

Module 3 – (L8-L11): Integrated Watershed Management
Introduction to Integrated Approach, Integrated Water Resources
Management, Conjunctive Use of Water Resources, Rainwater
Harvesting; Roof Catchment System.

WATERSHED MANAGEMENT

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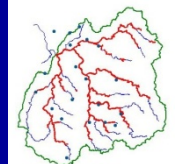
Department of Civil Engineering,
IIT Bombay

Lecture No - 9

Conjunctive Use of Water
Resources

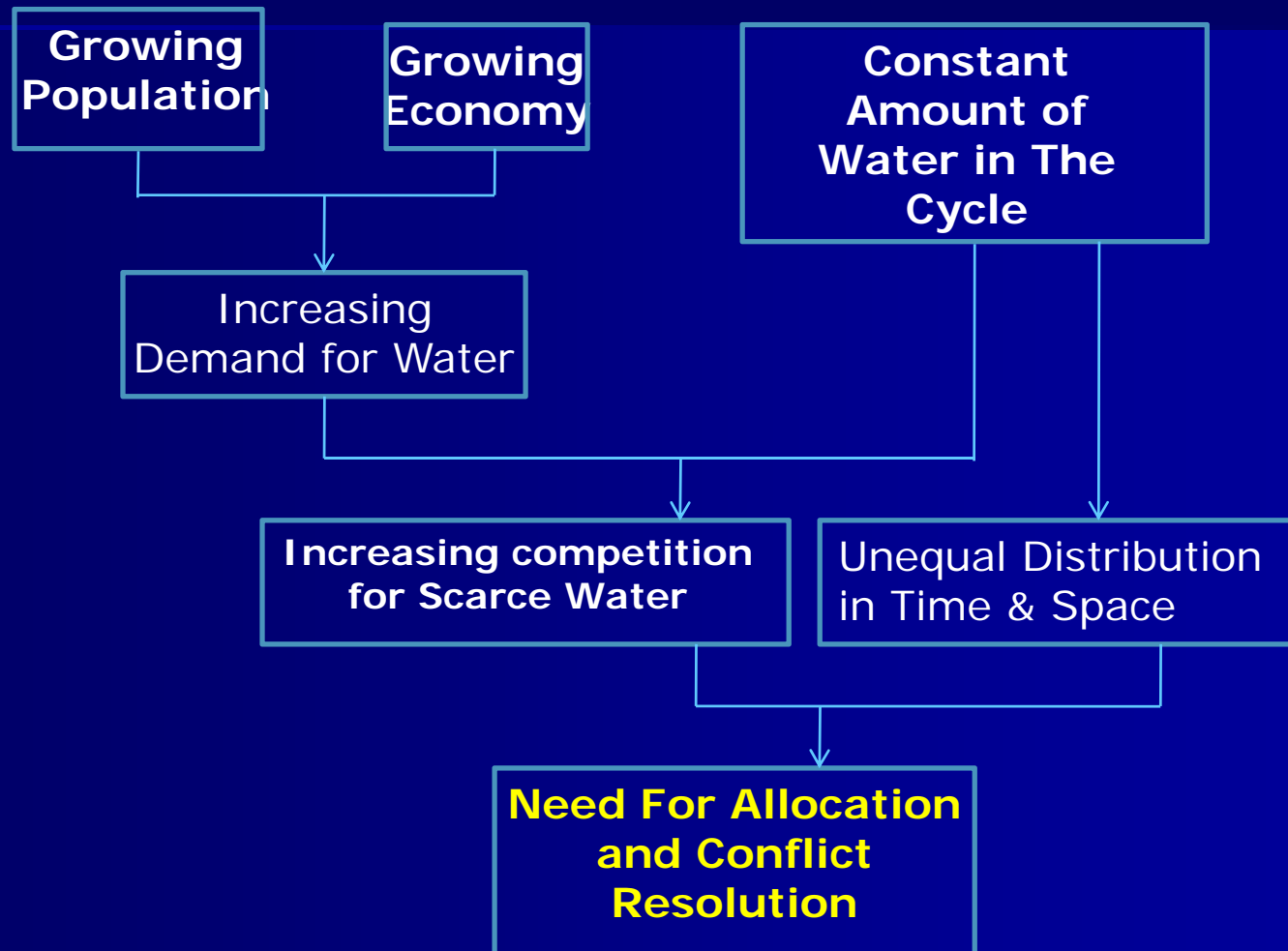
L9– Conjunctive Use of Water Resources

- **Topics Covered**
- Introduction to conjunctive use, Groundwater, Surface water, Conjunctive use, necessity, advantages, limitations, management, schemes, mechanisms, modeling, Case study
- **Keywords:** surface water, Groundwater, Conjunctive use, stream –aquifer interactions





Water Management problem?



