MINISTRY OF WATER RESOURCES

Ethiopian Water Technology Centre

(EWTEC)

BUTAJIRA – ZIWAY AREA DEVELOPMENT STUDY PROJECT

# Groundwater Modeling

AG – Consult

Consulting Hydrogeologists and Engineers

January 17, 2008

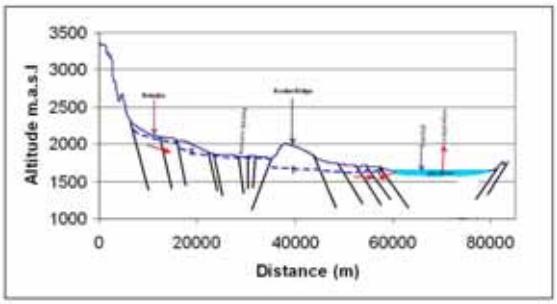
## Objective of the groundwater Modeling

- To indicate the potential pumping from the aquifers
- To indicate the response to the aquifer for groundwater development scenarios
- To indicate possible development options in different areas
- To use as input for the training program of EWTEC.

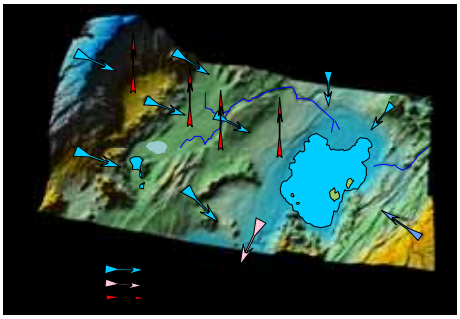
## Groundwater Modeling

- Model Assumptions
- Extent of Model
- Grid and Cell size
- Model Structure
  - Boundary Conditions
  - Groundwater Recharge
  - Aquifer Parameters
  - Groundwater Output
- Model Calibration (Steady & Transient)
- Simulation Results
- Interpretation of Simulation Result
- Development Concept

## Model Assumptions



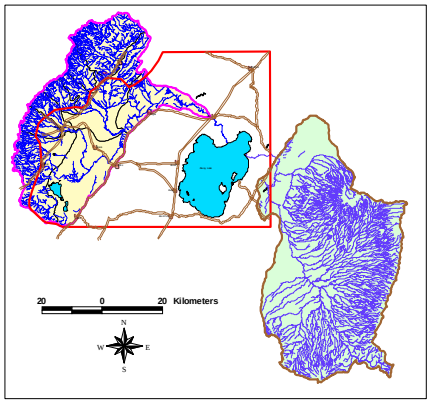

## Model Assumptions

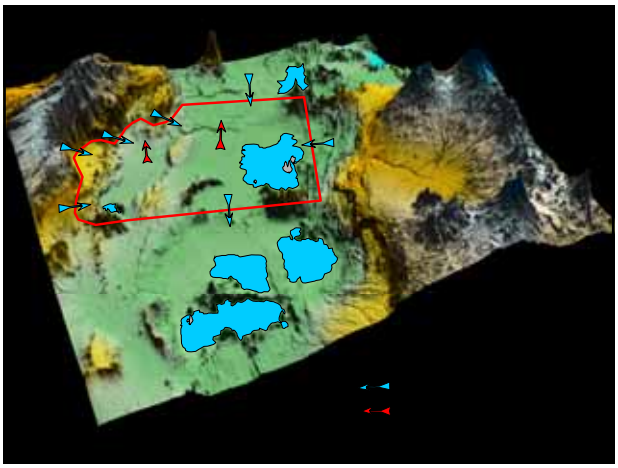


## Model Assumption

- Single layer
- Confined aquifers
- Recharge from the two main river catchments (Ketar and Meki Rivers) and the Ziway plain
- Groundwater output
  - Pumping
  - Groundwater outflow

