



Ground Water Hydrology

# Ghyben–Herzberg Relation & Groundwater Basin Management

(23C15A0105)

UNDER THE GUIDENCE OF

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# Ghyben–Herzberg Relation

The Ghyben–Herzberg Relation explains the interface between freshwater and saline water in coastal aquifers based on density differences.

## 👤 Developed by:

- W. Badon-Ghyben (1888–1889)
- A. Herzberg (1901)

They independently described how freshwater “floats” above denser saltwater underground near coastal zones.

## ⚖️ Principle:

Based on the Hydrostatic Equilibrium Principle, which states that the pressure at the same depth in both freshwater and saline water zones must be equal.

## 🌐 Importance:

- Predicts saltwater intrusion in coastal regions.
- Helps design groundwater extraction limits.
- Useful for sustainable aquifer management and coastal planning.



# Key Terms & Variables

Symbol	Definition	Meaning / Units
 $\rho_s$	Density of saline water	$\approx 1025 \text{ kg/m}^3$
 $\rho_f$	Density of freshwater	$\approx 1000 \text{ kg/m}^3$
 $h_f$	Height of freshwater table above Mean Sea Level (MSL)	meters (m)
 $h_s$	Depth of saline interface below MSL	meters (m)



# Derivation of the Ghyben–Herzberg Relation

## ⚖️ Principle Used:

👉 Hydrostatic equilibrium — pressure at the same depth in both freshwater and saline water must be equal.

### Step 1: Pressure balance at the interface

$$\rho_s g h_s = \rho_f g (h_f + h_s)$$

### Step 3: Rearrange terms

$$h_s (\rho_s - \rho_f) = \rho_f h_f$$

### Step 2: Simplify by canceling $g$

$$\rho_s h_s = \rho_f h_f + \rho_f h_s$$

### Step 4: Final Ghyben–Herzberg Relation

$$h_s = \frac{\rho_f}{\rho_s - \rho_f} \times h_f$$

# Example & 40:1 Rule

## Given Data:

- Density of Saline Water ( $\rho_s$ ) = 1025 kg/m<sup>3</sup>
- Density of Freshwater ( $\rho_f$ ) = 1000 kg/m<sup>3</sup>

## Using Ghyben–Herzberg Relation:

$$h_s = \frac{\rho_f}{\rho_s - \rho_f} \times h_f$$

Substitute values:

$$h_s = \frac{1000}{1025 - 1000} \times h_f$$

$$h_s = \frac{1000}{25} \times h_f = 40h_f$$

## Result:

For every 1 unit (m or ft) of freshwater head above MSL,  
 ↘ the saltwater interface lies 40 units below MSL.

