

$$B = \mu_0 \rho_i^{1/2} C_A$$

$$= \frac{\sqrt{\pi} \pi^{3/2} L}{P} \sqrt{\rho_i^{1/2} + \rho_i^{1/2}}$$

The determination of the magnetic field is weakly sensitive to errors in the determination of the plasma density in the loop, because the magnetic field is proportional to the square root of the density. For a quite wide range of plasma number densities, from 10^9 to $6 \times 10^9 \text{ cm}^{-3}$, the value of the magnetic field is in the range from 4 to 30 G. Using TRACE 171 Å and 195 Å images of the loop, taken on 4 July 1999 to determine the plasma density, the magnetic field in the loop was estimated to be 13–19 G (ref. 12). It is to be noted, however, that improved diagnostics of the loop length, the oscillation period, and the plasma density in the loop will significantly improve the method's precision.

The Reynolds number

The observed dissipation of the resonant global mode may be due to viscous and resistive dissipation that have a similar effect on the wave dissipation. The dependence of the wave amplitude decay rate on the resistive dissipation coefficient is

well-known. Viscous dissipation in a fluid is expressed in terms of the dimensionless Reynolds number R . Similarly, the magnetic diffusion coefficient gives rise to the dimensionless magnetic Reynolds number (or the Lundquist number) S .

Applying the numerically determined scaling laws⁷ which connect the oscillation decay time and the Reynolds R and Lundquist S numbers, the values of $R = 10^{5.3-6.1}$ and $S = 10^{5.0-5.8}$ have been estimated. The Reynolds number deduced from the observations is eight to nine orders of magnitude smaller than the classical value of $R = 10^{14}$. Likewise, the Lundquist number is seven to eight orders of magnitude smaller than the commonly quoted classical value of $S = 10^{13}$ for coronal plasma. And making use of these modern values, the possibility of heating the corona by MHD waves has been investigated¹³ (Dwivedi and Pandey, unpublished).

In conclusion, the new method of MHD coronal seismology, based on high resolution observations of the coronal wave activity, can become a powerful tool for the inference of physical parameters in the solar corona.

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COMMENTARY

Linking of major rivers of India—Bane or boon?*

B. P. Radhakrishna

Water shortage is going to be the most serious problem that the country will be facing in the 21st century. Painting a grim picture of water shortage in Karnataka, the Chief Minister of the state recently declared that the only solution to the problem of water shortage is the linking of rivers. The state is presently facing a severe drought. Instead of taking up measures to alleviate distress and reduce the hardship of farmers, the Chief Minister was only projecting a mirage promis-

ing better days ahead with plenty of water to be brought from the north by linking major rivers. He had obviously no clear conception of how this magic could be achieved.

It is not just the Chief Minister of Karnataka alone, but the Chief Ministers of other states of India are also repeating the same *mantra*. The Prime Minister of India, too, has joined in the chorus and has announced in the Parliament massive financial support for implementing such a scheme. The cost of the project is estimated to be a staggering sum of Rs 560,000 crores or Rs 56,000 crores a year, if it has to be completed in a decade.

The Central Government appears to be quite serious about implementing the project in spite of serious deficiencies in the information base. Suresh Prabhu, a former minister, has been made the Chairman of the Task Force for Linking Rivers and has been given Cabinet rank. Former Water Resource Secretary C. B. Thatte is made the Member Secretary and a new Ministry is in the offing. The scheme envisages effecting 30 river links in the next two years. Construction of over 1000 km of link canals is envisaged and 10,000 mW of electricity for lifting 11,000 cusecs of water would be required. No less than

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400 new reservoirs are programmed to be constructed.

Identification of water-rich and water-poor basins: Modalities of transfer

What we are concerned about is how inter-basin water transfers can be really effected, involving massive transfer of waters from basins with a surplus to basins which are in deficit. There is no unanimity of opinion in identifying basins with surplus water. Mahanadi and Godavari according to Central Government sources have surplus water while the State Governments of Orissa and Andhra Pradesh dispute this claim. There are arguments among the experts about the flow data furnished. The agreements enforced for sharing is over water that did not exist. The story is no different in other states.

This idea of inter-basin transfer started with K. L. Rao, an engineer in the service of the Government of India in 1972. He envisaged the construction in stages of a Ganga-Cauvery Canal, drawing nearly 60,000 cusecs of flood flows of the Ganga near Patna for about 150 days in a year and link it up with river Cauvery in the south.

