains biodiversity, protects water quality, provides flood control
6) Supports riparian habitat: provides natural water filtration and supports native vegetation

Basic Design

- Provide public education on benefits of conservation
- Collaborate with stakeholders and indigenous groups to determine areas of conservation
- Target areas that provide large scale ecosystem services
- Implement and protect long-term conservation of areas

Advantages

Provides flood protection
Maintains water storage
Protects water quality (long-term)
Supports aquatic habitats
Facilitates bio-diversity
Provides natural aesthetic

Disadvantages

Typically occurs on crown land
Requires multi-stakeholder cooperation
Decreases area's extraction potential
Requires regulation
Can cause social tensions



Cross Vane

Purpose

1) Regulates water flow: stabilizes water flow and deflects stream flow to channel centre
2) Reduces erosion: prevents bank erosion by concentration flow towards channel centre
3) Sediment control: decreases slopes upstream and downstream of vane, reducing erosion
4) Restoration: creates and supports "pool" formations in streams, increases stream flow diversity
5) Increases soil moisture: allows water to infiltrate soil, recharges ground water, promotes vegetation

Basic Design

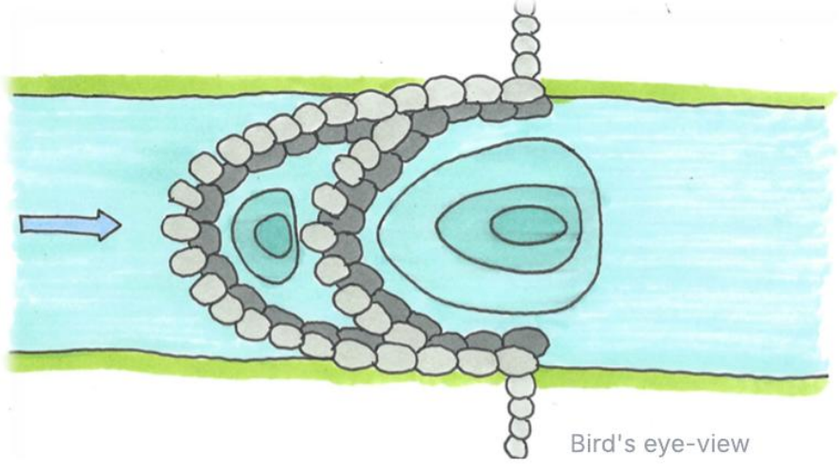
- Spans the entire channel, provides grade control, and focuses flow to channel centre
- Can be constructed with wood (logs), stones (boulders) or both
- Applicable for streams with slight to moderate meandering and natural riffle-pool sequencing
- For streams with moderate to high gradient and constant flow
- Configured as two single arm vanes that connect at the centre of the stream
- High and low flow must be considered and designs should not prevent fish passage

Advantages

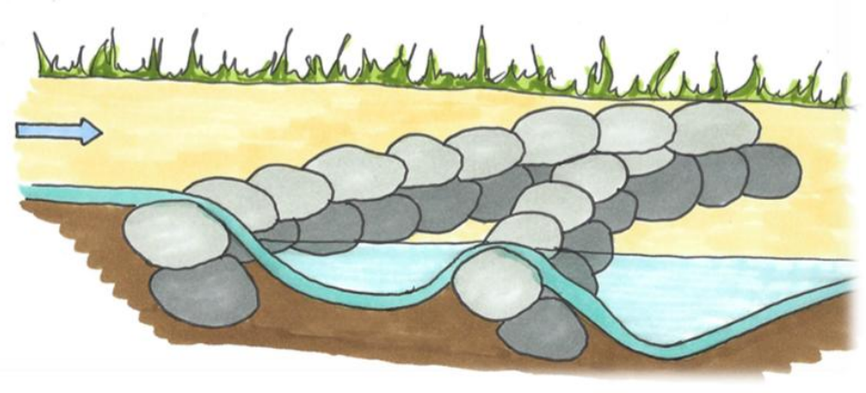
Redirects main flow
Reduces erosional stress on banks
Promotes riparian vegetation growth
Creates riffle-pool environments
Can protect infrastructure

Disadvantages

Requires large equipment
Risk of damage during high flows
Limited benefit on water quality
Sediment accumulation
Requires flowing water
Costly



Bird's eye-view



Cross sectional

J-Hook Vane

Purpose

1) Regulates water flow: stabilizes water flow and deflects flow to channel centre
2) Reduces erosion: prevents bank erosion by concentration flow towards channel centre
3) Sediment control: reduces bank erosion
4) Restoration: creates and supports "pool" formations in streams, increases stream flow diversity
5) Naturalizes streams: forces streams to follow natural pathways, protects overall stream stability

Basic Design

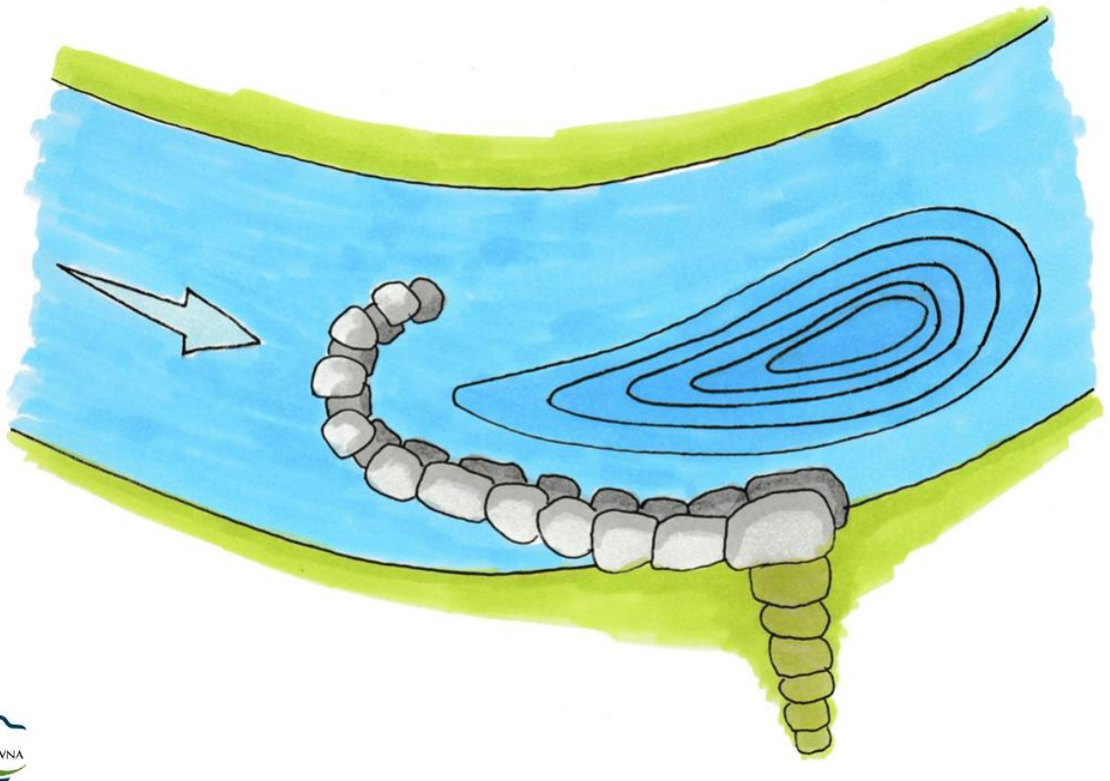
- Spans base flow channel, deflects flow from the banks, creates turbulence, and disspates energy
- Can be constructed with wood (logs), stones (boulders) or both
- Applicable for streams with slight to moderate meandering and natural riffle-pool sequencing
- For streams with moderate to high gradient and constant flow
- Configured as one single vane that ends in a hook shape at the centre of the channel

Advantages

Redirects main flow
Reduces erosional stress on banks
Promotes riparian vegetation growth
Creates riffle-pool environments
Can protect infrastructure

Disadvantages

Requires large equipment
Risk of damage during high flows
Limited benefit on water quality
Sediment accumulation
Requires flowing water



Reconnecting Meanders

Purpose

1) Restores natural flow: re-establishes natural flow patterns
2) Water flow regulation: stabilizes water flow by naturalizing water movement and capturing runoff
3) Reduces erosion: natural flow patterns reduce water velocity and erosion
4) Increases soil moisture: increases wetted area footprint and contributes to ground water recharge
5) Restoration: reconnecting meanders restores natural physical habitat diversity
6) Increases riparian habitat: newly wetted areas increase riparian areas

Basic Design

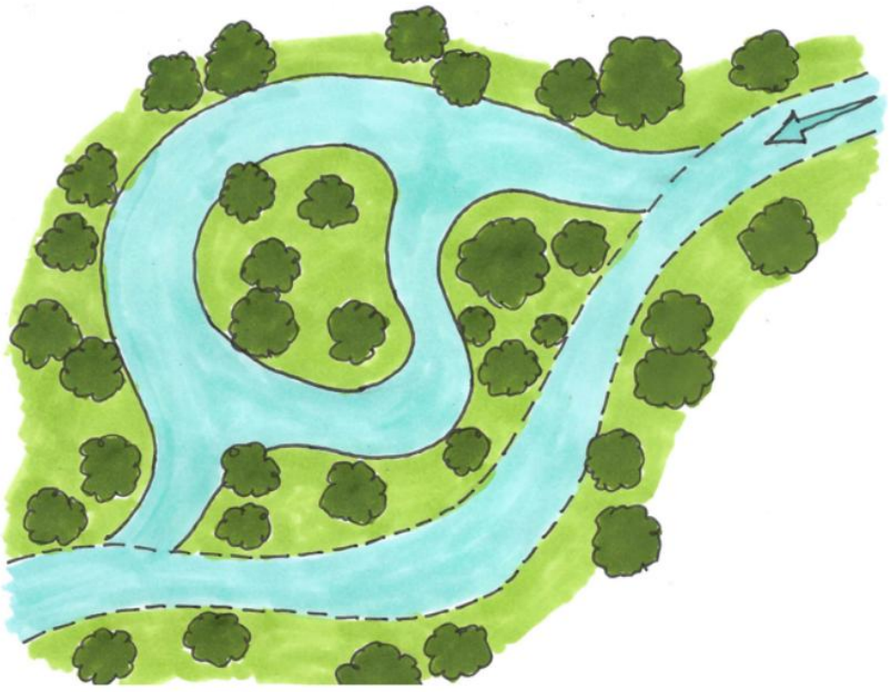
- A meander is a U-form shaped area of a river or stream
- Reconnecting meanders requires creating new meandering courses or reconnecting cut-off meanders
- Reconnected meanders create new flow conditions that continue to shape the body of water
- Can require removal of infrastructure that supports channelization
- Requires relatively large areas of land to support meanders, newly wetted areas, and wetlands
- Requires strategic design, ecological thoughtfullness, and long-term planning

Advantages

Provides flood protection downstream
Provides water storage
Increases ecosystem services
Improves water quality (long-term)
Increases aquatic habitats
Facilitates bio-diversity

Disadvantages

Can cause temporary nutrient increase
New meanders can impact sedimentation
Requires extensive planning
Requires adequate hydrology
Labour intensive
Costly



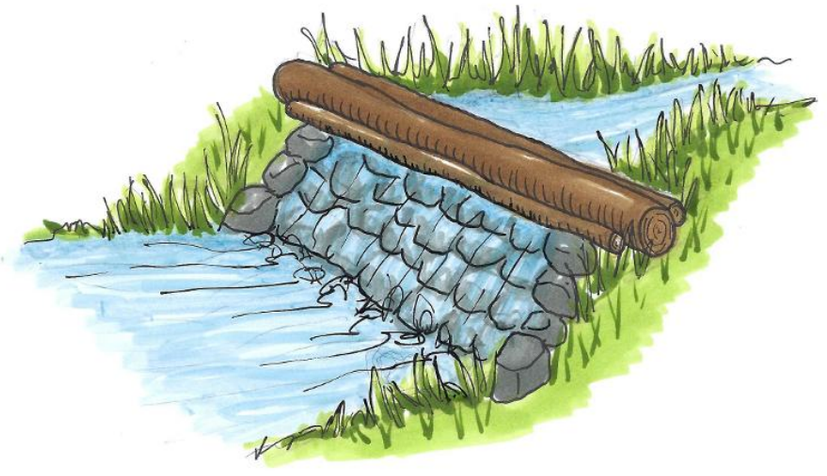
Rock Check Dams

Purpose

1) Reduces erosion: by slowing water, soil erosion is prevented
2) Sediment control: structures trap sediment and reduce downstream movement
3) Water flow regulation: stabilizes water flow and reduces flash flooding in channels
4) Increases soil moisture: allows water to infiltrate soil, recharges ground water, promotes vegetation
5) Restoration: used to stabilize water courses, increase water storage and provide aquatic habitats

