Saltwater Intrusion Modeling of the Affected Sedimentary Aquifers in Metro Manila

Mapua University

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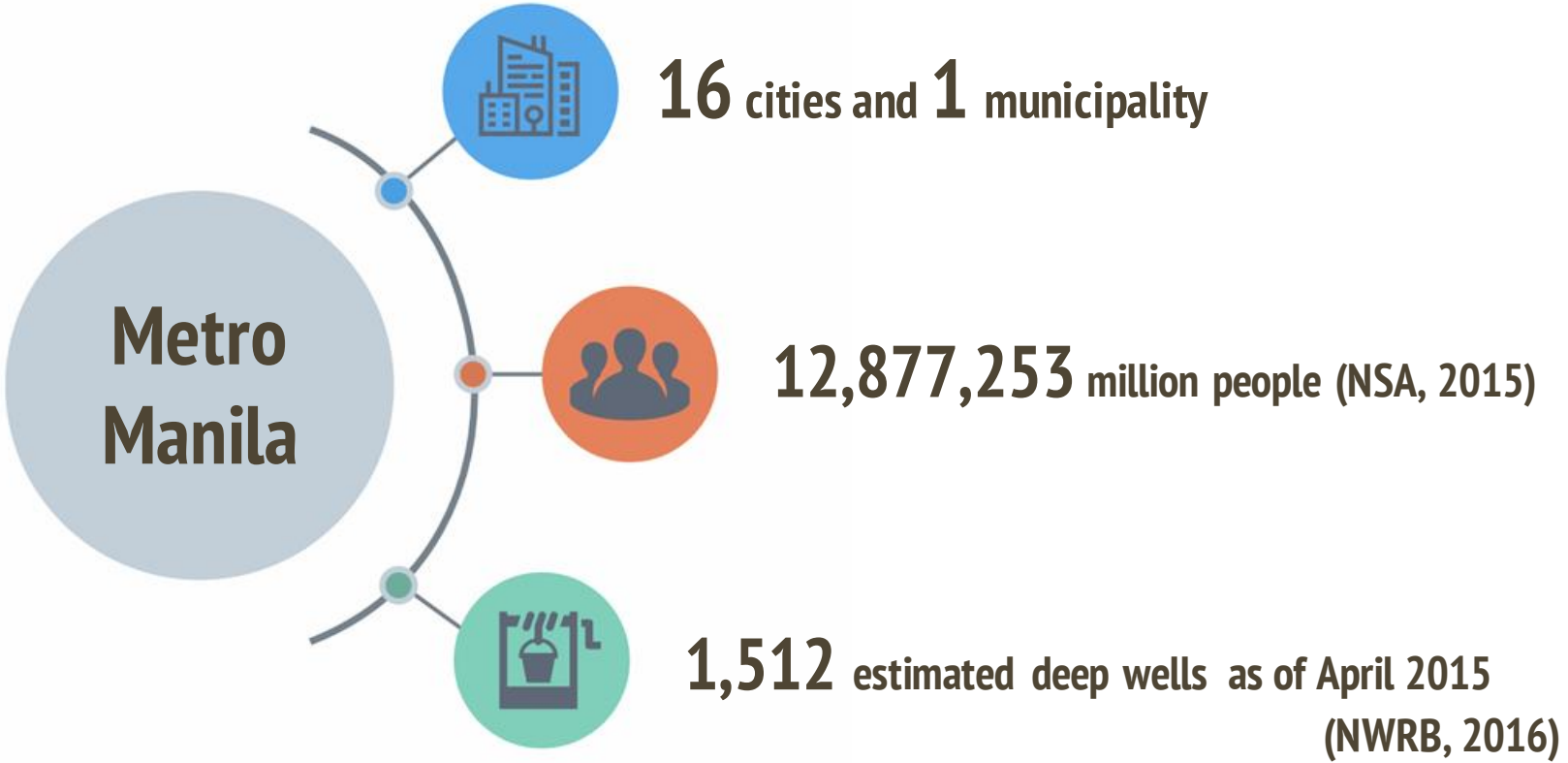
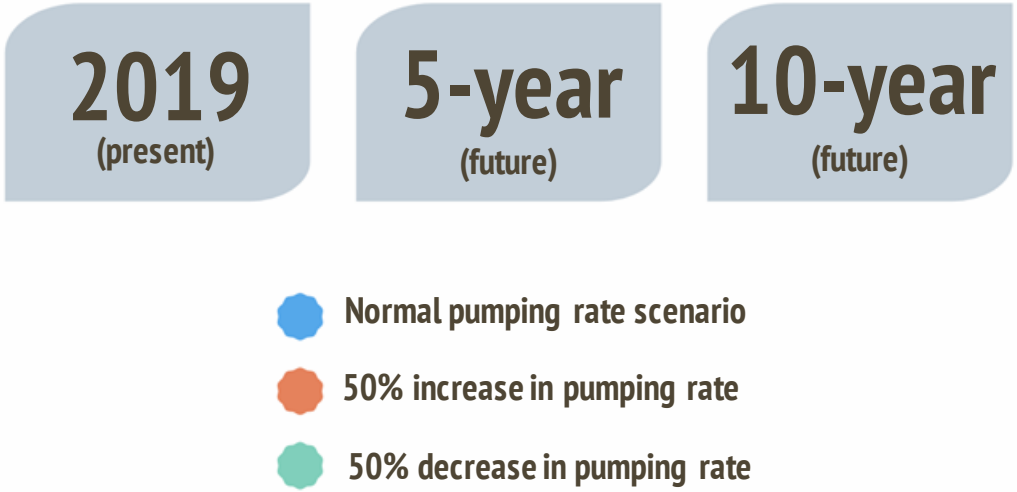
Jonah Trisha H. Sison


Metro Manila
16 cities and 1 municipality
12,877,253 million people (NSA, 2015)
1,512 estimated deep wells as of April 2015
(NWRB, 2016)

Objective

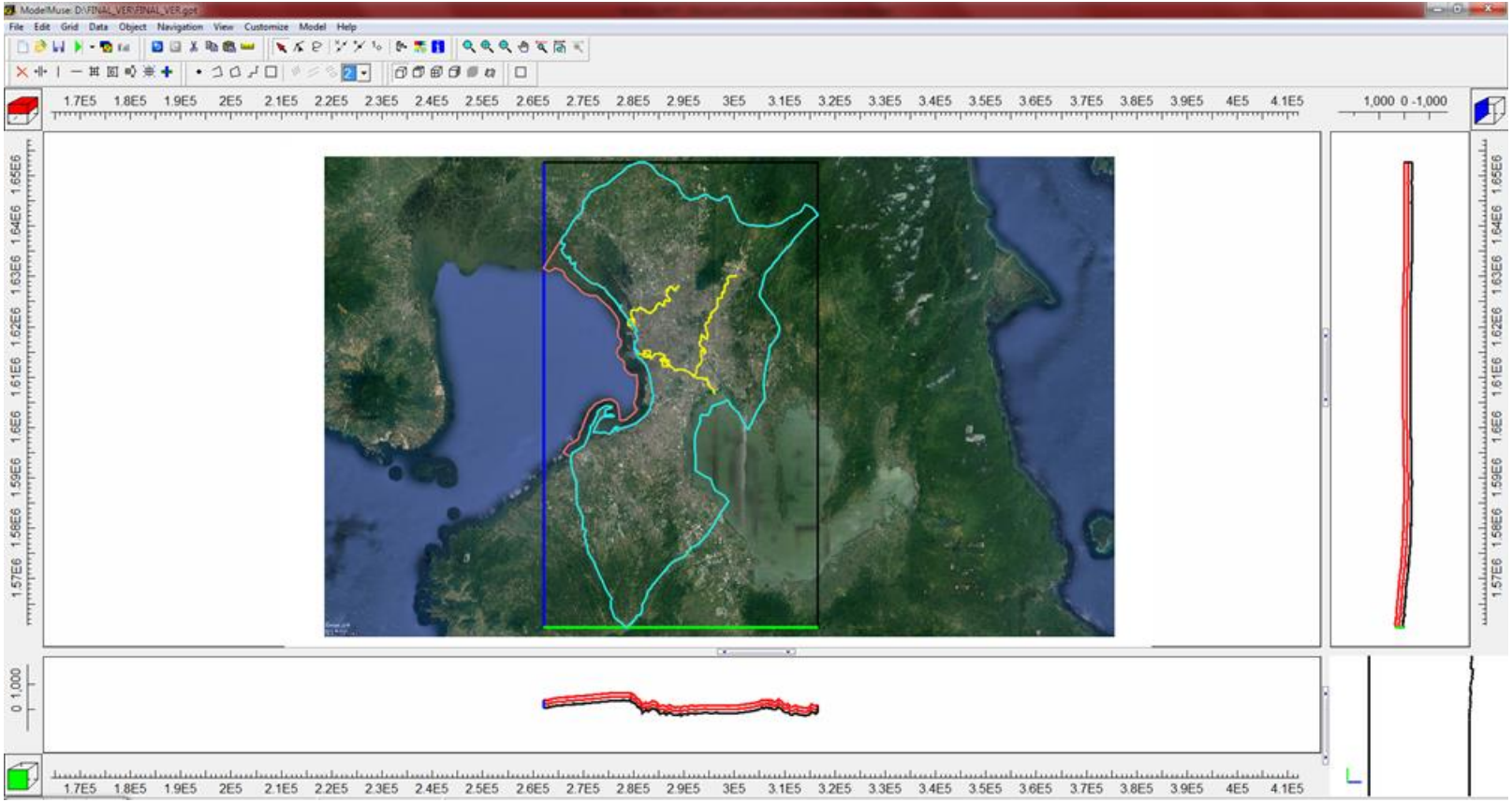
- To simulate groundwater and saltwater interaction and map the saltwater/freshwater interface of Metro Manila:



