Understanding, Analyzing and Modelling Watershed Interventions

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Background

- Water group at CTARA
  - Considerable amount of work in rural drinking water for past several years
    - Policy interventions
    - Research
    - Implementation
    - Monitoring and Evaluation
  - Need felt to gain understanding of Watershed Development
    - To strengthen the technical base about watershed interventions
    - To understand its role in solving drinking water issue
    - To understand the role of modelling in strengthening the technical soundness and effectiveness of watershed structures
  - Some initial steps taken in this direction
    - Dharamvir Kumar’s MTP Thesis in 2009 – Groundwater Recharge Simulator
    - Directed Research Component of Field Stay in Mokhada, 2012

Overview

- Understanding watershed development scenario in India in brief – history , impacts and some issues
- What is watershed? What is watershed intervention? - Some techniques and methods
- Coming to specific watershed intervention – Ikharichapada , Mokhada
- Modelling Ikharichapada intervention – its need and tools used
- Conceptual model of Ikharichapada
- Conclusions
- Future work

Watershed development scenario in India -1

- Historically, government watershed development programmes have always been linked with land development
    - Drought Prone Area Development Programme (DPAP, 1972)
    - Desert Development Programme (DDP, 70's)
    - National Watershed Development Programme for Rainfed Areas (NWDPRA, 1986)
    - Integrated Wasteland Development Programme (IWDP, 1989)
- 1980s –
    - Demonstrations in Sukhomajri and Ralegan Siddhi of participatory approach to watershed development
    - World Bank and NGO funded watershed development projects
    - Research projects taken up by CSWCRTI, CRIDA etc

Watershed development scenario in India -2

- Main philosophy behind watershed development evolved – socio economic development of backward areas (like wastelands, drought-prone or desert areas) through soil and water conservation works for improvement in agricultural production
- 1994 – Common guidelines for all watershed projects
  - Equity in distribution of benefits
  - People's participation
  - Institutional setup etc.
- Guidelines revised – 2001, 2003 (Hariyali guidelines) and 2008 (IWMP – Integrated Watershed Management Programme)
  - More stress on role of PRIs
  - Robust 'entry-point' and 'exit' strategies for ensuring equity and sustainability
  - Inclusion of rainfed areas and forest areas

Watershed development scenario in India -3

- Impacts of watershed programmes
  - Various studies by government agencies, government research institutes, NGOs, academicians etc. – results mixed, but overall a rosy picture
  - Critique by some –
    - Successful watershed projects are outnumbered by large number of failed projects
    - Most of the studies either depend on indirect impacts for evaluation which depends on mere perception of respondents OR
    - The studies depending on direct impacts for assessment don’t follow rigorous benchmarks for comparing values beforehand and after
    - Watershed projects have failed to convert large number of drought-prone areas into drought-proof areas

Watershed development scenario in India -4

- Some issues
  - Lack of scientific approach in watershed projects
    - No protocol or guidelines for predicting or estimating the effectiveness of water or soil conservation techniques
    - Success criteria mainly include indirect impacts like income generation, people's participation, institutional setup etc.
    - No protocol or guidelines for measuring direct impacts like reduction in soil runoff, increase in groundwater
  - Severe neglect towards drinking water issue, as the whole discourse is based on land development for increase in agricultural incomes

Objectives

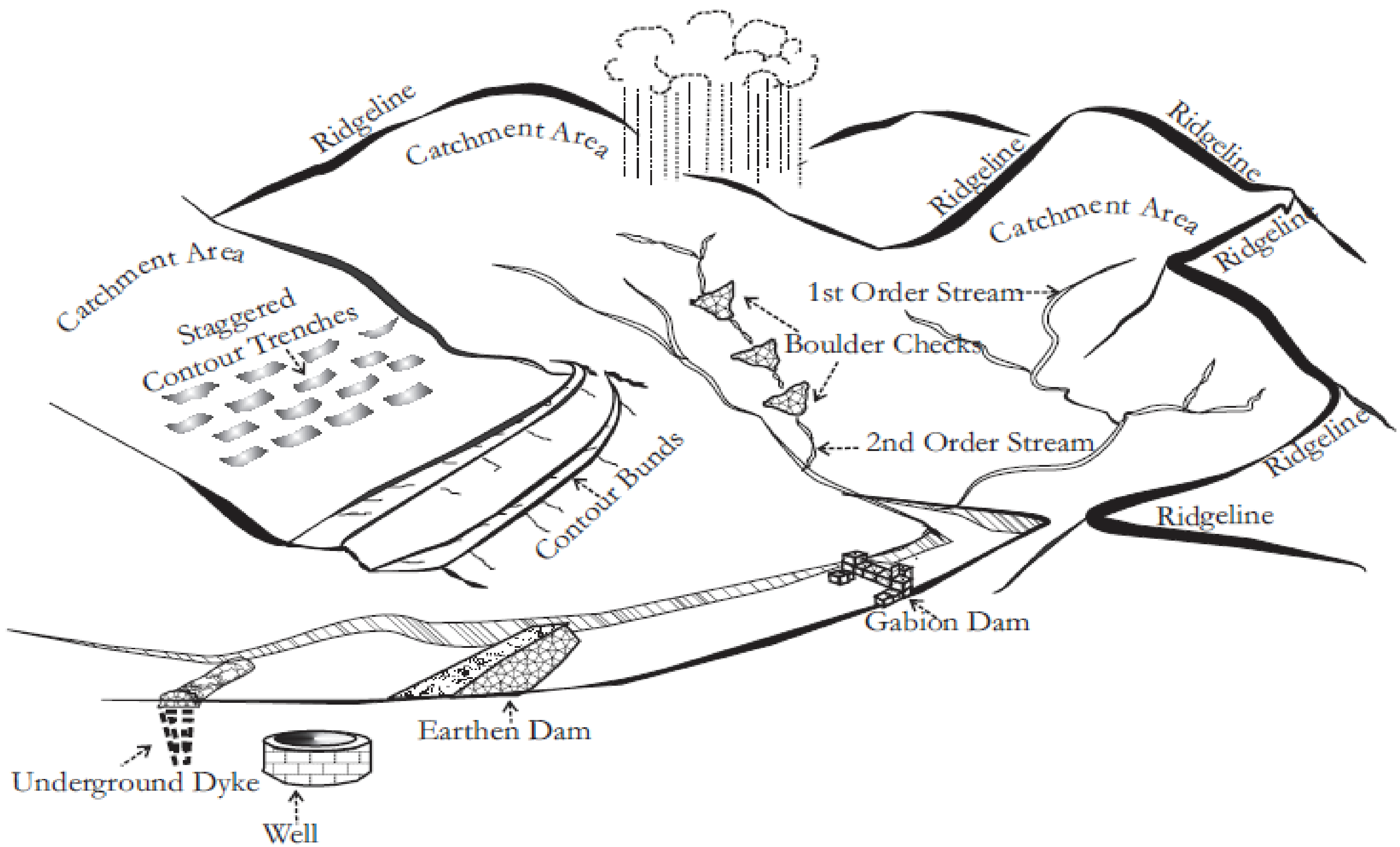
- To understand the technical aspects of watershed development
- To understand the role of watershed development in solving drinking water issue
- To understand the role of modelling in quantifying and estimating the results of watershed interventions
- **To create a development protocol for technical evaluation and estimation of watershed works, which will help in planning of watershed development**

