Meeting with GSDA on GW Recharge Plans

Team IIT Bombay

09/04/2020

Overview

- Objective
  - To calibrate
    - GW recharge during monsoon - using GSDA methodology (WTF method)
    - Rabi AET (using IITB model soil moisture and GW extraction data of GSDA)
- Brief about IITB water balance model and GSDA model
- GSDA GW Recharge Plan Analysis -
  - Interim report prepared
  - Letter sent to GSDA regarding doubts and issues in reports
  - Calibration on field - ongoing

IITB Water Balance Model

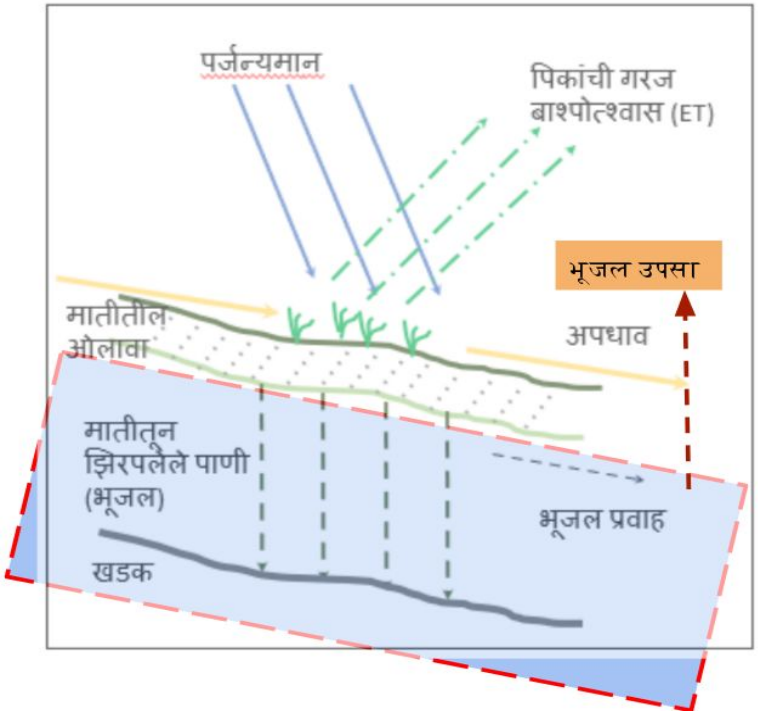
Soil water balance method

Inputs

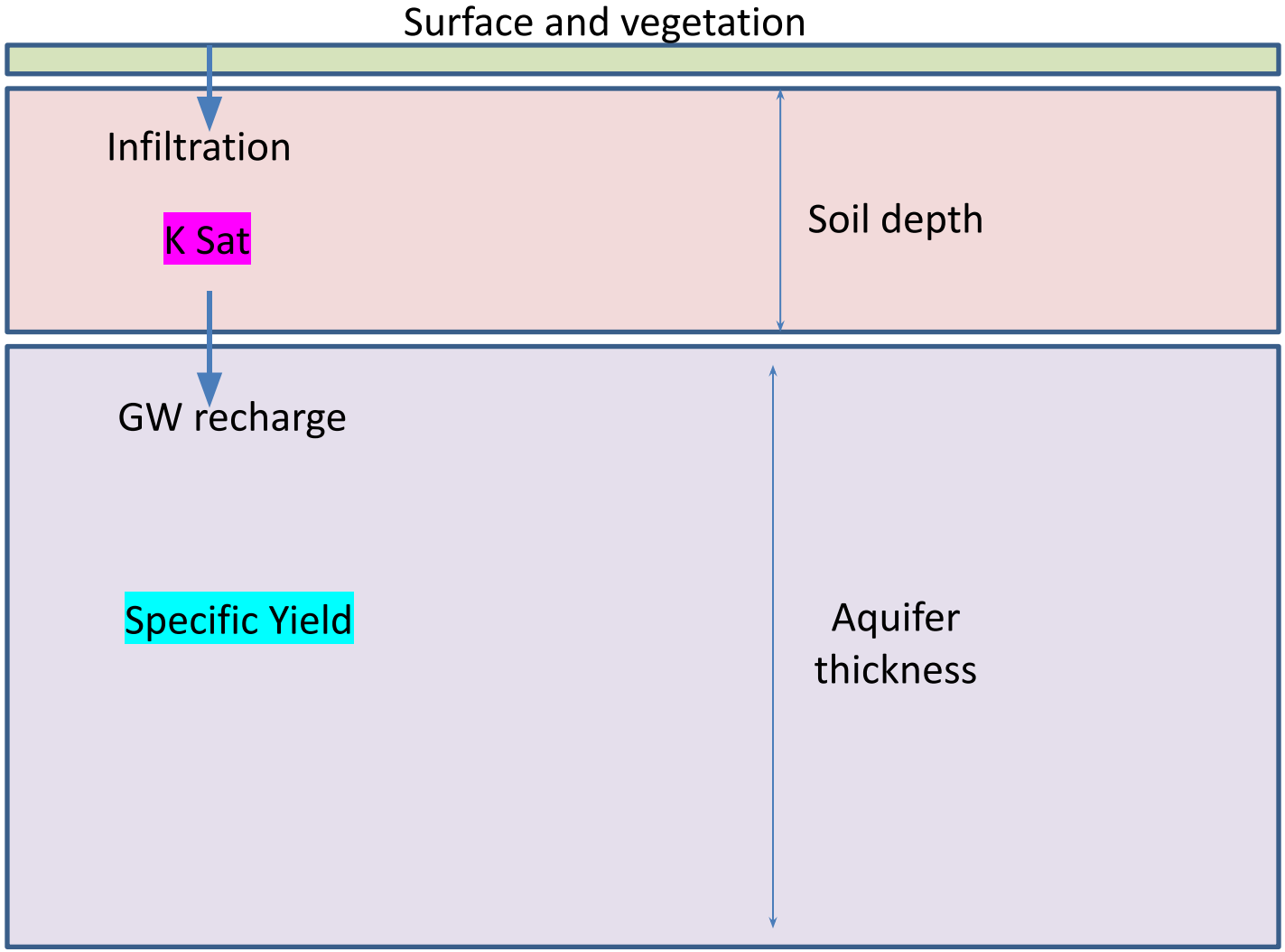
- Weather data - hourly rainfall, wind speed. Temperature, etc
- Terrain data – DEM, slopes
- Soil data – Texture, Depth (Field capacity, Wilting point, Ksat etc.)
- Land use and land cover data – Cropping pattern, forest cover etc.

