



Client Name: City of Charlottesville Page 1 of 82

Project Name: Ragged Mountain Dam Project Project No.: 168539

Calculation Title: Packer Test Data Analysis

Calculation No./File No.: 51.1001

Verification Method:  Check and Review  Alternate Calculations

**Objective** Determine the permeability of water based on the packer test data. Determine behavior of permeable joints or fractures based on plots of permeability with changes in pressure and the lugeon pattern.

Unverified Assumptions Requiring Subsequent Verification			
No.	Assumption	Verified By	Date

Refer to Page \_\_\_\_\_ of this calculation for additional assumptions.

This Section Used for Software-Generated Calculations	
Program Name/Number: _____	Version: _____
Standard B&V Application Used? <input type="checkbox"/> Yes <input type="checkbox"/> No	
If no, list approved deviation permit number below and attach approved deviation permit.	

Review and Approval						
Rev	Prepared By	Date	Verified By	Date	Approved By	Date
0	B. Gomer <i>B. Gomer</i>	8/13/10	<i>[Signature]</i>	10-29-10		



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**References:**

1. B&V, Geotechnical Field Guide for Site Investigations, March 2009.
2. B&V, Packer Pressure Testing Field Sheets for the Lower Ragged Mountain Dam, July 2010 (attached)
3. Quinones-Rozo, C., *Lugeon Test Interpretation, Revisited*, 30<sup>th</sup> Annual United States Society on Dams Conference, 2010. p. 407 (attached)

**Design Basis:**

None

**Definition of Units and Constants Used:**

ft = feet

psi – pounds per square inch (1 psi = 2.77 inches of water = 2.308 ft of water )

cfm = cubic ft per minute

gpm – gallons per minute (1 cfm = 7.481 gpm)

Lugeon – 1 liter per meter per minute at 10 bars of pressure (1 Lugeon = 12.42 \* (Q/L) \* (145 psi / P<sub>X</sub>)) (Ref. 2)

1 foot of head = 0.433 psi

Q – Measured flow to test interval in gpm

L – Length of the test interval in ft

P<sub>X</sub> – Test pressure applied to the test interval in psi (P<sub>X</sub> = P<sub>GX</sub> + 0.433 (D<sub>WL</sub> + H<sub>G</sub>), Reference 1)P<sub>GX</sub> – Surface gage pressure in psiH<sub>G</sub> – Height of surface pressure gage above grade in ftD<sub>WL</sub> – Depth to static groundwater level prior to test in ft**Analysis:**

Packer tests were completed in each of the three concrete and rock core borings at the Lower ragged Mountain Dam to assess the amount of potential water leakage through the concrete. Packer tests isolate an interval of the core hole with inflatable packers, pressurize the interval with water, and record the effective pressure in the interval and the resulting flow rate out of the interval (Reference 1). Typically, the packer test is repeated three to five times at two to three different pressures within each interval. An estimate of the resulting flow (permeability) – in velocity (feet per day or similar) or lugeons (defined as one liter per meter per minute at 10 bar of pressure) – is then calculated. The resulting permeability is not a true permeability since the concrete or rock is not a true porous medium. Instead, the packer test provides a relative measurement of potential leakage through joints or fractures.

Prior to initiating packer testing in the core holes at the Lower Ragged Mountain Dam, the initial water level was measured, the flow meter and pressure gages were checked for accuracy, and the potential frictional resistance of the 1-inch diameter pipe was measured (flows less than 10 gallons per minute did not produce a measurable increase in pressure). The packers were also measured to determine the minimum pressure required to reach the approximate core hole diameter. This minimum pressure was then used to avoid over or under pressurizing the packers within the dam. Initially, a single packer test was completed that isolated the bottom of the core hole approximately 3 to 5 feet below the base of the dam. Then, multiple tests were completed by isolating an 8.5 feet long interval with an inflatable double-packer (straddle) system, and repeating the test in each interval three times at pressures of 5, 10, and 5 psi (the low test pressures were intended to avoid over pressurizing the dam). Flow rate and water pressure were measured at the surface using inline gages. Water pressure was controlled using an inline ball valve and a bypass valve that allowed discharge away from the core hole. All field data was recorded on B&V packer pressure testing field sheet (Reference 1).

The recorded field data are used to calculate the permeability (References 1 and 3). The calculation of permeability helps provides a diagnostic tool to determine the nature of flow through narrow cracks due to dilation by the applied pressure, infilling from loose material, and potential wash out of weak material. Intervals where little or no flow was observed indicate tight concrete. Minor flow may be leakage and possible wash out at the walls of the core hole around the packers, or minor joints or fractures within the dam. Higher volume flows likely represent joints or

fractures that are hydraulically connected with the exterior of the concrete. Flow may be laminar or turbulent when permeable joints or fractures are present. The permeability of the joints and fractures may decrease due to infilling by loose material or increase due to wash out as the packer test continues (the low pressures and short duration of the packer tests completed during this investigation were intended to minimize washout). Test intervals were intended to overlap at least 1 foot in order to better define which joints or fractures identified during the subsurface investigation may be the source of any potential leaks. Additional tests were completed in selected locations to better identify the permeable zones. Attachment 1 provides the field data sheets. Attachment 2 provides the field data used in the calculations, data reduction, computer-aided calculations, and plots for each packer test.

An example calculation for Boring BV-1 Test 1 is provided below:

Given the field data      Test interval: 57 - 70.7 ft below grade (top of concrete)  
                                     Radius of core hole: 3.75 inches = 0.313 feet  
                                      $D_{WL} = 10.82$  ft below grade (top of concrete)  
                                      $H_G = 38$  inches = 3.17 ft above grade (top of concrete)  
                                      $P_{GX} = 5, 10, 5$  psi  
                                      $P_{TX} = 5$  psi +  $0.433 (10.82 \text{ ft} + 3.17 \text{ ft}) = 5 + 6.06 = 11.06$  psi = 11.1 psi  
                                     =  $10$  psi +  $0.433 (0.82 \text{ ft} + 3.17 \text{ ft}) = 10 + 6.06$  psi = 16.1 psi

Stage	Test Pressure (psi)	Four Minutes of Flow Meter Readings			
		First (gallons)	Second (gallons)	Third (gallons)	Last (gallons)
1	11.1	15835.2	15835.6	15835.9	15836.2
2	16.1	15854.5	15856.6	15858.5	15860.7
3	11.1	15862.3	15863.1	15863.9	15864.6

Table 1 – Final Four Minutes of Readings for Flow Meter

The following values are calculated:

Center of test interval:  $(70.7 \text{ ft} + 57 \text{ ft})/2 = 63.9 \text{ ft}$   
 Length of test interval:  $70.7 \text{ ft} - 57 \text{ ft} = 13.7 \text{ ft}$   
 Flow rates for stage 1:  $(15835.6 - 15835.2 \text{ gallons}) / 1 \text{ minute} = 0.4 \text{ gpm}$   
 $(15835.9 - 15835.6 \text{ gallons}) / 1 \text{ minute} = 0.3 \text{ gpm}$   
 $(15835.6 - 15836.2 \text{ gallons}) / 1 \text{ minute} = 0.3 \text{ gpm}$   
 Average flow rate:  $(0.4 + 0.3 + 0.3) / 3 = 0.3 \text{ gpm}$   
 And for all stage:

Stage	Final Three Flow Rates			Average Flow Rate (gpm)
	Second (gpm)	Third (gpm)	Last (gpm)	
1	0.4	0.3	0.3	0.3
2	2.1	1.9	2.2	2.1
3	0.8	0.8	0.7	0.8

For Stage 2, which has the largest flow, the permeability is computed by adjusting psi to equivalent ft of water and gpm to cfm, and applying the following equation for saturated flow (Reference 1):

$$K = (Q * \text{Log}_e(L/r)) / (2\pi * L * H) \quad (\text{for } L \geq 10r)$$

Check the requirement:  $L = 13.7, 10 * 0.313 \text{ ft} = 3.1 \text{ ft} (13.7 \text{ ft} \geq 3.1 \text{ ft})$

$16.1 \text{ psi} = 16.1 \text{ psi} * 2.308 \text{ ft of water per psi} = 37.16 \text{ equivalent ft of water}$

$2.1 \text{ gpm} = 2.1 \text{ gpm} / 7.481 \text{ gallons per ft}^3 = 0.281 \text{ cfm}$

$$K = (0.281 \text{ cfm} * \text{Log}_e(13.7 \text{ ft} / 0.313 \text{ ft})) / (2\pi * 13.7 \text{ ft} * 37.16 \text{ ft})$$

$$= (0.281 \text{ cfm} * 3.779) / (3198.7 \text{ ft}^2) = 0.00033 \text{ ft per minute}$$

$$= 0.00033 \text{ ft per minute} * 60 \text{ minutes} * 24 \text{ hours} = 0.47 \text{ feet per day}$$

For Stage 2 the Lugeon value is calculated using the formula from Reference 3 where the conversion factor of 12.42 applies when Q is in gpm, L is in ft, and  $P_x$  is in psi:

$$\text{Lugeons} = 12.42 * (Q/L) * (145 \text{ psi} / P_x)$$

$$= 12.42 * (2.1 \text{ gpm} / 13.7 \text{ ft}) * (145 \text{ psi} / 16.1 \text{ psi})$$

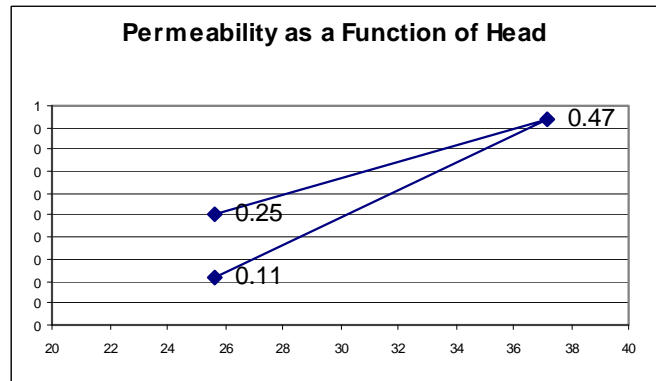
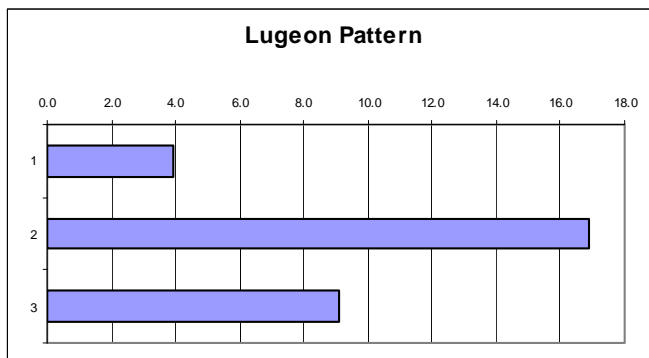
$$= 12.42 * 0.15328 * 9.0062 = 17.1 \text{ Lugeons}$$

(difference due to rounding pressure and length quantities)

For all the stages of BV-1 test 1 the following results are found:

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	25.62	0.3	0.04	7.64E-05	0.11	3.9
2	37.16	2.1	0.28	0.000326	0.47	16.9
3	25.62	0.8	0.10	0.000176	0.25	9.1

These results are plotted to interpret the results:



Based on Reference 1, these results indicate dilation of the joints or fractures with increasing pressure. Reference 1 recommends selecting the lowest Lugeon value or permeability as the value most likely to be observed under *in situ* conditions; therefore, the permeability is selected as 0.11 ft/day or 3.9 Lugeons.

