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Groundwater & River Flows

Dr. R. Jagadiswara Rao

Professor of Geology (Retired)

Sri Venkateswara University

Tirupati, AP 517502

rjagadiswara@gmail.com &

jagadiswara@yahoo.com

Flows in Rivers

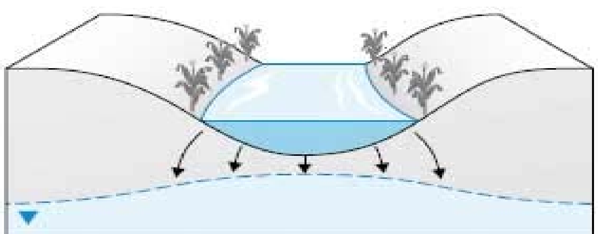
- The purpose of this Presentation is not to define e-flows. It only aims at studying the existing flows in rivers and suggest methods by which river flows can be enhanced through proper groundwater management.
- Water in riverbeds flows as both surface and ground water runoff with considerable interaction between the two types of waters.
- The ultimate average flow as surface runoff in a river is the difference between the average monsoon runoff and water that could be harnessed. While these flows are highest in the Brahmaputra & Meghna rivers, they are almost zero in the rivers of Kutch-Saurashtra-Luni, Pennar, those between Pennar & Kanyakumari, and Cauvery.
- The difference between the replenishable groundwater and groundwater so far harnessed in a river basin can be taken as almost equal to the average flow of groundwater runoff beneath the riverbed. While these flows are highest in the rivers of Brahmaputra-Meghna, Mahanadi, and Brahmani-Baitarni, it is lowest in the rivers of Indus, those between Pennar & Kanyakumari, Cauvery, and Kutch-Saurashtra-Luni.
- The following Table gives river-wise details of average flows.

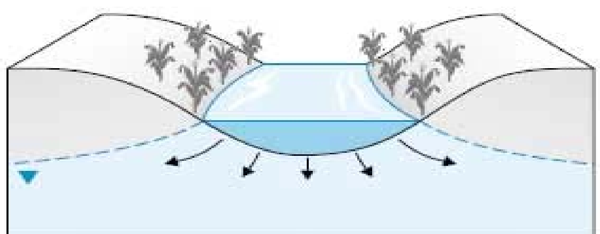
Utilisable Surface Water & Groundwater Resources in River Basins of India in Cubic Km per Year		
River Basins	Average Monsoon Runoff & % Available as flow	Replenishable Groundwater & % Available as flow (1999)
Indus	58.6 (21.5%)	25.5 (15.6%)
Ganga	401.3 (37.7%)	171.7 (52.3%)
Brahmaputra-Meghna	477.5 (95.0%)	29.7 (73.7%)
Godavari	107.1 (28.8%)	46.8 (63.7%)
Krishna	61.0 (4.9%)	26.6 (52.8%)
Cauvery	18.9 (100.5%)	13.6 (41.8%)
Pennar	6.2 (0%)	5.0 (51.7%)
Between Mahanadi & Pennar	15.3 (14.4%)	22.8 (65.4%)
Between Pennar & Kanyakumari	16.0 (0%)	20.9 (40.9%)
Mahanadi	60.2 (16.9%)	21.3 (72.3%)
Brahmani-Baitarni	32.6 (43.9%)	5.9 (71.7%)
Subarnarekha	9.7 (29.9%)	2.2 (68.9%)
Cambay	14.1 (64.5%)	7.9 (52.7%)
Kutch-Saurashtra-Luni	13.6 (0%)	13.9 (43.9%)
Narmada	36.9 (25.5%)	11.9 (63.9%)
Tapi	16.2 (0.4%)	8.2 (54.1%)
Western Ghats	178.1 (79.7%)	18.3 (60.3%)
India as a whole	1,523.3 (55.1%)	452.2 (54.3% - 51% in 2004)

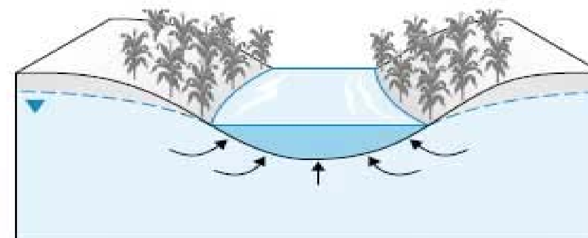
Classification of Rivers (Streams)

Based on relative proportions of surface and ground water runoff, rivers or streams can be classified as follows.