through detailed understanding of

specific watershed interventions in Mokhada block

Technical aspects of Watershed Development -1

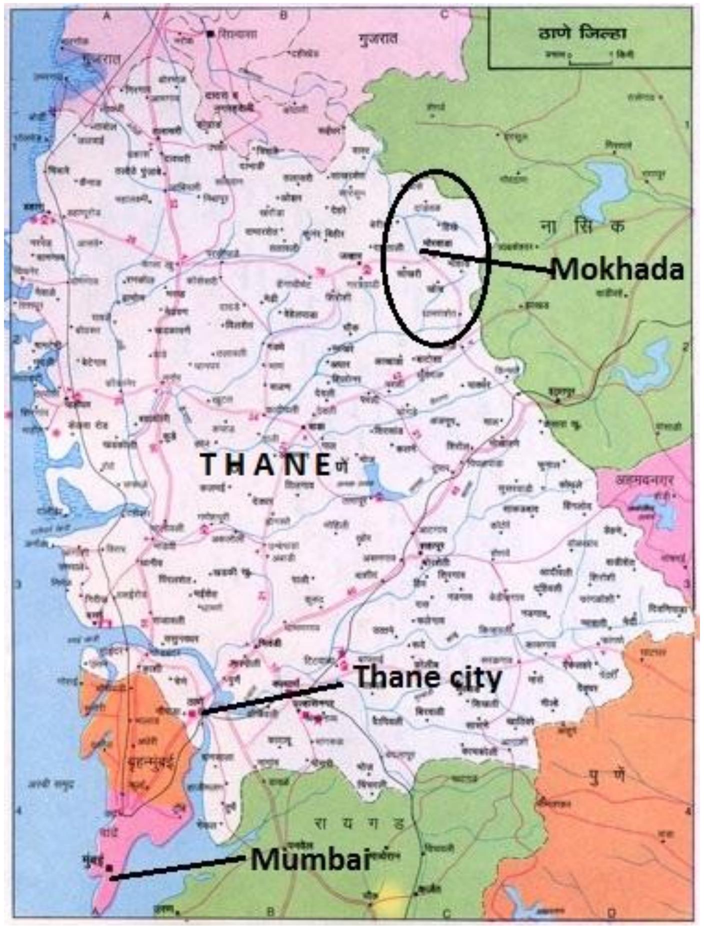
- What is watershed?
  - Watershed is the hydro-geological unit of area from which the rain water drains through a single outlet



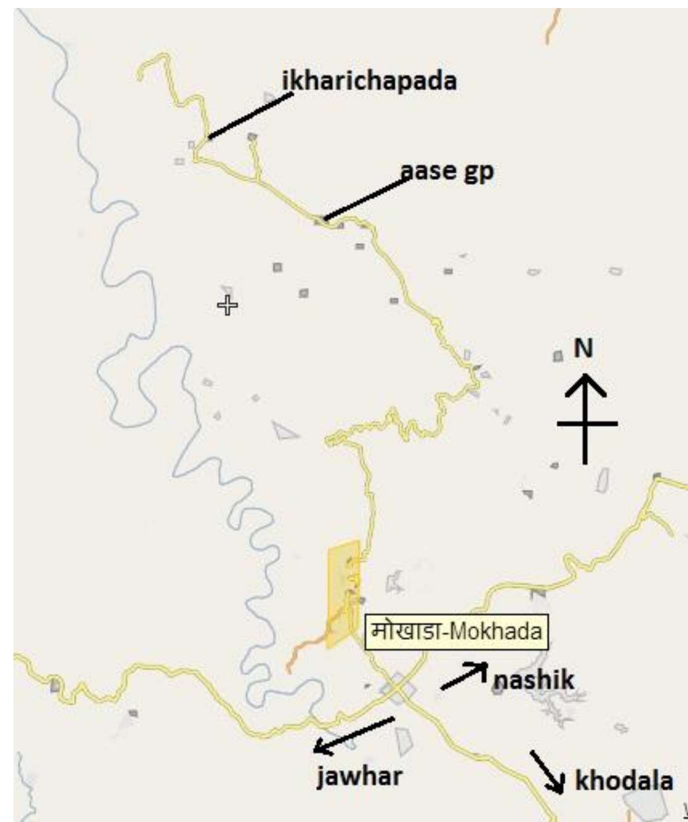
Technical aspects of Watershed Development -2

- What is watershed development?
  - Refers to any measures or interventions done at watershed level for conservation of natural resources like soil, forests, water or
  - measures taken for changes in land use, water use or cropping pattern in order to increase the net water stored within the watershed
- Different techniques
  - Ridge area treatment
    - Contour bunds, contour trenches, afforestation etc
  - Drainage line treatment
    - Loose boulder checks, gabions, Subsurface bunds, earthern dams, check dams etc.

Ikharichapada scenario -1



	Latitude	Longitude
Ikharichapada	20.0277°	73.3116°



Ikharichapada scenario -2

- Demography
  - Mokhada block is the most backward, tribal block of Thane district
  - Suffers from large number of developmental problems like poverty, malnutrition, water scarcity and lack of proper basic infrastructure
  - Ikharichapada –
    - 100% tribal (28 households, 206 souls)
    - Subsistence, rainfed farming (paddy, *varai*, *nachani*)
    - Very low yearly incomes
- Geography, Geology of the region
  - Northern tip of Western Ghats (heavy rainfall during monsoon)
  - Hilly terrain (elevations vary from 150m to 400m in Aase GP)
  - Part of Deccan Basaltic Province (shallow hard rock)