The computer-aided calculations for all the packer tests are provided in Attachment 3.

**Conclusions:**

Table 2 summarizes the field data, the calculated permeability, and the interpretation of the result for each boring.

Table 2 Packer Test Results Summary					
Boring	Test No.	Packer Test Type	Depths	Permeability	Tested Material
			(feet)	(Lugeons)	
BV-1	1	Single	57.0-70.7	3.9	Bedrock
	2	Double	44.1-52.6	0.0	Concrete
	3	Double	49.1-57.6	0.0	Dam Interface
	4	Double	36.5-45.0	3.1	Concrete
	5	Double	29.0-37.5	0.7	Concrete
	6	Double	21.5-30.0	5.6	Concrete
	7	Double	14.0-22.5	6.9	Concrete
	8	Double	6.5-15.0	0.6	Concrete
BV-2P	1	Single	67.0-83.6	0.0	Bedrock
	2	Double	59.3-67.8	210	Dam Interface
	3	Double	52.0-60.5	0.0	Concrete
	4	Double	63.0-71.5	142	Dam Interface
	5	Double	44.5-53.0	3.4	Concrete
	6	Double	37.0-45.5	8.5	Concrete
	7	Double	30.5-39.0	7.9	Concrete
	8	Double	22.9-31.4	15	Concrete
	9	Double	15.5-24.0	0.0	Concrete
	10	Double	9.5-18.0	3.5	Concrete
BV-3	1	Single	44.0-58.7	0.0	Bedrock
	2	Double	36.5-45.0	0.0	Dam Interface
	3	Double	28.8-37.3	8.3	Concrete
	4	Double	21.5-30.0	0.0	Concrete
	5	Double	18.0-26.5	0.0	Concrete
	6	Double	10.5-19.0	1.4	Concrete
	7	Double	6.0-14.5	5.9	Concrete
Notes: Double = test using a double (straddle) packer to isolate an interval of the core hole Single = test using a single packer test to isolate the bottom of the core hole					

**Attachments:**

1. Reference 2 (50 pages)
2. Reference 3 (1 page)
3. Excel Plots and Computer-Aided Calculations (25 pages)



Owner: City of Charlottesville  
Project: Ragged Mountain Dam Project  
Project No: 168539  
File No: 51.1001  
Title: Packer Test Data Analysis

Computed by: BMG  
Date: 08/13/2010  
Verified by: TPH  
Date: 10/29/10  
Page: 6 of 6

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## Attachments

1. Attachment 1 – Reference 2 (50 pages)
2. Attachment 2 – Reference 3 (1 page)
3. Attachment 3 – Excel Plots and Computer-Aided Calculations (25 pages)


























































**PACKER PRESSURE TESTING**

Sheet 1 of 2

 Boring No. BV-2P Test No. 7 Test Interval: 30.5-39  
 Step No(s) 1,2,3

Surface Gage units <u>PSIG</u>	Transducer		Time from Start (min)	Flow Meter Reading units <u>g/s</u>	Time between Reading (min)	Δ Flow Meter units <u>g/s</u>	Flow Rate (per min)
	Pressure units	Reading					
Step No. <u>1</u>							
<u>5</u>			<u>1</u>	<u>15791.8</u>	<u>—</u>	<u>—</u>	<u>—</u>
<u>5</u>			<u>2</u>	<u>15791.8</u>	<u>1</u>	<u>0.0</u>	<u>0.0</u>
<u>5</u>			<u>3</u>	<u>15791.8</u>	<u>1</u>	<u>0.0</u>	<u>0.0</u>
<u>5</u>			<u>4</u>	<u>15792.2</u>	<u>1</u>	<u>0.4</u>	<u>0.4</u>
<u>5</u>			<u>5</u>	<u>15792.5</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>6</u>	<u>15792.9</u>	<u>1</u>	<u>0.4</u>	<u>0.4</u>
Step No. <u>2</u>							
<u>10</u>			<u>7</u>	<u>15793.4</u>	<u>1</u>	<u>0.5</u>	<u>0.5</u>
<u>10</u>			<u>8</u>	<u>15793.5</u>	<u>1</u>	<u>0.1</u>	<u>0.1</u>
<u>10</u>			<u>9</u>	<u>15793.9</u>	<u>1</u>	<u>0.4</u>	<u>0.4</u>
<u>10</u>			<u>10</u>	<u>15794.3</u>	<u>1</u>	<u>0.4</u>	<u>0.4</u>
<u>10</u>			<u>11</u>	<u>15794.6</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
Step No. <u>3</u>							
<u>5</u>			<u>12</u>	<u>15794.6</u>	<u>1</u>	<u>0.1</u>	<u>0.1</u>
<u>5</u>			<u>13</u>	<u>15794.7</u>	<u>1</u>	<u>0.1</u>	<u>0.1</u>
<u>5</u>			<u>14</u>	<u>15795.0</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>15</u>	<u>15795.3</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>16</u>	<u>15795.6</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
















**PACKER PRESSURE TESTING**

Sheet 1 of 2

 Boring No. BV-3 Test No. 1 Test Interval: 44-58.7  
 Step No(s). 1, 2, 3

Surface Gage units <u>psi</u>	Transducer <u>None</u>		Time from Start (min)	Flow Meter Reading units <u>gallons</u>	Time between Reading (min)	Δ Flow Meter units <u>gpm</u>	Flow Rate (per min)
	Pressure units	Reading					
Step No. <u>1</u>							
<u>5</u>			<u>2</u>	<u>15547.4</u>	<u>2</u>	<u>0.00</u>	<u>0</u>
<u>5</u>			<u>3</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
<u>5</u>			<u>4</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
<u>5</u>			<u>5</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
Step No. <u>2</u>							
<u>10</u>			<u>6</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
<u>10</u>			<u>7</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
<u>10</u>			<u>8</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
<u>10</u>			<u>9</u>	<u>15547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
Step No. <u>3</u>							
<u>5</u>			<u>11</u>	<u>11547.4</u>	<u>2</u>	<u>0.00</u>	<u>0</u>
<u>5</u>			<u>12</u>	<u>11547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>
<u>5</u>			<u>13</u>	<u>11547.4</u>	<u>1</u>	<u>0.00</u>	<u>0</u>

*all values actually 15537.4 → 15547.4*

**PACKER PRESSURE TESTING**

Sheet 2 of 2

**BV** Boring No. BV-3 Transducer Serial No. Gage only  
 Groundwater Level (DWL) 6.2 (Ft.) Calibration Factor (C) \_\_\_\_\_  
 Test Interval 438 - 58.7 (single pack) (Ft.) Zero Reading (R<sub>0</sub>) \_\_\_\_\_  
 Depth (D) 51.3 (Ft.) Date of Test 7/18/10  
 PBL: P<sub>0x</sub> = 5, 10, 5 Rig Supervisor B. Bona

**DEFINITIONS** *41.4' top depth*

**PACKER PRESSURE TESTING**  
 (Adapted for use with pressure transducer)  
 in English Units

**TEST PRESSURE**

- Baseline Pressure:** = P<sub>BL</sub>  
 P<sub>BL</sub> = 1.0 psi/ft x D = \_\_\_\_\_ psi
- Transducer Pressure:** P<sub>TX</sub>  
 P<sub>TX</sub> = (F) x P<sub>BL</sub> where (F) ranges from 0.5 to 1.0  
 Transducer Reading: R<sub>1</sub>  
 P<sub>TX</sub> = C (R<sub>0</sub> - R<sub>1</sub>) where: R<sub>0</sub> = Zero Reading  
 R<sub>1</sub> = Required Reading  
 C = Calibration Factor
- Gage Pressure:** P<sub>GX</sub>  
 P<sub>GX</sub> = P<sub>TX</sub> - 0.433 [D + H<sub>g</sub>]
- Test Pressure:** P<sub>X</sub>  
 P<sub>X</sub> = P<sub>TX</sub> - 0.433 [H] where: H = D - DWL

*Handwritten calculations:*  
 $P_{GX} = P_{TX} + 0.433 H - 0.433 (D + H_g)$   
 $= P_{TX} + 0.433 [H - D - H_g]$   
 $= P_{TX} + 0.433 [H - (D - DWL) - H_g]$   
 $= P_{TX} - 0.433 [D - DWL]$

**PRESSURE CALCULATIONS - STEPS**

Step No.	Pressure Factor (F)	Pressure (P <sub>TX</sub> )	P <sub>TX</sub> /C	Transducer		Gage Pressure (P <sub>GX</sub> )	Head (H)	Test Pressure (P <sub>X</sub> )
				Reading R <sub>1</sub>	Range			
1	0.5	27.8			+0.1 P <sub>TX</sub> /C	5	45.1	8.2
2	1.0	37.8			-0.1 P <sub>TX</sub> /C	10	45.1	13.2
3	0.5	27.8				5	45.1	8.2