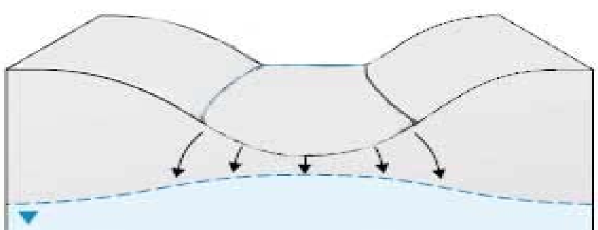
- In a losing stream, groundwater flows away from the stream. If seepage is excessive, surface water will be in direct contact with groundwater. Wells constructed away from the stream give more yield. In extreme cases, the entire surface water seeps into the underground to form a lost stream with no surface runoff at all.
- In a gaining stream, groundwater flows towards the stream. Wells constructed in the stream bed give more yield than those constructed away from the stream.
- Streams flowing in impervious terrains carry no groundwater at all. Such streams do not recharge groundwater. Water in them is best used through direct pumping.

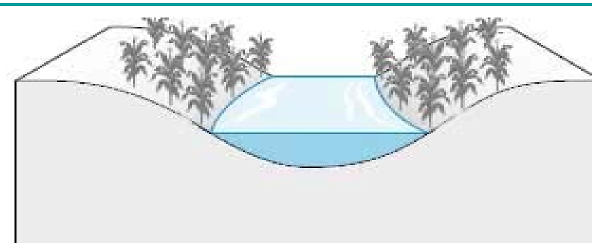

SEEPAGE FROM LOSING STREAM


LOSING (INFLUENT) STREAM


GAINING (EFFLUENT) STREAM

http://siteresources.worldbank.org/EXTWAT/Resources/4602122-1210186362590/GWM_Briefing_2.pdf


