

Ground Water Hydrology

Ghyben–Herzberg Relation & Groundwater Basin Management

(23C15A0105)

UNDER THE GUIDENCE OF



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.

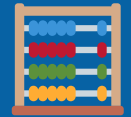
Importance:

- 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
 ρ_s	Density of saline water	$\approx 1025 \text{ kg/m}^3$
 ρ_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

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

¹/₃ ²/₄ Example & 40:1 Rule

Given Data:

- Density of Saline Water (ρ_s) = 1025 kg/m³
- Density of Freshwater (ρ_f) = 1000 kg/m³

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):

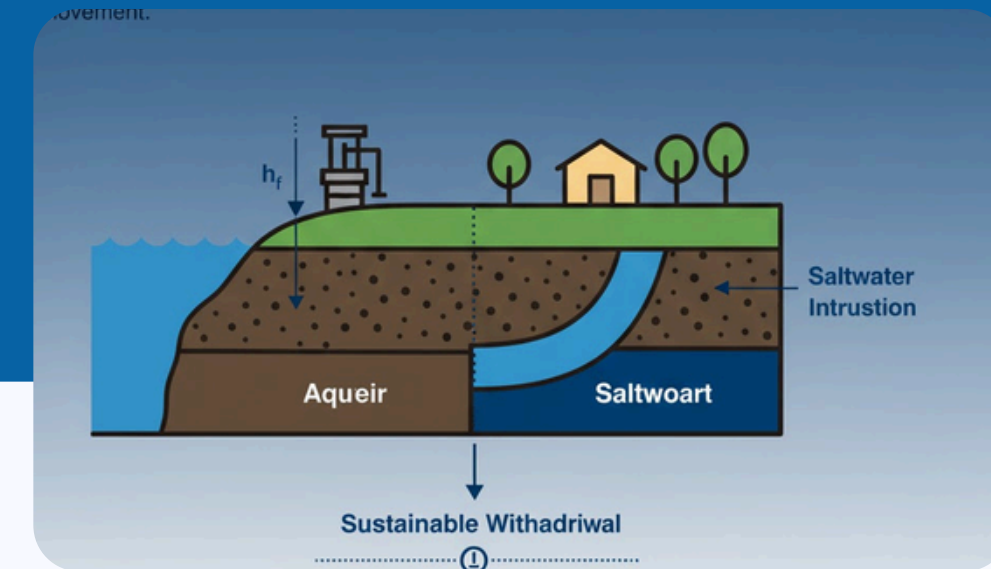
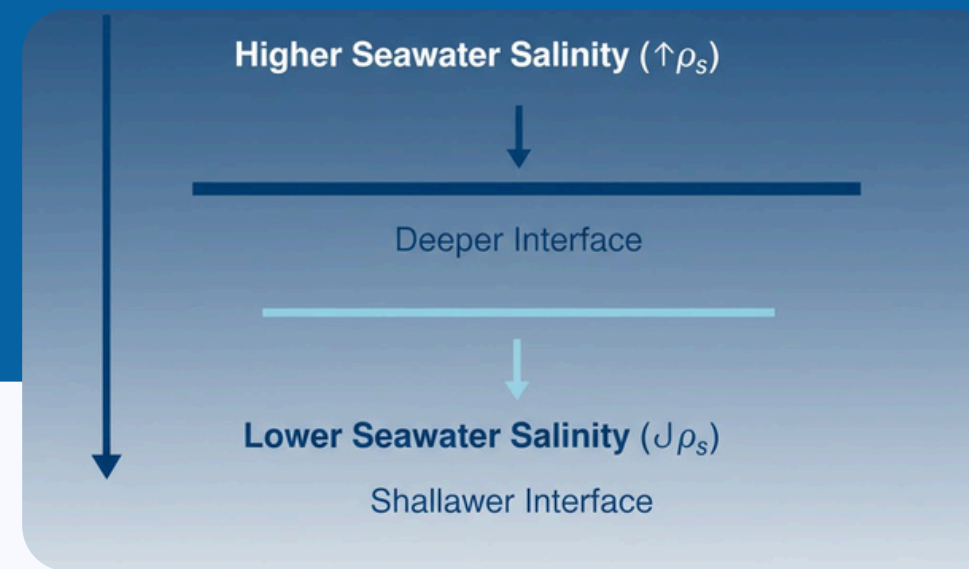
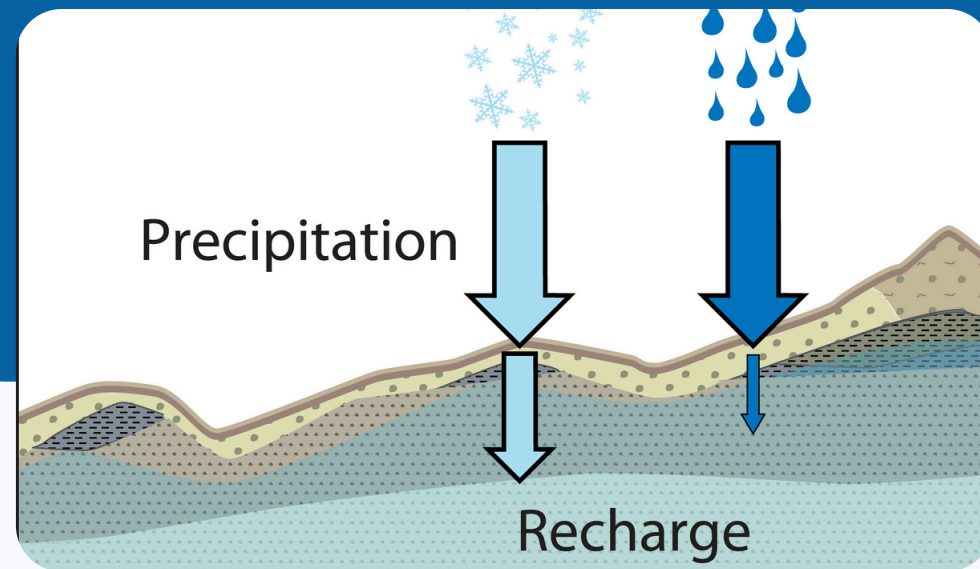
- 1 m rise in freshwater table → 40 m deeper saltwater interface.
- Used to estimate saltwater intrusion and safe pumping limits in coastal aquifers.

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 \rightarrow raises freshwater head (h_f).
- Droughts lower recharge \rightarrow saltwater moves upward.

🌊 2. Salinity Variations

- Higher seawater salinity ($\uparrow \rho_s$) \rightarrow deeper interface.
- Lower salinity ($\downarrow \rho_s$) \rightarrow shallower interface.

🏠 3. Aquifer Properties

- Permeability & porosity affect flow and pressure balance.
- Low-permeability layers restrict vertical movement.

🚰 4. Groundwater Extraction

- Over-pumping near coasts lowers h_f \rightarrow saltwater intrusion.
- Sustainable withdrawal maintains equilibrium.

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.

1.  Ensure Withdrawal Does Not Exceed Natural Recharge Rates.
1.  Prevent Over-Extraction
2.  Prevent Over-Extraction & Land Subsidence
3.  Control Water Quality Degradation
4.  Ensure Long-Term Water Availability 
5.  Protect Ecological Systems

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