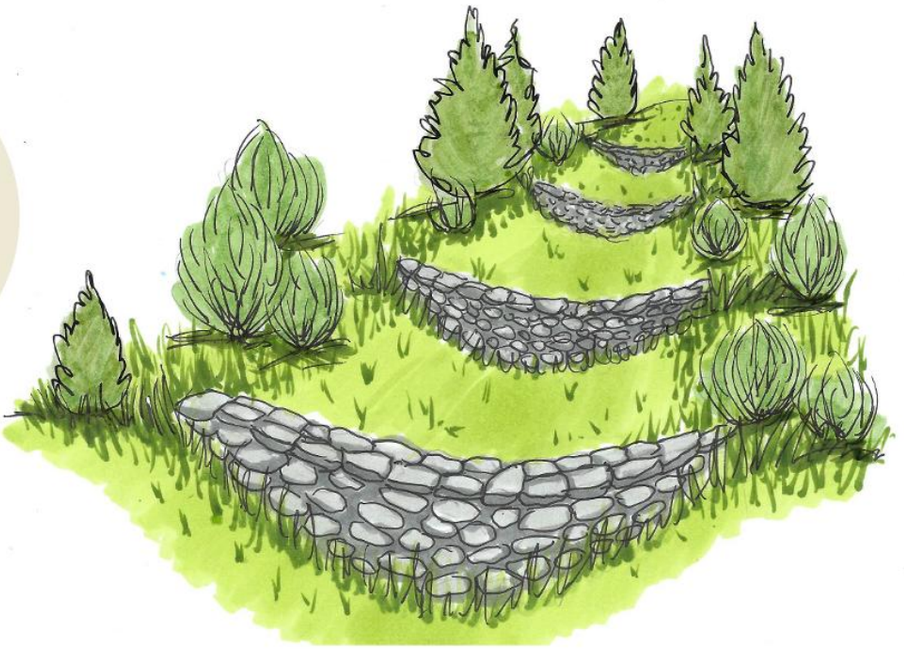
Basic Design

- Rock check dams are relatively small temporary structures that require maintenance
- Constructured within areas of concentrationed flow such as channels and ditches (< 10 acre drainage)
- Most effective when used in series
- Typically composed of rock, sand or gravel bags, and fibre logs
- Extends bank to bank with centre as the lowest point (24" max centre height)
- Inexpensive in materials



Advantages

Provides flood protection
Improves water filtration
Cost effective
Low maintenance
Creates aquatic habitats
Can conform to channel shapes



Disadvantages

Risk of damage during high flows
Limited benefit on water quality
Can reduce channel hydraulic capacity
Limited life span
Sediment accumulation
May require regular maintenance

Zuni Bowls

Purpose

1) Reduces erosion: by dissipating water energy, soil erosion and scouring is reduced
2) Water filtration: structures promote natural water filtration processes
3) Regulates water flow: stabilizes water flow and prevents headcuts from migrating upstream
4) Increases soil moisture: allows water to infiltrate soil, recharges ground water, promotes vegetation
5) Restoration: used to stabilize water courses and creates diverse aquatic habitats

Basic Design

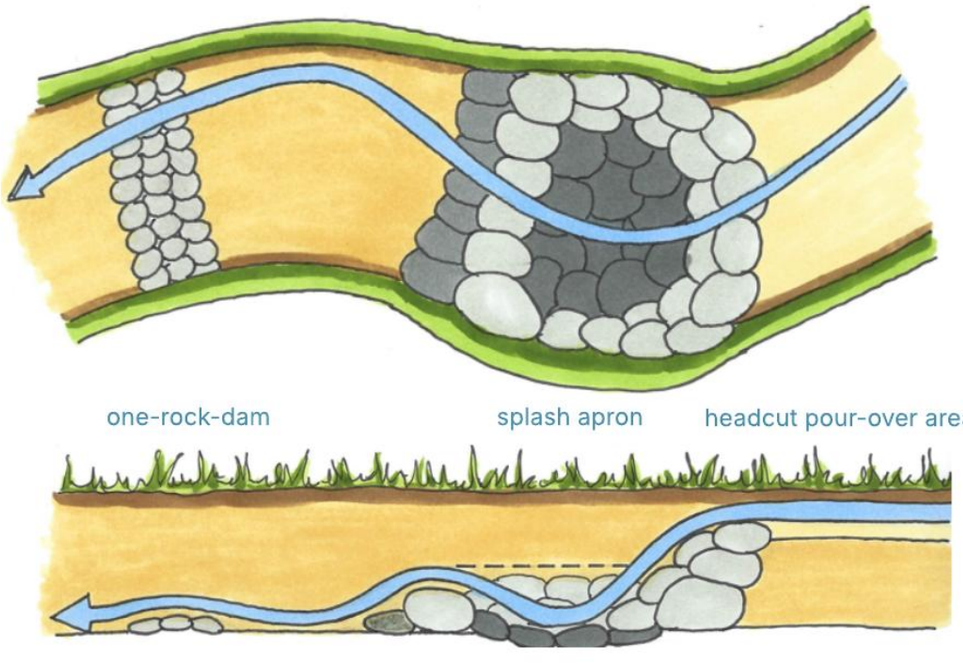
- Dissipates energy of falling water at the headcut pour-over
- Headcut control structure composed of rock lined step falls and plunge pools
- Develop a shallow trench full of rocks downstream of headcut to develop the "splash apron"
- Using large rocks, connect splash apron with headcut to develop pour over zone
- Create "one-rock-dam" downstream of trench to continue energy dissipation
- Splash aprons and one-rock-dams can exist in several series
- Scatter native grass and wildflowers seeds where zuni bowl is built

Advantages

Reduces erosion in water ways
Improves water filtration
Creates aquatic habitats
Can conform to channel shapes
Long term durability

Disadvantages

Labour intensive
Limited storage capacity
Sediment accumulation within bowl
Small-scale application only



Bird's eye-view

Cross sectional

Riparian micro-storage

This section covers micro-storage implemented within the riparian area near streams (Figure 3). Riparian or offside micro-storage provides resource management without directly intercepting water courses. These systems focus on water quantity and soil moisture retention. Off-side systems support vegetation and provide water treatment through ground filtration/infiltration. They have strong ecosystem values and increase the area's wildfire resilience.



Figure 3: Cistern analogue

Artificial Meanders

Purpose

1) Restores natural flow: establishes natural flow dyanmics
2) increases flood protection: widens the floodplain and increases capacity to withhold water
3) Reduces erosion: natural flow patterns will decrease water velocity and reduce erosion
4) Increases soil moisture: increases the wetted area footprint and contributes to ground water recharge
5) Restoration: meanders restore natural physical habitat diversity
6) Increases riparian habitat: newly wetted areas increase riparian areas

Basic Design

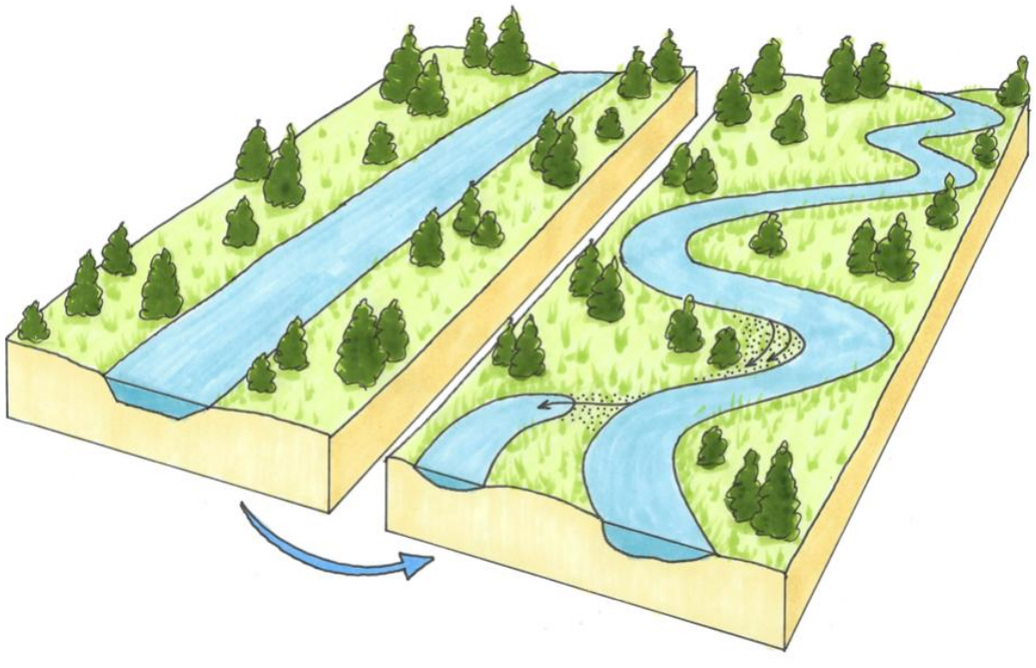
- A meander is a U-form shaped area of a river or stream
- Requires creating new meandering courses on an artifical stream
- Meanders create new flow conditions that continue to shape the body of water
- Might require removal of infrastructure that supports channelization
- Requires relatively large areas of land to support meanders, newly wetted areas, and wetlands
- Requires strategic design, ecological thoughtfullness, and long-term planning

Advantages

Provides flood protection downstream
Provides water storage
Improves water quality (long-term)
Creates aquatic habitats
Facilitates bio-diversity
Increases natural aesthetic

Disadvantages

Can cause temporary nutrient increase
New meanders can impact sedimentation
Requires extensive planning
Requires adequate hydrology
Labour intensive
Costly



Cistern Analogues

Purpose

1) Water storage: stores water for summer release and contributes to ground recharge
2) Water treatment: slows water movement promoting sediment settlement and allows natural filtration
3) Increases soil moisture: increases the wetted area footprint and contributes to ground water recharge