SEEPAGE FROM LOST STREAM

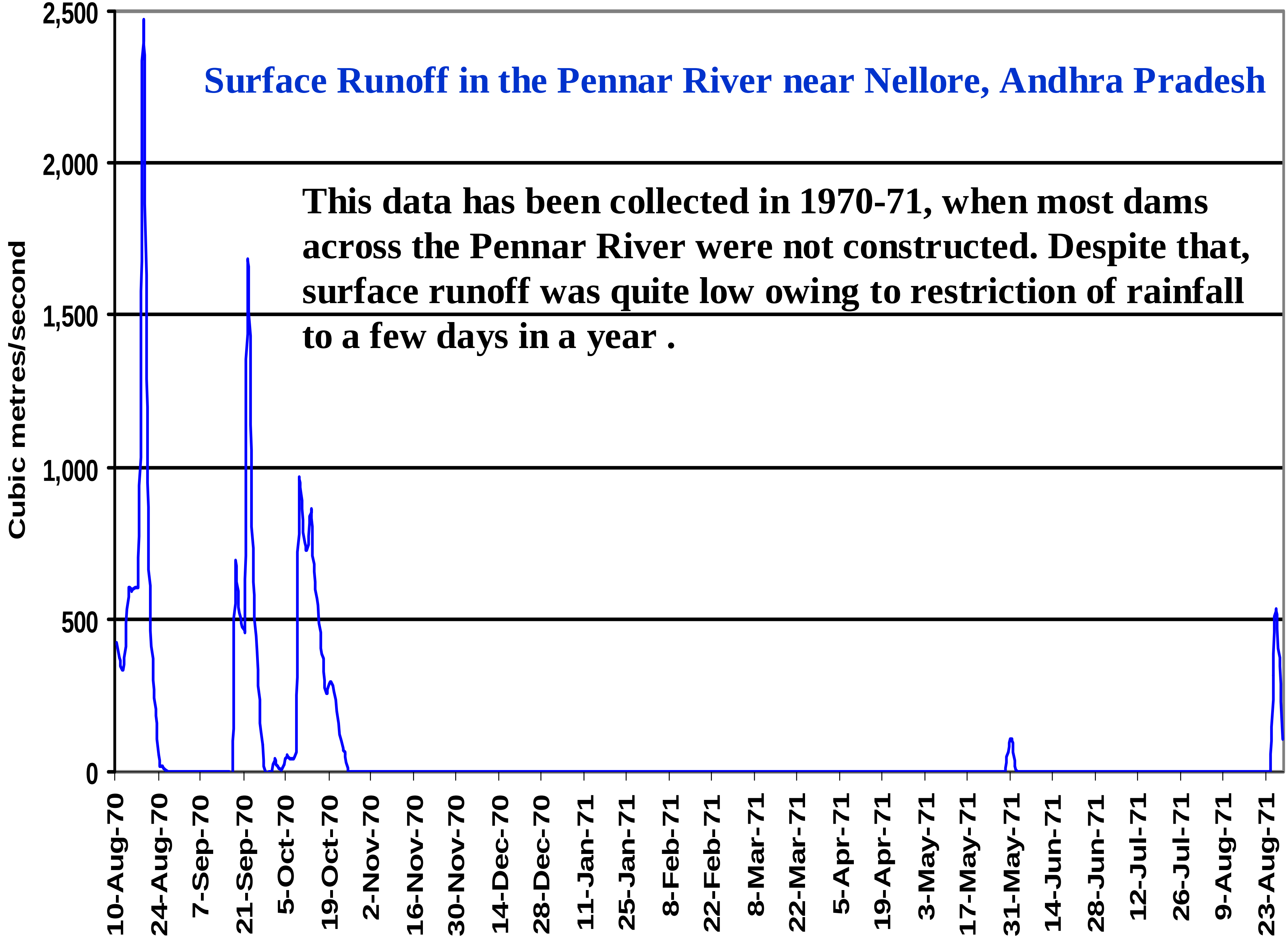

STREAM IN IMPERVIOUS TERRAIN (NO SEEPAGE)

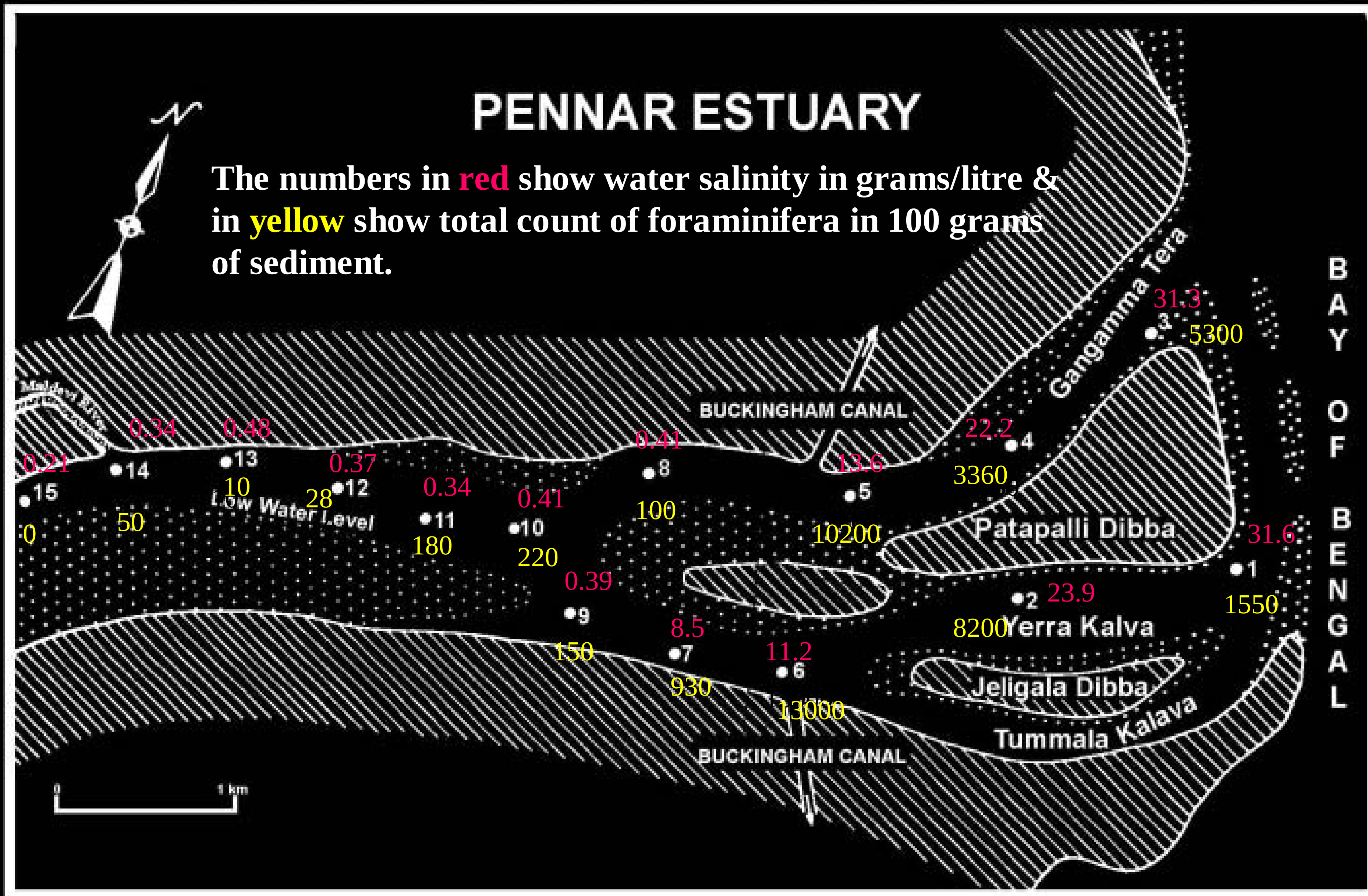
Failure to understand the interactions between surface and ground water runoff in riverbeds has led to costly mistakes. For example, irrigation water to 76,890 Ha of land in Kurnool district (AP) could not be so far provided through the Srisailam Right Branch Canal (SRBC) Project taken up in 1981 for want of completion of a reservoir across the highly-faulted Lost Gorakallu stream underlai by limestone caves (http://www.janmanch.org/newsletter/sandrp-update-jan2005.htm).

