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Bore Wells Vs. Open Wells: Water Crisis and Sustainable Alternatives in Kerala

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Abstract

Recently bore wells have been identified as an alternative to the increasing water/groundwater scarcity in Kerala. But whether bore wells could serve the purpose of open wells becomes a matter of debate. In this context conflicting arguments arise among people on the question of inter-linkage between groundwater in open wells and bore wells. Geologists, engineers and scientists held opposing position regarding this problem making the issue much more complicated than answered. This paper attempts to discuss the opposing arguments over groundwater inter-linkage in open wells and bore wells in the context of decreasing ground water table and feeble regulations in Kerala. The paper also presents the contemporary relevance in the findings of a report submitted by Cyriac Kurian, Hydrologist of Kerala Water Authority. The report highlights how the constant use of water in the bore wells caused depletion in water level in open wells. Thus the objective of the paper is to unravel the sustainability of bore wells as an alternate strategy to open wells in Kerala.

Keywords: Bore well, Groundwater, Water conflict, Sustainability, Regulation, Water right

Introduction

In Kerala, ground water is the main source of drinking water and about ninety percentage of the rural population depends on ground water sources. Groundwater potential of Kerala differs from place to place due to its varied hydro-geological characteristics. Kerala's demand for ground water is mainly for household purposes, agriculture and industrial needs. Recently there has been a spurt in groundwater extraction during the last decade and the state shows a heavy imbalance in the availability of ground water over the past ten years. The unsustainable extraction of groundwater by the land owners pretense threat to groundwater storage. The installation of large number of open wells and bore wells with high power centrifugal pumps alter the natural balance of ground water recharge which results in ground water depletion. The increased demand of groundwater associated with the varying land use pattern results into unregulated exploitation of ground water in many parts of the state. The shift from food crops to highly water intensive cash crops like rubber, pepper and coffee cause increased extraction of groundwater. The non-agricultural use of land affected the groundwater recharge and aquifer potential.

The construction boom in Kerala severely affected the replenishable capacity of groundwater as it is one of the major ingredients in the construction of buildings. The individual houses, major and minor buildings and skyscrapers continue its dependency on the same aquifer results in its degradation.

Ground water abstraction structures like wells have increased to five million in Kerala in accordance with the apartment and housing boom. The number of open wells in the state is estimated roughly as one well for every eight to ten person, means well density of Kerala is highest in the world. Sand mining, brick industry and quarrying also caused groundwater depletion in Kerala. As groundwater is the major source of drinking water, the acute scarcity during summer resulted into the emergence of groundwater markets in Kerala. Individual rationality has often led to unsustainable extraction of the resource, blind competition and elevated groundwater price in the open market.

In this context a groundwater estimation was conducted by the Central Ground Water Board (CGWB) in association with State Ground Water Department and other central as well as state agencies. A Ground Water Estimation Committee (GEC) was constituted in 2004 and 2009[i] and the estimation was conducted based on the Ground Water Estimation Methodology - 1997. In 2004 all the 151 blocks of Kerala were considered for ground water computation and classified into over-exploited, critical and semi-critical[ii] category based on the availability of ground water. In this assessment fifty blocks have moved into the unsafe category; among the fifty, five blocks were classified as over-exploited, fifteen as critical and thirty as semi-critical. Athiyannoor in Thiruvananthapuram tops the list of blocks with over exploited resources, followed by Kozhikode, Kasargod, Chittur and Kodungalloor. As per the new estimation in 2009, Chittur block belongs to over-exploited category and the three blocks namely Kasaragod, Malampuzha and Kodungallor belongs to critical category. The total groundwater utilisation is highest in Palakkad district (327.75 MCM) and lowest in Wayanad district (71.93 MCM) (CGWB, 2011). Based on the 2004 computation the five over-exploited blocks were declared as 'notified area' as per the Ground Water (Control and Regulation Act, 2002)[iii]. In notified areas like Kozhikode, permission from groundwater authority is necessary to dig a bore well. But unauthorised constructions are going on in notified areas. Allegations are few from these areas due to the ignorance of people about groundwater laws.

