308 Scientific Notebook #195 Q20000504006

LABORATORY NOTEBOOK

CNWRA / SWRI

NOTEBOOK NO.

ISSUED TO Jim Winterle

ON 10-9 19 96

DEPARTMENT

RETURNED 19

CNWRA
CONTROLLED
COPY 195

—SCIENTIFIC NOTEBOOK CO.—
2831 LAWRENCE AVE.
P.O. BOX 238
STEVENSVILLE, MI 49127
616-429-8285

Table of Contents

SCIENTIFIC NOTEBOOK CO.

Project No. 5708-661
TITLE Well Tracer Test Modeling Book No.______ 1

From Page No.____ Entries in this Log book will be made by Jim Winterle.

Objectives:
One of the primary objectives of this work is to determine if matrix diffusion occurs during groundwater transport in the tuffaceous rocks that underlie Yucca Mountain, NV. Matrix Diffusion could act to significantly retard any contaminant plume that might ocurr in the area. If matrix diffusion is indeed occuring, it is desirabe to quantify this process in order to determine the extent of retardation.

blank →

Tracer tests conducted at the "C-well complex" by the USGS ~~can~~ be helpful in this effort. Computer modeling will be used to fit theoretical curves to the field data. The model used depends on the method by which the tracer test was conducted.

Initial modeling will be based on input of a conservative tracer into an observation well "C#2", and monitoring the arrival of the tracer at a pumped well "C#3". A compiter code developed by Alan F. Moench of the U.S.G.S is used. Refer to WRR, 31 (8) pp 1823-1835, 1995 for a thorough discussion of theory and modeling.

This Book will document model inputs, changes to the model (if made), and modeling results compared to field data (Assuming USGS will be forthcoming in providing field data).

note that source software has been attached to a disk in Scientific Notebook #286

The Original model source code is Titled RCV2AMOS.F and is Linked to Subroutines in ZBSUBS.F and MACHCON.F. These are compiled using SUN F77 and can be found in ~~~/Dopey/GWitt/Moench~~

To Page No.______

Witnessed & Understood by me, [signature] Date 10-9-96

Invented by JACW 3/24/99 Date

Recorded by

From Page No.___

BLANK

To Page No.___

Witnessed & Understood by me, JRW | Date 10-9-96 | Invented by | Recorded by | Date

From Page No.___ Use of Alan Moench's model RCV2AMOS is described next:

A single input File is used - RCV2AMOS.INP - some descriptions of the input parameters are described in the source code. However, I found it necessary to refer to the Moench (1995) article.

Input File: RCV2AMOS.INP
- contains 10 Lines of input

Line 1 - 3 parameters: LOGT, NLC, NOX
- LOGT = set to 1 if output File is to have equal Time steps on Log plot
  = set to zero for arithmetic plot.
- NLC = when LOGT = 1, specifies # of Log cycles covered by output
- NOX = when LOGT=1, # of points per cycle

Line 2 - 5 parameters: TDFIRST, DELTD, TDP, XMUI, XMUW
- TDFIRST = First value of Dimensionless time
- DELTD = For LOGT = 0, Incremental increase in dimensionless time
- TDP = Time duration of Tophat pulse, only used when ~~INTPP~~ gm INPTRA = 2 (see Line 3). 1/7/97 gm
- XMUI = well bore mixing Factor for injection well. set to zero if no mixing occurs
- XMUW = same as XMUI For withdrawal well

Line 3 - 4 parameters: INPTRA, NTS, KT, IFLUX
- INPTRA = specifies Type of input ~~Puts~~ gm pulse for Tracer. Zero For constant input; 1 for Dirac (instantaneous) input; 2 for TopHat pulse.

To Page No.___

Witnessed & Understood by me, [signature] | Date 10-10-96 | Invented by | Recorded by | Date

From Page No.____

Line 3 (cont'd)

- NTS = Number of time steps - used in conjunction with DELTD when LOGT = zero.
- KT = Number of type curves to be generated. Program will vary value of GAMMA for each type curve, However, if KT > 1, the Last Type curve will be for SIGMA = zero (NO MATRIX storage)
- IFLUX = TRACE source Boundary Type:
  - 0 - In-situ concentration
  - 1 - FLUX Average concentration.

LINE 4 - 4 parameters: PE, RWD, RTARD, XMULT

- PE = Peclet # (see Table 1)
- RWD = Dimensionless Radius of Pumped well (see table 1)
- RTARD = RETARDATION Factor for fracture system. RTARD = 1 for a conservative Tracer
- XMULT = when KT > 1, This value is added to (GAMMA) for additional type curves.

LINE 5 - 3 parameters: BIGT, METH, NN

- BIGT = MAX value of Dimensionless Time
- METH = Method of Solution
  - =1 epsilon algorithm
  - 2 ordinary quotient difference
  - 3 quotient difference
  - (Test Runs show no difference between methods reflected in output)
- NN = Determines Truncation error. Tested as low as NN = 10 as high as NN = 40 w/no effect on Output. leave at 40

To Page No.____

Witnessed & Understood by me, [signature] Date 10-10-96 Invented by ____ Date ____ Recorded by ____

From Page No.____

LINE 6 - 2 parameters: N, IQD

- N = Number of size fractions. Use if Aquifer is well characterized and sizes of "MATRIX blocks" CAN be divided into distinct size groups. Otherwise N = 1 and estimate "effective" size of matrix blocks.
- IQD - set to zero to eliminate effect of matrix diffusion, set to 1 otherwise.

LINE 7 - FB(I) Number of FB VALUES on This Line should Equal N from Line 6. FB is the Fraction of size (I)

LINE 8 - GAMMA(I) (see Table 1) Dimensionless Diffusion parameter for matrix diffusion rate. (I) ~~##~~ is the size fraction. Should have N values

LINE 9 - SIGMA(I) (see Table 1) Dimensionless storage parameter for amount of tracer That CAN be stored in MATRIX. (N) values.

LINE 10 - SK(I) (see Table 1) Fracture skin Parameter for Resistance to matrix diffusion due to fracture coatings. Set to zero for no fracture skin effect. (N) values must be entered.