http://www.sewconstructions.com/inside/images/Gorakallu.jpg

Surface and Ground Water Runoff in the Pennar River

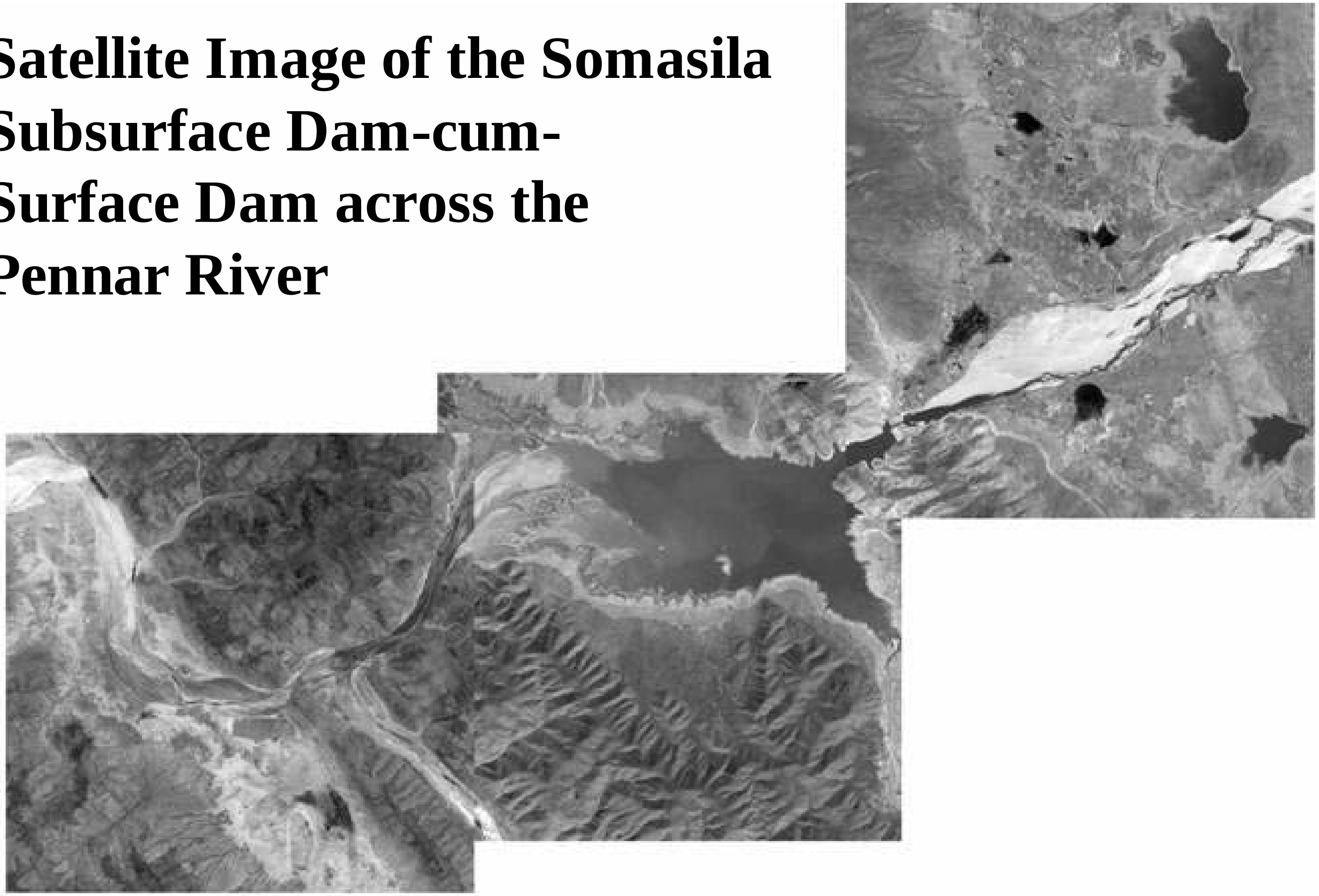
- While the entire surface runoff of the Pennar River is completely harnessed, 52% of the replenishable groundwater flows beneath riverbeds with some emerging to surface as base flow.
- From our work in the S V University on the ecology of foraminifera in the Pennar estuary during 1970-73, we could know that a good portion of groundwater runoff emerges as surface runoff to reduce the salinity of the estuary.
- As foraminifera thrives best in brackish waters, their population was found to be the highest in waters with a salinity between 10 and 15 grams/litre.
- We could know from studies on waters held in the Somasila reservoir constructed across the Pennar River since 1989 that they originate from different sources.
- The slides that follow illustrate the interactions between surface and ground water runoff in the Pennar River.


