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• What are structural interventions?
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• Other structures (offtakes, cross regulators, escapes etc)

Issues of Canal Lining: Cost/Benefit

• Canal lining is a very expensive element in canal construction - Cost of lining typically represents about 40 percent of the total cost.
• Before making such a large investment, there must be a clear idea of the benefits to be obtained
• The reduction of seepage losses is often assumed to be constant for the expected life of the lining to have a chance of achieving a favorable economic return
**Issues of Canal Lining: Seepage losses**

- Seepage losses typically represent 10 to 40 percent of diverted water
- Sedimentation reduces seepage
- Within 6 years of canal lining, losses return to around 60% of the initial seepage (WB)

**Benefits of Canal Lining**

- reduces seepage losses
- improves canal hydraulics
- reduces water-logging and salinization
- reduces weed growth
- improves equity and reliability of water distribution
- reduces maintenance (?)

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**Benefits of Canal Lining: Reduction of weed growth**

This benefit is questionable in some projects with old lined canals and poor construction joints.

**Quality of construction and concrete**

Saturation of the soils after commissioning of the canal may result:
- cracks in the slabs
- opportunity for seepage losses under most of the slab area
Estimates of Seepage Losses:  
*a source of doubt and concern*

- Difficult to compare the results of tests and estimates because of number of variables
- Checking seepage losses independently of operation records are expensive
- Published records often fail to record key variables

### Seepage Variables

- characteristics of the soils:  
  - porosity, permeability,  
  - chemistry, granulometry,  
  - stratigraphy
- geometry of canals
- position of water table
- chemistry of water and soils
- **sedimentation: self sealing effect**

### Seepage Variables (cont.)

- quality of construction
- **age of the canals**
- cycles of filling/draining
- maintenance

### Seepage Values: Pakistan

- Normally assumed 8 cfs/million ft² (0.23 m/day)
- Estimates of average losses up to outlets: 20 to 25 % of inflows at head of main canals
- range of measurement values: 0.15 to 0.30 m/day (0.06 to 0.57 m/day)
- ISRIP and IWMI measured 15 to 25 % average losses from the main and secondary system – CRBC, Fordwah, Eastern Sadiqia (1990-1995)
Measurements using ponding method (Singh, 1987)

- unlined canal 0.3 m/day
- lined canal 0.03 m/day

These data come from controlled tests in laboratories and experimental sections with excellent maintenance.

INDIA: PUNJAB brick lined canals

- Sunam branch (four-month old) 0.06 m/day
- Mudki distributary (15 km, 5-year old) 0.29 m/day
- Mukstar distributary (6-year old) 0.49 m/day

Watercourses (24): seepage losses from channel older than 4 years are comparable to losses from unlined channels

Canal Lining: A way to modernize the irrigation system?

- it is generally advocated by Irrigation Agencies to reduce seepage
- there are obstacles to canal lining: e.g. it interrupts irrigation services

Line or not to Line: The Debate

- Since seepage recharges the groundwater, overall water saving could be marginal
- Cost of pumping
- Deterioration of water quality, Waterlogging and salinization of adjacent lands
- Farmers use groundwater more efficiently
THE TECHNICAL CASE FOR CANAL LINING IS NOT STRAIGHTFORWARD

According to the WB-Experts

• Canal lining with 1% crack area has a seepage rate of 70% of that for unlined conditions (depth to water table: 8m)

• There is now strong evidence that hard surface linings deteriorate within a few years until seepage losses return to that for an unlined canal

Canal Lining: Questions?

• Do we really need lined canals to improve water delivery service to water users?

• Do we want to carry out this very expensive option and risk losing the valuable money that could be spent more effectively on other interventions?

Canal Lining: Options

• Avoid systematic canal lining as a norm!

• Serious documentation for lining to be done!

• Wherever canal lining is justified/needed use only high standards techniques (geo-membrane, reinforced concrete)

• Adjust operation and maintenance to the needs of lined canals.
Long Crested Weir - Design
### Exercise: Crest length of a Long Crested weir?

\[ Q = c \cdot Lc \cdot [h]^{3/2} \]

**Objective of control**
- Q1 \( \rightarrow \) H1
- Q2 \( \rightarrow \) H2
- Variation H = H2 - H1

\[ Lc = \left[ \frac{(Q/c)^{2/3} - (Q/c)^{2/3} \cdot h1 - h2}{h1 - h2} \right] \]

### Height of a Long Crested weir

**Objective:** Ensure that flow is not submerged for Q max!

*Partially submerged Drop is insufficient*

### Height of a Long Crested weir

Crest should be slightly higher than normal flow to allow a non-submerged flow on the crest
H crest = H normal + ∆hcrest
H flow = H crest + H1
Head losses = H1 + ∆hcrest

Backwater effect = Head losses/slope

Advantage of Mixed CR

Significant reduction of Crest Length

Part of ∆Q (Q1-Q2) is taken care by periodic gate adjustments thus H1-H2 is minimum and Length crest also.

Mixed CR: a Very good solution for improvement!

Adapting existing CR as Mixed Regulator with the construction of a Weir to control the water level.

Advantages: no need to have a permanent operator
Baffles
Canal Flow Measurement
Basic Options

1. Weirs
2. Flumes
3. Electronic devices
4. Rated sections

Weirs and flumes are based on Critical Flow Devices

For one depth, there is one corresponding flow rate

1. Weirs
2. Flumes
Headloss = Y2 - Y1

Diff. Weir Flumes

Parshall Flumes

Replogle Flumes (RBC)

TADLA Morocco

PK Albania

TADLA Morocco
6:1 downstream ramp
6:1 downstream truncated ramp

FLOW
FLOW

Replogle Flume - Ramp Recommendation

4-in Diameter Pipe
Install flush to concrete on both ends and flush to the bottom of the canal.
Flow Measurements

Accuracy !!!

WinFlume

A key issue:
Accuracy of gauge reading $\Delta H$

\[ Q = \beta H^\alpha \]

\[ \frac{\Delta Q}{Q} = \alpha \frac{\Delta H}{H} \]
Accurate of gauge reading: turbulence and waves

$\Delta Q/Q = \alpha \Delta H/H$

Higher the Head, higher the accuracy
Accuracy of measurement inversely proportional to flow width

\[ \frac{\Delta Q}{Q} = \alpha \frac{\Delta H}{H} \]

Head is low particularly at low discharge

Head max = 0.60 m

Accuracy at Q max = 250 l/s for 2 cm

Turbulence

\[ H = Q \alpha \Delta H \]
Accuracy of weir measurements increases with available head

High Head $\implies$ low width

Low head $\implies$ high width

Accuracy of weir measurements decreases with width of flow

3. Velocity sensor
   Doppler

Electronic doppler and ultrasonic meters are used where:
   - There is insufficient head available to install a flame (usually need at least 0.3 m)
   - The canal cannot be shut down for installation of a flame.
   - The canal is very large, and cost of a flame may be too great.

The ADFM shown here costs about $30,000 including installation. A large flame may cost $100,000.
Installing an ADFM at Headgate Rock Dam – CRIT – Arizona

Flow data from electronic devices is scattered and needs averaging if it is to be used for gate control.
4. Rated sections

No measurement without periodic calibration

THANK YOU