Annex 5 : Updated GW model

Updating the groundwater model

The impact on groundwater is one of the most important issues that are being associated with the project, that is part of the project has been designed to prevent impacts on the groundwater from infiltrating partially treated sewage.

The groundwater modeling prepared in the original EA of the project resulted that the groundwater quality will be improved after the operation of Part B of the project as the new infiltrated plume will wash out the old plume of partially treated water, however the EA has simulated a worst case scenario where the operation of Part B of the project is delayed and the EA recommended construction of remediation wells to pump out the effluent.

For the current work, the existing groundwater modeling provided during the design and the EA of the updated NGESTP study (2012-2013) is assessed and used as a reference. Visual Modflow (VMF) version 4.6 and its integrated modules are used in the current study. Our approach consists of updating the model to consider the delays in the implementation and operation of the designed stages of the treatment plant as well as the recovery schemes.

The most updated data provided by the client, up to year 2017, is used; i.e. the model was updated considering the followings:

- The actual infiltrated partially treated wastewater quantities and rates from 2012 to 2017,
- The updated locations and numbers of the recovery wells,
- The actual design of the first stage of the recovery wells (14 wells) that constructed by the end of year 2017.
- The updated time schedule for the operation of the treatment plant and the two stages of the recovery wells.

The assessment of the impacts on groundwater considered the abstraction rates of the recovery wells, the possible recharge in the agricultural lands and different scenarios for project implementation. Two scenarios are considered in the current impact assessment:

1. Without the implementation of recovery scheme.
2. With the implementation of recovery scheme. 27 recovery wells will be implemented on two stages; 14 wells that already constructed and to be operated by the end of 2019 and 13 wells to be operated by the end of 2021.

Both scenarios take into account the operation of the WWTP by the beginning of 2018. Therefore, partially treated wastewater will continue to be infiltrated until the beginning of 2018, then, 35,600 m^3/day of treated wastewater will be infiltrated.

1. Modeling Results without Recovery Scheme

Results of the model shows that, at the beginning of year 2018, the pollution plume extends to a distance of about 500 m (nitrate concentration contour line is 80 mg/l) in the North-West direction of the basin (See Figure 1); as wastewater with bad quality has been infiltrated in the basins since 2009 (15,000 – 20,000 m^3/day).