*Handwritten note:* read value














PACKER PRESSURE TESTING

Sheet 1 of 2

 Boring No. BV-3 Test No. 5 Test Interval: 18-265  
 Step No(s). 1, 2, 3

Surface Gage units <u>PSI</u>	Transducer		Time from Start (min)	Flow Meter Reading units <u>gal</u>	Time between Reading (min)	Δ Flow Meter units <u>gal</u>	Flow Rate (per min)
	Pressure units	Reading					
Step No. <u>1</u>							
				<u>15543.0</u>			
<u>5</u>			<u>1</u>	<u>15544.9</u>	<u>1</u>	<u>1.9</u>	<u>1.9</u>
<u>5</u>			<u>2</u>	<u>15545.0</u>	<u>1</u>	<u>0.1</u>	<u>0.1</u>
<u>5</u>			<u>3</u>	<u>15545.0</u>	<u>1</u>	<u>0.0</u>	<u>0.0</u>
<u>5</u>			<u>4</u>	<u>15545.0</u>	<u>1</u>	<u>0.0</u>	<u>0.0</u>
<u>5</u>			<u>5</u>	<u>15545.0</u>	<u>1</u>	<u>0.0</u>	<u>0.0</u>
Step No. <u>2</u>							
<del><u>10</u></del> <u>8</u>			<u>7</u>	<del><u>15557.9</u></del>	<u>2</u>		
<u>10</u>			<u>13</u>	<u>15554.5</u>	<u>1</u>	<u>3.3</u>	<u>3.3</u>
<u>10</u>			<u>14</u>	<u>15556.1</u>	<u>1</u>	<u>2.4</u>	<u>2.4</u>
<u>10</u>			<u>15</u>	<u>15557.5</u>	<u>1</u>	<u>1.4</u>	<u>1.4</u>
<u>10</u>			<u>16</u>	<u>15559.0</u>	<u>1</u>	<u>1.5</u>	<u>1.5</u>
<u>10</u>			<u>17</u>	<u>15561.2</u>	<u>1</u>	<u>2.2</u>	<u>2.2</u>
Step No. <u>3</u>							
<u>5</u>			<u>10</u>	<u>15550.6</u>	<u>3</u>	<u>2.7</u>	<u>0.9</u>
<u>5</u>			<u>11</u>	<u>15550.9</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>12</u>	<u>15551.2</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>19</u>	<u>15561.4</u>	<u>2</u>	<u>0.7</u>	<u>0.1</u>
<u>5</u>			<u>20</u>	<u>15561.7</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>21</u>	<u>15562.0</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>
<u>5</u>			<u>22</u>	<u>15562.3</u>	<u>1</u>	<u>0.3</u>	<u>0.3</u>











The test is conducted in five stages, with a particular water pressure magnitude associated with each stage. A single stage consists of keeping a constant water pressure at the test interval for 10 minutes by pumping as much water as required. The first stage is held at a low water pressure, increasing the pressure in each subsequent stage until reaching  $P_{MAX}$ . Once  $P_{MAX}$  is reached, pressures are decreased following the same pressure stages used on the way up, thus describing a “pressure loop”. Table 1 shows the pressure magnitudes customarily used during the five test stages.

Table 1. Pressure magnitudes typically used for each test stage

Test Stage	Description	Pressure Step
1 <sup>st</sup>	Low	$0.50 \cdot P_{MAX}$
2 <sup>nd</sup>	Medium	$0.75 \cdot P_{MAX}$
3 <sup>rd</sup>	Maximum (peak)	$P_{MAX}$
4 <sup>th</sup>	Medium	$0.75 \cdot P_{MAX}$
5 <sup>th</sup>	Low	$0.50 \cdot P_{MAX}$

During the execution of each stage, both *water pressure* (P) and *flow rate* (q) values are recorded every minute. Subsequently, average values for P and q are then used to compute the hydraulic conductivity for each stage. The hydraulic conductivity is expressed in terms of the *Lugeon value*, which is empirically defined as the hydraulic conductivity required to achieve a flow rate of 1 liter/minute per meter of test interval under a reference water pressure equal to 1 MPa (Equation 2).

$$\text{Lugeon Value} = \alpha \times \frac{q}{L} \times \frac{P_0}{P} \quad (2)$$

Since the Lugeon value is defined in SI units, it is required to introduce a dimensionless factor  $\alpha$  in Equation 2 to accommodate the use of different systems of units. This factor takes a value of 1 when the SI units system is used (q [lt/min], L[m], and P [MPa]) and a value of 12.42 when the English units system is used (q [gal/min], L[ft], and P [psi]). The term  $P_0$  corresponds to a reference pressure equal to 1MPa or 145 psi.

Under ideal conditions (i.e., homogeneous and isotropic) one Lugeon is equivalent to  $1.3 \times 10^{-5}$  cm/sec (Fell et al., 2005). Table 2 describes the conditions typically associated with different Lugeon values, as well as the typical precision used to report these values.

Table 2. Condition of rock mass discontinuities associated with different Lugeon values

Lugeon Range	Classification	Hydraulic Conductivity Range (cm/sec)	Condition of Rock Mass Discontinuities	Reporting Precision (Lugeons)
<1	Very Low	$< 1 \times 10^{-5}$	Very tight	<1
1-5	Low	$1 \times 10^{-5} - 6 \times 10^{-5}$	Tight	$\pm 0$
5-15	Moderate	$6 \times 10^{-5} - 2 \times 10^{-4}$	Few partly open	$\pm 1$
15-50	Medium	$2 \times 10^{-4} - 6 \times 10^{-4}$	Some open	$\pm 5$
50-100	High	$6 \times 10^{-4} - 1 \times 10^{-3}$	Many open	$\pm 10$
>100	Very High	$> 1 \times 10^{-3}$	Open closely spaced or voids	>100

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 1**

57	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
70.7	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
63.9	Center of Test Interval (feet)	3.17	Height of Gauge (feet above grade)
13.7	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

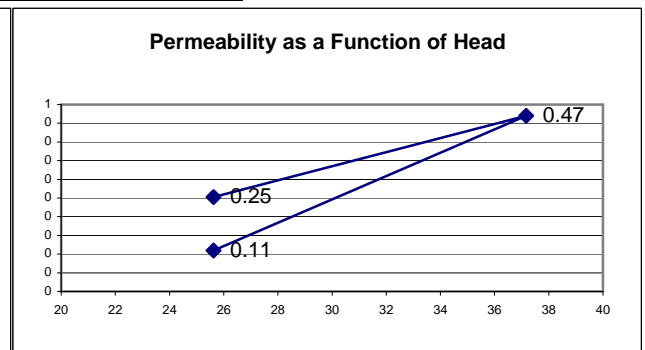
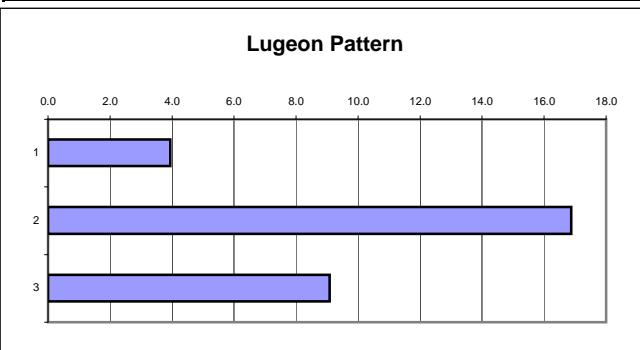
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	11.1	15835.2	15835.6	15835.9	15836.2	0.4	0.3	0.3	0.3
2	16.1	15854.5	15856.6	15858.5	15860.7	2.1	1.9	2.2	2.1
3	11.1	15862.3	15863.1	15863.9	15864.6	0.8	0.8	0.7	0.8
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	25.62	0.3	0.04	7.64E-05	0.11	3.9
2	37.16	2.1	0.28	0.000326	0.47	16.9
3	25.62	0.8	0.10	0.000176	0.25	9.1
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
13.7	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 2**

44.1	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
52.6	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
48.4	Center of Test Interval (feet)	1.33	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

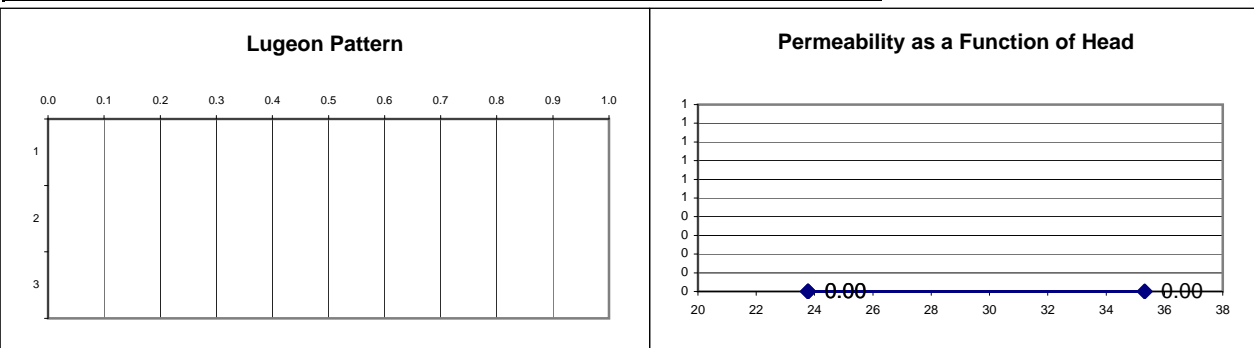
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	10.3	15854.5	15854.5	15854.5	15854.5	0	0	0	0.0
2	15.3	15854.5	15854.5	15854.5	15854.5	0	0	0	0.0
3	10.3	15854.5	15854.5	15854.5	15854.5	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	23.78	0.0	0.00	0	0.00	0.0
2	35.32	0.0	0.00	0	0.00	0.0
3	23.78	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 3**

49.1	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
57.6	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
53.4	Center of Test Interval (feet)	1.33	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

