SLUG TESTS

Slug tests are conducted in partially to fully penetrating wells to determine horizontal hydraulic conductivity or transmissivity of unconfined or confined aquifers. The tests are highly affected by well construction and borehole conditions and only stress a small volume of the aquifer (generally few feet around the well). Tests assume the aquifer is homogeneous and isotropic (generally assumed true for small volume of aquifer tested).

REFERENCES AND TYPES OF ANALYSES:

Bouwer and Rice (1976)	For a fully or partially penetrating well in either a confined or unconfined aquifer
Cooper and others (1967)	For a fully penetrating well in a confined aquifer
Hvorslev (1951)	For a well with various geometries
van der Kamp (1976)	For highly permeable aquifers that result in oscillatory water-level response

Slug tests involve removing, adding, or displacing a quantity of water or other known volume in a well or peizometer and monitoring the change in water level over time.

TWO PHASES OF A SLUG TEST

- Falling Head: Produce a rise in the water level and monitor the water-level decline.
- Rising Head Produce a drop in the water level and monitor the water-level rise.

TYPICAL METHODS OF PRODUCING CHANGE IN WATER LEVEL DURING A SLUG TEST

- Insertion/removal of a solid cylinder of known volume into/from the water column (most common – use a solid PVC cylinder)
- Addition of a known volume of water to the well (seldom used)
- Use of compressed gas to induce a water-level decline, then release the gas pressure while monitoring the water-level rise (used with moderate frequency; good for highly permeable aquifers, but not good for low permeability aquifers or for water-table wells)

SLUG-TEST ADVANTAGES OVER MULTIPLE-WELL TESTS

- Less expensive to conduct
- Less equipment needed
- Take less time to set up and obtain data
- Data interpretation and reporting time is shorter
- Tests can be done in small diameter wells
- There is no water to dispose of

SLUG-TEST DISADVANTAGES

- T and K estimates are less certain
- Test only a small volume of the aquifer
- May be applicable only to lower yielding aquifers

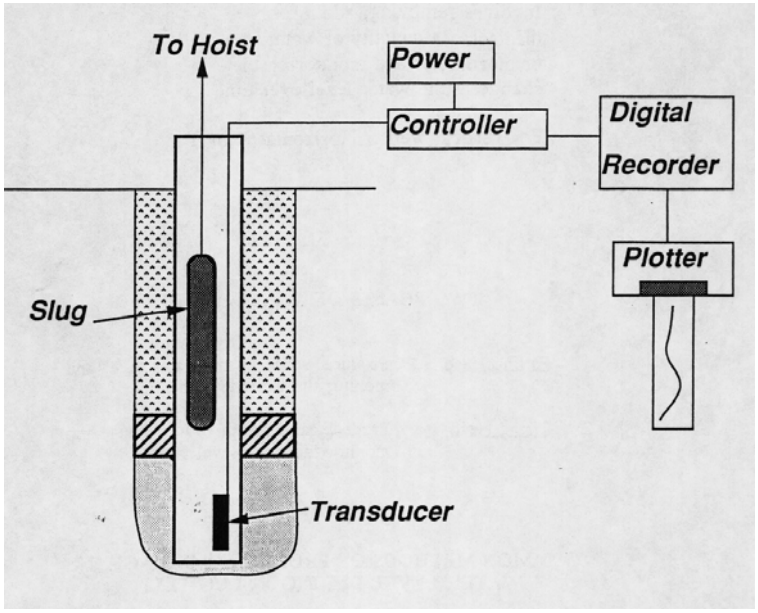


Figure – Suggested arrangement for conducting a slug test.

STEPS FOR CONDUCTING A SLUG TEST WITH A PVC CYLINDER

1. Obtain a clean length of poly rope and tie securely to decontaminated PVC slug (make sure rope length is at least 10 ft longer than depth of water from top of well casing).

2. Calculate the expected change in water level for the selected slug. Select an appropriately ranged pressure transducer (generally a 5-ft x 1.5-in PVC slug will displace about 2.5 ft of water; a 0-10 psi transducer allows the transducer to be placed sufficiently deep to avoid interference with the sinking slug and provide good resolution of water-level change).

3. Place the decontaminated transducer in the well below the expected level that the slug will sink and within its measurement range (a 0-10 psi transducer will be out of range if the head above it is greater than 23 ft). Account for expected rise in water level. Allow the transducer at least 10 minutes to equilibrate to water temperature. If the well is deep, allow at least 20 minutes to account for flex of the hanging cable.

4. Program the data logger for the transducer characteristics and the test. Set the test for a logarithmic time interval (10 minutes max interval generally appropriate)

5. Field calibrate the transducer by wrapping the cable with a piece of electrical tape, placing a folding ruler vertically on top of the well casing, moving the transducer up and down the well at 1-ft intervals and comparing with change indicated by logger (a few hundredths of a foot error over several feet of change is generally acceptable).

6. Lower the transducer to a set position in the well. The tape on the cable should be Even with the top of the well casing to identify if the transducer position has changed during the test. Secure the cable to the casing.