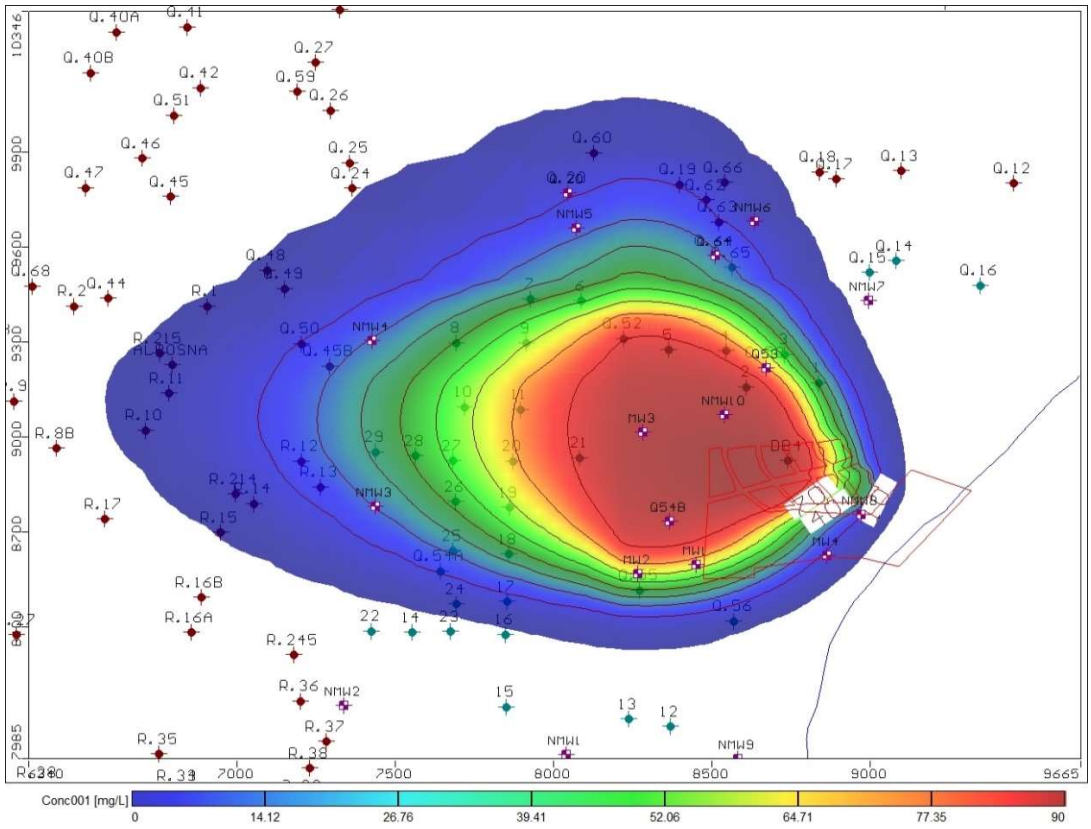


Figure 1: The pollution plume in year 2018 (before the infiltration of treated wastewater, no recovery)

Figure 2 shows the groundwater quality expectations in year 2019 after the operation of the treatment plant. Concentration of the infiltrated treated wastewater will be 10 mg/l. It can be noticed that there will still be polluted zones and some agricultural wells will be affected. Figure 3 shows the same scenario for year 2025 where the groundwater quality is highly improved. However, large polluted zone is still found in the North-west direction, where municipal and agricultural wells exist.

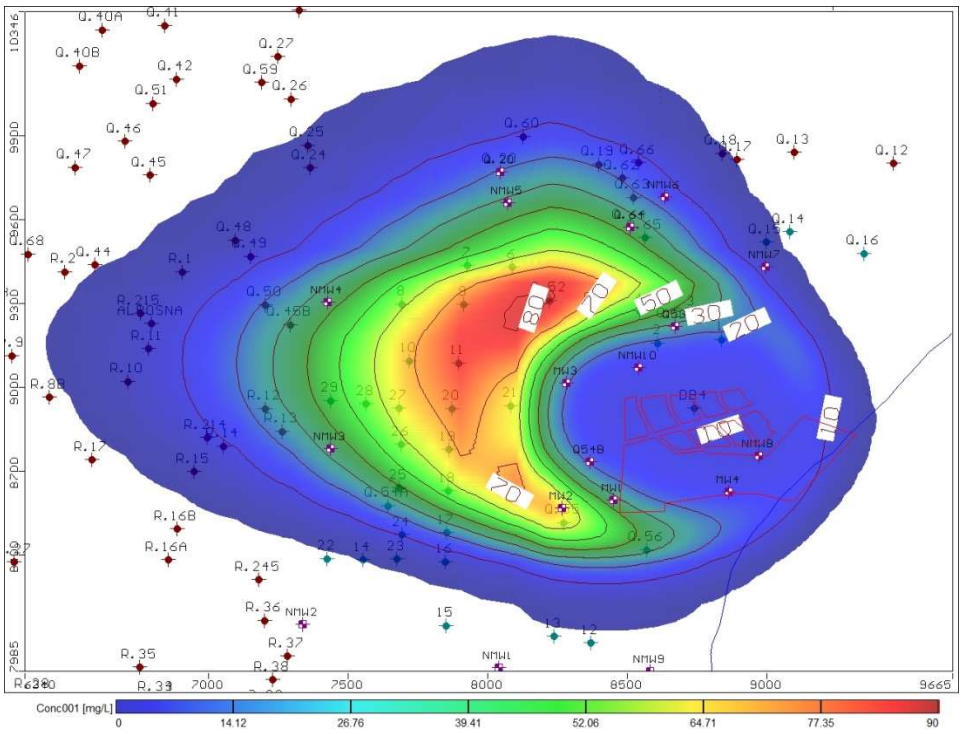


Figure 2: The pollution plume for year 2019 (35,600 m³ of treated wastewater is infiltrated starting from 2018)