Surface water Or Groundwater?

■ Issues:

- Precipitation & peak runoff of the rivers – only few months of the year - smallest water demand.
- Water development problem - transferring water from high supply season to the high demand season.
- Solution to the problem - surface water storage (reservoirs) or groundwater storage (aquifer recharge & use).
- Surface reservoirs have many drawbacks, especially:
- **evaporation**: water losses – more than 20 % of average annual runoff; More losses with a larger open water area.
- **sedimentation**: soil erosion results in siltation in the surface reservoirs and reduction of the storage capacity.
- **environmental impact** of surface reservoirs -undesirable for human health, flooding of inhabited or good agricultural land
- **distribution of water** from reservoir- costly canals.

WATERSHED MANAGEMENT

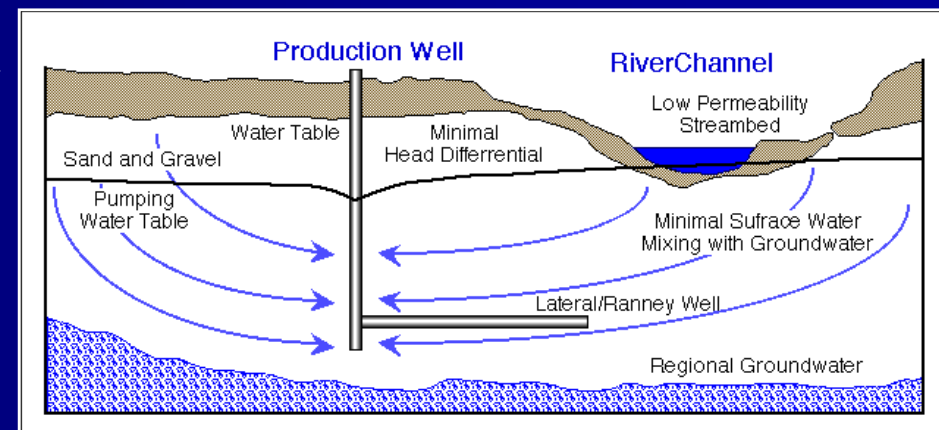
Surface water Or Groundwater?

	Groundwater storage	Small surface water reservoirs	Large dam reservoirs
Advantages	<ul style="list-style-type: none"> Little evaporation loss Ubiquitous distribution Operational efficiency Available on demand Water quality 	<ul style="list-style-type: none"> Ease of operation Responsive to rainfall Multiple use Groundwater recharge 	<ul style="list-style-type: none"> Large, reliable yield Carryover capacity Low cost per m³ water stored Multipurpose Flood control and hydropower Groundwater recharge
Limitations	<ul style="list-style-type: none"> Slow recharge rate Groundwater contamination Cost of extraction Recoverable fraction 	<ul style="list-style-type: none"> High evaporation loss fraction Relatively high unit cost Absence of over-year storage 	<ul style="list-style-type: none"> Complexity of operations Siting High initial investment cost Time needed to plan and construct
Key issues	<ul style="list-style-type: none"> Declining water levels Rising water levels Management of access and use Groundwater salinization Groundwater pollution 	<ul style="list-style-type: none"> Sedimentation Adequate design Dam safety Environmental impacts 	<ul style="list-style-type: none"> Social and environmental impacts Sedimentation Dam safety

(Ref.) Keller A., Sakthivadivel, R., Seckler David. Water Scarcity and the Role of Storage in Development. International Water Management Institute, Research Report 39.

