Sensitivity of Irrigation Structures

An alternative way of looking at fluctuations in irrigation systems without having to consider the difficulty of unsteady flow.

…helps answering the following questions:

- **HOW the system is affected by fluctuations?**
- **HOW the system generate fluctuations?**
- **HOW MUCH performance is affected by sensitivity?**
- **WHAT more cost-effective operational procedures ?**
- **WHERE collect information?**

Sensitivity of irrigation structures

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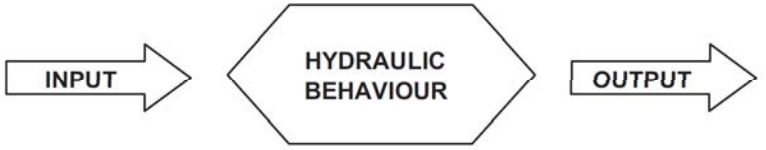
Input–output analysis

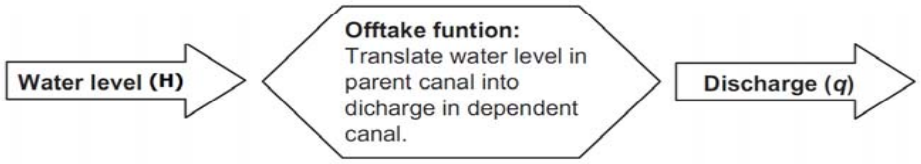


$$Sensitivity = \frac{Variation\ in\ output}{Variation\ in\ input}$$

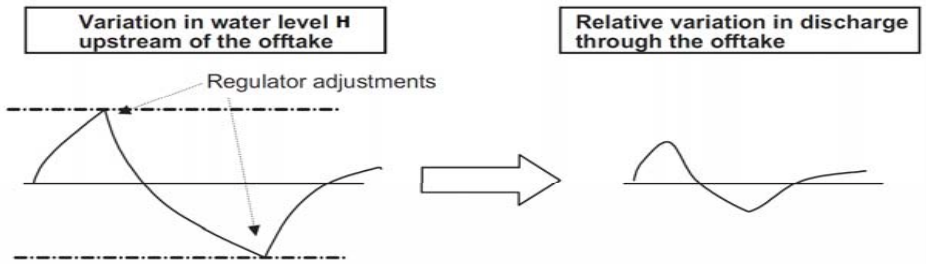
an alternative way of looking at fluctuations in irrigation systems without having to consider the difficulty of unsteady flow.

Offtake Structures Sensitivity

Input and output for offtake structures



Diversion behaviour of an offtake as a function of water depth variation



Offtake Structure sensitivity

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The discharge sensitivity to water depth at any structure is defined as the ratio of the relative variation of discharge through the structure (Δq/q) and water depth deviation (ΔH) upstream of the structure.

$$S_{offtake} = \frac{\Delta q / q}{\Delta H} \quad (unit: m^{-1})$$

Use of sensitivity

1. Estimate the reaction of an offtake when water depth in the parent canal varies (ΔH)

$$\Delta q/q = S_{offtake} \cdot \Delta H$$

Relative variation in discharge for various values of sensitivity			
	Sensitivity Indicator ($S_{Offtake}$)		
Water level variation in the parent canal (DH)	Low	Medium	High
	0.5 m^{-1}	1 m^{-1}	2 m^{-1}
+/- 0.05 m	2.5 %	5%	10%
+/- 0.10 m	5%	10%	20%
+/- 0.20 m	10%	20%	40%

Use of sensitivity

2. Estimating tolerance on water control

-setting water level control requirements for appropriate service delivery.

$$\Delta H_{permissible} = \frac{\left(\Delta q/q\right)_{set}}{S_{offtake}}$$

Sensitivity from hydraulic formula

$$q = M(head)^{\alpha} \qquad \Delta q/q = \alpha \frac{\Delta head}{head}$$

$$S_{offtake} = \frac{\Delta q/q}{head} = \frac{\propto}{head}$$

$$Orifice\ flow: Q = CA\sqrt{2gH} \qquad Weir\ flow: Q = CLH^{1.5}$$

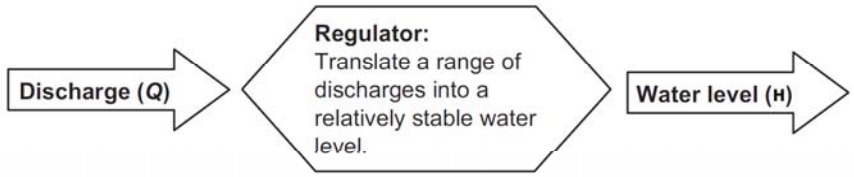
Overview of offtake sensitivity indicators

Structure	Variable studied	Definition	Geometrical formulation	Approximate formula (ignoring submergence)
Offtake (orifice)	Offtake discharge q as a function of the fluctuation in the supply water level ΔH	$S = \frac{\Delta q/q}{\Delta H}$	$S = \frac{0.5}{h_E}$	$S = \frac{0.5}{head}$
			h_E (head equivalent) includes effect of submergence	The "head" variable is the difference in head exerted on the structure (h_{US} - h_{DS})
Offtake (overshot)			$S = \frac{1.5}{head}$	Overshot offtakes are not frequent because they are highly sensitive