Outputs

- Monsoon runoff, recharge, AET, soil moisture

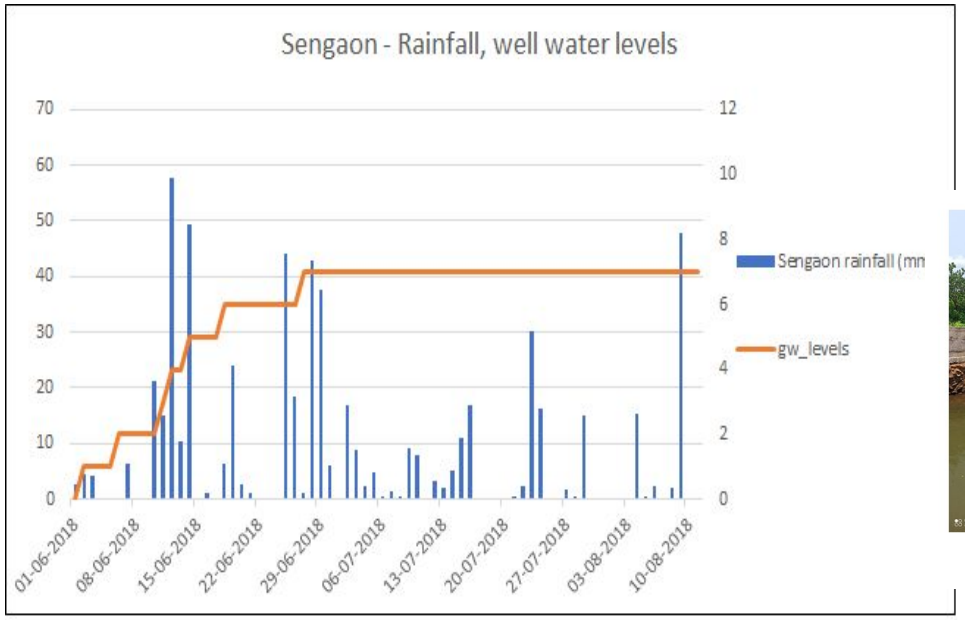


Key attributes which decide the GW recharge



Proposed Plan for Improving IITB GW Estimates

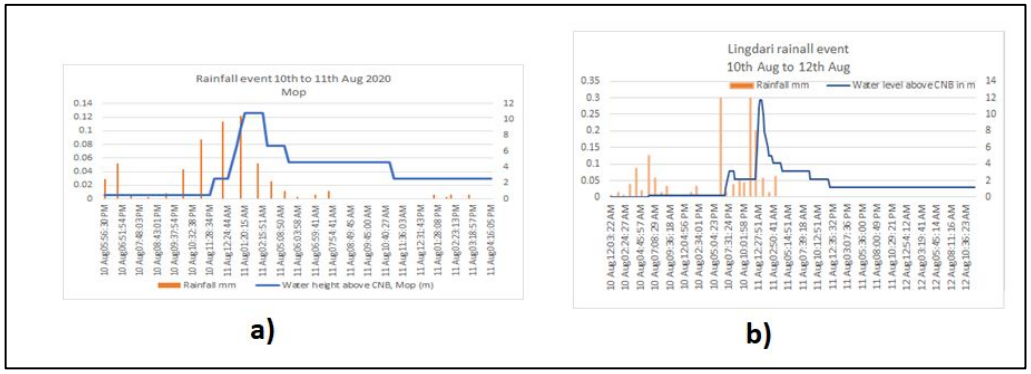
- Incorporation of Base flows
  - Limiting groundwater recharge by aquifer capacity and accounting excess recharge as base flows
- Dependency on GSDA
  - Data Requirement
    - Specific yield values for all the aquifers in project area
    - Aquifer thickness for all the aquifers in project area

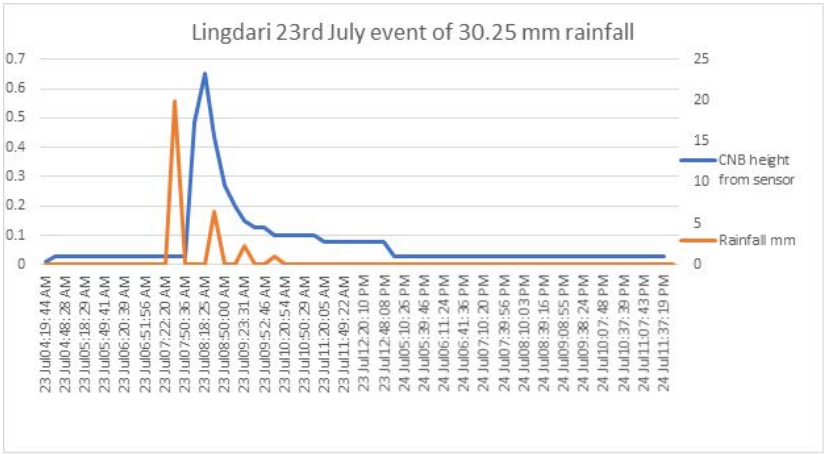

Sengaon - Rainfall, well water levels
70
60
50
40
30
20
10
0
12
10
8
6
4
2
0
Sengaon rainfall (mn
gw_levels
01-06-2018
08-06-2018
15-06-2018
22-06-2018
29-06-2018
06-07-2018
13-07-2018
20-07-2018
27-07-2018
03-08-2018
10-08-2018

a)

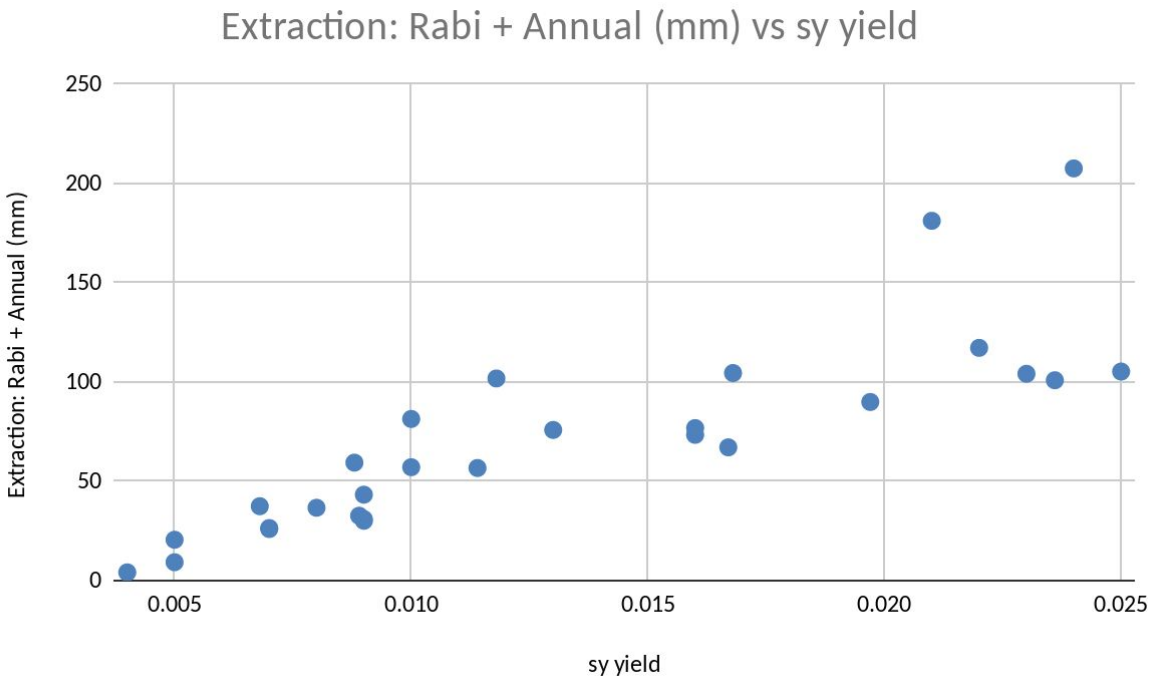
b)

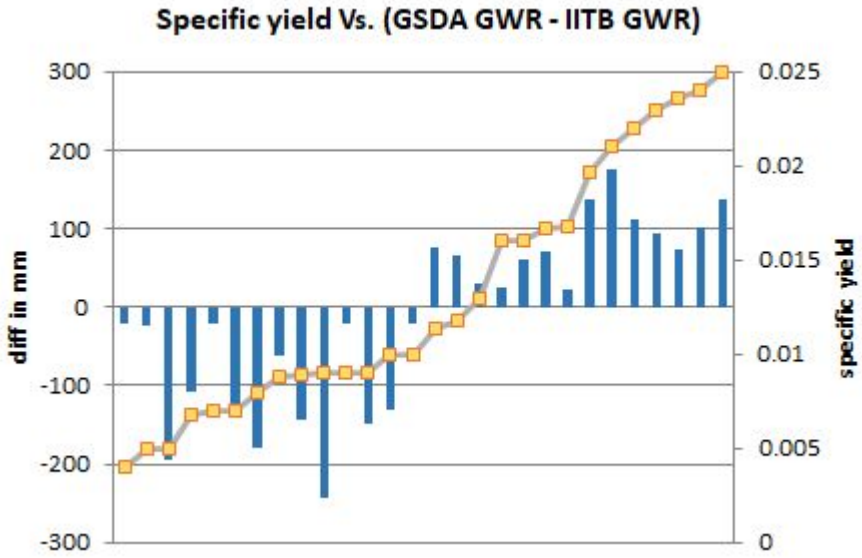
c)


Rainfall event 10th to 11th Aug 2020
Mop
Rainfall mm
Water height above CNB, Mop (m)
a)
Lingdari rainall event
10th Aug to 12th Aug
Rainfall mm
Water level above CNB in m
b)


Lingdari 23rd July event of 30.25 mm rainfall
CNB height
from sensor
Rainfall mm

Observations on Specific Yield





Issues in Specific Yield Calculations

- Missing water table level required for computing dry WTF
  - Assumed relationship of dry WTF with wet WTF
  - Dry WTF = (5/8) * Wet WTF