- To delineate the areas that are mostly affected based on the generated models

- based on the total abstraction rate of 5,887 lps in NCR as of 2013 (NWRB)

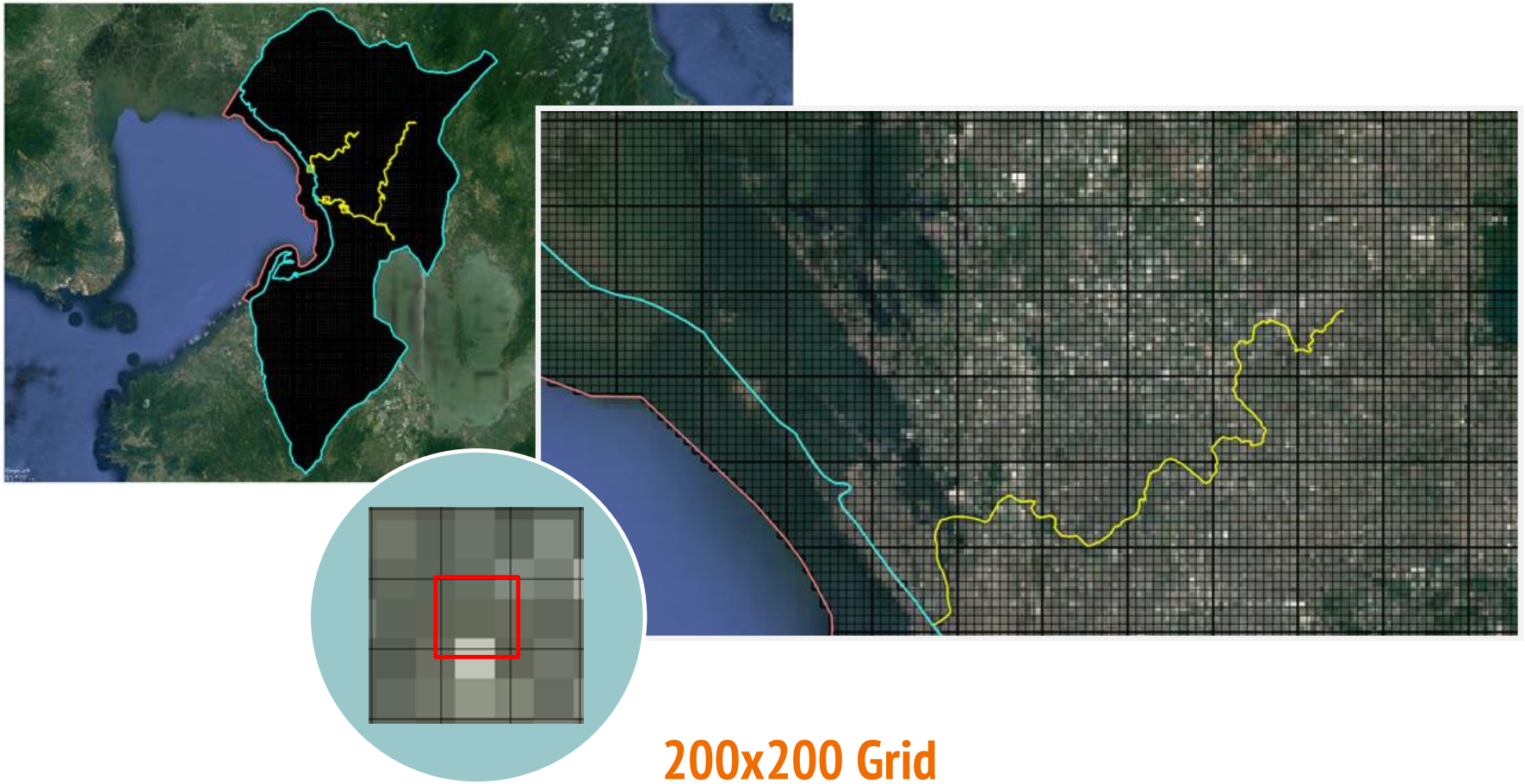
Modeling Process



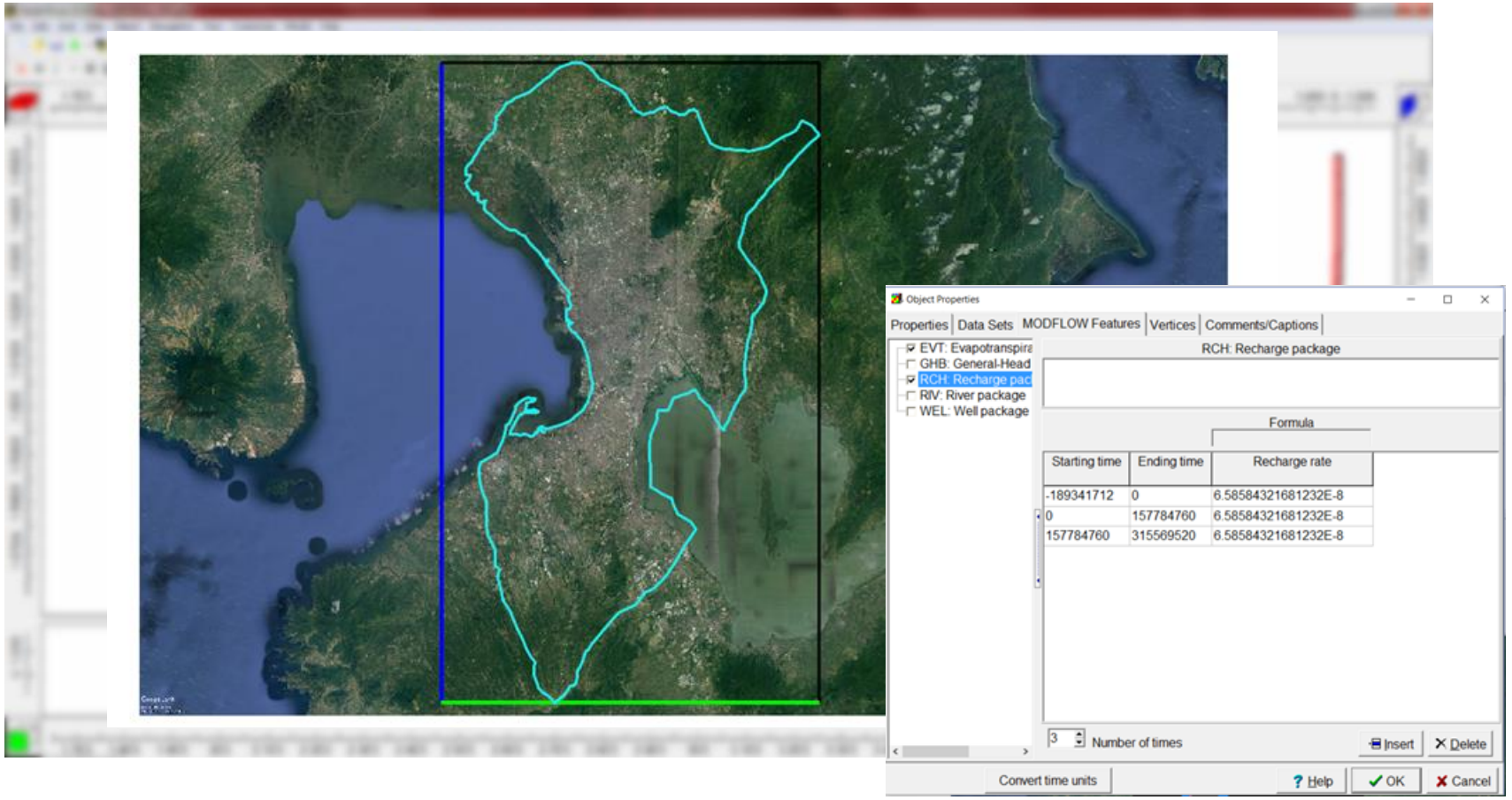
ModelMuse Interface

MODFLOW Packages

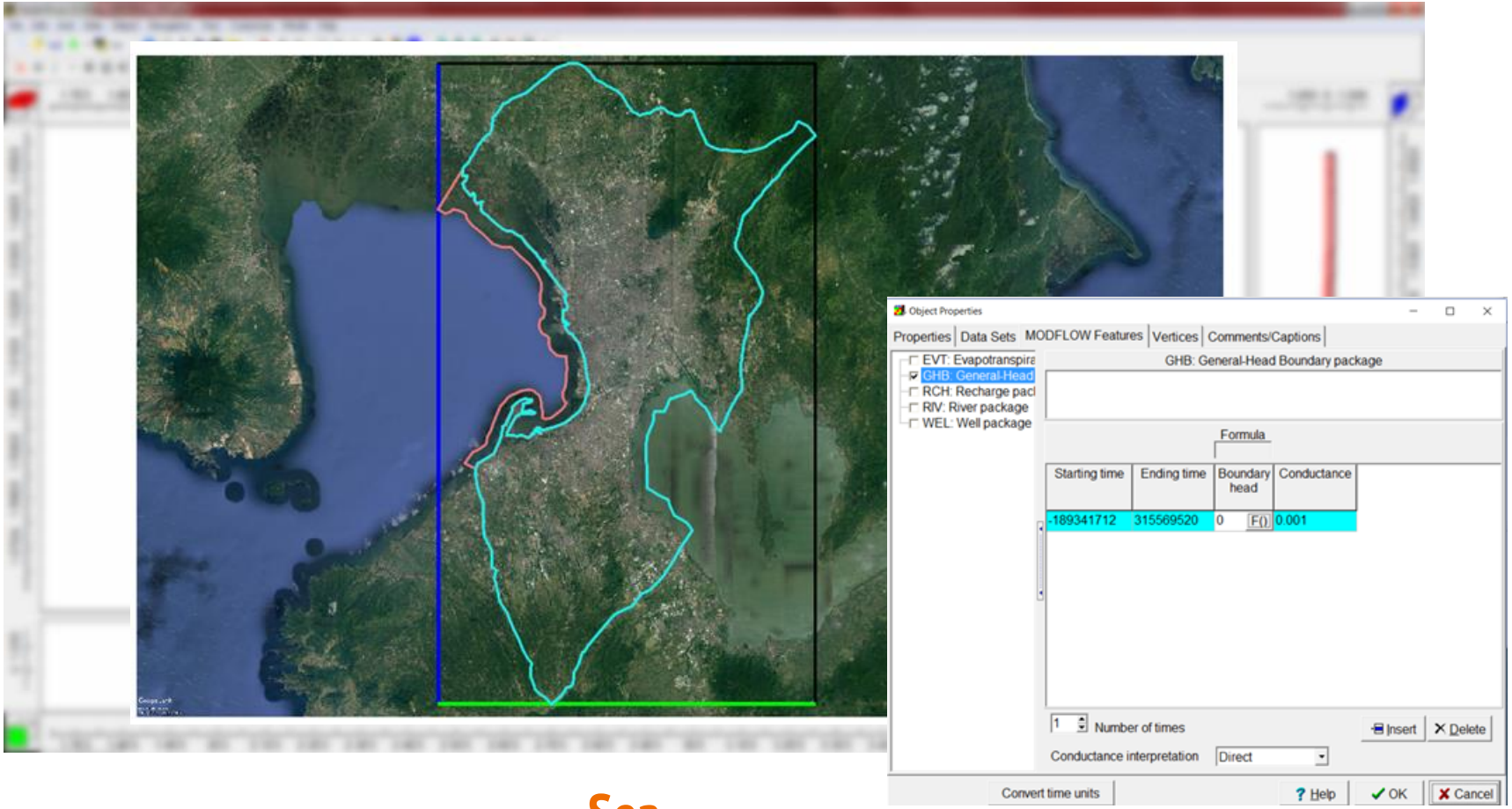
- Evapotranspiration (EVT)
- Recharge (RCH)
- General Head Boundary (GHB)
- River (RIV)
- Well (WEL)
- Seawater Intrusion 2 (SWI2)



