Peer Review (Group)

Summary

Group 1 aims to construct a model of the Onehunga Aquifer, considering the changes in both pressure and copper concentration, to recommend an appropriate extraction rate of water to the Auckland Regional Council. The key stakeholders include Watercare, the Ministry of Health, the Auckland Council, Ngāti Whātua and the other residents of the area. The possible recommendations are increasing the allowable extraction to 40 million litres per day, continuing the current limit of 20 million litres per day, reducing the limit to some recommended level, and suspending the aquifer usage.
Historical data on pressure, copper concentration and the extraction rate at the Onehunga Aquifer since 1980 are available to train the model. There is an observed negative correlation between the extraction rate and copper concentration.

The model incorporates two differential equations, one for each of copper concentration and pressure (shown below). The domain selected is the whole Onehunga Aquifer - treated as an open system, and there is assumed to be only one inflow and one outflow. The ODE for pressure takes into account forced extraction and a restoring term governed by Darcy's law. The ODE for copper concentration takes into account copper itself flowing in, copper being extracted and the copper that flows in due to a Darcy flow.

$$\frac{dP}{dt} = -a_p * q_{sink} - b_p * (P - P_0) \qquad M\frac{dc}{dt} = q_c + C * q_{sink} + C * \frac{bp}{ap}(P - P_0)$$

where $a_p = \frac{g}{A * \Phi}$ $\qquad b_p = \frac{g * k * \rho * A_{rech}}{A * \Phi * \mu * L}$

Assessment

Overall, our interpretation of the problem was similar to that of Group 1. For example, we agree that the model will provide insight by relating the extraction rate to the aquifer's copper concentration over time.
The model assumptions are generally reasonable and justified, for example the choice of domain and exclusion of any slow drainage terms. Also, the use of lumped parameter models and the choice of physics principles (conservation of mass and solute) are very appropriate for the model purpose. We agree that heat transfer and changes in temperature do not need to be considered in this model.
The research and data analysis to obtain estimates of parameters (such as the aquifer surface area and porosity) will also prove useful during the calibration phase, since they can be used as starting points and 'reality checks'.

Some of the model weaknesses relate to how variables and parameters are defined, for example:
- q_c not well defined in the copper ODE, and q_{sink} is defined as an amount rather than a rate
- The initial pressure and ambient pressure are considered the same parameter, P_0; this is not robust, since it may not be possible to calibrate the model assuming this specific case
- The initial copper concentration is not given as a parameter, despite being needed to calibrate the model
- Units are not stated, so there is some ambiguity (e.g. copper concentration could be ppm, mg/L, etc)

- The sink and source bodies are referred to in the ODEs, but their physical meanings are not explained

In regards to the conceptual diagram, the flows should be labelled appropriately. For example, the methods by which changes in pressure and copper concentration occur should be indicated for clarity. Ideally the physical meaning of each term in the ODEs should be described too (e.g. Darcy flow, surface recharge, extraction).

Recommendations

In general, the model could be improved by considering the above weaknesses and making the appropriate adjustments. For example, the units of all variables and parameters should be defined in the model formulation, and there should be a parameter for the initial copper concentration.

We recommend that the model takes two separate recharge ‘mechanisms’ into account, rather than just one. Although assuming one inflow simplifies the problem, it may not be valid here. This is because the pressure at the bottom boundary is higher than that at the top boundary, as hydrostatic pressure increases with depth (Davidson et al, 2011) - which is significant as the aquifer is very deep. Hence, the driving force for recharge will be different at these boundaries. Of note, Group 1’s model also assumes that the only inflow is from stormwater at the top control surface, however we believe that mass flow through other control surfaces due to pressure differences should be considered too. This change impacts both the pressure and copper concentration ODEs. We agree that assuming only one (strict) outflow - extraction - is valid, and with the reasoning provided for this.

Perhaps it might be appropriate to simplify the domain to a prism with constant cross sectional area and variable height, so that the complex geometry of the aquifer does not need to be considered in detail. We think that using a cylindrical domain is a reasonable assumption, and that the potential reduction in accuracy would be worth the reduction in experimental and computational costs. In particular, it would be difficult to accurately estimate the recharge area if the domain was chosen as the whole Onehunga Aquifer.

As previously mentioned, we also think the conceptual diagram should illustrate the processes occurring. For example, the arrow labelled ‘Cu Atoms’ appears to represent a pure copper flow, even though such a flow does not exist in this problem. Similarly, the recharge via rainwater should technically be on the top control surface. So for the sake of completeness, we recommend that this diagram is revisited and made more representative of the model ODEs.

Beyond the model formulation, we think the proposal should explicitly mention the resource consent application put forward by Watercare to the Auckland Regional Council. This is an important detail because it provides a basis for evaluating Watercare’s claim that increasing extraction to 40 million litres per day is viable.

Finally, the investigation mentions Ngāti Whātua, but does not go into detail on why they are such an important stakeholder and source of expert information regarding natural resources and environmental protection. The impacts they may have on the model and recommendation have not been elaborated on.

References

Davidson, P. & Wilson, S.(2011). Groundwaters of Marlborough, Chapters 7 and 9. Retrieved from https://www.marlborough.govt.nz/environment/groundwater/reports-and-special-investigations