## Extension of Model

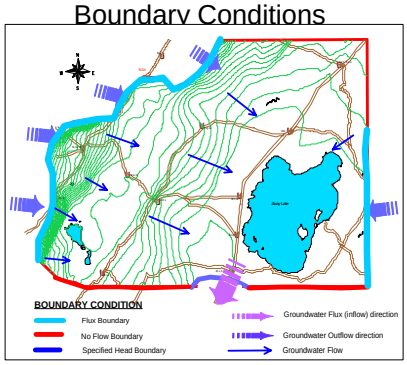


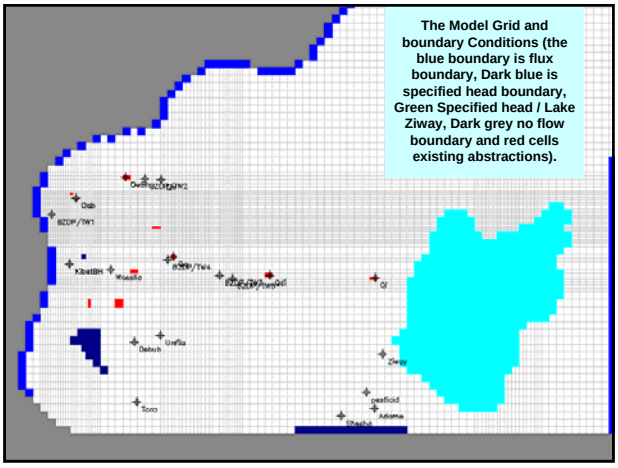



## Cell Size

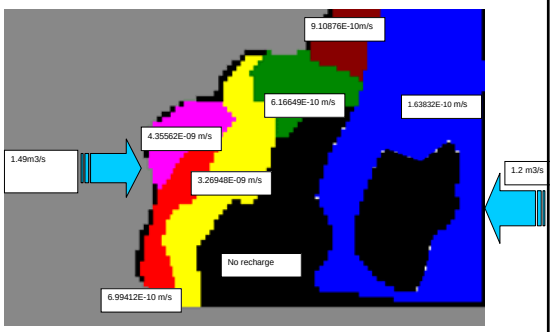
- This model area extends 62 km in the east direction and 110 km in the north direction. The model cell size varies from
  - 250 m X 250 m (the smallest cell),
  - 500 m X 500 m (medium size cell) and
  - 1000 m X 1000m (large size cell

## Model Structure
## Boundary Conditions




## Recharge



| | | Amount of Recharge Applied in the model | | | |
|---|---|---|---|---|---|
| | Area Km2 | mcm | m | m/s | m3/s |
| **Meki River Catchment** | | | | | |
| North-eastern Escarpment | 250.500 | 4.096 | 0.016 | 5.18526E-10 | 0.130 |
| Kuntane - Inseno – Kela plain | 450.660 | 49.155 | 0.109 | 3.45868E-09 | 1.559 |
| Butajira crescent | 167.000 | 22.939 | 0.137 | 4.35562E-09 | 0.727 |
| Cinder Cone areas | 208.000 | 4.588 | 0.022 | 6.99412E-10 | 0.145 |
| **Out of Meki Catchment** | | | | | |
| Eastern Zway | 142.600 | 4.096 | 0.029 | 9.10876E-10 | 0.130 |
| Rift plain | 1022.000 | 5.28 | 0.0052 | 1.63832E-10 | 0.167 |
| | 283.000 | 1.46 | 0.0052 | 1.63832E-10 | 0.046 |
| | **2524.150** | **87.522** | **0.295** | **9.360E-09** | **2.905** |

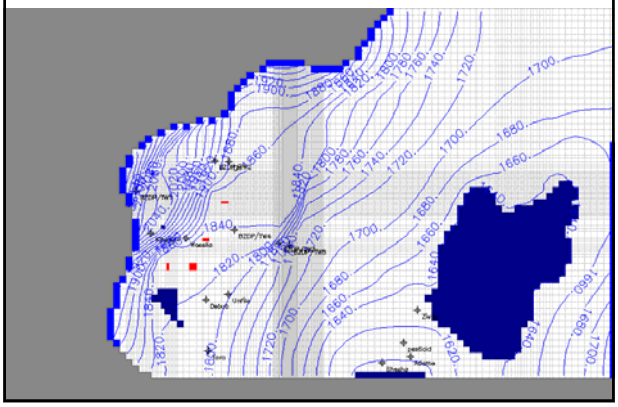
| Catchment | Area Km2 | M3/s |
|---|---|---|
| Meki Catchment | 854.68 | 1.49 |
| Ketar Catchment | 980.38 | 1.20 |