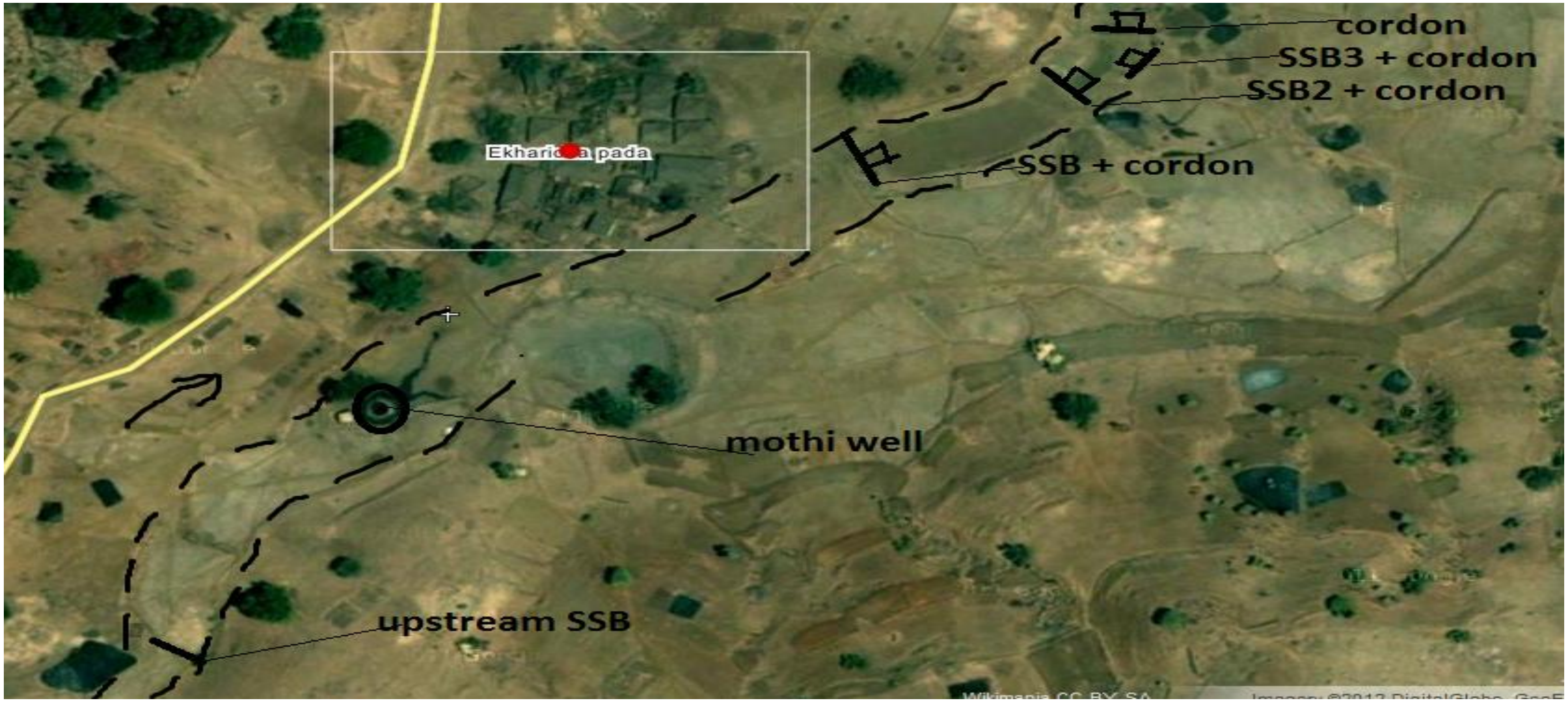
Ikharichapada scenario -3

- Drinking water scenario in Ikharichapada before the intervention
  - Dependence on groundwater for domestic water
  - Water runs off due to shallow hard rock and slopes
  - Low porosity and specific yield of basalt leads to low percolation and hence very low groundwater storage
  - Wells in the region have very low yields and dry up in few months after monsoon ends
  - Hence acute scarcity of water during dry months
  - Large dependence on insufficient and irregular tanker supply

Name of the source	Active / Inactive	Distance from the hamlet	Dries in
Mothi well	Active (primary source)	50m	March
Jalswarajya well	Inactive (poor water quality)	50m	-
Pond	Active (not for drinking)	50m	March
Waal River	Active	5km	-

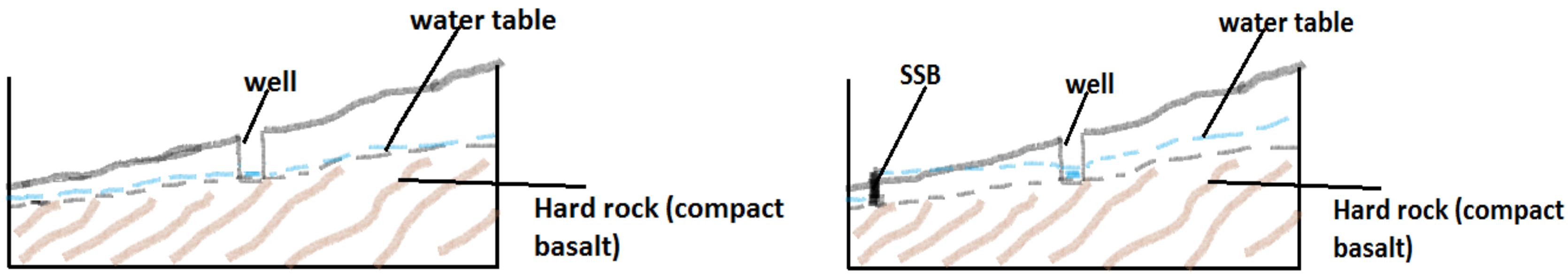
Ikharichapada scenario -4

- Watershed intervention in Ikharichapada (2010)
  - *Akshay Jal* programme of NGO, AROEHAN (Activities Related to Organization of Education, Health and Nutrition)
  - Technical help by *Natural Solutions*

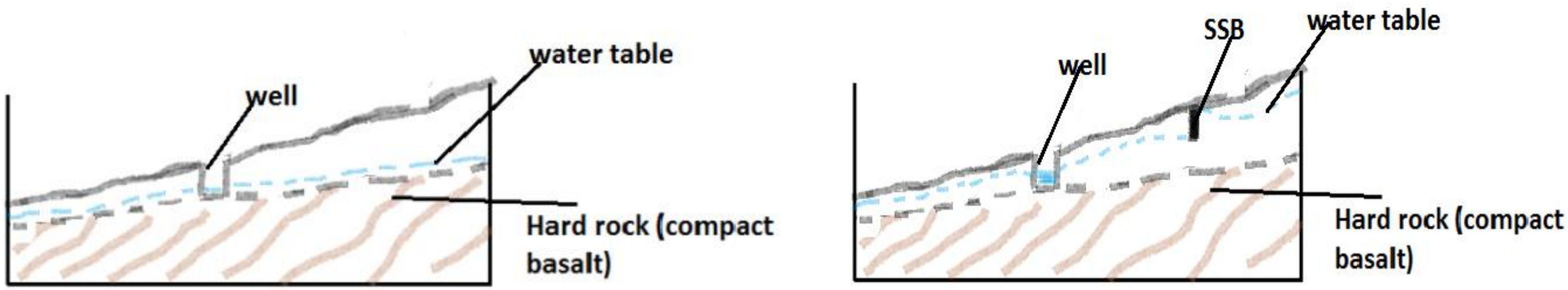


Ikharichapada scenario -5

- Subsurface bunds as the solution



Downstream subsurface bund



Upstream subsurface bund

Ikharichapada scenario -6

- Impacts of the watershed interventions in Ikharichapada
  - Water level in the Mothi well rose in the year 2011 and also in 2012
    - In 2011, the well did not go dry
    - In 2012, the well went dry in 2^{nd} week of May (had to depend on tanker for last two-three weeks of dry season
  - The reasons for well getting dry in May in the 2^{nd} year, according to NGO and local people
    - More people from neighboring villages coming for water on the well
    - More brick making due to more availability of water leading to more burden on the well
  - Overall positive results according to local people and NGO

Modelling Ikharichapada intervention -1

- Need for technical analysis and modelling
  - The results of the intervention although positive, are variable. This makes scientific explanation of the impacts difficult
  - As there is variation in demand, consumption of water per year, and variation of dependence of neighboring villages on the well, the simple well level monitoring approach towards cost-benefit analysis is inadequate
  - A quick study of interventions by a senior geologist Dr. Himanshu Kulkarni concluded that downstream bunds will not be much effective in raising water levels in the well. Hence there is a need to do thorough impact assessment of individual bunds
  - NGO, AROEHAN is planning to replicate this intervention in other water scarce regions in Mokhada

Modelling Ikharichapada intervention -2

- Modelling
  - GMS (Groundwater Modeling Software) version 7.1 was used to model Ikharichapada scenario
  - GMS is basically a GUI (Graphical User Interface) layer over actual groundwater flow equation solver, MODFLOW
  - MODFLOW (a 3D finite difference flow model developed by United States Geological Survey (USGS) department. MODFLOW version 2000 was used in the present study
- Approach
  - Basic learning of the science of groundwater flow and logic of MODFLOW and GMS
  - Building a conceptually correct framework of Ikharichapada scenario based on key observations and data from the field