The spurt of bore wells

It is clear that in Kerala groundwater is subjected to over exploitation and mismanagement. Regarding groundwater extraction structures open wells dominated the scene for years. Recently there is a trend towards bore well construction as open well construction entails larger cost and time. Though bore well gives hard water which is not good for household purposes people opt for it because of the impracticalities involved in open well construction. Moreover a bore well can be constructed within six hours even in the limited space available within the compound of one's own land. It does not take much space like that of open wells; even a person having less than 3 cents of land can afford to dig it. Adding to these advantages of bore well there exists innumerable constraints to dig an open well. For instance, in housing colonies, where houses are closely situated digging of open wells is almost impossible. The difficulties range from health reasons (presence of coliphom bacteria in open well water as a result of nearby septic tanks) to strict conditions stipulated in Kerala Building Rules. As per the building rules which are applicable to Panchayats as well, the permission of the secretary is necessary for digging open wells (Section 18, 103-109)[iv]. Though these conditions do not follows strictly people refrain from digging open wells due to these stringent conditions. Since water supply from the water authority cannot be relied upon, many people become compelled to dig bore wells. Very few people refrain from constructing bore well as it gives hard water.

When bore wells are rampant in use for so many years people become aware about the adverse effects it creates. Issues reports from places where bore wells causes water depletion in nearby open wells. Though legal actions related to conflict over the use of bore wells found less among people, in many places all over Kerala local people attempt to prevent bore well construction. As such the bore well

construction agencies dig it during night time to escape from the public protest. Bore wells become an alternative source to drinking water and emerging as a model in Kerala. Though legal actions found less, certain issues in Kerala points to the harm made by bore wells on other water users. One of such instance is the Plachimada issue[v], in Palakkad district where the uncontrolled water withdrawal through bore wells resulted into water depletion in nearby open wells. Soon after three years the Coca-cola company in Plachimada, was forced to close due to public protest which got national as well as international attention. The Plachimada struggle acted as an eye opener to the people in Kerala. In this circumstance digging bore wells in Kerala becomes problematic.

In spite of the problems mount with bore well use, many people opt for it in rural/urban areas because of cost-efficiency. Also there are supporting arguments among engineers and few geologists for bore wells. They argue that water extraction through bore wells do not affect the water availability in open wells as both take water from different aquifers. As per geological science water from both open well and bore well is considered as groundwater. Groundwater is stored in the aquifers seen below earth's surface. There are mainly three types of aquifers. They are, (a) confined aquifers, (b) unconfined aquifers and (c) semi-confined aquifers. Confined aquifers situate in between the hard rocks seen deep under the earth and unconfined aquifers situate on the surface terrain of the earth. It is also to be noted that the confined aquifers and unconfined aquifers are separated by the natural constructions under earth. Out of these aquifers, open wells draw water from unconfined aquifers; bore wells and tube wells draw water from confined aquifers. Since open wells draw water from the unconfined aquifers that affect the water level in the nearby open wells, and not that in the bore wells. Similarly, bore well draws water from the confined aquifers that affect the water level in the nearby bore wells and not that in the open wells. This entails the conclusion that drawing water from the bore well, irrespective of the quantity of water drawn, does not affect the water level in the open wells. This argument is based on the hypothesis that all bore wells drawn water from confined aquifers alone.[vi] This position is affirmed by most of the engineers in Kerala. On the strength of this argument bore wells are indiscriminately digging in Kerala for household, agricultural and industrial purposes as well as for constructing single/multi-storied buildings. Dependence on the same bore wells and aquifer continue for long time and gallons of water is drawn in many parts of the state.