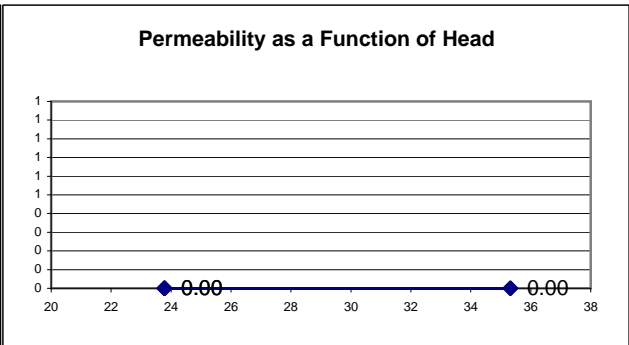
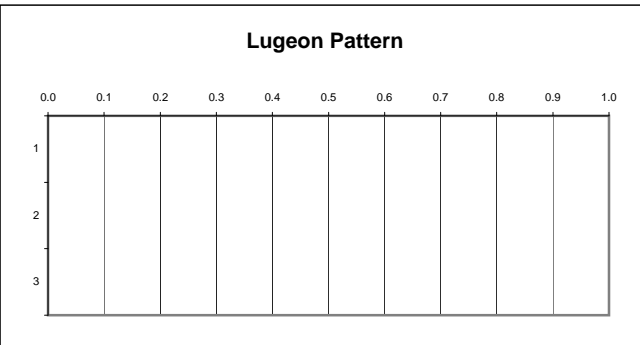
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	10.3	15853.5	15853.5	15853.5	15853.5	0	0	0	0.0
2	15.3	15853.5	15853.5	15853.5	15853.5	0	0	0	0.0
3	10.3	15853.5	15853.5	15853.5	15853.5	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	23.78	0.0	0.00	0	0.00	0.0
2	35.32	0.0	0.00	0	0.00	0.0
3	23.78	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 4**

36.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
45.0	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
40.8	Center of Test Interval (feet)	4.00	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

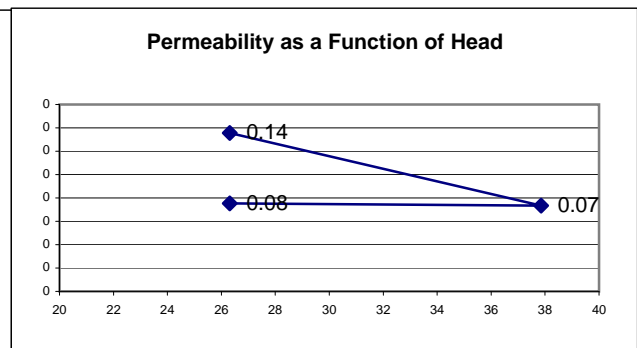
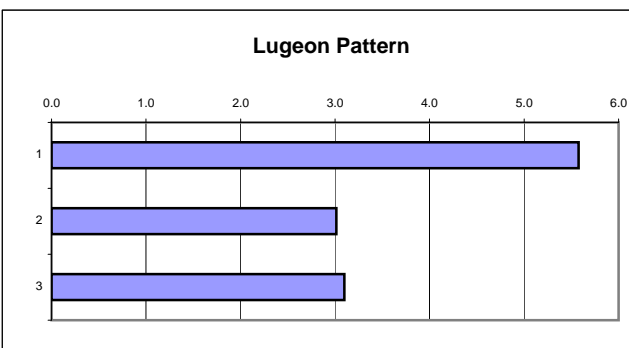
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings				Final Three Flow Rates			Average Flow Rate (gpm)
		First (gallons)	Second (gallons)	Third (gallons)	Last (gallons)	Second (gpm)	Third (gpm)	Last (gpm)	
1	11.4	15852.0	15852.4	15852.6	15852.9	0.4	0.2	0.3	0.3
2	16.4	15853.2	15853.4	15853.6	15853.9	0.2	0.2	0.3	0.2
3	11.4	15853.8	15854.0	15854.1	15854.3	0.2	0.1	0.2	0.2
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	26.32	0.3	0.04	9.43E-05	0.14	5.6
2	37.86	0.2	0.03	5.1E-05	0.07	3.0
3	26.32	0.2	0.02	5.24E-05	0.08	3.1
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 5**

29	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
37.5	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
33.3	Center of Test Interval (feet)	1.33	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

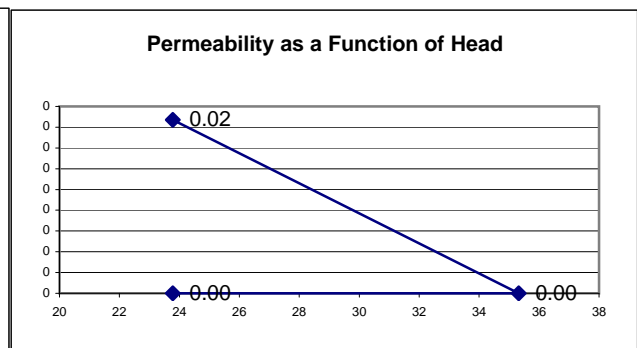
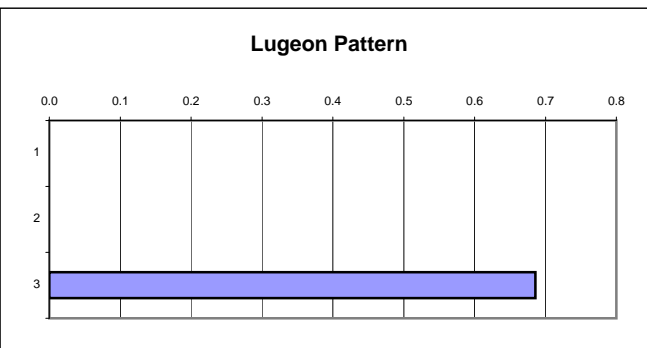
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	10.3	15853.3	15853.3	15853.3	15853.3	0	0	0	0.0
2	15.3	15853.3	15853.3	15853.3	15853.3	0	0	0	0.0
3	10.3	15853.0	15853.1	15853.1	15853.1	0.1	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	23.78	0.0	0.00	0	0.00	0.0
2	35.32	0.0	0.00	0	0.00	0.0
3	23.78	0.0	0.00	1.16E-05	0.02	0.7
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 6**

21.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
30.0	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
25.8	Center of Test Interval (feet)	4.00	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

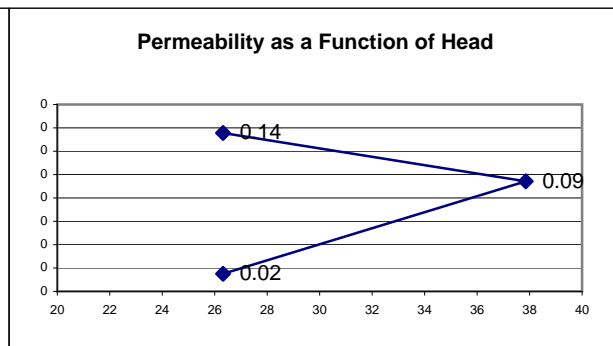
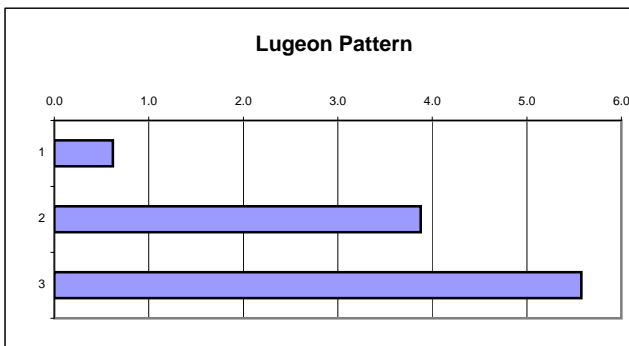
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings				Final Three Flow Rates			Average Flow Rate (gpm)
		First (gallons)	Second (gallons)	Third (gallons)	Last (gallons)	Second (gpm)	Third (gpm)	Last (gpm)	
1	11.4	15852.4	15852.4	15852.4	15852.5	0.0	0.0	0.1	0.0
2	16.4	15853.1	15853.3	15853.7	15854.0	0.2	0.4	0.3	0.3
3	11.4	15854.3	15854.6	15854.9	15855.2	0.3	0.3	0.3	0.3
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	26.32	0.0	0.00	1.05E-05	0.02	0.6
2	37.86	0.3	0.04	6.55E-05	0.09	3.9
3	26.32	0.3	0.04	9.43E-05	0.14	5.6
4						
5						

	10 x Radius of Core Hole
Length (ft)	(ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge +  
 Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 7**

14	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
22.5	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
18.3	Center of Test Interval (feet)	5.75	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

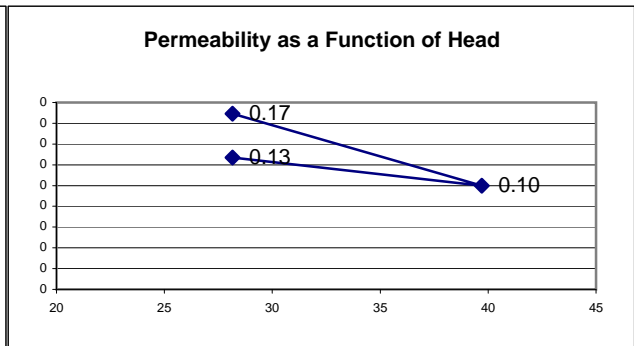
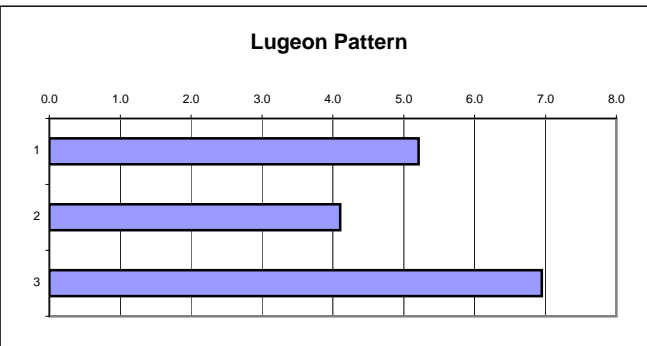
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	12.2	15854.9	15855.0	15855.4	15855.8	0.1	0.4	0.4	0.3
2	17.2	15856.3	15856.6	15857.0	15857.3	0.3	0.4	0.3	0.3
3	12.2	15857.5	15857.9	15858.3	15858.7	0.4	0.4	0.4	0.4
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	28.16	0.3	0.04	8.81E-05	0.13	5.2
2	39.70	0.3	0.04	6.94E-05	0.10	4.1
3	28.16	0.4	0.05	0.000117	0.17	6.9
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-1 Test: 8**

6.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
15.0	Bottom of Test Interval (feet)	10.82	Depth to Groundwater (feet below grade)
10.8	Center of Test Interval (feet)	3.00	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