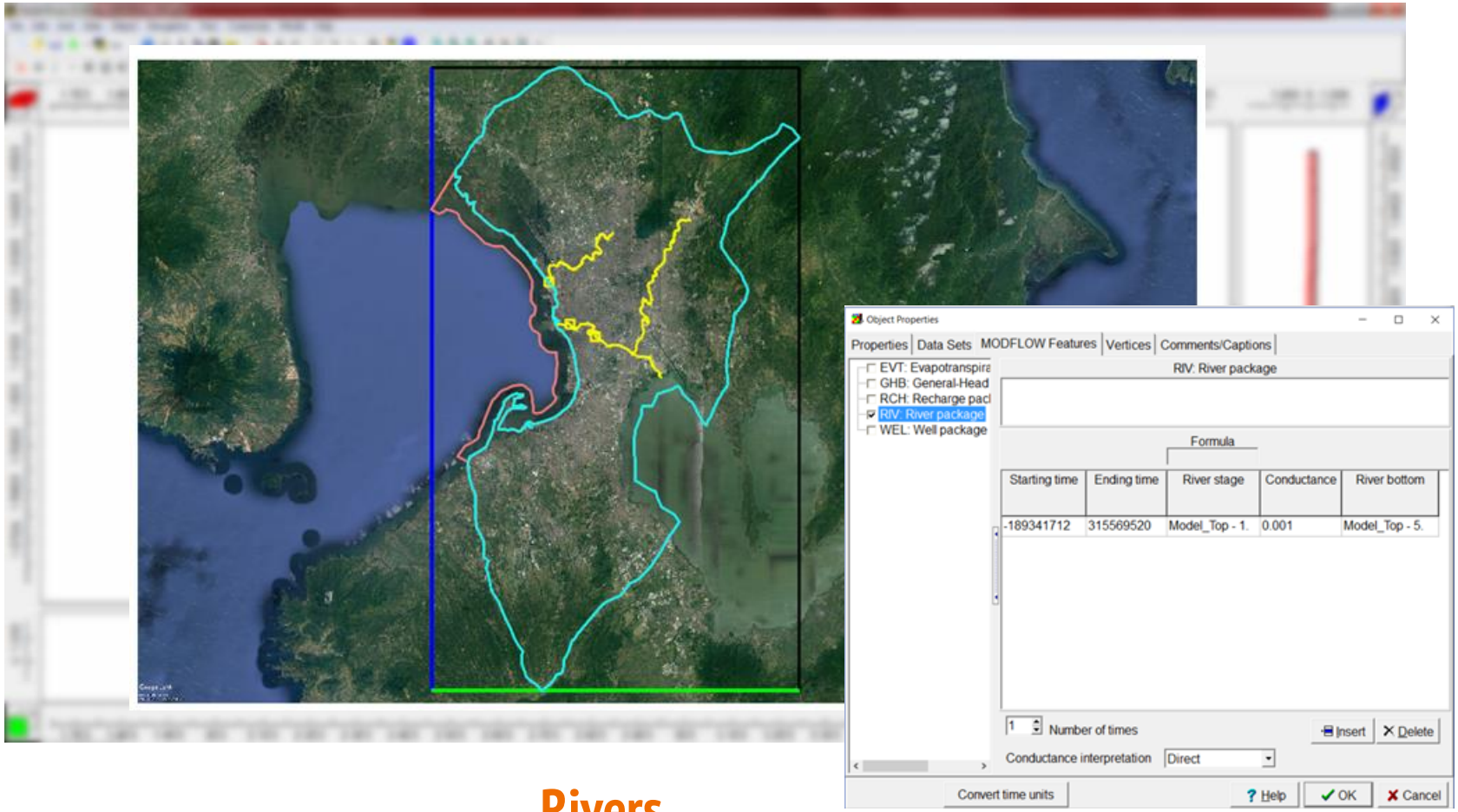
200x200 Grid


Object Properties
Properties
Data Sets
MODFLOW Features
Vertices
Comments/Captions
EVT: Evapotranspira
GHB: General-Head
RCH: Recharge pac
RIV: River package
WEL: Well package
RCH: Recharge package
Formula
Starting time
Ending time
Recharge rate
-189341712
0
6.58584321681232E-8
0
157784760
6.58584321681232E-8
157784760
315569520
6.58584321681232E-8
3
Number of times
Insert
Delete
Convert time units
Help
OK
Cancel

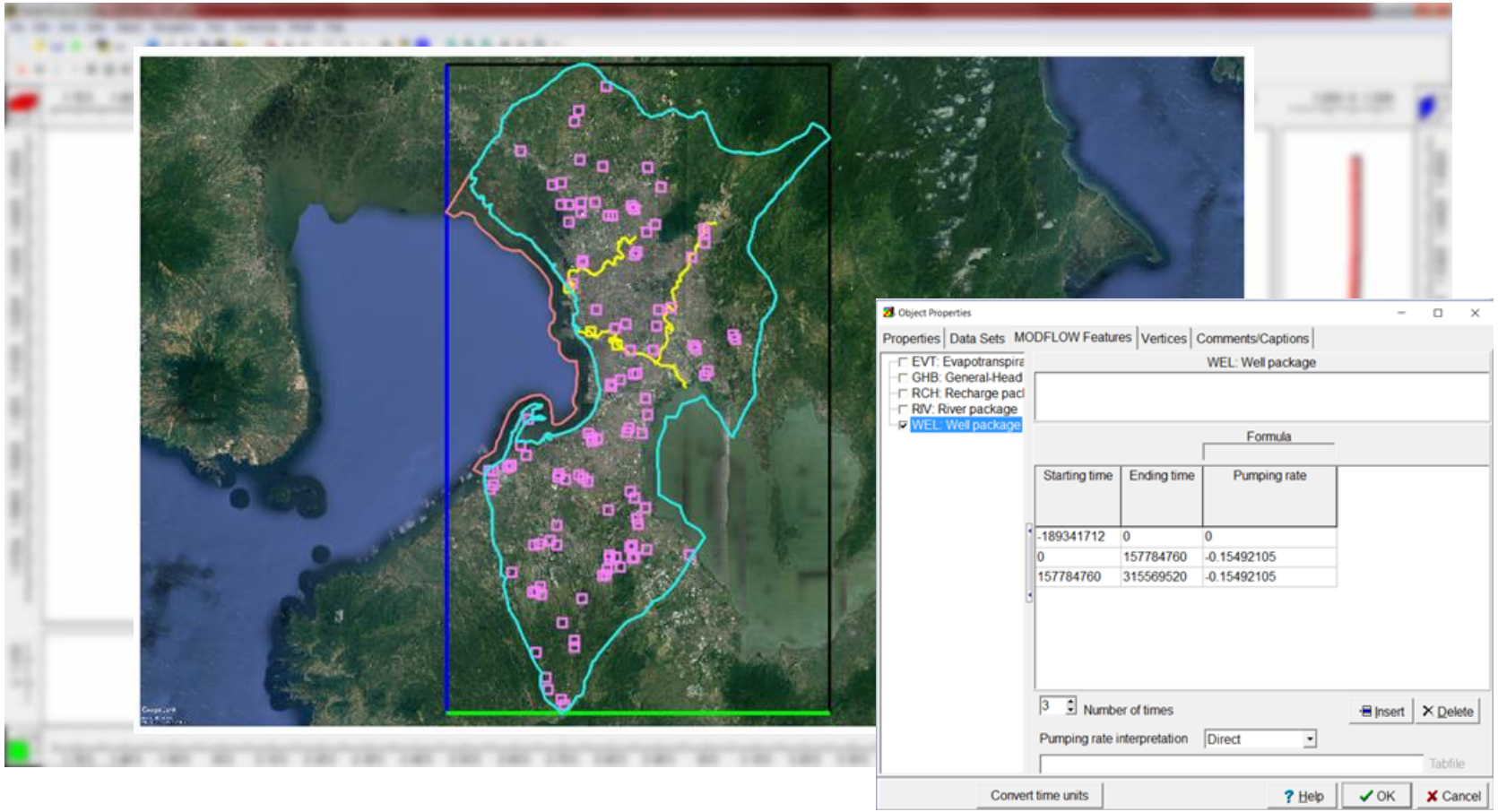
Aquifer


Object Properties
Properties
Data Sets
MODFLOW Features
Vertices
Comments/Captions
EVT: Evapotranspira
GHB: General-Head
RCH: Recharge pacl
RIV: River package
WEL: Well package
GHB: General-Head Boundary package
Formula
Starting time
Ending time
Boundary head
Conductance
-189341712
315569520
0
F()
0.001
1
Number of times
Insert
Delete
Conductance interpretation
Direct
Convert time units
Help
OK
Cancel

Sea


Object Properties
Properties
Data Sets
MODFLOW Features
Vertices
Comments/Captions
EVT: Evapotranspira
GHB: General-Head
RCH: Recharge pacl
RIV: River package
WEL: Well package
RIV: River package
Formula
Starting time
Ending time
River stage
Conductance
River bottom
-189341712
315569520
Model_Top - 1.
0.001
Model_Top - 5.
1
Number of times
Insert
Delete
Conductance interpretation
Direct
Convert time units
Help
OK
Cancel