The other argument is based on the theory that the water in the open wells and that in the bore wells are inter-related. According to this argument, bore wells drawn water not only from confined aquifers but also from unconfined aquifers. The advocates of this theory assert that no bore well in Kerala draws water from confined aquifers. Majority of the bore wells in Kerala draw water from unconfined and semi-confined aquifers, i.e. water is drawn from the fractured hard rock aquifers, which are not unconfined aquifers. Because fractures in the deep hard rocks are connected to the fractures in the weathered rocks on the surface earth. Open wells are situated on the weathered rocks of the earth; it means that fractures on the hard rocks and weathered rocks are inter-linked. Water accumulates in the bore well from above through these fractures. This leads to the conclusion that the aquifers found in the fractured hard rocks are really unconfined aquifers. While constructing a bore well these fractures can be seen when the hard rocks are drilled. Bore wells draw water from the fractures with water availability[vii]. Every fracture need not necessarily have water availability in them; hence water cannot be expected from every bore well. After construction bore wells extract water from the fractures, thus the bore well seems to be filled with water. This process continues when the pumping is going on from the bore well. As a result, water from the above open wells reach the bore wells and the water level in the open wells go down.

It is clear that water availability in the bore wells are directly related to water availability in the fractures which are connected with open wells[viii]. However water availability in the fractures is dependant in nature. Certain fractures provide water in plenty and from such bore wells approximately one lakh litres of water can be pumped in one hour. If large fractures are available then water can be drawn incessantly for months. Such bore wells are called Artesian wells. If plenty of water is available in the fractures seen in the hard rocks, then it does not need to draw water from the fractured weathered rocks. Per se that kind bore wells do not affect the water availability in open wells. The above detailed argument concludes that there are various types of aquifers and fractures exist below the surface earth, we cannot conclusively or authentically say that all bore wells adversely affect/do not affect the water level in the open wells. This largely depends on the nature of aquifers as well as the structure and size of the fractures in the region where the bore well is drilled.

The above mentioned fact is evident in the report submitted in 1995 by Sri. Cyriac Kurien, Hydrologist of Kerala Water Authority. The report entitled 'Interim Report on Monitoring Cheekode Project–Phase I' describes the inter-relation between bore wells and open wells. The report based on the experiments conducted as part of the Cheekode project implementation, unfortunately did not get proper attention from the authorities. The project, also known as 'Danida Project' was started by Kerala Water Authority in 1990s with the help of Government of Denmark, for water supply to Kundotty–Cheekode region in Malappuram district. Water supply was started by constructing bore wells, instead of depending on other water resources. But in no time it was noticed that water level in the open wells was dropped and people in the locality started allegations against the project. In order to get a true picture of the situation, a scientific study was conducted by the leading officials themselves. Finally the report was prepared based on field measurements conducted on the bore wells constructed for the project.

While conducting the field tests, no recharge of ground water was noticed by the team members. Moreover, due to summer most of the rivers had gone dry and the local people started resistance against to the project. Owing to public protest, pumping in certain bore wells were stopped for 22 days and pumping in certain other bore wells were reduced to half. It was in these circumstances that the study on the consequences of bore well pumping on open well was conducted. The objective of the study was to identify whether there was any variation in the water level in open wells within the radius of 300 meters from the bore wells. It was noticed that bore wells are tapping water from the fractured zone as in normal case. Open wells were situated on the weather zone and bore wells drew water from the fractured zone. Following were the observations made consequent on the study and pumping tests:

1. When pumping started water moved downwards from weathered zone to fractured zone through fractures.
2. As a result, when pumping proceeds, water level in the open wells decreases.
3. The greater the distance between bore wells and open wells, the lesser the water depletion in open wells.
4. The decrease in water level in the open wells is proportional to the pumping in bore wells.
5. When pumping was suspended for 22 days, water level in the open wells was raised by 75% in almost 66% of the wells. That is, in scientific terms, 75% of draw down was noticed.
6. It was noticed that even after the pumping was stopped for 2-3 days water level in the open wells continued to decrease. This was due to the fact that water was flowing down to the fractured zone, where the bore wells situated.
7. In 34% of open wells water level lowered even though no pumping was done in the bore wells under study. Because these 34% of open wells were situated down below those pumping bore wells.