Basic Design

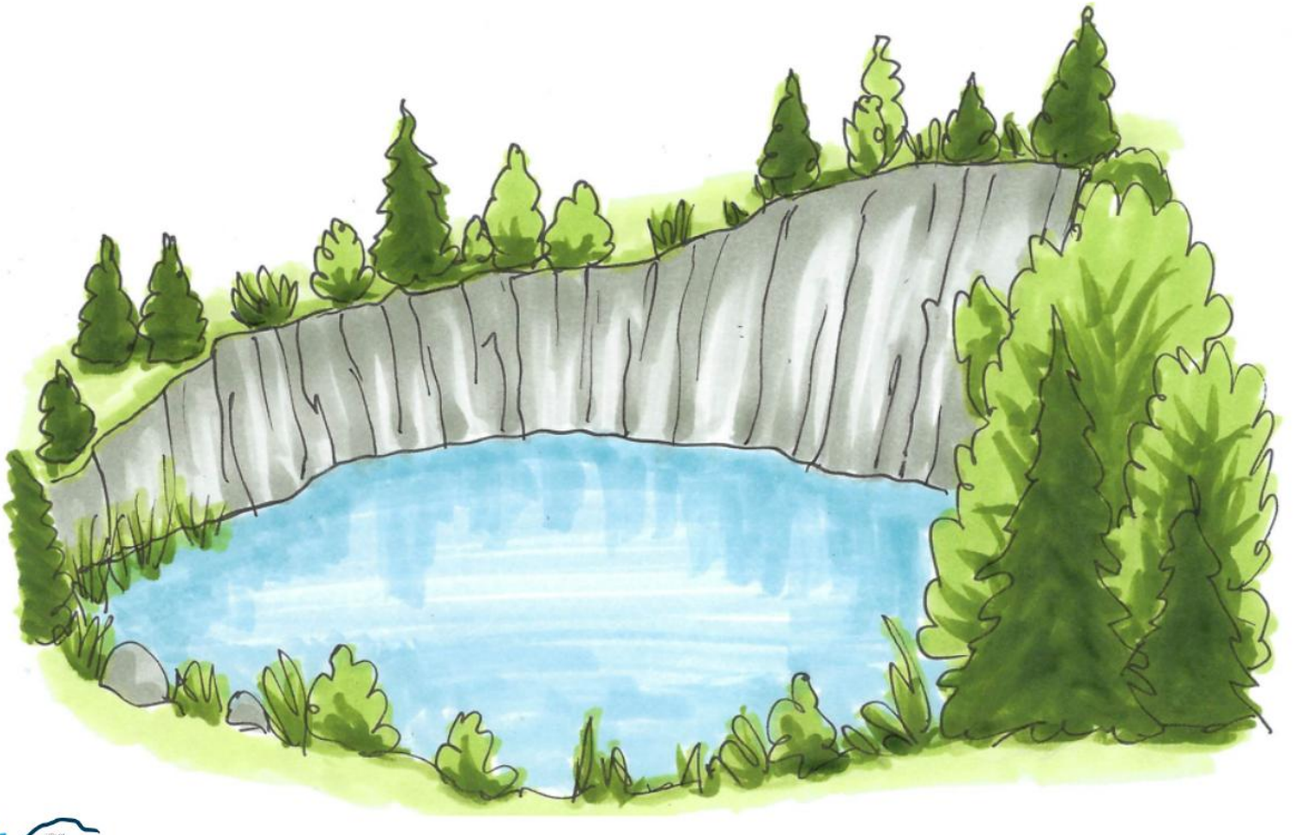
- Must intersect ground water
- Requires large depressed area
    - Naturally depressed areas or constructed
- Basins are typically deep and situated in areas with permeable soil
- Requires access for maintenane and sediment removal

Advantages

Creates open water
Provides water storage
Promotes ground water recharge
Promotes natural filtration
Traps sediment

Disadvantages

Not applicable in steep areas
Risk of temporary poor water quality
Requires thoughtful planning
Costly



Floodplain Waffle Gardens

Purpose

1) Restoration: increases vegetation, supports agriculture in arid areas
2) Maintains soil moisture: below-ground vegetative area is kept moist by mounded earth walls
3) Supports vegetation: water is directed to roots and maximumes water use in dry climates
4) Reduces active water demand: plants within waffle depressions are less susceptible to drought

Basic Design

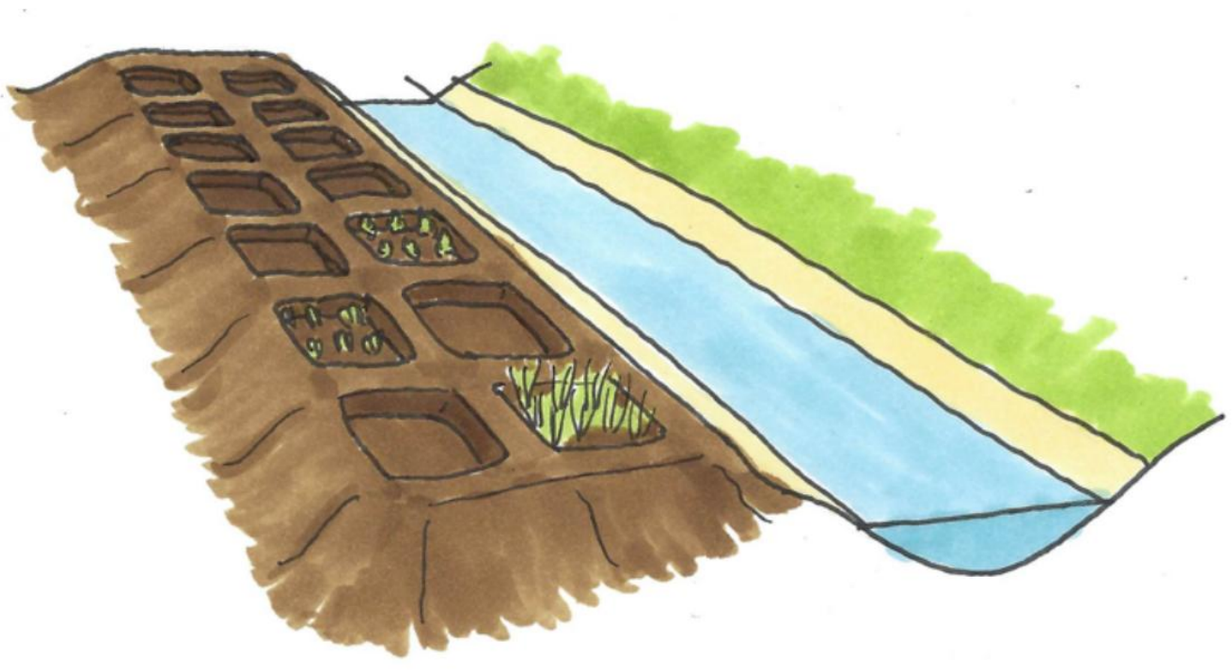
- Has been implemented for thousands of years by The Zuni (Indigenous peoples of Zuni River Valley)
- Can be implemented in urban and rural settings
- Ideal for floodplains
- Can be designed to utilize freshet or run-off
- "Waffle-like" depressions that are planted with native vegetation
- Selected native vegetation must be drought and sun tolerant

Advantages

Increases post logging regrowth
Cheap

Disadvantages

Requires relatively flat land
Can require maintenance



Lined Detention Basins

Purpose

1) Water storage and flood water management: creates an impermeable barrier for water storage
2) Stabilizes soils: lined detention ponds prevent loose soils from entering the water system
3) Water treatment: typically used in urban settings to contain and remove contaminants in stormwater

Basic Design

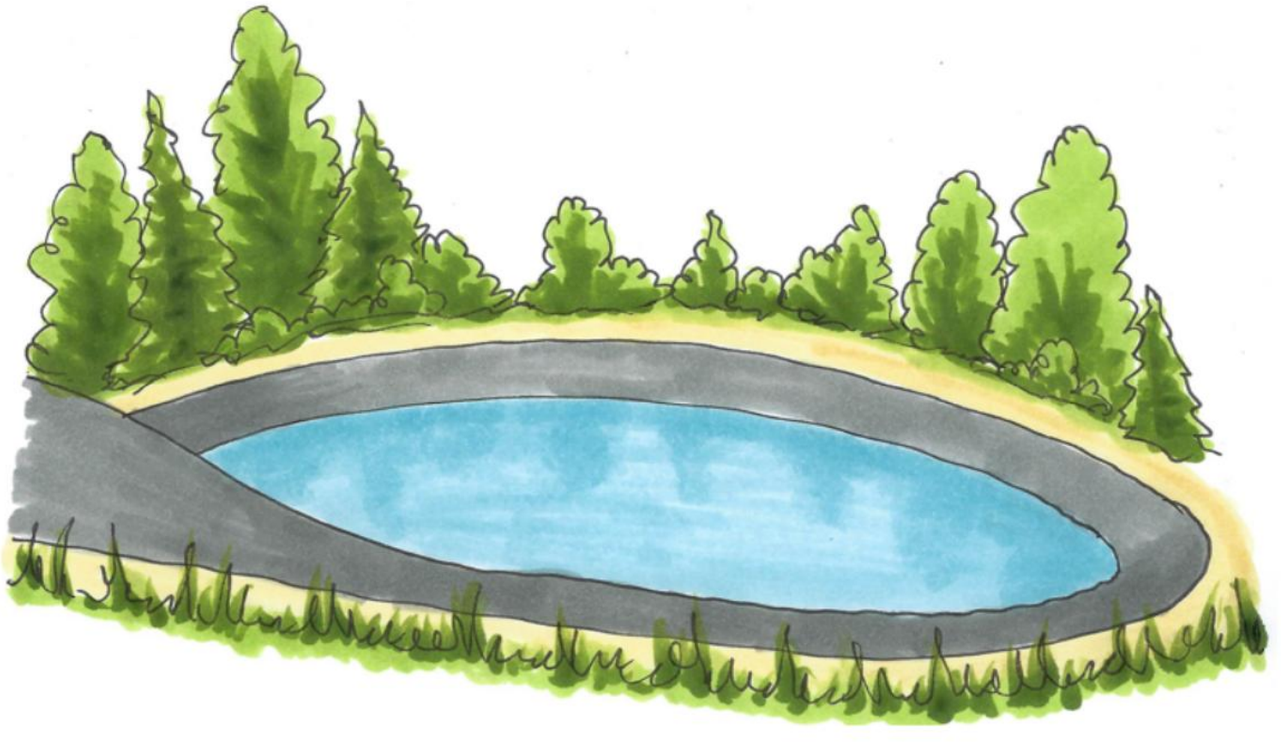
- Large depressed area lined to promote water retention
- Requires base flow into system
- Primarily designed for urban areas
- Type of liner depends on environment and development purpose

Advantages

Creates open water
Provides water storage
Holds contaminants within basin
Traps sediment
Rapidly fills after storms

Disadvantages

Unnatural appearance
Does not recharge ground water
Not applicable in steep areas
Risk of poor water quality
Requires active management
Costly



Mulch Basins

Purpose

1) Water storage: holds water within mulch basin for ground based filtration, captures surface run-off
2) Water treatment: mulch is a natural filter that provides water filtration
3) Increases soil moisture: mulch causes water to widely and deeply infiltrate soil
4) Flood protection: mulch will absorb large quantites of water when strategically placed

Basic Design

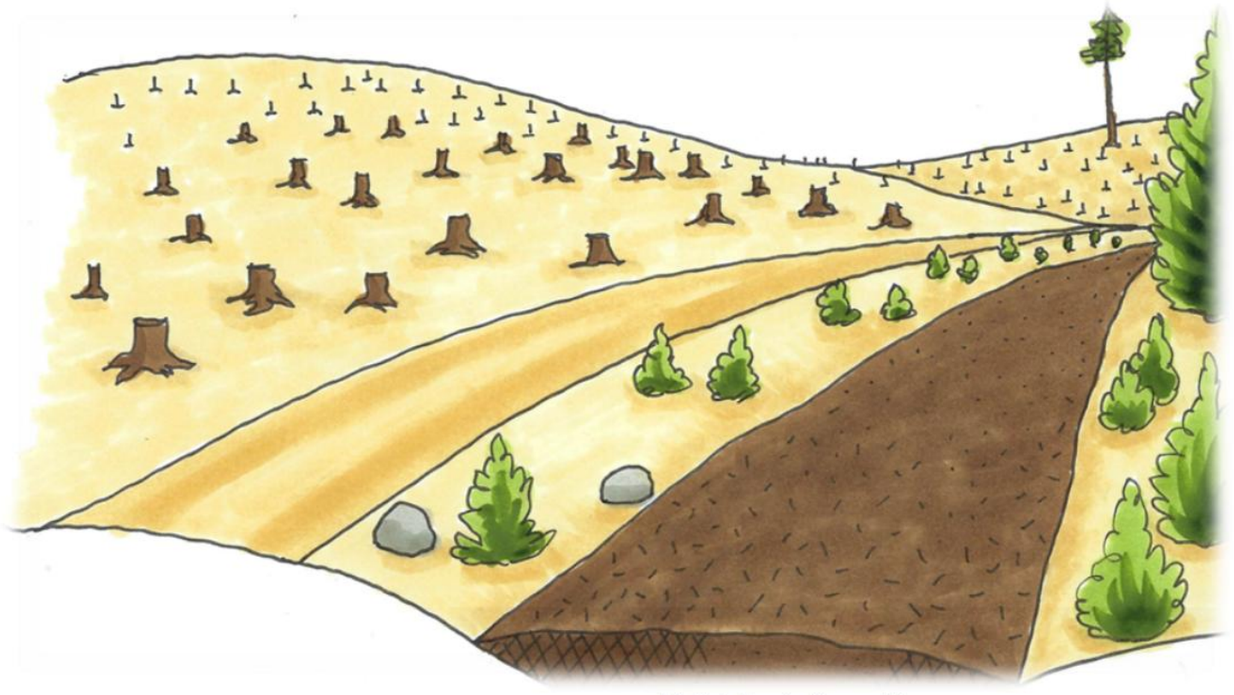
- Outside of stream or creek channel
- Dug out trench that is back filled with mulch
- Mulch basin is situated in an area that recieves natural water drainage and rain water
- The mulch basin will fill with water, capture moisture, and provide water infiltration to surrounding soil