## 40:1 Rule (Key Concept):

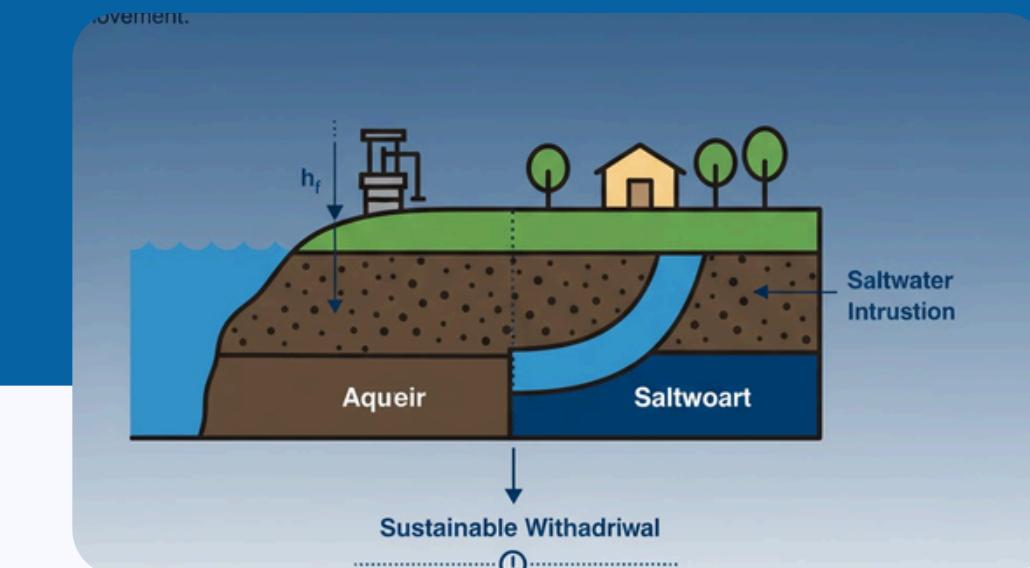
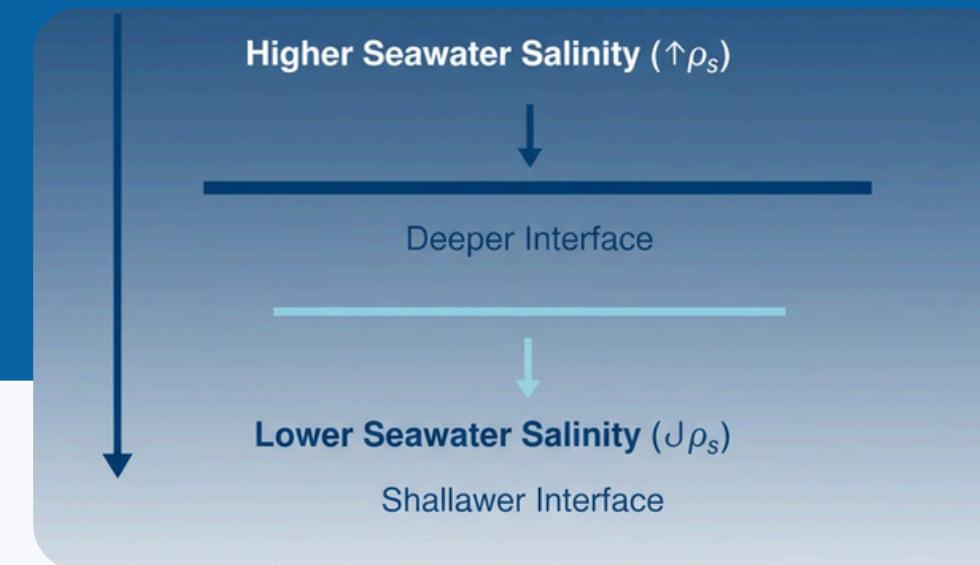
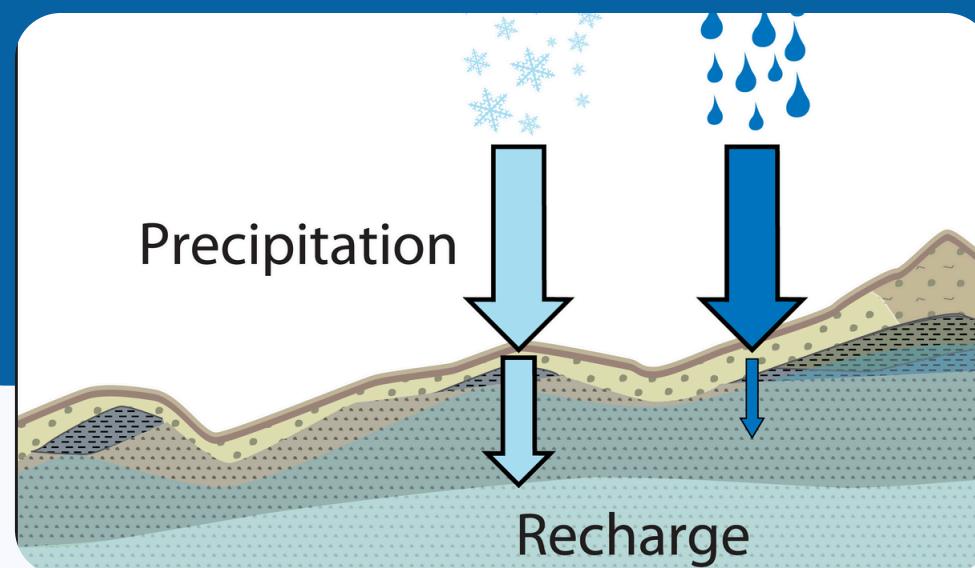
- 1 m rise in freshwater table → 40 m deeper saltwater interface.
- Used to estimate saltwater intrusion and safe pumping limits in coastal aquifers.

## Insight:

A small drop in freshwater level can cause a large upward movement of saline water — a major issue in coastal groundwater management.

