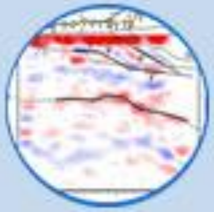
# Sustainability in management of groundwater is effective jointly with scientific inputs and stakeholder's decision making

Shakeel Ahmed, N.C. Mondal & V.M. Tiwari

**CSIR-National Geophysical Research Institute, Hyderabad, India**

International Workshop on Science, Technology, Innovation and Management for Water Sustainability, CSIR-NISTADS, New Delhi, India

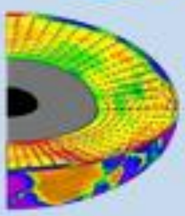
# Major Research Areas



Geodynamics

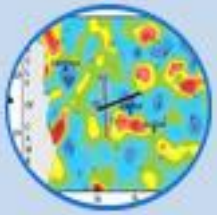
Groundwater

Mineral and Engineering Geophysics



Theoretical Geophysics

Geochemistry and Geochronology



Hydrocarbon Exploration

Seismology

Special Activities

# CSIR - NATIONAL GEOPHYSICAL RESEARCH INSTITUTE

A Premier Research Institute in Solid Earth

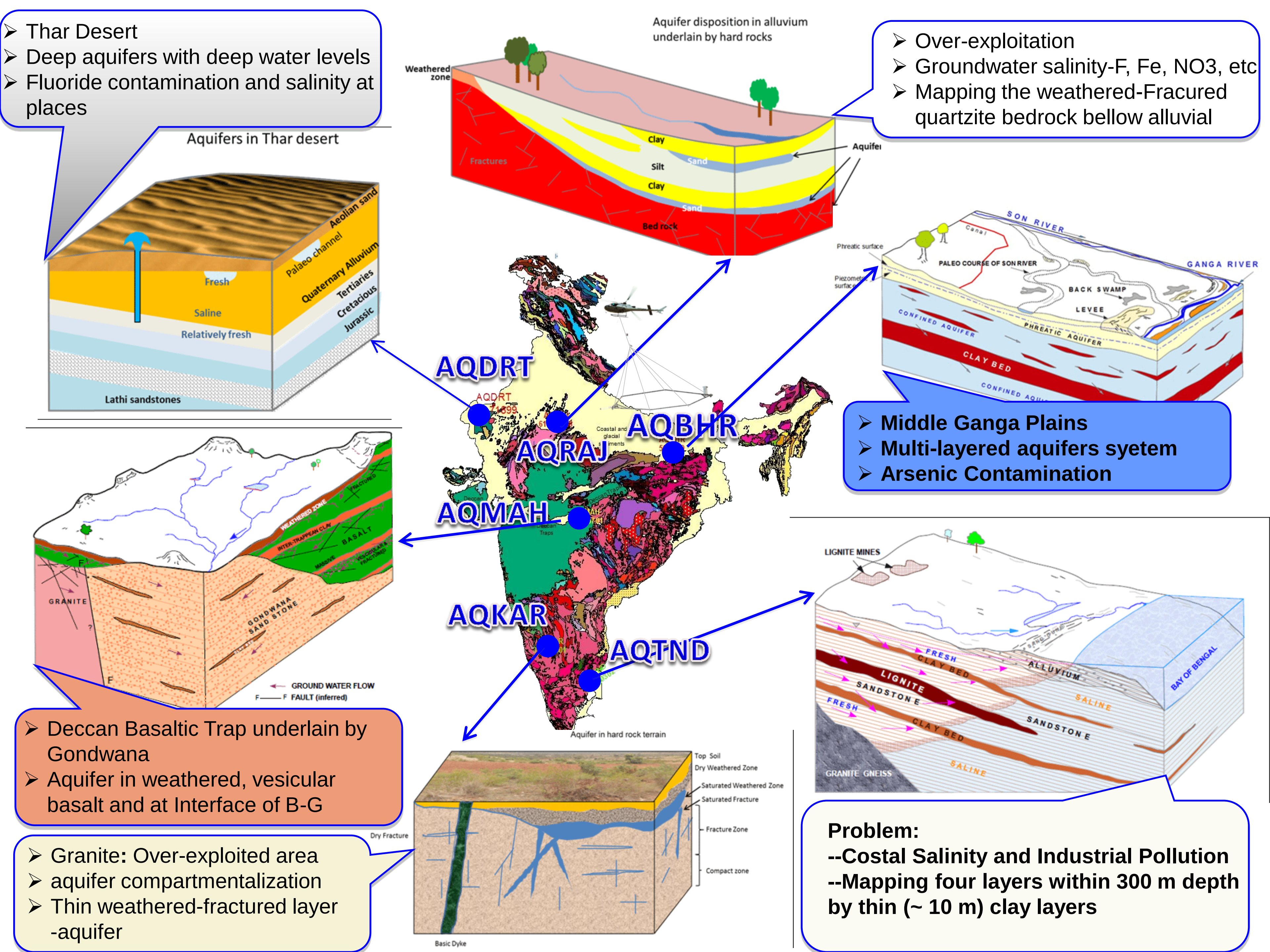
75 Years of CSIR Touching Lives

## Research Themes

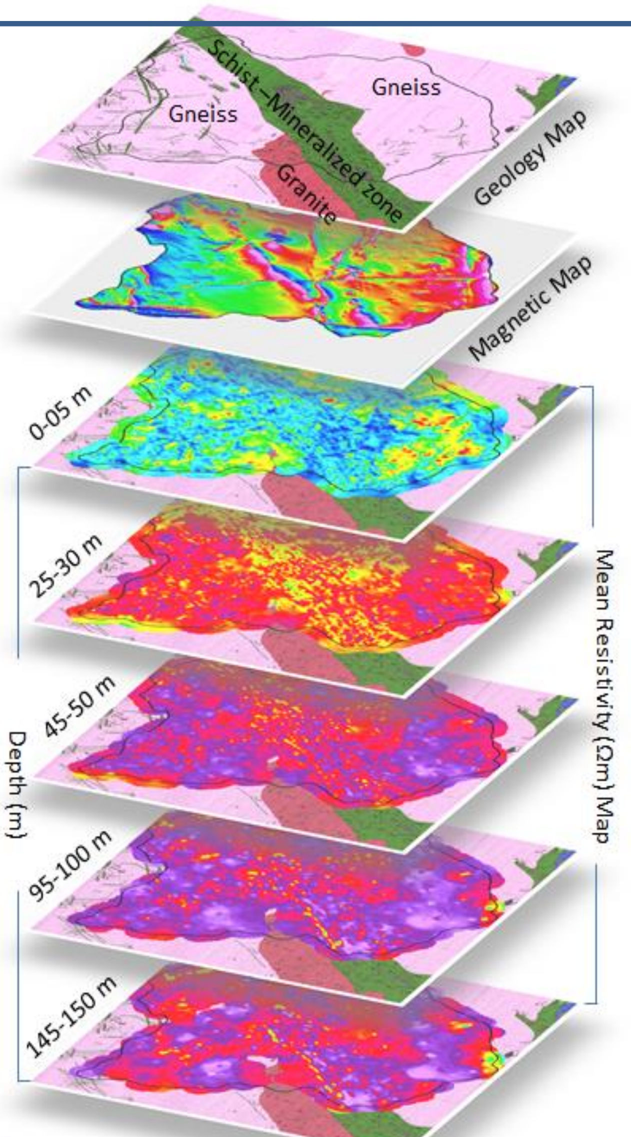
- Geodynamics
  - Overview
  - Heat Flow & Heat Production Studies
  - Seismic Tomography
  - Evolution Of Sutures/Shallow Mantle Boundaries
- Geochemistry and Geochronology
  - Overview
  - Geochemistry
  - Geochronology Isotope Studies
  - Paleomagnetism
  - Paleoclimate Studies
- Groundwater
  - Overview
  - Aquifer Mapping
  - Aquifer Recharge
- Hydrocarbon Exploration
  - Overview
  - Controlled Source Seismics
  - Gravity & Magnetic
  - Magnetotellurics and Deep Resistivity Sounding
  - Gas Hydrates and Other Conventional Resources
- Mineral and Engineering Geophysics
  - Overview
  - Mineral Physics
  - Engineering Geophysics
  - Airborne Geophysics
- Seismology
  - Overview
  - Earthquake Precursory Studies and Tsunami Modelling
  - Passive Seismology
  - South India/NE Studies
  - Seismological Observatory
- Theoretical Geophysics
  - Overview
  - Time Series Analysis and Geophysical Data Modelling
  - Theoretical and Computational Geophysics
- Special Activities
  - Overview
  - GPS and Antarctia
  - Magnetic Observatory
  - CSIR 800