To Page No.____

Witnessed & Understood by me, [signature] Date 10-10-96 Invented by ____ Date ____ Recorded by ____

Project No.
Book No. TITLE

From Page No.

Following is the table of dimensionless parameters from Moench (1995)

Table 1. Dimensionless Expressions

Information potentially subject to copyright protection was redacted from this location. The redacted material is from the following reference:

Moench, A.F. "Convergent Radial Dispersion of a Double Porosity Aquifer with Fracture Skin: Analytical Solution and Application to a Field Experiment in Fractured Chalk." Water Resources Research. Vol. 31, No. 8. pp. 1,823-1,835. 1995.

Table 1 and Notation from Moench (1995)

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
[signature]	10-10-96	Recorded by	

Project No.
TITLE Book No.

From Page No. Estimation of Model Parameters:

~~To~~ First, I want to put together what is known about the aquifer parameters based on other studies. Two reports by Geldon (1993, 1996) do a good job of describing the site of the "C-wells" and are used for much of the parameter estimation.
Well C#2 is the injection well; well C#3 is the pumped well. Here we investigate "Phase-1 Tracer Test"

* The distance between the wells, r_L, is 30.4 m

* radius of the pumped well, r_w, is 0.251 m

USGS (personal communication) reports Total of 7,907,000 gallons pumped during 46 days of Tracer

* Test: this converts to $Q_o = 650\ m^3 d^{-1}$.

* This tracer test was conducted over the full thickness of the Bullfrog member of the Crater Flat Tuff (~180 m). However in well C#2, nearly all production comes from a 36 m fracture zone; in well C#3 nearly all production comes from a 46 m thick zone. Taking the average thickness of production zones,

* $h = 41\ m$ (Geldon, 1996, Tables 5 & 6)

Geldon (1993, Table 6) lists fracture frequency in well C#1 as $0.54\ m^{-1}$ in central Bullfrog member, and $1.07\ m^{-1}$ in the lower Bullfrog. These fractures dip on average of 76°

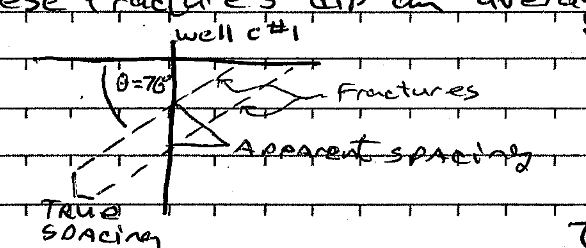


Fig 1.

Taking the average fracture frequency of $0.81\ m^{-1}$ gives an apparent spacing of 1.25 m. Correcting this for dip angle of fractures: (Fig 1)

$$\text{True spacing} = \text{apparent spacing} \cdot \cos\theta$$
$$= 1.25 \cdot \cos 76°$$
$$= 0.30\ m$$

* indicates calculation performed.

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
[signature]	10-10-96	Recorded by	

From Page No.____

PARAMETER ESTIMATION CONT'D

Given that the production zones are "very heavily" fractured compared to the "sparsely to moderately" fratured areas in the rest of the Bullfrog member it is probably a good assumption that the fracture spacing is less in the productive zones.

I will begin by estimating fracture spacing of 0.2 m. The parameter b' is the "effective" radius, or half fracture spacing, Therefore, $b' = 0.1$ m

The Tracer used is 5 Kg NaI dissolved in 500 L of water. This is considered to be a conservative Tracer, so $R = 1$ and $R' = 1$

From NUREG-1464, 1995, Appendix B, $\phi_f = 1.3\times10^{-5}$ and $\phi' = 0.19$ to 0.32 - Taking the Average, $\phi' = 0.26$. These are the fracture and matrix porosities, respectively, for Bullfrog welded Tuff. These are probably very rough estimates - curve fitting will give us more insight.

Based on a Review by Gelhar (1992, Fig 3), on a scale of 30 m, the longitudinal dispersivity $\alpha_L = 1$ m ~~s~~ JRW.

We are now Ready to compute initial estimates for model inputs based on Aquifer characteristics. Assume well bore mixing is negligible.

~~RWD = R = 1~~ JRW JRW 1/7/97

INPTRA = 1 (tracer ~~added~~ as pulse)

PE = $P_e = r_L/\alpha_L = 30/1 = 30$

RWD = $r_w/r_L = .25/30.4 = 0.008$

RTARD = R = 1

SIGMA = $\cancel{(\phi' R')/[R(1-\phi_f)^{-1}\phi_f]}$ JRW 1/7/97 $= \dfrac{\phi'(1-\phi_f)}{\phi_f} = \dfrac{0.26\cdot 1}{1.3\times10^{-5}}$

SIGMA = 20000 (seems high but lets press on)

To Page No.________

Witnessed & Understood by me,	Date	Invented by	Date
[signature]	10-10-96	Recorded by	

From Page No.____

GAMMA - This is a parameter I hope to obtain from modeling but let's get an initial estimate.

$$\gamma = D'[r_L^2 - r_w^2]\,\pi\, h\, \phi_f\, [R\, \rho_0\, \mu\, (b')^2]^{-1}$$

D' is effective Diffusion parameter in absense of sorption

errors corrected in Red JRW 1/7/97

$$D' \simeq \frac{\phi' \cancel{\tau} D_m}{\tau \cancel{\phi}}$$ ~~ASA~~ JRW

Assume $\tau = 1.5$

and $D_m = 10^{-9}\ \frac{m^2}{s} = \cancel{8\times10}$ JRW

$D_m = 8.6\times10^{-5}\ m^2\,d^{-1}$

$D' \simeq \cancel{10^{-4}}$ JRW 6×10^{-5}

$\gamma = \cancel{[10^{-4}[424]\,\pi\,41]/[650(0.1)^2]}$ JRW $6\times10^{-5}[924]\pi\cdot41/[650(0.1)^2]$

~~$\gamma \simeq 2$~~ JRW ~~$\gamma = 0.3$~~ JRW $\boxed{\gamma \simeq 1}$ also seems high

SK - There is no way to estimate SK at this time. For now, assume No fracture skin: SK = 0

* Sigma seems very high, Let's try to get another estimate of ϕ_f.