Ikharichapada conceptual model -1

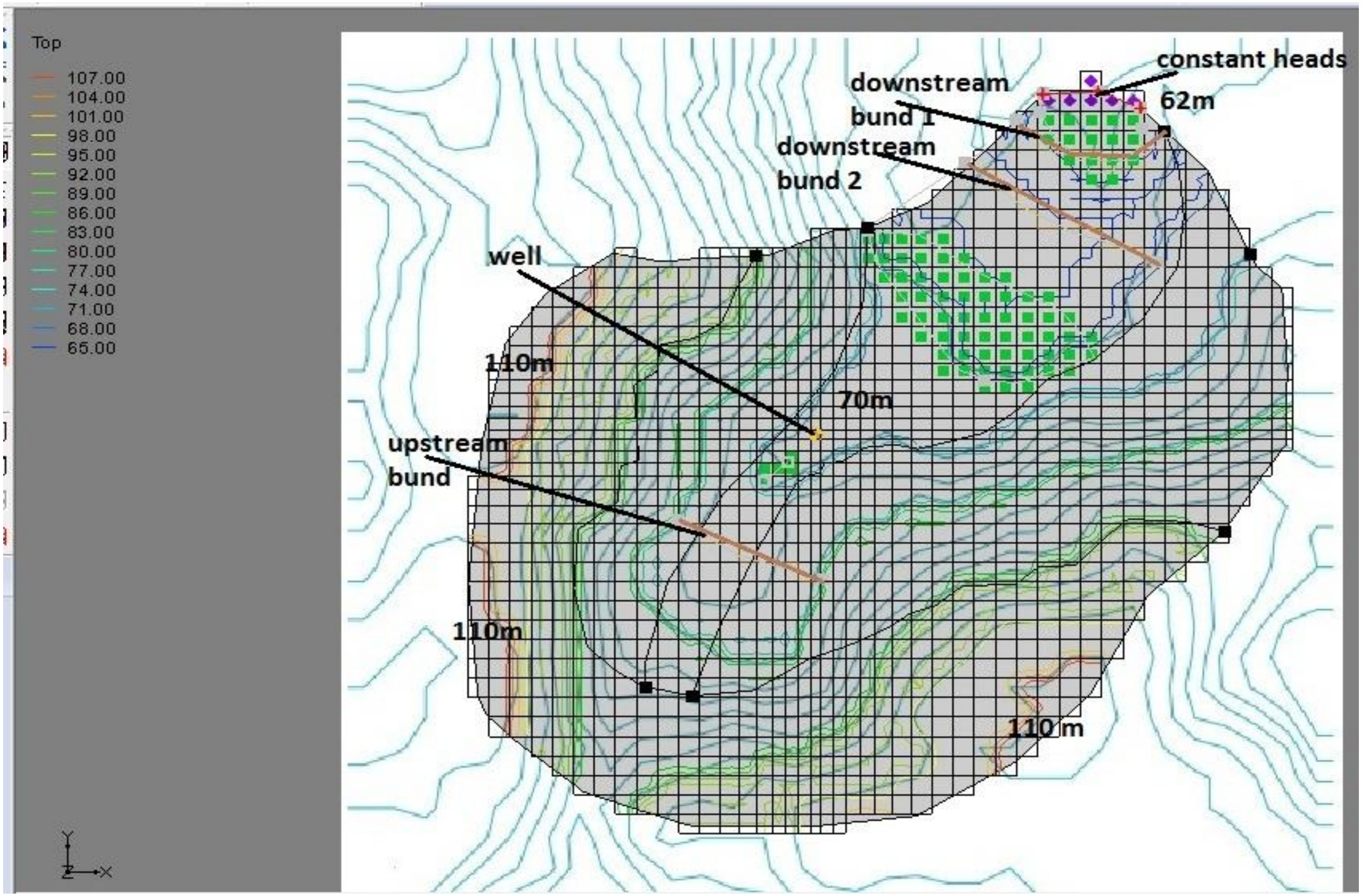
- Aim – to develop a model which is conceptually correct i.e. a first cut model which matches with the field conditions

- Approach –
  - Key observations on field
    - Positions of wells, subsurface bunds, stream etc.
    - Location of springs and water logging in fields and its duration
    - Life of springs before and after the interventions
    - Water levels in the well at different times

Ikharichapada conceptual model -2

- Secondary data
  - Getting elevation and contour data
  - Geological data specific to basaltic terrain
  - Rainfall data
  - Water withdrawal from well
- Overlaying contour data and elevation data over the grid and marking the watershed boundary
- Developing framework for parameter refining or a system of variables where the unknown variables like hydraulic conductivity and thickness of the layer are adjusted through series of iterations to reach to a model which is conceptually correct and matches with the field conditions