Stream – Aquifer Interactions

- Till late 1950's Surface and Ground water dealt separately
- Interaction between surface & groundwater
- Hydraulic connection between aquifer systems & surface water sources



Conjunctive Use of Surface & Groundwater

- **Conjunctive use** - combined use of surface water resources & groundwater, in a unified way, to optimize resource use & minimize adverse effects of using a single source.
- **Conjunctive use** - actively managing aquifer systems as an underground reservoir. During wet years, when more surface water is available, surface water is stored underground by recharging the aquifers with surplus surface water. During dry years, the stored water is available in the aquifer system to supplement or replace diminished surface water supplies.
- **Judicious use** of surface & ground water is **conjunctive use**.

Conjunctive Use

Why?

- Surface water
 - lower delivery
 - low extraction costs
 - variability in supply
 - water logging
- Groundwater
 - reliable supply
 - expensive to pump
 - decline in GW table

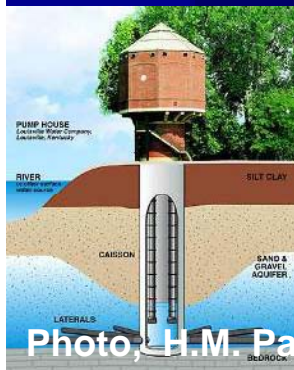
What?

- Operation of a GW basin in coordination with a SW reservoir system
- Artificially recharge the basin during years of above average precipitation
- Water can be withdrawn during years of below average precipitation, when SW supplies are below normal

Necessity of Conjunctive Use

- Groundwater and surface water are closely linked
- Groundwater maintains the base flow of rivers, and water in rivers can infiltrate into the ground.
- Abstraction of surface water and groundwater cannot be planned in isolation — one will affect the other. eg. abstraction of groundwater can reduce base flow contribution to rivers by lowering water table.
- If carefully planned, however, the conjunctive use of rivers and groundwater can even out the seasonal variations in river flow. In the summer when the river flow is low, water moves from the aquifer into the river, so that more water can be drawn from the river d/s. Rainy season, water flows from River to aquifer.

Pumping from wells also intercepts some of the natural base flow to the river.



Photo, H.M. Patel, 2007

Conjunctive Use - Advantages

- Exploits storage capacity of an aquifer & ease of transport of water by a river/ channel.
- Aquifer is used to store surface water when there is an excess of it & it would otherwise be wasted, say in winter.
- River is used to transport water from the aquifer to where it is needed when river discharge is too low on its own, as often happens in summer
- Conjunctive use can reduce abstraction from rivers when discharge is low by using groundwater instead.
- Problems of water logging/ groundwater over use reduced
- Sustainable water management

Conjunctive Use - Limitations

- Increased energy consumption for pumping from wells and for coping with reduction in pump efficiency, due to large fluctuations of water levels.
- Appropriate management plans to be developed.
- Construction of appropriate groundwater recharge structures
- Administrative difficulties in defining acceptable and equitable groundwater rates, when surface water is available.
- People apathy – people participation essential

Conjunctive Use - Challenges

- Isolated use of surface water ignoring optimal groundwater use in irrigation command -resulted into various environmental problems.
- Storage of excess surface water underground in an aquifer -a type of conjunctive use called managed aquifer recharge - makes the most of excess water by directing it into the ground where it can be stored for future use.
- Managed aquifer recharge is not a simple process, & it is difficult to do on a useful scale; it cannot absorb large volumes of flood water in a short time.
- It involves transferring water from surface to underground, - by dispersing it over the surface to increase infiltration, or through aquifer injection wells.
- Surface dispersal involves diverting water into an unlined canal or shallow lagoon in permeable sediments or rock so that the water can percolate downwards into the aquifer.
- It works best in areas with highly permeable soils and unconfined aquifers, and where land is inexpensive.

Conjunctive Management

- **Conjunctive management** - coordinated use of available surface water & groundwater supplies to meet water demands & increase water supply reliability.
- Concept of conjunctive water management consists of maximizing the use of surface water during the time supply is plentiful & saving groundwater for the periods when surface water supplies are short.
- Development of conjunctive management plan - includes consideration of surface water & groundwater hydrology, water demand characteristics, water quality, surface & underground storage capacities, conveyance capacity, capital & O&M costs.