I have reviewed this notebook and find it in general compliance with QAP-001. Minor variances with QAP-001 conveyed to J. Winterle. There is sufficient information for another qualified person to repeat the activity.

E. C. P[signature]

1/7/97

To Page No.________

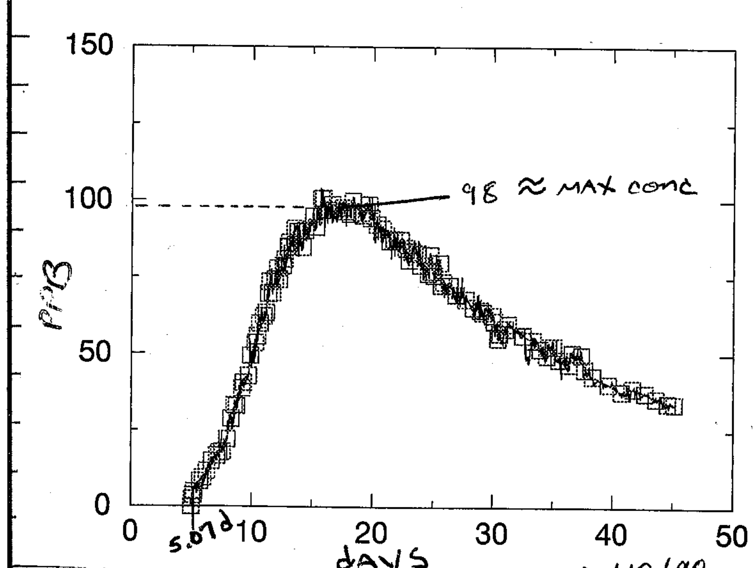
Witnessed & Understood by me,	Date	Invented by	Date
[signature]	10-10-96	Recorded by	

From Page No.____ Welcome Back!

After a very long Interruption, I am back to modeling C-well data.

Iodide Test

- tracer data provided by Chad Glen. filename = iodide.asc.
  - data is missing start time (only has time and date sample was taken); however, from Umari and Gelden Draft report, first Iodide above detection limit arrived at 5.07 days.
  - tracer data from iodide.asc processed into plot file such that first iodide arrives in 5.07 days. (see below) → iodide.btc
  - xvgr used to pick 100 points off curve. This file will be used for fitting model → iodide.piks
- 5.9 Kg of tracer ~~(KI)~~ (NaI) was injected with 500 L water RW 2/18/98
- $C_{MAX} \approx 98$ ppb



iodide breakthrough curve from c-well test begun on 2/13/96. squares represent 100 data points that will be used for least-squares model fit.

Files Plotted: iodide.asc = all points
iodide.piks = 100 picks

2/18/98

Fig 2-18-98-1

To Page No.______

Witnessed & Understood by me, | Date 2/18/98 | Invented by | Date | Recorded by

From Page No.____

Moench curves are plotted with the ordinate in terms of C/C_{MAX}, where C_{MAX} is max. observed conc.

- There is a good deal of noise in breakthrough data, but 98 ppb is about in the middle of noise at C_{max}.
- generated C/C_{max} breakthrough curve file → iodide.ndim
- for dirac-type input, model plots dimensionless concentration in terms of:

$$C_D = \frac{C}{M} \cdot \left[\pi h \phi_F (r_L^2 - r_w^2)\right] \quad \text{eq. \# 1-18-98.1}$$

where M is mass injected → 5.9 kg
h is aquifer thickness → 41 m
ϕ_F is fracture porosity → unknown
r_L is distance from pumped well center to the injection well → (30.4 m)
r_w is pumped well radius → (0.251 m)

(RW 1-18-98) In the above eqn, the ~~variables~~ term in square brackets is also part of the γ' parameter (see pg. 6 for defn).

- Model output is also in terms of dimensionless time (t_D)

$$t_D = \frac{t \cdot Q_p}{\left[\pi h \phi_F (r_L^2 - r_w^2)\right]} \quad \text{eq. 1-18-98-2}$$

where Q_p is pump rate → 650 m³/d
t is clock time

since ϕ_F is the only variable we can write $C_D(\phi_F)$ and $t_D(\phi_F)$

$$C_D = 20174.3 \cdot \phi_F \cdot C$$
$$\left[\frac{m^3}{Kg}\right] \cdot [\,] \cdot \left[\frac{Kg}{m^3}\right]$$

$$t_D = 0.005461 \cdot \phi_F \cdot t \rightarrow \boxed{\text{time in days}}$$

To Page No.______

Witnessed & Understood by me, | Date 2/18/98 | Invented by | Date | Recorded by

From Page No.___ let's take a crack at getting ballpark model parameters:

1. GAMMA (γ) = $\dfrac{D'(r_L^2 - r_w^2)\pi h \phi_f}{R\, q_0\, \mu\, (b')^2} = \dfrac{D'(r_L^2 - r_w^2)\pi h (1-\phi_F)}{R\, q_0\, b^2}$

Let $\boxed{b = 1\ m} \cong$ half fracture spacing

$h = 41$ m

$q_0 = 650\ m^3/d$

$\boxed{\phi_F = 0.01}$

$\boxed{\mu = \phi_F/(1-\phi_F)}$

$R = 1$ for conservative tracer

$D \approx 2 \times 10^{-11} \frac{m^2}{s} = 1.728 \times 10^{-6}\ m^2/d$

$\gamma = \dfrac{1.728 \times 10^{-6} \frac{m^2}{d} \cdot 119{,}028.4\ m^3 \cdot \cancel{0.01}\ [0.99]}{\cancel{1} \cdot 650 \frac{m^3}{d} \cdot \cancel{0.01} \cdot \cancel{1\ m^2}}$

$\boxed{\gamma = 3.13\ E-4}$

2. SIGMA (σ) = $\dfrac{\phi_m R_m}{R\, \mu} = \dfrac{\phi_m R_m (1-\phi_F)}{R\, \phi_F}$

Let $R_m = 1$ for conservative tracer

$\phi_m = 0.2$ for Bullfrog tuff

$\sigma = \dfrac{0.2 \cdot \cancel{1} \cdot 0.99}{\cancel{1} \cdot 0.01}$

$\boxed{\sigma = 19.8}$

3. S_K = Fracture skin Factor = $\dfrac{D'}{K_s b}$

where K_s is mass transfer coeff.