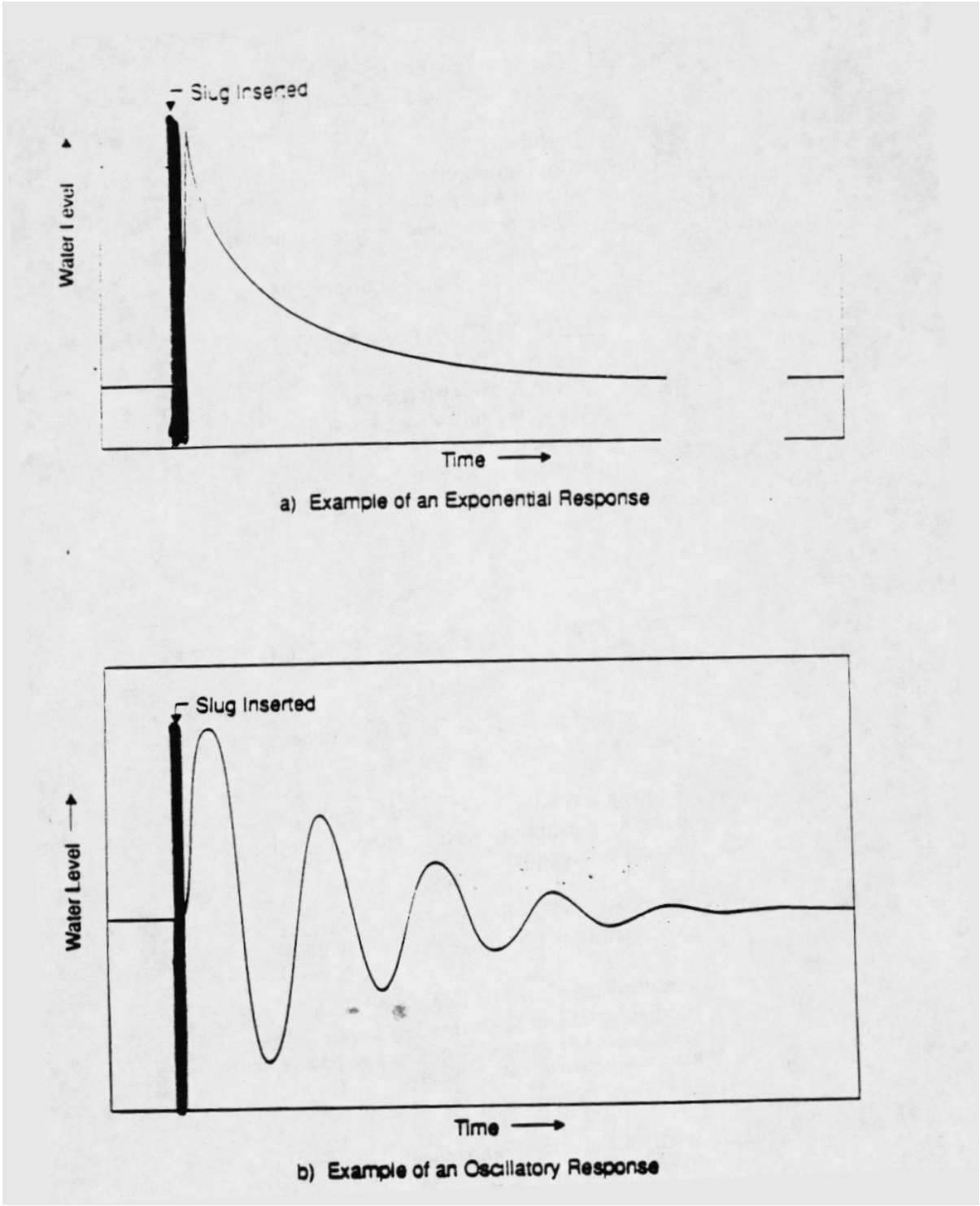
7. Lower the slug slower in short 2-3 ft increments, so that it can be determined when it strikes the water surface. Raise the slug to just above the water surface and periodically check the water level on the data logger to determine when the level is static.

8. Zero the reference level on the data logger. Start logging the test (on data logger) a few seconds before the slug is dropped into the water (to ensure the first few seconds of the tests are not logged).

9. Periodically monitor the water level to determine when it has returned to a static level.

10. Set up another test. Re-zero the reference level.

11. Start logging the test a few seconds before pulling the slug completely out of water in a smooth continuous action.



Figures – Examples of (a) exponential water-level response in aquifer with low to moderate hydraulic conductivity, and (b) oscillatory water-level response in aquifer with high hydraulic conductivity.

