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Water Policy Research

HIGHLIGHT

Mapping the Hydrological Processes in a Community-reconfigured River Basin

Some Conceptual Issues and Results from a Simple Dry Run

The debate around the hydrological impacts of decentralized water harvesting at the river basin level has been raging for quite some time without any signs of an emerging consensus. While critics have doubted the net positive impact of such interventions, farmers as well as policy makers seem to have ignored the critics, based largely on evidence from individual farmers and/or village-level impact studies.

This highlight presents some early results from an attempt to quantify the hydrological impact of AKRSP's water harvesting work in the Meghal river basin. In the process, we discuss new ways of combining data from multiple sources to study the impact of decentralized water harvesting at the river basin scale. Faced with absence of good quality data from formal sources, we make a case for using the vibrant and well-developed observant hydrology to supplement the increasingly accessible public domain data and some primary data collected through relatively simple techniques using local NGOs and students.

Sunderrajan Krishnan and Shilp Verma

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Mapping the Hydrological Processes in a Community-reconfigured River Basin

Some conceptual issues and results from a simple dry run[1]

Research highlight based on Verma and Krishnan (2012)[2]

Arguments and counter-arguments

The Saurashtra region of Gujarat has a unique hydrologic history. Being semi-arid, the region is prone to droughts. The geology, mainly composed of basaltic rocks, is unable to retain much ground water andsustain the agricultural economy during drought years. Even with many small to medium sized public irrigation systems, most allegedly constructed above capacity (Kumar et al. 2008), Saurashtra enjoys near-zero inter-year surface storage. A three year drought spell in late 1980s resulted in massive public unrest. The situation was so grave that trains had to be used for transporting drinking water. There was a serious threat of mass migration from the region and collapse of the agrarian economy.

The droughts triggered a community response in which various organizations, NGOs, religious groups, philanthropists and media came together to start a mass movement for water conservation. Initially, the major activity that the mass movement advocated was that of recharging dug wells during monsoon. With time, and as the movement spread, various modes of decentralized water harvesting and augmentation of artificial recharge come to the fore. Towards the mid and late 1990s, the focus of the movement shifted towards the construction of check dams. Several thousands of these check dams across Saurashtra have transformed the hydrology of river basins. It has been argued that these check dams have contributed significantly towards sustained agricultural growth and towards reviving the groundwater levels in the region (Shah et al. 2009; Jain 2012).

However, the precise nature and extent of the hydrological impacts of check dams has been actively debated without any signs of arriving at a consensus. Broadly, the debate may be characterized as between water resource engineers and hydrologists (*skeptics*) on one hand and practitioners and promoters (*supporters*) of mass-based distributed water conservation on the other.

- At the broadest level, it is a debate about water rights. There are questions on whether one can re-allocate surface run-off that has already been *committed* to medium and large public reservoirs. The argument in favor of distributed storages is that the water stored in large reservoirs available to only a few people in the command area. Therefore, equity dictates that distributed storages be preferred even if they result in adverse impacts on centralized storages downstream.
- Skeptics have argued that the total evaporation from several distributed storages would be greater than from a single, equivalent storage since the latter would have lower exposed surface area. The supporters retort that while this might be true, acentralized storage would only recharge groundwater in a limited area. Distributed storages, on the other hand, results in greater and more accessible groundwater recharge over a larger part of the basin.
- Skeptics have also doubted the extent to which decentralized groundwater recharge can contribute to agrarian prosperity. It has been argued that during the monsoon season, the basaltic aquifers of Saurashtra get fully recharged very quickly, within a few spells of rain. On offer is very little groundwater storage after which any additional recharge is not possible. The supporters argue that the little available recharge is enough to provide invaluable, life-saving irrigation during dry spells. Further, by storing some of the surface run-off at the time when aquifers are saturated (monsoon), check dams allow for slow and delayed recharge after the monsoon, which would not have happened without the surface storage.
- Finally, skeptics have argued that most of the check dams built under the mass-movement are poorly located and inefficient for the purpose they are designed. They propose that if decentralized water

[1]This IWMI-Tata Highlight is based on research carried out by INREM Foundation and its partners with support from AKRSP (I). This is not externally peer-reviewed and the views expressed are of the authors alone and not of IWMI or its funding partners.

[2]This paper is available on request from p.reghu@cgiar.org

harvesting is to be promoted, it must be done based on *scientific principles*, after elaborate hydrological measurements and planning. The supporters however claim that localized aquifer knowledge and farmer-experience is widely used in the design and siting of check dams.

In view of these arguments, we revisit the critical concept of '*dependability*' used in water resources in the context of such reconfigured river basins. The definition of this concept, we believe, is central to the debate and can help in resolving the current state of disagreement and confusion.

Conceptual Issues

The Concept of Dependability

Water supply dependability is a criterion often employed for the design of water impounding structures. Originally, and still largely, used in the context of large water storages, the concept may also be applied (with suitable modifications) in the context of smaller structures.

In the context of a water storage, the dependability of a storage structure is often defined as *the proportion of unit time (generally years) when the structure is stored to its full capacity*. It is generally expressed as a percentage e.g. a storage structure might be expected to reach full storage in 4 out of every 5 years; in other words, it would be said to have 80 percent dependability. In the context of numerous, often cascading, smaller water impounding structures in a river basin, however, this particular definition might not be appropriate. For instance, many of these structures are so small that they get filled over for several times every season; except in extreme dry situations. Some drain out so quickly that they never ever fill to full storage, except for heavy storm situations.

Often, as it happens for these structures, the criteria for their usefulness – whether to impound water or to recharge – is not very clear during the design and also during construction. But the purpose of the structure becomes clear with the first few seasons. This behavior of the structure – how much it impounds (for how many times), or how much it recharges – becomes the expectation from the water impounding structure. *Dependability* also then needs to be defined according to this expectation.