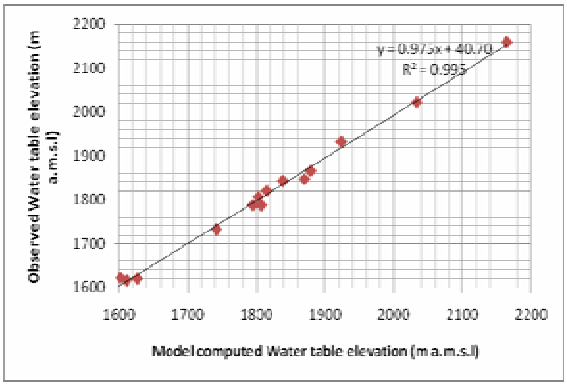
The total amount of recharge applied in the model is **5.59** m3/s

# Aquifer Transmissivity

- As initial input transmissivity obtained from test pumping are used

# Model Calibration (Steady State)

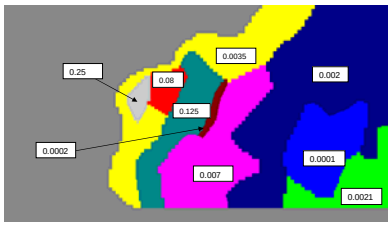




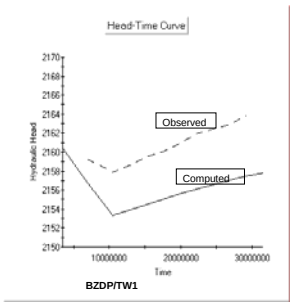

# Lake Water Balance

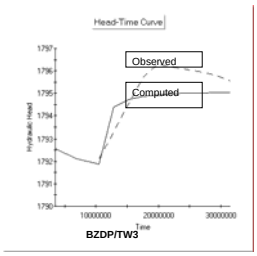
| Description | Input ($M^3/s$) | Output (M3/s) | Balance (M3/s) | Remark |
|---|---|---|---|---|
| Meki River Input | **9.23** | | | |
| Katar River | **13.10** | | | |
| Direct Rainfall On lake surface | **10.59** | | | |
| Bulbula River flow from the lake | | **6.06** | | |
| Evaporation from Lake surface | | **26.05** | | |
| Groundwater | **2.80** | **2.80** | | Model Result |
| Total | **36.08** | **35.27** | **0.81** | The balance accounts probably for change in storage of the lake for about 0.06 m change in lake level |

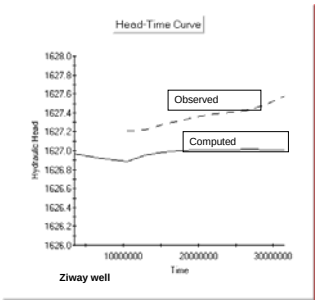
# Model Calibration (Transient)




Calibrated Storage Coefficient



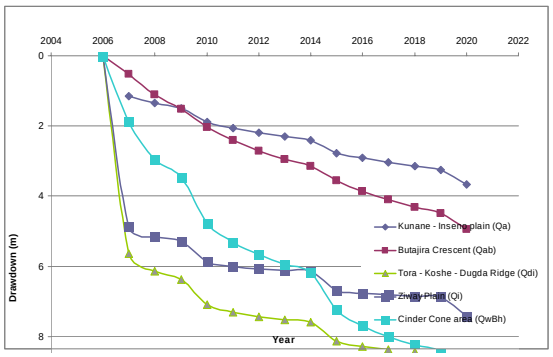

# Simulation Result

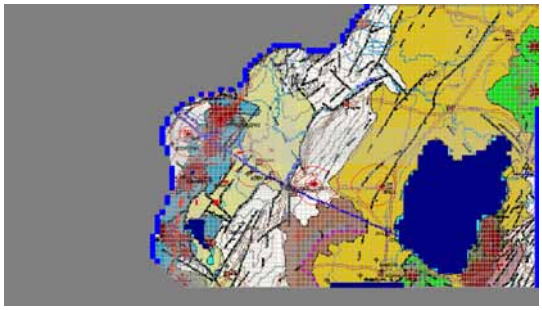
- Conditions of Simulations
  - Water Supply Demand of the population in the model area up to 2020 (373 l/s)
  - Estimate the amount of water that can be pumped for draw down of 15 m and 10 m.