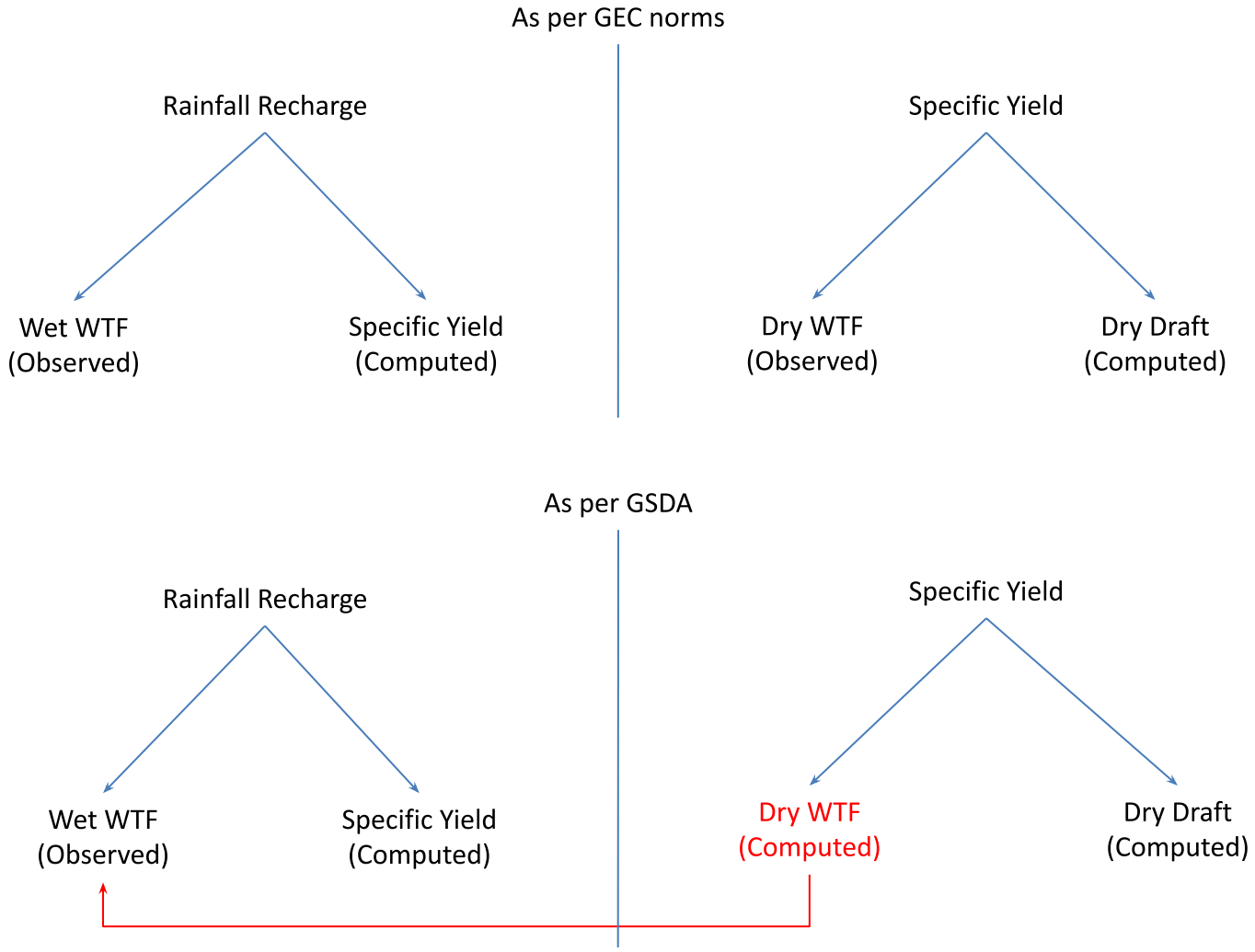
5/8	3/6	2/6	4/8	No factor is used as such	Total clusters where data is available
15	2	1	1	4	23

- Equation used by GSDA
  - Does not consider base flows and recharge from dry GW draft
- Area considered for calculation of specific yield

Cultivable Area	Total Area	Total clusters where data is available
15	8	23

- Dry draft used: Both Dug wells as well as bore wells for Jan-May
- Use of simple average instead of weighted average (Ignoring size of the villages)

Specific Yield



Other Issues

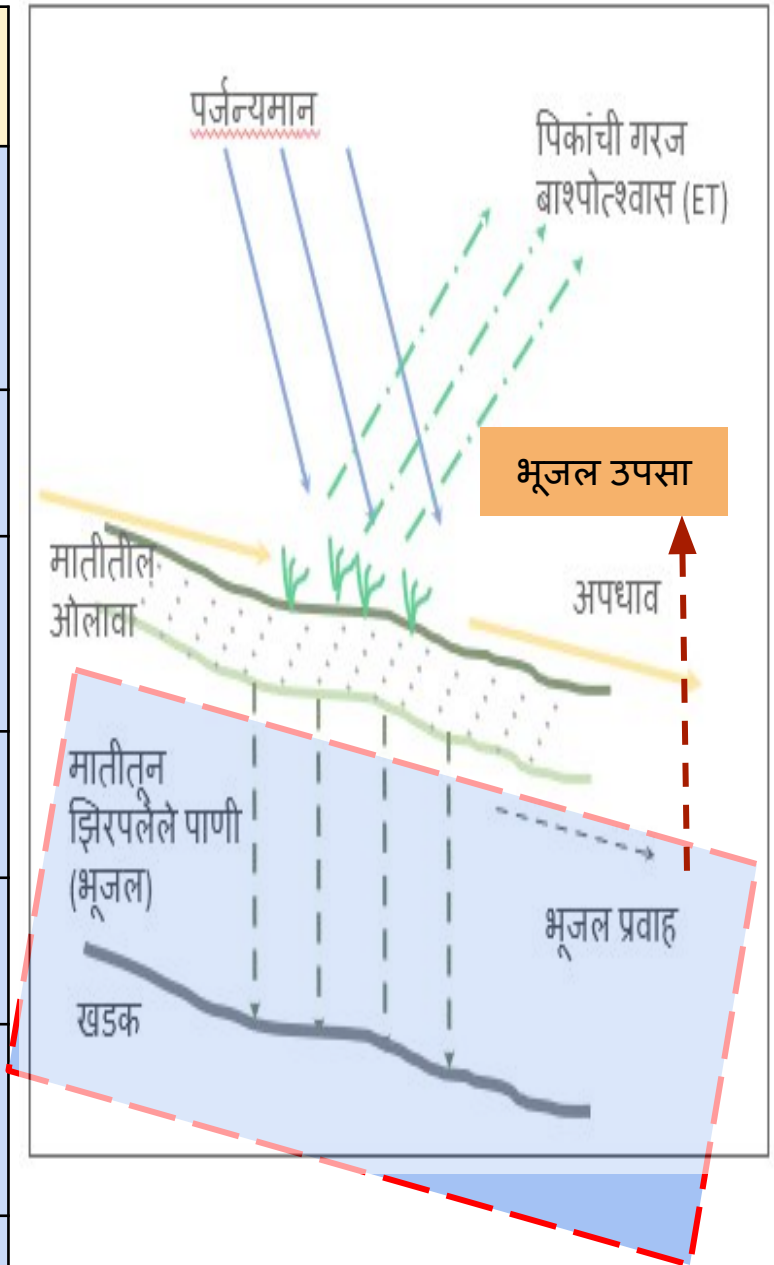
- Related to WTF
  - Inconsistency in Report and Data
  - Inconsistency in WTF within Report

WTF is consistent	WTF is NOT consistent	WTF could not be calculated	Data received
5	8	3	16

  - Incorrect reference used
- Incorrect equation for Monsoon Recharge
- Observation on relationship of specific yield and extraction
- Observation on specific yield values: On lower side in some clusters
- Error in calculation of GW draft for agriculture use: Use of simple average
- Average unit draft per well: On higher side (8-10 TCM)
- Accounting of GW recharge once wells are full but rainfall continues

Groundwater Budget = GW Available - GW Draft

	IITB Water Budget	GSDA Groundwater Budget
Rainfall	Used in computation of groundwater recharge	Not used in any computation
AET	Computed	Not considered
Runoff	Computed	Not considered (Only in Recharge Plan and not in Groundwater Budget)
Soil Moisture	Computed	Not considered
Groundwater Recharge	Computed	Computed
Groundwater Draft / Extraction	-	Computed
	-	Computed



Surface Runoff

- Runoff Generated in Cluster = Cluster Area * 75 % dependable rainfall of average annual rainfall * Runoff coefficient for the area
  where, runoff coefficient is taken from Strange Table Method
- When runoff is computed using this method, it does not consider some of the important factors like
  - Rainfall of the concerned year
  - Rainfall distribution for the year
  - Rainfall intensity of the rainfall events

	RUN OFF ESTIMATION	
1	Total catchment area (Cluster area) in Ha	3132.00
2	Average annual rainfall in mm	715.74
3	75% dependable rainfall in mm	514.00
4	Average slope of area in %	2 to 4
5	Run off coefficient for the area in fraction	0.12
6	Run off yield from the area in TCM	1851.33
7	Utilizable Run off for harvesting in TCM = 65% of Row 6 (35% left as riparian rights of the downstream)	1203.36
8	Run off booked for existing WCS structures in **TCM**	145.00
9	Run off ultimately available for harvesting (7-8) in **TCM**	1058.36
10	No. of fillings assumed	2.00
11	Approximate water storage capacity that can additionaly be created (50% of 9) in **TCM**	529.18