ANALYSIS OF SLUG TEST BY THE BOUWER AND RICE (1976) METHOD

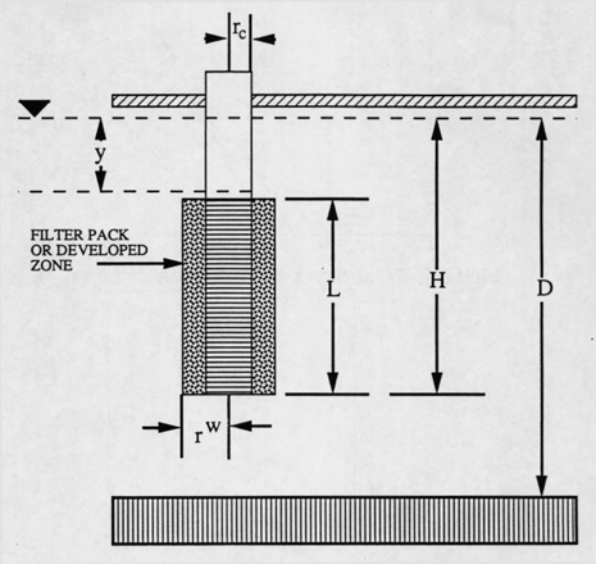


Figure – Geometry for typical well-aquifer arrangement in slug test and analysis by the Bouwer and Rice (1976) method.

r_c = Radius of the well casing
r_w = Radius of the filter pack or developed zone
y = Change from initial water level
D = Distance between initial water level and base of aquifer
H = Distance between base of well and initial water level
L = Length of well screen

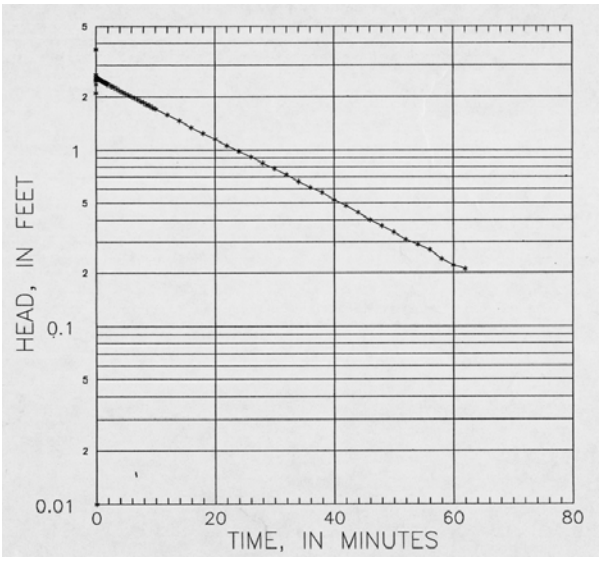


Figure – Typical plot of water level as a function of time, as used for estimating Horizontal hydraulic conductivity by the Bouwer and Rice method (1976)

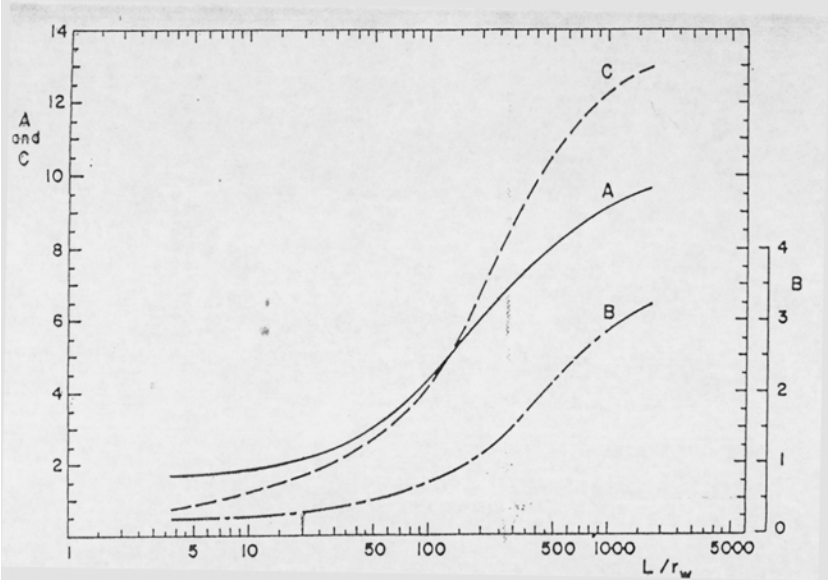


Figure – Curves relating coefficients A, B, and C to L/r_w for analysis of slug tests by Bouwer and Rice (1976) method.

Data for Bouwer and Rice (1976) method obtained from semi-log plot of water-level change as a function of time:

$1/t \ln yo/yt =$

$t = t_t - t_o$
y = head at time t_t, t_o

$\ln [(D-H]/ r_w =$

case 1	D = H, use curve C
case 2	= > 0, < 6, use calculated value
case 3	> 6, use 6

$\ln Re/ r_w =$

REFERENCES:

Bouwer, H. and Rice, R.C., 1976, A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells: Water Resources Research, v. 12, no. 4, p. 423-428.

Cooper, H.H., Jr., Bredehoeft, J.D., and Papadopulos, I.S., 1967, Response of a finite-diameter well to an instantaneous charge of water: Water Resources Research, v. 3, p.263-269.

Hvorslev, M.J., 1951, Time lag and soil permeability in ground-water observations: U.S. Waterways Experimental Station, U.S. Army Corps of Engineers, Vicksburg, Ms., 49 p.

van der Kamp, G., 1976, Determining aquifer transmissivity by means of well response tests: Water Resources Research, v. 12, no. 1, p. 71-77.