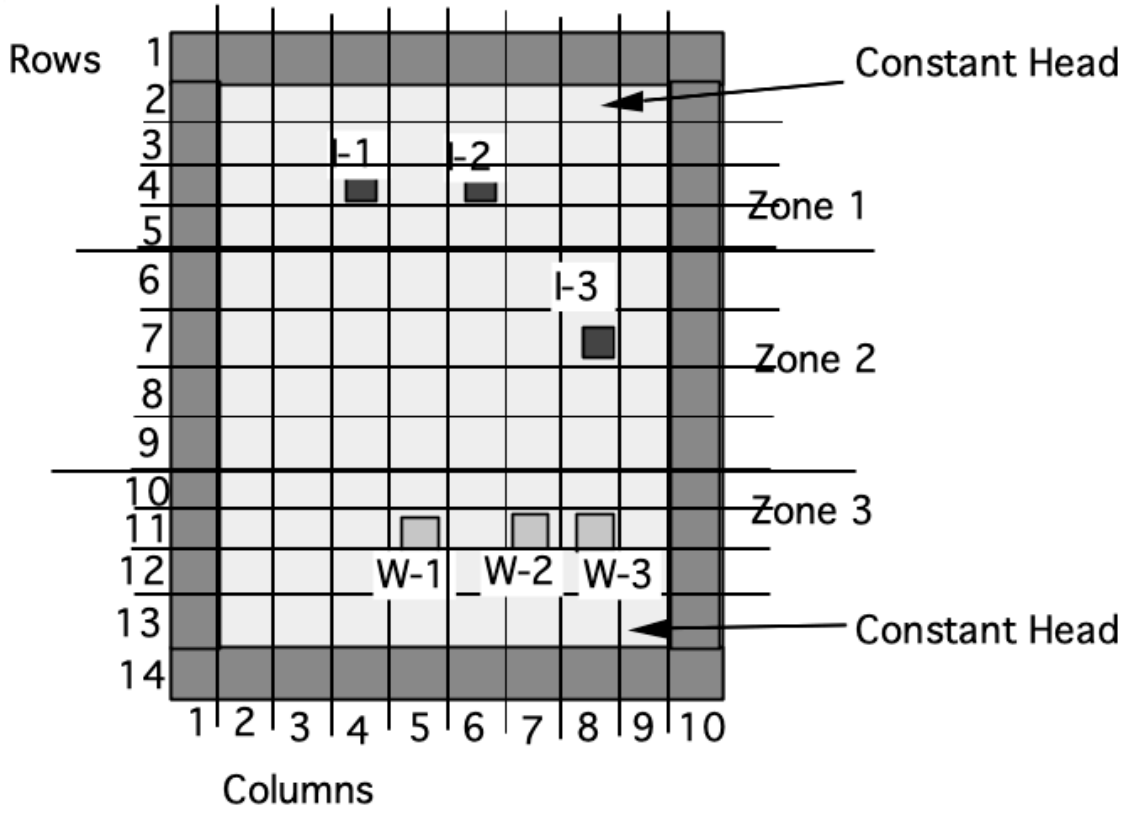
Project-2024

November 19, 2024

1 USGS MODFLOW6 Project

A 300-ft thick aquifer is used for water supply. The aquifer is also under consideration as a disposal field for treated waste water (aquifer-storage-recovery), where the filtration and dilution capacity of the aquifer will be used to receive the waste water for intentional re-use.

The figure below is a plan-view representation of a conceptual model of the aquifer. Each cell in the schematic is $1,500$ feet by $1,500$ feet.



The northern constant head boundary is set at h=600 ft. The southern edge constant boundary varies from 540 ft to 520 ft as one traverses from east to west. Three water supply wells, W-1, W-2, and W-3 are already in service. Hydrologic data suggests that the aquifer system has three distinct zones with different hydraulic characteristics. These characteristics are tabulated below.

Zone	K(cm/sec)	n
1	4.72	0.20
2	1.57	0.20
3	0.47	0.20

The longitudinal dispersivity has been estimated as $\alpha_l = 50\ m$ and the transverse dispersivity has been estimated at $\alpha_t = 20\ m$. The drinking water wells supply water at the rates tabulated below.