Groundwater Budget

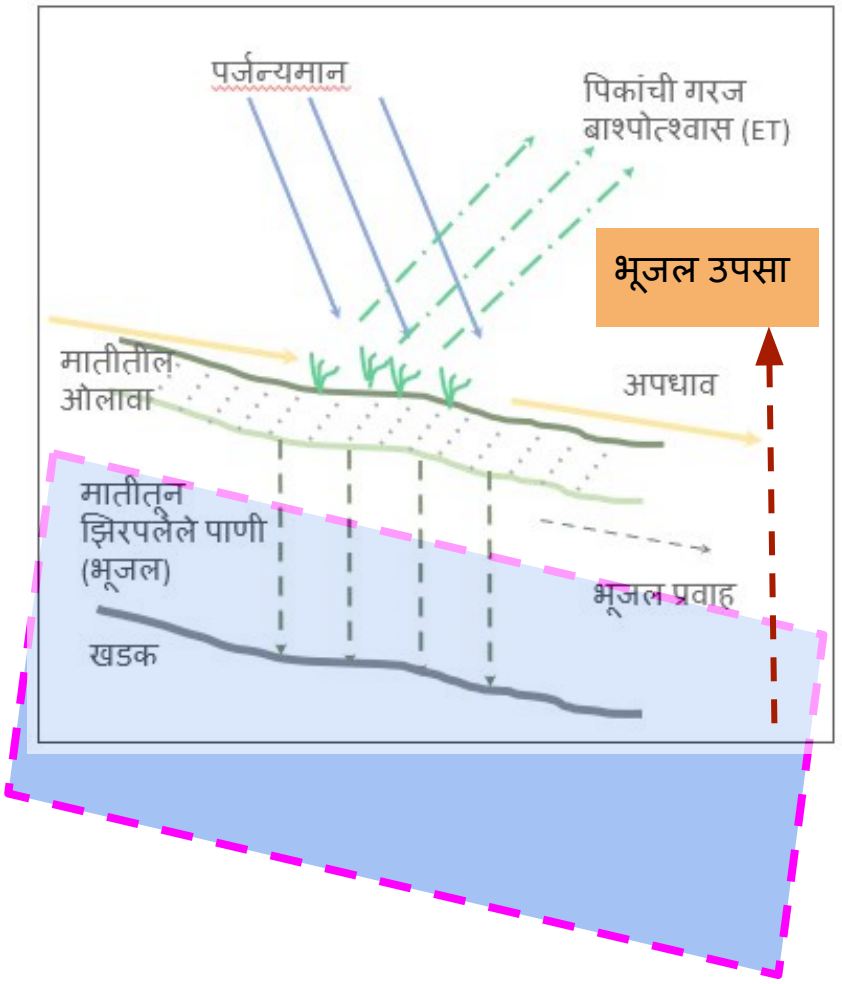
GW Budget = GW Available - GW Draft

[surplus (+), deficit (-)]

where,

GW Available = GW Recharge - Base flows,

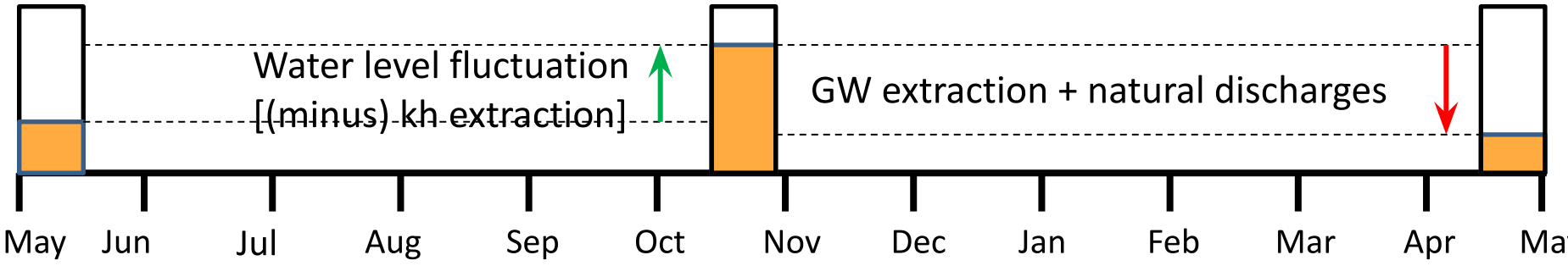
GW Draft = Extraction for (Domestic + Agriculture) use

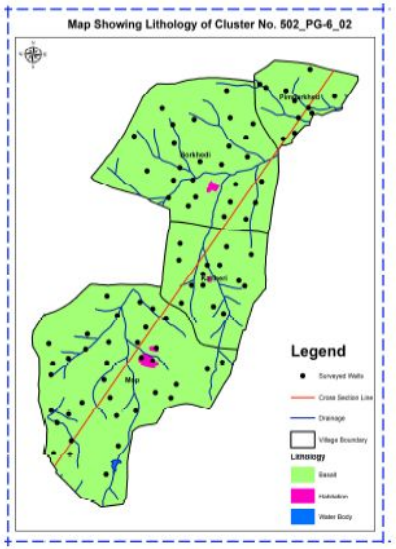


Important Components of GW Budget To be Used

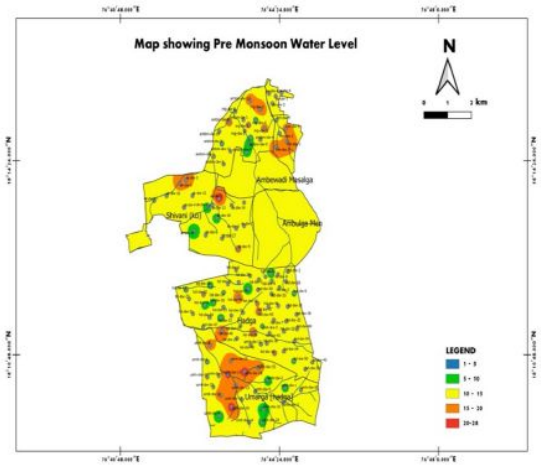
- Groundwater Recharge
- Groundwater Draft for Agriculture

Groundwater Recharge

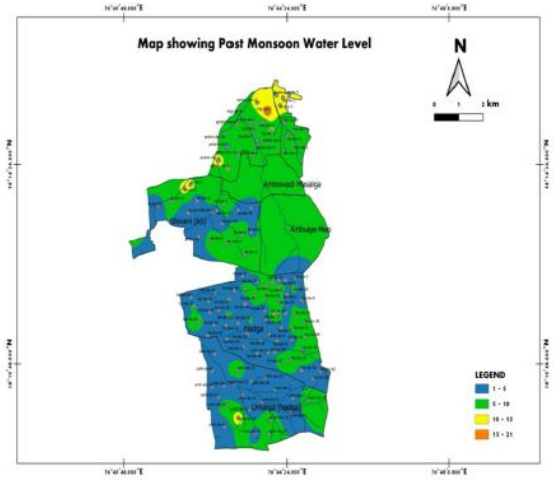




Map showing selected wells for sampling



Pre-monsoon water levels



Post-monsoon water levels

Groundwater extraction - Well Census Method

Total GW draft = unit draft per well (ham) x number of wells in the watershed

unit draft per well (ham) = discharge per hour in cum/hr x pumping hours per day x total pump operation days