# Simulation Result

- With 373 l/s pumping draw down doesn't exceed 10 m

| Year | Butajira Crescent | | Cinder Cone and basaltic area | | Kuntane – Inseno Plain | | Tora – Koshe – Dugda Ridge | | Ziway Plain | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pumping (l/s) | Draw Down (m) | Pumping (l/s) | Draw Down (m) | Pumping (l/s) | Draw Down (m) | Pumping (l/s) | Draw Down (m) | Pumping (l/s) | Draw Down (m) |
| 2007 | 20 | 0.5 | 42 | 1.9 | 63 | 1.15 | 58 | 5.6 | 27 | 4.9 |
| 2015 | 30 | 3.5 | 63 | 7.2 | 95 | 2.77 | 87 | 8.1 | 41 | 6.7 |
| 2020 | 36 | 4.9 | 74 | 9.6 | 112 | 3.66 | 103 | 9.1 | 48 | 7.4 |



| Zones | Pumping Location | UTM X | UTM Y | Pumping rate M3/s) | Pumping rate l/s) | DD (m) | Pumping rate M3/s) | Pumping rate l/s) | DD (m) |
|---|---|---|---|---|---|---|---|---|---|
| ıjira crescent | Koto | 427800 | 896527 | 0.04 | 40.00 | 10.41 | 0.06 | 60 | 15.8 |
| er Cones and saltic areas | Shereshera | 434409 | 899337 | 0.05 | 50.00 | 10.41 | 0.07 | 70 | 14.7 |
| tane-Inseno- ela Plain | Elle | 445969 | 900356 | 0.25 | 250.00 | 10.0 | 0.38 | 375 | 15.4 |
| | Inseno | 440768 | 888720 | 0.25 | 250.00 | 10.41 | 0.38 | 375 | 15.8 |
| Koshe Dugda ridge | Koshe | 453674 | 886221 | 0.07 | 70.00 | 8.87 | 0.11 | 105 | 16 |
| | Dugda | 459530 | 899063 | 0.05 | 50.00 | 8.8 | 0.08 | 75 | 14 |
| | Debub Goto | 439188 | 876635 | 0.1 | 100.00 | 9.2 | 0.15 | 150 | 14 |
| iway Plain | Abosa | 467764 | 885848 | 0.05 | 50.00 | 8.0 | 0.10 | 100 | 14.5 |
| | Adami Tulu | 463513 | 870489 | 0.2 | 200.00 | 3.76 | 0.30 | 300 | 5.7 |
| | Meki | 481380 | 902405 | 0.05 | 50.00 | 7.0 | 0.08 | 75 | 11.3 |
| | | | | **1.11** | **1110.00** | | **1.69** | **1685** | |
| **nt of total recharge** | | | | **20%** | | | **31%** | | |

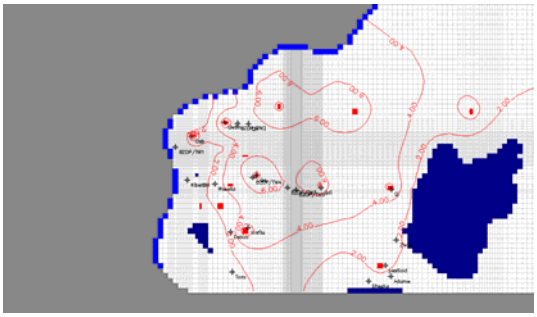


**Figure 1. Drawdown shown on red circles on the grid for 1.1 m3/s pumping.**

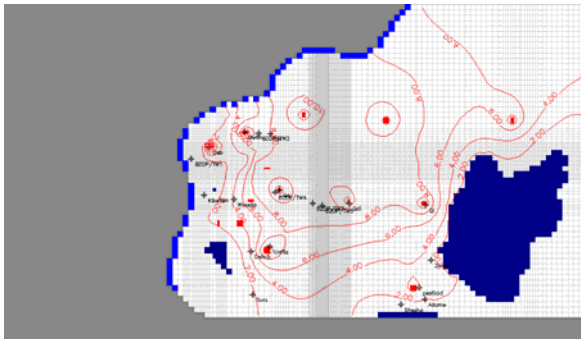


**Figure 1. Drawdown shown on red circles on the grid for 1.7 m3/s pumping.**

## Model Limitation

- No indicative storage coefficient values are available for the study area.
- The thickness of each aquifer formation is not defined,
- Recharge to the model is only considered by taking in to account only the surface water catchment.