Advantages

Provides ground water recharge
Supports natural soil infiltration
Low cost

Disadvantages

Requires maintenance
Requires large drainage areas
For flat or gently sloped areas



Mulch Basin (trench)

Riparian Hugelkultur Gardens

Purpose

1) Restoration: increases vegetation and supports agriculture in arid areas
2) Maintains soil moisture: wood within the berms retain water and provide nutrients to vegetation
3) Supports vegetation: supports plants during drought periods by excellent water retention
4) Reduces active water demand: water is retained with wood and released during dry periods

Basic Design

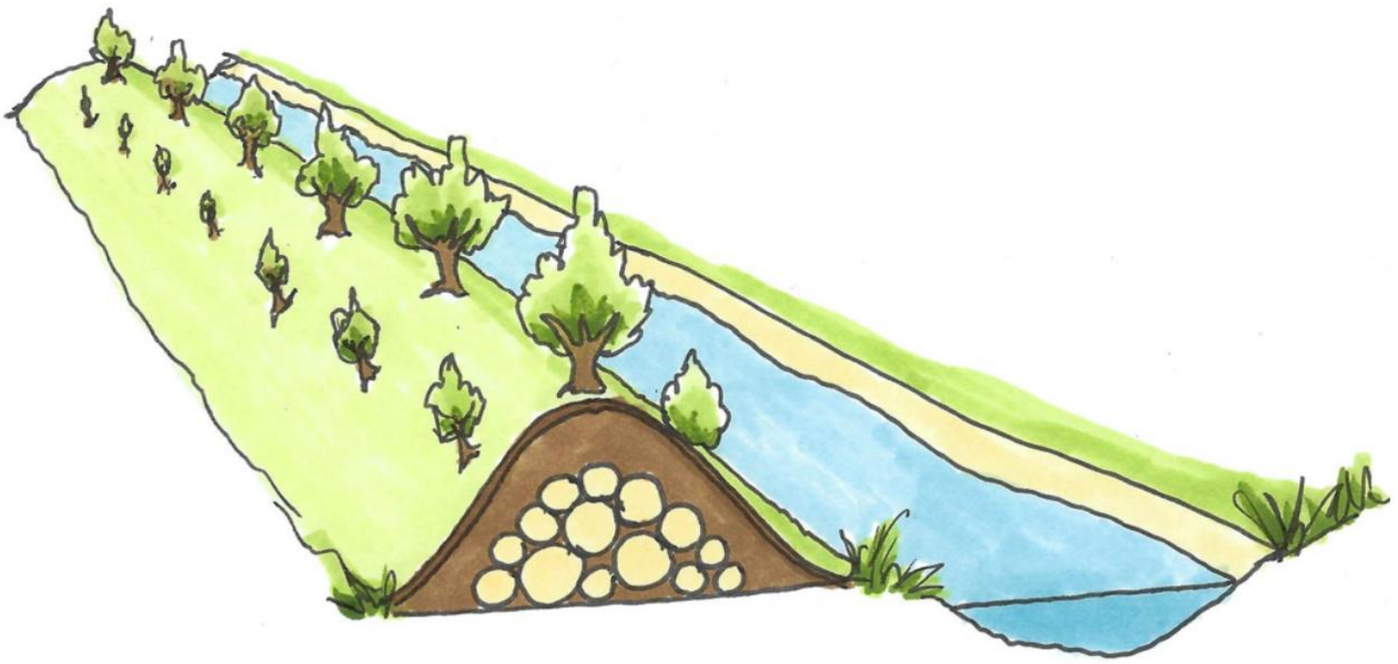
- Raised berm within floodplain or close to stream
- Base of berm is composed of wood and is topped with soil and organics
  - Tip: Fill crevaces between wood with soil to deter rodents

Advantages

Materials are cheap
Supports plants during drought

Disadvantages

Expensive
Prone to rodent issues
Requires thoughtful design



Stormwater Gardens/ Bioretention Cells

Purpose

1) Water treatment: promotes natural water filtration and can improve water quality
2) Water storage: creates areas that collect and pools water, captures run off, stores freshet and rain
3) Increases soil moisture: allows water to infiltrate soil, recharges ground water, promotes vegetation
4) Restoration: creates aquatic habitats, wetlands, and supports riparian vegetaion

Basic Design

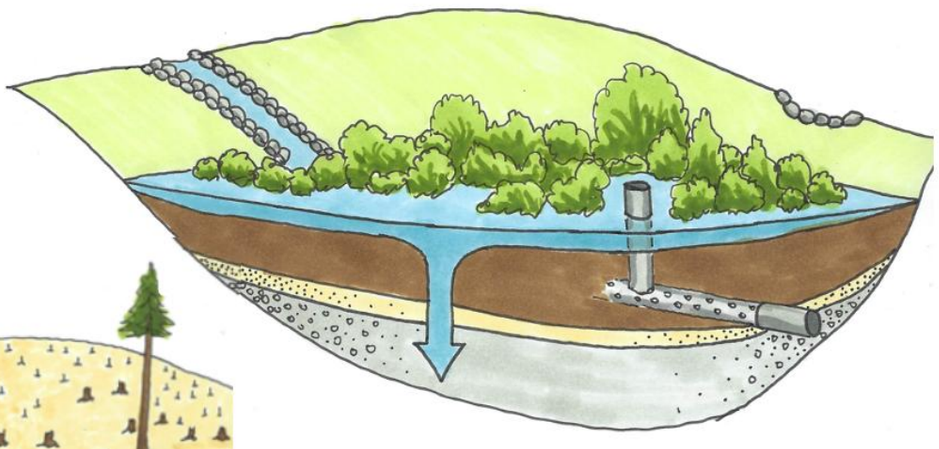
- Can be implemented in urban and rural settings
- Located within natural, or constructed, depressions that collect water
- Can be filled with sandy soil and mulch to increase water treatement
- Typically designed to be very shallow and promote ground infiltration

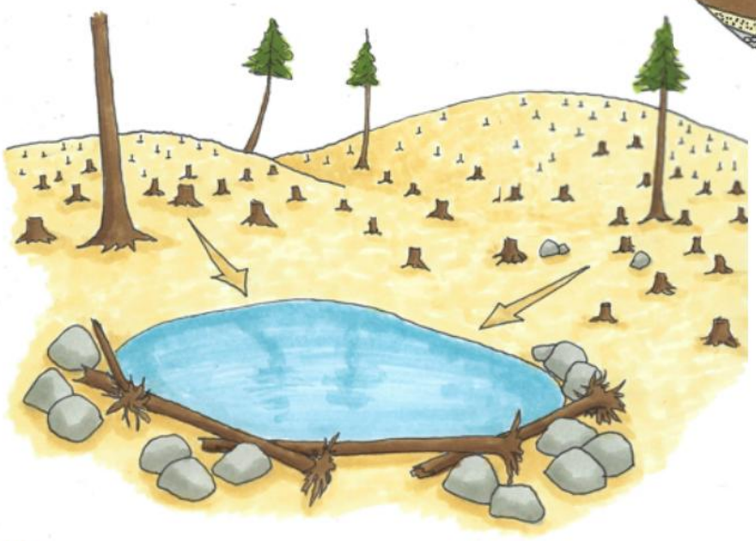
Advantages

Provides habitat restoration
Increases soil moisture
Promotes vegetation
Can be very simple

Disadvantages

Can require maintenance
Requires drainage or flow





Unlined Detention Basins

Purpose

1) Water storage and flood water management: creates an atrifical area for water collection
2) Restoration: increases wetted areas, facilitates wetland formations, promotes natural bioremediation
3) Water treatment: slows water movement promoting sediment settlement and allows natural filtration
4) Increases soil moisture: increases the wetted area footprint and contributes to ground water recharge

Basic Design

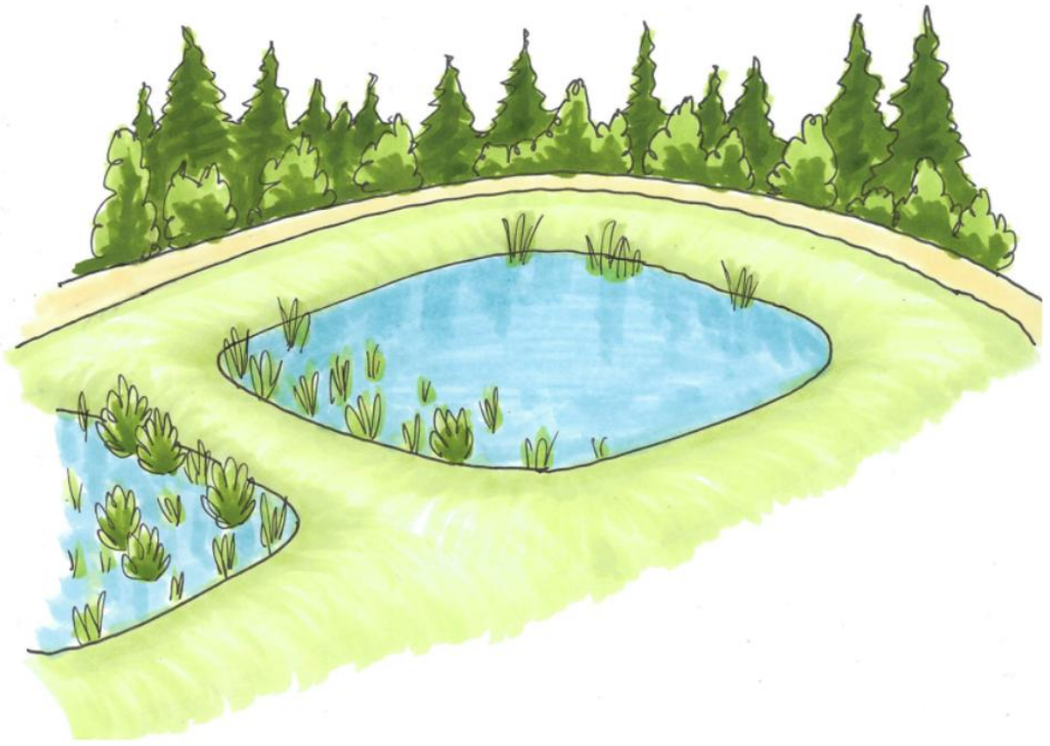
- Must intersect ground water
- Requires large depressed area
- Basins are typically shallow and situated in areas with permeable soil for infiltration
- Utilizes native plants within and around basin
- Requires access for maintenane and sediment removal

Advantages

Creates open water
Provides water storage
Promotes ground water recharge
Promotes natural filtration
Traps sediment

Disadvantages

Unnatural appearance
Not applicable in steep areas
Risk of short term poor water quality
Requires thoughtful planning
Costly



Adjacent micro-storage

Adjacent micro-storage created outside of streams is aimed at storing run-off and increasing soil moisture retention (Figure 4). Adjacent micro-storage techniques provide water for vegetation and recharge groundwater. Water storage relies on surface run off and should aim to minimize impacts on natural water courses. Adjacent features such as created wetlands and swales help vegetation remain green and therefore resistant to wildfire.