However, it could become very difficult to have a separate definition of dependability for every storage structure. Also, one would also argue that it is not fair to define dependability post-construction. That should be a part of planning. It is therefore clear that the standard definition of dependability adopted in water resources planning does not suffice for small water harvesting structures. In this case, we need a more nuanced, localized definition that incorporates the purposes that the structure serves and is acceptable to the user-community.

Redefining Dependability

If we then go about redefining dependability, one could also be open to a more dynamic definition of water impounding structures. For example, a structure which was built to store water on the surface could now be seen as a percolation structure completely. This has happened with many communities who prefer recharging as a more equitable process of water distribution than direct pumping (one can contest this assumption though). If we then keep this concept too loose, then, one must also fix certain boundaries as to what parameters to keep constant. A way to define dependability could then be:

The *Dependability* of a water harvesting structure is defined as the proportion of unit time (generally years) when the structure satisfies the (dynamic) purpose for which it is perceived (by an observer).

Some important concepts are introduced here:

1. That of a purpose for the structure being different necessarily from that of only surface storage
2. Of this purpose being dynamic, relating to current and future requirements
3. The purpose depending upon the observer

Stretching the concept of dependability to customize it to the current requirement of changing basin hydrology is crucial. What we will observe then is that with changing development of the basin and changing purpose of structure, the dependability also is a dynamic concept.

Hydrologic Analysis of Meghal River Basin

The arguments and analysis such as above continue, but they have not yet been applied to the river basin scale in this region. The Meghal river basin has been witness to all the events discussed above for the rest of Saurashtra. In addition to the broader water harvesting movement, the extensive work of AKRSP (I) has been catalytic in Meghal over the past two decades. Since 2002, AKRSP (I) has embarked on an effort for river basin management of Meghal and has facilitated a river basin wide voluntary and informal group of village leaders. The government has also contributed via the 60:40 model of building check dams under the *Sardar Patel Sahbhagi Jalsanchay Yojana* (Sardar Patel Participatory Water Conservation Scheme). This led to the construction of more than one lakh water harvesting structures across Gujarat, including hundreds in the Meghalriver basin. Apart from check

dams, there is the temporary placement of cement bags filled with stones, mud and sand – *Boribandhs* – during the time of low stream flows directly on small streams and above existing check dams on the larger ones, for capturing late season flows. A few hundred such *Boribandhs* are placed every year, in a semi-orchestrated manner throughout the river basin, keeping into mind sufficiency of stream flows, making sure that the flow is not too much to topple the bags, while also trying to ensure minimum downstream impacts.

Basin Profile

Meghal is a small river in southern Saurashtra, Gujarat (80 km. long, 472 km^2 catchment). The river originates from Kanada hills in the Gir forest area and flows towards the Arabian Sea close to Chorwad town. The Meghal river basin lies entirely within Junagadh district of Gujarat. Its catchment area comprises of dry deciduous forest, agricultural plains and the coastal flats. The geology comprises mainly of Basaltic and Gaj limestone aquifers. A total of 55 villages lie within this river basin, most of them falling in Maliya *taluka* and a few in the neighboring *talukas* of Mendarda and Keshod. The average annual rainfall in the river basin is around 800 mm. The main monsoonal (*kharif*) crop is groundnut and the main winter (*rabi*) crop is wheat. Several *Kesar* Mango orchards are also found and summer-*Tal* (sesame) is a recent phenomenon. Around 30-40 years back, the Meghal River is recalled to have been perennial. However, after years of appropriation of water for agriculture and other uses, the river became seasonal (with water flowing for only 4-5 months) by the late-1980s.

There are four sub-basins within Meghal – the main Meghal river sub-basin, the Vrajmi sub-basin, the Kalindri sub-basin and Lathodariyo sub-basin. Lathodariyo first flows into Meghal, followed by Vrajmi and then Kalindri (Figure 1; Figure 9). There are three large reservoirs in the

