WHY NOT SMALL DAMS ATTAIN ASSURED SUCCESS: EXPERIENCES OF GUJARAT, INDIA

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1. INTRODUCTION

India being a country with rich history and traditions, water harvesting and water conservation are the domains with opulent inheritance. Indian history has also been associated with deeply rooted social values focusing on the principle that the water is a common resource sharable amongst the stakeholders without any monetary consideration and without any right of encroaching the riparian rights of the populations inhabited in the downstream of any watercourse. Gujarat is a state of India with extreme water scarcity and hence the Government of Gujarat tried to resurrect the traditional systems of water harvesting and got constructed over 0.15 million small dams across rivulets and rivers in last fifteen years. The experience of small dams is thus very rich and the issues with them have been studied and presented in this paper. Some case studies are discussed in brief as reference only but general diagnosis made therefrom is very important.

2. MOVEMENT FOR SMALL DAMS ON LARGE SCALE IN GUJARAT

2.1 BACKGROUND FOR MOVEMENT

Gujarat is divided in to four regions - South Gujarat which also includes Central Gujarat, North Gujarat, Saurashtra and Kachchh as shown in Fig. 1. South Gujarat is water rich and is also having clayey soil, North Gujarat is water stressed and having alluvial soil, Saurashtra is facing shortage of water and is having a mix of black cotton soil with gravels whereas Kachchh is having sandy soil and a large area of desert. Coastal length of Gujarat is the highest in India which is 1664 kilometers.

Except South and Central Gujarat there has been scanty water in the entire state. If compared the per capita water availability, it is much less than India’s average and from 2001 onwards there is a significant reduction therein which has caused concern. This is because of population growth, development of industries and climate change. Quality of groundwater has also been an issue in Gujarat. Electrical conductivity, Chloride, Nitrate and Fluoride are the parameters on which the quality of groundwater is monitored regularly. When quantity and quality of groundwater were found declining and deteriorating, some interventions were felt necessary. Gujarat started from a very bad scenario and worked among many challenges. Overall scenario of Gujarat i.e. surface water and groundwater is shown in Table-1.

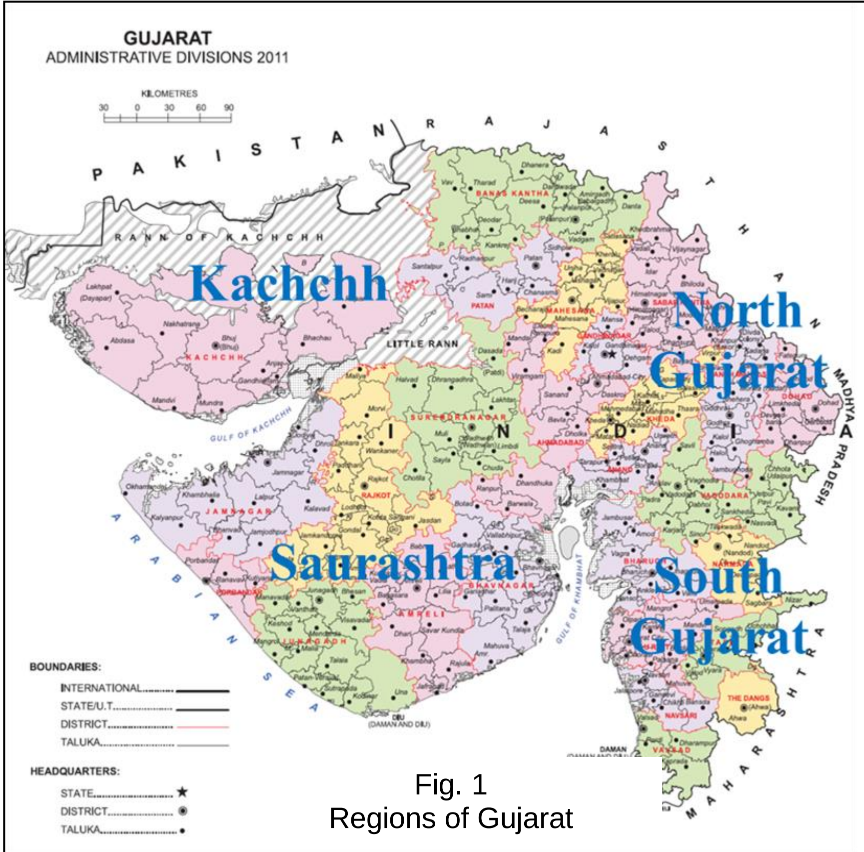

Fig. 1
Regions of Gujarat

Table 1
Surface water scenario of Gujarat

REGION	**AREA IN % OF GUJARAT**	**SURFACE WATER Mm^3**	**GROUND WATER Mm^3**	**TOTAL WATER Mm^3**	**PER CAPITA AVAILABILITY m^3 PER ANNUM**
South and Central Gujarat	25	31750	3950	35700 (71 %)	1695 *(1880)
Saurashtra	33	3600	4300	7900 (16 %)	487 *(540)
North Gujarat	20	2100	3300	5400 (11 %)	309 *(343)
Kachchh	22	650	450	1100 (2 %)	658 *(730)
Total	**100**	**38100**	**12000**	**50100 (100 %)**	**893 *(990)**