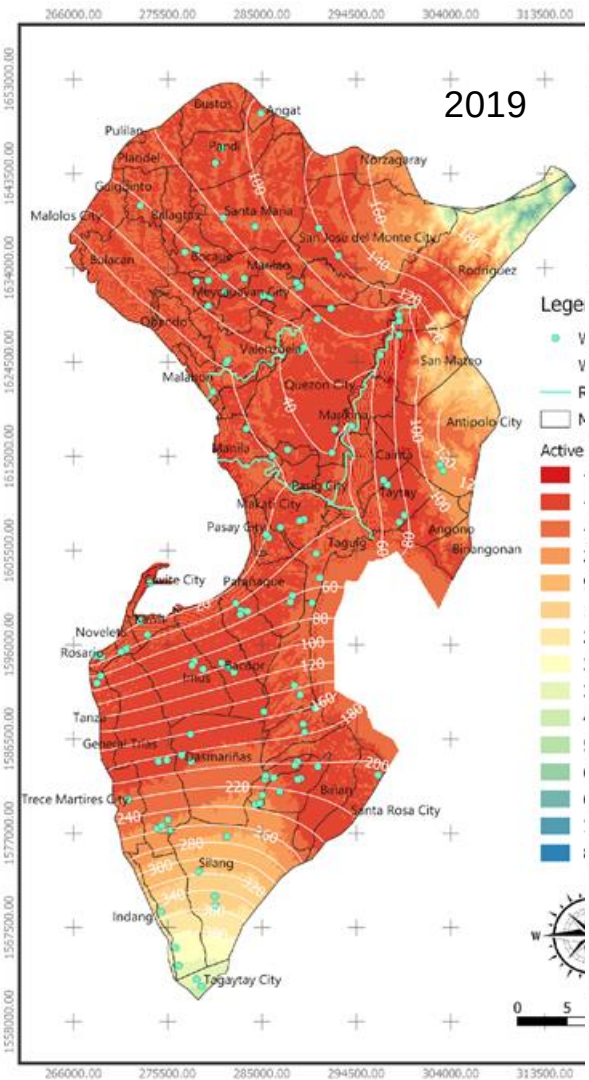
Rivers

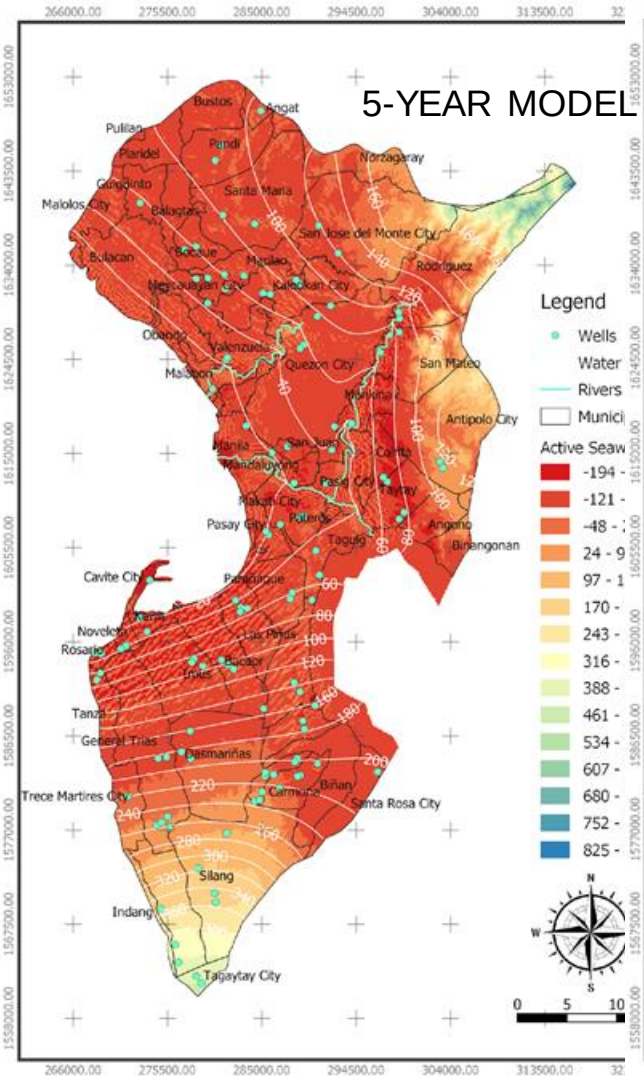

Object Properties
Properties
Data Sets
MODFLOW Features
Vertices
Comments/Captions
EVT: Evapotranspira
GHB: General-Head
RCH: Recharge pacl
RIV: River package
WEL: Well package
WEL: Well package
Formula
Starting time
Ending time
Pumping rate
-189341712
0
0
0
157784760
-0.15492105
157784760
315569520
-0.15492105
3
Number of times
Insert
Delete
Pumping rate interpretation
Direct
Tabfile
Convert time units
Help
OK
Cancel