To Page No.______

Witnessed & Understood by me, [signature] Date 2/19/98 Invented by Date Recorded by

From Page No.___

we want to ignore fracture skin effect, for now. According to Moench $S_K < 0.001$ is negligible skin resistance. so we can use

$\boxed{S_K = 0.0001}$

- Lets hold on to these numbers and review the moench method for fitting the model to the data.

1. Find arrival time of non-sorbing tracer. use this as basis for estimating R_F for any tracers that arrive later

2. Record the following for each tracer
   - Mass injected (M)
   - C_{max}
   - Percent Mass Recovered
   - Free water Diffusion coefficient (Temperature dependent)
   - Retardation Factors estimated for step #1.

3. Evaluate Peclet no. as follows:
   a. Generate family of type curves for single porosity ($\sigma = 0$), non-sorbing tracer, covering range of expected Peclet no., say $10 < Pe < 100$. Use Log-Log scale
   b. Plot tracer data in terms of C/C_{max} versus time, using Log-Log.
   c. overlay tracer plot on type-curve plot and find and align type curve that matches rising limb of data. This gives value for $\underline{\underline{Pe}}$
   d. Pick match point on type curve where $C_D = 1$ and $t_D = 1$

To Page No.______

Witnessed & Understood by me, Date 2/19/98 Invented by Date Recorded by

From Page No.

3e. Read match point on tracer data plot to see what time it lines up with. This is a rough estimate of arrival time (t_a).

f. t_a can be used to estimate ϕ_f using the eqn

$$t_a = \frac{\pi h \phi_f (r_L^2 - r_w^2)}{Q_0}$$

$$\phi_f = \frac{t_a\, Q_0}{\pi h (r_L^2 - r_w^2)}$$ $\boxed{\text{eq 2-19-98-1}}$

4. Type ~~curve~~ curve matches: ignoring fracture skin, SK can be set to zero JRW 2/19/98

$$\boxed{S_K = 0}$$

a. again, use plot of tracer on log-log scale in terms of C/C_{max} vs. time.

b. overlay dimensionless type curves for different values of σ or/and γ to get best fit. Match points should be noted

c. from match points - read t_a to get time of pure advective transport. Ideally, this should be the same for all tracers.

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
[signature]	2/19/98	Recorded by	

From Page No. 2/19/98

4. d. Where match point lines up on ordinate, can be used to determine the percent mass recovered (PMR), PMR should be 100 percent if a perfect tracer test is matched perfectly by a type curve. This is not to be confused with the actual mass recovered, that would require pump test to run forever to get all mass back. PMR refers to the fact that, in an ideal type curve, eventually 100% mass will be recovered, PMR is determined by difference between actual curve and ideal curve (e.g. $\frac{C_{max}(\text{actual})}{C_{max}(\text{predicted})}$)

$\boxed{\text{eq 2-19-98-2}}$

$$PMR = \frac{C_{max}\left[\pi h (r_L^2 - r_w^2)\right]\phi_f \cdot M_{PV}}{M} \times 100$$

where: - M_{PV} is match point value on vertical ($\frac{C}{C_{max}}$) axis

- M = mass of injected tracer

Actually, I find the term "percent mass recovered" to be misleading. It would be more appropriate to call it "percent predicted peak" or "percent of ideal recovery"; But I'll stick with convention.

JRW 2/20/98

2/20/98

OK, now lets' generate type curves.

First set $\sigma = 20$, range of γ from 10^{-5} to 10^{-2}

- WAIT! on second thought, I need to estimate Pe from type curves of $\sigma = 0$

- Curve matching gives estimated Peclet #, Pe = 10, and pure advection travel time, t_a = 22.3 days. (see graph on next page