Conjunctive Management - Objectives

- Evaluation of water resources - quantification of surface & ground water in space & time - to determine water balance.
- Identification of critical areas of water logging & soil salinity.
- Matching demands of various sectors with available water resources & evolve strategy to meet demand of the future.
- Mathematical modeling - to simulate hydro geological situation, generation of various scenarios, optimum development plans.
- To evolve plan for controlling problem of rising water levels by adopting technique of conjunctive use and drainage.
- To prepare sector/block wise plans for development of ground water resource in conjunction with surface water based on mathematical model results.
- To test sustainability of present irrigation pattern w.r.t. Conjunctive use & suggest improvement for future. .
- To evaluate the economic aspect of groundwater development plan w.r.t. cost benefit ratio.

Conjunctive use - Schemes

- **Aquifer recharge** - basin recharge / injection wells- used when no suitable land for a recharge basin, or with confined aquifers.
- Aquifer storage and recovery schemes - use the same borehole to inject and recover water -**water banking**.
- **Storm runoff** - can be used for managed aquifer recharge
- In some areas - **use sewage effluent** for managed aquifer recharge
- Another type of conjunctive use is the use of groundwater to increase the flow of a river, **called river augmentation**. Advantage -river can be used to convey groundwater to its destination.
- Effect is similar to river regulation, except water is stored underground instead of in surface reservoirs.

Artificial Recharge Techniques

□ **Direct surface techniques**

- Flooding
- Basins or percolation tanks
- Stream augmentation
- Ditch and furrow system
- Over irrigation

□ **Direct sub surface techniques**

- Injection wells or recharge wells
- Recharge pits and shafts
- Dug well recharge
- Bore hole flooding
- Natural openings, cavity fillings.

□ **Combination surface – sub-surface techniques**

- Basin or percolation tanks with pit shaft or wells.
- **Indirect Techniques**
 - Induced recharge from surface water source.
 - Aquifer modification.

Conjunctive Use & Irrigation Development

- Use of groundwater helps cope with peak demands for irrigation & hence reduce size of canals and consequently construction costs.
- Supplemental supplies from groundwater ensure proper irrigation scheduling, even if rainfall fails or is delayed
- Groundwater withdrawals lower the water table thus reducing the risk of water-logging, soil salinization and consequent wastage of water for leaching the soils;
- Surface & subsurface outflows are minimized, causing reduction in peak runoff;
- When conjunctive use is integrated with artificial recharge, need for lining canals reduced- seepage feeds groundwater
- Conjunctive use allows utilization of saline or brackish ground – or surface – water resources, -by mixing with freshwater, or by using alternate resources for irrigation.

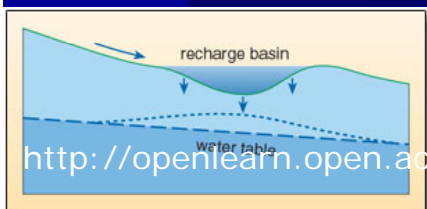
Conjunctive Use Planning

- Develop Local Partnership
- Basin Assessment
- Data Collection
- Modeling Analysis
- Alternatives Evaluation
- Pilot Project
- Feasibility Study
- Implementation and Monitoring.

Ground Water Hydraulic Management Models (Management models) which incorporates a groundwater simulation model as constraint in the Management model - can be efficiently used in planning the conjunctive use of water.

Conjunctive Water Use - Mechanism

- Use of mathematical models for conjunctive use – simulation optimization models – Optimum use
- Tackle problem of rise in water level – water logging – drainage
- Tackle salinity problems
- Reschedule operation of canals
- Manage crop water requirements – proposed surface & ground water use pattern in time & space.
- Demand & supply management
- Development of suitable surface storage schemes
- Development of suitable groundwater recharge schemes



Conjunctive Use – Concerns & Solutions

Concerns

- Heightened competition for withdrawals
- Increasing in-stream flow regulations
- Compelling groundwater quality issues
- Environmental concerns

Solutions

- Formulation of permitting programs and establishment of regulatory agencies
- Formulate the overall goal of the permitting systems
- Protection of surface and groundwater bodies
- Use of Mathematical techniques