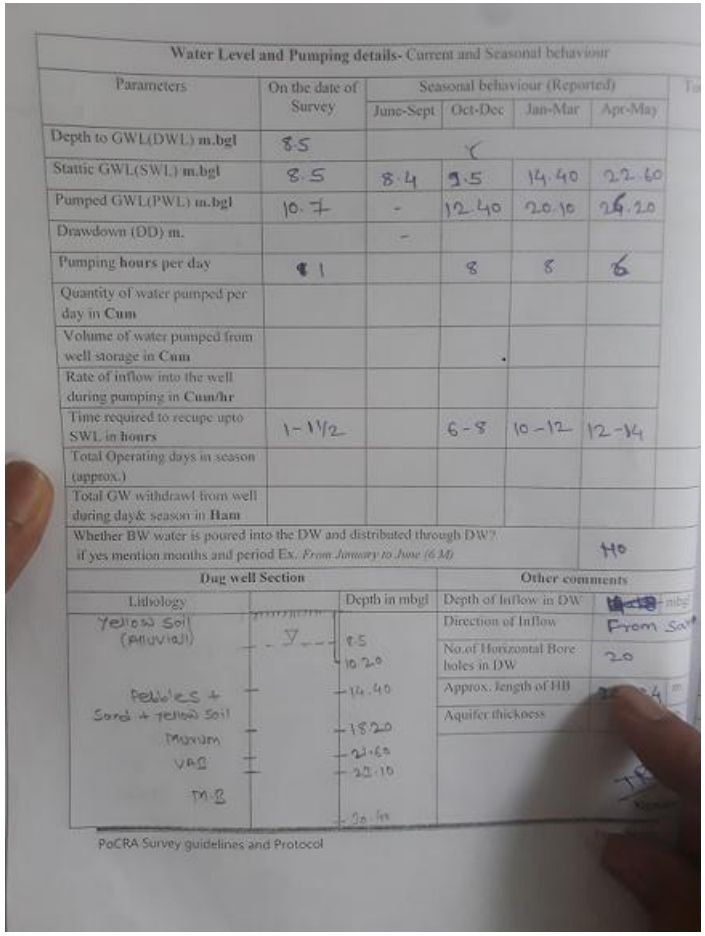
- This is computed season-wise as extraction pattern changes as per the season
- The data for discharge, pumping hours per day and total operational hours to calculate unit draft per well is collected by GSDA (Hydrogeological Survey)
- Number of wells in watershed is taken from the secondary data (as per revenue record)

Groundwater extraction - Cropping Pattern Method

Total GW draft = Σ[extraction per ha for (crop i, irrigation method j) x area under crop i, method j]

- This is computed for all seasons - kharif, rabi and summer
- It requires -
  - Farmer level data - through questionnaires for few selected farmers
  - Cropping pattern of farmer, irrigation method, number of irrigations
  - Amount of water per irrigation = assumed 0.067 ham for flood
  - Aggregate cropping pattern for the cluster
- Extrapolation to whole village
  - Method used to extrapolate farmer level irrigation data to cluster is not explained
  - Different cases of number of irrigations provided are not fully considered
    - Only two cases considered viz. No irrigation and Required (Desired) irrigation

Data and survey formats used by GSDA



Water Level and Pumping details- Current and Seasonal behaviour

Parameters	On the date of Survey	Seasonal behaviour (Reported)			
		June-Sept	Oct-Dec	Jan-Mar	Apr-May
Depth to GWL(DWL) m.bgl	8.5				
Stattic GWL(SWL) m.bgl	8.5	8.4	9.5	14.40	22.60
Pumped GWL(PWL) m.bgl	10.7	-	12.40	20.10	26.20
Drawdown (DD) m.		-			
Pumping hours per day	1		8	8	6
Quantity of water pumped per day in Cum					
Volume of water pumped from well storage in Cum					
Rate of inflow into the well during pumping in Cum/hr					
Time required to recupe upto SWL in hours	1-1½		6-8	10-12	12-14
Total Operating days in season (approx.)					
Total GW withdrawl from well during day& season in Ham					

Whether BW water is poured into the DW and distributed through DW? if yes mention months and period Ex. *From January to June (6 M)* — Ho

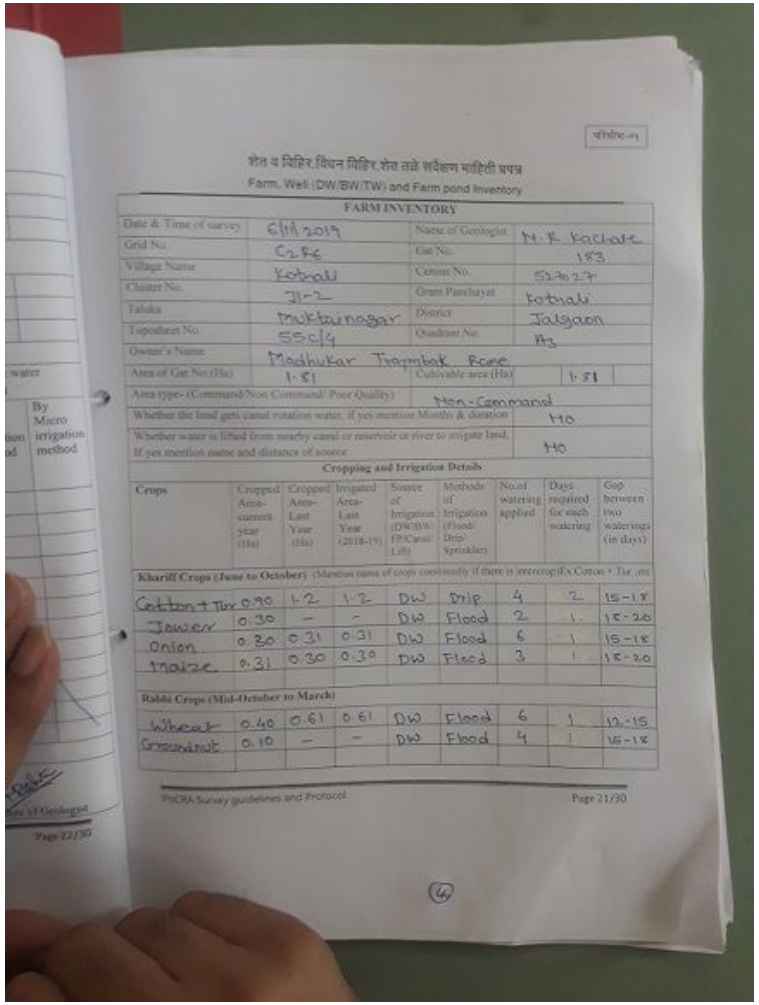
Dug well Section

Lithology	Depth in mbgl
Yellow Soil (Alluvial)	8.5
	10.20
Pebbles + Sand + Yellow Soil	14.40
Murum	18.20
VAS	21.60
	22.10
TM.B	

Other comments

Depth of Inflow in DW	mbgl
Direction of Inflow	From So
No.of Horizontal Bore holes in DW	20
Approx. length of HB	m
Aquifer thickness	

PoCRA Survey guidelines and Protocol



शेत व विहिर,विंधन विहिर,शेत तळे सर्वेक्षण माहिती पत्र

Farm, Well (DW/BW/TW) and Farm pond Inventory

FARM INVENTORY

Date & Time of survey	6/11/2019	Name of Geologist	M.R. Kachare
Grid No.	C2F6	Gat No.	183
Village Name	Kothali	Census No.	528027
Cluster No.	31-2	Gram Panchayat	Kothali
Taluka	Muktainagar	District	Jalgaon
Toposheet No.	55c/4	Quadrant No.	A3
Owner's Name	Madhukar Trambak Rane		
Area of Gat No.(Ha)	1.81	Cultivable area (Ha)	1.81
Area type- (Command/Non Command/ Poor Quality)	Non-Command		
Whether the land gets canal rotation water, if yes mention Months & duration	No		
Whether water is lifted from nearby canal or reservoir or river to irrigate land, If yes mention name and distance of source	No		

Cropping and Irrigation Details

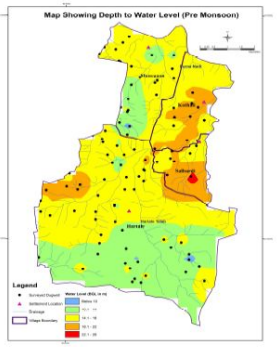
Crops	Cropped Area-current year (Ha)	Cropped Area-Last Year (Ha)	Irrigated Area-Last Year (2018-19)	Source of Irrigation (DW/BW/ FP/Canal/ Lift)	Methods of Irrigation (Flood/ Drip/ Sprinkler)	No.of watering applied	Days required for each watering	Gap between two waterings (in days)
Kharif Crops (June to October) (Mention name of crops continously if there is intercrop)Ex Cotton + Tur ,etc								
Cotton + Tur	0.90	1.2	1.2	DW	Drip	4	7	15-18
Jawar	0.30	-	-	DW	Flood	2	1	15-20
Onion	0.30	0.31	0.31	DW	Flood	6	1	15-18
Maize	0.31	0.30	0.30	DW	Flood	3	1	15-20
Rabbi Crops (Mid-October to March)								
Wheat	0.40	0.61	0.61	DW	Flood	6	1	12-15
Groundnut	0.10	-	-	DW	Flood	4	1	15-18

PoCRA Survey guidelines and Protocol — Page 21/30

WTF method for computing GW recharge

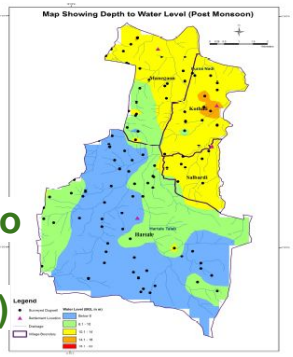
iv) **Depth to groundwater level map – Pre-monsoon (Summer) (Fig-10):**

Depth to groundwater level in summer varies from 8 to 21 mbgl; however the depth to GW level between 11 to 18 mbgl is more common.