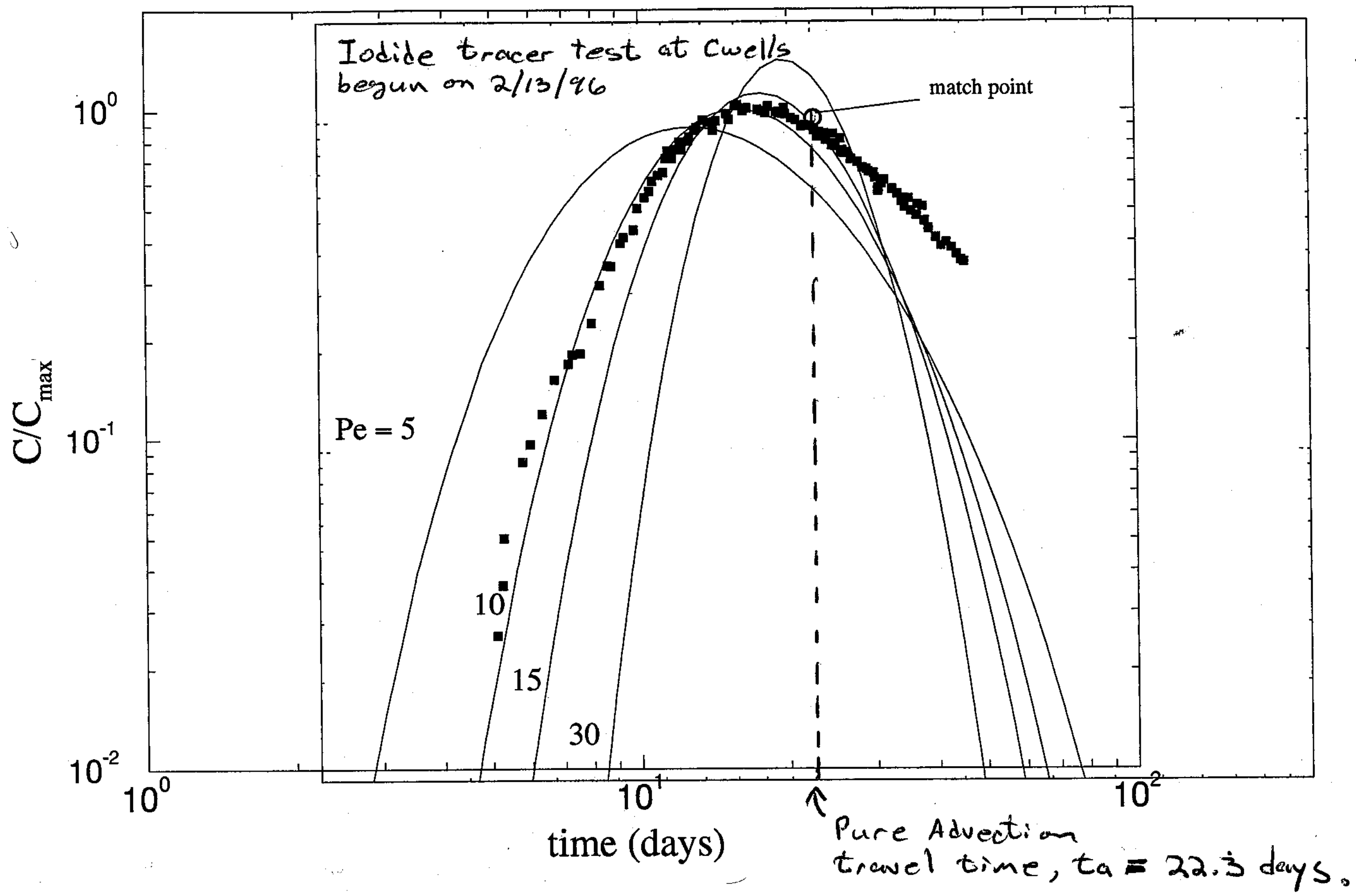
- Geldon et al estimated Pe = 11 and t_a = 17.75d.

To Page No. →

Witnessed & Understood by me,	Date	Invented by	Date
[signature]	4/20/98	Recorded by	

From Page No.____

Peclet.match.xvg



[signature] 2/19/98

from $t_a = 22.3$ d, we can estimate ϕ_F

$$\phi_F = \frac{t_a\, Q_0}{\pi h (r_c^2 - r_w^2)} = \frac{22.3\,d \cdot 650\ m^3 d^{-1}}{119{,}029\ m^3}$$

$$\boxed{\phi_F = 0.122}$$

- Geldon et al (1997) estimated ϕ_F to be 0.086, based on Pe of 11 and t_a of 17.75 d. So, I AM pretty close to what they got. (Hurrah!)

To Page No.____

~~Witnessed & Understood by me,~~	Date	Invented by	Date
[signature]	2/20/98	Recorded by	

From Page No.____

Here are some problems I see with this method.

1) the value for ϕ_F is pretty darn high. Furthermore, if one considers that really, this however, is the porosity for only the two productive zones within the Bullfrog – Tram interval. If I use the full interval thickness for h (180 m), then ϕ_F is much lower

$\phi_F' = 0.028$ which is much more what we expect. Therefore, ϕ_F is the fracture porosity of the productive interval. DOE used only "Transmissive thickness" of Bullfrog Tram interval.

2/25/98

Fit type curves for $\sigma = 20$ (see plot on next page). For fit to $\gamma = 0.007$, match point is 23 for t_D and 2.2 for C/C_{max}.

* note that match point of 23 is very close to t_a of 22.3 days.

* vertical match point (2.2) can be used to estimate PMR using eqn 2-19-98-2

$$PMR = \frac{C_{max}\,[\pi r_c^2 - r_w^2]\,\phi_F \cdot MP_v}{M} \times 100$$

$$PMR = \frac{0.098\ \frac{g}{m^3} \times 119{,}029\ m^3 \times 0.122 \cdot 2.2}{5{,}900\ g} \times 100$$

$$PMR = 53\,\%$$

* The actual mass recovered was estimated at at 47% at time test ended. The model can be constrained by fact that PMR must be greater than actual recovery, but cannot be greater than 100% →

To Page No.____

Witnessed & Understood by me,	Date	Invented by	Date
	2/26/98	Recorded by [signature]	

From Page No.___ 2/27/98 Continue Fit of 2-13-96 Tracer test.

* The PMR that I obtain from this type curve fit is probably quite low, even though it falls within constraints. This is because 47% mass was recovered at end of test; but looking at fig 2-18-98-1, The area under this curve represents ~~50~~ 47% of total mass; if you extent this curve in your mind, it looks like you could get at least another 10% more of The total mass. Thus, I would guess That PMR should be closer to 60%, perhaps higher. But we really aren't too far off.