* Indicates figures based on 2001

Fig. 2 shows that in Saurashtra and Kachchh there are many small river basins coupled with low yields due to scanty rainfall. In South and Central Gujarat, a few but big river basins are there. Table 2 shows that rainfall and number of river basins are inversely proportionate and therefore in Saurashtra and Kachchh, rivers are many but small and non-perennial. Medium and major dams are feasible on a few rivers because of such a discrepant situation. In total 85 major and medium dams have been constructed as per availability of sites and no more sites are technically feasible for such dams.

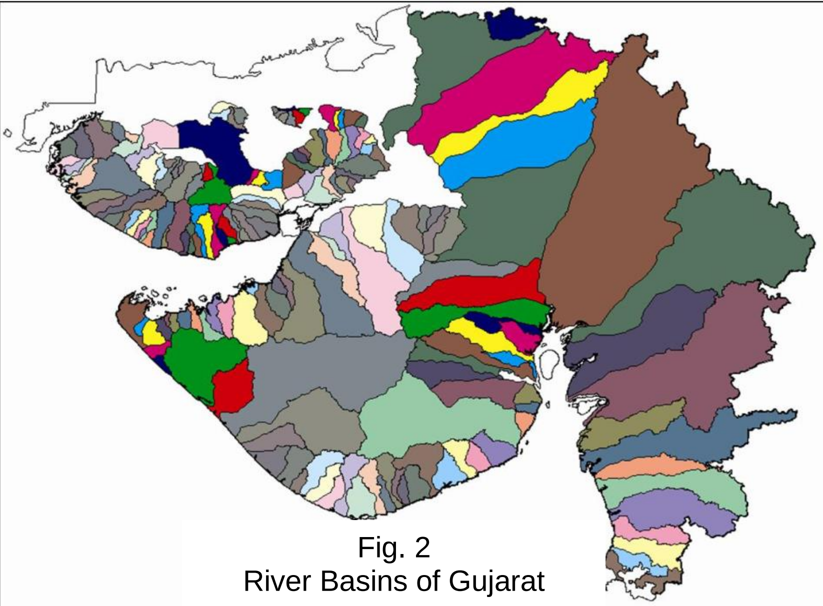

Fig. 2
River Basins of Gujarat

Table 2
Rainfall Distribution of Gujarat

Name of Region	**Annual Rainfall in mm**	**No. of River Basins**
North, Central and South Gujarat	800 to 2000	17
Saurashtra	400 to 800	71
Kachchh	Less than 400	97

Technical feasibility became a major challenge for the construction of major and medium dams in Gujarat and hence small dams were the only way-out for water conservation. Small dams in large number in distributed manner were constructed from the year 2000 onwards. Acute water shortage and lack of feasibility of major and medium dams became the main reasons for the said approach. Government of Gujarat targeted a large area under rainfed agriculture to be covered under protective irrigation. The movement aimed at constructing small dams at many locations in a short period of about 10 years so that protective irrigation could be provided to a large area which was not in the command of any medium or major irrigation project. By doing so, minimum one crop i.e. Kharif – monsoon crop, could be reliably taken by the farmers in such areas.

2.2 RESULTS OF MOVEMENT

In total more than 1,50,000 small dams were constructed in a short period of about 10 years with the concept of distributed water resource management and immediate benefits remained very encouraging. Summary of a study carried out by the Indian Institute of Management, Ahmedabad underlines some important achievements of the movement as following.

- Average 7 wells in surrounding could be recharged.
- Ground Water Table came up between 3 and 9 meters.
- Soil fertility was improved.
- Quality of drinking water was improved.
- Electricity consumption for drawl of water from ground was reduced.
- Overall prosperity increased in villages.
- The government had to make less expenditure compared to contract approach.
- Instant results were found.
- Change in attitude of people as well as government officers was witnessed.
- Where checkdams (small dams) are constructed, land prices have gone up by 20 %.
- Crop Yield has been improved by 35 %.
- Approximately 10 hectors of land is benefited by each checkdam (small dam).
- 8 to 10 families could get sustenance.
- Control on salinity could be effectively done.