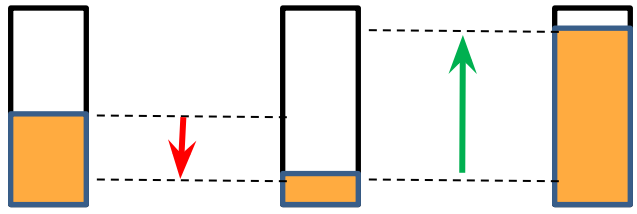


v) **Depth to groundwater level map – Post-monsoon (Winter) (Fig-11):**

Depth to groundwater level in winter varies from 2 to 15 mbgl; however the depth to GW level between 3 to 14 mbgl is more common



Case I: Summer (2018) to Winter (2018) (Recharge 2018)

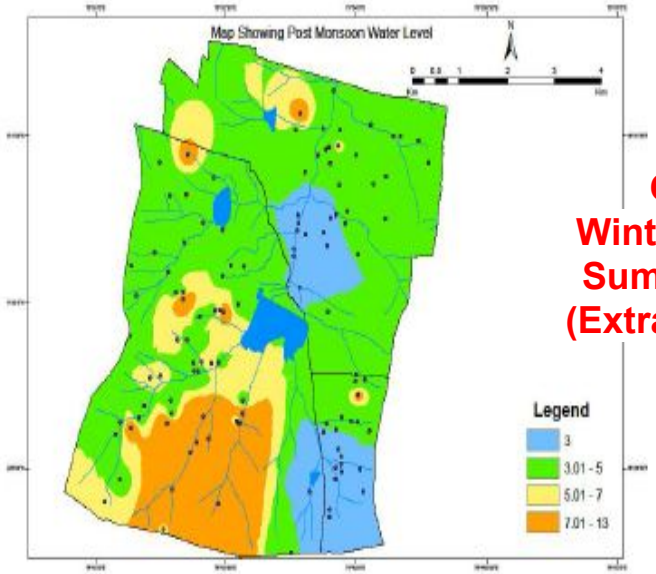


Wrongly estimated recharge (2018)

Actual recharge (2019)

Depth to groundwater level map – Post-monsoon (Winter 2018) (Fig-11):

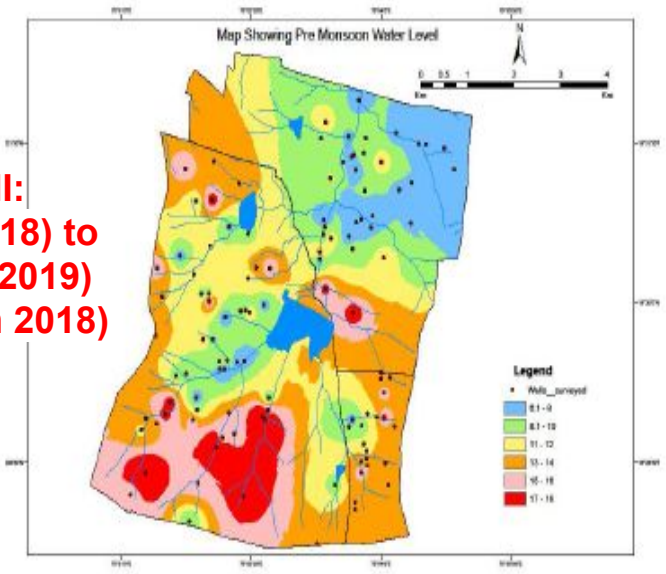
Depth to groundwater level in winter 2018 varies from 3 to 13 m bgl. However the depth to GW level between 3 to 7 m.bgl is more common.



Case II: Winter (2018) to Summer (2019) (Extraction 2018)

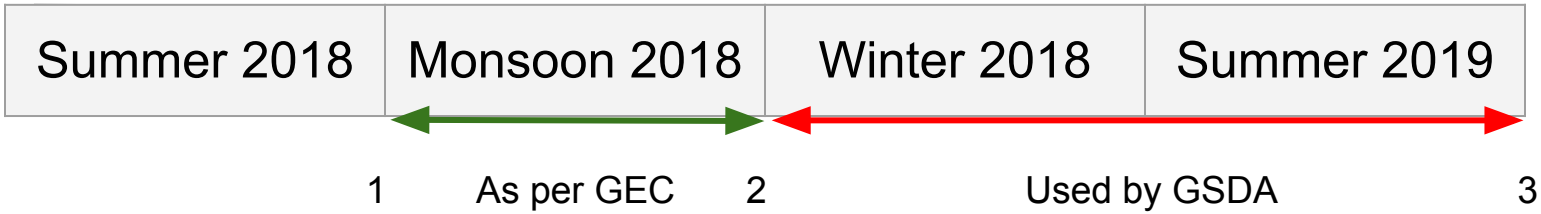
Depth to groundwater level map – Pre-monsoon (Summer 2019) (Fig-12):

Depth to groundwater level in summer 2019 varies from 6 to 18 m bgl. However the depth to GW level between 8 to 12 m.bgl is more common.



Incorrect reference for WTF has been used at least for 5 out of 28 clusters

GW Recharge Computation for 2018-2019 Using Post-monsoon to Pre-monsoon WTF



- Incorrect reference implies errors in computation of GW Recharge
- Only case when even incorrect WTF can have correct result is case II explained below

Recharge for 2018-2019 using WTF		Case I (Extraction more than Recharge)	Case II (Extraction and Recharge are equal))	Case III (Extraction less than Recharge)
1	GW level Pre-monsoon 2018 in mgl (@ end of summer 2018)	8	9	10
2	GW level Post-monsoon 2018 in mgl (@ start of winter of 2018)	3	3	3
3	GW level Pre-monsoon 2019 in mgl (@ end of summer 2019)	9	9	9
4 = (1-2)	WTF which should have been used as per GEC method	5	6	7

GW Recharge in Monsoon (For all 28 Clusters)

As per GEC 2015, groundwater recharge during monsoon season is given as,

Total Groundwater recharge during monsoon

= (Rise in water level in monsoon * Specific yield * Area) + Gross groundwater draft

=1+(4-3).....(from GEC GW Estimation Table)

Whereas GSDA has computed the same using following equation,

Total Groundwater recharge during monsoon

= (Water table fluctuation * Specific yield * Area)

+ Recharge from WCS

+ Gross groundwater draft

+ Recharge from surface water irrigation

= 1+2+(4-3)+5.....(from GSDA GW Estimation Table)

WTF includes recharge due to WCS and surface water irrigation

Groundwater Estimation		
Monsoon Recharge		**TCM**
1	Rainfall recharge during monsoon (by WTF) in TCM =(area × wtf × sy) (4605*7*0.013)	3254.16
2	Recharge from WCS during monsoon in Ham	47.00
3	Recharge from groundwater irrigation during monsoon in TCM (considered 10 % of water applied)	82.90
4	Groundwater Draft during monsoon in TCM	829.00
5	Recharge from Surface water irrigation during monsoon in TCM	0
6	Total groundwater recharge during monsoon in TCM =(1+2+(4-3)+5)	**4047.26**

Inconsistency in WTF Used

- WTF reported in section 4. F. vi of the recharge plan
- WTF used while calculating GW Recharge during Monsoon

vi) **Annual groundwater fluctuation map (2018-19) (Fig-13):**

Annual GW level fluctuates between 3 to 11 m. But major part of the area shows the GW fluctuations between 3 to 9 m. Thus average WTF for the cluster is considered as 6 m.