Ikharichapada conceptual model -3



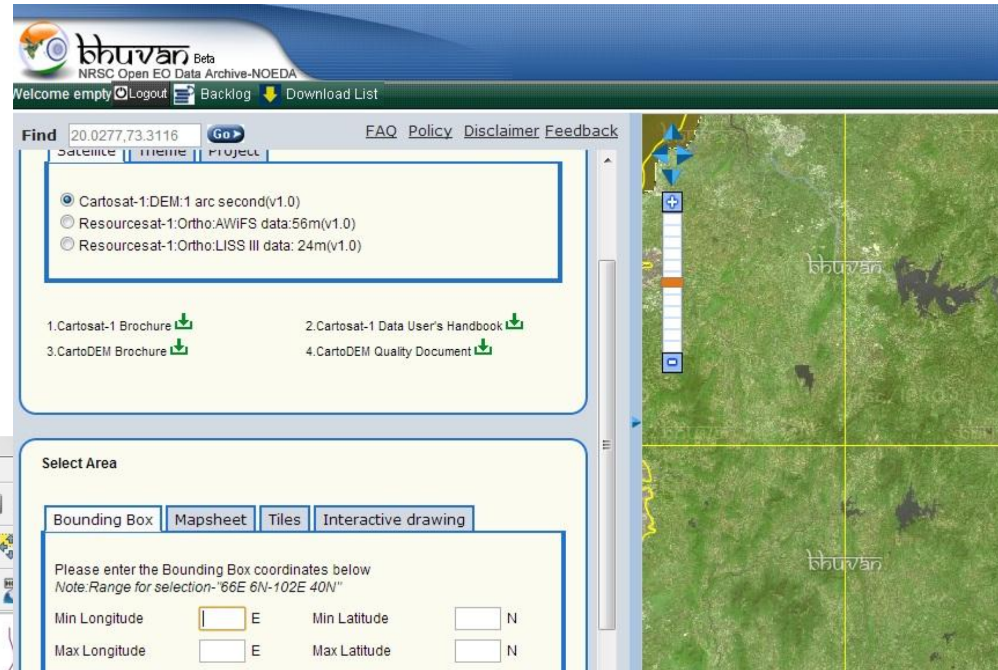
Ikharichapada conceptual model -4

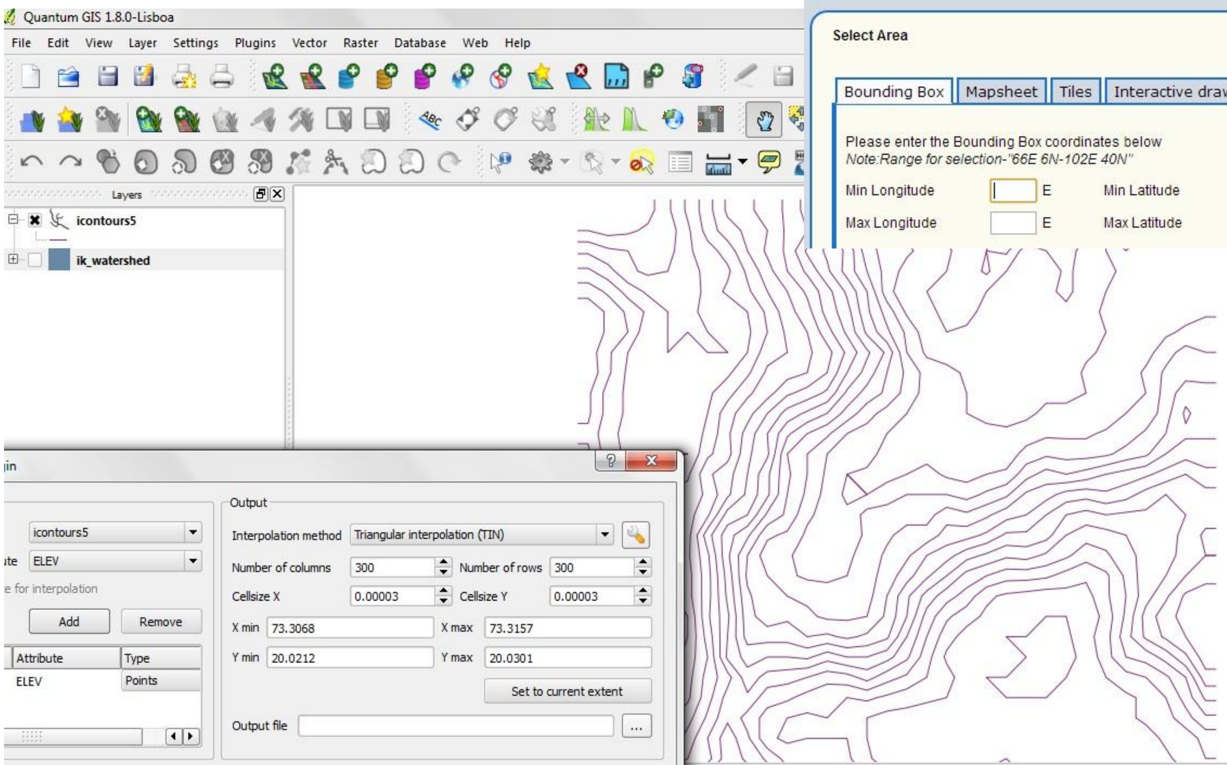
- Key observations from field

No	Observation
1	The well is 10m deep and is located within the stream
2	The water level in the well is just 2m below surface during monsoons
3	The dependence on well is less in monsoon (about 6 cum/day) and increases as the dry season progresses (at the end of dry season, withdrawal is almost 12 cum/day)
4	The fields downstream to the well are water logged during monsoon
5	The springs downstream to well (just close to the outlet of watershed) used to exist till late-December or early-January before intervention; after intervention they continue till March
6	The watershed tapers towards the outlet; thick in highly elevated areas and thins out in the direction of stream flows
7	Three layers: topmost soil layer, followed by slightly porous vesicular amygdaloidal basalt, followed by impermeable compact basalt layer

Ikharichapada conceptual model -5

- Secondary data
  - Getting elevation data
    - DEM to Contour
    - Contour to TIN





Ikharichapada conceptual model -6

- Other Secondary data

Parameter	Value
Rainfall data (average of last 10 year-data of Mokhada)	2700 mm per annum
Infiltration rate (assumed)	Less than 10% of rainfall i.e. 2mm per day OR 0.002 m per day
Specific yield of the whole watershed	0.03 (of vesicular basalt)

- Assumptions and constraints
  - Only single layer was considered
  - Geological layer considered as homogeneous and isotropic
  - Three conductivity zones – high (along the stream bed), medium (in the vesicular basalt region i.e. medium elevations) and low (in the compact basalt region i.e. high elevations)
  - Leakage characteristic of barrier package used for subsurface bunds (0.04) – means barrier was considered almost leak-proof
  - As single layer was considered, barriers were simulated for the whole thickness of the layer; but in reality barriers are only 3-4 m deep into the ground

Ikharichapada conceptual model -7

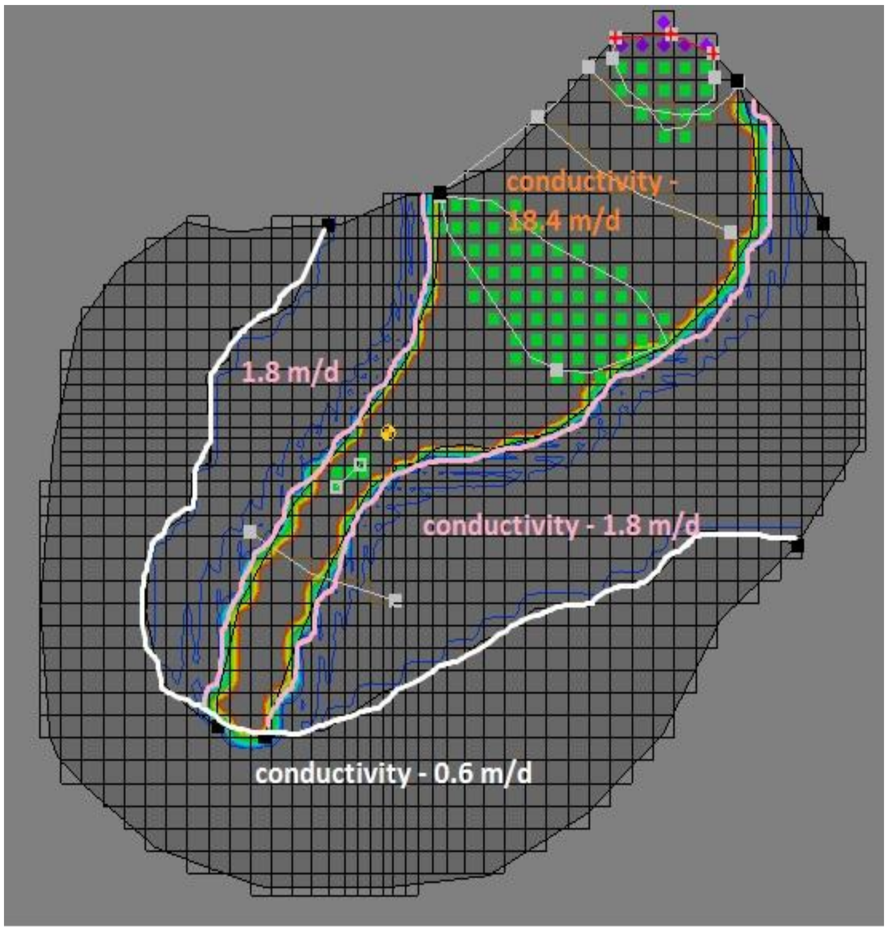
- Steady state and transient state parameters

Stress period	Type	No. of days	Period
1	Steady state	1	30th Sep – 1st Oct 2012
2	Transient state	249	2nd Oct 2012 – 7th Jun 2013

Parameter	Steady state	Transient state
Recharge rate	0.0022 m/d	0
Well discharge	-6 cum/d	2nd Oct to 8th Jan: -8 cum/d; 9th Jan to 18th Apr: -10 cum/d; 19th Apr onwards: -12 cum/d
Constant heads	61.5 m	Gradually decreases from 61.5 m to 54.8m

Ikharichapada conceptual model -8

- Refining the model to develop a system of variables



High conductivity region	Medium conductivity region	Low conductivity region
20 m/d	4 m/d	0.6 m/d

- Bottom values of the layer (i.e. thickness)
  - In the upper catchment, the layer thickness reduced from 37m to 22 m
  - In the middle region, the thickness reduced from 18m to 13m
  - Near the watershed mouth, the thickness ranged from 11m to 8m

Ikharichapada conceptual model -9

- Model scenarios
  1) With no intervention – ***"no bund"***
  2) With only downstream sub-surface bund just near the outlet of watershed (at elevation 62m) – ***"only ds 1"***
  3) With only downstream sub-surface bund upstream of the downstream bund and downstream of well (at elevation 65m) – ***"only ds 2"***
  4) With both downstream sub-surface bunds – ***"both ds"***
  5) With only upstream sub-surface bund, i.e. upstream of the well (at elevation 75m) – ***"only us"***
  6) With all three sub-surface bunds – ***"all bunds"***