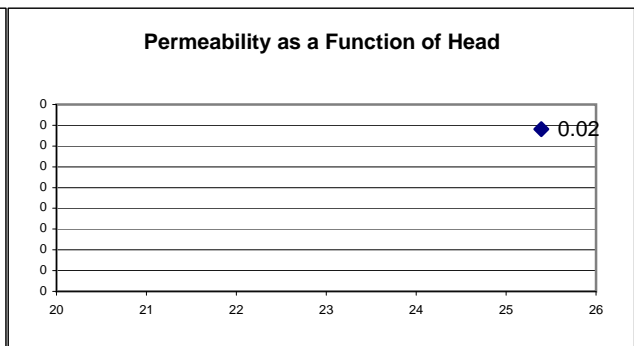
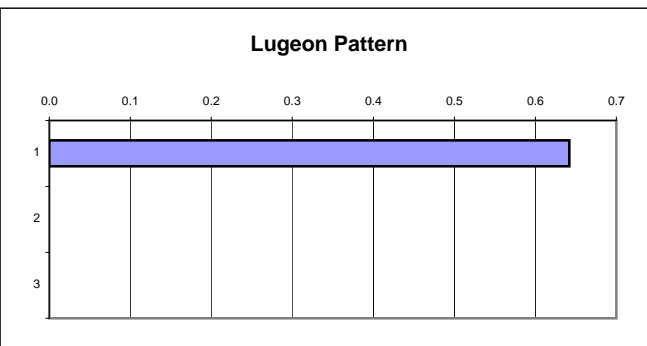
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	11	15864.2	15864.3	15864.3	15864.3	0.1	0.0	0.0	0.0
2						0.0	0.0	0.0	0.0
3						0.0	0.0	0.0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	25.39	0.0	0.00	1.09E-05	0.02	0.6
2	0.00	0.0	0.00			
3	0.00	0.0	0.00			
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 1**

67	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
83.6	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
75.3	Center of Test Interval (feet)	1.92	Height of Gauge (feet above grade)
16.6	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

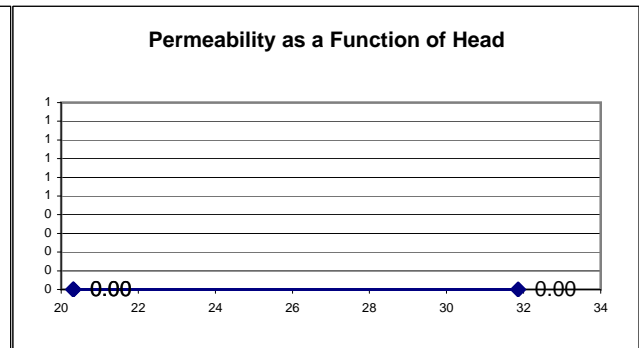
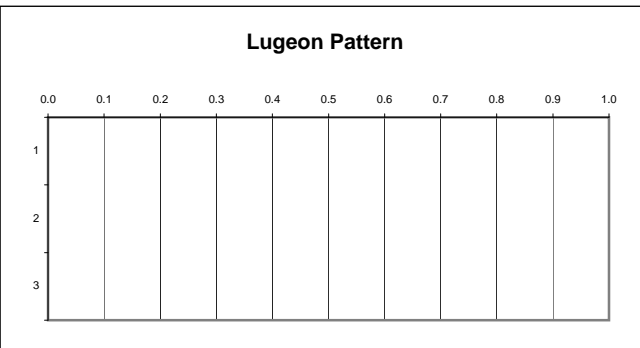
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	8.8	15581.1	15581.1	15581.1	15581.1	0	0	0	0.0
2	13.8	15581.1	15581.1	15581.1	15581.1	0	0	0	0.0
3	8.8	15581.1	15581.1	15581.1	15581.1	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	20.31	0.0	0.00	0	0.00	0.0
2	31.86	0.0	0.00	0	0.00	0.0
3	20.31	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
16.6	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 2**

59.3	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
67.8	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
63.6	Center of Test Interval (feet)	1.42	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

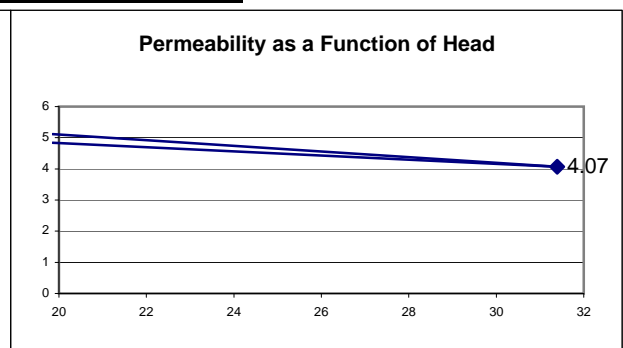
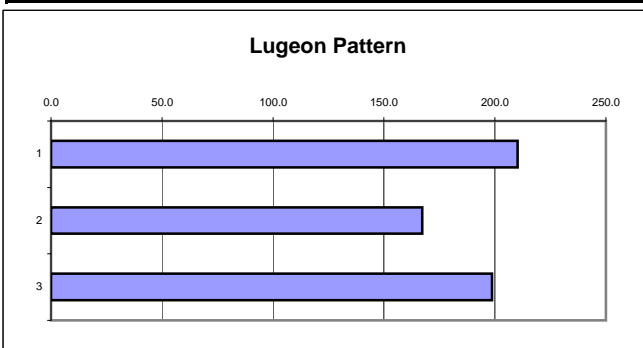
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	8.6	15603.5	15612.3	15620.7	15629.1	8.8	8.4	8.4	8.5
2	13.6	15639.2	15650.0	15660.9	15671.4	10.8	10.9	10.5	10.7
3	8.6	15680.2	15688.2	15696.2	15704.4	8	8	8.2	8.1
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		Lugeons
		(gpm)	(cfm)	(ft/min)	(ft/day)	
1	19.85	8.5	1.14	0.003554	5.12	210.2
2	31.39	10.7	1.43	0.002827	4.07	167.2
3	19.85	8.1	1.08	0.00336	4.84	198.7
4						
5						

	10 x Radius of Core Hole
Length (ft)	(ft)
8.5	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

Owner: City of Charlottesville  
 Project: Ragged Mountain Dam Project  
 Project No.: 168539  
 File No.: 51.1001  
 Title: Packer Test Data Analysis

Computed by: BMG  
 Date: 8/13/2010  
 Verified by: TPH  
 Date: 10/29/2010  
 Page: 11

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 3**

52	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
60.5	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
56.3	Center of Test Interval (feet)	3.5	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

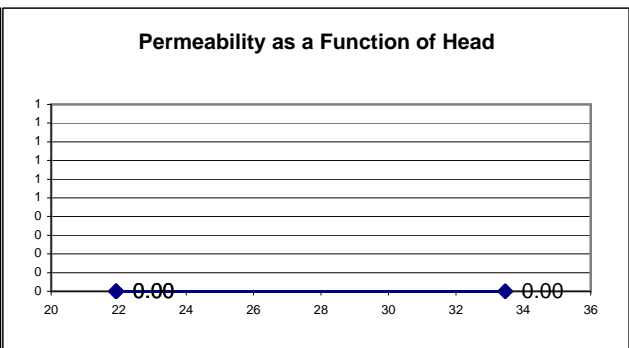
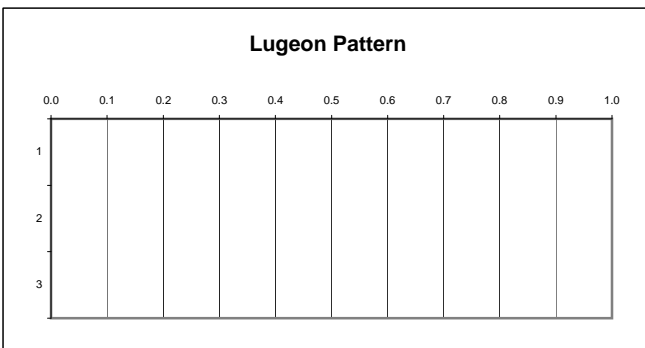
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.5	15710.8	15710.8	15710.8	15710.8	0	0	0	0.0
2	14.5	15711.0	15711.0	15711.0	15711.0	0	0	0	0.0
3	9.5	15710.9	15710.9	15710.9	15710.9	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		Lugeons
		(gpm)	(cfm)	(ft/min)	(ft/day)	
1	21.93	0.0	0.00	0	0.00	0.0
2	33.47	0.0	0.00	0	0.00	0.0
3	21.93	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 4**

63	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
71.5	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
67.3	Center of Test Interval (feet)	2.58	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

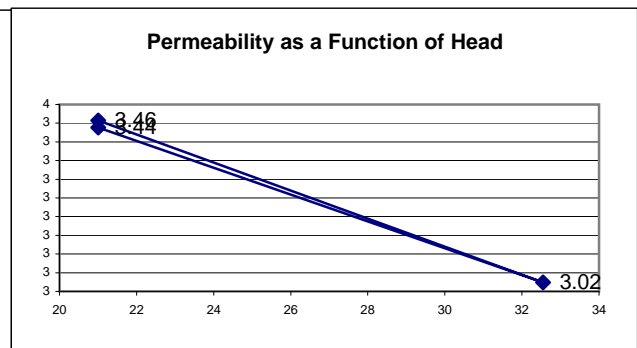
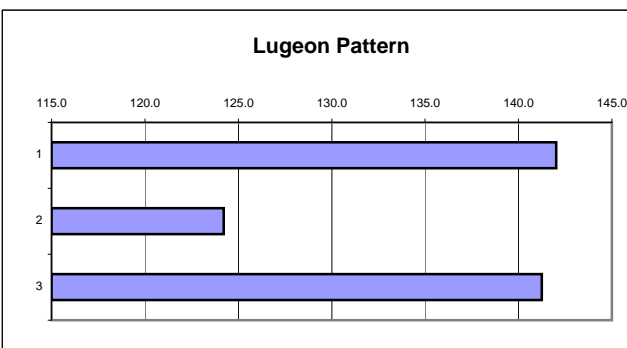
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.1	15716.5	15723	15728.8	15734.8	6.5	5.8	6	6.1
2	14.1	15734.8	15742.9	15751.2	15759.6	8.1	8.3	8.4	8.3
3	9.1	15766.5	15772.8	15778.4	15784.7	6.3	5.6	6.3	6.1
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	21.01	6.1	0.82	0.002401	3.46	142.0
2	32.55	8.3	1.11	0.0021	3.02	124.2
3	21.01	6.1	0.81	0.002388	3.44	141.2
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.7.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 5**