Surface Runoff in the Pennar River near Nellore, Andhra Pradesh
This data has been collected in 1970-71, when most dams across the Pennar River were not constructed. Despite that, surface runoff was quite low owing to restriction of rainfall to a few days in a year .
Cubic metres/second
2,500
2,000
1,500
1,000
500
0
10-Aug-70
24-Aug-70
7-Sep-70
21-Sep-70
5-Oct-70
19-Oct-70
2-Nov-70
16-Nov-70
30-Nov-70
14-Dec-70
28-Dec-70
11-Jan-71
25-Jan-71
8-Feb-71
22-Feb-71
8-Mar-71
22-Mar-71
5-Apr-71
19-Apr-71
3-May-71
17-May-71
31-May-71
14-Jun-71
28-Jun-71
12-Jul-71
26-Jul-71
9-Aug-71
23-Aug-71



The work involved analysis of water and sediment samples at 15 stations for 12 months from the Pennary estuary for various parameters including salinity and total foraminifera.

Satellite Image of the Somasila Subsurface Dam-cum-Surface Dam across the Pennar River



This satellite image was taken in a year of drought before the Krishna river water could be imported into the Pennar River. The surface water in the reservoir represented the unutilised groundwater of around 2 cubic kilometres per year in the upstream. Had a subsurface dam alone without surface dam was constructed, the groundwater would have emerged as surface runoff to provide adequate flows in the downstream.

A satellite image of the same reservoir captured in 2008 - a year of good rainfall after establishing the Krishna-Pennar Link. The reservoir water includes surface and ground water runoff from the upstream of the Pennar basin, besides water imported from the Krishna River. Groundwater stored beneath the reservoir remains static to enable reservoir water to flow in the canals by gravity flow.

Dam waters to Ensure Downstream Flows

- The present practice is to divert entire water obstructed by a dam across a river for use at places far away from the river and thereby impoverish flows downstream of the same river.

- It is necessary to take a policy decision to release some water from the dam to downstream of the same river to ensure downstream river flows and provide water for various uses for those living close to the river.