Figure 4: Adjacent water storage – created wetland

Boomerang Berms

Purpose

1) Increases soil moisture: berms retain water around a single tree or planted area
2) Water conservation: captures runoff by redirecting to plant bases and replenishes ground water
3) Supports vegetation: supports plants during drought periods by focusing water to plant base

Basic Design

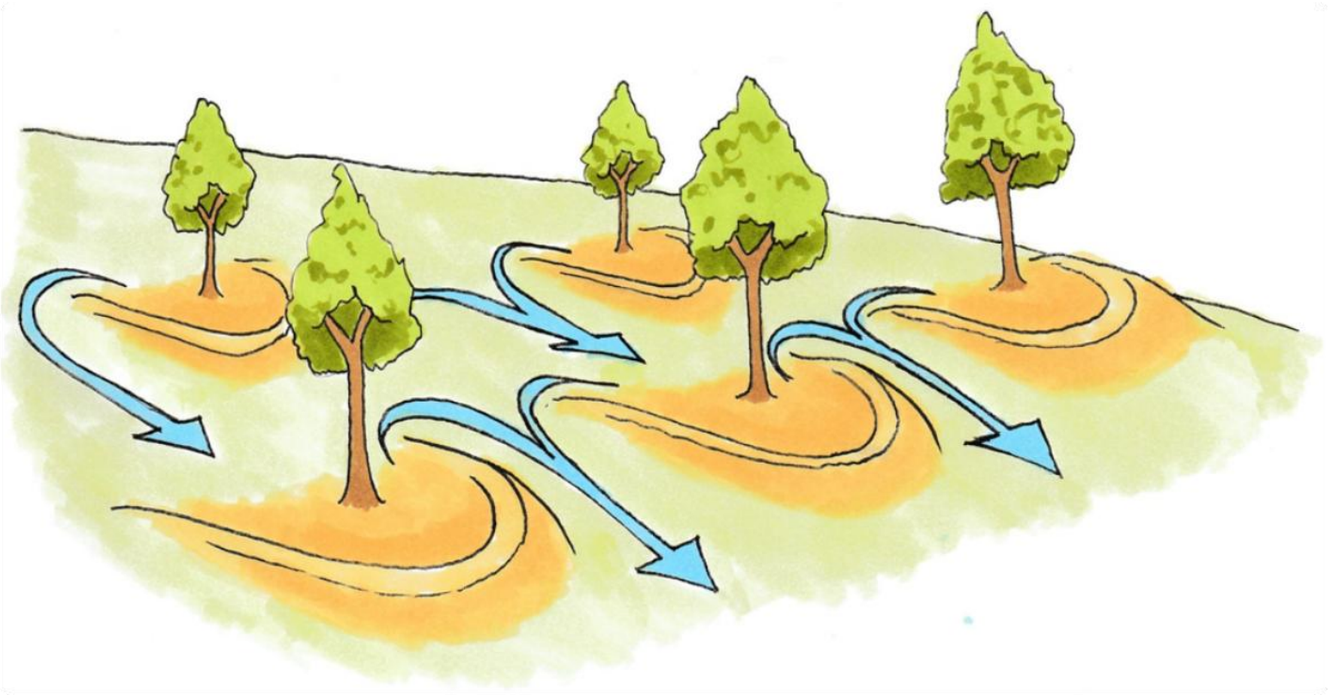
- Acts as a small dam to retain water in a designated area
- Half-moon shaped earthwork used to provide drought protection to plants and trees
- Located on downhill side of tree or planted area
- Directs water to base of plants
- Can utilize mulch to increase water retention

Advantages

Materials are cheap
Supports plants during drought
Simple technique

Disadvantages

Labourous
Does not support large areas



Burnt Slope Stabilization

Purpose

1) Reduces runoff: captures water run off from slopes and facilitates pooling
2) Reduces erosion: reduces volume of surface run off and slows sediment transport
3) Increases water storage: retains water within the soil

Basic Design

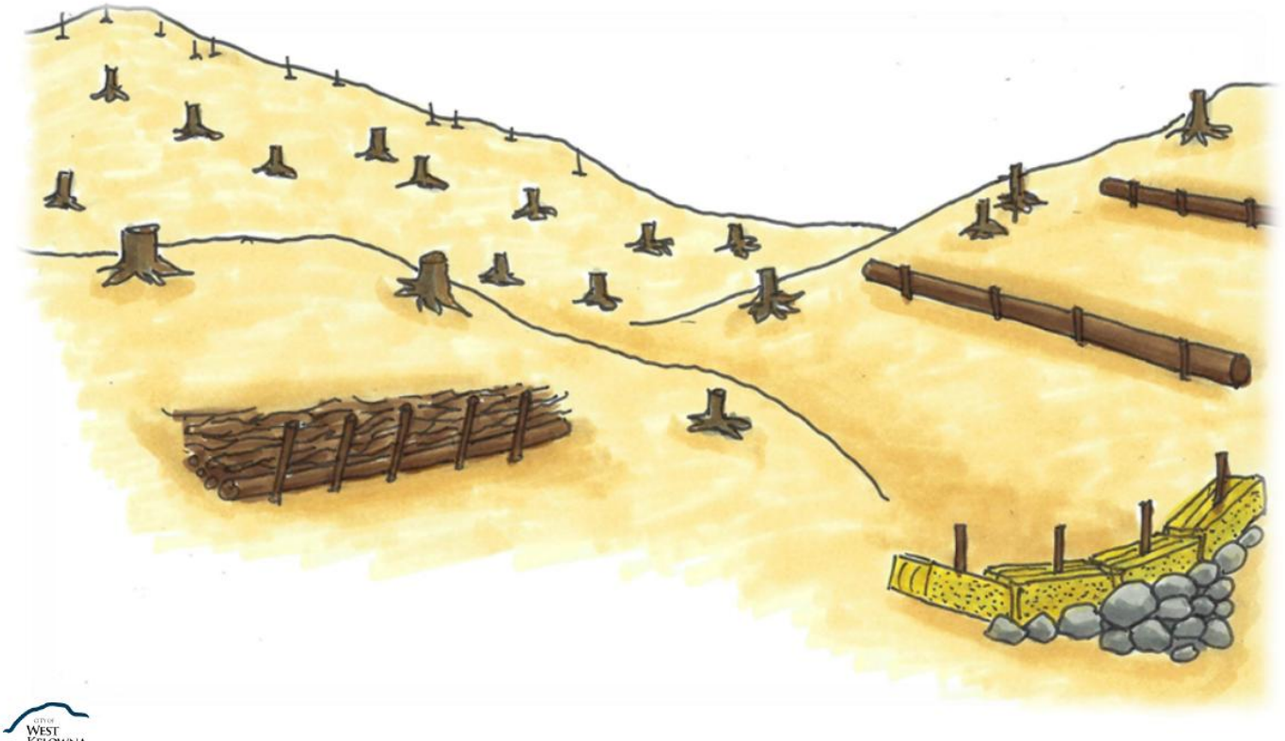
- Conduct post-fire assessment
    - determine burn severity
    - conduct soil and hydrological analysis
- Select stabilization techniques
- Use burnt logs on natural contours to stabilize slopes
- Structures should be placed in natural run off pathways

Advantages

Improves water quality
Reduces sedimentation into streams
Supports remediation after wildfires

Disadvantages

Typically conducted on crown land
Requires environmental surveys



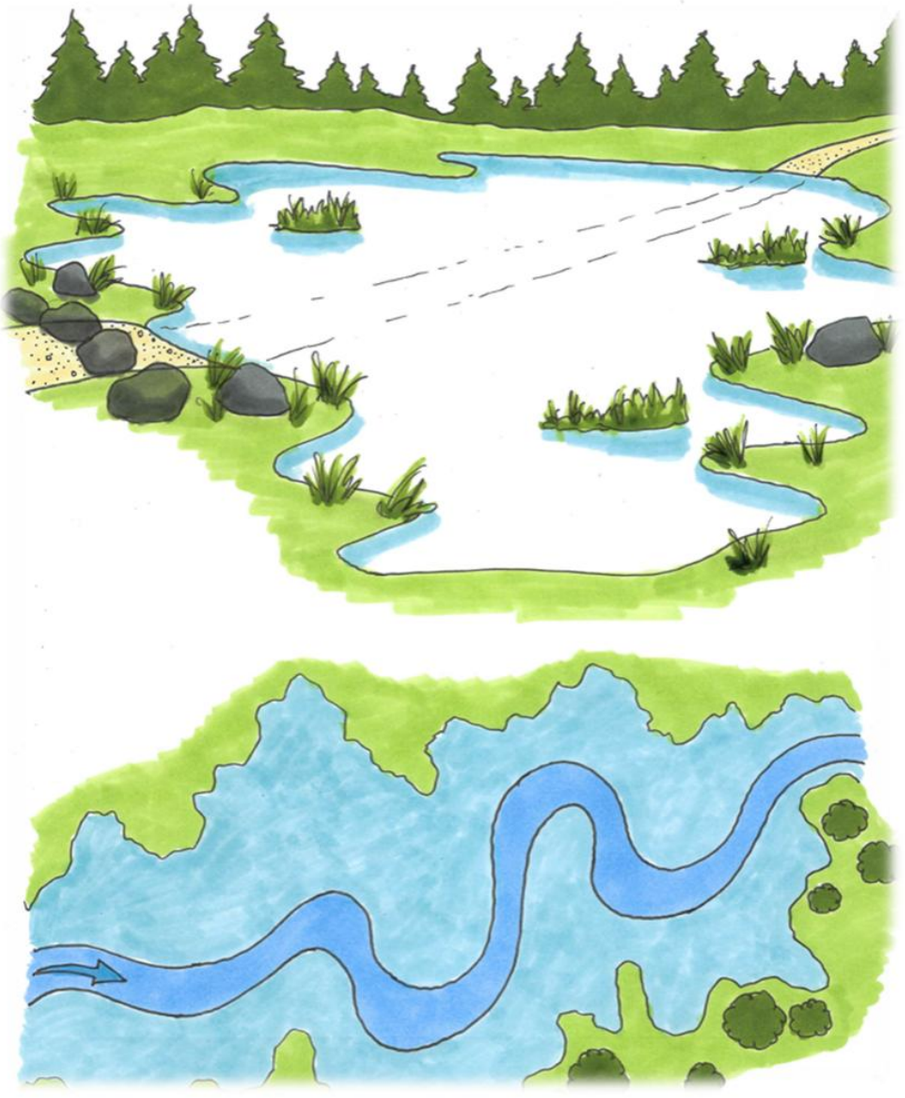
Created Wetlands

Purpose

1) Increases soil moisture: wetlands retain water within the soil and increase the flood plain area
2) Recharges ground water: connected to groundwater and contribute to recharge
3) Water conservation: captures runoff, increases water storage, and replenishes ground water
4) Water treatment: wetlands provide ecosystem services that contribute to water treatment
5) Supports wildlife and vegetation: supports wildlife and vegetation sensitive to drought

Basic Design

- Conduct a site assessment by a QEP
    - Determine water source, water flow, seasonal water levels
    - Conduct soil analysis and assess topography for suitability
- QEP should provide or approve wetland design
- Select appropriate native plants that support wetland development
- Consider wildlife implications



Advantages

Provides ecosystem services
Improves water quality
Provides aquatic habitats
Can be used to decomission roads

Disadvantages

Requires groundwater connection
Costly and laborous

Expanding Riparian Corridors

Purpose

1) Water treatment: riparian areas provide ecosystem services that contribute to water treatment
2) Water conservation: stores water, increases water storage, and recharges ground water
3) Increases soil moisture: increases soil's water retention and increases the flood plain's footprint
4) Captures sediment: reduces erosion, filters sediment, traps sediment moving downstream
5) Bioremediation: supports wildlife and vegetation, sequesters carbon, provides shade