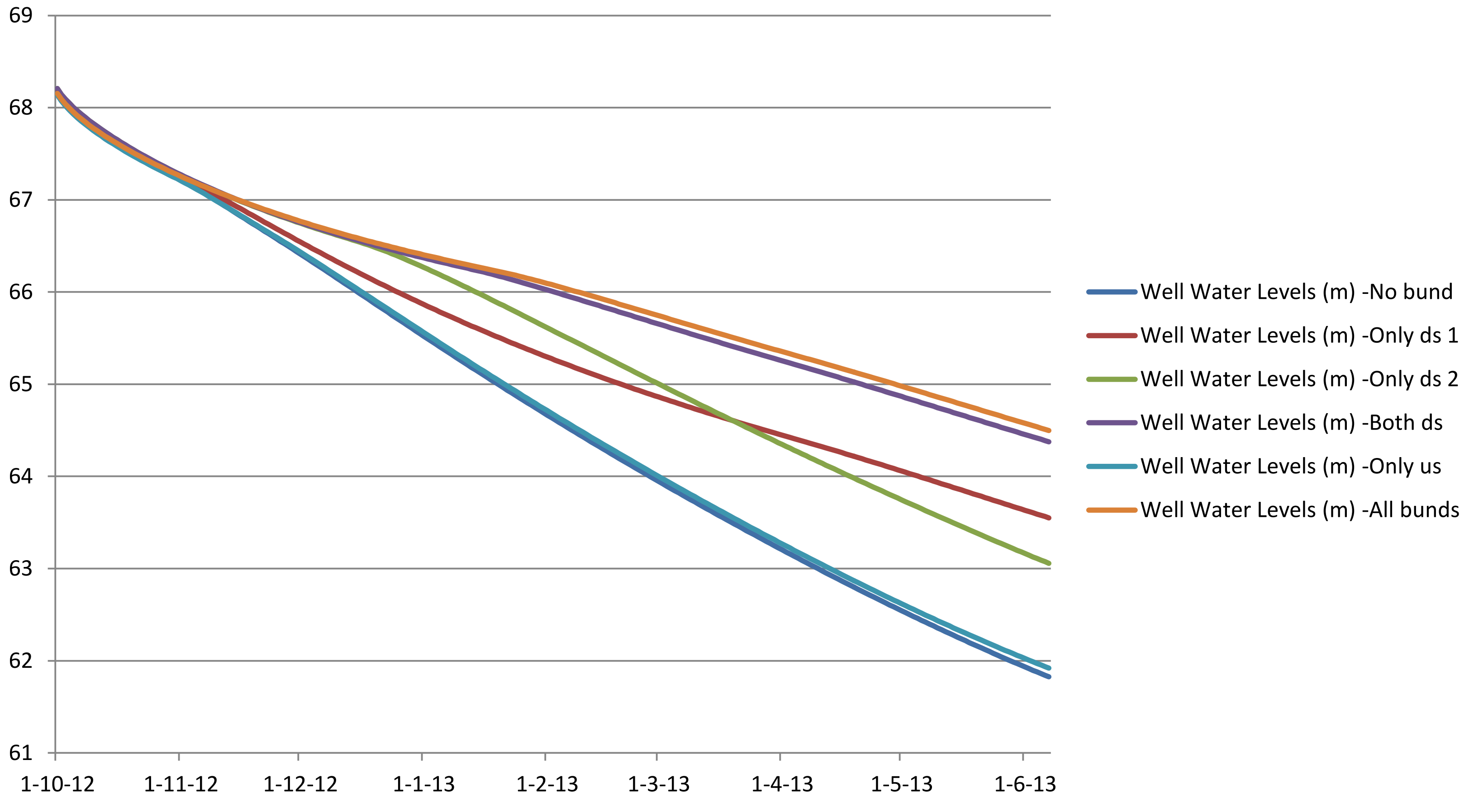
Ikharichapada conceptual model -10

- Running the model
  - Impact on well

Scenario	Well heads as on 1st Oct 2012	Well heads as on 7th Jun 2013	Change in heads (m)	Net increase over “no bund” condition
No bund	68.19	61.82	-6.36	0
Only ds 1	68.19	63.55	-4.64	1.72
Only ds 2	68.20	63.06	-5.15	1.21
Both ds	68.20	64.38	-3.83	2.53
Only us	68.13	61.92	-6.21	0.15
All bunds	68.15	64.5	-3.65	2.71

