Attachment: Cone of Influence

Calculations I. Required information

USDWdepth = 760 feet	depth to the base of the lowermost USDW (feet)
GWdepth = 0 feet	depth to the top of groundwater (feet). Zero feet means ground water at surface
Porosity = 0.08	porosity of the injection interval (fraction)
Pstatic = 3567.15 psi	measured static pressure in the injection interval at the start of the permitted injection period (psi). Note this static pressure should be depth adjusted to the top of the injection interval
InjIntervalDepth = 8239 feet	depth to the top of the injection interval (feet).
h = 245 feet	net thickness of the injection interval (feet)
viscosity = 1.14 cp	viscosity of the native injection interval fluid (cp)
brineSG = 1.05	specific gravity of the native injection interval fluid (dimensionless)
ct = 6×10^{-6} psi^{-1}	total system compressibility for the injection interval (psi^{-1})
k = 2.7 md	effective permeability of the injection interval to the injectate (md)
r_w = 0.3 feet	radius of the individual injection wellbore (feet)
r = 1320 feet	radius where to calculate the pressure rise. At the well r = r_w and r_w is determined from the individual injection wellbore (feet)
FWgrad = 0.433 psi/feet	fresh water density as a pressure gradient (psi/feet)
APmudwt = 9.5 lb/gal	mud density in abandoned wellbores (lb/gal)
FWwt = 8.33 lb/gal	fresh water density (lb/gal)
Tpermit = 87,600 hours	permit life (hours)
Qpermit = 700 barrels/day	permit injection rate (barrels/day)
B = 1.0 RB/STB	formation volume factor for injectate (reservoir bbls/surface stock tank bbls, rvb/stb). Usually assumed to be 1

II. Calculate the allowable pressure rise above static pressure in an abandoned well

Note: Make two calculations as needed depending if area wells are mud-filled or brine-filled:

1. Assume a mud filled borehole using the minimum mud weight determined for wells in the area
2. Assume a brine-filled borehole using the density of the native injection interval fluid

This calculation assumes no mud fallback in a well and no mud gel strength. It represents the amount of pressure change needed to cause upward movement of a full column of mud in an abandoned well.

AllowPressRiseAtAP = [(InjIntervalDepth)*(APmudwt)*(FWgrad/FWwt)] – Pstatic
= [8239 * 9.5 * (.433/8.33)] – 3567.15
= 501.4 psi

III. Calculate the cone of influence (COI) using dimensionless variables (Methodology taken from Appendix C of Society of Petroleum Engineers Monograph 5)

Note: Allowable pressure rise is determined first and then used to calculate the radial distance at which it occurs.

Dimensionless pressue, Pd:

Pd = (AllowPressRiseAtAP* k * h)/(141.2*Qpermit*B* viscosity)]
= (501.4 * 2.7 * 245)/(141.2*700*1*1.14)
= 2.944

Dimensionless time, td:

td = 0.0002637 * k * [Tpermit/(ct*porosity*viscosity*r_w^2)]
= 0.0002637 * 2.7 * [87600/(6 x 10^{-6}*0.08*1.14*0.3^2)]
= 1.266 x 10^9

Dimensionless radius, rd:

rd = $(td/e^{[(2*Pd)-0.80907]})^{0.5}$
= $(1.266 \times 10^9/e^{[(2*2.944)-0.80907]})^{0.5}$
= 2.808 x 10^3

Calculate the radial distance of the cone of influence, COIradius:

COIradius = rd*rw
= 2.808 x 10^3 * 0.3
= 842 feet

IV. Projected pressure increase at a distance r away from the injector

Note: The radius r is known and the pressure rise is calculated

Dimensionless time, td: Same as before except r is the radial distance from the injection well where pressure rise is to be calculated. This example assumed 1320'

td = 0.0002637 * k * [Tpermit/(ct*porosity*viscosity*r_w^2)]
= 0.0002637 * 2.7 * [87600/(6 x 10^{-6}*0.08*1.14*0.3^2)]
= 1.266x10^9

Dimensionless radius, rd: Different equation since r is a known radial distance

rd = r/rw (At the well rd = 1 because r = r_w)
= 1320/0.3
= 4400

Dimensionless pressure, Pd: Different equation to calculate the pressure buildup at known radial distance, r

Pd = 0.5*[ln(td/rd^2) + 0.80907]
= 0.5 * [ln (1.266x10^9/4400^2) + 0.80907]
= 2.5

PressureRise = 141.2*Q*B*viscosity*Pd/(k*h)
= 141.2 * 700 * 1 * 1.14 * 2.5/(2.7*245)
= 426 psi