8. During the period of study there was little water flow in the nearby stream. During summer this stream may become dry and if water pumping continues at this rate from the bore wells during drought, the open wells would become dry.

Consequent to the study following proposals were made to raise the water level in the open wells based on the above observations:

1. To have water in the open wells they have to be deepened at least 5 meter more (to their present depth).
2. Water from other sources to provide drinking water to the affected people may be worked out.
3. Constructing a number of barrages in the streams will definitely help recharge of the weathered zone in which these open wells are located.

The investigation team submitted the report to Government with the above mentioned findings and suggestions. But no attention was given to the landmark findings on the negative impact of bore wells. Still studies related to the interaction of water in the open well and that in the bore well is found less in Kerala.

In Kerala tube wells are also in rampant use for extracting groundwater. There are differences between bore wells and tube wells though common people use the terms alternatively. The major difference is that tube wells drawn water from confined aquifers; its construction and structure is also different from that of bore wells. In Kerala tube wells are drilled mainly in the sedimentary terrain found in the region from Kollam to Thirur and in the Vizhinjam–Poovar region. (The so called tube wells found in other regions apart from the Kollam-Thirur and Vizhinjam–Poovar region are actually bore wells). When this region is drilled for tube wells a sandy strata can be noticed among the different stratas of earth. Holes are made in that part of the pipe for tube well; then water filtering through the sand reaches the tube well. The bottom of the pipe is sealed as such water will be stored in the pipe. In coastal areas, water is available within 6 meters of depth. Such tube wells constructing in coastal areas are called filter points, or shallow tube wells. Since shallow tube wells draw water from unconfined aquifers, this might adversely affect the water table in the open wells. Tube wells like open wells will get easily recharged and do not cause water depletion in open wells as it takes water from confined aquifers.

Legal nuances of the problem

Groundwater anywhere in India is subject to over exploitation as the laws related to groundwater are not state-of-the-art and efficient. The law to depend for groundwater related conflicts is the age old British law, i.e. the Indian Easement Act, 1882. As per Indian Easement Act 1882 the landowner owns the water below his land and he has exclusive right to extract and use the ground water. An easement is a property right that gives its holder a non-possessory interest in another person's land. It allows the easement holder to use the property that he or she does not own or possess. But it does not allow the easement holder to occupy the land or exclude others from the land unless they interfere with the easement holder's use. In contrast, the possessor of the land may continue to use the easement and may exclude everyone except the easement holder from the land. Right of way, right to light, right to standing or flowing water are examples of Easement Right. According to Indian Easement Act 1882 the land for the beneficial enjoyment of which the right exists is called the dominant heritage, and the owner or occupier thereof the dominant owner; the land on which the liability is imposed is called the servient heritage, and the owner or occupier thereof the servient owner. An easement may be permanent, or for a term of years or limited period, or subject to periodical interruption. Apart from the Easement provisions the Act also mentions about the rights of the owner i.e., the dominant owner. As per article 7 (a) and (b) the owner enjoys exclusive right over an immovable property, to enjoy and

dispose of the same and all products thereof and accessions thereto and to enjoy without disturbance by another the natural advantages arising from its situation.

Article 7 also grants exclusive rights to the owner over groundwater. Article 7 (g) assures the right of every owner of land to collect and dispose within his own limits of all water under the land and on its surface which does not pass in a defined channel. As per the above provisions the right to groundwater is not an easement right, because in the exercise of this right no servient heritage is required. Instead groundwater is identified as a 'natural advantage' that is coexistent with the land. A dominant heritage is absent here as in the case of easement right, since groundwater is a right attached to land which should be available to the owner without any disturbance by another. As such groundwater is not an easement right and it cannot be separated from land rights for others use. Clauses 7 (f) to (j) clearly illustrates the position of surface water and the rights of every land owner over it with a view to ensure access to water along with property rights. But it excludes the provisions related to ground water.