# ⚠ Practical Considerations

📌 Theoretical Relation Assumes Ideal Conditions, but in real-world aquifers, several factors alter the interface depth:



- 🌧 1. Rainfall & Recharge Rate
- Heavy rainfall increases recharge → raises freshwater head ( $h_f$ ).
  - Droughts lower recharge → saltwater moves upward.

- 🌊 2. Salinity Variations
- Higher seawater salinity ( $\uparrow \rho_s$ ) → deeper interface.
  - Lower salinity ( $\downarrow \rho_s$ ) → shallower interface.

- gneiss 3. Aquifer Properties
- Permeability & porosity affect flow and pressure balance.
  - Low-permeability layers restrict vertical movement.
- faucet 4. Groundwater Extraction
- Over-pumping near coasts lowers  $h_f$  → saltwater intrusion.
  - Sustainable withdrawal maintains equilibrium.

# Groundwater Basin Management



## Definition:

Groundwater Basin Management is the sustainable planning, development, and protection of underground water resources within a defined aquifer or basin area.



## Goal:

To balance water extraction and natural recharge, preventing both depletion and pollution while ensuring long-term water security.



## Alternative Definition:

It is the strategic control and monitoring of groundwater to meet present needs without compromising the ability of future generations to meet theirs.



## Core Focus Areas:

- Recharge Management: Enhancing natural and artificial replenishment.
- Usage Regulation: Controlling withdrawal to maintain balance.
- Water Quality Protection: Preventing contamination and saline intrusion.
- Stakeholder Coordination: Engaging communities and industries.



# Key Objectives of Groundwater Basin Management

## 1. Sustainable Use of Groundwater

- Ensure withdrawal does not exceed natural recharge rates.

## 2. Prevent Over-Extraction & Land Subsidence

- Avoid aquifer depletion that causes ground sinking.

## 3. Control Water Quality Degradation

- Protect against pollution, saline intrusion, and contamination.

## 4. Ensure Long-Term Water Availability

- Support agriculture, industry, and domestic use.

## 5. Protect Ecological Systems

- Maintain wetlands, rivers, and habitats dependent on groundwater.

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2. Prevent Over-Extraction & Land Subsidence
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# Key Activities of Groundwater Basin Management

## 1. Monitoring Water Levels & Quality

- Track groundwater depth, flow, and chemical quality.

## 2. Regulating Pumping

- Control extraction to prevent overuse and saltwater intrusion.

## 3. Promoting Artificial Recharge

- Use rainwater harvesting or treated water to replenish aquifers.

## 4. Public Participation & Awareness

- Educate communities, farmers, and industries about sustainable use.

## 5. Policy & Planning

- Implement usage permits, zoning, and management guidelines.



# Major Components of Groundwater Basin Management

## 1. Assessment of Resources

- Quantity of groundwater
- Quality and contamination levels
- Recharge rate and usage patterns

## 2. Monitoring Systems

- Track water levels, pumping rates, and quality trends
- Use sensors, wells, and data logging

## 3. Regulatory Measures

- Permits for extraction
- Usage restrictions
- Aquifer zoning

## 4. Artificial Recharge Projects

Recharge aquifers using rainwater or treated wastewater

Reduces depletion and maintains balance

## 5. Public Participation & Awareness

Stakeholder engagement

Education programs for farmers, industries, and communities

## Case Studies – Groundwater Basin Management

### California, USA – SGMA (2014)

📌 Problem: Severe overdraft of aquifers in Central Valley.



Action:  
SGMA passed; local agencies created Groundwater Sustainability Plans (GSPs)

Established Groundwater Sustainability Agencies (GSAs)

📊 Measures: Pumping limits, monitor water levels & quality, plan for 50-year sustainability

✓ Results: Improved aquifer management, long-term water security, local accountability

## Case Studies – Groundwater Basin Management

### Gujarat, India – PGWM

📌 Problem: Excessive extraction for irrigation; declining water table



- Action:
  - Villagers trained to map aquifers, monitor levels, decide cropping patterns
  - 📊 Measures: Community monitoring, water-saving practices, stakeholder involvement
  - ✅ Results: Reduced overuse, improved water table, increased community awareness

**Ground Water Hydrology**

**Thank For  
Your Attention**

**End of Presentation**

