Chapter 47: Kennedy's and Lacey's Theory of Regime Channels

Introduction

Designing stable channels for irrigation, drainage, and flood control is a key aspect of water resources engineering. Channels that neither silt up nor scour are termed *regime channels*. The development of regime theories has played a vital role in understanding how natural and artificial channels adjust themselves over time to reach a state of equilibrium. Two major theories have historically contributed to this understanding:

- **Kennedy's Theory (1895)** – Based on empirical studies of the Upper Bari Doab Canal System in Punjab.
- **Lacey's Theory (1930)** – A more refined theory based on observations from a wide range of canal systems.

This chapter presents both theories in detail, exploring their assumptions, derivations, limitations, and applications.

47.1 Regime Channels – Concept

A **regime channel** is a channel flowing under constant discharge and carrying sediment load in such a way that over time, its cross-sectional shape, bed slope, and other characteristics adjust to achieve a stable state. In this state, there is no significant erosion (scouring) or deposition (silting). These channels form naturally or gradually adjust if constructed under suitable conditions.

Three types of regime stages are commonly defined:

1. **Initial Regime** – Immediate response after the canal is put into use.
2. **Quasi Regime** – Intermediate stage, where some stability exists.
3. **True Regime** – Final equilibrium state, achieved over time with stable discharge and sediment load.

47.2 Kennedy's Theory of Regime Channels

47.2.1 Historical Background

R.G. Kennedy developed his theory in 1895 based on observations of stable channels in the **Upper Bari Doab Canal** system in British India. He attempted to find a relationship between channel dimensions and flow characteristics in alluvial soils.

47.2.2 Key Assumptions

1. The channel carries silt-laden water in suspension.
2. There is no scouring or silting in the channel.
3. The bed slope and cross-section adjust to produce critical velocity, which prevents deposition or erosion.
4. The critical velocity depends on the depth of flow.

47.2.3 Critical Velocity Concept

Kennedy introduced the concept of **critical velocity (Vc)** — the minimum velocity required to prevent silting in the channel. He gave the empirical relation:

$$V_c = 0.55 \cdot D^{0.64}$$

Where:

- V_c = critical velocity (m/s)
- D = depth of flow (m)

He later included a **critical velocity ratio (m)** to adjust for sediment properties:

$$V = m \cdot V_c = m \cdot 0.55 \cdot D^{0.64}$$

- $m > 1$: coarser sediments (higher velocity needed to avoid silting)
- $m < 1$: finer sediments

47.2.4 Limitations of Kennedy's Theory

- Based only on one canal system.
- Lacks general applicability to various sediment sizes and discharges.
- Does not provide a method to compute slope directly.
- Does not consider bed width explicitly in velocity expression.

47.3 Lacey's Theory of Regime Channels

47.3.1 Background and Development

Lacey expanded upon Kennedy's ideas, conducting broader field studies on various canals in alluvial soils. His theory is more comprehensive and widely used for the design of stable channels.

47.3.2 Basic Assumptions

1. Channel is in regime (true equilibrium).
2. The sediment load and size are constant over time.
3. Uniform discharge flows constantly.

4. Channel cross-section is approximately semi-elliptical.
5. The channel material is the same as that being transported.

47.3.3 Lacey's Regime Equations

Lacey developed four empirical equations to describe regime conditions:

(a) Velocity Equation

$$V = k_1 \cdot f^{1/2} \cdot R^{2/3}$$

Where:

- V = velocity (m/s)
- f = silt factor
- R = hydraulic radius (m)
- $k_1 = \frac{1}{2.5}$

Later simplified to:

$$V = 0.48 \cdot f^{1/2} \cdot R^{2/3}$$

(b) Discharge Equation

$$Q = A \cdot V$$

Combined with the velocity equation and using empirical relations, Lacey gave:

$$Q = 2.5 \cdot V^5 / f^2$$

(c) Wetted Perimeter (P)

$$P = 4.75 \cdot \sqrt{Q}$$

(d) Regime Slope (S)

$$S = \frac{f^5}{Q^{1/3}}$$

Or alternatively:

$$S = \frac{V^5}{140 \cdot Q}$$

(e) Silt Factor (f)

$$f = 1.76 \cdot \sqrt{d}$$

Where d is the mean sediment size in mm.

47.3.4 Design Procedure using Lacey's Theory

1. **Determine discharge** Q and sediment size d.
2. **Compute silt factor** f using $f = 1.76 \cdot \sqrt{d}$.
3. **Assume initial velocity or compute from**:

$$V = \left(\frac{Q \cdot f^2}{2.5} \right)^{1/5}$$

4. **Find area** A from $A = Q/V$.
5. **Determine wetted perimeter** $P = 4.75 \cdot \sqrt{Q}$.
6. **Calculate hydraulic radius** $R = A/P$.
7. **Estimate slope** S using:

$$S = \frac{V^5}{140 \cdot Q}$$

47.3.5 Limitations of Lacey's Theory

- Based on empirical data – may not hold outside Indian alluvial regions.
- Does not explicitly handle non-uniform sediment loads.
- Assumes semi-elliptical sections; actual channels may vary.
- Does not consider bank erosion or vegetative resistance.

47.4 Comparison between Kennedy's and Lacey's Theories

Aspect	Kennedy's Theory	Lacey's Theory
Developed by	R.G. Kennedy (1895)	G. Lacey (1930)
Based on	Upper Bari Doab Canal	Various canal systems
Type	Semi-empirical	Empirical
Focus	Critical velocity for non-silting	Regime flow with stable section
Sediment factor	Critical velocity ratio (m)	Silt factor (f)
Channel slope	Not directly addressed	Explicitly given
Wetted perimeter	Not considered	$P = 4.75\sqrt{Q}$
Limitations	Limited data, no slope	Based on specific sediment sizes

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47.5 Modern Developments and Relevance

Although Kennedy's and Lacey's theories laid the foundation for channel design in alluvial soils, modern techniques now use:

- **Computational Fluid Dynamics (CFD)**
- **Sediment transport models**
- **GIS-based channel simulation**
- **Machine learning for sediment rating curves**

However, for conceptual understanding and preliminary design, Kennedy's and Lacey's theories are still included in civil engineering curricula and design handbooks due to their simplicity and practical value.