Figure 1 Meghal basin map from Google Earth with location of large reservoirs

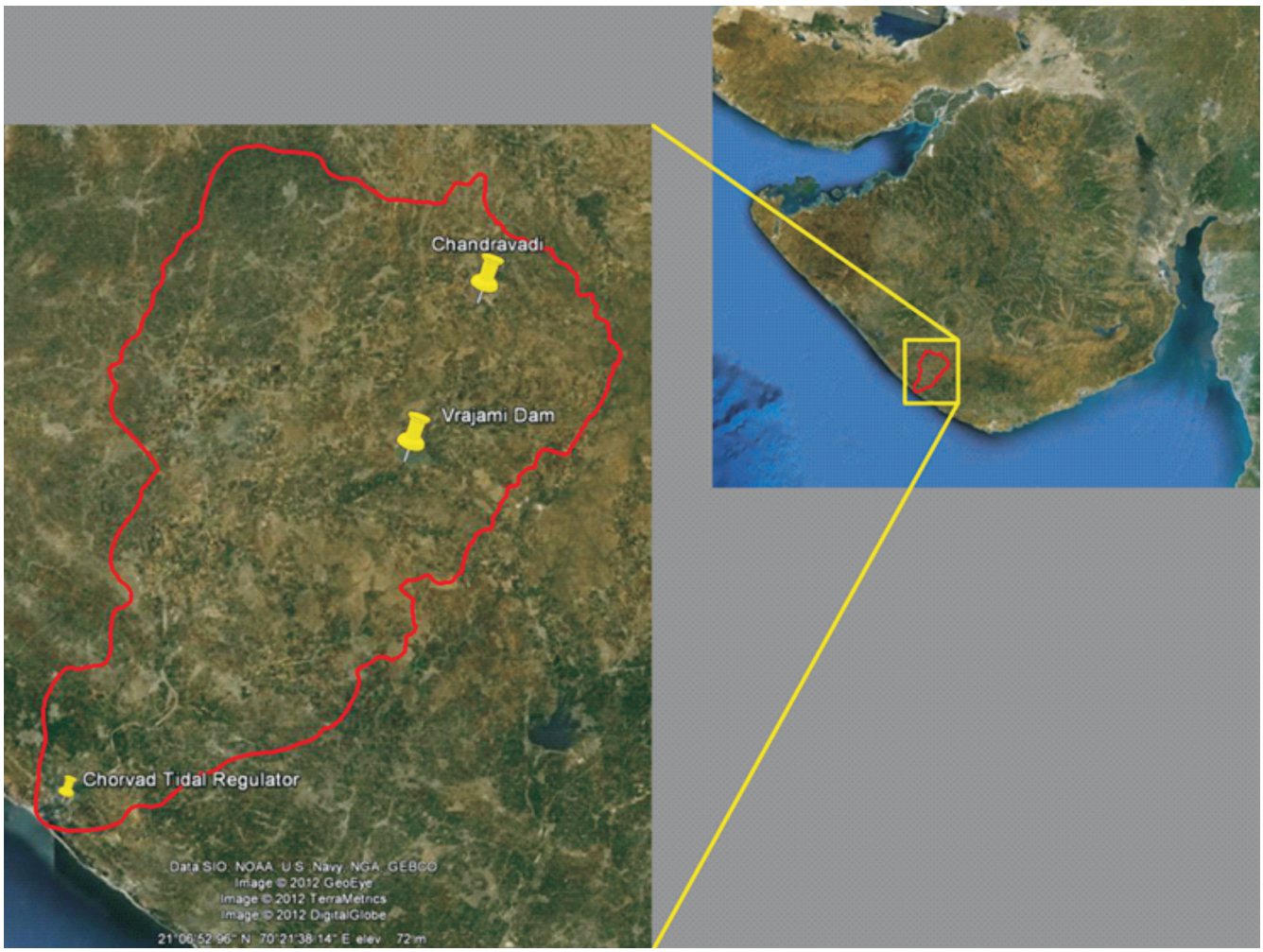
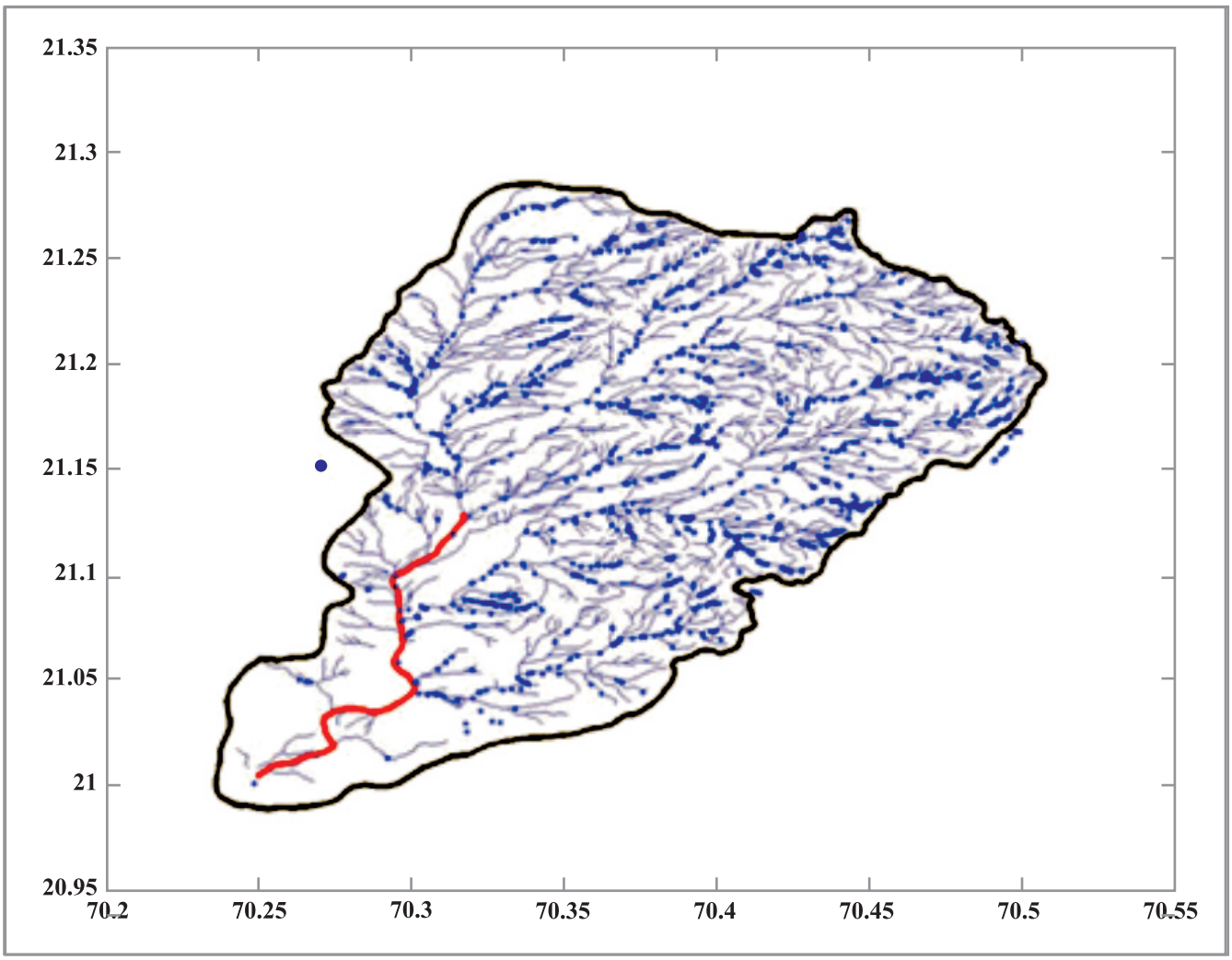