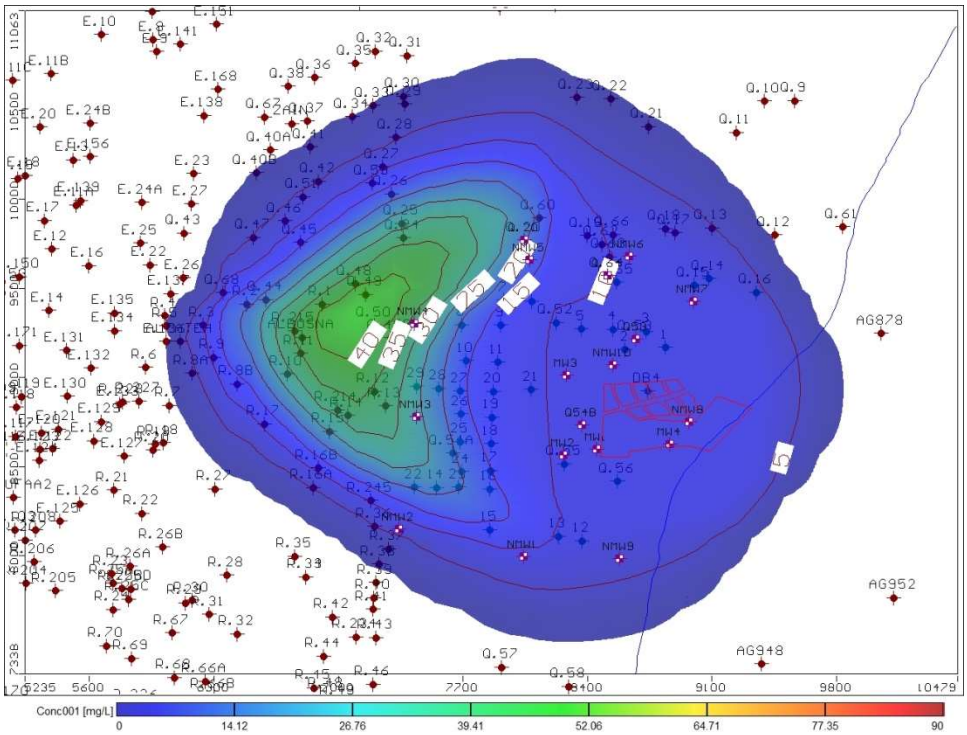


Figure 3: The pollution plume for year 2025 (35,600 m³ of treated wastewater is infiltrated starting from 2018)

2. Modeling Results with Recovery Scheme

A total of 27 recovery wells, designed to recover the infiltrated treated wastewater, will be implemented and operated on two stages:

- **Stage 1**: 14 wells, located in the North West direction of the basins, are designed to be operated by the end of 2019.
- **Stage 2**: 13 wells, located in the North and the South direction of the basins, are designed to be operated by the end of 2021.

In order to specify the optimal locations of these wells, several runs of the model were carried out, as part of the project design, on the base that these wells should be able to capture all pollution; these locations were modified to go in line with the delay in the operation of the treatment plant. Figure 4 shows the pollution plume after the implementation of the first stage of the recovery wells, it can be noticed that the plume is restricted to pass the 14 recovery wells. In addition, it reduces the dilution of the pollutants in the area after the recovery wells.

