*What are initial conditions? Describe various approaches to determining initial conditions for a groundwater model.*

Initial conditions are piezometric head values in all points of a streamlines at the initial point of time. They represent the state of the groundwater regime and heads at the beginning of groundwater simulation.

Initial conditions are used in transient simulations only and these are different in steady state solutions. In transient state, model calculates changes in the system due to any stress applied. Therefore, the response of the system is related to the initial conditions used in the simulation. However, in steady-state, the starting heads affect the efficiency of solution, but the final correct solution should not be affected by different starting heads.

In determining the initial conditions of a groundwater flow model, ideally would be that the transient model simulation start from a steady-state condition, then the initial conditions could be generated from a steady state simulation of the period of equilibrium. If a simulation did not start from a steady-state conditions, then a period of equilibrium should be chosen to start the simulation and make the determination of initial conditions (model should simulate the transient period from the period of equilibrium).

*The initial conditions are parameter values set for the initial run of the model. Depending on the model’s calculations, their value can have a significant impact or very little at all. Some approaches to determining the initial conditions of a groundwater model include obtaining field measurements of head values at observation wells, hydraulic conductivities from soil cores for a modeling area or referencing geologic maps. No matter the provenance, an important step in determining the initial conditions, the modeler must make assumptions about the temporal and spatial distributions for the initial conditions. The modeler then has the option to test parameter sensitivity to determine what the impact each parameter has on the model and also create an ensemble of models that reflect the initial conditions but yield various results.*

*What does it mean for a groundwater model to be ‘spun up’?  How can we go about achieving this and how would we know if we are done?  What can happen if you run transient models on a groundwater model that is not spun up?*

Spin-up is a term that describes the length of time or the number of recursive runs that are needed to reach a point at which the state of the model at the end of a current run is the same as the state at the end of a previous run (equilibrium). It also means that the model is responding to the forcing in a consistent manner, regardless of the initial conditions. This state is reached if there is no change in model output over time due to the initial conditions.

Regardless of the initial conditions, the model itself adjusts in order to reach equilibrium. The original state, however, dictates spin-up and how long the model takes to reach equilibrium. Wet initial conditions are faster in spin-up than dry initial conditions.

If we run the transient models on a groundwater model that has not been spun up then it would be difficult to determine the initial conditions which can be used both for simulations and calibration of the model.

*A groundwater model is “spun up” when it has finally reached a dynamic equilibrium. Achieving equilibrium can be observed when there the state of the model follows a cyclical pattern and runs through this cycle endlessly no matter how much extra time the model is allowed to go on for. Running groundwater models that are not spun up can result in conclusions that don’t reflect the expected forecast. Models should result in spun up conditions so that the modeler can be sure their model is stable.*

*Groundwater is generally the slowest moving component of the hydrologic cycle. Describe (1) the speeds at which groundwater flows compared to surface water (2) the time scales over which water tables and groundwater heads respond to changes in pumping vs recharge in both confined and unconfined systems?  What are the implications of these timescales for how we model groundwater systems?*

The highest rate of groundwater flow is in karst systems. However, in many cases the flow can be as low as 1 foot per year, decade, and/or even centuries. Also, it is faster in the areas where the hydraulic conductivity values are higher. Groundwater flow is much slower than surface water flow, where surface water has a possibility to speed up to high velocities in the steep river channels or due to currents.

Regions with changes in climate patterns and/or sustained groundwater pumping with unequally distributed recharge can face the groundwater depletion over time. In the unsaturated zone a considerable amount of groundwater can be found, however, it won’t be affected with pumping since the capillary forces hold it tightly. In the saturated zone, which is completely filled with groundwater, the water pressure is high to enter the well and the water levels can be lowered by pumping. Pumping always cause the decline in groundwater levels at the well. Although, the pumping of a single well has a local effect on groundwater flow the pumping of many wells in large areas may have a regionally notable effects on groundwater.

On the other hand, depending on the recharge rate, the infiltration of water into the ground (aquifer) may, also, take hours, days, or even years which also depends on aquifer properties. In unsaturated zone recharge is higher and then flows slowly to the saturated zone to groundwater discharge areas. Estimating the time scale of recharge is difficult because of the dependence on nonlinear soil characteristics, and modeling is intensive since it requires simulation of Richards’ equation (a nonlinear partial differential equation without analytical solution). Therefore, we use stress periods to analyze all the parameters that may change over the time we run the model.

*Groundwater flow often uses velocity units of m/day whereas surface water is measured in m/s due to the relatively high speeds of surface water. In all cases, confined aquifers transmit changes in groundwater heads at higher rates than unconfined aquifers of the same storage capacity and hydraulic conductivity because the higher-pressure gradients found in the confined aquifer allow these changes to propagate faster. Of course, the answer to this question also depends on the distance of observation from the location of pumping and recharge. In pumping, the effects of radial flow cause the pumping impacts to drastically reduce at distance because of the cross-sectional area that greatly increases for the cone of depression. The implications of these realities are that we as modelers need to build our models according to large timescales that incorporate decades if not quarter centuries.*