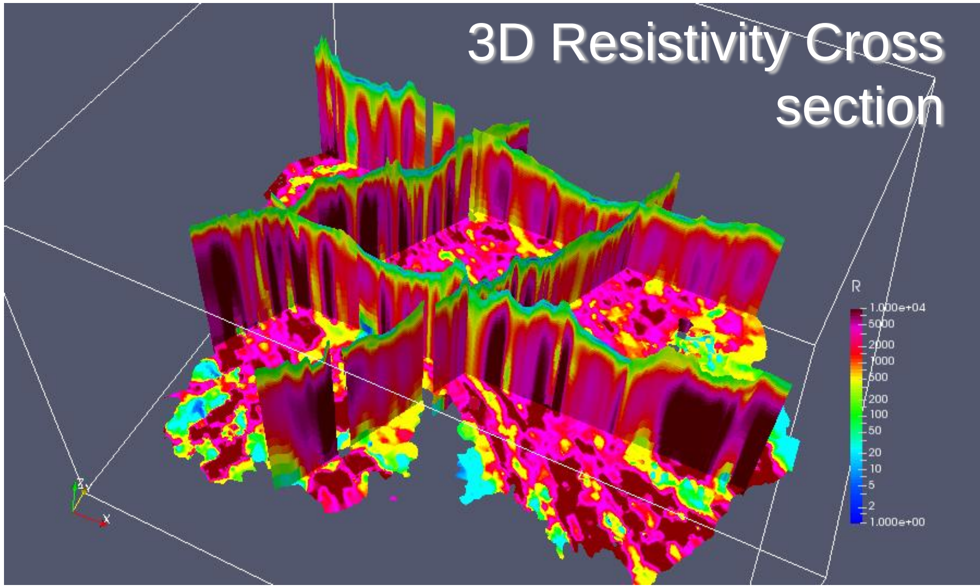
# Groundwater Prospective

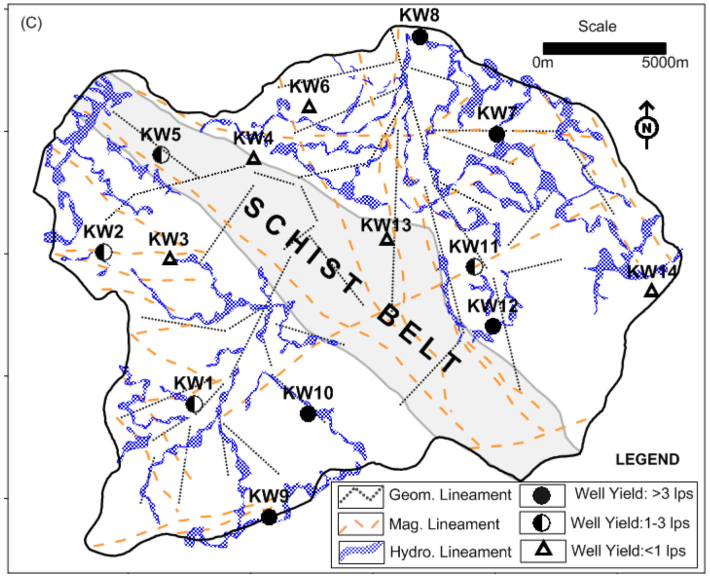
- A major program of NGRI since its inception is groundwater exploration & management,
- Exploration for groundwater using resistivity surveys has been extensively applied in water-stressed areas to delineate the configuration of different aquifer,
- The studies also focus on dynamics of aquifers due to variable parameters such as precipitation, recharge and extraction that are required to model the groundwater flow.
- NGRI has expertise in R-C analog modeling but now upgraded to numerical modeling.
- NGRI has unique capability in the country to undertake tracer studies for visualization of hydrodynamic changes due to aquifer over-exploitation.
- Facilities for groundwater dating are established and applied to complex hydrological systems.
- **CSIR-NGRI has very successfully carried out state-of-the-art Heliborne Transient Electromagnetic investigation first time in India and obtained fascinating results on the aquifer systems and its spatial characteristics covering almost all types of geological formation present in the country.**
- Efforts are on to enhance natural water systems and treatment for safe and sustainable water supply in India.


➢ Thar Desert
➢ Deep aquifers with deep water levels
➢ Fluoride contamination and salinity at places
Aquifers in Thar desert
Aeolian sand
Palaeo channel
Quaternary Alluvium
Tertiaries
Cretacious
Jurassic
Fresh
Saline
Relatively fresh
Lathi sandstones
Aquifer disposition in alluvium underlain by hard rocks
Weathered zone
Clay
Silt
Clay
Sand
Sand
Fractures
Bed rock
Aquifer
➢ Over-exploitation
➢ Groundwater salinity-F, Fe, NO3, etc
➢ Mapping the weathered-Fracured quartzite bedrock bellow alluvial
SON RIVER
Canal
Phreatic surface
Piezometric surface
PALEO COURSE OF SON RIVER
GANGA RIVER
BACK SWAMP
LEVEE
CONFINED AQUIFER
PHREATIC AQUIFER
CLAY BED
➢ Middle Ganga Plains
➢ Multi-layered aquifers syetem
➢ Arsenic Contamination
AQDRT
AQRAJ
AQBHR
AQMAH
AQKAR
AQTND
Deccan Traps
WEATHERED ZONE
FRACTURED
INTER-TRAPPEAN CLAY
BASALT
MASSIVE
VESICULAR & FRACTURED
GRANITE
GONDWANA SAND STONE
GROUND WATER FLOW
FAULT (inferred)
➢ Deccan Basaltic Trap underlain by Gondwana
➢ Aquifer in weathered, vesicular basalt and at Interface of B-G
Aquifer in hard rock terrain
Top Soil
Dry Weathered Zone
Saturated Weathered Zone
Saturated Fracture
Fracture Zone
Compact zone
Dry Fracture
Basic Dyke
➢ Granite: Over-exploited area
➢ aquifer compartmentalization
➢ Thin weathered-fractured layer -aquifer
LIGNITE MINES
ALLUVIUM
BAY OF BENGAL
FRESH
CLAY BED
LIGNITE
SANDSTONE
SALINE
GRANITE GNEISS
Problem:
--Costal Salinity and Industrial Pollution
--Mapping four layers within 300 m depth by thin (~ 10 m) clay layers

# Pilot Aquifer Mapping Project AQKAR, Tumkur District, Karnataka-Crystalline Hardrock



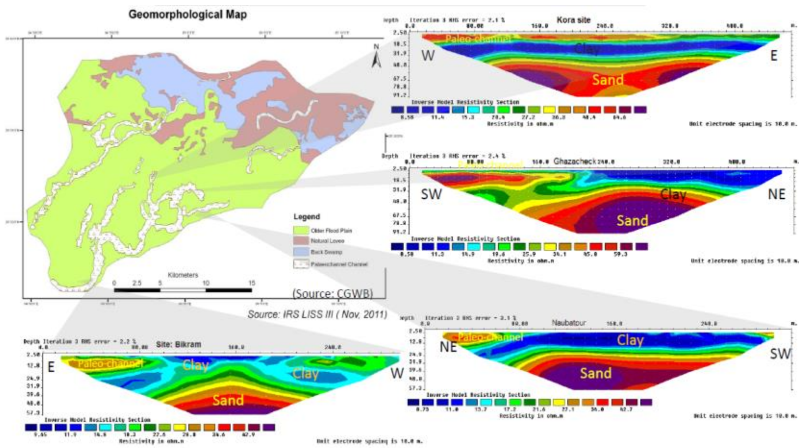



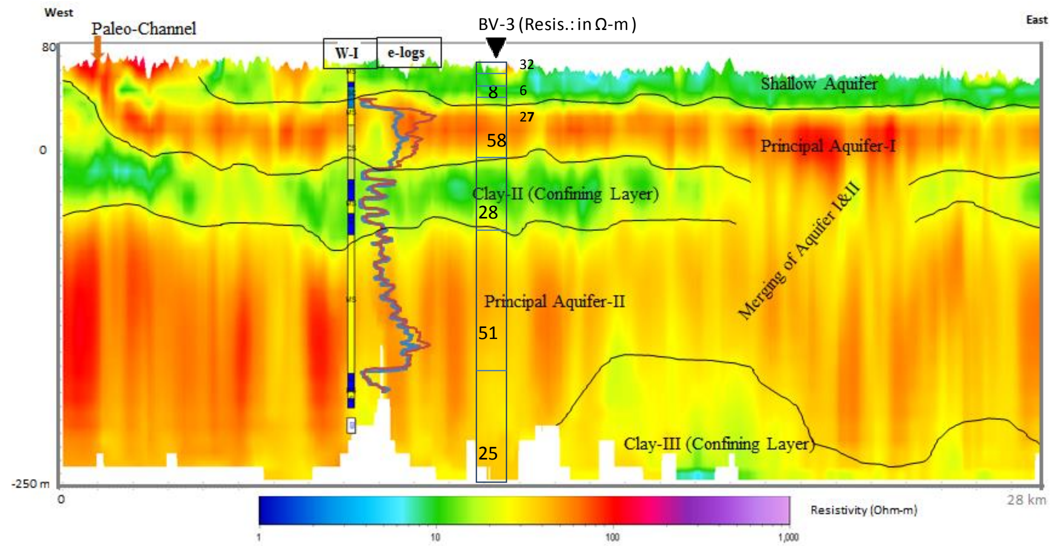

NATIONAL GEOPHYSICAL RESEARCH INSTITUTE

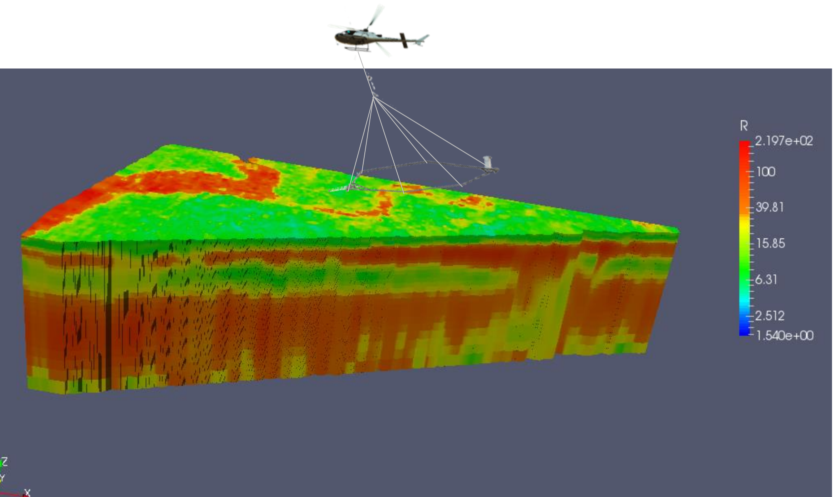
# Pilot Aquifer Mapping Project AQBHR, Patna District, Bihar – *Ganga Alluvium*