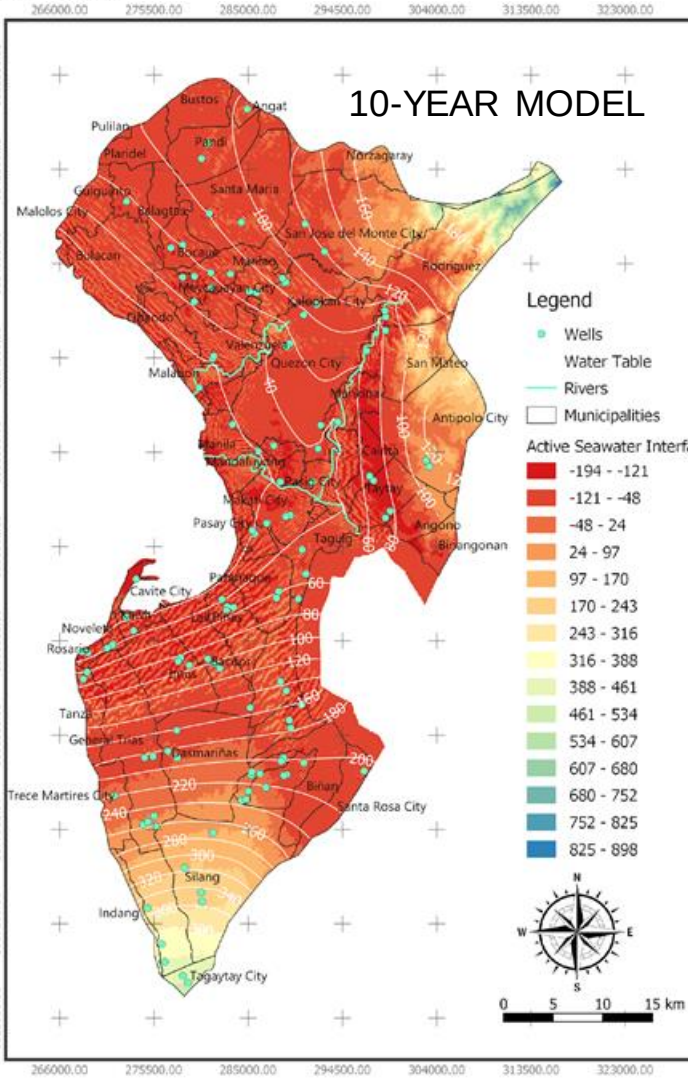
Wells

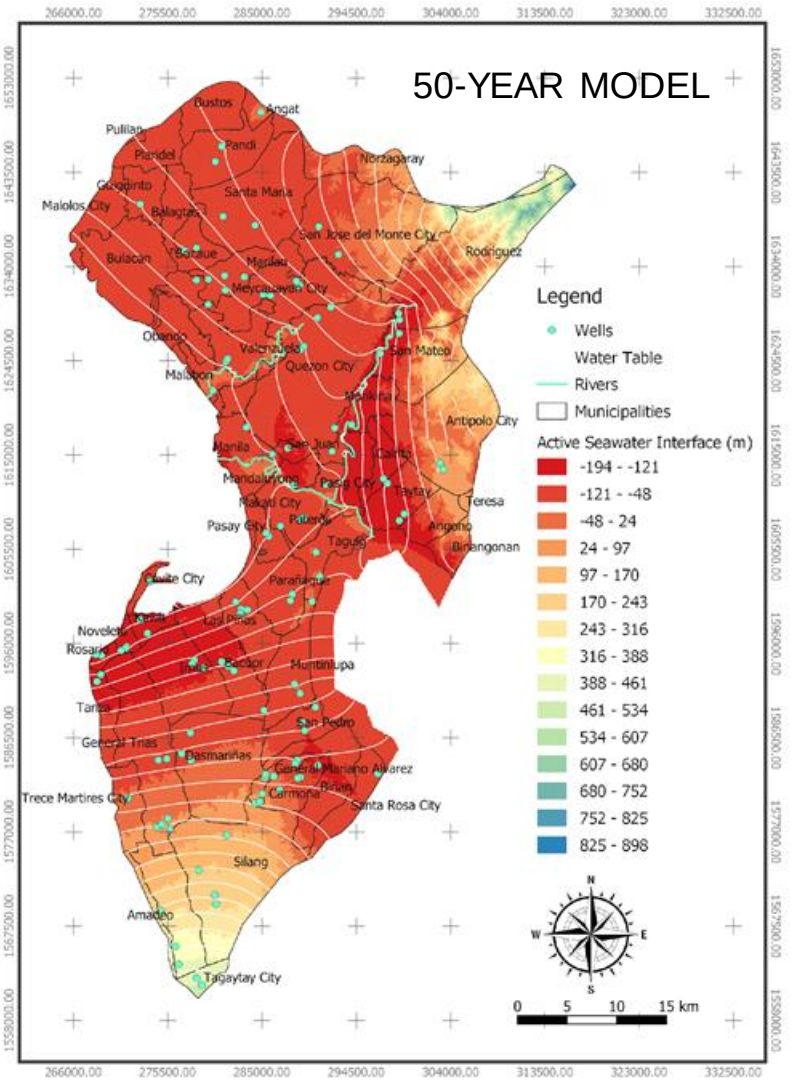
Results and Discussion

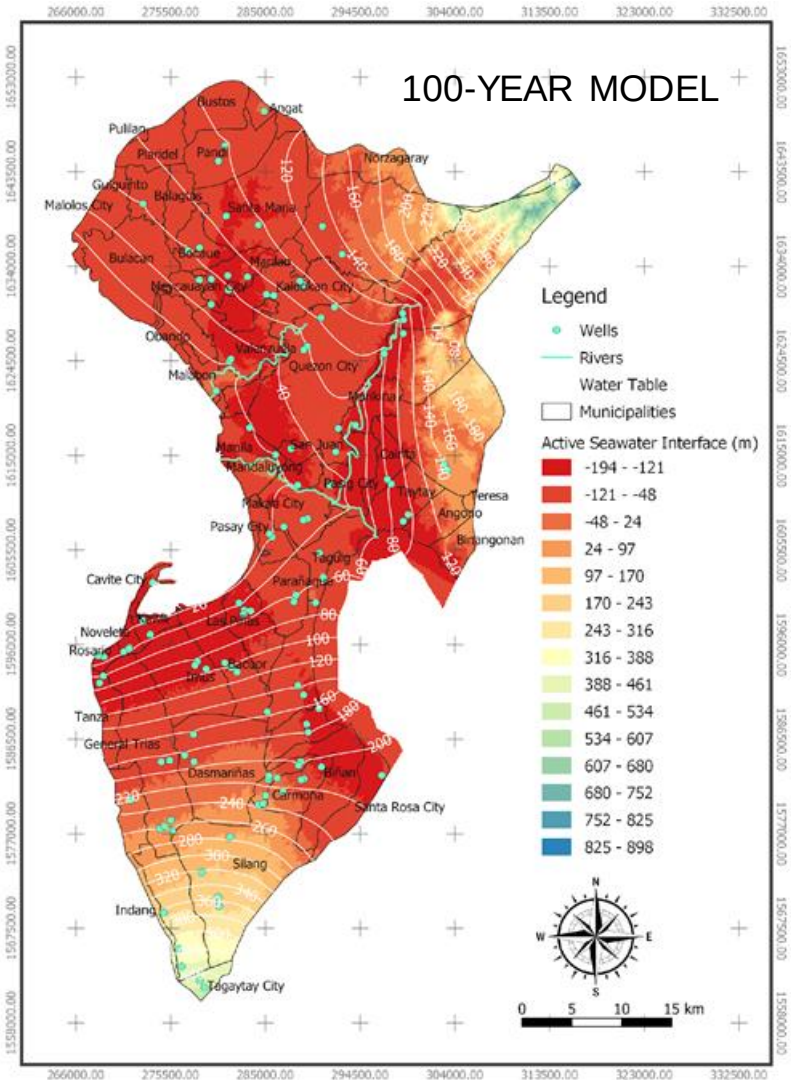
Normal Pumping Rate

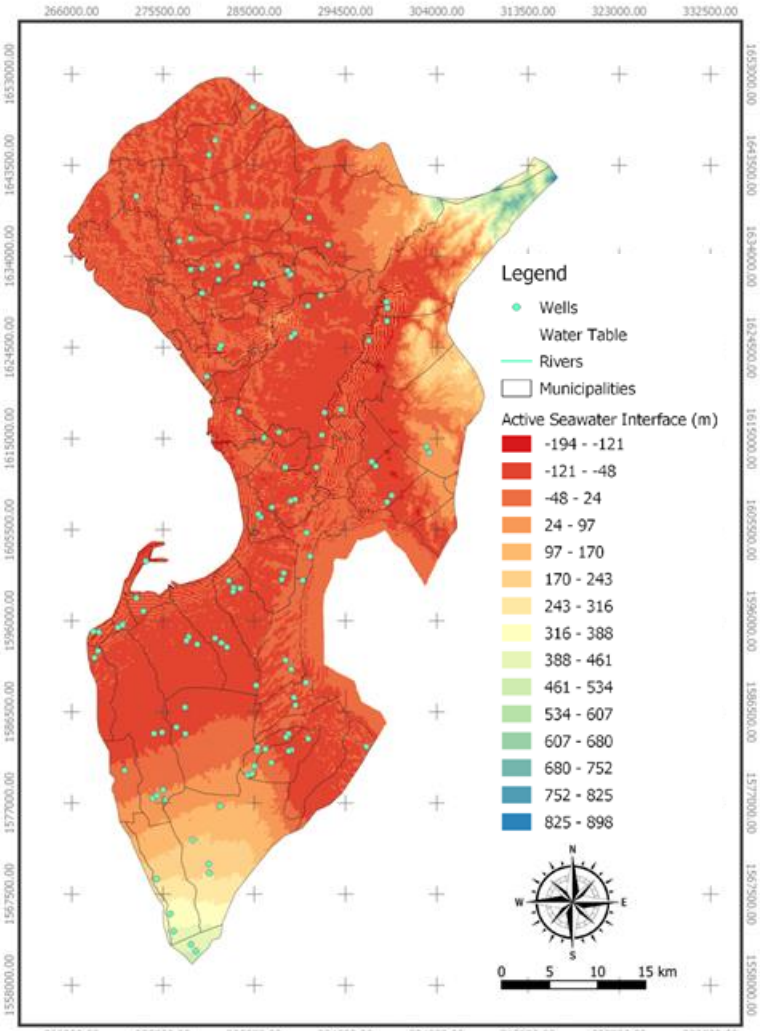

2019
Bustos
Angat
Pulilan
Pandi
Norzagaray
Malolos City
Santa Maria
San Jose del Monte City
Bulacan
Rodriguez
Meycauayan City
Obando
Valenzuela
San Mateo
Malabon
Quezon City
Marikina
Antipolo City
Manila
Pasig City
Taytay
Makati City
Pasay City
Taguig
Angono
Binangonan
Cavite City
Parañaque
Kawit
Novelete
Rosario
Bacoor
Imus
Tanza
General Trias
Dasmariñas
Trece Martires City
Biñan
Santa Rosa City
Silang
Indang
Tagaytay City
Lege
Active
0 5


5-YEAR MODEL
Bustos
Angat
Pulilan
Pandi
Norzagaray
Malolos City
Santa Maria
San Jose del Monte City
Bulacan
Rodriguez
Meycauayan City
Obando
Valenzuela
San Mateo
Malabon
Quezon City
Marikina
Antipolo City
Manila
Pasig City
Taytay
Makati City
Pasay City
Taguig
Angono
Binangonan
Cavite City
Parañaque
Novelete
Rosario
Bacoor
Imus
Las Piñas
Tanza
General Trias
Dasmariñas
Trece Martires City
Biñan
Carmona
Santa Rosa City
Silang
Indang
Tagaytay City
Legend
Wells
Water
Rivers
Municipalities
Active Seaw
-194 -
-121 -
-48 - 24
24 - 97
97 - 170
170 -
243 -
316 -
388 -
461 -
534 -
607 -
680 -
752 -
825 -
0 5 10