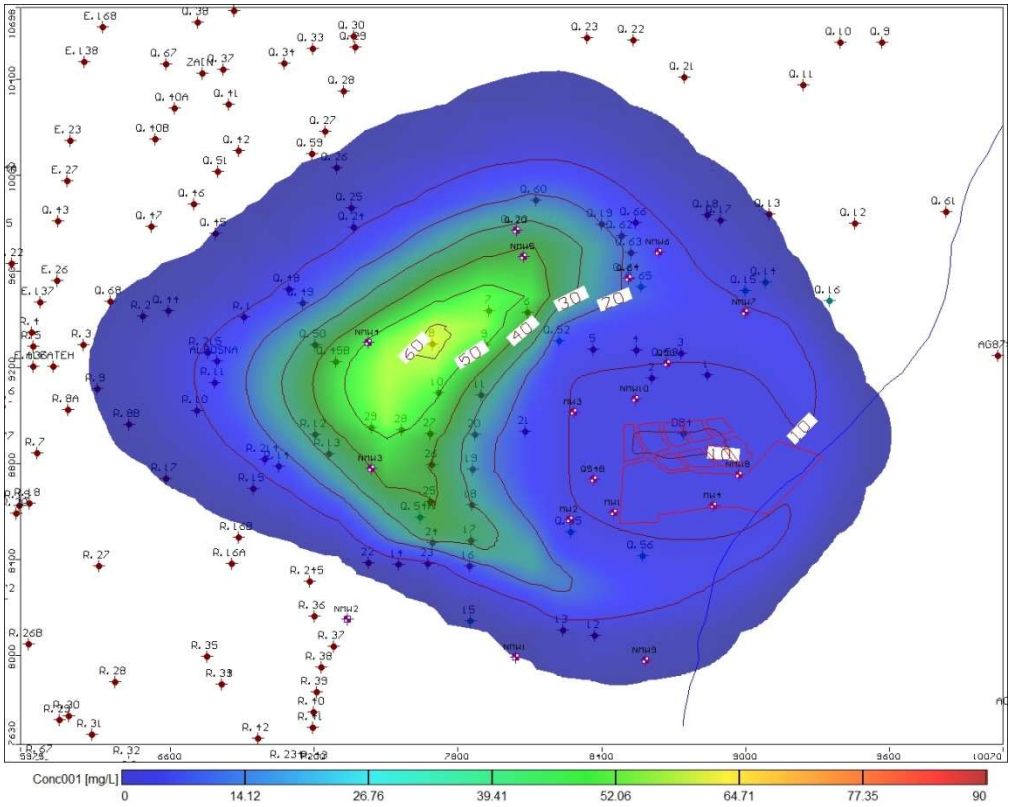
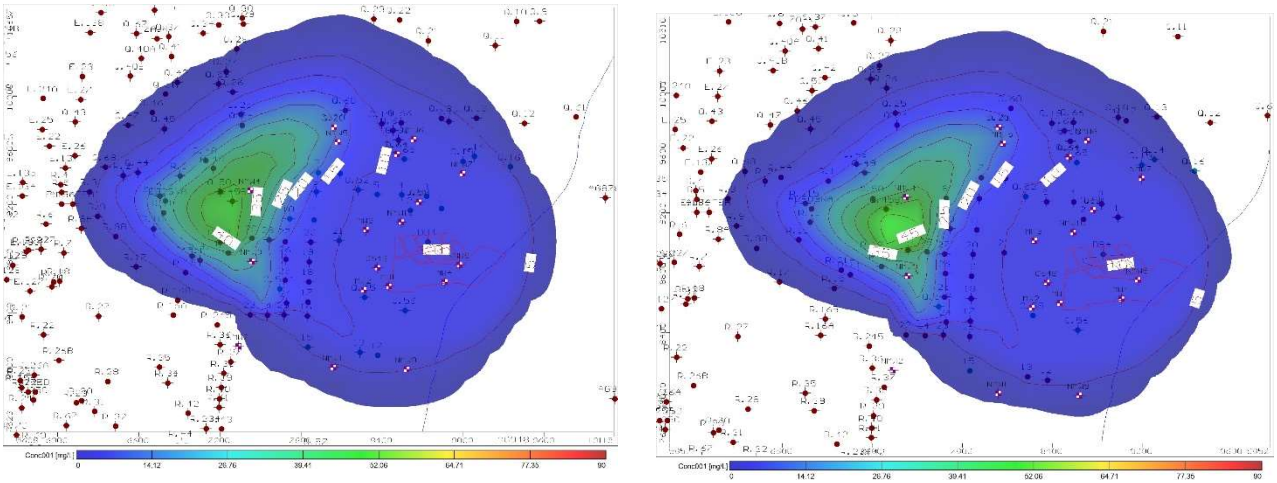


Figure 4: Pollution plume in 2021 (after the implementation of the first 14 wells in 2019)

The second stage of the recovery wells is intended to be implemented to restrict the expansion of the pollution plume; i.e. if only 14 wells continue to operate, the pollution will be extended and more wells will be at risk in year 2025 as shown in Figure 5 (a). In addition, polluted zone will be found in the North-west direction with concentration of pollution of 40 mg/l. While Figure 5 (b) shows that the pollution plume is restricted to pass the 27 recovery wells. In addition, the area of the polluted zone in the North-west direction will be smaller than that the area in the case of operating 14 wells. The presence of this pollution zone in the north-west direction

is due to the delay of construction and operation of the 14 wells (stage 1) and 13 wells (stage 2). The pollution escapes the recovery wells and it is difficult be recaptured using the recovery wells since the remaining polluted area is in the downstream. This polluted area will disappear due the dilution with the existing groundwater which will take time. As shown in Figure 6 in year 2042 the pollution disappears.