## Palaeo-channels:



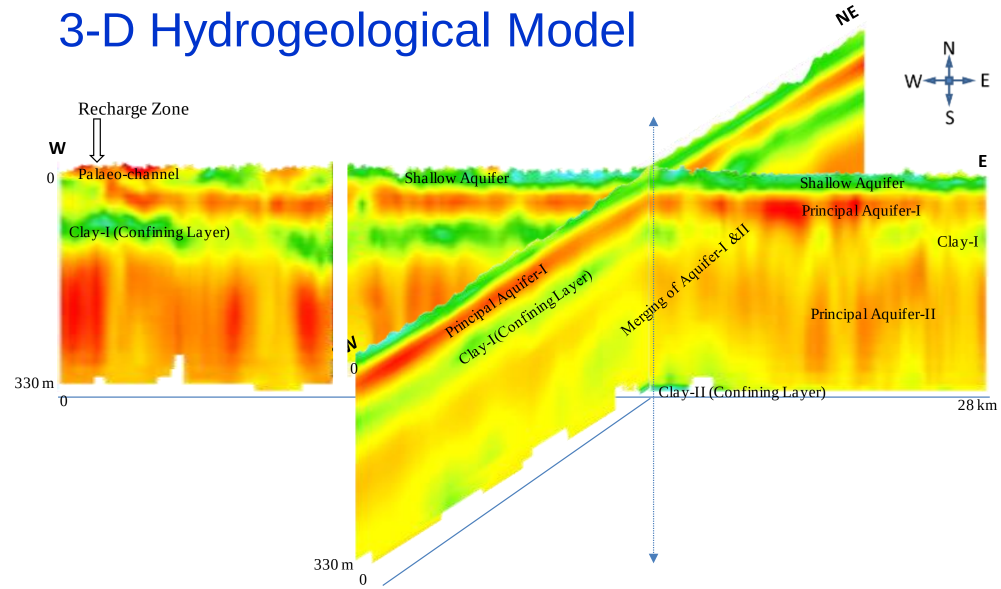

## Delineation palaeochannels & aquifer system



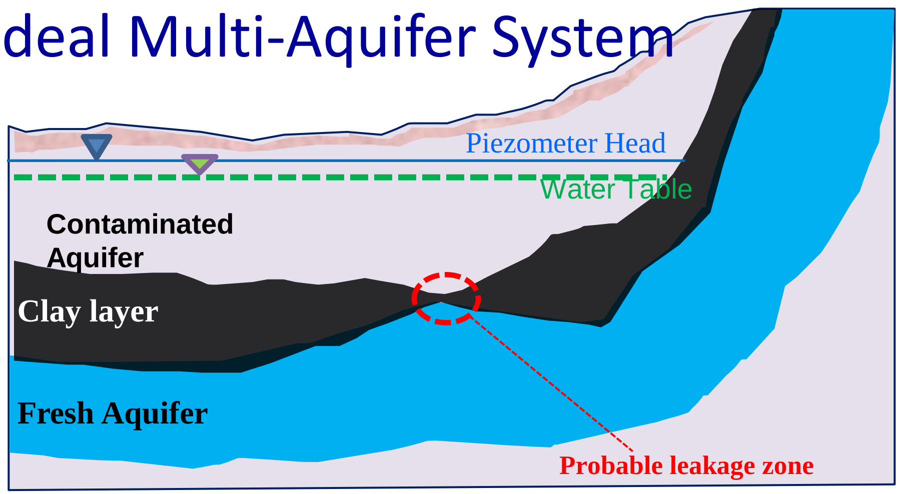



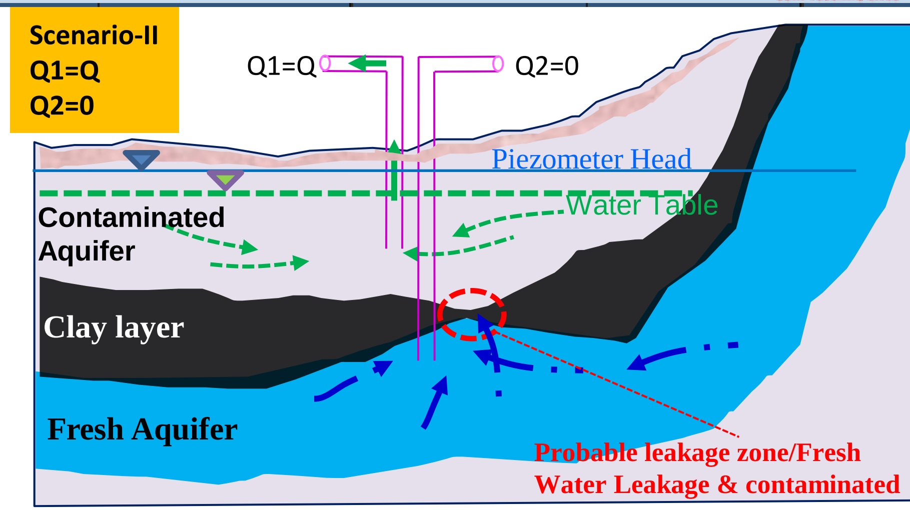

## 3-D Resistivity Model

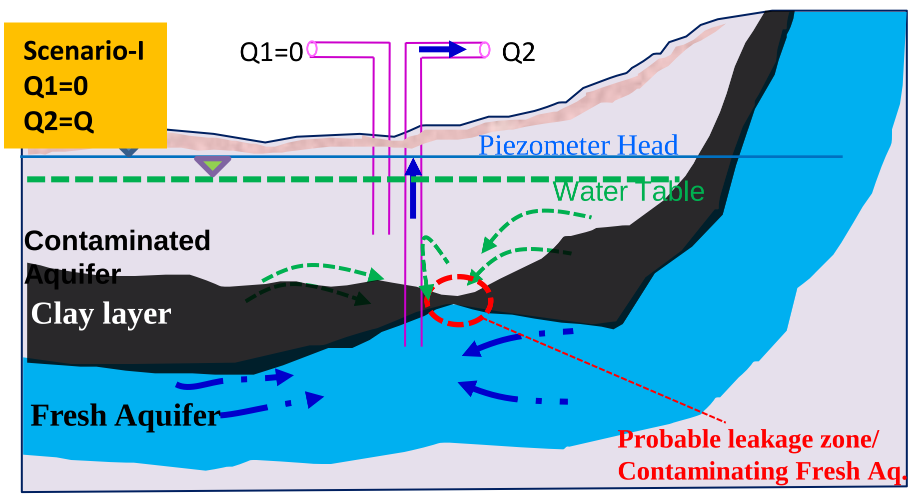
## 3-D Hydrogeological Model

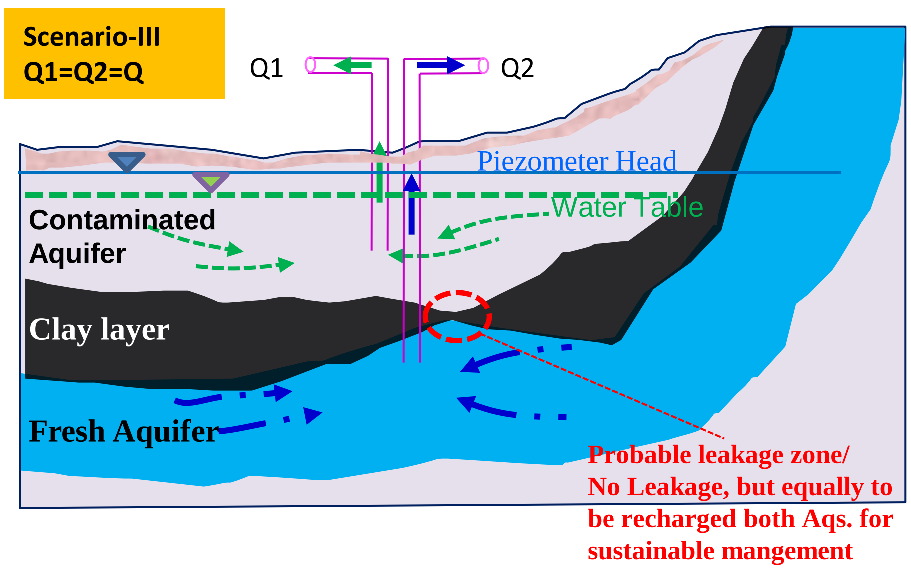


# Ideal Multi-Aquifer System



**Sustainability in management of groundwater is effective jointly with scientific inputs and stakeholder's decision making**