Well	Q(cfs)
W-1	16.0
W-2	7.0
W-3	7.0

The proposed re-use scheme will inject tracer-labeled waste-water into the aquifer into any of the three injection sites, I-1, I-2, or I-3. The goal is for the concentration of the non-toxic tracer to never exceede 250 mg/L at the water production wells. The tracer is added just before injection as a dilution indicator so that the water utility can shut down a well if the water in that well is not sufficiently diluted (much like the tracer added to natural gas to detect leaks). The tracer concentration at the injection point is 1000 mg/L (the operation goal is the dilute the waste water four fold before it reaches the drinking water wells).

Determine using MODFLOW6 the answers to the questions below.

1. Can 30 cfs of waste water be injected at I-3 and meet the water quality goal (4:1 dilution at drinking water wells)?
2. Is it possible to inject more waste water (higher flow or different location)?
3. Find the maximum volume that can be injected (at any or all of the three sites) and meet the water quality goal - this is the "regulatory assimilative capacity of the system." Does this volume exceed the drinking water demand currently satisfied by the three wells?
4. Assume that instead of a non-toxic tracer, the injection water concentration represents some particular water quality parameter. Assuming that the injection rate never exceedes the demand rate, what is the maximum waste load (mg/sec) that can be put into the aquifer and meet the raw water quality goal?

Submit your response as a Modeling Report; below is a suggested layout for such a report

0. Title Page: Title of the Report; Author(s); Date; Affiliation/Institution

1. Introduction: Objective is to evaluate the feasibility of injecting tracer-labeled wastewater into the aquifer without exceeding water quality goals at drinking water wells. Injection must achieve a 4:1 dilution (250 mg/L threshold) at the production wells W-1, W-2, and W-3, starting from an injection concentration of 1000 mg/L.

2. Problem Statement: Evaluate injection scenarios at sites I-1, I-2, and I-3 considering:

- Feasibility of injecting 30 cfs at I-3.
- Potential for higher injection rates or alternative locations.
- Maximum allowable injection volume meeting water quality goals (regulatory assimilative capacity).

- Maximum waste load (mg/sec) at allowable injection rates.

3. Assumptions and Parameters:

- Aquifer Properties
- Well Production Rates:
- Tracer concentration:
- Water quality threshold:

4. Modeling Methodology

- Flow Calculations: Simulate groundwater velocity using Darcy's Law and account for the influence of production wells.
- Transport Modeling: Model advection, dispersion, and dilution to predict tracer concentrations at wells.
- Dilution Criteria: Evaluate tracer concentrations at each production well to ensure C_goal is met.

5. Results:

- Scenario 1: Injection of 30 cfs at I-3. Tracer concentration at wells: W-1: [Concentration] mg/L ;W-2: [Concentration] mg/L; W-3: [Concentration] mg/L; Evaluation: [State whether 30 cfs injection meets the goal].
- Scenario 2: Higher Injection Rates or Alternative Locations. Injection rate: [Maximum rate feasible for each site, I-1, I-2, I-3]. Evaluation: [State if higher injection rates meet the goal].
- Scenario 3: Regulatory Assimilative Capacity. Maximum injection volume: [Calculated capacity in cfs or m^3/s]. Comparison to well demand: [State if capacity exceeds current drinking water demand].
- Scenario 4: Maximum Waste Load. Maximum injection rate: [Rate that satisfies water demand]. Waste load: [Calculated maximum mg/secmg/sec].

6. Discussion

- Feasibility: Summarize the feasibility of injection scenarios.
- Sensitivity Analysis: Discuss key parameters affecting the results (e.g., dispersivity, porosity).
- Limitations: Highlight assumptions that could impact accuracy.

7. Recommendations

- Proposed injection site(s) and rates.
- Monitoring strategies to ensure compliance with water quality goals.
- Consideration of alternative aquifer management strategies if goals cannot be met.

8. Conclusions

- Summarize findings, including the maximum allowable injection volume and waste load.

9. Appendices

- Appendix A: Detailed calculations (flow modeling, dilution ratios).
- Appendix B: Maps/visualizations of flow and tracer concentration.
- Appendix C: Tables of input parameters and results.

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