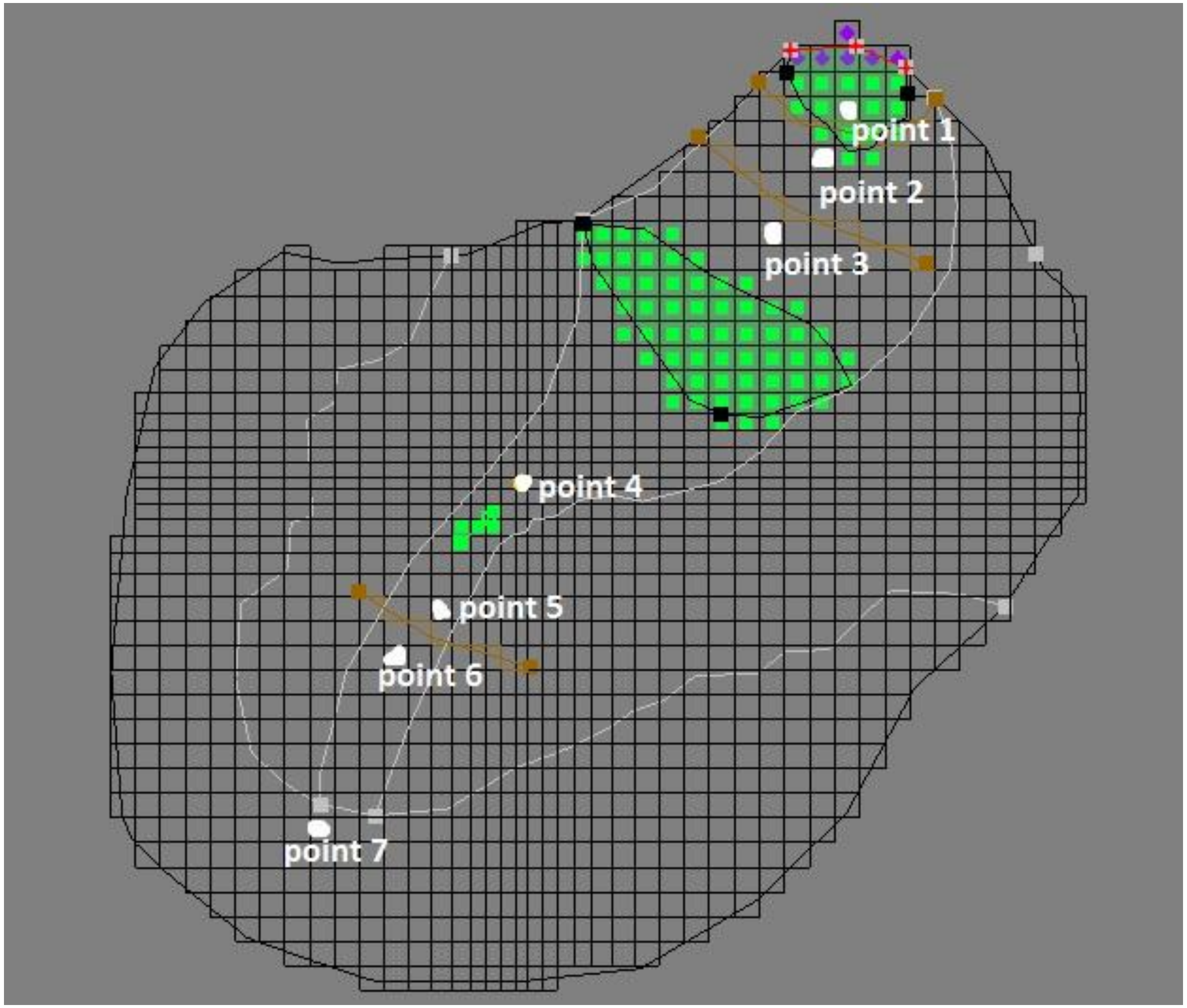
Ikharichapada conceptual model -10

- Running the model
  - Impact on well



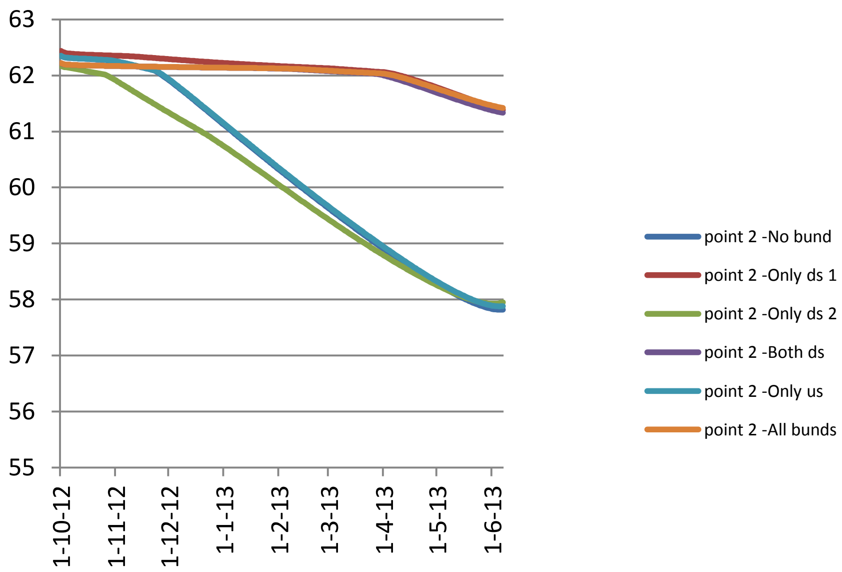
Ikharichapada conceptual model -10

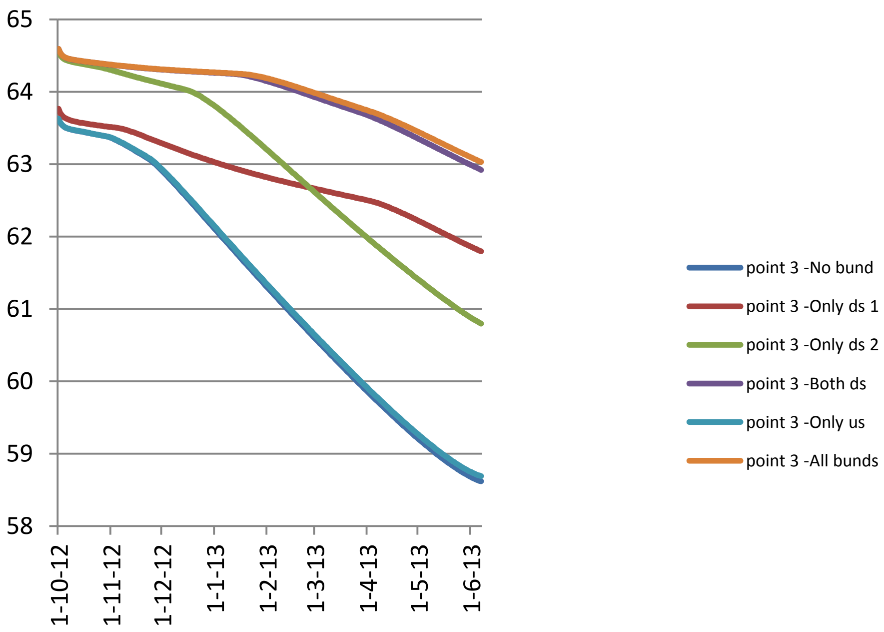
- Running the model
  - Impact on other points in watershed



Ikharichapada conceptual model -10

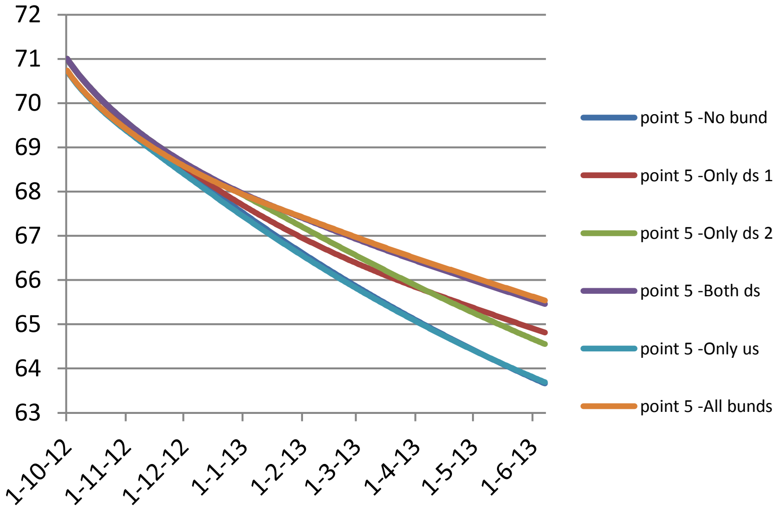
- Running the model
  - Impact on points 2 (between two downstream bunds) and 3 (just above upstream bund) – shadow regions

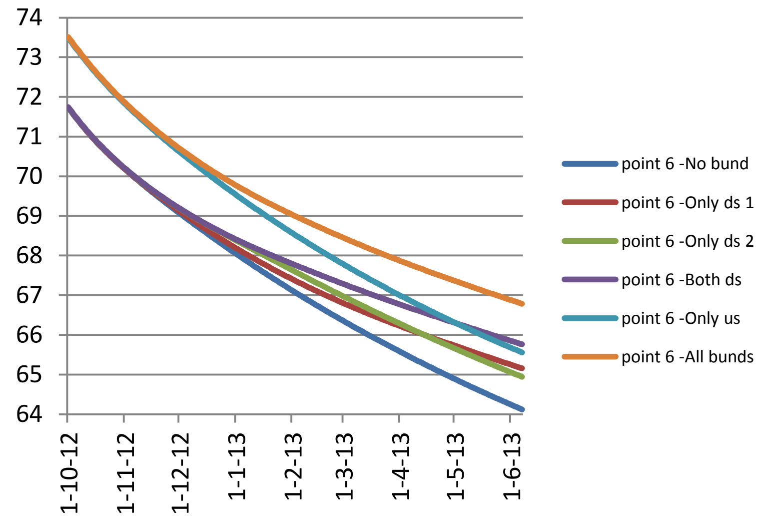


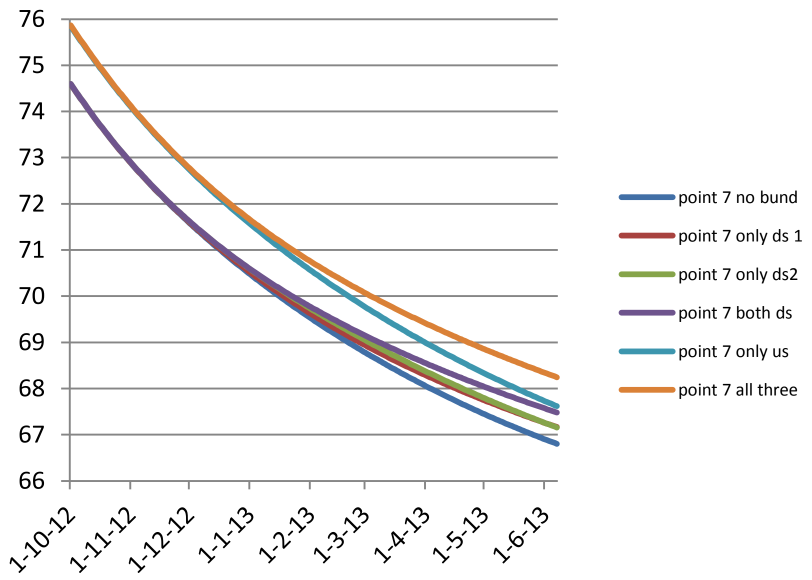


Ikharichapada conceptual model -11

- Running the model
  - Impact on points 5, 6 and 7 (shadow regions)