# Groundwater balance

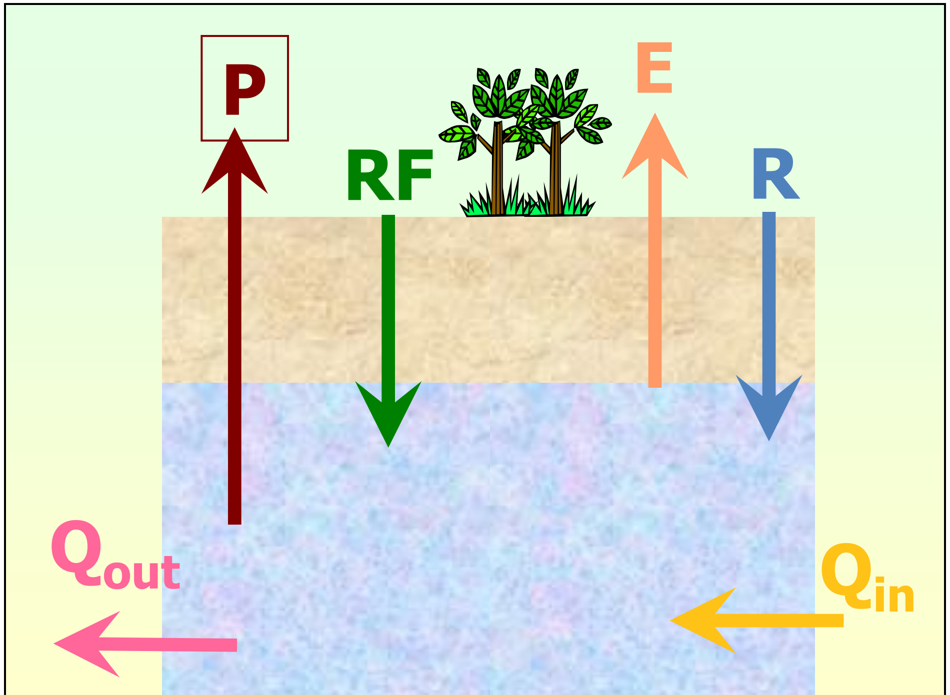
## Outflows:

- **Pumping flow [P]**
- **Water evaporation [E]**
- **Horizontal OUT-flow [$Q_{out}$]**

## Inflows:

- **Recharge [R]**
- **Horizontal IN-flow [$Q_{in}$]**
- **Return flow [RF]**

**1324 cells of 200x200 m size**




Baseflow is nil and ET redefined as E

$$R + RF + Q_{in} = E + P + Q_{out} \pm \Delta S$$

*ΔS*: storage variation = Sy . Δh

# Groundwater balance for a Normal Monsoon Year

| Flows | Value (mm/yr) |
|---|---|
| Recharge | + 97 |
| Return flow | + 86 |
| Horiz. IN flows | + 3 |
| Pumping | - 190 |
| Evaporation | - 3 |
| Horiz. OUT flows | - 2 |
| ***TOTAL*** | **-9** ± 2 |
| Rainfall (monsoon) | 789 |

**Annual Depletion =0.9 ± 0.2 m**

# Groundwater balance for a Weak Monsoon Year

| Flows | Value (mm/yr) |
|---|---|
| Recharge | + 70 |
| Return flow | + 69 |
| Horiz. IN flows | + 3 |
| Pumping | - 183 |
| Evaporation | - 1 |
| Horiz. OUT flows | - 3 |
| ***TOTAL*** | **-45** ± 7 |
| Rainfall (monsoon) | 543 |

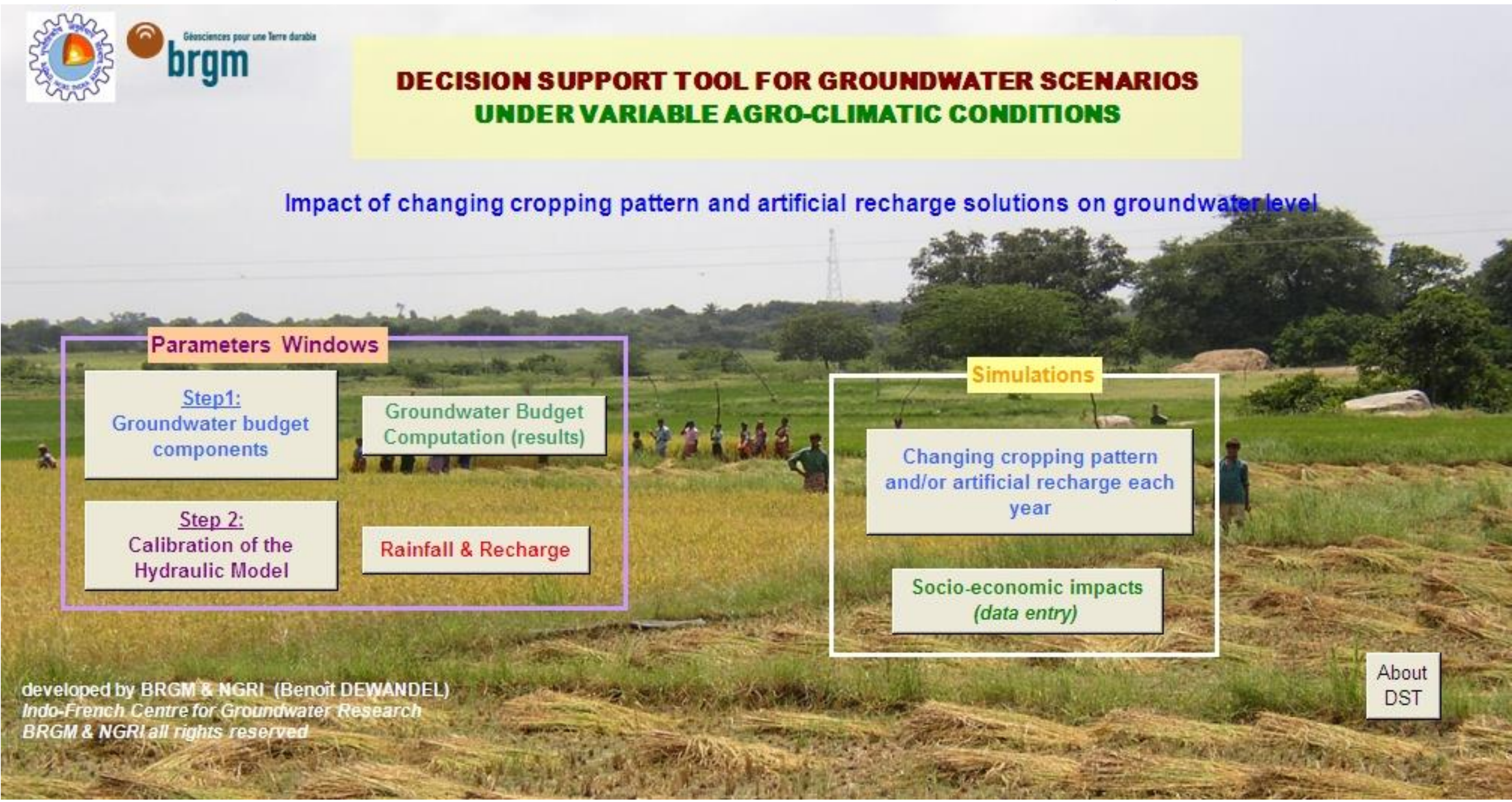
**Annual Depletion =3.2 ± 0.6 m**

# Groundwater balance for a Good Monsoon Year

| Flows | Value (mm/yr) |
|---|---|
| Recharge | + 156 |
| Return flow | + 86 |
| Horiz. IN flows | + 3 |
| Pumping | - 195 |
| Evaporation | - 2 |
| Horiz. OUT flows | - 3 |
| ***TOTAL*** | **+ 42** ± 18 |
| Rainfall (monsoon) | 824 |

**Annual increase =3.0 ± 0.6 m**

# DST – GW Ver 2.1



Géosciences pour une Terre durable
brgm
DECISION SUPPORT TOOL FOR GROUNDWATER SCENARIOS
UNDER VARIABLE AGRO-CLIMATIC CONDITIONS
Impact of changing cropping pattern and artificial recharge solutions on groundwater level
Parameters Windows
Step1: Groundwater budget components
Groundwater Budget Computation (results)
Step 2: Calibration of the Hydraulic Model
Rainfall & Recharge
Simulations
Changing cropping pattern and/or artificial recharge each year
Socio-economic impacts (data entry)
About DST
developed by BRGM & NGRI (Benoit DEWANDEL)
Indo-French Centre for Groundwater Research
BRGM & NGRI all rights reserved