10-YEAR MODEL
Bustos
Angat
Pulilan
Pandi
Norzagaray
Malolos City
Santa Maria
San Jose del Monte City
Bulacan
Rodriguez
Meycauayan City
Obando
Valenzuela
San Mateo
Malabon
Quezon City
Marikina
Antipolo City
Manila
Pasig City
Taytay
Makati City
Pasay City
Taguig
Angono
Binangonan
Cavite City
Parañaque
Novelete
Rosario
Bacoor
Imus
Tanza
General Trias
Dasmariñas
Trece Martires City
Biñan
Santa Rosa City
Silang
Indang
Tagaytay City
Legend
Wells
Water Table
Rivers
Municipalities
Active Seawater Interfa
-194 - -121
-121 - -48
-48 - 24
24 - 97
97 - 170
170 - 243
243 - 316
316 - 388
388 - 461
461 - 534
534 - 607
607 - 680
680 - 752
752 - 825
825 - 898
0 5 10 15 km

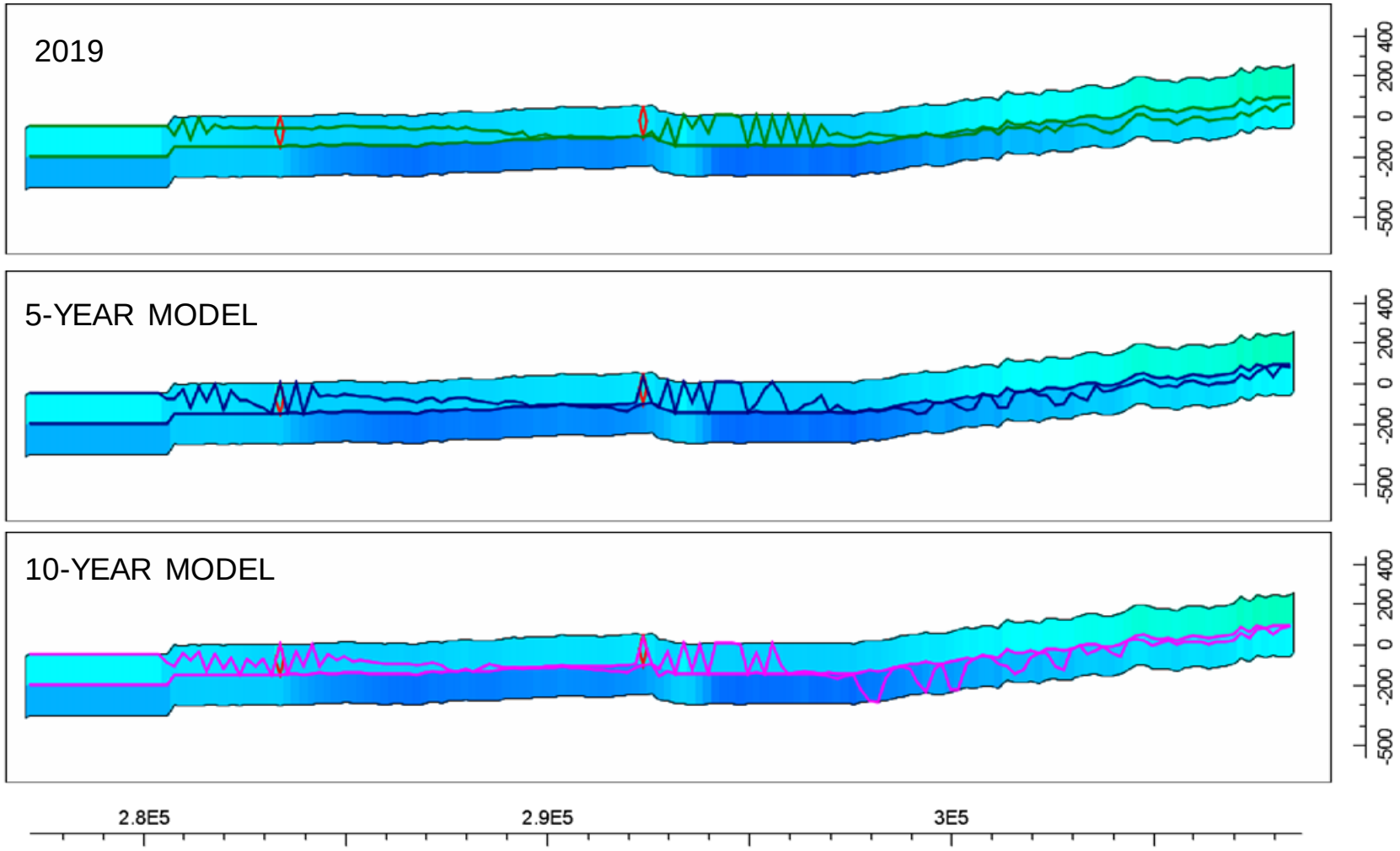

50-YEAR MODEL
Legend
Wells
Water Table
Rivers
Municipalities
Active Seawater Interface (m)
-194 - -121
-121 - -48
-48 - 24
24 - 97
97 - 170
170 - 243
243 - 316
316 - 388
388 - 461
461 - 534
534 - 607
607 - 680
680 - 752
752 - 825
825 - 898
0 5 10 15 km
Bustos
Angat
Pulilan
Pandi
Plaridel
Norzagaray
Guiguinto
Santa Maria
Malolos City
Bulacan
San Jose del Monte City
Rodriguez
Meycauayan City
Obando
Valenzuela
Quezon City
San Mateo
Malabon
Marikina
Antipolo City
Manila
San Juan
Cainta
Mandaluyong
Pasig City
Taytay
Teresa
Makati City
Pasay City
Taguig
Angono
Binangonan
Cavite City
Parañaque
Las Pinas
Noveleta
Rosario
Bacoor
Muntinlupa
Tanza
San Pedro
General Trias
Dasmariñas
Carmona
Santa Rosa City
Trece Martires City
Silang
Amadeo
Tagaytay City