Rainfall recharge during monsoon (by WTF) in TCM =(area × wtf × sy)
(4605*7*0.013)

- WTF calculated using data (as shared by GSDA) for 16 reports

No. of cluster where data is received	No. of clusters where WTF could not be calculated	No. of clusters where WTF used for calculation is consistent with WTF calculated from raw data	No. of clusters where WTF used for calculation is NOT consistent with WTF calculated from raw data
16	3	5	8

No explanation or details are provided in the recharge plan on if any specific method is used while considering WTF for overall cluster

Out of 8 clusters where WTF is not consistent, 2 clusters shows error of about 75 mm and other 2 of about 25 mm

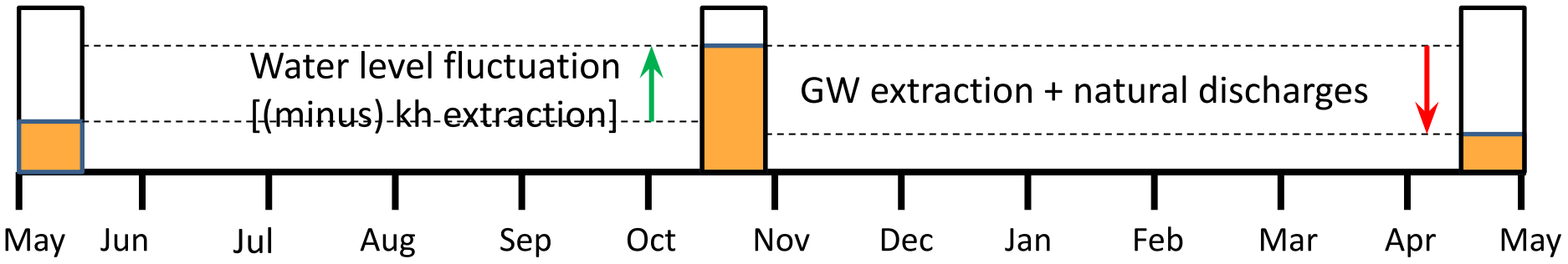
Issues with the raw data shared (16 Clusters)

- Use of different data formats
  - Inconsistency in data points collected
    - Pumping data is not available in 2 clusters and is provided only partly for 10 clusters
    - Data on cropping pattern is either missing or only partly provided in most of the clusters (available only for a cluster)
  - Difficulties in using a standard method for analyzing data received
- What data is important for IITB for GW recharge calculation
  - Pre and Post monsoon water level (For WTF to be used)
  - Pump discharge, pumping hours, operational days in monsoon (for calculation of GW extraction in monsoon)

To compute groundwater recharge both of the above mentioned data points are essential

Specific Yield Calculated by GSDA

- No clarity on the data used for computation of the specific yield
- The method of computing specific yield using dry season method is very much sensitive to the groundwater extraction
  - Extraction data needs to be accurate to the maximum possible extent
- If GSDA has computed specific yield for all the studied clusters then they must have used
  - Water table levels at the start of Rabi (Post-monsoon) and at the start of next monsoon (Pre-monsoon) : This data is missing in raw data
  - Pumping data: Either is not consistent or missing in raw data



	Sanjarpur	Sanjirabad	Manjari	Malunja	Maholi	Hadiyabad		
Area cultiv	270	170	1700	500	820	270		3730
density	34.07	17.06	19.35	45.00	20.12	35.93		28.59
WTF	4.9	4.53	4.59	4.77	4.05	5.43		4.71
dry wtf	3.063	2.831	2.869	2.981	2.531	3.394		2.94
Dry Draft	24.88	10.89	152.63	28.31	32.58	11.84		261.1308
Dft DW	16.640	7.230	103.280	14.400	26.600	7.740		175.89
Sy	0.030	0.023	0.031	0.019	0.016	0.013	0.022	0.022
Sy DW	0.020	0.015	0.021	0.010	0.013	0.008	0.015	0.015
	0.025	0.019	0.026	0.014	0.014	0.011	0.018	
RF recharge	39.8144	17.4317	244.203	45.29	52.12	18.95	417.80928	

	Sanjarpur	Sanjirabad	Manjari	Malunja	Maholi	Hadiyabad
Area cultiv	270	170	1700	500	820	270
density	=92/2.7	=29/1.7	=329/17	=225/5	=165/8.2	=97/2.7
WTF	4.9	4.53	4.59	4.77	4.05	5.43
dry wtf	=D36*(5/8)	=F36*(5/8)	=H36*(5/8)	=J36*(5/8)	=L36*(5/8)	=N36*(5/8)
Dry Draft	=SUM(D27:E28)	=SUM(F27:G28)	=SUM(H27:I28)	=SUM(J27:K28	=SUM(L27:M2	=SUM(N27:O2
Dft DW	=SUM(D27:D28)	=SUM(F27:F28)	=SUM(H27:H28)	=SUM(J27:J28)	=SUM(L27:L28	=SUM(N27:N2
Sy	=D38/(D34*D37)	=F38/(F34*F37)	=H38/(H34*H37)	=J38/(J34*J37)	=L38/(L34*L37	=N38/(N34*N3
Sy DW	=D39/(D34*D37)	=F39/(F34*F37)	=H39/(H34*H37)	=J39/(J34*J37)	=L39/(L34*L37	=N39/(N34*N3
	=AVERAGE(D40,	=AVERAGE(F40,I	=AVERAGE(H40,	=AVERAGE(J4	=AVERAGE(L4	=AVERAGE(N4
RF recharge	=D34*D36*D40	=F34*F36*F40	=H34*H36*H40	=J34*J36*J40	=L34*L36*L40	=N34*N36*N40

Other Observations on Specific Yield

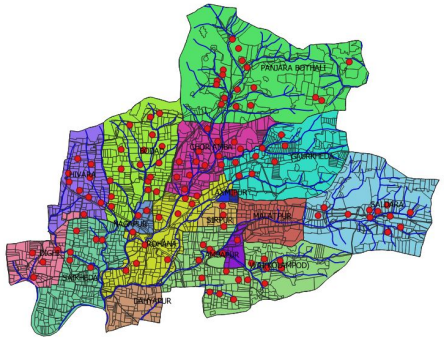
5.9 NORMS FOR ESTIMATION OF RECHARGE

5.9.1 Norms for specific yield

S.No	Formation	Recommended Value (%)	Minimum Value (%)	Maximum Value (%)
(a)	Alluvial areas			
	Sandy alluvium	**16.0**	12.0	20.0
	Silty alluvium	**10.0**	8.0	12.0
	Clayey alluvium	**6.0**	4.0	8.0
(b)	Hard rock areas			
	Weathered granite, gneiss and schist with low clay content	**3.0**	2.0	4.0
	Weathered granite, gneiss and schist with significant clay content	**1.5**	1.0	2.0
	Weathered or vesicular, jointed basalt	**2.0**	1.0	3.0
	Laterite	**2.5**	2.0	3.0
	Sandstone	**3.0**	1.0	5.0
	Quartzite	**1.5**	1.0	2.0
	Limestone	**2.0**	1.0	3.0
	Karstified limestone	**8.0**	5.0	15.0
	Phyllites, Shales	**1.5**	1.0	2.0
	Massive poorly fractured rock	**0.3**	0.2	0.5

Other Issues / Observations

- Pumping hours data (and hence GW extraction) for April-May as mentioned in the report is not consistent with the raw data for some of the clusters (at least 6 out of 16)
- Number of wells/borewells considered for aggregation while calculating GW draft
  - As per revenue record
  - No clarity on number of operational wells considered while aggregating
- Average unit draft per well: On higher side in some clusters
  - Possibly because selected wells are in concentrated in stream proximity
- Error while using spreadsheet formulae (1-2 clusters)
  - Average calculated



Wardha cluster - 504_WRWN-03_01

		Saldara	
Well Type		DW	BW
Total no. of irrigation wells in the area		35	1
Total no. of wells in use		35	1
Total no. of wells surveyed		11	1
No of perennial wells (perennial pumping)		2	1
% of perennial wells (perennial pumping)		18	100
Average depth of wells in the area in m		9	45
Average pump discharge/well /per hour (cum/hr)		21	20
Average pumping hours a day	June-Sept	0	0
	Oct-Dec	5	6
	Jan-March	2	6
	April -May	4	3
Average pump operation days	June-Sept	0	0
	Oct-Dec	24	40
	Jan-March	17	30
	April -May	15	20
	Total	56	90
Average annual draft of a well (unit draft) in Ham	June-Sept	0	0
	Oct-Dec	0.24	0.48
	Jan-March	0.07	0.36
	April -May	=G17*G1	
	Total	3*G9/10	
Total groundwater draft in the area in Ham	June-Sept	000	
	Oct-Dec	8.57	0.48
	Jan-March	2.54	0.36
	April -May	4.41	0.12
	Total	15.52	0.96
	Total	16.48	
	TOTAL		

Average pump operation days							
June-Sept							0
Oct-Dec	15	25	35	40	20		23.8
Jan-March	13	20	20	25	10		17.3
April -May							15
Average annual draft of a well (unit draft) in Ham							
June-Sept							0
Oct-Dec	0.117	0.18	0.315	0.36	0.216		0.2028
Jan-March	0.108	0.18	0.216	0.27	0.09		0.1642
April -May							0.025
Total groundwater draft in the area in Ham							
June-Sept							
Oct-Dec							
Jan-March							
April -May							