44.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
53.0	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
48.8	Center of Test Interval (feet)	5.50	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

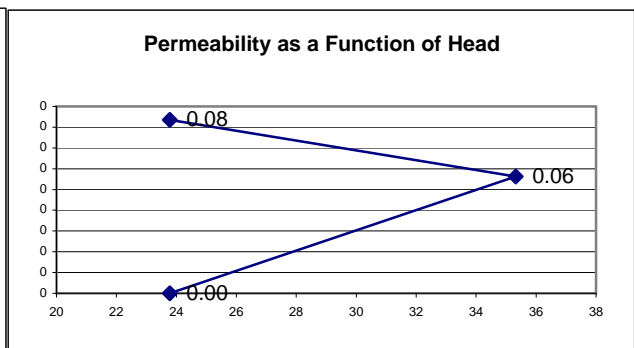
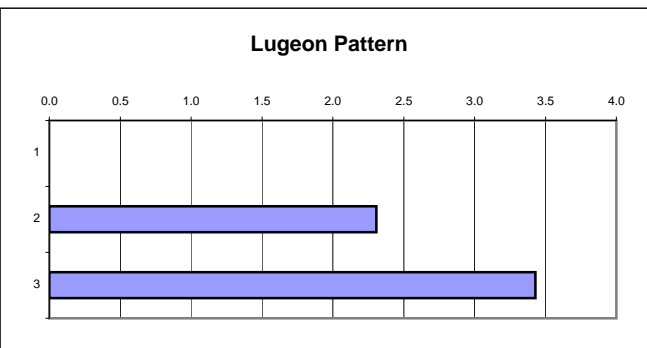
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	10.3	15787.1	15787.1	15787.1	15787.1	0	0	0	0.0
2	15.3	15787.7	15787.8	15788.0	15788.2	0.1	0.2	0.2	0.2
3	10.3	15788.5	15788.6	15788.8	15789.0	0.1	0.2	0.2	0.2
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	23.78	0.0	0.00	0	0.00	0.0
2	35.32	0.2	0.02	3.9E-05	0.06	2.3
3	23.78	0.2	0.02	5.8E-05	0.08	3.4
4						
5						

	10 x Radius of Core Hole
Length (ft)	(ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge +  
 Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input**      **Boring: BV-2P**      **Test: 6**

37	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
45.5	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
41.3	Center of Test Interval (feet)	2.75	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

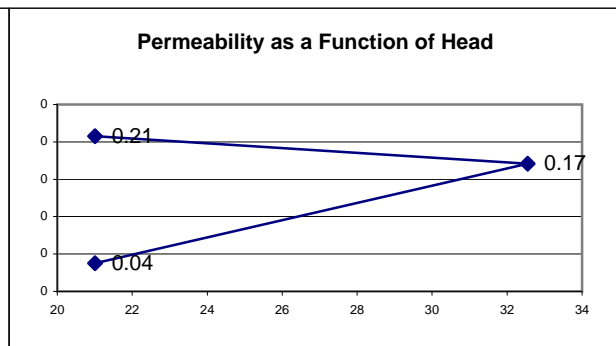
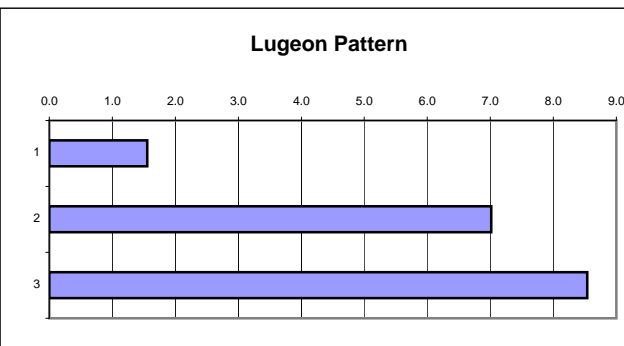
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.1	15788.2	15788.2	15788.3	15788.4	0.0	0.1	0.1	0.1
2	14.1	15789.6	15790.0	15790.6	15791.0	0.4	0.6	0.4	0.5
3	9.1	15791.7	15792.0	15792.4	15792.8	0.3	0.4	0.4	0.4
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	21.01	0.1	0.01	2.62E-05	0.04	1.6
2	32.55	0.5	0.06	0.000119	0.17	7.0
3	21.01	0.4	0.05	0.000144	0.21	8.5
4						
5						

	10 x Radius of Core Hole
Length (ft)	(ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge +  
 Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 7**

30.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
39.0	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
34.8	Center of Test Interval (feet)	4.25	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

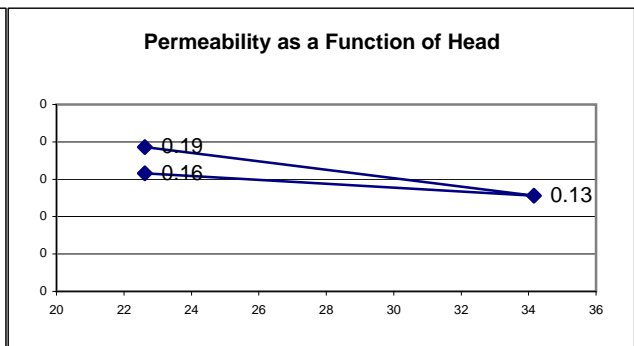
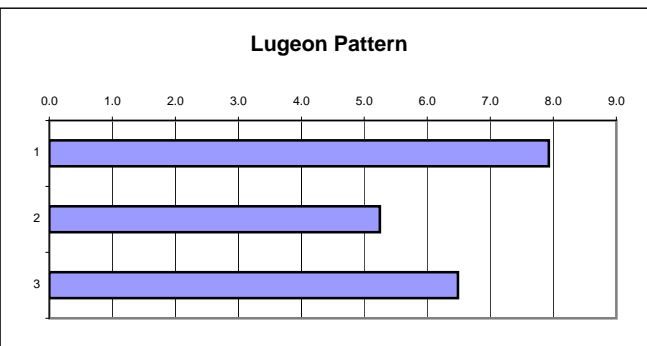
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.8	15791.8	15792.2	15792.5	15792.9	0.4	0.3	0.4	0.4
2	14.8	15793.5	15793.9	15794.3	15794.6	0.4	0.4	0.3	0.4
3	9.8	15794.7	15795.0	15795.3	15795.6	0.3	0.3	0.3	0.3
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	22.62	0.4	0.05	0.000134	0.19	7.9
2	34.16	0.4	0.05	8.87E-05	0.13	5.2
3	22.62	0.3	0.04	0.00011	0.16	6.5
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

Owner: City of Charlottesville  
 Project: Ragged Mountain Dam Project  
 Project No.: 168539  
 File No.: 51.1001  
 Title: Packer Test Data Analysis

Computed by: BMG  
 Date: 8/13/2010  
 Verified by: TPH  
 Date: 10/29/2010  
 Page: 16

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 8**

22.9	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
31.4	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
27.2	Center of Test Interval (feet)	1.92	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

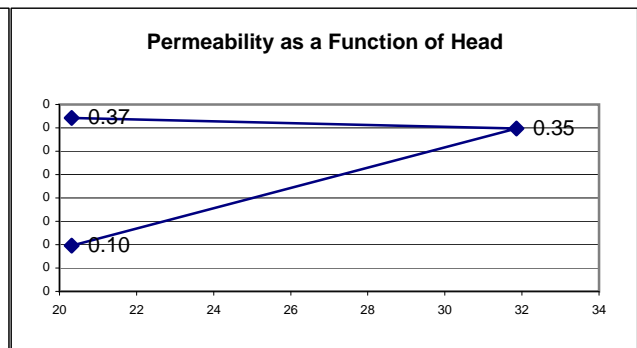
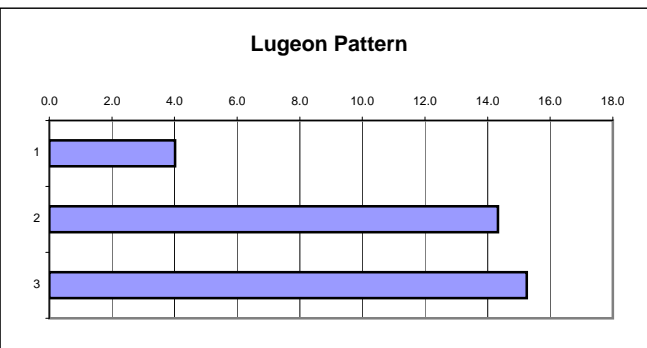
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	8.8	15796.5	15796.6	15796.8	15797.0	0.1	0.2	0.2	0.2
2	13.8	15798.0	15798.9	15799.8	15800.8	0.9	0.9	1.0	0.9
3	8.8	15802.6	15803.5	15804.0	15804.5	0.9	0.5	0.5	0.6
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	20.31	0.2	0.02	6.78E-05	0.10	4.0
2	31.86	0.9	0.12	0.000242	0.35	14.3
3	20.31	0.6	0.08	0.000258	0.37	15.2
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

Owner: City of Charlottesville  
 Project: Ragged Mountain Dam Project  
 Project No.: 168539  
 File No.: 51.1001  
 Title: Packer Test Data Analysis

Computed by: BMG  
 Date: 8/13/2010  
 Verified by: TPH  
 Date: 10/29/2010  
 Page: 17

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 9**

15.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
24.0	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
19.8	Center of Test Interval (feet)	4.25	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