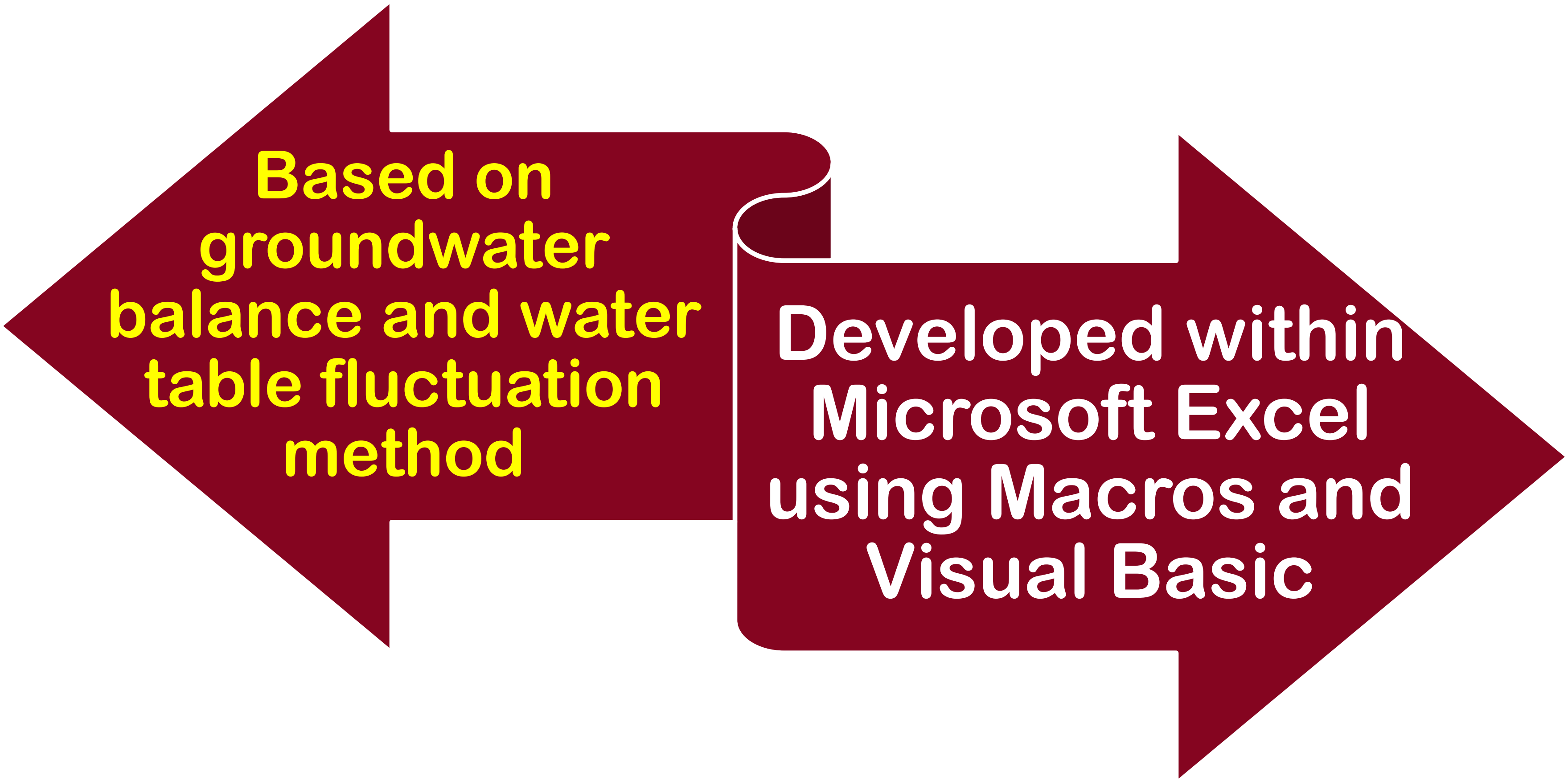
Community Involvement with Scientific input

# People's participation for Rainfall measurements

**DST- GW is especially dedicated to:**

**Hard Rock Aquifers**
**(granite, gneiss, etc.)**

These are typical conditions in **Southern India** but also of several other regions of the world (e.g., **Africa, South America**)


Based on groundwater balance and water table fluctuation method
Developed within Microsoft Excel using Macros and Visual Basic

# DST-GW requirements (data, HR)

| Field data | Number | Periodicity |
|---|---|---|
| Water levels | 30-35 | Twice a year |
| Abstraction rates | 30 | Twice a year |
| Geology & Geophysics | Entire watershed | 1 |
| Soil properties | Entire watershed | 1 |

## DST-GW requirements (data, HR)

| Other data | Number | Periodicity |
|---|---|---|
| Population | Entire watershed | 1 |
| Livestock and Poultry | Entire watershed | 1 |
| Land use map | Entire watershed | 2/year |
| Total tank area | Entire watershed | 1 |
| DEM | Entire watershed | |
| Meteo Data | 1 station | Daily |
| Electricity | | 1 |

# Specificities of the DST-GW

## The Rainfall-Recharge model

Recharge Trend Maheshwaram

| Your data are | 4 points | |
|---|---|---|
| | Rainfall [mm/y] | R [mm]_Maheshwaram |
| Jun2001May2002 | 852.5 | 99.2 |
| Jun2002May2003 | 683.0 | 70.8 |
| Jun2003Jun2004 | 1041.0 | 160.4 |
| Jul2004Jun2005 | 458.0 | 9.8 |
| Jul2005 | | |

Option1

| Automatic generated recharge model | Accept Y/N |
|---|---|
| Recharge-Rainfall model | Y |

Y=aX+b
Y=Recharge [mm/year]
X=Annual Rainfall [mm/year]

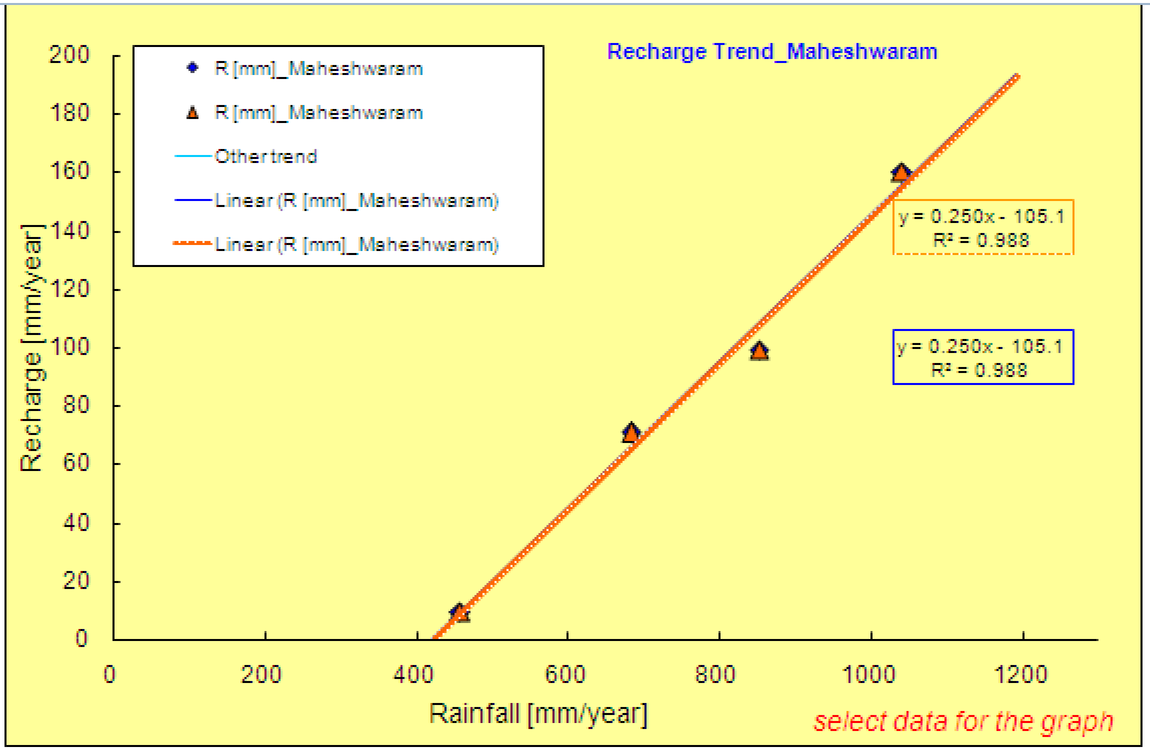
| | |
|---|---|
| a | 0.251 |
| b | -105.117 |

Option2: Other Trend

| If you are not satisfied with the generated model you may enter an other recharge model | Accept Y/N |
|---|---|
| | N |

Y=aX+b
Y=Recharge [mm/year]
X=Annual Rainfall [mm/year]