Situation of groundwater could be significantly improved has been recorded by the Government. The basis of study was the number of overexploited and dark blocks varying from 1997 to 2013. Table 3 clealry shws that the demand-supply imbalance got gradually improved in Gujarat. Obviously this was because the surface water storage was improved significantly by constrcuting many small dams which finally resulted in to reduction in demand of groundwater. Over-exploited blocks and critical blcoks decreased with passage of time, saline blaocks also got decreased and in contrast the safe blocks got increased. This is the net results of the sensibly planned recharge interventions. The intense efforts from 2001 to 2005 led to this effect in a short period which was really a big change. Controlling worsoning groundwater scenario is really a huge challenge and that too, when the area to be addressed is vast. The encouraging results gave a boost to the concept of small dams and they were further constructed.

Table 3
Enhancement in Groundwater Scenario

YEAR	Over Exploited Blocks (G.W. Development Above 100%)	Critical Blocks (G.W. Development Between 90% and 100%)	Semi-Critical Blocks (G.W. Development Between 70% and 90%)	Safe Blocks (G.W. Development Below 70%)	Saline Blocks (G.W. T.D.S above 2500 ppm)
1997	35	13	45	122	9
2002	30	13	62	105	14
2007	26	8	51	125	14
2009	27	6	50	127	14
2011	24	5	13	172	10
2013	22	6	9	177	10

3. RECENTLY SURFACED ISSUES WITH SMALL DAMS

3.1 STRUCTURAL VULNERABILITY

Small Dams are not designed as per the standards for major and medium dams due to large number and economic viability. Return period for flood discharge calculations is generally taken as 1 in 25 years which makes it more susceptible to failure because of underestimation of floods while designing.

Fig. 3
Bodywall failure – Village - Kundawa, Taluka – Dhanpur, District - Panchmahal

In small dams, foundations can rarely be taken up to sound rock and have to be founded on alluvial strata. Moreover, scour depth is also not considered with required flood discharge and soil characteristics of foundation and therefore in some cases foundation failure owing to ineffective or short cut-off results in to structural failure. Sometime sufficient energy dissipation is not ensured because of low return period taken in to account for computation of flood. Sometime the bed and banks are firm in semi-mountainous regions but the velocity is very high because of steep gradient which causes high pressure on the bodywall and it fails.

A small dam was constructed at village – Kundawada, Taluka – Dhanpur, Distrcit – Panchmahal in Central Gujarat across a small rivulet 10 meter wide. Height of the dam was 2.0 meter considering the depth of the rivulet and the storage capacity was 0.04 Million Cubic Meter. The cost of the construction was Rs. 0.18 million. Fig. 3 shows the image of this small dam. It was constructed in year 2002. It was across a rivulet in semi-mountainous region and hence the topography was rocky and the bed and banks were firm. In the monsoon of year 2012 the bodywall of the dam collapsed because of transverse flexure and shear due to gushing flow. Because of rocky bed, the bodywall was directly founded on it and therefore the flexure and shear subjected the bodywall to slide and sink. In semi-mountainous regions, the flow is generally powerful due to steep gradient which induces high pressure on the bodywall. The vulnerability in such regions is of different type as compared to the dams in alluvial strata across mildly sloping streams.

Fig. 4
Bodywall failure – Village - Bhatia, Taluka – Talod, District - Sabarkantha

A small dam was constructed near village – Bhatia, Taluka – Talod, District Sabarkantha on River Khari in the year 2004. Its length was 95 meter and height was 2.0 meter. Its cost of construction was Rs. 2.1 million. It was constructed in the form of a concrete box filled with sand to provide necessary dead weight to act as a gravity structure without adequate cut off depth. The river bed was sandy for quite a significant depth. The design was carried out as a weir on permeable foundation. In 2005 there was a devastating flood in this river. As the cut-off was not provided, water flow undermined the foundation and the soil beneath the bodywall got scoured and hence the entire bodywall failed in shear and bending due to its own weight as shown in Fig. 4. Another small dam was constructed near village – Gadhi, Taluka – Prantij, District Sabarkantha on the same river in the year 2004. Its length was 45 meter and height was 2.0 meter. Its cost of construction was Rs. 1.53 million. It was also constructed with same design philosophy. In 2005 it was also destroyed in the same manner as shown in Fig. 5. Its remnants were also dragged away by the flow of water. However, the abutments were intact. In both the cases, foundation failure due to lack of sufficient cut-off was the reason of structural failure. Had the design been carried out for scientifically worked out sour depth, the cut-off would have made the dams much costlier and hence to make them economically viable some technical requirements were ignored which resulted in to failure of several dams like these. Mostly such dams were constructed in a series on a river.