An equally fantastic project was conceived by Dastur (a pilot by profession) who suggested construction of garland canals, one for the Himalayan watershed and the other for the Sahyadri (Western Ghats) watershed. A National Commission on Integrated Water Resource Development was presumably formed, which examined the project in great detail and rejected the whole proposal as not feasible. This was as recently as in 1997.

A fully government-sponsored National Water Development Agency is functioning at New Delhi since 1982. Liberally funded by the Government of India, it is fully managed by engineers in their ex-officio capacity. No names are mentioned or technical qualifications given. There is not a single representative of the public in any of the unwieldy committees full of ex-officio Chief Engineers of the innumerable ministries of the Government of India. There is no accountability. Although the agency has claimed achieving many things, **we are not aware of a single technical report issued by it on any of the so-called projects.** At no stage in the formulation

of the studies, representatives of people have been consulted. Governments think that the people are of the nature of hired labourers who will only be glad at finding chances of employment and earning a few rupees extra by way of wages.

Absence of data

The surprising fact is that the actual stream flow data for major rivers and their tributaries are non-existent. Collecting reliable stream flow data is an expensive affair and a very difficult task which can only be taken up by a team of experts and **even where some type of data does exist it is kept as top secret and not made available to the public, published for general information.** Rainfall data are no doubt more accurate and are available for a longer number of years but even here, there have been no systematic attempts at estimating the amount of runoff generated for various intensities of rainfall over various types of topographic features which characterize the physiography of the country. Water availability based on rainfall-runoff relations continues to be based on a number of assumptions which frequently go wrong. Basic data for a venture of this magnitude are thus lacking and the whole scheme, based on wrong premises, may prove environmentally and economically ruinous.

Lack of evidence of similar projects in other parts of the world

Examples of similar projects attempted in other countries of the world are few and full details are not available. Mention has been made of an attempt by Israel to divert the waters of Jordan and Yarmuck rivers but it is not clear how far this politically sensitive issue has been resolved and at which stage this project stands. California in USA appears to be the only successful state to have transferred surplus water from the hilly north to the fertile plains of south California over a distance of 720 km.

Another project, referred to as the 'Peace Pipeline' project, involves the transfer of water from Turkey to Arabia over a distance of 3000 km. Whether Israel and Iraq, which would be seriously affected by such a diversion, would accept such a project remains to be seen. Political implications of such projects are of such serious magnitude that it is doubtful whe-

ther they will ever become real propositions. We have the Sutlej-Yamuna link canal, 306 km long on which over Rs 850 crores have already been spent and is languishing since 1980. The well-advertised link canal remains the most expensive and useless ditch ever built. Nearer home, there is the Telugu-Ganga project languishing for years. The canal passes through arid tracts of Guntur and Nellore districts and we may be certain that not a drop of water will be allowed to reach Chennai.

Diversion of flood waters

It is no doubt true that many of the rivers in the north of India are frequently affected by floods and discharge copious amounts of water during the monsoon months of June to September. However, no single dam or a series of dams can be expected to store this water and bring the flow under control. Also, in the case of existing major dams, instances are known where they have been held responsible for causing floods rather than controlling them! It will not be possible to control floods where the magnitude of the river water flow is of the order of 5 to 16 m above the danger level.

Apathy against construction of big dams all over the world

Big dams received a big push from politicians and bureaucracy pouring enormous amounts of borrowed money in the early years of independence. There has however been hardly any attempt at questioning the extent of damage caused or in evaluating whether the promises of food, water and prosperity for all have actually been realized. The diversion of rivers and construction of a long system of canals in a densely populated country like India will involve displacement of people on a colossal scale and the people affected are never likely to agree with such measures. All over the world, community reaction is to prevent construction of large dams. Preserving rivers in free-flow condition is considered ecologically necessary and the construction of large dams is now legally prohibited in Sweden and also in parts of USA. The technical challenges to be faced in redrawing the geography of the country are many and full of dangerous consequences and the mad rush in pursuit of such a chimera will prove

disastrous. The cost of the project is so stupendous that any water made available will cost so much that governments will have to be forever subsidizing farmers. What long-term impact this massive borrowing will have on the economy is difficult to foresee.

Alternate scheme for rainwater harvesting and conservation of water resources

Instead of indulging in such fanciful schemes with disastrous consequences, it would be more sensible to encourage the traditional practice of conserving rainwater where it falls. This is the only measure which will mitigate the ill-effects of droughts over a major part of India. Before indulging in implementation of projects costing enormous amounts of money it would be far safer and prudent to examine whether we have used available resources wisely and well. It is only after such an exercise that we can go seeking for water from neighbouring states.