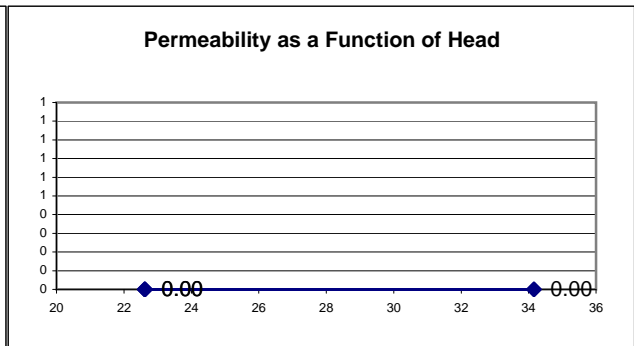
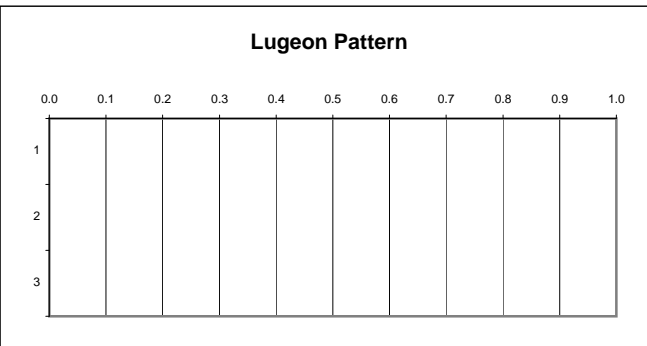
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings				Final Three Flow Rates			Average Flow Rate (gpm)
		First (gallons)	Second (gallons)	Third (gallons)	Last (gallons)	Second (gpm)	Third (gpm)	Last (gpm)	
1	9.8	15804.0	15804.0	15804.0	15804.0	0.0	0.0	0.0	0.0
2	14.8	15804.3	15804.3	15804.3	15804.3	0.0	0.0	0.0	0.0
3	9.8	15804.1	15804.1	15804.1	15804.1	0.0	0.0	0.0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	22.62	0.0	0.00	0	0.00	0.0
2	34.16	0.0	0.00	0	0.00	0.0
3	22.62	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-2P Test: 10**

9.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
18.0	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
13.8	Center of Test Interval (feet)	5.17	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

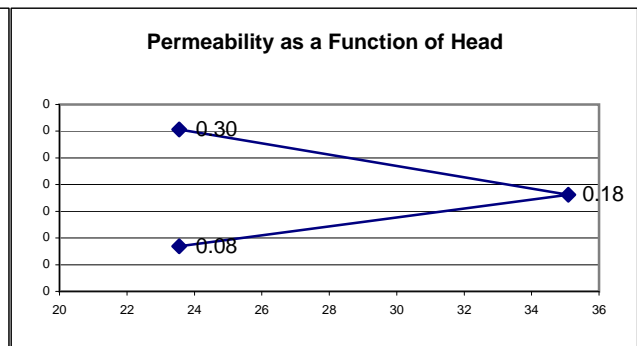
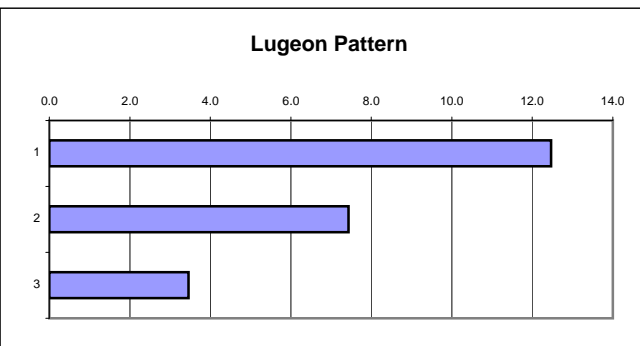
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings				Final Three Flow Rates			Average Flow Rate (gpm)
		First (gallons)	Second (gallons)	Third (gallons)	Last (gallons)	Second (gpm)	Third (gpm)	Last (gpm)	
1	10.2	15805.3	15805.8	15806.5	15807.1	0.5	0.7	0.6	0.6
2	15.2	15810.6	15811.1	15811.7	15812.2	0.5	0.6	0.5	0.5
3	10.2	15813.3	15813.5	15813.7	15813.8	0.2	0.2	0.1	0.2
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	23.55	0.6	0.08	0.000211	0.30	12.5
2	35.09	0.5	0.07	0.000126	0.18	7.4
3	23.55	0.2	0.02	5.85E-05	0.08	3.5
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.7.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-3 Test: 1**

44	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
58.7	Bottom of Test Interval (feet)	6.2	Depth to Groundwater (feet below grade)
51.4	Center of Test Interval (feet)	1.3	Height of Gauge (feet above grade)
14.7	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

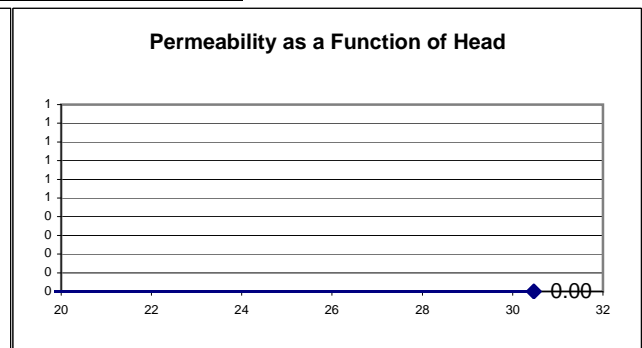
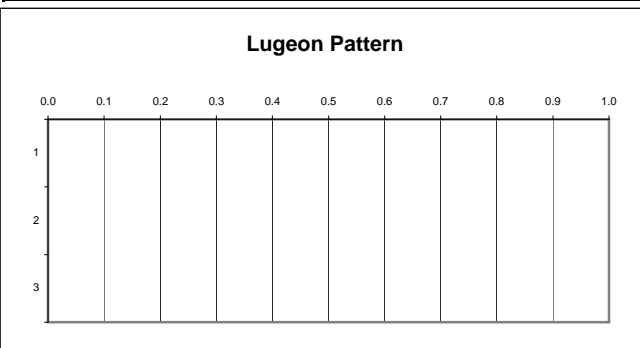
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	8.2	15547.4	15547.4	15547.4	15547.4	0	0	0	0.0
2	13.2	15547.4	15547.4	15547.4	15547.4	0	0	0	0.0
3	8.2	15547.4	15547.4	15547.4	15547.4	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		Lugeons
		(gpm)	(cfm)	(ft/min)	(ft/day)	
1	18.93	0.0	0.00	0	0.00	0.0
2	30.47	0.0	0.00	0	0.00	0.0
3	18.93	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
14.7	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-3 Test: 2**

36.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
45	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
40.8	Center of Test Interval (feet)	3.83	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

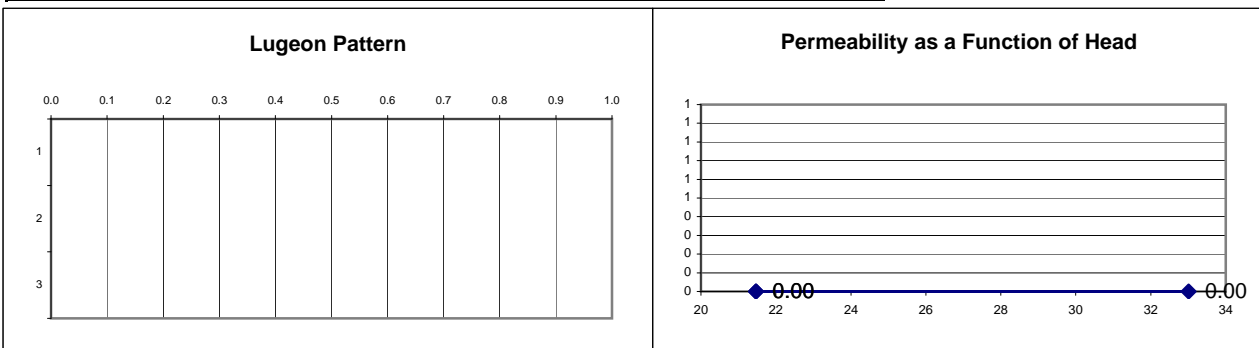
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.3	15542.0	15542.0	15542.0	15542.0	0	0	0	0.0
2	14.3	15542.0	15542.0	15542.0	15542.0	0	0	0	0.0
3	9.3	15542.0	15542.0	15542.0	15542.0	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	21.47	0.0	0.00	0	0.00	0.0
2	33.01	0.0	0.00	0	0.00	0.0
3	21.47	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-3 Test: 3**

28.8	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
37.3	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
33.1	Center of Test Interval (feet)	1.83	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

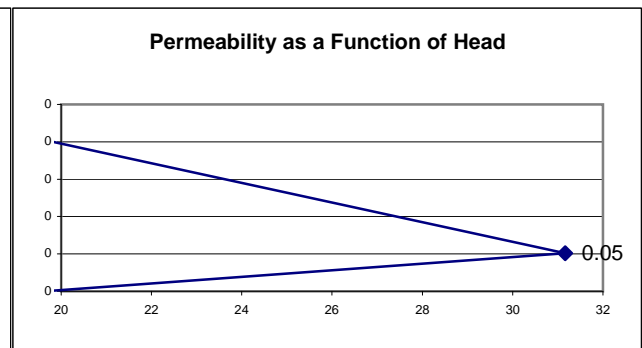
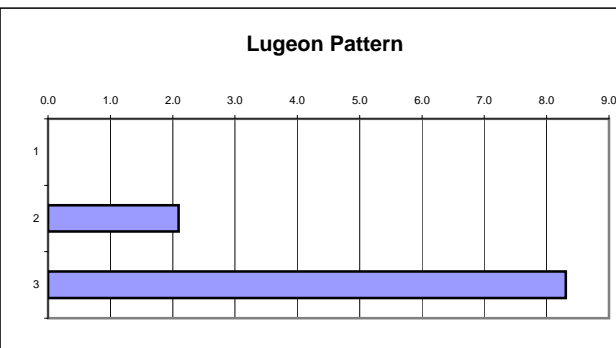
Stage	Test Pressure (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	8.5	15542.2	15542.2	15542.2	15542.2	0	0	0	0.0
2	13.5	15542.5	15542.6	15542.7	15542.9	0.1	0.1	0.2	0.1
3	8.5	15542.7	15543.0	15543.3	15543.7	0.3	0.3	0.4	0.3
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		Lugeons
		(gpm)	(cfm)	(ft/min)	(ft/day)	
1	19.62	0.0	0.00	0	0.00	0.0
2	31.16	0.1	0.02	3.54E-05	0.05	2.1
3	19.62	0.3	0.04	0.00014	0.20	8.3
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	27.7 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

Owner: City of Charlottesville  
 Project: Ragged Mountain Dam Project  
 Project No.: 168539  
 File No.: 51.1001  
 Title: Packer Test Data Analysis

Computed by: BMG  
 Date: 8/13/2010  
 Verified by: TPH  
 Date: 10/29/2010  
 Page: 22

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-3 Test: 4**

21.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
30.0	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
25.8	Center of Test Interval (feet)	3.83	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