| | |
|---|---|
| a | |
| b | |




*The Maheshwaram trend is presented for information*

<<

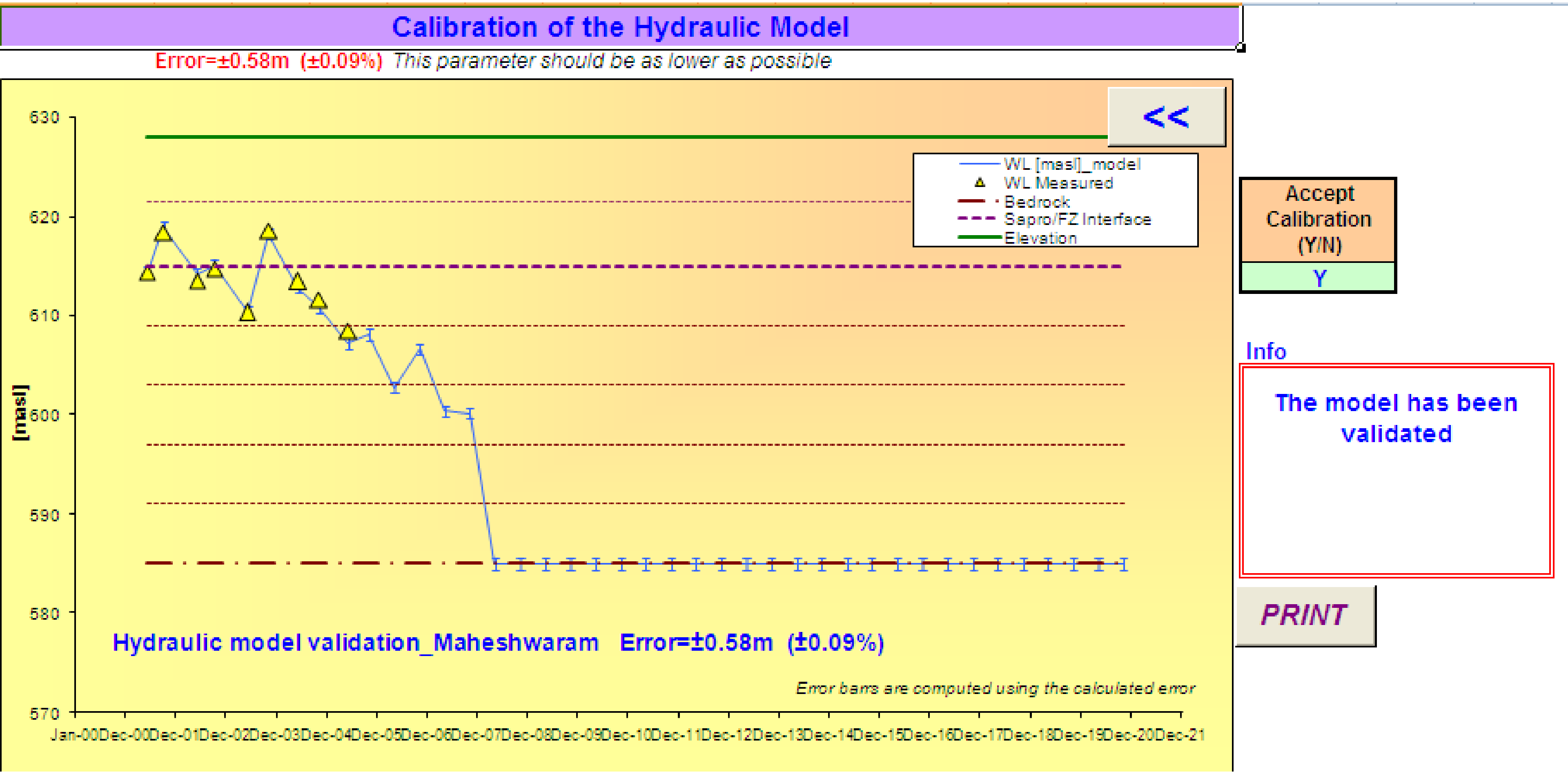
PRINT

Info

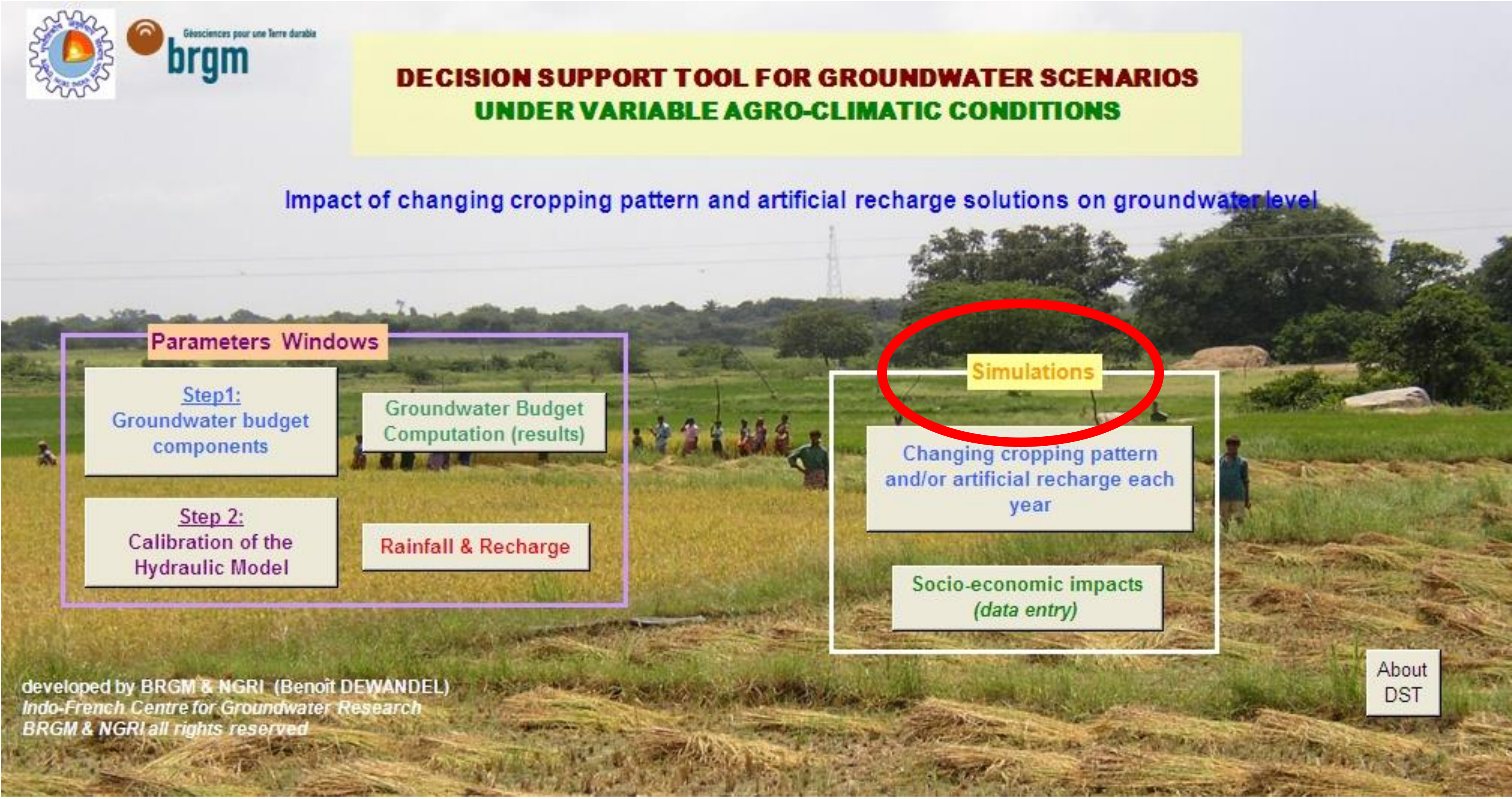
Option 1: Automatic generated model has been selected

## Specificities of the DST-GW

# Calibration of the Hydraulic Model



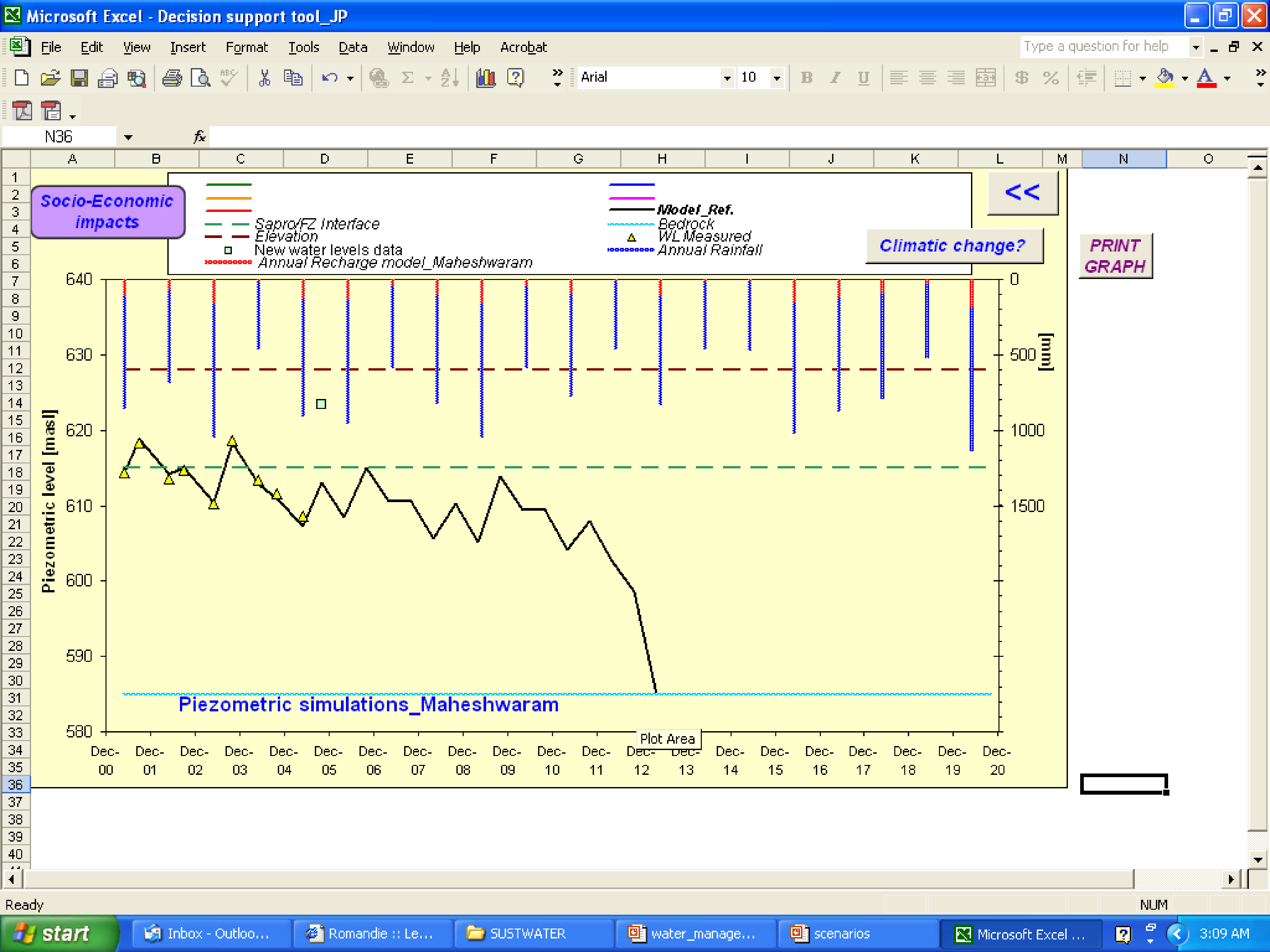
# Simulating Scenarios with the DST-GW



# Simulating Scenarios with the DST-GW

## Just 5 examples among many possible scenarios

1. **No change: Business as usual**
2. **Effect of a good monsoon**
3. **Changing cropping patterns**
4. **Increase domestic/industrial uses**
5. **Changing cropping pattern with Artificial recharge**