In major dams that have been constructed, loss by evaporation is nearly 30%. Are we constructing these structures at enormous cost only to allow nearly half of the water to evaporate? In the open system of channels we have adopted for transporting water over long distances, loss through seepage and evaporation is enormous and the alternative of conveying through pipes has apparently not been considered. There are no regulatory structures and fields are literally flooded with water. There is no control over the crops to be grown in times of water deficiency. Farmers are allowed to grow more and more of sugarcane and go even for a third crop of rice! Can this be termed wise utilization of water?

Reduce water consumption by the affluent in cities

The actual requirement of water for drinking and keeping alive per person is just two litres a day. This is what a large majority of poor people are subsisting on today. We are told that in USA per capita consumption per person is 1300 gallons (~ 5910 l) per day. Is it our intention to imitate their lifestyle and waste this amount of water? If this is the aim, the entire water resources of the country will not be able to meet such extravagant demands.

India is not badly off when compared to many other parts of the world with respect to water availability. The average amount of rainfall received over the plains of India is 117 cm as against the global average of only 70 cm. This annual precipitation amounts to as much as 370 million hectare metres of water which is adequate for our requirement. It is for us to manage these resources wisely and well. Government organizations from the Prime Minister downward are for linking of rivers, while rainwater harvesting, a much saner and practical proposition, has not even entered their minds. A task force has been formed to examine the modalities of this proposal for interlinking of rivers. Similar agency has not been thought of for promoting rainwater harvesting which is more urgent.

Rainwater harvesting to be attempted on a massive scale

The most obvious way to preserve as much rain water as possible is to impound it where it falls. This is what our ancestors tried to do and succeeded, as is evidenced by the numerous bunds, tanks and ducts that are characteristic features of the south Indian landscape. Instead of promoting such efforts and keeping the structures in good condition we have allowed them to fall into disuse. These structures once full with water have just disappeared, becoming victims of rapacious estate builders and cities have been allowed to expand without limit creating pockets of enormous water consumption. Extensive deforestation of hill slopes has allowed rain water to run-off and disappear in no time. Major dams are no doubt constructed at enormous expense but these structures can at best store only one year's requirement and no more and benefit only a small section of the population living in river valleys. The water requirement of the large sections of the population living in regions away from major rivers has never been taken into consideration – they remain totally neglected and literally left high and dry with no agency caring to allay their distress.

Rainwater harvesting is not something new – it has been practiced from times immemorial. Some NGOs have made a beginning in reviving this technique and several success stories are reported especially in Rajasthan, Maharashtra and Madhya Pradesh, which should convince

government agencies of the efficacy of this technique in solving water problems of the country as a whole. What is now needed is a big push to the programme as vigorously espoused by the Centre of Science and Environment to take a great forward step in this direction and make it a mass movement. Serious attention has to be given to the construction of farm ponds. A pond measuring 2000 sq ft with 1 m depth can provide water for a hectare.

If we are to fight drought on a large scale, the construction of small water storage tanks at site is inevitable. The tanks of south India elicited the following admirable tribute from the famous British statesman Edmund Burke, which speaks of the efficacy and importance of preserving the structures as 'guardians and protectors and nourishers of mankind'.

'These are the monuments of real kings, who were the fathers of their people, testators to the posterity which they embraced as their own. These are the grand sculptures built by ambition; but by the ambition of an insatiable benevolence, which not content with reigning in the dispensation of happiness during the contracted time of human life had strained with all the reachings and gropings of a vivacious mind to extend the dominion of their bounty beyond the limits of Nature and perpetuate themselves through generations and generations, the guardians and protectors and nourishers of mankind.'

A recent French study shows that the indigenous technology developed earlier and perpetuated in Vijayanagar times (1336–1565) is one of such an extraordinary character that it has taken into consideration changes in topography, soil system and run-off flow pattern in a changing climatic environment. It has not only stored rainwater but effectively prevented soil erosion.

Prevent wastage of water

Judicious usage of water is a practice which our farmers have failed to adopt, especially in the fields supplied with canal water. Although water is literally allowed to flood their fields, the yields are less compared to farmers who use the resource judiciously. Many modern gadgets are now available like sprinklers and drip irrigation pipes which can further

economize the use of water. Engineers do admit that an enormous amount of canal water is being wasted. Vast amounts have been spent on major irrigation projects, no part of which (not even the maintenance cost) is borne by the beneficiary, the farmer. Irrigation as a consequence, has remained a major sick industry in all states. Droughts are caused not through lack of rains but due to the adoption of wrong agricultural policies and reckless usage of water.