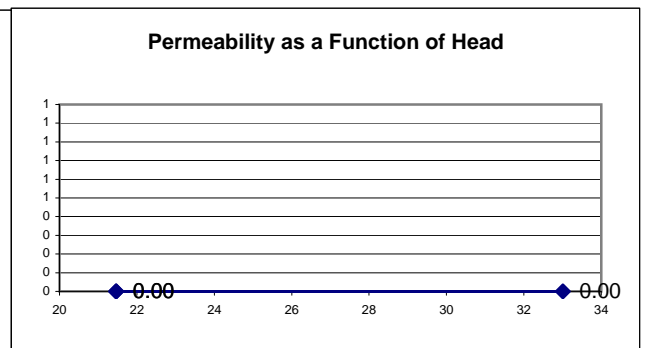
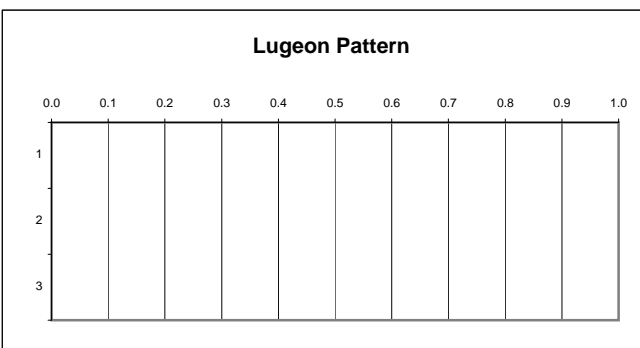
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.3	15543.8	15543.8	15543.8	15543.8	0	0	0	0.0
2	14.3	15544.0	15544.0	15544.0	15544.0	0	0	0	0.0
3	9.3	15543.7	15543.7	15543.7	15543.7	0	0	0	0.0
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	21.47	0.0	0.00	0	0.00	0.0
2	33.01	0.0	0.00	0	0.00	0.0
3	21.47	0.0	0.00	0	0.00	0.0
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

Owner: City of Charlottesville  
 Project: Ragged Mountain Dam Project  
 Project No.: 168539  
 File No.: 51.1001  
 Title: Packer Test Data Analysis

Computed by: BMG  
 Date: 8/13/2010  
 Verified by: TPH  
 Date: 10/29/2010  
 Page: 23

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-3 Test: 5**

18	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
26.5	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
22.3	Center of Test Interval (feet)	1.92	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

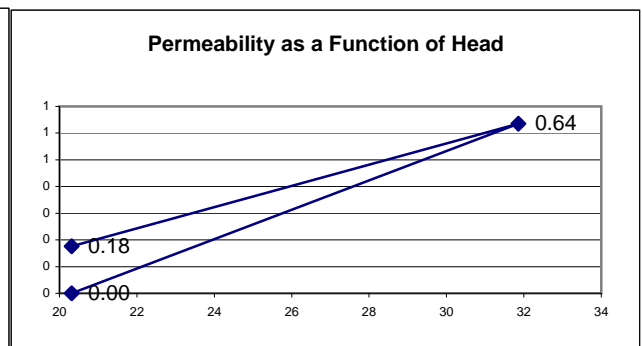
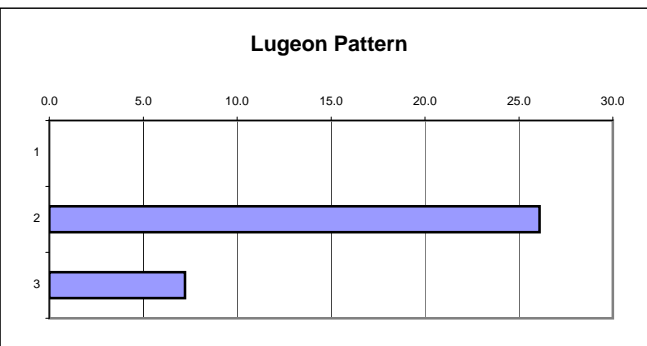
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	8.8	15545.0	15545.0	15545.0	15545.0	0	0	0	0.0
2	13.8	15556.1	15557.5	15559.0	15561.2	1.4	1.5	2.2	1.7
3	8.8	15561.4	15561.7	15562.0	15562.3	0.3	0.3	0.3	0.3
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	20.31	0.0	0.00	0	0.00	0.0
2	31.86	1.7	0.23	0.000441	0.64	26.1
3	20.31	0.3	0.04	0.000122	0.18	7.2
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input Boring: BV-3 Test: 6**

10.5	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
19.0	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
14.8	Center of Test Interval (feet)	4.25	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

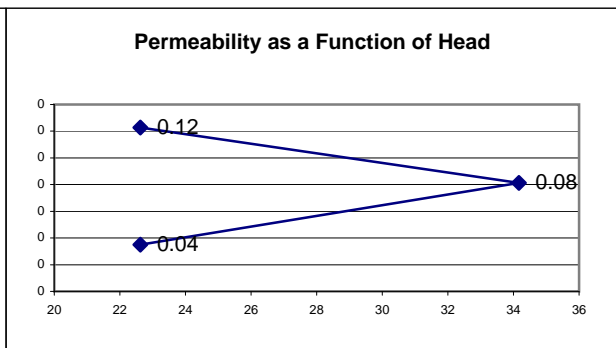
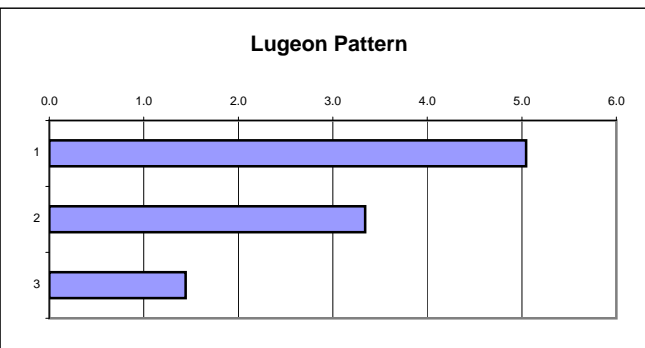
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.8	15563.0	15563.3	15563.5	15563.7	0.3	0.2	0.2	0.2
2	14.8	15564.2	15564.4	15564.7	15564.9	0.2	0.3	0.2	0.2
3	9.8	15564.9	15565.0	15565.1	15565.1	0.1	0.1	0.0	0.1
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	22.62	0.2	0.03	8.53E-05	0.12	5.0
2	34.16	0.2	0.03	5.65E-05	0.08	3.3
3	22.62	0.1	0.01	2.44E-05	0.04	1.4
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars

Owner: City of Charlottesville  
 Project: Ragged Mountain Dam Project  
 Project No.: 168539  
 File No.: 51.1001  
 Title: Packer Test Data Analysis

Computed by: BMG  
 Date: 8/13/2010  
 Verified by: TPH  
 Date: 10/29/2010  
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U.S. Bureau of Reclamation Packer Test Data Reduction (following Black & Veatch Geotechnical Field Guide, March 2009)

**Input**      **Boring: BV-3**      **Test: 7**

6	Top of Test Interval (feet)	3.75	Radius of Core Hole (inches)
14.5	Bottom of Test Interval (feet)	6.8	Depth to Groundwater (feet below grade)
10.3	Center of Test Interval (feet)	3.83	Height of Gauge (feet above grade)
8.5	Length of Test Interval (feet)		

**Packer Pressure Testing Records**

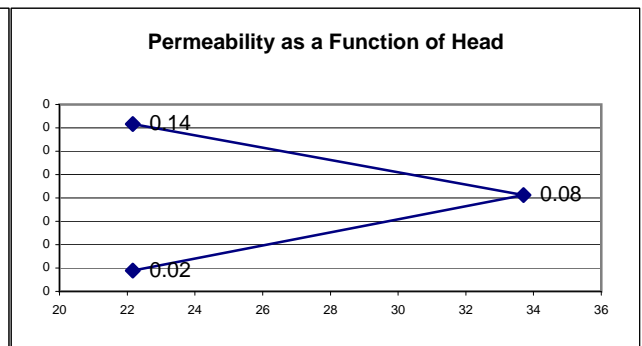
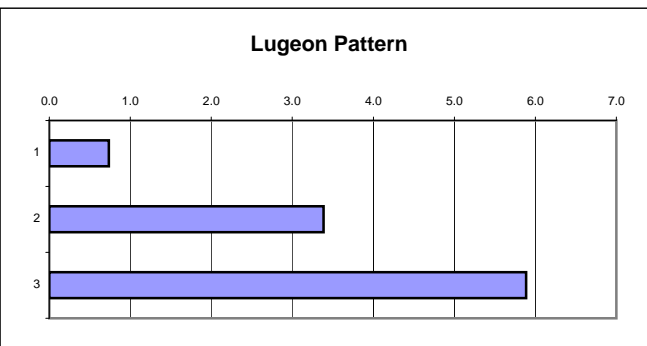
Stage	Test Pressure <sup>1</sup> (psi)	Final Four Flow Meter Readings (gallons)				Final Three Flow Rates (gpm)			Average Flow Rate (gpm)
		First	Second	Third	Last	Second	Third	Last	
1	9.6	15565.2	15565.2	15565.2	15565.3	0.0	0.0	0.1	0.0
2	14.6	15565.7	15566.0	15566.2	15566.4	0.3	0.2	0.2	0.2
3	9.6	15566.4	15566.7	15567.0	15567.2	0.3	0.3	0.2	0.3
4									
5									

**Calculation**

Stage	Equivalent Head of Water (feet)	Average Flow Rate		Permeability		
		(gpm)	(cfm)	(ft/min)	(ft/day)	Lugeons
1	22.16	0.0	0.00	1.24E-05	0.02	0.7
2	33.70	0.2	0.03	5.72E-05	0.08	3.4
3	22.16	0.3	0.04	9.95E-05	0.14	5.9
4						
5						

Length (ft)	10 x Radius of Core Hole (ft)
8.5	3.1

Assumptions Valid?  
 YES



<sup>1</sup>Test Pressure = Surface Gauge Pressure + Pressure due to Height of Gauge + Pressure due to Height of Water above Water Table - Frictional Loss due to Pipes

**Conversions**

1 gallon	3.78541 liters
1 bar	14.5038 psi
1 psi	2.77 Inches H2O
1 ft <sup>3</sup>	7.48052 gallons

**Units**

psi = pounds per square inch  
 gpm = gallons per minute  
 m = meters  
 cfm = cubic feet per minute  
 Lugeon = 1 liter / m / minute @ 10 bars