There is no clear definition for groundwater and its ownership rights in the Easement Act. Thus it is argued that treating groundwater as an easement would give rise to legal remedies. Courts also noted that there are differences in matters related to surface and groundwater and they cannot be governed by same law. In India the common law principles emerged in Britain continue to be followed in groundwater laws. The British legacy based on individual property rights still follows in India and many other commonwealth nations. Thus the right to groundwater as an inalienable part of the right to land, is supported by customary and statutory laws in India[ix] (Vani, 2009: 435-470). Statutory and customary laws in India treat groundwater as a dependant entity which cannot control directly. As per the provisions, the ownership rights of the land owner over available natural resources is inter-twined with his rights over land.

Statutory and customary laws on groundwater

For centuries, the common law tradition was followed in many nations like India, United States, Canada, Australia, etc. As such courts seldom initiated a move towards separating the land rights and water rights. When it flooded with groundwater misappropriation cases, it relied on public trust doctrine[x] as well as the fundamental right to water rather than attempting to separate land and water rights. For instance the Supreme Court in Kesoram Industries/State of Bengal Case ruled that, "deep underground water belongs to the state in the sense that the doctrine of Public Trust extends there too. Holder of a land may have only a right to user and cannot take any action or do any harm as a result where the rights of others are affected". In certain other cases the exclusive right of the land owner was further emphasised in many judicial verdicts and courts tried to regulate the groundwater extraction through statutory laws. Copping with that the central government circulated a model bill among the states and they enacted conformity legislations. A series of acts were implemented throughout the nation with a view to regulate the groundwater use. The Kerala Ground Water (Control and Regulation) Act 2002 is an initiative in that direction aims to regulate the groundwater use.

Kerala enacted the legislation with few other states as per the directives of central government and CGWB. As per this act, the entire power to control ground water use is vested in the Ground Water Authority. Though the Authority is created in Kerala it has not been functioning effectively in preventing ground water exploitation. It is also found that exercising direct control over groundwater extraction is difficult. Landowners use invisible structures like narrow centrifugal pumps beneath the ground to extract groundwater. Big farmers usually have costly groundwater extracting mechanism to irrigate their farmhouse, weakens the aquifer potential and affects the neighboring wells. The situation gets worsened during summer when possibility for water markets also rise; it is observed that all over Kerala

farmers sell groundwater at the time of acute water scarcity and attains huge profit. Thus controlling groundwater extraction through millions of wells and tubes becomes problematic.

Recently there is a legislative trend in many countries that attempt to change the nature of groundwater from a private property to a public resource. This change enables the state to adopt the position of guardian or trustee of groundwater resources, to grant rights and introduce measures to prevent aquifer depletion, groundwater pollution and water resources planning. Many nations continued the trend following Israel who enacted legislation towards this direction in 1959 itself. The development of bringing private waters into public domain continues in Spain, Italy, France, Morocco, Greece, etc. In India no attempt has been made in this direction; the States enacted the groundwater regulation acts without any declaration of state ownership over the resources. The Central Model Bill as well as the State Acts deals with groundwater users without referring to the ownership rights of groundwater. All the acts except the Maharashtra act aim at regulating the use of wells through licensing including the Kerala Act. It doesn't attempts to separate land and water rights. The Maharashtra Water Resources Regulatory Authority (MWRRA)[xi] Act, 2005 is an initiative to separate land and water rights by converting the groundwater right to a usurfructuary right. However it fails to redefine property rights over groundwater (Ibid).