Figure 2 Stream Network and location of Check Dams



basin. The largest one on Vrajmi River is known as Chandravadi dam (near M. Vandervad village). This dam was constructed by the Salinity Ingress Prevention Cell (SIPC) of Gujarat government and is mainly intended as the recharge dam providing salinity protection to coastal areas. Overflow and leakages from this dam result in water flowing through the Vrajmi River for a longer duration than the other streams. Another medium sized dam is on the Meghal River. Further downstream, near Chorwad, is the tidal regulator constructed by the SIPC to prevent direct ingress of high tide water.

Hydrological Data for Meghal River Basin

Figure 2 shows the stream networks of Meghal river basin generated in Arc-GIS Spatial Analyst program using Topo-sheets. The main Meghal River has been marked in red color. The blue dots represent locations of dams (both large and small). A total of 850 dams have been plotted. The storage potential of these dams has been individually estimated in 2004 and 2009 via surveys conducted by AKRSP (I) and cross-checked and verified by our 2011 survey.

Tables 1 shows the summary of sub-basin wise storage potential according to the 2009 survey conducted by AKRSP (I). From the total of 916.63 MCFT of storage, around 630 MCFT is storage from the 2 medium sized reservoirs at Dudhaala, Chandrawadi and the tidal regulator at Chorwad. The rest is storage from check dams (so around 30 percent of the total storage). If we do not account for the Chorwad storage since it is not directly available to the river basin users as a whole, this proportion comes to around 40 percent of the total storage. The general perception among farmers is that the smaller check dams get filled several times in a season whereas the same is not true for the larger dams. If we apply this reasoning and bring in a average number of fills as 2.5 (a rough average, based on discussions with farmers

Table 1 Summary of sub-basin wise storage potential from survey conducted by AKRSP (I) in 2009

Stream / Sub-Basin	AKRSP(I)		GOVT./OTHER		TOTAL	
	No. of Structures	Capacity (MCFT)	No. of Structures	Capacity (MCFT)	No. of Structures	Capacity (MCFT)
Lathodariya	58	16.04	140	46.76	198	62.80
Meghal	125	57.08	217	307.01	342	364.09
Vrajami	86	31.47	361	426.72	447	458.19
Kalindri	37	11.02	122	20.20	159	31.22
Total	**306**	**115.61**	**840**	**800.69**	**1146**	**916.63**

but subject to modifications), we get a gross total storage as 1130 MCFT, out of which 63 percent is that from small check dams. Though this estimate is rough, it reflects the importance of small storages in influencing river basin hydrology.

Figure 3 shows daily rainfall data in mm recorded at Maliya from 1981 till 2002. The variation in annual rainfall is shown in Figure 4. The average annual rainfall is 800 mm and standard deviation is 414 mm; with a very high coefficient of variation of 0.5. Thus, inter-year variation in rainfall is very high. The minimum rainfall during this period is 71 mm only and maximum is 1635 mm. In fact, recently in 2010-11, a total of around 1800 mm was recorded during the season at Dudhaala dam. The average number of rainy days is 50, with minimum of 28 rainy days and maximum of 67 rainy days. If we look for the number of days that experienced a minimum of 10 mm rainfall, we find that on an average, there are only 14 such days (minimum of 2 and maximum of 27 such days over the 1981 – 2002 time period).

These statistics reveal that much of the mean annual rainfall falls in merely 10-20 days of the year with a 0.5 coefficient of variation, highlighting the need for basin-wide storages to capture this rainfall. In order to make an assessment of how much such storage potential can be created and where, we need to have fairly accurate information on stream-flows, recharge coefficients, evaporation rates for the entire basin.

Figure 5 shows the daily stream-flow data from Gadu station for the period 1981 till 2002. This data is subject to measurement errors and gaps. Data for two years was excluded from our analysis as the records were incomplete. Given the associated errors, we decided to carry out the analysis at an annual level in order to better understand the relationship between rainfall and runoff.

Figure 6 shows this relationship and a sigmoidal type function fitted so that there is an asymptote to a straight line at higher values. There is no significant runoff up to rainfall of around 400 mm after which, runoff increases