Conjunctive Management - Modeling

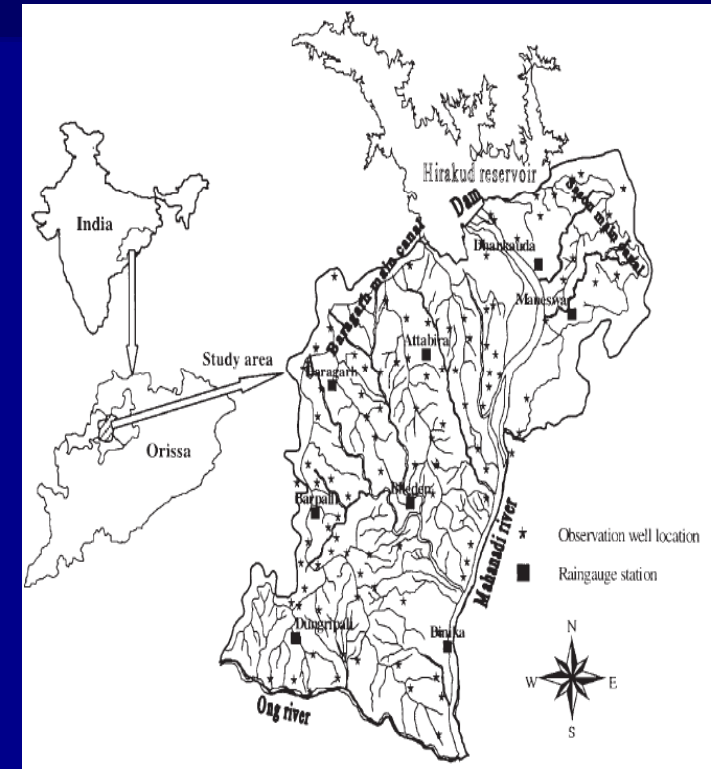
- Surface water simulation – Hydrologic modeling - Simulation of interrelationships among hydrologic processes – distributed model in space & time – eg. MIKE-SHE
- Groundwater simulation – groundwater flow, stream-aquifer interactions– distributed model in space & time – eg. MODFLOW
- Optimization model – Optimal surface & groundwater allocation – Simulation optimization models – eg. : Linear programming; Dynamic programming, evolutionary AI techniques such as GA, PSO etc.
- Integrated modeling approach

Conjunctive Water Use Projects in India

- **Projects** (Ref: http://cgwb.gov.in/groundwater/conjunctive_use.htm)
 - Indira Gandhi nahaar paryojna, stage - I, Rajasthan
 - Sarda sahayak irrigation project, U.P.
 - Tungabhadra canal command area, Andhra Pradesh & Karnataka
 - Ghataprabha canal command area, Karnataka
 - Hirakud canal command area, Orissa
 - Mahi- kadana canal command area, Gujarat
 - Nagarjuna sagar project, Andhra Pradesh
 - Indira gandhi nahaar pariyojna stage - II, Rajasthan
 - Kosi canal command area, Bihar
 - Gandak canal command, Bihar
 - Sriram sagar canal command area, Andhra Pradesh
 - Western Yamuna canal command area, Haryana
 - Rushikulia canal command area, Orissa

Case Study: Conjunctive Use

- Hirakud Canal Command Area, Orissa, India, covering an area of about 2540 km²
- Total length of canal network - 3500 km
- Average slopes : 1-6%
- Surface drainage – Mahanadi
- Mean annual rainfall 1245 mm - 90% June – October
- Depth to water level
 - 0.8 -9.7m bgl (pre-monsoon)
 - 0.3-4.03 m bgl (post-monsoon)
 - 0 to 2 mbgl (monsoon)



Ref: Raul S. K., Panda S. N., Hollaender H., Billib M., Sustainability of rice-dominated cropping system in the Hirakud canal command, Orissa, India, Irrig. & Drain. 57: 93–104 (2008) Wiley Interscience.

Case Study: Conjunctive Use ..