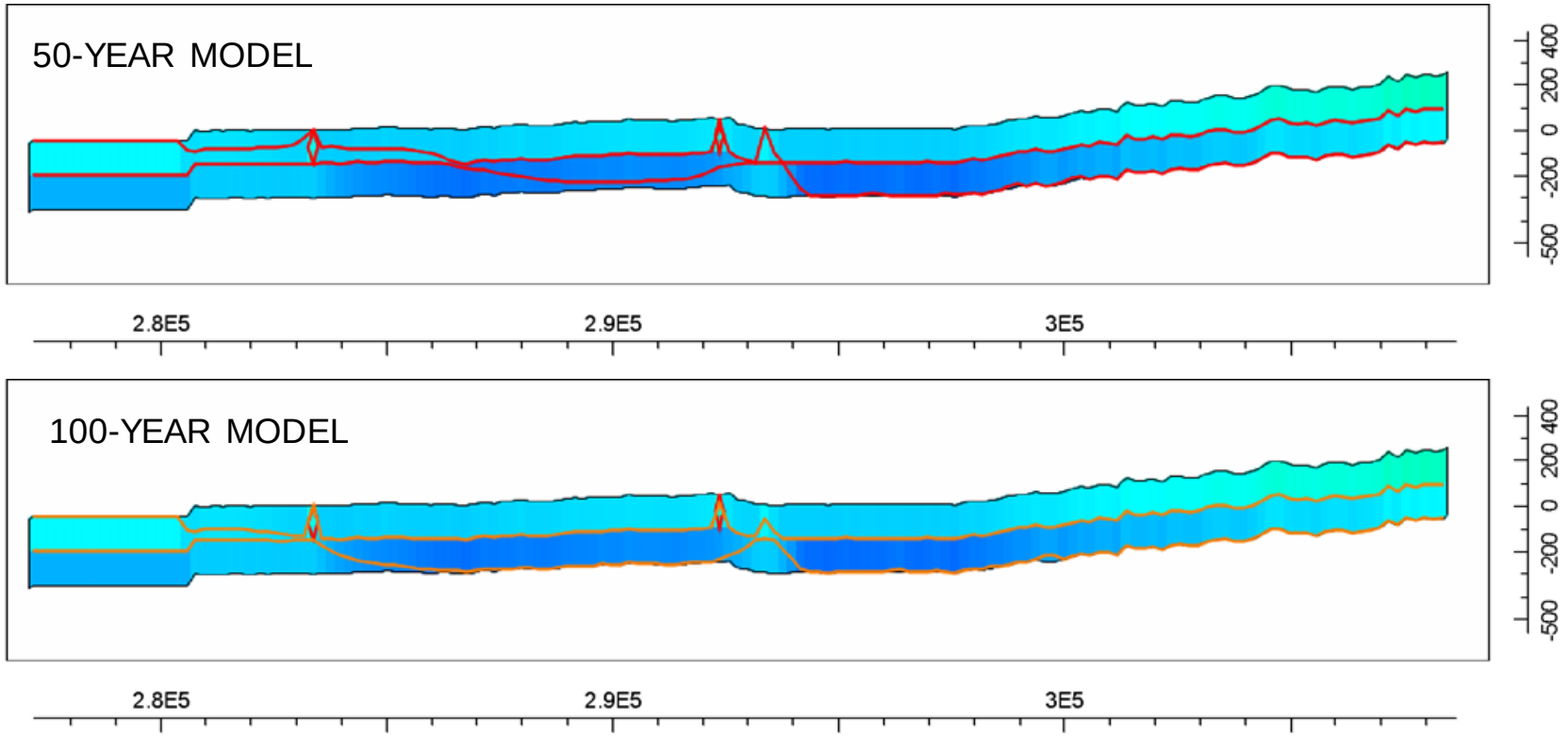

100-YEAR MODEL
Legend
Wells
Rivers
Water Table
Municipalities
Active Seawater Interface (m)
-194 - -121
-121 - -48
-48 - 24
24 - 97
97 - 170
170 - 243
243 - 316
316 - 388
388 - 461
461 - 534
534 - 607
607 - 680
680 - 752
752 - 825
825 - 898
0 5 10 15 km
Bustos
Angat
Pulilan
Pandi
Plaridel
Norzagaray
Guiguinto
Bulacan
Malolos City
Santa Maria
Meycauayan City
Obando
Valenzuela
Quezon City
Malabon
Marikina
Manila
San Juan
Cainta
Mandaluyong
Pasig City
Taytay
Teresa
Makati City
Pasay City
Angono
Binangonan
Taguig
Cavite City
Parañaque
Las Pinas
Noveleta
Rosario
Bacoor
Tanza
General Trias
Dasmariñas
Carmona
Santa Rosa City
Silang
Indang
Tagaytay City

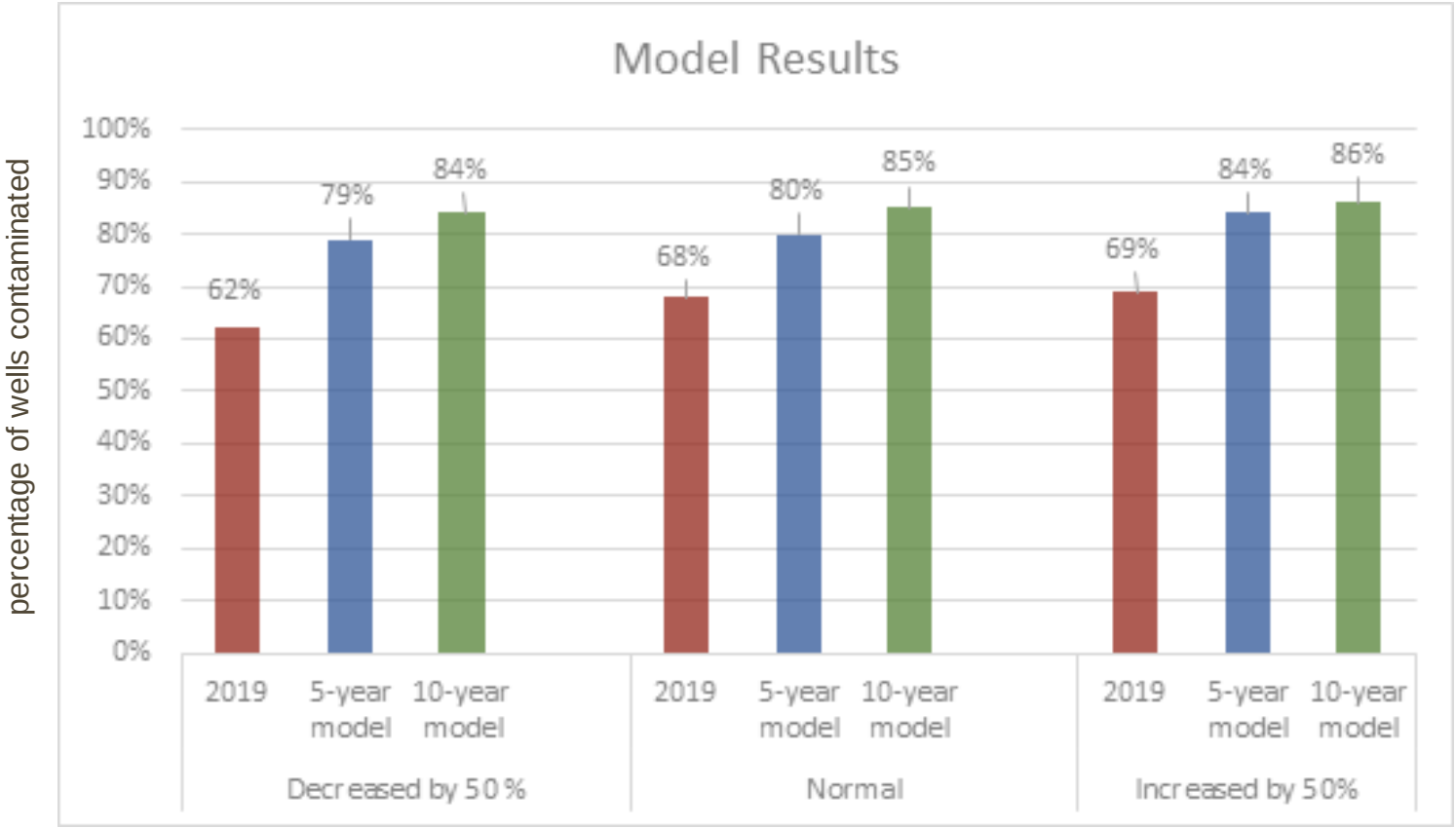


Moving Image of the 2019, 5, 10, 50 and future 100-year Map

Cross sections for Normal Pumping Rate


2019
400
200
0
-200
-500
5-YEAR MODEL
400
200
0
-200
-500
10-YEAR MODEL
400
200
0
-200
-500
2.8E5
2.9E5
3E5


50-YEAR MODEL
400
200
0
-200
-500
2.8E5
2.9E5
3E5
100-YEAR MODEL
400
200
0
-200
-500
2.8E5
2.9E5
3E5


Model Results
percentage of wells contaminated
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
62%
79%
84%
68%
80%
85%
69%
84%
86%
2019
5-year model
10-year model
Decreased by 50%
Normal
Increased by 50%

Conclusion

- Saltwater intrusion into the coastal aquifers can be a larger problem in Metro Manila if over extraction persists in the following years

- For the 2019 model
    - in Cavite, Imus and Bacoor are greatly affected while General Trias and Dasmarinas are partly affected
    - in Metro Manila – Quezon City, Pasig, Makati and Paranaque are affected;
    - Bulacan and Laguna areas are slightly affected
    - Towns of Taytay and Cainta in Rizal are greatly affected

- 5-year and 10-year models
    - Whole area of Bulacan and Metro Manila as well as parts of Laguna and Rizal becomes greatly affected
    - Cavite except towns of Silang and Indang is greatly affected

Recommendation

- If permissible, pumping tests should be conducted specifically for areas that lack records on static water level for better calibration for future models.
- Longer stress periods with multiple time steps should be simulated to better visualize the drastic changes in the active seawater interface

Acknowledgement