Figure 3 Daily Rainfall (mm), 1981-2002

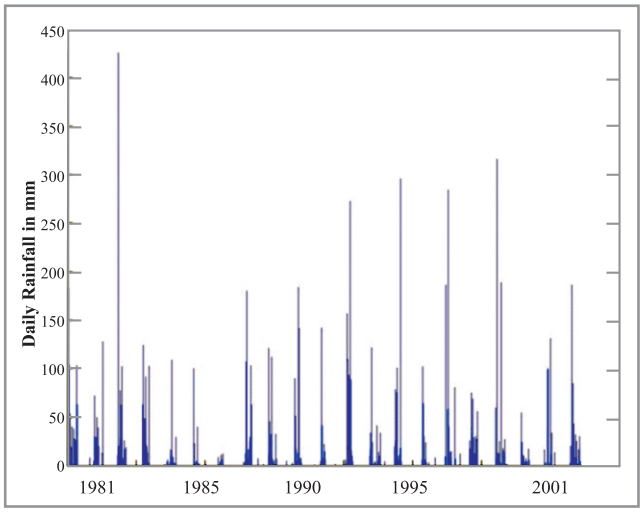


Figure 4 Annual Rainfall (mm), 1981-2002

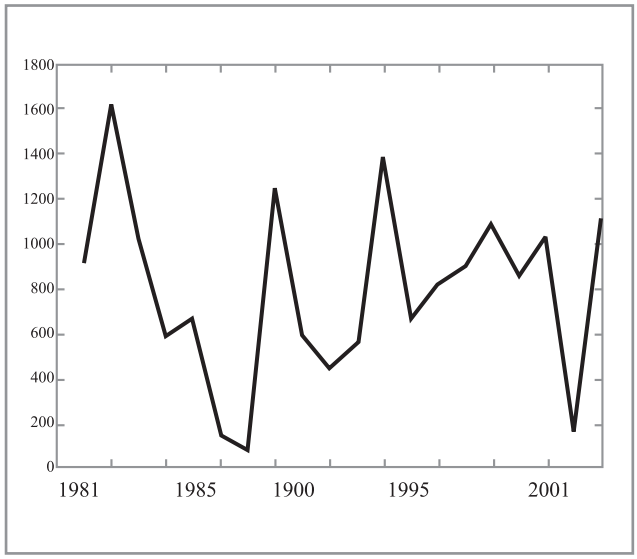


Figure 5 Stream flow data at Gadu (m3/s), 1981-2002

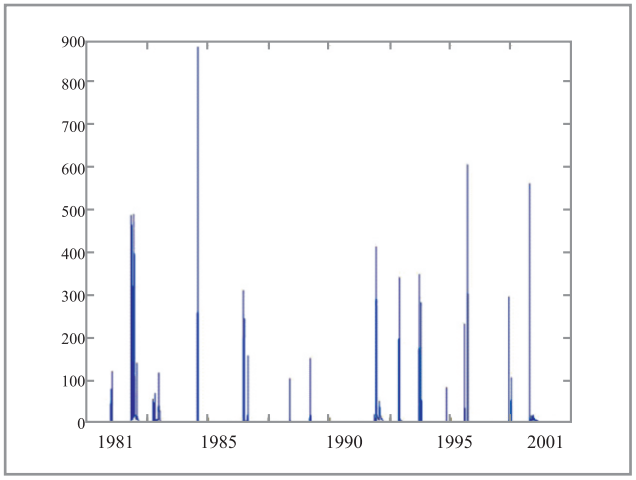
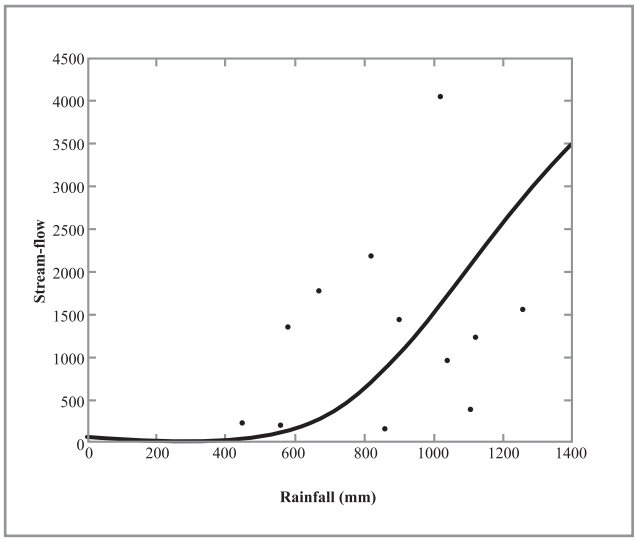


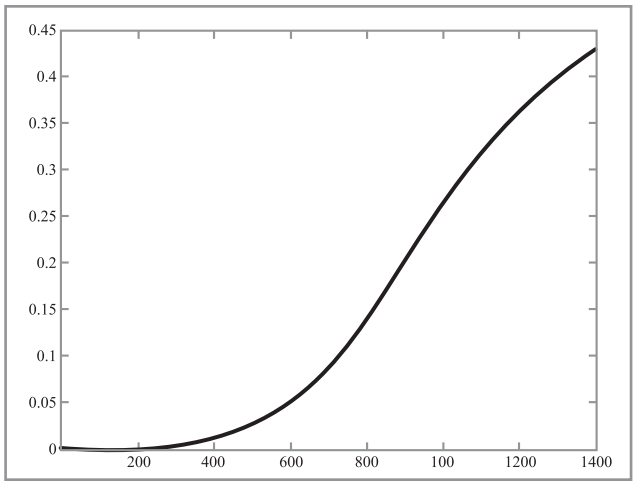
Figure 6 Relationship between annual rainfall and runoff in Meghal basin



indicating overland flow after complete saturation of the aquifers and soils. However, there are significant deviations of the observed data points from this fitted curve, therefore, this relationship can only be taken as an indicative first cut lumped understanding of the rainfall-runoff process in the Meghal river basin.

The description of the curve fitted is as follows. An asymptotic sigmoid type function, exponential at low values and straight line at higher values is fitted using the function of the form:

Figure 7 Runoff as a function of annual rainfall



$$y = a_0 + \frac{a_1 x + a_2}{1 + \exp(-a_3(x + a_4))}$$

Linking annual stream-flow y to annual rainfall x as modeled in Figure 7,we get:

$$y = 61 + \frac{4x - 2000}{1 + \exp(-0.005(x - 800))}$$

Further, we can compute the rainfall-runoff coefficient annually as a function of rainfall simply as:

$$\sigma = \frac{annual\ runoff}{annual\ rainfall}$$

As can be seen (Figure 7), this ratio σ is equal to 0 for rainfall less than 300 mm. Then it rises and is equal to around 0.15 for the mean annual rainfall level of 800 mm. It rises close to 0.40 for annual rainfall greater than 1200 mm. These initial assessments of basin-wide hydrology give us a broad picture of basin behavior. Further, if we wish to understand the behavior of storage, recharge into aquifers and upstream-downstream linkages, we need a basin level hydrological model.