Basic Design

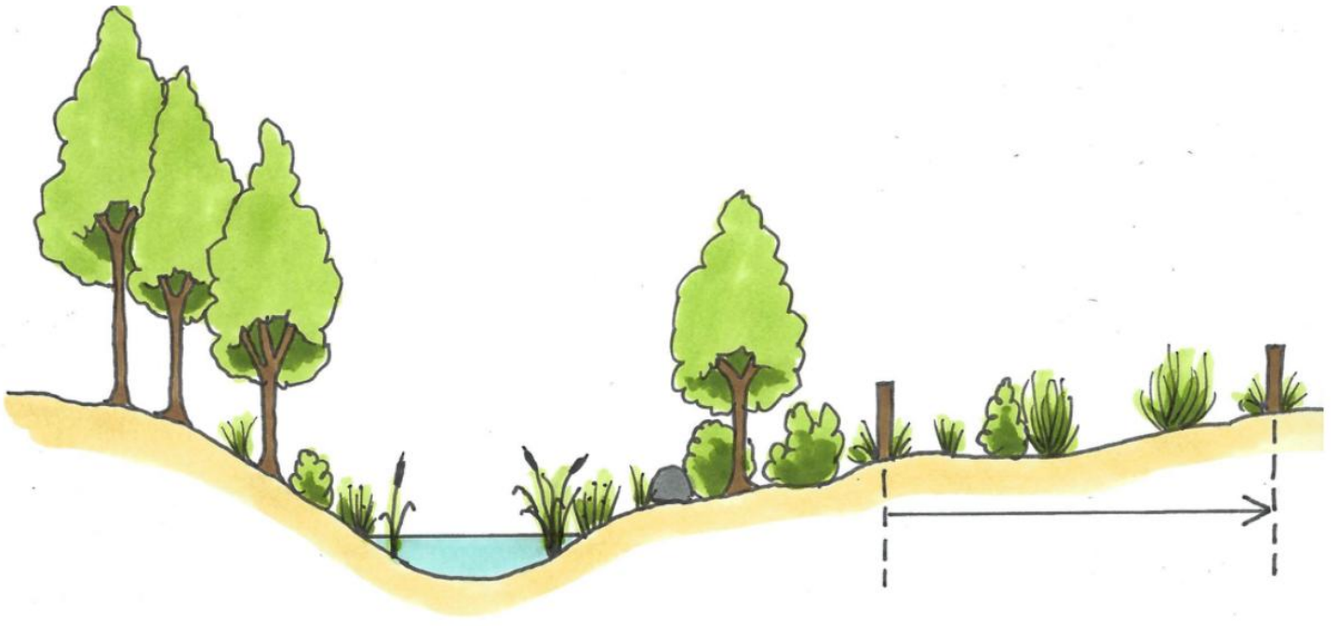
- Expansion of riprarian corridors
- Conduct a site assessment by a QEP
    - determine water source, water flow, seasonal water levels
    - conduct soil analysis and assess topography for suitability
- QEP should provide or approve riparian design
- Select appropriate native plants that support wetland development
- Consider wildlife implications

Advantages

Improves water quality
Creates aquatic habitats
Increases natural ecosystem services
Provides shade

Disadvantages

Requires groundwater connection
Laborous



Infiltration Basins

Purpose

1) Water storage: stores water for ground based filtration
2) Water treatment: increases wetted areas and promotes natural bioremediation
3) Increases soil moisture: increases the wetted area footprint and contributes to ground water recharge

Basic Design

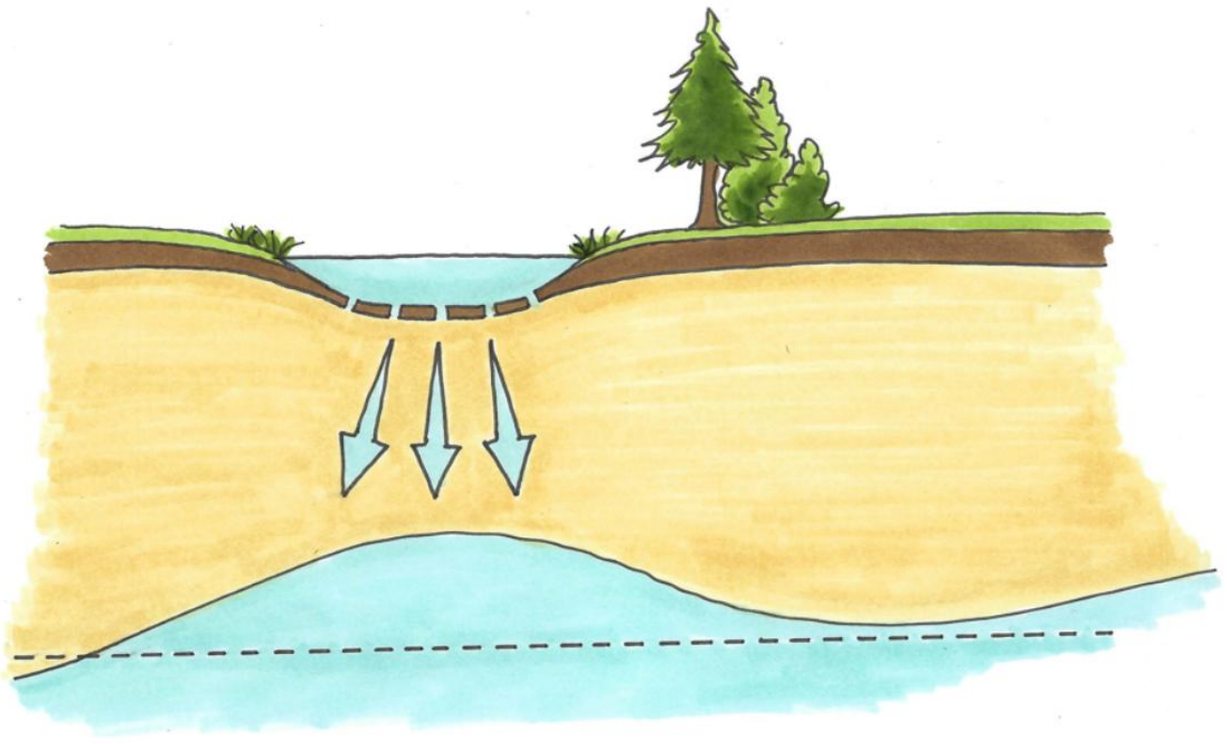
- Requires geotechnical investigations to confirm capacity for ground water infiltration
- Basins are typically shallow and require permeable soils for infiltration
- Created by excavation or berming
- Utilizes native plants within and around basin

Advantages

Provides ground water recharge
Supports natural filtration
Low cost

Disadvantages

Not applicable in steep areas
Risk of short-term poor water quality



Off-side Watering

Purpose

1) Water quality protection: reduces negative cattle influences on water ways
2) Decreases nutrient loading: reduces cattle waste in streams that add nutrients to waterways
3) Minimizes pathogen contamination: reduces direct water contamination from cattle waste
4) Bioremediation: protects vegetation from cattle trampling
5) Reduces erosion: prevents cattle trampling of riparian areas and reduces sediment in streams
6) Protects cattle: provides safe drinking area for cattle

Basic Design

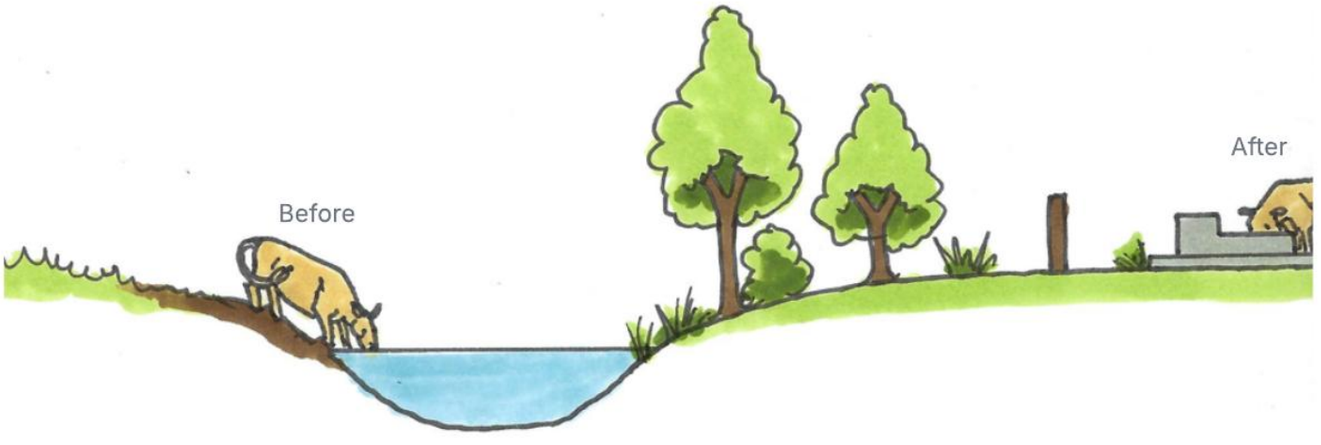
- Determine water source for off-side watering (well/spring, piped water, storage tanks)
- Develop water delivery system (piping, pumps, troughs)
- Determine "waterer" best for cattle owner
- Promote and ensure easy cattle accessibility

Advantages

Increases source water protection
Improves water quality
Reduces pathogens in waterways
Prevents riparian trampling

Disadvantages

Requires stakeholder collaboration
Can be costly



Swales (Distribution Ditches)

Purpose

1) Recharges ground water: retains water within depressioned centre and recharges ground water
2) Flood protection: captures run off and directs flow
3) Water treatment: vegetation and soil filtration supports natural water treatment processes
4) Supports vegetation: supports plants during drought periods by maintaining wetted soils

Basic Design

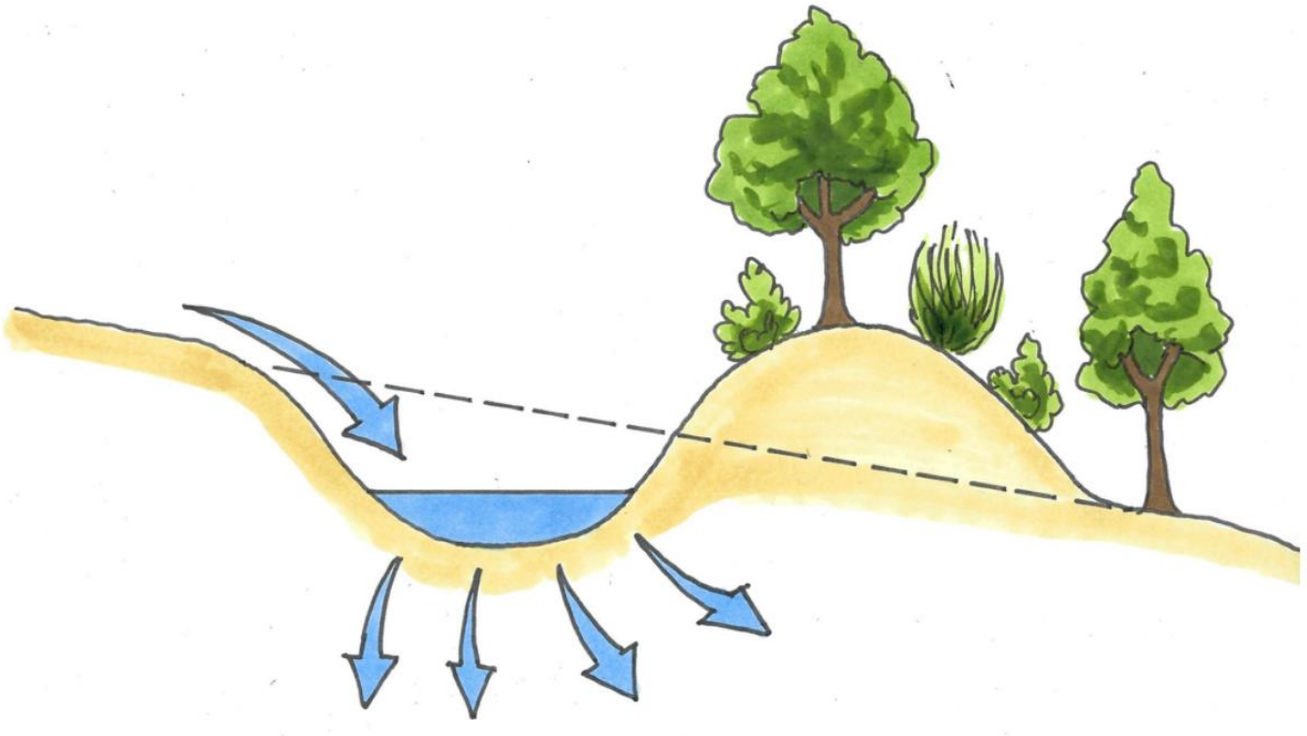
- Shallow, broad, linear depression designed to capture water
- Typically used in conjunction with berms
- Most effective on gentle slopes (prevents erosion)
- Plant native vegetation along swales to support water absorption and filtration

Advantages

Materials are cheap
Captures water from large area
Recharges groundwater
Simple technique

Disadvantages

Labourous
Can require maintenance
Sediment accumulation



Micro-storage Case Study

LAC conducted basic surveys on 34 sites within the Lambly and Powers creeks watersheds during early June 2024 (Figure 5; Figure 6). Of the 34 sites, several sites were combined resulting in 20 general surveyed areas (Figure 6). Appendix 3 lists general observations recorded during the basic surveys (Table 5).