JRW 2/27/98

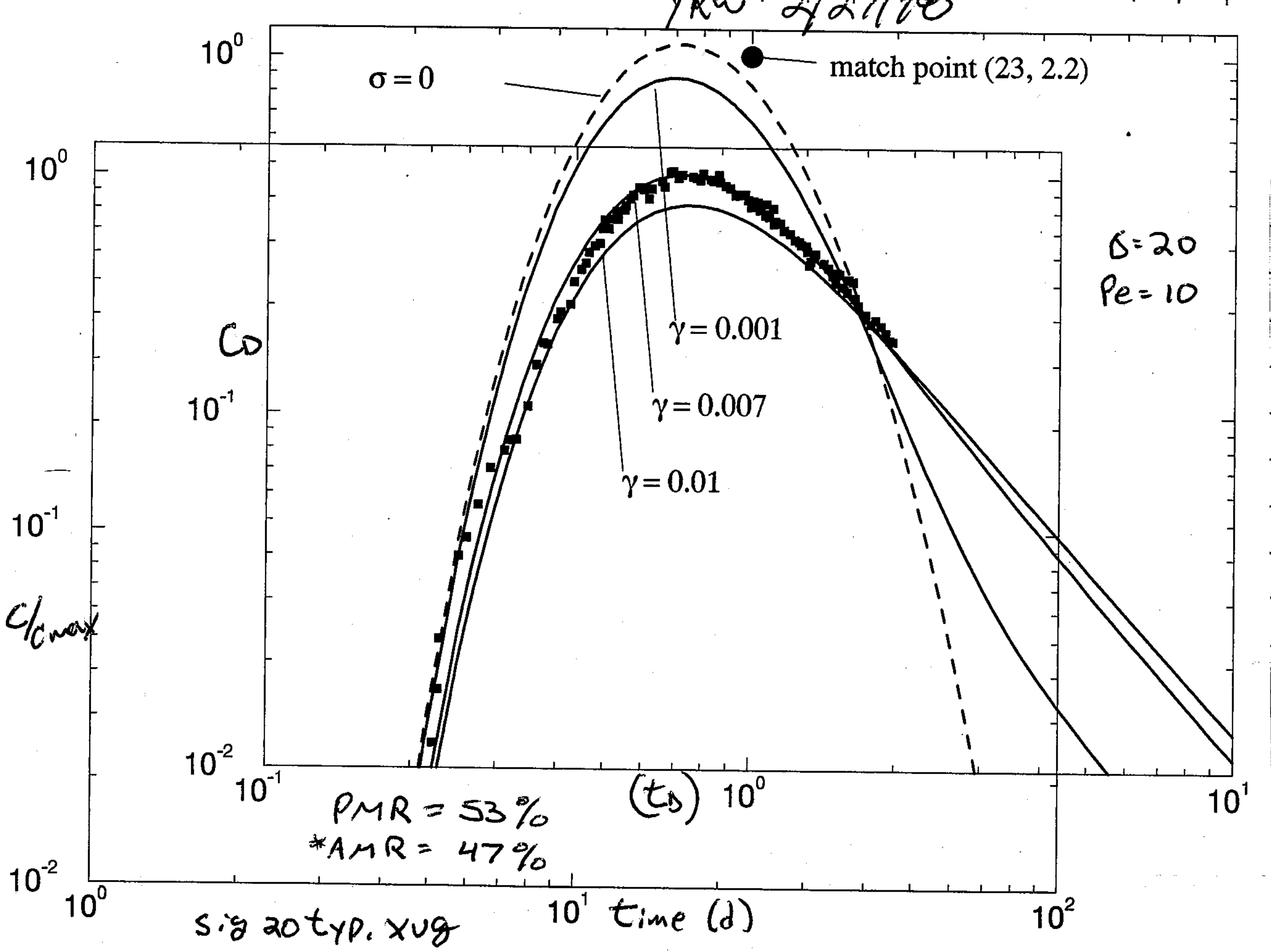


Fig 2-27-98-1

*AMR = Actual Mass Recovered at end of test.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	2/27/98

From Page No.___ 2/27/98. based on a value of $\gamma = 0.007$, let's see what this tells us.

$$\gamma = \frac{D'(r_L^2 - r_w^2)\pi h \phi_f}{R q_0 \mu (b')^2} = 0.007$$

$$\frac{D' \phi_F}{R \cancel{q_0} \mu (b')^2} = 5.88 \times 10^{-8}\ \cancel{m^{-3}} \cdot 650\ \cancel{m^3}\ d^{-1} \cdot 1$$

$$\frac{D' \phi_F}{\mu b'^2} = 3.82 \times 10^{-5}\ \cancel{d}^{-1} \cdot \frac{1\cancel{d}}{86400s}$$

$$\frac{D' \phi_F}{\mu b'^2} = 4.42 \times 10^{-10}\ s^{-1}$$

given the rather high value estimated for ϕ_F, b' is Probably fairly low in The transmissive interval, say around 0.1 m for back of envelope purposes. Then,

$$D' \cong [4.42 \times 10^{-10} \cdot 0.01]\ \frac{m^2}{s} \cdot \mu$$

$$\cancel{\boxed{D' \simeq 4.4 \times 10^{-12}\ \frac{m^2}{s}}}$$

JRW 2/27/98

This is a fairly low value for D' ~~which is around what we might expect for a large anion. This is about an order of magnitude smaller than what Triay et al estimated for TcO_4^- anions.~~

~~Forgot to multiply by $\mu = \frac{\phi_F}{1-\phi_F} = 0.14$~~

~~$\boxed{D' \approx 6.1 \times 10^{-13}\ \frac{m^2}{s}}$ For $b' = 0.1$ m~~

~~which is about Two orders of magnitude lower Than typical lab values.~~

JRW 2/27/98

Also forgot to multiply by $1/\phi_F$ (ie. $\frac{\mu}{\phi_F}$) correction gives

$$D' \approx 5.1 \times 10^{-12}\ \frac{m^2}{s} \quad \text{for } b' = 0.1m$$

about 1 order of magnitude lower Than typical lab values in tuff (Triay et al)

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
	2/27/98	Recorded by [signature]	

From Page No.

2/27/98

- Note that a slight increase in 'b' will bring Diffusion coeff (D') more in line with what is commonly observed in the lab.

3/2/98 No Entry This day

4-21-98

Interpretation of Cwell Hydraulic & TRACER TESTS.

- UE25 c#3 pumped in all tracer tests
  Flow distribution
  - Bullfrog (lower): 70%
  - Upper Tram : 20%
  - All other : 10%

Observation Wells

C#2 30.4 m from c#3 at sfc
All intervals respond to pumping

C#1 68.4 m from c#3 at sfc
All intervals respond.

ONC-1 842.8 m from c#3 at sfc.
only extends 36 m below w.t. and includes calico Hills and Prow Pass separated by Packers. Lower transducer in Prow Pass used for Pressure head data.

To Page No.

Witnessed & Understood by me, | Date | Invented by | Date 4-21-98
Recorded by

From Page No.