MeghalBasinSim: A simple MATLAB simulation

Given the basic understanding of overall basin hydrology and processes in the river basin, we proceed to develop a conceptual model for the river basin. The field of hydrologic modeling is well developed since the 1960s when computer simulation was first used with models such as the Stanford Watershed Model. Since then, various groundwater models have been developed – the TOPMODEL by Bevan and Kirkby in late 1970s; the HEC-HMS models in 1970s by US Corps; DHSVM by the Washington group in 1990s; inHm, MIKE-SHE, WMS

(Watershed Modeling system) and many others. However, very rarely, if ever, have river basins such as Meghal been modeled. The challenges that Meghal and Meghal–like basins present are therefore rare and unique. On the one hand, there is extreme paucity of information from formal sources such as government based monitoring and university research while on the other; there is high availability of data and information from non-formal sources such as NGO monitoring, farmer experience and observations etc. Ethnographic research has brought out in many cases, a descriptive picture of such hydrology. Moreover, the availability of Google Earth images, including some historical digital imagery, has expanded the notion of spatial hydrologic data. How does one translate from a story to numbers, and bridge the information gap from informal observation to formal science? Hydrologic models, though having analytic and predictive capability, require extensive and intensive data which is not always easy to obtain. At the same time, qualitative and conceptual information available from non-formal sources cannot directly be used in the established, available models.

We have made an attempt to use spatial data from field surveys and satellite images; utilize NGO generated data; conduct specific surveys using local students; capture qualitative information based processes from group discussions; and move towards a type of basin hydrologic modeling which takes into account all these source and can be used in an analytic and predictive manner. The framework of model behavior has been that of HEC-HMS, but the additional aspect of aquifers and interactions have been added. Therefore one can think of our model as a run-down version of HEC-HMS – since it does not have multiple process options for recharge, evaporation, runoff etc. – but also an enhancement in terms of including aquifers. The aquifers here are not modeled explicitly as in, say, MODFLOW or in MIKE-SHE, and are simple bucket models which interact with the surface catchment and storages.

Figure 8 Conceptual picture of hydrological model

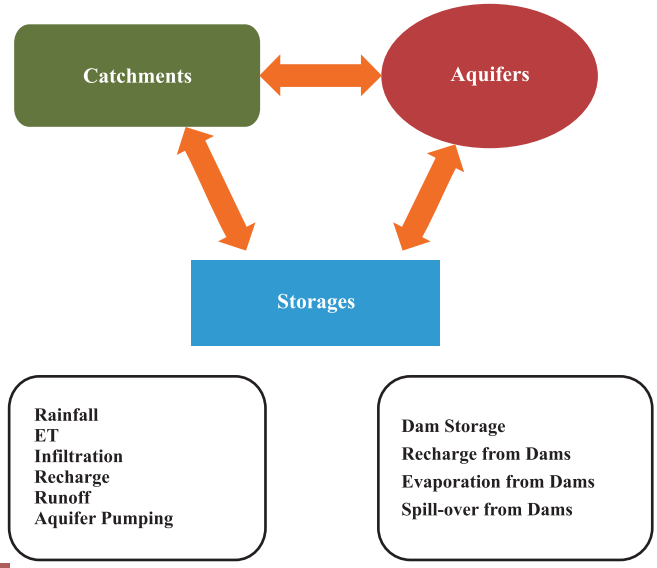


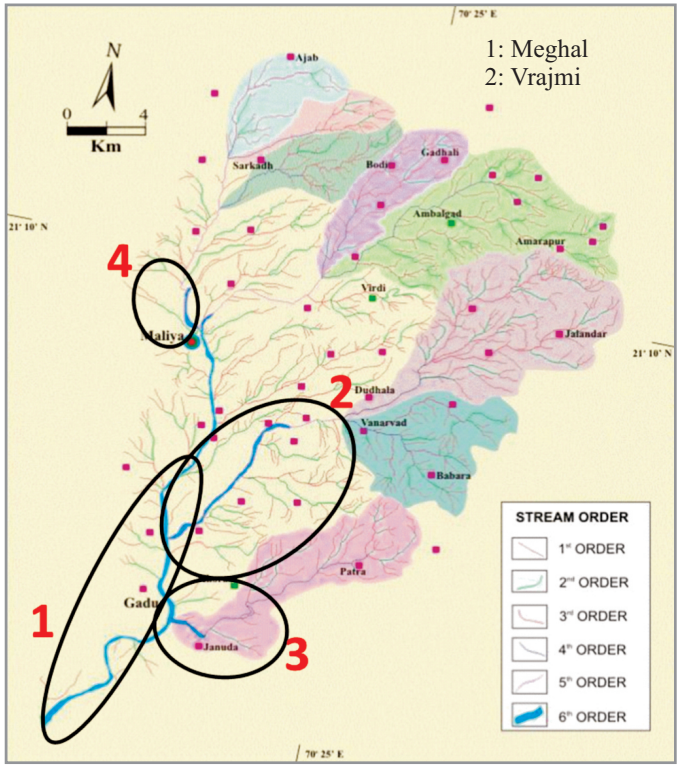
Figure 8 shows the conceptual structure of the hydrologic model we used, referred to as MeghalBasinSim. Three main entities are explicitly represented: catchments, aquifers and storages. Rainfall drives the entire process over catchments. This is distributed for every time step into ET loss, runoff and infiltration. The infiltration develops into recharge if the aquifer storage is less than aquifer capacity. The runoff flows into storages. Within each storage, for every time step, there is evaporation, infiltration into aquifer (again developing as recharge if aquifer storage is less than capacity) and when the storage is beyond capacity, it flows downstream into other storages. The aquifers have pumping specified for every time step; this pumping is subject to the availability of sufficient storage.