Regulator sensitivity

The water depth sensitivity along the canal, at a regulator or at any other section, is expressed as the variation of water depth resulting from a relative discharge variation

Input and output for a cross-regulator



$$S_{Regulator} = \frac{\Delta H}{\Delta Q / Q} \quad (unit: m)$$

Water-level variation for various values of sensitivity and discharge perturbations

	Sensitivity indicator ($S_{Regulator}$)		
Relative variation in canal discharge	0.5 Low	1	2 High
	(m)		
+/-0.05 (or 5%)	0.025	0.05	0.10
+/-0.10 (or 10%)	0.05	0.10	0.20
+/-0.20 (or 20%)	0.10	0.20	0.40

$$\Delta H = S_{Regulator} \cdot \Delta Q / Q$$

$$S_{Regulator} = \frac{head}{\Delta Q / Q} = \frac{head}{\alpha}$$

Overview of regulator sensitivity indicators

Structure	Variable studied	Definition	Geometric formulation	Approximate formula (ignoring submergence
Regulator (orifice)	Water level as a function of the relative variation in discharge Q	$S = \frac{\Delta H}{\Delta Q / Q}$	$S = 2.h_E$	$S = 2 \cdot head$ The "head" variable is the difference in head exerted on the structure ($h_{US} - h_{DS}$)
Regulator (weir)			$S = \frac{head}{(3/2)}$	$S = 0.66 \bullet head$ Head is equal to water height above weir crest if not submerged

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SENSITIVITY INDICATORS ASSESSMENT

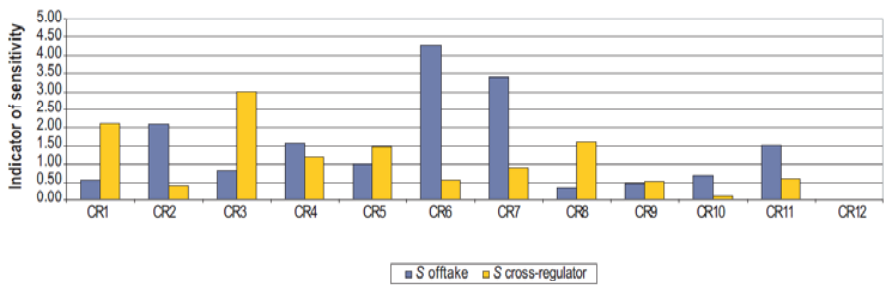
Hydraulic computation:

$$S_{Offtake} \approx \frac{\alpha}{Head} \qquad S_{Regulator} \approx \frac{Head}{\alpha}$$

Direct measurements: initiate a variation of input measure the resulting deviation of outputs

$$S_{Offtake} = \frac{\Delta q / q}{\Delta H} \qquad S_{Regulator} = \frac{\Delta H}{\Delta Q / Q}$$

Sensitivity of cross-regulators along the SMIS, Nepal



Variations in discharge experienced by the offtakes along the SMIS main canal for a water level change of 0.1 m

CR	1	2	3	4	5	6	7	8	9	10	11
S offtake	0.6	2.0	0.8	1.6	1	4.3	3.4	0.35	0.5	0.7	1.5
						(%)					
Variation in discharge (+ or - initial setting value)	6	20	8	16	10	43	34	3.5	5	7	15

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Operational rules for tolerance and frequency of adjustment as a function of the sensitivity at the cross-regulator along the SMIS main canal, Nepal

Cross-regulator	Features	Tolerance on water-level control	Frequency of adjustment of the CR
CR1	S regulator high (2) S offtake low	Tolerance 0.1 acceptable	More frequent adjustment
CR2	S regulator low (0.4) S offtake high (2)	Reduced tolerance should be sought (±5 cm)	Low frequency sufficient
CR3	S regulator very high (3) S offtake low (0.8)	Tolerance 0.1 acceptable	More frequent adjustment
CR4 & CR5	S regulator average (< 1.5) S offtake average (< 1.5)	Tolerance 0.1 acceptable	Average frequency adjustment
CR6 & CR7	S regulator low (< 1) S offtake high (>3.5)	Reduced tolerance should be sought (±5 cm or below)	Average frequency adjustment
CR8–CR11	S regulator average or below S offtake average or below	Tolerance 0.1 acceptable	Average frequency adjustment

Flexibility indicator or Proportional indicator

Flexibility indicator (F) expresses the link between the relative variations in Q in the parent canal and the dependent canals.

$$F = \frac{\Delta q/q}{\Delta Q/Q} = \frac{\Delta q/q}{\Delta H}\frac{\Delta H}{\Delta Q/Q} = S_{offtake} S_{Regulator}$$

F=1	Proportional	Fluctuations are divided uniformly.
F<1	Underproportional	Fluctuations are diminished in offtaking canals
F>1	Hyperproportional	Fluctuations are exacerbated in the offtaking canals.

Propagation of waves for different flexibilities