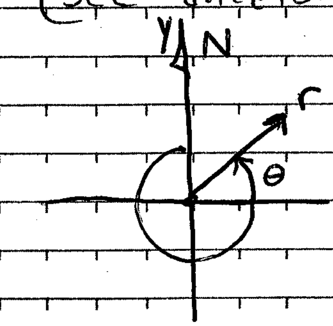
H-4 2245 m from c#3
Piezometers installed in upper packed-off interval that includes Prow Pass, Bullfrog, Tram, and upper Lithic Ridge tuff; and in lower packed interval in lower Lithic Ridge tuff. Both packed intervals monitored by transducers, only upper used in analysis

WT-14 2249 m from c#3 at sfc.
extends ~ 53 m below WT.
open to TSw and Calico Hills fmtns.
no packers.

WT#3 3526 m from c#3 at sfc
~ 48 m below wt.
open to Bullfrog Tuff

4/27/98

Created Flow Transmissivity ellipse program
(see directory ../cwell/ellipse)



Using Polar Coordinates:

angle θ is with respect to North ($0° < \theta < 360°$) with pumped well at the origin.

r = length of ray from origin

$$r = \frac{1}{\sqrt{T}}$$

where T is Transmissivity between pumped and observation wells

For Polar coordinate conversion:

$$x = r \,\cancel{\cos}\, \sin \theta \qquad y = r \,\cancel{\sin}\, \cos \theta$$

$$\tan \theta = \frac{y}{x} \qquad r^2 = x^2 + y^2$$

note: sin & cos changed because θ begins from North = 0. JRW 5/1/98

To Page No.

Witnessed & Understood by me, | Date | Invented by | Date 4-27-98
Recorded by

From Page No. 5/12/98

Using N-S as y-axis and E-W as x-axis, a Transmissivity ellipse is given by

$$Ax^2 + Bxy + Cy^2 = 1 \qquad \text{eqn 5-12-98.1}$$

converted to polar coordinates gives

$$A r^2 \sin^2\theta + B r^2 \sin\theta\cos\theta + C r^2 \cos^2\theta = 1$$

$$\downarrow$$

$$r^2\left[A\sin^2\theta + B\sin\theta\cos\theta + C\cos^2\theta\right] = 1$$

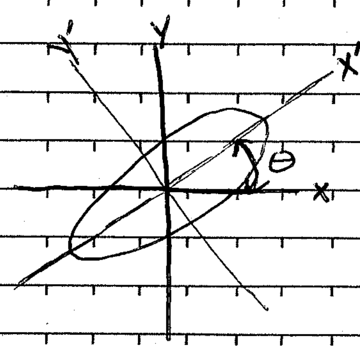
OR

$$\frac{1}{r^2} = A\sin^2\theta + B\sin\theta\cos\theta + C\cos^2\theta$$

JAW 5/12/98 here $1/r^2$ = directional Transmissivity, so $(T(\theta))$

$r = 1/\sqrt{T(\theta)}$

To find principal coordinates x', y' you need to rotate x-y through an angle.



This removes the "xy" term from eqn 5-12-98.1

To do this, rotate coordinate axis through angle θ, where

$$\cot 2\theta = \frac{A-C}{B}$$

$$\downarrow$$

$$\frac{1}{\tan 2\theta} = \frac{A-C}{B} \rightarrow \tan 2\theta = \frac{B}{A-C}$$

$$2\theta = \arctan\left(\frac{B}{A-C}\right)$$

$$\boxed{\theta = \frac{1}{2}\arctan\left(\frac{B}{A-C}\right)}$$

Then substitute

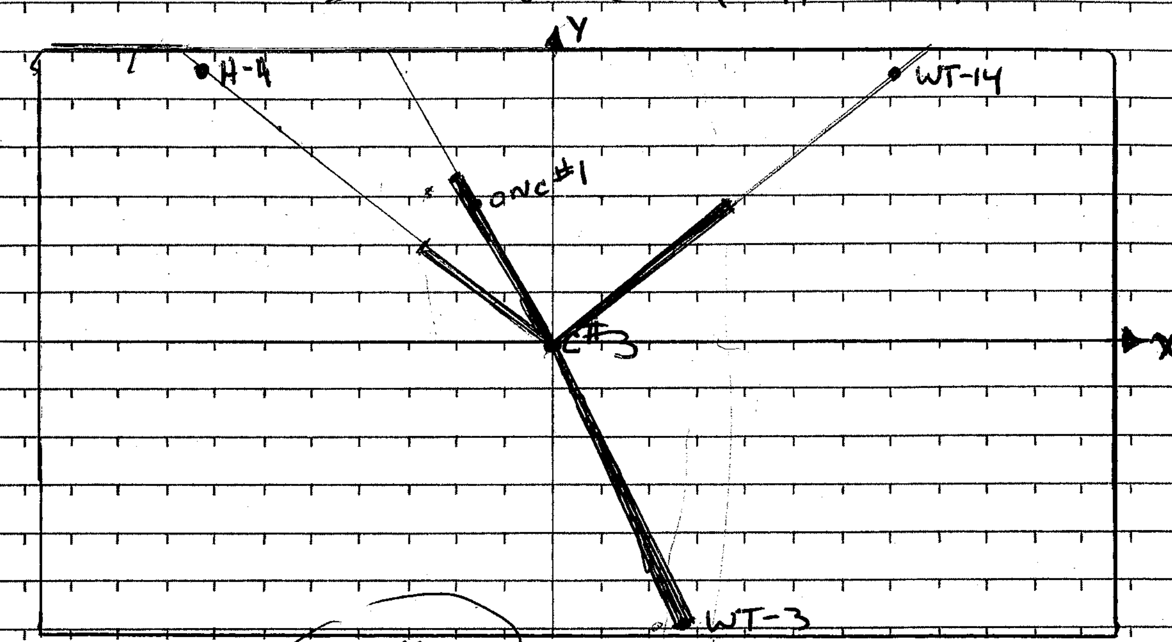
$$x = x'\cos\theta - y'\sin\theta$$
$$y = x'\sin\theta + y'\cos\theta$$