The model can be run with any desired time step, e.g. daily, weekly, monthly etc. In each case, data on process drivers such as rainfall and pumping need to be provided for every time step. Several parameters are needed to drive the model– catchments (area, coefficients for ET, runoff and infiltration); aquifers (area, depth and specific yield); and storages (storage capacity, coefficients for evaporation and infiltration). Connections need to be specified between all three entities – catchments, aquifers and storages. For example if there are 4 aquifers, 3 catchments and 10 storages, then a 4x4 matrix of aquifer-aquifer linkages, a 3x3 matrix of catchment-catchmentlinkages, a 10x10 matrix of storage-storage linkages, 3x4 matrix of catchment-aquifer linkages, 3x10 matrix of catchment-storage linkages, 10x10 matrix of storage-storage linkages and 10x4 matrix of storage-aquifer linkages has to be specified.

The model can then be used for:

1. Basin level simulation of stream flows with daily water balance of catchment, aquifers and storages
2. The behavior of check dam storages in terms of evaporation, infiltration and overflows
3. Recharge into aquifer and impact of pumping
4. Looking at optimal level of storages in the basin in terms of upstream-downstream tradeoffs
5. Predicting longer term behavior of the basin due to climatic changes and land use or water interventions

Figure 9 Four sub-basin model for Meghal River



The model described here (MeghalBasinSim) has been developed in the MATLAB simulation package. Developed as a single code with subroutines for recharge, runoff, etc., it is available for further development for academic and research purposes. The model can be modified for further refinement as including rainfall-runoff hydrographs, utilizing stage-discharge relationships, internal calibration with runoff data, etc.

MEGHALBASINSIM: A SIMPLE DRY RUN

We model the Meghal river basin with 4 sub-basins having 4 coincident aquifers and all internal storages lumped together as 4 storages (Figure 9).

The parameters used in the model are shown in Table 2. For storage, an evaporation coefficient of 0.02/day/volume and infiltration coefficient of 0.02/day/volume are used. The daily rainfall records (as shown in Figure 3) are used to drive this model. For the aquifer pumping, we use a seasonal requirement with no groundwater irrigation requirement for first 100 days of the model year (starting from June) assuming mostly rain-fed conditions and some supplemental irrigation which is met from ET requirements already accounted for, 60 mm depth for next 100 days and 100 mm depth for remaining season of the summer crop.

The simulations are run for a period of 20 years at a daily time step. In these 20 years, the basin is undergoing varied rainfall conditions, so we hope to capture long term behavior with this exercise. Figure 10 shows storage behavior of the Meghal sub-basin storages over the 20 year simulation period. As can be seen, there is a dip in storage during the lean rainfall years around late-1980s. What can also be seen here is that the storage gets completely depleted after around 100-150 days of the model years. In some years, the time period goes down to 50-60 days as well.

The behavior of the aquifer is different (Figure 11). There is a steady decline in aquifer storage over the years from 1981 onwards till the end of the decade. The aquifer is completely empty by the end of this continuous arid period. Then it recovers again to stabilize in the mid-1990s. The intra annual behavior is characterized by a peak during the monsoon when the aquifer almost fully saturates and then reaches the trough during the summer season.

Since in this dry run we have used similar specific yield and depth parameters, the behavior of aquifers in different sub-basins is similar. But, there are magnitude differences since the density of surface storage is different. This we compare in Table 3. As can be seen, the Vrajmi sub-basin (with a medium sized reservoir built exclusively for recharge and high density of check dams) has the highest proportion (43 percent) of total recharge contributed by artificial recharge. As compared with this, only 18 percent of the total recharge in Kalindri sub-basin is contributed by artificial recharge.

The component of artificial recharge for the Meghal basin as a whole is 32 percent of the total recharge of 71.49 MCM. From our model parameters, the maximum storage capacity of aquifers in the entire basin is 88.79 MCM. From the perspective of aquifer capacity, this means that there is further potential for artificial recharge in the basin. This needs to be confirmed by many other factors such as surface runoff availability, aquifer capacity during peak monsoon flows, land availability for recharge, etc.

Further refinements to this model can be many:

a) Taking into account aquifer parameters derived from ACWADAM's geological survey in the Meghal basin in 2001 (ACWADAM 2001);

b) Running the model at a finer scale, taking villages as catchments and small storages within each village catchment as one unit. The larger dams and main river storages can be taken separately;

c) Introducing a rainfall-runoff hydrograph;

d) Calibrating the simulated runoff with runoff records available;

Table 2 Parameters used in Meghal BasinSim dry run

Sub-basins	Area (Ha.)	Storages (MCM)	Aquifer depth (m)	Aquifer specific yield	ET coefficient	Runoff coefficient	Infiltration coefficient
Meghal	15,952	10.30	20	0.01	0.40	0.40	0.20
Vrajmi	14,197	12.90	20	0.01	0.40	0.40	0.20
Kalindri	5,998	0.88	20	0.01	0.40	0.40	0.20
Lathodariyo	8,251	1.77	20	0.01	0.40	0.40	0.20

e) Improving the storage model with stage-discharge relationship and an evaporation model;

f) Understanding the system of large and small dams in Vrajmi and their syncretic relationship;

g) Comparing Meghal and Vrajmi sub-basins for late season flows;

h) Bringing in temporary *boribandhs* on large and small streams to look at their impact on basin hydrology; and

i) Computing long-run storage dependability for specific storages and storage purposes.