## Interpretation of Simulation Results

- The current study shows the water supply demand of the population (373 l/s) up to year 2020 within the study area will be quantitatively satisfied, in spite of the water quality problems in some zones.
- Pumping up to 1.7m$^3$/s is feasible assuming a maximum drawdown of 15 m, indicating additional pumping capacity of 1.32 m$^3$/s.
- Major amount of water can be drawn from Kuntane – Inseno-Kela plain, Tora-Koshe-Dugda Ridge and Ziway Plain

## Appropriate pumping Technologies for each Zone

- Butajira Crescent
- Cinder Cones and basaltic area
- Kuntane-Inseno - Kela Plain
- Tora-Koshe-Dugda Ridge
- Ziway Plain

## Butajira Crescent

| Depth to GW (m) | 2 –20.<br>Shallow groundwater area |
|---|---|
| Appropriate pumping Technologies | - Rope pumps<br>- Hand pumps<br>- Solar Pumps<br>- Animal Driven Pumps<br>- Wind Pumps<br>- Some other low cost technologies can be used<br>- Submersible pumps |

## Cinder cones and basaltic areas

| Depth to GW (m) | > 40 m |
|---|---|
| Appropriate pumping Technologies | - Afridev pumps for few locations<br>- Extra-deep Hand pumps (such as India Mark II)<br>- Submersible pumps<br>- Wind pumps |

## Kuntane – Inseno – Kela Plain

| Depth to GW (m) | 5 - 30 |
|---|---|
| Appropriate pumping Technologies | - Rope pumps<br>- Hand pumps<br>- Solar Pumps<br>- Animal Driven Pumps<br>- Wind Pumps<br>- Some other low cost technologies can be used<br>- Submersible pumps |

## Tora- Koshe - Dugda Ridge

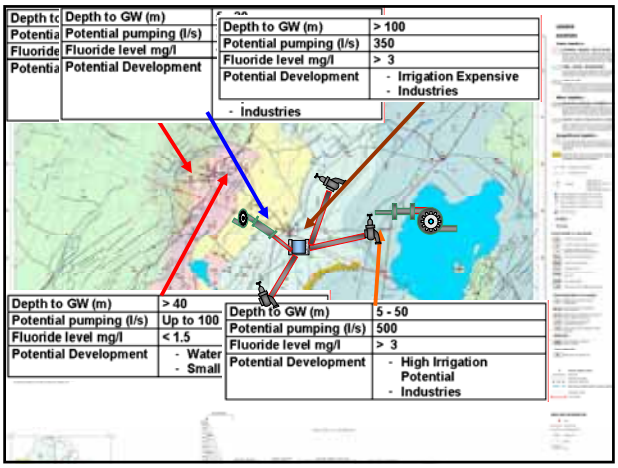
| Depth to GW (m) | > 100 |
|---|---|
| Appropriate pumping Technologies | - Submersible / turbine pumps |

## Ziway Plain

| Depth to GW (m) | 5 - 50 |
|---|---|
| Appropriate pumping Technologies | - Rope pumps<br>- Hand pumps<br>- Solar Pumps<br>- Animal Driven Pumps<br>- Wind Pumps<br>- Submersible pumps<br>- Some other low cost technologies can be used |

## Development Concept

- To propose the development concept the following are considered.
  - Water Quality
  - Depth to groundwater level
  - Groundwater Potential
- For development the following are considered
  - Water Supply
  - Irrigation
  - Industry




## Relevance of Outputs Of The Study

- The Relevance of the Study output for EWTEC
- The Relevance of the Study output for the community

## The study output for EWTEC

- The study output will be used by EWTEC for its training, and therefore, six volume reports are prepared.
  - Geology
  - Test Drilling
  - Hydrogeology
  - Water Quality
  - GIS
  - Socio-Economy
- Practical field training can be conducted in the different zones encompassing different geology, topography, depth to groundwater, and water quality

## The Study Result For the Community

- The study result indicated what to develop at which location and its potential and suitable pumping technologies.
- Except Tora-Koshe-Dugda Ridge and Cinder cone areas, the other places have groundwater that can be developed at household or community level.
- Any development agent in the area can develop the resource for the community with relevant appropriate and low cost technology.