In customary practices as well landowners generally regard wells as part of their private property denying others the right to restrict his extraction of groundwater. Instances can be sited from all over India where access to water for the landless is denied everyday. Those who possess marginal amount of land also subject to water poverty. Unequal access to land simultaneously gives rise to wastage of water among the affluent and inadequate availability of safe drinking water to the poor community. The inequality in land rights gives large land owners a disproportionately larger access to groundwater which opens the possibility of water trade in the emerging water market. Similarly, land reforms in Kerala also played a crucial role in determining the rights over groundwater. It by and large failed to abolish the intermediaries and to implement effective land ceiling, caused inequitable access to land and thereby water resources. Moreover in Kerala the absence of statutory laws paved way to the emergence of legal pluralism in groundwater governance. The pluralistic nature of ground water rights is highly visible in Kerala society. The social laws and customs governed the major chunk of ground water management in Kerala for long years which ensured the equitable distribution of water to a certain extent. Situation changed in accordance with the change in land use pattern and other external factors. Increasing water scarcity, water pollution, water conflicts as well as the increasing water scarcity and demand are the immediate consequences of such changes. This situation invites concrete statutory laws regulating groundwater extraction in Kerala.

Conclusion

In this context, where unregulated extraction of groundwater through bore wells are increasing in the absence stringent laws, the sustainability of bore wells as an alternative to open wells becomes a critical matter for debate. Thus scientific studies pertaining to the relation between bore wells and open wells seems to be the need of the hour. Social scientists intervened where scientific community failed to respond to the increasing conflicts over bore wells. Social scientists can make the issue live on discussion, can conduct field studies among people but are unable to find geological facts. Lack of scientific studies on this matter lead to ground water exploitation in Kerala. Scientific truth should unravel with a view to regulate the booming construction of bore wells in Kerala and thereby to conserve the precious groundwater resources. Scientific reports can also alleviate policy discussion and legislative processes regarding groundwater control and conservation. Different from Kerala neighboring states like Tamil Nadu and Andhra Pradesh, used to depend on bore wells for years are now reluctant to

dig more bore wells due to salt water intrusion[xii]. When the neighboring states desist from digging bore wells, people in Kerala are attracted towards bore wells. Instead of depending on bore wells as an alternative, the rain water harvesting methods and structures in Kerala should improve to increase the ground water table as rainwater availability in Kerala is high. People in Kerala are not hesitant to spend lakhs of rupees to deepen the open wells or to dig bore wells, show a prejudice towards constructing rain water harvesting structures. Orientation towards rain water harvesting modeling the *Pani Panchayath* system in the state of Rajasthan can be worked out under the auspices of local self-governments. The report of the Gadgil committee to preserve the Western Ghats is also worth mentioning in this context.

However improving rain water harvesting methods alone does not serve the purpose of increasing ground water table in Kerala. Because there is a great apprehension regarding the simultaneous growth of bore wells and rain water harvesting structures. It is a fact that ground water table can increase through the continuous use of rain water harvesting methods. But if bore wells continue their water extraction the water stored through rain water harvesting may go down directly to the bore wells through the fractures seen in the weathered rocks and hard rocks. If this phenomenon persist those who built the rain water harvesting structures may not be the beneficiaries of its result. Groundwater becomes the monopoly of those who use bore wells than people who struggle for conserving the valuable resource. Thus Geologists and engineers in Kerala should intervene in this matter instead of being grouped over the matter and publish their findings in order to ensure conservation of ground water.

Regarding equal access to groundwater newer land reforms attempt to bring effective redistribution of land is one of the available remedy in Kerala. Because proper decentralisation of land power ensures decentralization of groundwater rights. In this perspective land struggle in Kerala can also incorporate the issue of ground water accessibility in the larger availability of land. Attempts to separate land and water rights through state level statutory laws can be experimented in Kerala following the Maharashtra model. Identifying groundwater rights as a separate entity necessitates rigorous land reform measures in Kerala. Moreover, the land policy of the state should be sound enough to ensure the efficient management of land and its natural resources. The policy should adopt an integrated approach in dealing with land and natural resources. The Kerala Land Use Board can act in this direction which already established its policies with an eye to protect the natural resources. As the nature of land use determines the quality and quantity of groundwater availability obligatory guidelines should be issued with regard to land appropriation. At the national level, Easement Law can be amended in a manner which separates land and water rights or it can incorporate groundwater as an Easement right in its provisions. Parliament can model the new trend emerging worldwide for separating land and water rights as a remedy to groundwater exploitation.