- **Availability & Demand Of Water**
- Utilizable ground water resources
 - 508.04 MCM (Kharif); 764.44 MCM (Rabi)
- Availability of surface water
 - 1360.8 MCM (Kharif); 1494.8 MCM (Rabi)
- Annual water demand (2025)
 - 49.89 MCM (Domestic); 261 MCM (Industrial)
- **Problems in the study area:**
- Water logging (1994)
 - 1494 sq.km (Post-Monsoon); 174 sq.km (Pre-Monsoon)
- Causes
 - Topographic setup; unlined canals
 - over irrigation
 - predominant paddy cultivation during kharif and rabi

Case Study: Conjunctive Use ..

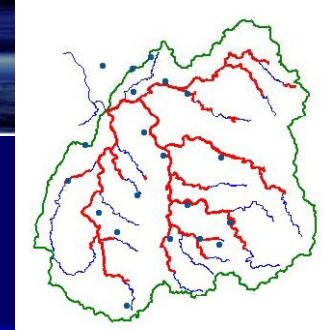
- **Conjunctive use plan.**
- Various possible conjunctive use strategies have been tested with the ground water simulation model
- Demand for irrigation (Kharif & Rabi) can be met from
 - surface water (90%); ground water (10%)
- Surface water irrigation - cheaper - maximum use of available surface water in conjunction with groundwater to get maximum return
- Development of groundwater
 - 17,526 dug wells
- Water logging reduces with increase in use of groundwater
- Additional investment of Rs.953.99 million the B.C ratio worked out to 1.66.

Case Study: Conjunctive Use ..

- **Lessons learnt:**
- During monsoon, majority of the command remains waterlogged & it is required that groundwater withdrawal during non-monsoon period be increased so that groundwater reservoir will have sufficient capacity to accommodate monsoon recharge.
- During non-monsoon period, there is no danger of water logging but still there is a lot of scope for groundwater development.
- Increasing storage through a combination of groundwater & large & small surface water facilities
- Judicious allocation of water
- Vigilant monitoring to avoid over irrigation
- Creating public awareness
- Necessity of public participation

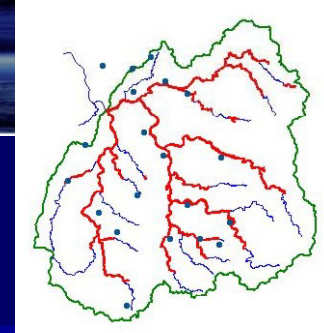
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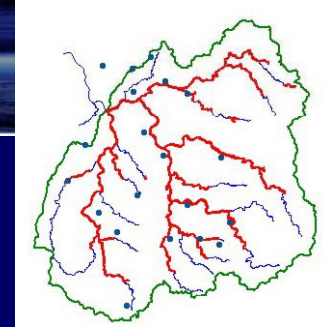
Tutorials - Question!..?.

- **Illustrate the Conjunctive Use of Surface & Groundwater with a case study.**
- For case studies Ref: (Ref: http://cgwb.gov.in/groundwater/conjunctive_use.htm)
- Identify the problems of using surface water/ groundwater alone.
- Study the demand for the area
- Illustrate how conjunctive use can be used to solve the problems.
- Discuss the lesson learnt.



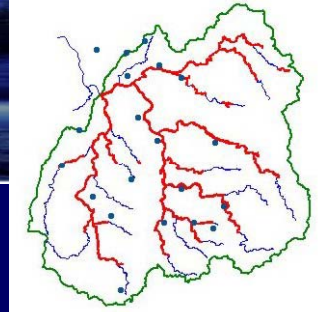
Self Evaluation - Questions!

- Discuss the issues related to overuse of surface water & groundwater.
- What is the necessity of conjunctive use?.
- Discuss advantages & limitations of conjunctive water use.
- Illustrate groundwater recharge techniques within the perspective of Conjunctive water management.



Assignment- Questions?.

- Discuss stream – aquifer interactions and importance in conjunctive use.
- Describe conjunctive management of surface water & groundwater with various challenges.
- Discuss conjunctive use plan and mechanisms.
- How to develop conjunctive management model for a watershed?.



Unsolved Problem!

- For your Watershed area, prepare a master plan for conjunctive use of surface & groundwater.
- Identify the supply & demand.
- Check the applicability of modeling tools.
 - Carry out detailed study
 - Consider integrated approach for surface & ground water
 - Consider options for groundwater recharge

WATERSHED MANAGEMENT

THANK YOU

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