Error In Average Values

	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	Average
How it is entered in data		15									15
What it should have been so as to use formula in excel	0	15	0	0	0	0	0	0	0	0	1.5

Data used for illustration is of Saldara village from Arvi cluster of Wardha		
Total no of wells in use in a village	35	35
Avg pump discharge/well/hr	21	21
Avg pumping hours	4	4
Avg operational days in April-May	15	1.5
Avg draft of a well in April-May	0.126	0.0126
Avg annual draft of a well (assuming computation for other seasons is correct) in Ham	0.4436	0.3302
Total draft (Ham)	15.524	11..556

Calibrating GW Recharge With 2018/2019 As Reference

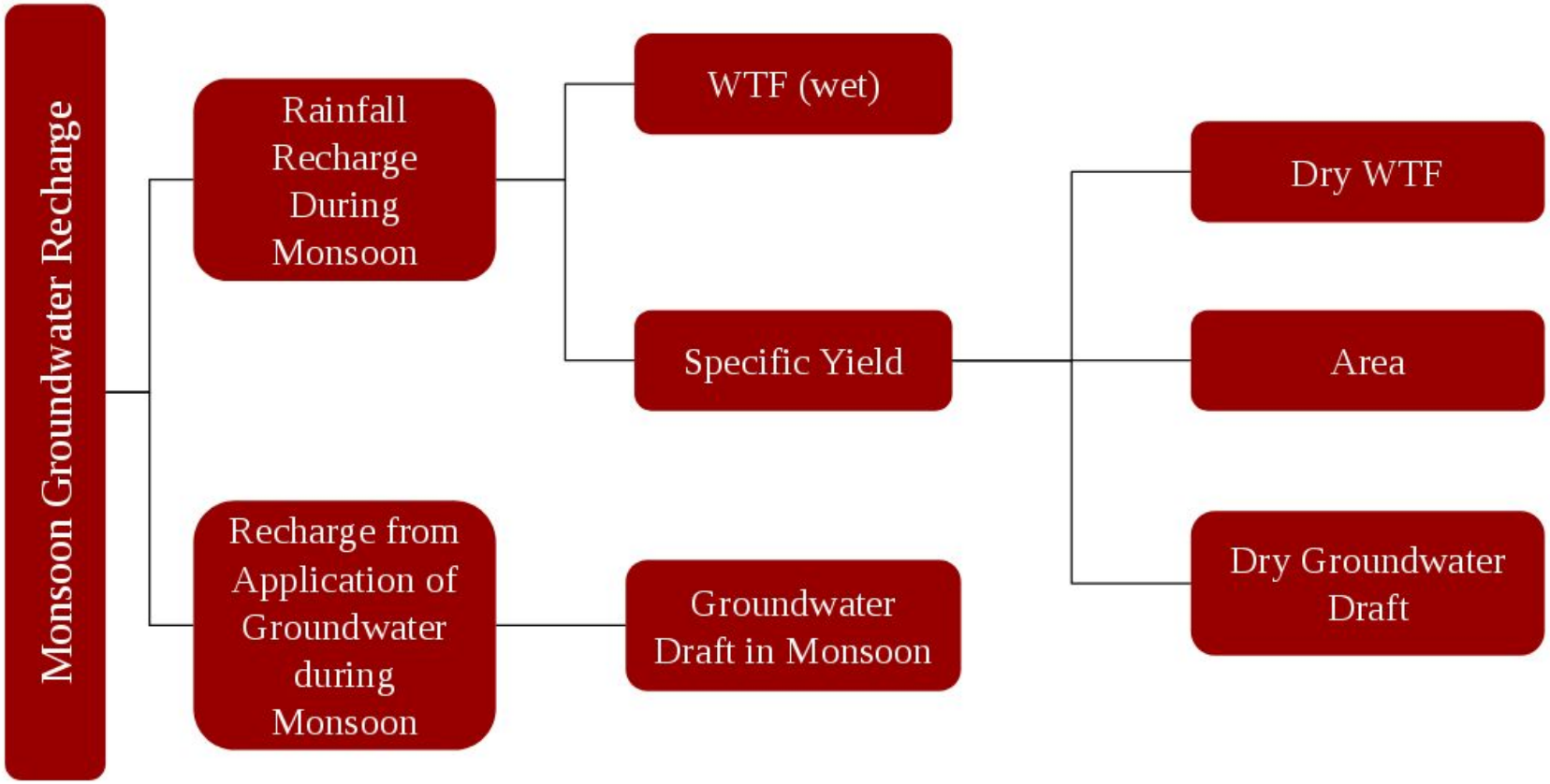
Issues in calibrating model based on results of GSDA for 2018-2019 / 2019-2020

- For clusters where incorrect WTF is used
  a. **What about WTF error? How do we address it while calibrating?**
  b. Difficulties in ground truthing the data used (which is mostly dynamic data i.e. subject to change for different years)
  c. It is also difficult to understand and quantify error in calculating groundwater draft for each and every cluster (inconsistency)
  d. Error in the computing GW recharge during Monsoon due to use of different equation
     i) Ignored given its little contribution to overall recharge
     ii) Can be calibrated (Either using GSDA data or MLP app data for WCS)
- For clusters where correct WTF is used
  - Even when correct WTF has been used, issues mentioned as b, c and d persist.
  - Data on WTF can be used in its entirety only when corresponding pumping data is available: This is not the case for any of the cluster

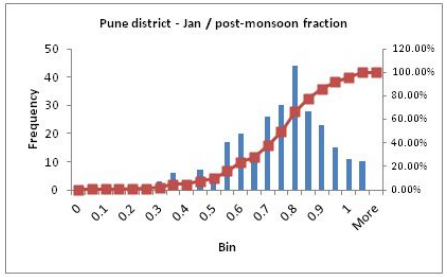
All these factors make this method of calibration unsuitable as far as feasibility of execution and reliability of results is concerned.

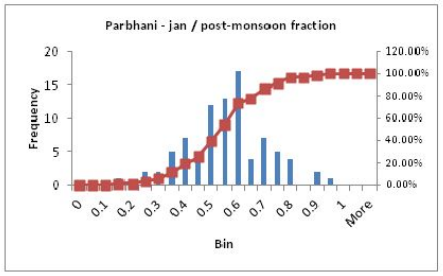
IITB team shall work on the modified strategy to use whatever data we have got from GSDA in next phase (phase iv).

Source of Error in GWR Computation



THANK YOU!!!


Pune district - Jan / post-monsoon fraction
Frequency
Bin
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
More
0.00%
20.00%
40.00%
60.00%
80.00%
100.00%
120.00%


Parbhani - jan / post-monsoon fraction
Frequency
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0.4
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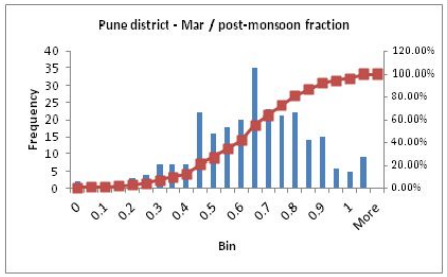
Pune district - Mar / post-monsoon fraction
Frequency
Bin
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0.3
0.4
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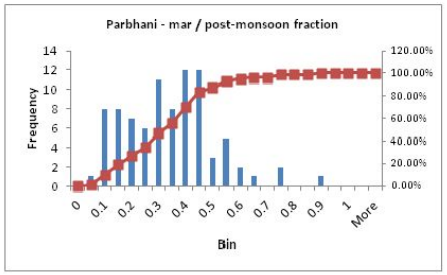
Parbhani - mar / post-monsoon fraction
Frequency
Bin
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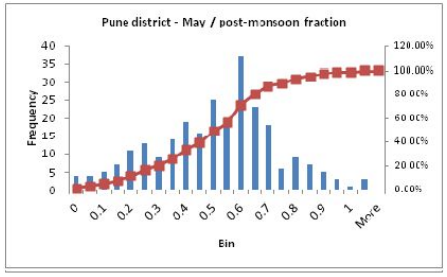
Pune district - May / post-monsoon fraction
Frequency
Bin
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0.1
0.2
0.3
0.4
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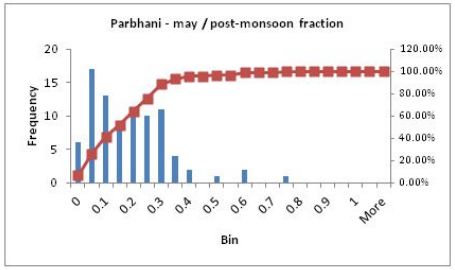
Parbhani - may / post-monsoon fraction
Frequency
Bin
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0.1
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