(a) **(b)**

Figure 5: Pollution plume in 2025: (a) without the implementation of Stage 2 of the recovery wells and (b) after the implementation of stage 2 of the recovery wells

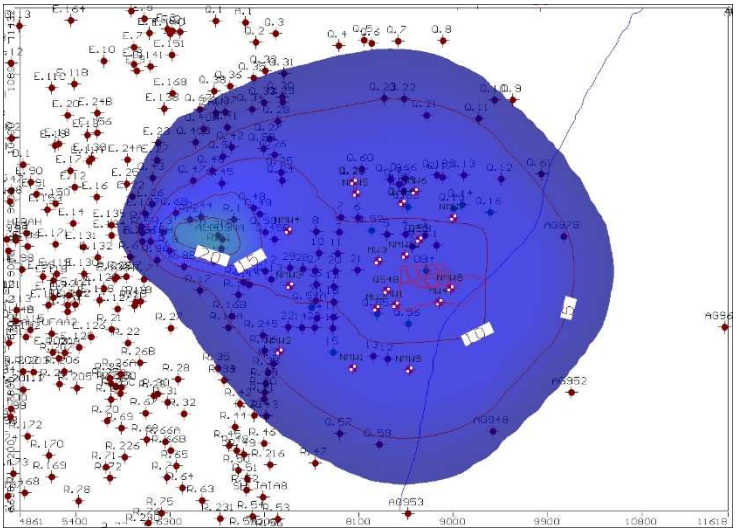


Figure 6: Pollution plume in 2042 after the implementation of stage 2 of the recovery wells

Based on the groundwater modeling and analysis, monitoring plan should be developed. The monitoring plan should include the mitigation measures which has to be considered during the operation of the effluent recovery

scheme. The monitoring plan includes the provision of the monitoring wells location, monitoring indicators (parameters to be monitored) and monitoring frequency.

3. Impacts of the Project on Groundwater Elevation

The current water table elevation in the area around the basins is 2 m above mean sea level, as shown in Figure 7. After the operation of the first stage of recovery wells by the end of year 2019, about 20,000 m3/day of groundwater will be recovered (abstracted). This will affect the groundwater table as shown in Figure 8; which indicates the reduction in the water table elevation after two years of operation of the first stage of recovery wells.

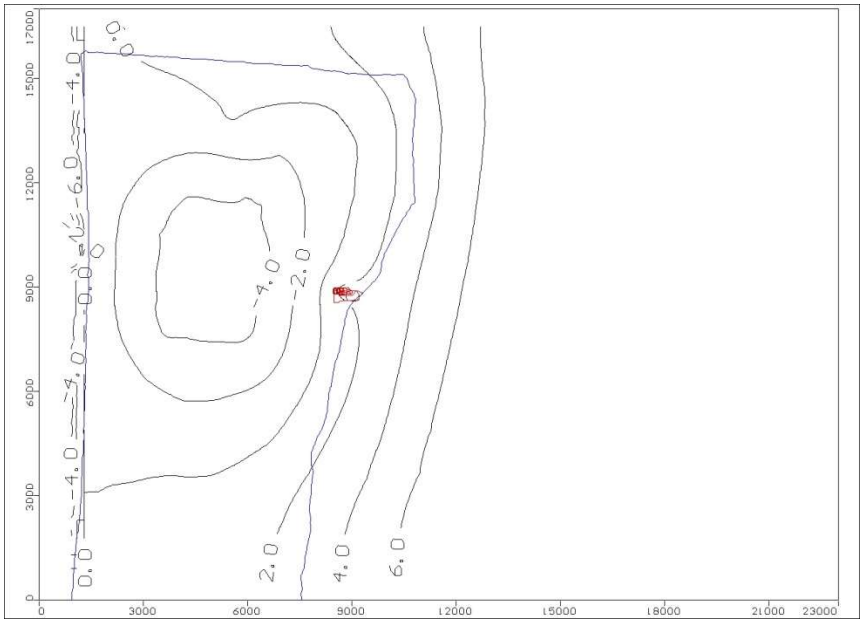


Figure 7: Groundwater Table before the implementation of the first stage of recovery wells in 2018