Discussion

The unique hydrology of river basins such as Meghal has been discussed here. These semi-arid river basins, as can be found all over Saurashtra, have main streams ranging in length between 50 and 200 Km. In these short stretches, there are a few hundred, if not thousands, storages, which seem to have significantly altered the basin hydrology and caused major changes to aquifer dynamics. The hydrological data availability in this region is very poor. Whatever stream flow records are available, are not believed to be very reliable. But there is, as several studies show, a vibrant and well-developed observant hydrology (see, for instance, Krishnan 2008; Krishnan et al. 2009). This has, in part, led to the current hydrologic dynamism

Figure 10 Meghal sub-basin surface storage behavior over the simulated 20 year time period

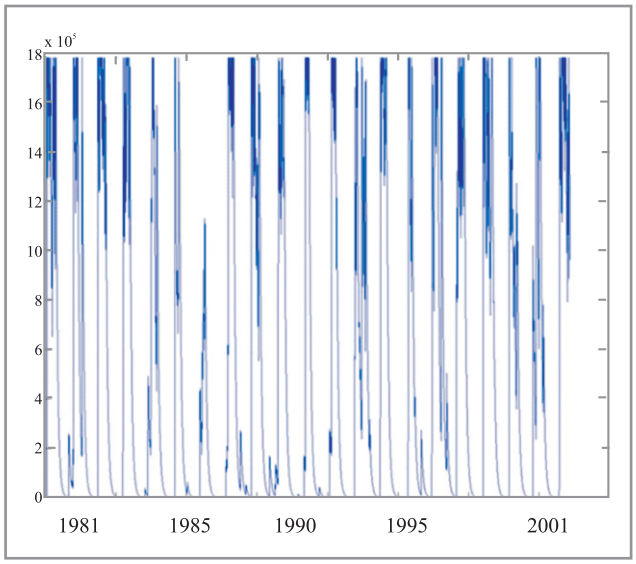


Figure 11 Meghal sub-basin aquifer storage behavior over the simulated 20 year time period

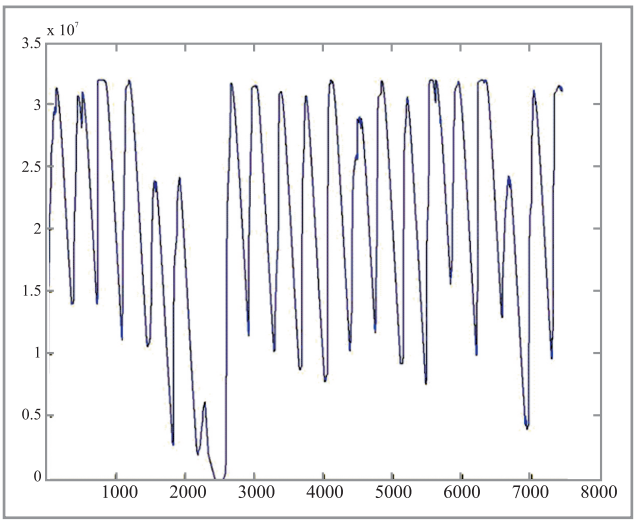


Table 3 Comparing percentage of artificial recharge to total recharge in each sub-basin aquifer

Sub-basin aquifers	Proportion of Annual Recharge contributed by Artificial Recharge	Average Annual Recharge (Natural and Artificial)
Meghal	33 percent	25.59 MCM
Vrajmi	43percent	23.27 MCM
Kalindri	18percent	9.47 MCM
Lathodariyo	22percent	13.14 MCM
TOTAL	**32 percent**	**71.49 MCM**

characterized by numerous conservation structures.

This study has not gone to the extent to utilizing raw subaltern hydrology, but still hydro logic data collected by non-hydrologists (NGO staff and local students) has been extensively used. Such data has been verified and then anchored to newer field observations with GPS locations of storages and cross-confirmation from Google Earth satellite images. These and other qualitative inputs from field workers have strengthened the background for this work. The crude basin hydrology model we developed (*MeghalBasinSim*) has used the conceptual understanding of the river basin, with the aim of arriving at a larger dynamic picture of river basin behavior. The parameters can be improved and refined further and the model can be scaled down to improve its predictive capability.

The insights that have been derived here, such as about the behavior of aquifers over years, the intra-seasonal storage and the sub-basin aquifer recharge variations, all offer further reason to use such a simple model for answering key questions about the basin. What it shows is that, though faced by poor data and uncertainty, there is scope for simple models to better understand the hydrological processes and to capture the community-led reconfiguration of river basins in Saurashtra.

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About the IWMI-Tata Program and Water Policy Highlights

The IWMI-Tata Water Policy Program (ITP) was launched in 2000 as a co-equal partnership between the International Water Management Institute (IWMI), Colombo and Sir Ratan Tata Trust (SRTT), Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations. Through this program, IWMI collaborates with a range of partners across India to identify, analyze and document relevant water-management approaches and current practices. These practices are assessed and synthesized for maximum policy impact in the series on Water Policy Highlights and IWMI-Tata Comments.

Water Policy Highlights are pre-publication discussion papers developed primarily as the basis for discussion during ITP's Annual Partners' Meet. The research underlying these Highlights was funded with support from IWMI, Colombo and SRTT, Mumbai. However, the Highlights are not externally peer-reviewed and the views expressed are of the author/s alone and not of ITP or either of its funding partners.

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