Microsoft Excel - Decision support tool_JP
Socio-Economic impacts
Sapro/FZ Interface
Elevation
New water levels data
Annual Recharge model_Maheshwaram
Model_Ref.
Bedrock
WL Measured
Annual Rainfall
Climatic change?
<<
PRINT GRAPH
Piezometric level [masl]
[mm]
Piezometric simulations_Maheshwaram
640
630
620
610
600
590
580
0
500
1000
1500
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
Dec-07
Dec-08
Dec-09
Dec-10
Dec-11
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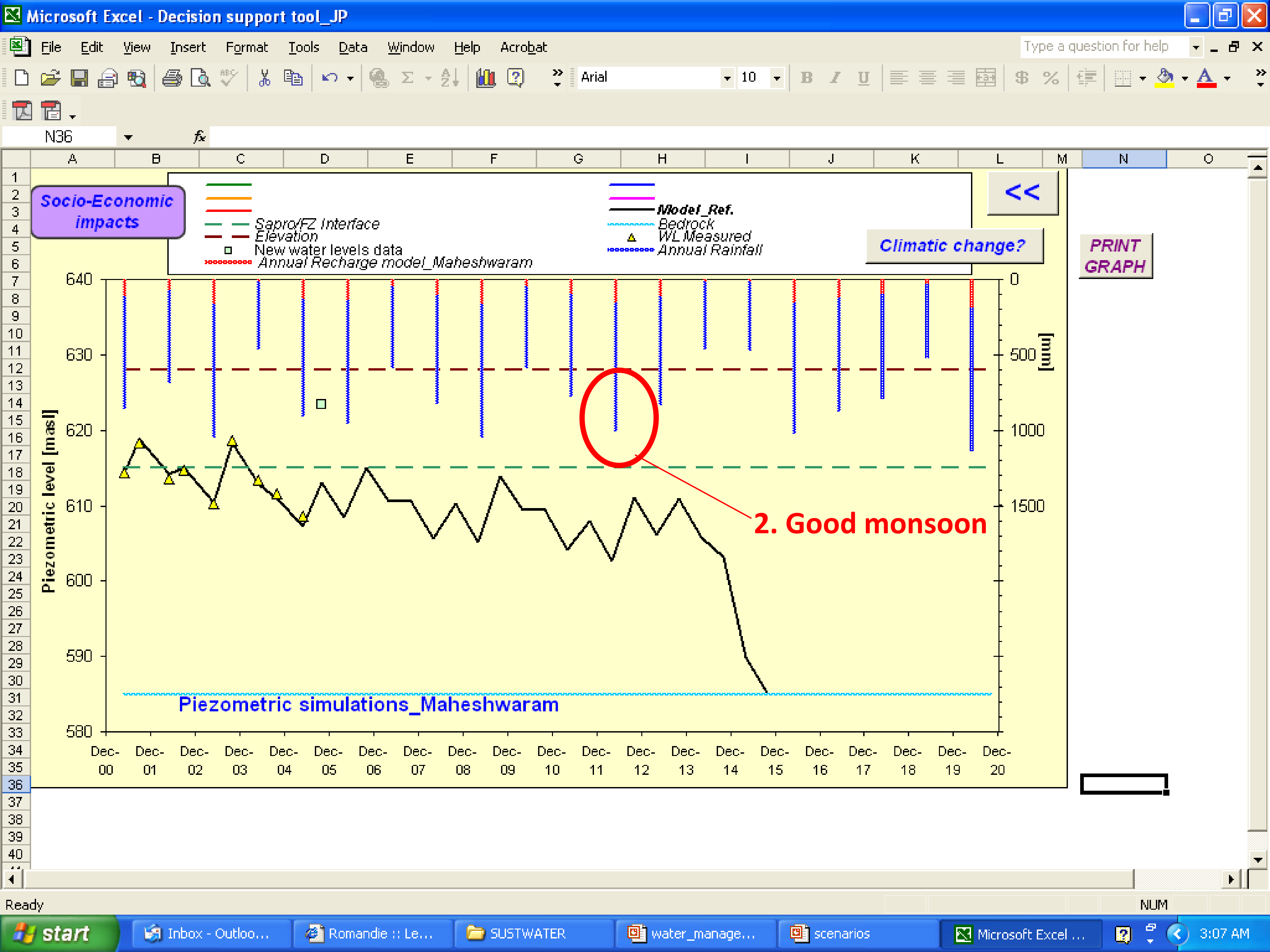
Dec-14
Dec-15
Dec-16
Dec-17
Dec-18
Dec-19
Dec-20