The 20 general sites were rated by eight questions listed in Appendix 3 (Table 6). Sites given a designation of moderate or high represent areas where micro-storage techniques could be applied (Figure 6). These sites do not represent pre-determined areas for micro-storage but serve as a list of sites that can be resurveyed and explored for water storage.



Figure 5: LAC team member conducting basic survey, June 2024

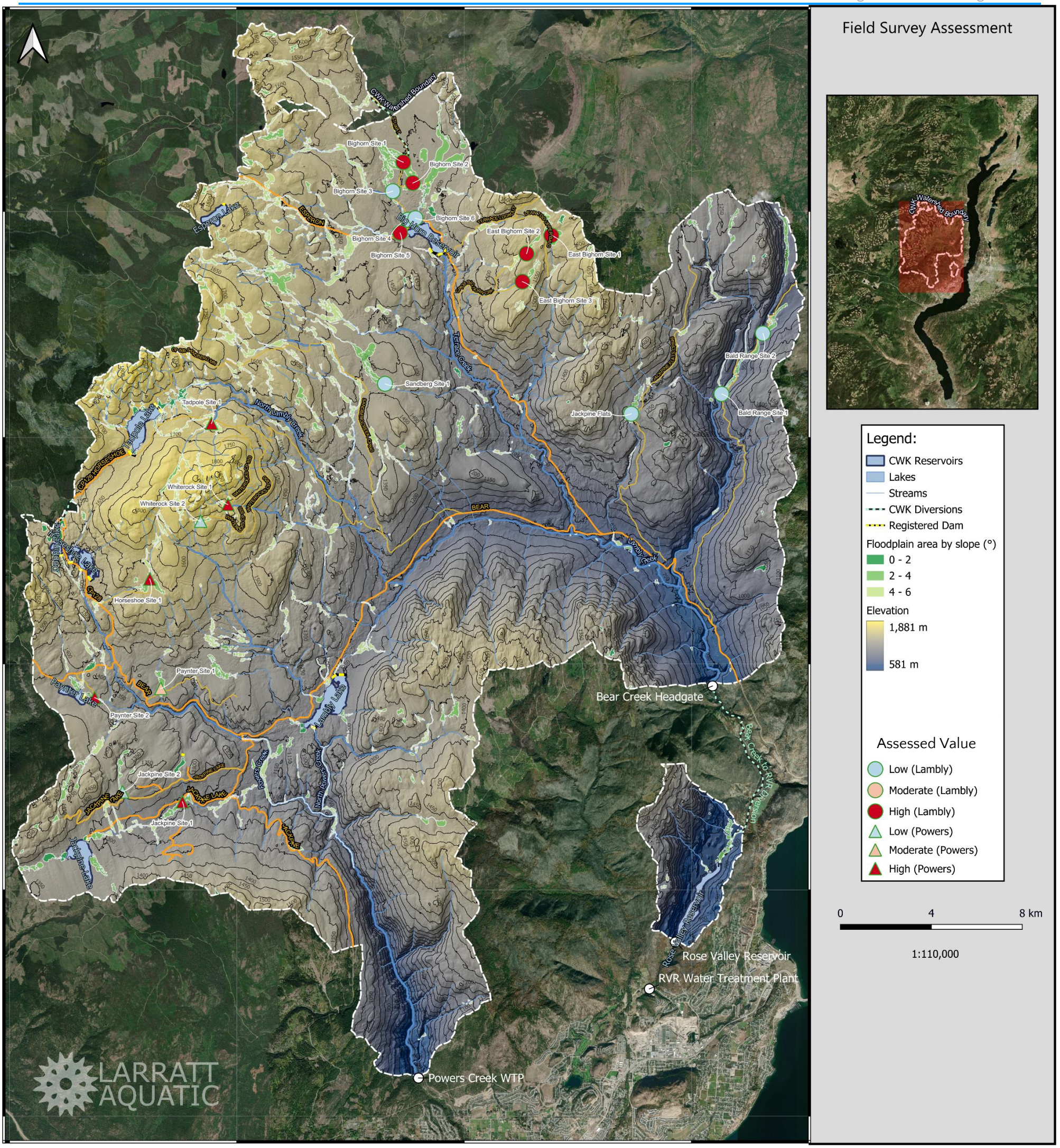


Figure 6: Surveyed sites and micro-storage potential, 2024

Surveyed Sites and Applicable Micro-storage Techniques

Suggestions and examples of micro-storage types applicable at each survey site are listed below. Only sites rated with "high" or "moderate" assessment value were considered (Figure 6; Table 4).

Table 4: Surveyed sites and applicable micro-storage types

Site	Applicable Micro-storage Type(s)	Key Field Notes
Bighorn Area		
Site 1	Riparian and Adjacent	-Pooling water and wetlands throughout general area -Old creek beds dried out -Old roads present for accessibility
Site 2	In-stream, Riparian and Adjacent	-Area represents periphery of a larger wetland complex -Pooled water and active creek present -Historic dead-end logging road available for accessibility
Site 5	In-stream, Riparian and Adjacent	-Wet soil, pooling water, and creek present -Erosion evident in creek -Low elevation from road prevents flooding FSR
East Bighorn Area		
Site 1	In-stream, Riparian and Adjacent	-Large and wet floodplain, creek and pooled water present -Functioning wetland -Erosion evident around culverts
Site 2	In-stream, Riparian and Adjacent	-Access road negatively influenced by hydrology -Large, wet area with active algae blooms
Site 3	Riparian and Adjacent	-Series of pooling water -Risks flooding FSR
Tadpole, Whiterock and Horseshoe Area		
Tadpole Site 1	In-stream, Riparian and Adjacent	-Riffle-pool stream present -Visible undercutting of creek banks -Low elevation from road prevents flooding FSR -Remediation would be hidden from FSR
Whiterock Site 1	In-stream	-Small creek from natural area flowing into logged area -Low risk of flooding FSR
Horseshoe Site 1	In-stream, Riparian and Adjacent	-Visible undercutting of creek banks -Creek system present -Access may be difficult
Paynter Area		
Site 1	Riparian and Adjacent	-Pooling water and wet soils present -Wetlands intercepted by road -Remediation can be used to decommission FSR -High potential for increasing wetland connectivity
Site 2	Riparian and Adjacent	-Lots of wildlife sign (moose, bear, deer, frogs/toads) -Large wetted/wetland area for consideration -Low elevation from road prevents flooding FSR
Jackpine Area		
Site 1	Riparian and Adjacent	-Excellent moose habitat -Low risk of flooding FSR -Easily accessible

Macro-storage Concepts

Creating new reservoirs is a challenging task, dominated by land rights, ecosystem disturbances, and stakeholder interests. Dams are expensive to build and maintain. Further, the initial flooding period induces poor water quality. Balanced against these concerns is the obvious and significant benefit of increased water storage to meet community and environmental flow needs. Climate change causes greater hydrological variability, and more storage will be vital to provide the same level of water security. The altered watershed hydrology caused by flooding new reservoirs has benefits through stable flows and deficits through fragmenting the stream ecosystem. A checklist for biological and limnological considerations for creating new reservoirs is provided in Figure 8.

Raising existing reservoirs also has significant impacts and benefits. They are similar but less severe than flooding a new reservoir. The scale of impact depends on the new flooded footprint – its size, soils and final water depth. For example, a situation where the footprint covers fine organic soils that will have extensive shallows susceptible to wave suspension will have more water quality issues than raising a reservoir over a rocky steep-sided bowl. A checklist for biological and limnological considerations for raising an existing reservoir is provided in Figure 9.