End Notes

[i] As per the new estimation in 2009 Chittur block belongs to over-exploited category and the three blocks namely Kasaragod, Malampuzha and Kodungallor belongs to critical category.

[ii] Over-exploited Areas, where stage of ground water development is more than 100% both pre-monsoon and post-monsoon ground water level shows a significant decline. Critical Areas, where stage of ground water development is more than 90% but less than 100% and either pre-monsoon or post-monsoon or both shows a significant long term decline in ground water level. And areas where ground water development is more than 100% but neither pre-monsoon nor post-monsoon ground water level show a significant long term decline. Semi-critical Areas, for cautious ground water development - areas where ground water resource assessment shows a stage of ground water development more than 70%

but less than 90% and either pre-monsoon or post-monsoon ground water level shows significant long term decline.

iii The Kerala Ground Water (Control and Regulation Act) 2002, intend to control groundwater extraction in the State. The Ground Water Authority in Kerala is created on the basis of this Act. The provisions in the act also deals with the construction and usage of open wells and bore wells, mechanisms of control and penalty.

[iv] If permission is obtained, the conditions in section 104 related to construction of buildings have to be adhered for constructing an open well. For example, the well should be 1.5m distant from the boundaries of the neighbors property, it can built either attached to the existing building, or inside the building, or set apart from the building. There should not be any leach pit, sock pit, refuse pit, earth closet or septic tank within a radius of 7.5 metre from the open well. As per rule 105, the well should be protected with a wall of one metre height. The permit obtained adhering to the conditions have to be renewed every year after two years.

[v] The Plachimada issue is a popular agitation against ground water exploitation by Coca-cola Company in Palakkad district, Kerala. The agitation was successful enough to threaten the corporate strength as the company terminated its production in Kerala.

[vi] Reply to author's article in Mathrubhumi weekly by K.V. Mohanan, 'Jalanirapp Kurayunnathil Kuzhal Kinarukal Alla Villain', July 14-20-2013.

[vii] While digging a bore well, the region up to hard rock is sealed with a casing pipe except on the hard rock. Sealing is not necessary in the hard rock because that would prevent the flow of water from the fractures to the bore well. Normally, the life of a bore well is twenty years. By this time clay may deposit in the fractures and water flow gets blocked. The clay deposits have to be cleared for further availability of water.

[viii] The argument detailed is based on a discussion, the author had with Sri. Cyriac Kurien, Hydrologist, Kerala Water Authority.

[ix] Land Acts, such as Madras Land Encroachments Act of 1905, the Maharashtra Land Revenue Code 1966, the Madhya Pradesh Land revenue Code 1959 and the Orissa Prevention of Land Encroachment Act, 1972 refer to all water resources over which the rights of the state and private persons are defined, except groundwater.

[x] The public trust doctrine is the principle that certain resources are preserved for public use, and that the government is required to maintain them for the public's reasonable use.

[xi] The Maharashtra Act attempts to achieve some measure of equity by providing that every landholder in the command area of a river basin is entitled to water, and that in times of scarcity, each landholder shall, as far as possible, be given a quota adequate to irrigate at least one acre of land, Section 12(6) (a) and (b), and that the Water Resources Authority shall ensure that the principle of 'tail to head' irrigation is implemented by the River Bain Agency , Section 12 (7).

[xii] Salt water intrusion occurs in bore wells situate close to sea. Through the fractures under earth salt water from the sea intrudes into bore well and the water becomes salty. Due to the phenomenon, many bore wells in Tamil Nadu and Andhra Pradesh have become useless.

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