Fig. 5
Bodywall failure – Village - Gadhi, Taluka – Prantij, District - Sabarkantha

3.2 VULNERABILITY OF RIVER BANKS

When a small dam is constructed across a small water course with poor banks and the bodywall of the dam is strong enough, the water either outflanks the banks or erode one of the banks during flood.

A small dam was constructed at village – Saliav, Taluka – Kalol, Distrcit – Mahisagar in Central Gujarat across a small river 75 meter wide. Height of the dam was 2.2 meter considering the depth of the river and the storage capacity was 3 Million Cubic Meter. The cost of the construction was Rs. 5.68 million. It was constructed in 2012-13. The next monsoon resulted a significant flood and the left bank of the rivulet was eroded and the water made its waterway from the left of the dam as shown in Fig. 6. When the height of the bank is low, waterway is not sufficient for large floods in the post construction scenario, and banks are not sufficiently firm and the dam is strong, such situations happen.

Fig. 6
Bank erosion – Village - Saliav, Taluka – Kalol, District - Mahisagar

3.3 SILTATION

Channels in alluvial strata are generally flat and carry heavy silt. Small dams across such channels are silted up in a very short period and hence their storage capacity is reduced drastically. In order to maintain the storage capacity of such structures, periodical desilting is required which is not economical.

Fig. 5
Siltation in reservoir Village – Sureli, Taluka – Kalol, District - Mahisagar

In rivers in alluvial strata, because of the flat gradient at bottom, desilting is required for a significant length and hence is costly. Tendency of river to attain regime also causes siltation when the flow is checked. Siltation depends on the parameters like geograohy and soil property of catchment area, cross-sectional area of river, longitudinal slope, velocity, silt charge, etc. but has no relationship with the size of the obstruction and hence whether the dam is big or small, quantum of silt settles in the same quantity. Therefore, reduction of storage in percentage is much more with the small dams. Removal of silt leads to very high maintenance cost in small dams constructed on rivulets or rivers passing through alluvial soils.

A small dam was constructed near village – Sureli, Taluka – Kalol, Distrcit – Mahisagar in Central Gujarat on a small river name by Goma having 100 meter width. Height of the dam was 2.0 meter and the storage capacity was 2.50 Million Cubic Meter. It was constructed in 2012-13 with a cost of Rs. 14.4 Million. It was found that its storage capacity was reduced by 80% because of siltation in only 3 years. Fig. 5 is the image of this small dame from its downstream and it suggests that the silt mound on the reservoir side is taller than even the height of the dam at somewhere upstream.

Fig. 6
Siltation in reservoir Village – Kalol, Taluka – Kalol, District - Mahisagar

A small dam was constructed near village – Kalol, Taluka – Kalol, District – Mahisagar in Central Gujarat on the same river. Height of the dam was 2.0 meter and the storage capacity was 2.75 Million Cubic Meter. It was constructed in 2012-13 with a cost of Rs. 21.8 Million. It was found that its storage capacity was reduced by 82% because of siltation in only 3 years. Fig. 6 is the image of this small dame from its side which clearly suggests that water is there in the stilling basin which the dam received a few days before and the reservoir is almost completely silted up and the silt is also wet. The dam is strong enough to resist the soil pressure with saturated soil on one side with the other side empty.

If the dam was not strong to take this much force, it would have failed due to the force of soil pressure that was exerted due to siltation.

4. CONCLUSION

Generally, the small dams are constructed on the sites which are not suitable for large dams. Their benefits are viewed in a specific perspective like recharge, protective irrigation, avoidance of land acquisition, short gestation period, economy, etc. But at the same time some issues are also associated with them which are due to ignoring some crucial technical requirements to make them economically viable. Some issues are because of the scale and independent of the technical parameters. For example, quantum of siltation is irrespective of the size of obstruction but that reduces significantly the storage of a small dam and is a scale related issue. All the issues related to the small dams are required to be paid proper heed at. By doing so, the vulnerability of them would be possible to be ascertained *a priori* and that is how it would be feasible to either make the small dams viable against the challenges paused by the site situations or to avoid problematic sites so that public funds could be saved. The factor of chance remaining in the design of the small dams is also necessary to be appreciated and controlled for their reliable success level. If some lessons discussed here are learnt with a positive mindset, appropriate site and size selection would be done to attain the real benefits of the small dams. While the sizes and financial resources for such dams remain small, the technological issues and aspects of hydrological and siltation remain at par with the large dams. Hence, the planning of small dams must proceed with appropriate safeguards without which their benefits will be short-lived giving rise to wastage of financial resources.