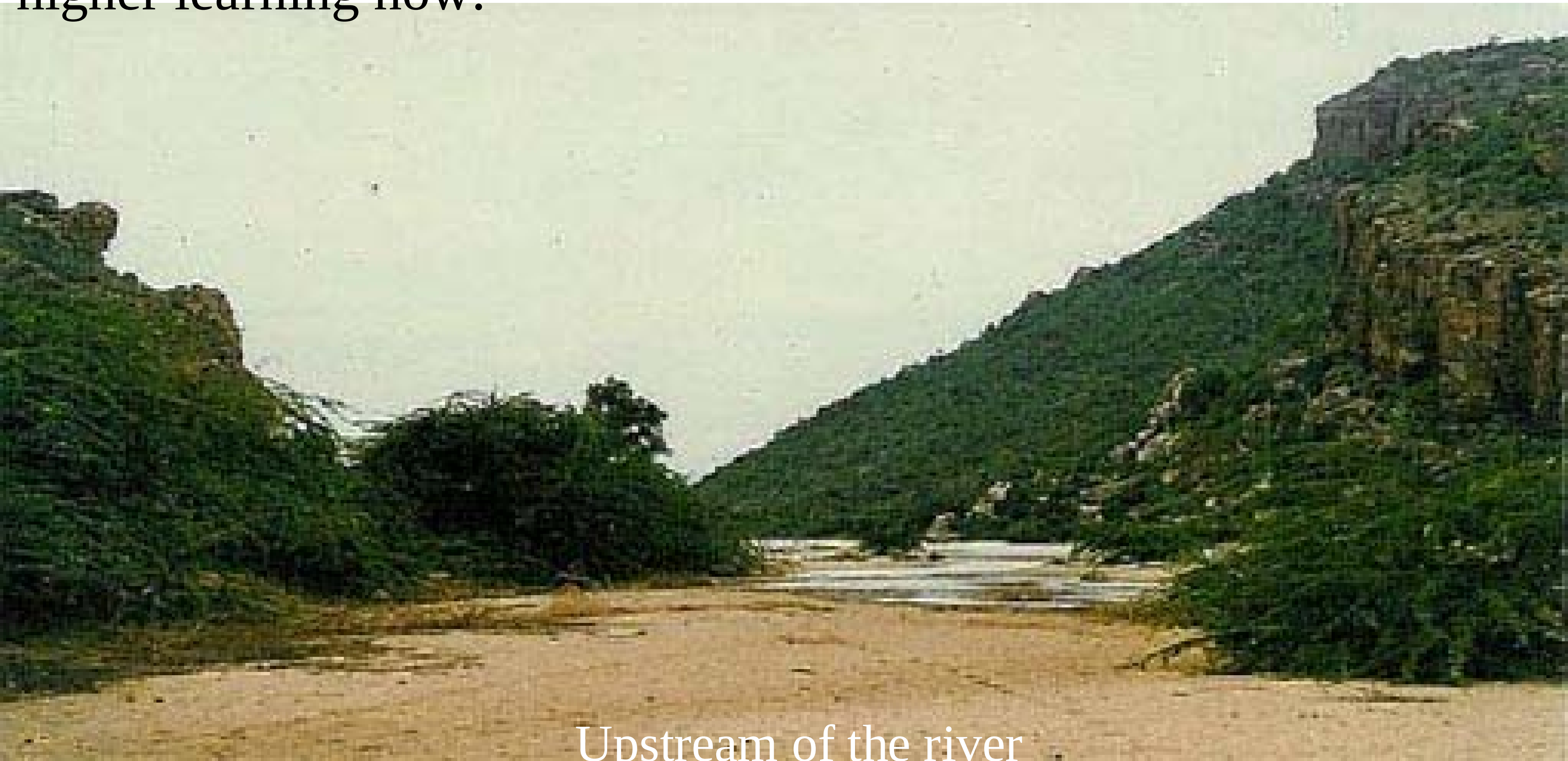
Check Dams to Ensure Flows

- Check dam is an obstruction created above the bed level across a losing stream to arrest a portion of the surface runoff in the upstream. Construction of a cascade of such dams at close intervals gives a perennial look to the river throughout its course.
- Such structures give best results in streams underlain by formations of low permeability to recharge shallow dug wells used by farmers to irrigate dry crops in limited land holdings.
- This methodology gave good results for the river Aravari in Rajasthan, where the farmers were not greedy and willing to share equitably the limited water available.
- The Aravari method can be successfully implemented in other losing rivers where the above conditions are fulfilled.
- This method is not successful in gaining streams, or where the level of groundwater development is high, or where the stakeholders are not disciplined for equitable sharing of the limited groundwater available.