Providing excess water for irrigation knowing full well that it leads to lower yields, subsidizing water and giving free electricity, encouraging farmers to grow water-guzzling crops like sugarcane and paddy – these are measures over which governments have exercised no control and created man-made drought. Subsidy promotes wasteful use of water. Excessive use of water has in fact degraded the black soils of Maharashtra and Karnataka.

Forced changes in food habits

Agricultural policies adopted by the Central and State Governments have further contributed to the aggravation of drought conditions. Although ragi and jowar are the staple food grains of the Karnataka State, in the war years, their cultivation was neglected and imported wheat was forced on the people. Now the demand for wheat has shifted to North India and large quantities are imported at enormous cost. The food habits of a large section of the people have been disturbed and there is now a reluctance on the part of farmers to grow ragi and jowar although the soils of Karnataka are ideally suited for growing these grains needing minimum requirement of water. Governments have exercised no control. Governments are in favour of sugarcane lobby.

If the farmers of Mandya cut down on sugarcane cultivation and if Tamil Nadu can give up their claim for growing a third crop of paddy at the time of unprecedented drought like the current year, there would be no dearth of water in the Cauvery Basin.

Large-scale utilization of groundwater in deltas

Large-scale utilization of groundwater especially in the delta region is particularly feasible. If the farmers are reluctant, the State should take the initiative to develop a system of borewells and supply water for irrigation. According to

an earlier UNDP estimate, the groundwater potential of the Cauvery delta is considerable, more than the storage capacity of the Krishnarajasagara reservoir. Is it wise to allow this quantity of water to remain unutilized? Would it not be a better investment than bringing water from Godavari or Ganga?

In areas away from river valleys, groundwater is the only source of drinking water. Over-exploitation of this precious resource has gone to such an extent that the water table has steadily declined from 10 m to 100 m. Wells have been drilled to 300 m depth and beyond to strike water. Despite these clear danger signals, our politicians and bureaucratic administrators have continued to support the drilling of more and more borewells. If this process continues, all the easily available groundwater near the surface will be exhausted, making it dry as dust.

If further deterioration of groundwater level has to be prevented, sinking of fresh wells to deeper levels should be strictly prohibited. All existing borewells should be licensed and allowed to utilize only prescribed quantities of water. Sale of groundwater should be strictly prohibited. If these measures, which may appear drastic, are not undertaken immediately, there will be no drinking water in our villages and towns this summer.

Recharging groundwater reservoir

Nature has provided inter-connected reservoirs of vast extent underground. Skills have to be developed for arresting rainwater where it falls and allowing it to recharge these groundwater reservoirs. Afforestation of catchment areas, contour bunding, levelling of land, creation of farm ponds and checking dams across nallas, gully plugging are measures aimed at arresting the flow of water on the surface and directing it below ground. Presently no serious thought is being given to this important aspect and rainwater and, along with it, soil are rapidly getting washed away. Apart from this grave loss, through soil erosion, there is the greater risk of rapid siltation and significant reduction in the storage capacities of surface reservoirs.

Groundwater escaping into the sea

A certain amount of precipitated rainwater flows from the coastal region into the sea

through porous rocks and sediments, this component being designated as Submarine Ground Water Discharge (SGWD). As far as I am aware, no study has been made to estimate this discharge along the coastal belts of India especially along the east. Studies elsewhere (*Nature*, 1996, **380**, 612–614) have indicated that this flow could be as high as 40% of surface flow!

A water-hungry country like India cannot afford to lose this amount of water which could be made available for irrigation. The establishment of groundwater resource potential in the deltaic region is a more important subject for investigation than the linking up of rivers. Regional Research Institutes dealing with hydrology should take note of this subject and come forward with constructive suggestions.

Water not just a matter of engineering – it is a more complicated problem

Committees formed for water resource development, invariably dominated by civil engineers who favour large projects involving huge amounts of money, bulldoze all saner counsels. The Ministry of Water Resources appears to be only too eager to extend its full support for such projects which will add to their importance in trying to mediate between warring State Governments. The proposed scheme if implemented will surely exacerbate the situation. Although we are a democracy, the people are never consulted, their wishes are completely ignored and fate of the displaced people is nobody's business.

How many of these chief engineers who sit on these committees have read Anil Agarwal's book on *Indian Traditional Harvesting System* which has inspired many to become ardent crusaders of rainwater harvesting.