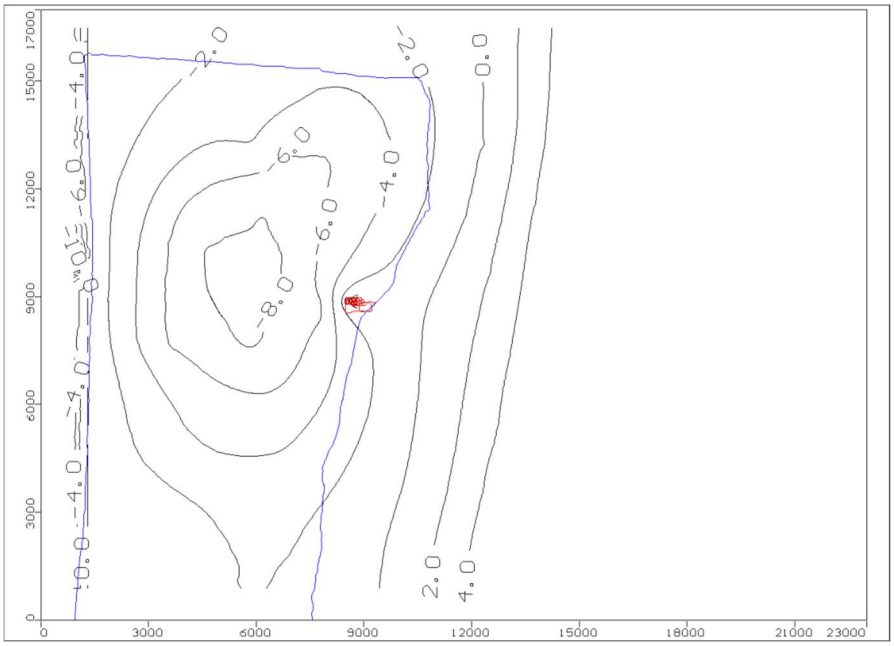
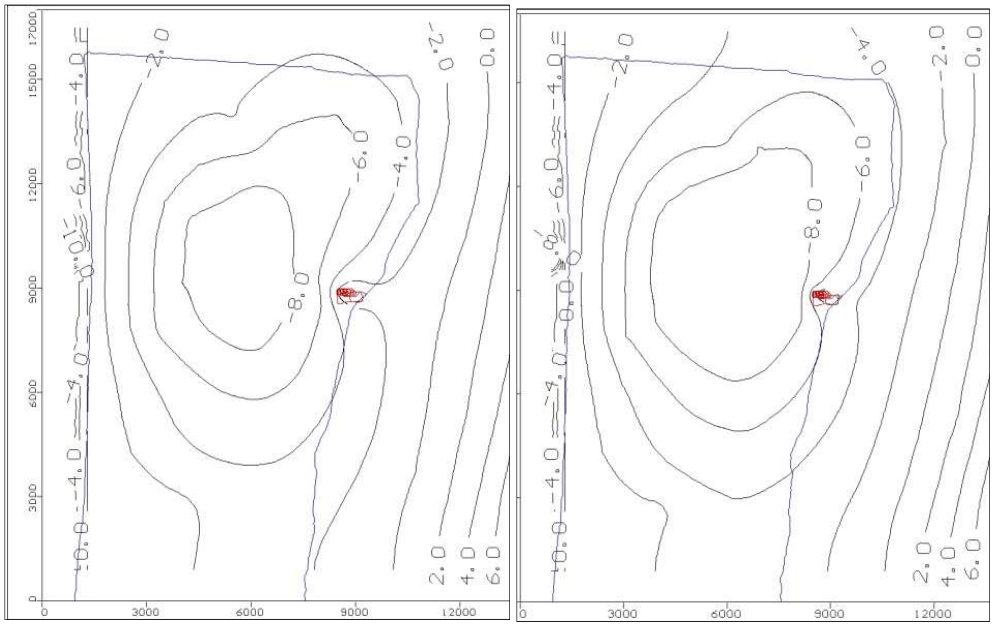


Figure 8: Groundwater Table before the implementation of the second stage of recovery wells in 2021

In 2030, the model estimated that the water table elevation, in the area around the basins, will be between 2 m and 4 m below mean sea level if the second stage of recovery wells is not implemented, as shown in Figure 9 (a). While, in the same area, the water table elevation will be between 4 m and 6 m below mean sea level if the second stage is implemented; as about 18,000 m3/day of groundwater will be abstracted through 13 recovery wells (See Figure 9 (b)).



(a) (b)

Figure 9: Ground water Table in 2030, (a): without the implementation of the second stage of the recovery wells, and (b): with the implementation of the second stage of the recovery wells.