Microsoft Excel - Decision support tool_JP
Socio-Economic impacts
Sapro/FZ Interface
Elevation
New water levels data
Annual Recharge model_Maheshwaram
Model_Ref.
Bedrock
WL Measured
Annual Rainfall
<<
Climatic change?
PRINT GRAPH
Piezometric level [masl]
[mm]
2. Good monsoon
Piezometric simulations_Maheshwaram
640
630
620
610
600
590
580
0
500
1000
1500
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
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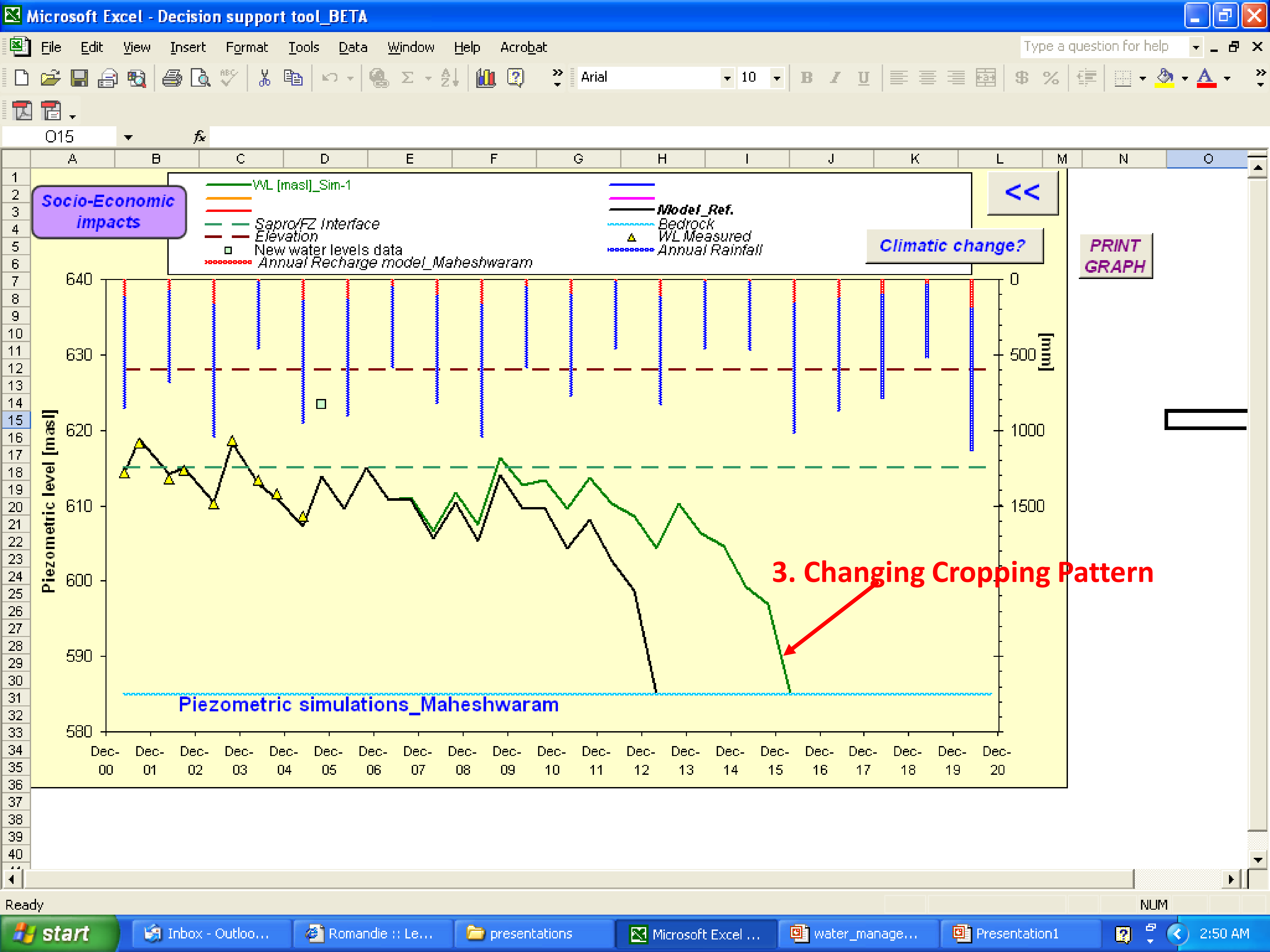
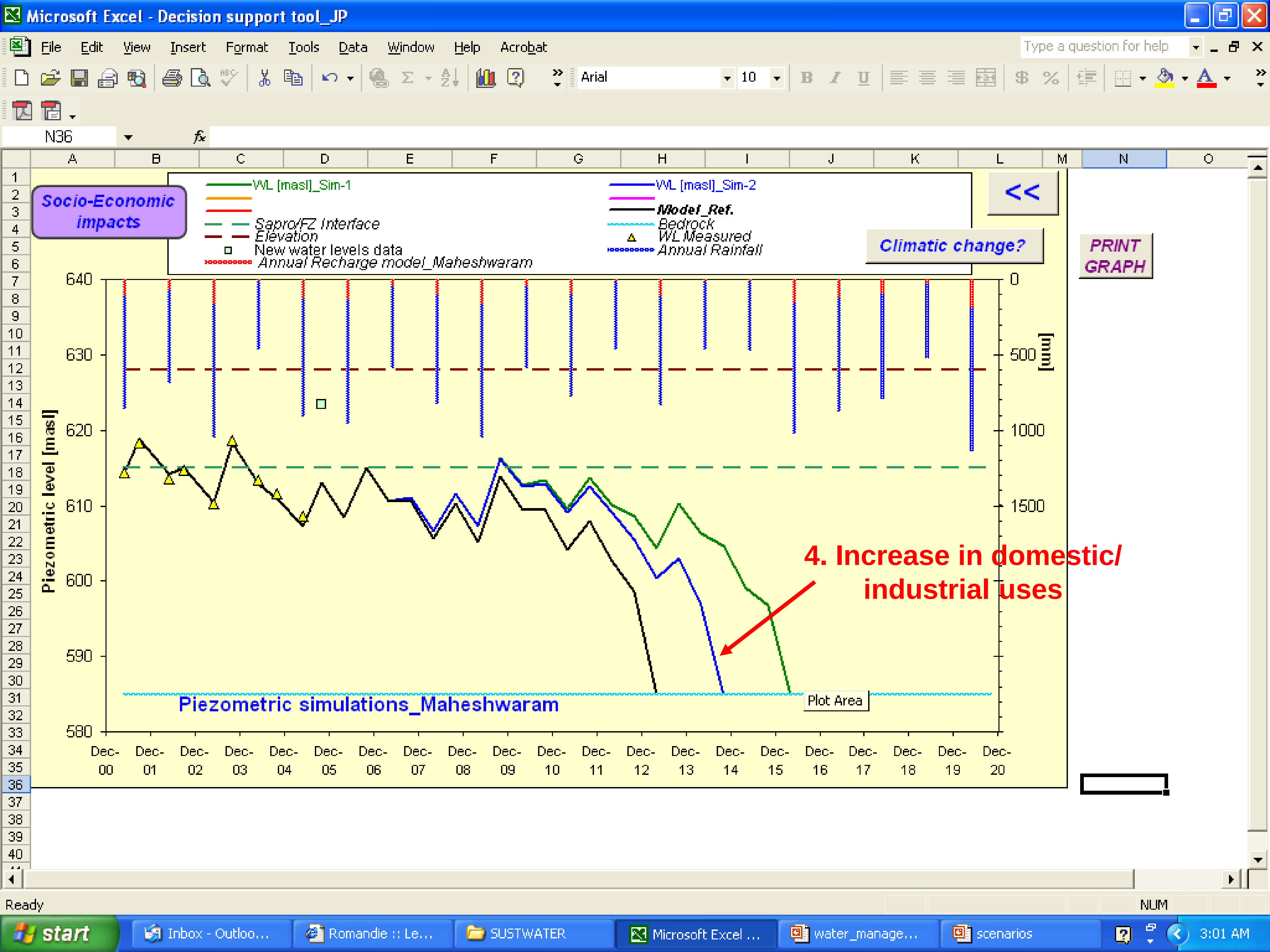


Microsoft Excel - Decision support tool_BETA
Socio-Economic impacts
WL [masl]_Sim-1
Sapro/FZ Interface
Elevation
New water levels data
Annual Recharge model_Maheshwaram
Model_Ref.
Bedrock
WL Measured
Annual Rainfall
Climatic change?
<<
PRINT GRAPH
Piezometric level [masl]
[mm]
3. Changing Cropping Pattern
Piezometric simulations_Maheshwaram


Microsoft Excel - Decision support tool_JP
Socio-Economic impacts
WL [masl]_Sim-1
WL [masl]_Sim-2
Model_Ref.
Sapro/FZ Interface
Bedrock
Elevation
WL Measured
New water levels data
Annual Rainfall
Annual Recharge model_Maheshwaram
<<
Climatic change?
PRINT GRAPH
Piezometric level [masl]
[mm]
4. Increase in domestic/ industrial uses
Piezometric simulations_Maheshwaram
Plot Area
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06
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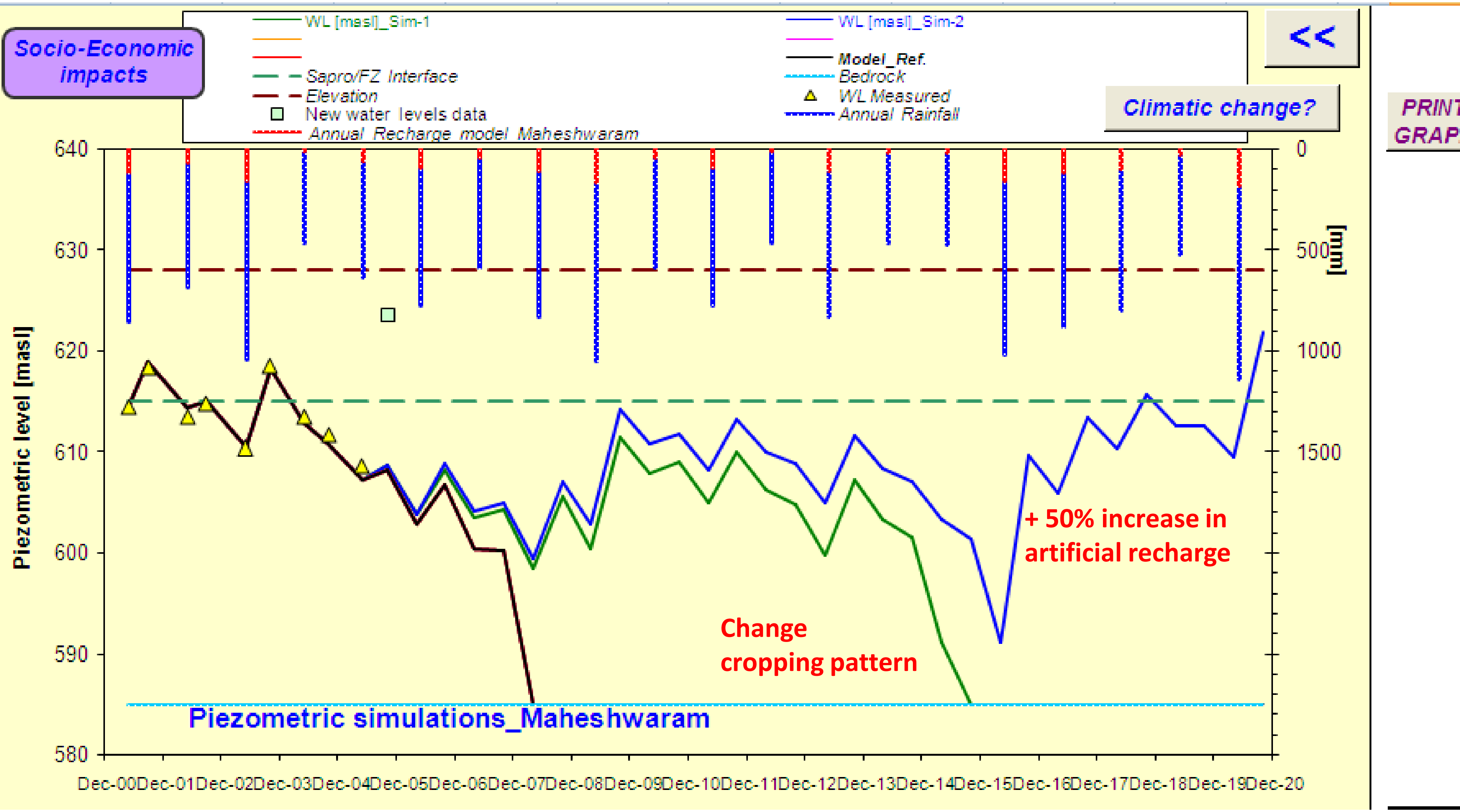
Dec-19
Dec-20

# A sustainable scenario



**DST-GW is adapted to watersheds between 10-100 km$^2$**

**Advantages of the DST**

- * Accurate method
- * Geological structure of the aquifer taken into account
- * Module for simulation of future scenarios
- * Simpler than groundwater modeling package
- ***Provides information when to use GW**

Thank You