Resource mapping programme

More than 30 years ago, a scheme had been introduced by the Government of Karnataka of producing maps on village scale (cadastral maps available with the Revenue Survey Department), which are on a sufficiently large scale, easy to read and understand by laymen. In each map, the extent of cultivable land was shown in yellow colour and where irrigation had

been practised with the aid of groundwater, the position of the drilled as well as open wells was shown in red and the surrounding areas in green. Depth to water was also indicated and principal crops grown were listed. A cross-section of the well was included as an inset showing soil depth, weathered and hard rock and the probable depth at which water is likely to be struck. Seasonal fluctuation in water table was also shown. What is more important, an attempt was made to show the marginal land which could be developed into horticultural farms. The higher ground could be developed as a recharge area.

Maps could be further improved with information output by remote sensing agencies by marking ground contours at 5 m intervals which would facilitate erection of contour bunds and ditches. A further development could be the construction of a series of surface storage tanks in the recharge area for storing rainwater.

Mapping also envisaged preparation of an action plan together with an estimate of cost for desilting tank beds, erection of contour bunds and ditches, construction of storage tanks, costs of ground preparation for growing trees, drilling of borewells where feasible, etc. The map would thus give full information about existing conditions and what is possible. Details would be known by every villager. Work could go on year after year with active participation of the people including construction of green houses, cooperative marketing societies, preparation of food grains in consumable form rather than as raw seeds and all the other activities aimed at value-added productivity. The present practice is to allot lump-sum amounts for rural development without a clear picture of how it is going to be spent. Bulk of the money is spent on drilling borewells which in most cases will fail.

An officer of the Department of Geology or a research scholar in a university department could prepare nearly a dozen maps per year and in present day of laptop computers, information can be transferred and added as and when it becomes

available. Such a programme should be made to work on a war footing enlisting the services of undergraduate and graduate students undertaking a course in geology in our university colleges. Submission of a quota of maps could be made compulsory before the award of a degree.

What is to be done?

What we need in India is an effective plan to deal with drought and the inter-linking of rivers is no solution – it is a smoke-screen to delude the people. We have food in our godowns, we have work to get done and what is needed is a massive programme of productive work so that people can earn money and buy food. Such employment should be used to build productive assets – the best being a massive water conservation programme that will provide relief against future drought.

It is extremely important that people should be involved in all plans and phases of rural development. Schemes conceived in Delhi cannot be thrust on the people. Citizens have a choice and a voice and must not be treated simply as wage labourers.

If what is proposed is implemented, the enormous amounts of money spent on rural development will be usefully spent on the welfare of the farmers and they will be freed from the spectre of crop failures due to drought.

That drought this year, is clearly a government created one, is bad enough but what is appalling is the solution offered for its colossal failings by way of linking rivers, a scheme which is never going to be a reality. The progress of the Telugu–Ganga canal is an example.

All over the world, there is a perceptible trend to move away from gigantic projects of dubious utility and concentrate on smaller self-sustainable schemes with the community and the human being at the centre of the development process. More than 50 years after we have won our freedom, it is heart-rending to see abject poverty still stalking our rural as well as the urban workforce. It is imma-

terial and futile to discuss how many ‘hunger-deaths’ have occurred in Orissa or some other part of the country.

As Amartya Sen has observed recently in Delhi, a large number of our children and youth are so malnourished and deficient in a balanced diet requirement that many will perish due to disease and deprivation even before they reach their adulthood. Wholesome nutrition, minimum clothing and shelter, and elementary education still elude a large percentage of our population. If all these youngsters are gainfully engaged in the management of the life-giving water-harvesting already practised by our ancestors, we may still be able to convert our teeming millions into an asset from the present liability and pave the way for sustainable development.

It is rather strange and lackadaisical on the part of the government to take such vital decisions involving public expenditure and affecting the lives of large population without an intensive public debate. There appears to be undue haste in the matter that deserves detailed discussion, public hearings and debate on all aspects.

Can we expect better counsel to prevail on the government? Can it give greater attention to rainwater harvesting, which is practically feasible and beneficial all over the country and give up grandiose ideas of linking river waters of India?

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Editors' Note:

Historically, the idea for linking India's rivers to provide both navigation and irrigation facilities has been attributed to Sir Arthur Cotton who worked in India in the 19th Century. The current discussion on linking the major rivers may be a fitting tribute to Cotton whose 200th birth anniversary falls this year.