Subsurface (SS) Dams to Ensure Flows

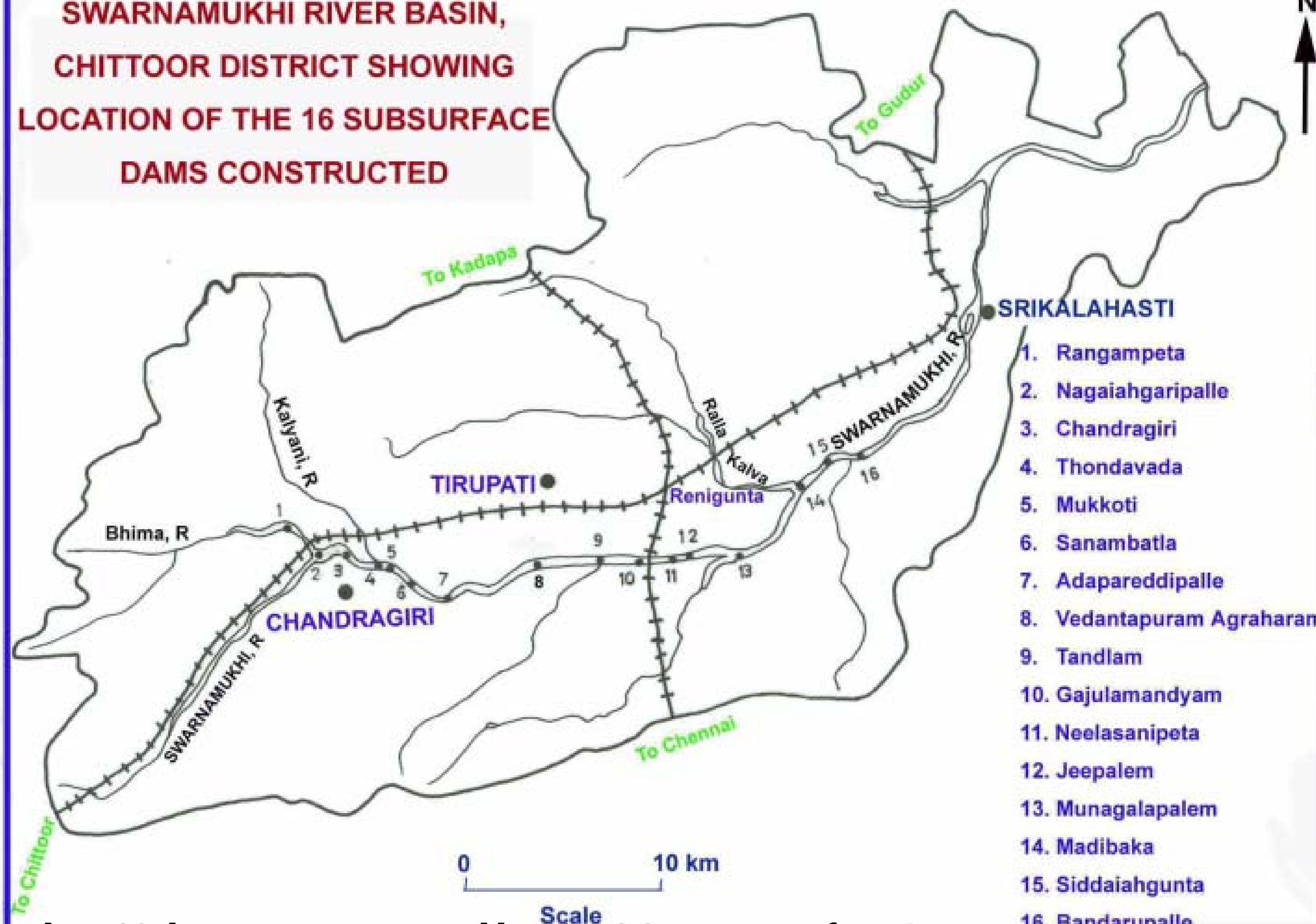
- An SS dam is an obstruction created below the bed level across a gaining stream to prevent entire groundwater flow occurring in permeable sand underlying the stream.
- It is essential to conduct detailed scientific investigations to select suitable sites for their construction.
- It is also essential to execute construction of an SS dam under scientific supervision to ensure that no water obstructed escapes downstream through its sides or bottom.
- Once an SS dam is properly constructed, groundwater after saturating the upstream sand emerges as surface runoff to flow downstream.
- Groundwater stored upstream of the SS dam can be used through shallow infiltration wells or filter point wells.
- The top of an SS dam can be fixed through negotiation to ensure equitable distribution of groundwater between the upstream and downstream users and thereby avoid conflicts between them.
- The SS dam component of the Somasila reservoir can be considered as one of the best examples of a successful SS dam constructed in India.

View of a natural subsurface dam across the Papaghni River, a tributary of the Pennar River becoming perennial while passing through a gorge owing to significant reduction in the volume of sand beneath the river. These flows have helped the gorge portion to develop well in the past through construction of a famous Gandi Anjaneya temple in the past and through creation of an institute of higher learning now.



Upstream of the river

SWARNAMUKHI RIVER BASIN, CHITTOOR DISTRICT SHOWING LOCATION OF THE 16 SUBSURFACE DAMS CONSTRUCTED



These SS dams were constructed by 10 NGOs at a cost of Rs. 4 crores.

The complex nature of the river is such that, despite construction of SS dams, sizeable groundwater in the upstream could escape downwards from the sides and bottom of the SS dams constructed. As a result, they have not served the purpose for which they were constructed.