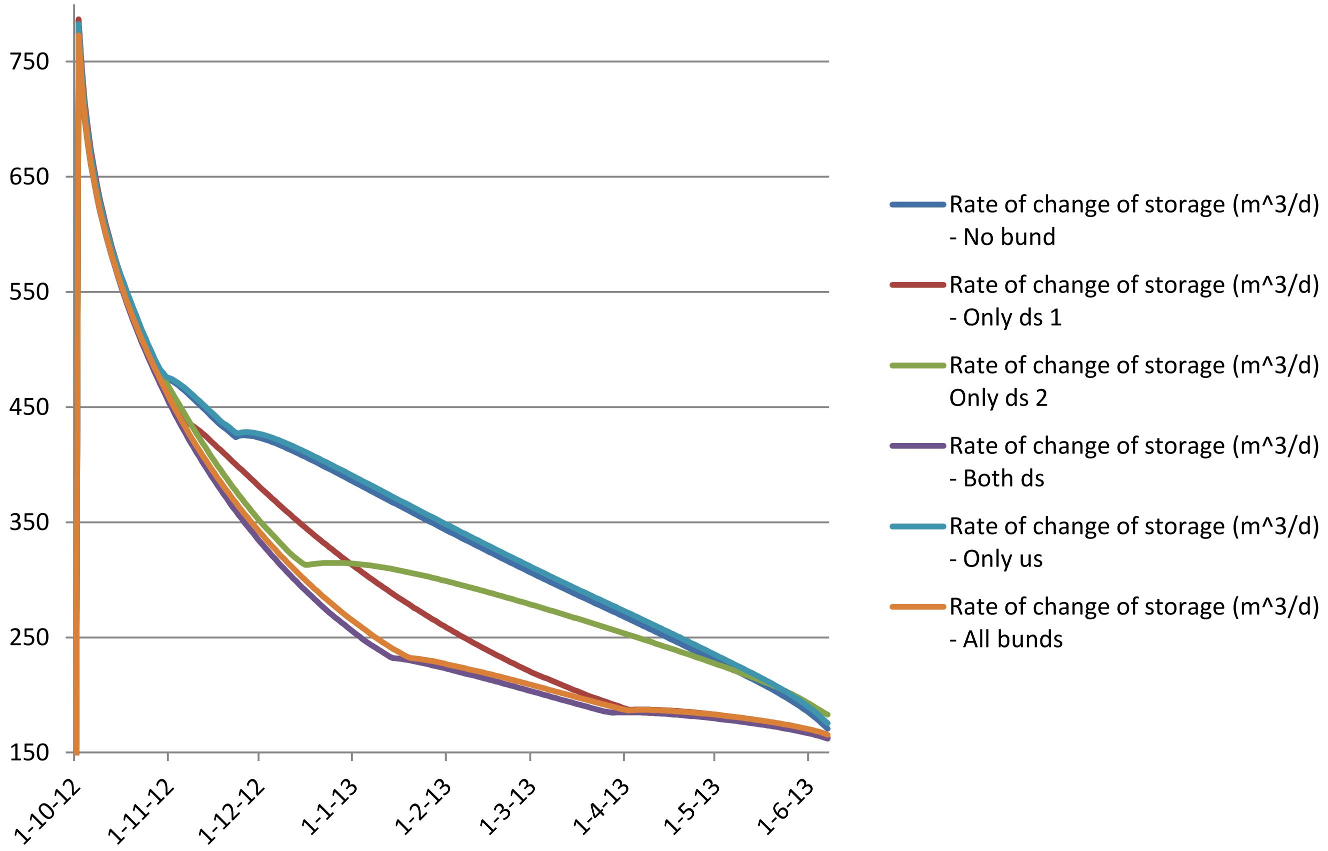






Ikharichapada conceptual model -12

- Running the model
  - Impact on net water storage in the watershed



Ikharichapada conceptual model -13

– Impact on net water storage in the watershed

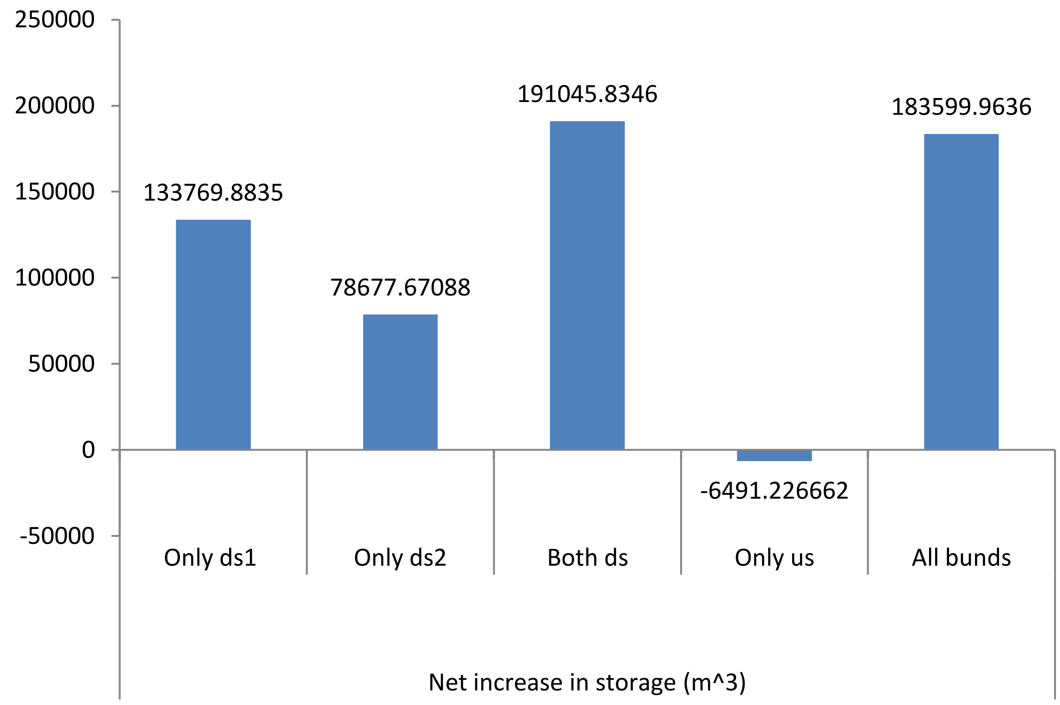
$$Total\ area\ of\ watershed = 403596.4\ m^2$$

$$Total\ no.of\ cells\ in\ watershed\ model = 1319$$

$$Average\ area\ of\ each\ cell = 305.9866\ m^2$$

$$Net\ water\ stored\ in\ each\ cell$$

$$= Average\ area\ of\ each\ cell\ \times height\ of\ water\ column\ at\ that\ cell$$



Ikharichapada conceptual model -14

- Conclusions
  - Based on the key observations, secondary data and assumptions, a conceptually correct model which satisfies the on-field conditions, was developed
  - The model along with its constraints and approximations, showed that the upstream subsurface bund was far less effective (in fact had negative impact) on the well
  - On the other hand, the downstream bunds were far more effective in raising the water levels in well as well increasing net water storage in the watershed
  - A similar model can be used effectively to demonstrate the predictability of other watershed interventions like CCT, check dam etc. at an elementary level

Future Work -1

- Refining current model
  - Shifting to two layers
    - Geological survey required (Electrical resistivity survey ER or Multi-electrode Resistivity Imaging methods MERI)
  - Verification of parameters
    - Conductivity tests
      - In-situ, Augerhole method as well as laboratory method for measuring soil conductivity
      - Conductivity from ER or MERI methods for different basalt layers
    - Constant heads
      - Monitoring heads at watershed outlet for getting known heads condition by boreholes or trial data

Future Work -2

- Towards larger objective
  - Developing a simple protocol to assess and evaluate the technical soundness of water harvesting structures and watershed interventions

Thank you