Figure 7: Existing reservoir in Bear (Lambly) watershed, 2024

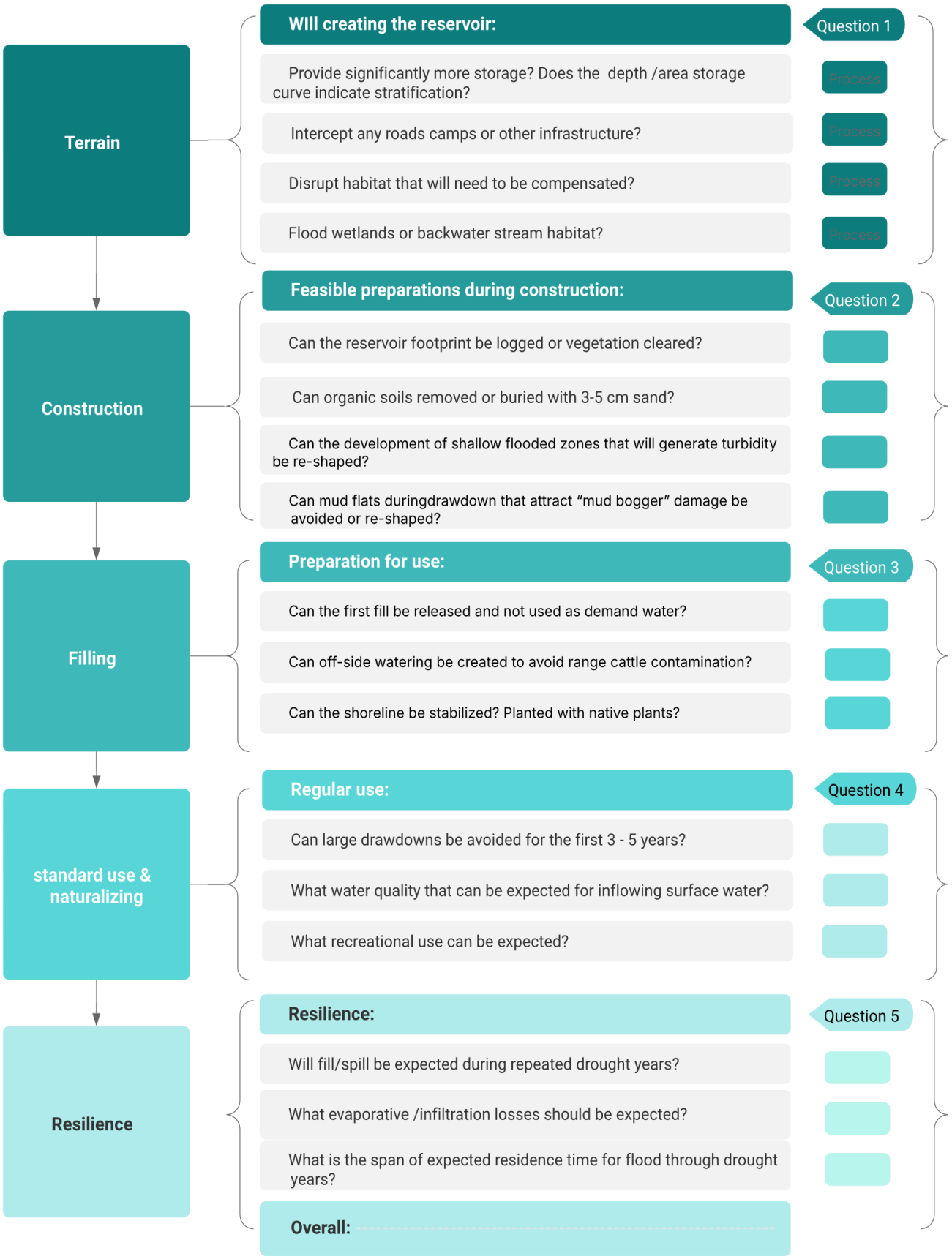


Figure 8: Flooding a new reservoir checklist for water quality

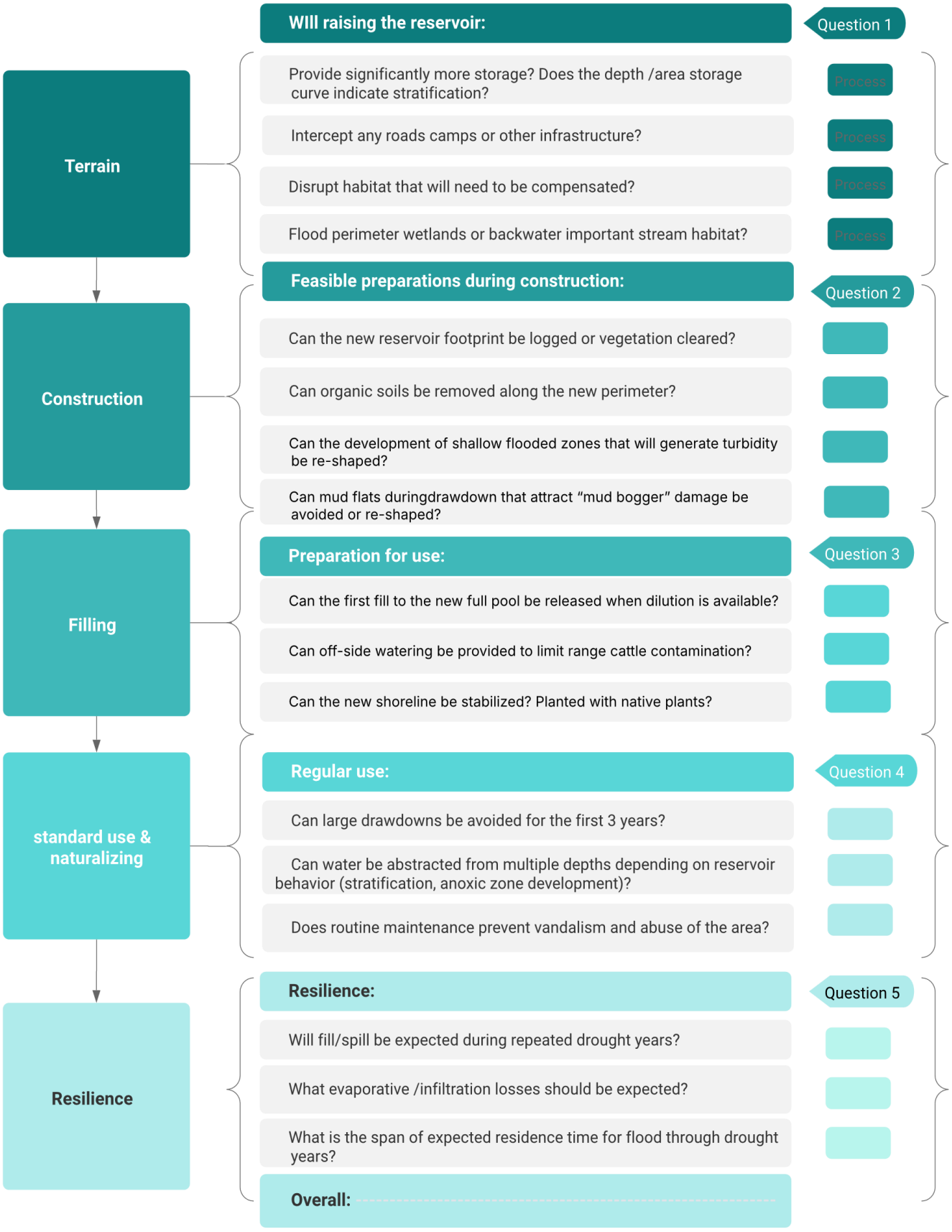


Figure 9: Raising an existing reservoir checklist

Closing Remarks

Implementation of water storage can protect water quantity and support natural ecosystem services. Micro-storage's small-scale permits both in-stream and out-of-stream applications that are uniquely tailored to their environment. Macro-storage provides large-scale water storage that can be incorporated into centralized water systems. This document serves as a preliminary framework aimed at providing initial steps for developing water storage.



Figure 10: Surveyed site, 2024

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Associated Engineering (2020). Okanagan Environmental Flow Needs Project Phase 1 and 2 Summary report March 2020.
Environmental Flow Needs (EFN) Project https://obwb.ca/efn/

B.C. Water Sustainability Act (WSA) 2016
https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/water-sustainability-act

Hydrologic Connectivity Study https://obwb.ca/projects/ohcm/

Lake Evaporation Study https://obwb.ca/wsd-index/data/lake-evaporation/

Okanagan Climate Indicators Dashboard https://obwb.ca/indicators/

Okanagan Climate Guide https://okanaganwater.ca/okcdg/

Okanagan Hydrologic Modelling Project https://www.obwb.ca/docs/obwb_report_2020-okanagan-hydrologic-modelling.pdf

Okanagan Groundwater Monitoring Project
https://obwb.ca/projects/okanagan-groundwater-monitoring-project/

Okanagan Hydrologic Modelling Project https://www.obwb.ca/docs/obwb_report_2020-okanagan-hydrologic-modelling.pdf

Hydrologic Connectivity Study https://obwb.ca/projects/ohcm/

Lake Evaporation Study https://obwb.ca/wsd-index/data/lake-evaporation/

Okanagan Water Supply and Demand Project https://obwb.ca/wsd-index/
Guidebook for Constructed Wetlands in the Okanagan https://obwb.ca/guidebook-for-constructed-wetlands-in-the-okanagan/

Source Water Protection Toolkit https://sourcewaterprotectiontoolkit.ca/

Syilx Water Law/Declaration
https://www.obwb.ca/newsite/wp-content/uploads/terbasket_siwlkw_water_responsibility.pdf

Syilx Water Strategy
https://syilx.org/wp-content/uploads/2022/04/Syilx-Water-Strategy-2022-Edition.pdf

Wetland Enhancement and Restoration
https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/best-management-practices/wetland_ways_ch_11_enhancement.pdf

Appendices

Appendix 1: Links for Invasive Plant Management

Document Title	Link
BC Ministry of Forest, Invasive Plant Program "Flood Mitigation – Invasive Plant Guidelines"	https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/guidance-resources/invasive_plant_and_knotweed_guidelines_for_provincial_sediment_removal_for_flood_mitigation.pdf
BC Invasive Species Council "Preventing The Spread of Invasive Species During Forest Management Activities"	https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/forestry-bp-09-11-2013-web.pdf
BC Government "Integrated Pest Management Act"	https://www.bclaws.gov.bc.ca/civix/document/id/loo91/loo91/604_2004
BC Government "Invasive Species Management in BC"	https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/invasive-species/management

Note: Non-exhaustive list of resources

Appendix 2: Additional Micro-Storage Details

		Water retention	Additional Advantages	Site Considerations / Disadvantages	$ - $$$$
in-stream	low <1m dams	Rock+ Log sill dam or steps	obstructs floodwater -increases infiltration and riparian vegetation, can use stoplogs for variable height	must be located away from infrastructure that could be affected by a failure during high flows	$$
		Rock check dams or steps	obstructs floodwater - increase infiltration and riparian vegetation, conforms to contours	must be located away from infrastructure that could be affected by a failure during high flows	$
		Inflatable PVC coffer (bladder) dams	fast, inflated/deflated with water for variable height, removable, PVC	need inner baffles so cannot roll out of position, may need anchoring, not aesthetic	$$-$$$
		Inflatable rubber weirs	flexible high tensile rubber-coated fabric clamped to foundation, air or water inflated	min height 0.5m; max length 100 m	$$$$
		Beaver dam analogues	obstructs floodwater to infiltrate and increase riparian vegetation	beavers may be attracted to the structure, increasing its size to where structure failure is a concern	$
		zuni bowls	halts head cutting on streams	labour intensive	$
off-side	redirect flows	Reconnecting meanders	expands ponded slow water habitat	area should become a conservation area due to its increased wildlife value	$-$$$
		Cross vane	redirects main flow	need backhoe to move large rock, woody debris	$$-$$$
		J-vane	moved main flow away from eroding banks	need backhoe to move large rock, woody debris	$$-$$$
	natural gardens	Storm rain gardens	habitat restoration and can incorporate positioned slash	position in shallow depressions behind stop logs	$
		Serpentine storm channels	allows for groundwater recharge	probably need backhoe	$$$
		floodplain waffle gardens	expands post logging regrowth potential	slope should be < 3 – 5%	$$-$$$
		Riparian hugel gardens	buried woody debris retains moisture for local regrowth	bury slash in rows on contour~ bioswales	$$$-$$$$
	constructed storage	Detention basins - lined	creates open water, can trap silt	must have base flow into system; steep slopes not appropriate | >0.5 ha	$$$$
		Detention basins unlined	daylights groundwater captures sediment	must intersect ground water | >0.5 ha |	$$-$$$
		Cistern analogues	stores water for summer release	needs backhoe to bury cistern/develop site	$$$
		Artificial meanders	increase floodplain width	Shallow terraine needed	$$-$$$$
		mulch basins	slow and sink water to support trees, shrubs	flat or gentle slopes only	$-$$
adjacent	recharge groundwater	bioretention cells	creates wetland	area should become a conservation area due to its increased wildlife value	$$$
		Infiltration basins	recharges groundwater	Keep minimum of 15 m from slopes >14% | bottom of unit >1 m to water | <4 ha	
		Berms - boomerang shaped	water harvesting mound, supports tree regrowth	align so overflow from upper boomerang feeds 2 lower boomerangs	
		Swales – distribution ditches	fast forest regrowth on swale wall and recharges groundwater	build on correct contours to prevent slope failure, slope should be ~<15 degrees	$$$$
	flow spreading	Created wetlands – closed roads	micro-wetlands trap silt, accelerate regrowth	build as part of protected road closure	$$$-$$$$
		Created wetlands – near streams	habitat and WQ benefits	stream freshet flow and groundwater connection needed | 1 – 10 ha SA |	$$$$
		Freshet flow spreading (floodwater irrigation)	expands riparian vegetated zones (shade, cooler)	install pick-up screened box and perf. pipe in pools to pick up freshet only	$$-$$$
		Expanding key riparian corridors	protects habitat around wetlands and reservoirs	area should become a conservation area due to its increased wildlife value	$
		Off-Side watering	limits trampling/loafing in stream areas	at cattle access points	$$-$$$
		burnt slope stabilizing to prevent gullying	embed burnt logs on contour to stabilize slopes and prevent gullying	best on slopes < xx%	$
CONTROL	CONTROL	CONTROL AREA + Before/after	install Piezometers, calc detained water at surface + est soil water detention drone b/a	_____n.a._____	
conserve	conservation	Conserve wetlands	swamp marsh bog fen	educate backcountry users	
		Conserve wet meadows		block mud bogging	
		No roads paralleling streams	prevents siltation, downcutting and slope failures	expensive to reloacte/rebuild so start with re-directing new road construction away from riparian areas	
		Conserve all riparian corridors	protects habitat around wetlands and reservoirs	width varies depending on values from 30 - 100 m	
		Re-slope closed roads	addresses gullying, sediment transport	requires restoring road cx to near-original grade	

$	labour only
$$	<1000.00 CND
$$$	<5000.00 CND
$$$$	>5000.00 CND

Appendix 3: Case Study Survey

Table 5: Questions for basic entry level survey

Parameters	Description of notes
Upland plants	Loosely identified plants present
Wetted plants	
Dead and down material	Rated amount of dead and down material
Soil wetted?	Identified wetted soils
Is there pooling water?	Identified pooling water
Is there a creek here already	Identified creeks present
Is there a clearly defined bank full	Identified when possible
Mark Top of Bank/Top of Ravine	
Is there erosion already occurring?	Listed when clear erosion occurred
Is this creek strong enough to remove remediation?	Identified when possible
Does it look like water was or could be here?	
Can we redirect flows here?	
Can you see where drainage would occur?	
Can we reconnect meanders	
Are there "unnatural" influences in this area?	Identified anthropogenic factors such as logging, culverts and roads
Is there beaver or wildlife sign?	Identified when possible
OTHER:	Included general observations and personal opinions on suitability

Table 6: Rating used to identify site suitability for micro-storage

Rating parameter	Value Assigned
Wetted Soil?	Yes = +1 No = -1
Pooling Water?	
Creek Present?	
Wildlife sign?	
Practical site?	
Accessible?	
Appeared suitable for remediation	
Potential for connecting nearby wetted areas?	Yes = +1 No = 0
Overall Site rating	
Poor	Total = 0-2
Moderate	Total = 3-5
Good	Total = 6-8

----------END OF REPORT ----------