SS Dams to Help Groundwater Flow beneath Riverbeds to Emerge as Surface Runoff

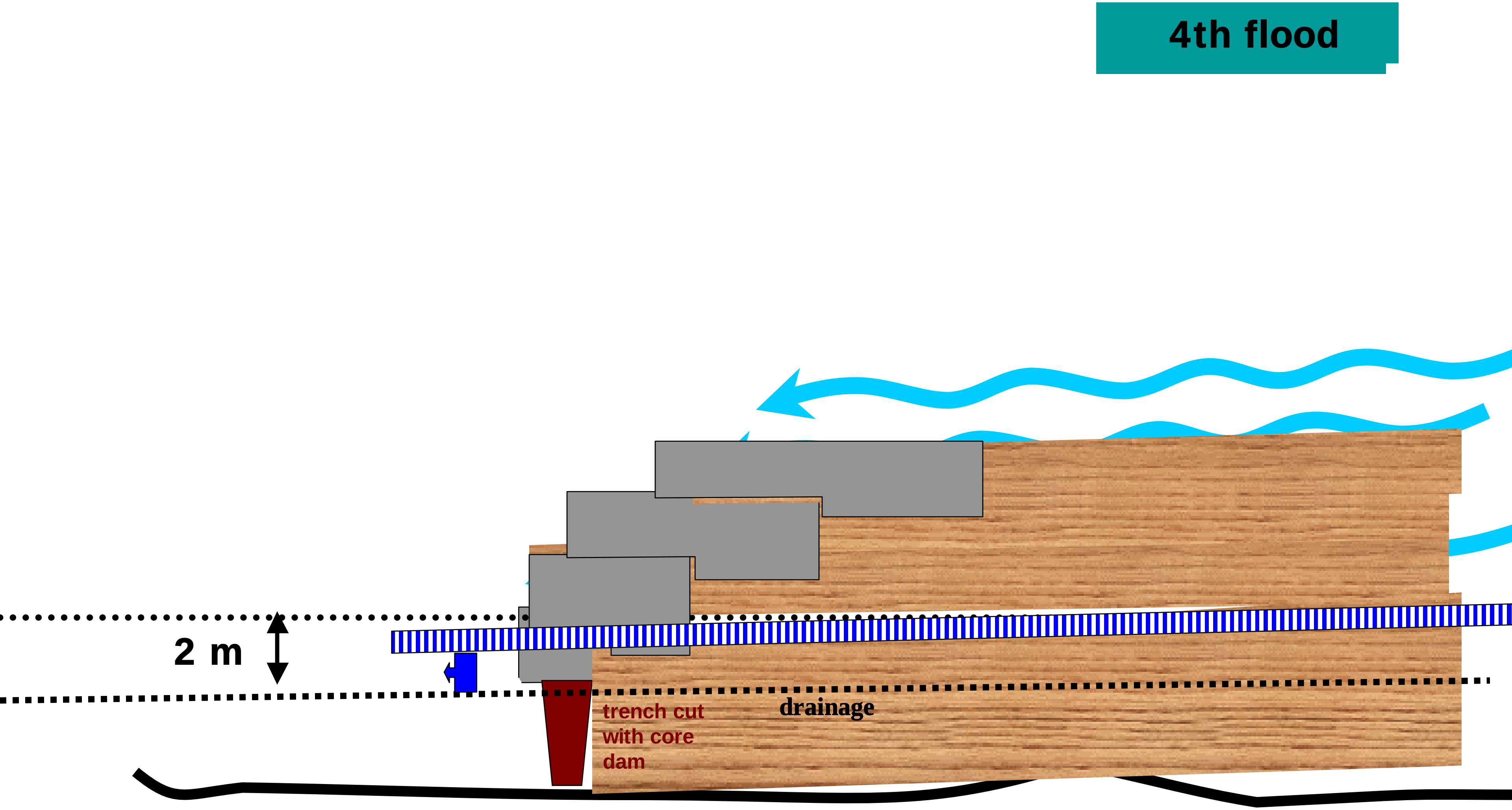
- Our studies have indicated that around 2 cubic kilometres per year of groundwater from the Pennar River was joining the sea as groundwater runoff. With the construction of the Somasila SS dam-cum-surface dam across the Pennar River, this groundwater was getting collected as surface water in the reservoir. Had an SS dam alone without surface dam was constructed at this place, the groundwater would have emerged as surface runoff to provide adequate flows in the downstream of the river.
- It is worthwhile to construct subsurface dams across all the rivers of India joining the sea at suitable sites selected by scientific methods so that groundwater runoff beneath these rivers presently joining the sea could be made to emerge as surface runoff.
- A portion of these flows could be diverted into the existing canal networks in the downstream to irrigate lands by gravity flow, while the remaining flows could serve other purposes such e-flows and prevention of sea water intrusion.

Sand Dams to Ensure E-Flows

While sand dam is similar to a check dam as far as creation of an obstruction across a stream rising above the bed level, they differ from each other in the following ways.

- The primary purpose of a check dam is to collect surface water, while a sand dam collects both sand and groundwater within sand.
- While a check dam is constructed in one installment across a stream, the height of a sand dam is increased progressively during a period of some four years.
- The sediment accumulated upstream of a check dam consists of a mixture of sand, silt and clay. While the sediment allowed to be accumulated upstream of a sand dam consists of only uniform sand of high hydraulic conductivity.
- Evaporation losses of water stored in a check dam is considerable, while such losses are minimal in the case of sand dams.
- Depletion of groundwater caused by legal and illegal mining of sand accumulated in the riverbeds is overcome through construction of sand dams rather than check dams.

Schematic Diagram Showing the Progressive Increase of a Sand Dam During Each Flood to Collect Sand, While Silt and Clay Are Lost in Flood Waters



E 016°26.910 / S 23°19.109 SSD Namibia

While viewing the slide show, left click on this slide four times to experience animation.

View of a sand dam constructed in Namibia. Surface runoff in the downstream of the sand dam can be enhanced by letting groundwater into the downstream by a pipe. Groundwater can be tapped in the upstream through infiltration wells and filter point wells constructed directly on the sand dam.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