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by JAW	5/12/98

From Page No. 5/12/98

Fitting ellipse to cwell Data observation wells Identified on pp 20-21



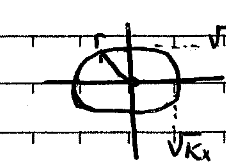
Approx angles

onc#1	35° JAW 5/12/98 ~~28°~~ ccw from N	T =	11,000 $\frac{ft^2}{d}$
H-4	53° ccw from N	T =	7,000 "
WT-14	307° " " "	"	14,000 "
WT-3	202° " " "	"	28,000 "

From Freeze & Cherry, pg 36

$$\frac{X^2}{K_x} + \frac{Y^2}{K_y} = 1 \qquad \text{for principal axes aligned w/ Transmissivity}$$

$$\frac{1}{r^2} = \frac{\cos^2\theta}{K_x} + \frac{\sin^2\theta}{K_y}$$

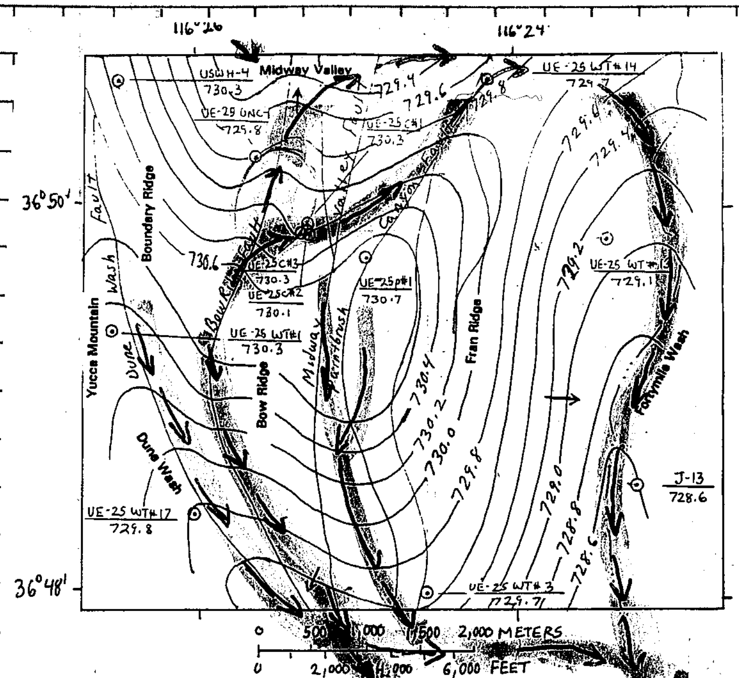


To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by JAW	5/12/98

From Page No.

5-14-98 Lets think about setting up a model. From Geldon et al. (1997) the following WTR sfc. contour map is inferred for c-well region:



EXPLANATION

USW H-4 / 730.3 — BOREHOLE WITH BOREHOLE NUMBER ABOVE LINE AND WATER-LEVEL ALTITUDE, IN METERS ABOVE NGVD OF 1929 BELOW LINE

730.0 — POTENTIOMETRIC-SURFACE CONTOUR - Shows altitude above NGVD of 1929 at which water would have stood in tightly cased wells completed in the Miocene tuffaceous rocks in May 1995. Water-level altitude in UE-25 p#1 estimated from the measured hydraulic head of Paleozoic carbonate rocks and the vertical head gradient between the Paleozoic carbonate rocks and Miocene tuffaceous rocks in the borehole. Arrow indicates approximate direction of ground-water flow. Contour interval is 0.2 meter.

FAULT TRACE

Figure 4 - Potentiometric surface of the Miocene tuffaceous rocks in the vicinity of the C-hole complex, May 1995 (Water-level altitudes from Graves and others, 1997; Geldon and others, in review)

ARW 5/14/98

Highlighted areas with arrows show surface drainage patterns which are more-often-than-not associated with Faults.

IF you believe this MAP, some interesting items are:

1) Ridge in water table contour is associated with paintbrush canyon fault system

2) A lesser ridge associated with Bow Rige Fault which has considerable offset and many splays (Day et al map) [>100m offset]

3) A trough is associated with Dune Wash Fault which also has much offset (~100m) but fewer splays.

To Page No.

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by [signature] 5-14-98

From Page No.

5-14-98

Q. Are ridges associated with recharge from below along fault, or from above through wash bottoms?

* Review of S^4Z model (Cohen et al, 1997), a Sub-Site-Scale Sat. Zone model:
- Geologic framework taken from Clayton et al (1997)
- Hydrologic Properties based largely on C-Hole data from Geldon (1993, 1996, 1997)
- Temp. anomalies at w.t. near SCF and PCF may be due to upwelling through faults from Paleozoic aquifer.
- Fracture properties obtained from Sonnenthal et al (1997) and Sweetkind et al (1997)
- dual porosity formulation was developed for future use
- All Faults treated as vertical - location is coincident with surface trace; only North-trending faults which have greatest displacement we considered — most of these are block bounding.
- Fault zones can have unique properties, but they are treated as displacement only in this report.
- Hydraulic conductivities for each model layer are the bulk conductivity of fracture and matrix. eg., TSw → $k = 10^{-12}\ m^2$; Porosity is fracture porosity only.

[signature]

To Page No.

Witnessed & Understood by me, | Date | Invented by | Date 5-14-98
Recorded by [signature]

From Page No.___ 6/9/98 Review of Streltsova-Adams (1978)
"Well Hydraulics in Heterogeneous Aquifer formations"

- This paper is used to interpret wells from C-Well hydraulic tests.

- "For analysis of the fractured aquifer, it is essential to know where the pressure measurements are recorded — in the fracture or in a section with merely inter-granular porosity."

From above quote, this might explain why all intervals responded to pumping in C-wells, but pressure response varied. i.e., some of the packed-off intervals may not have been well-connected to fracture system.

Rate of distribution of pressure change is proportional to hydraulic diffusivity coefficient $K = k/S_s$ [unitless?]

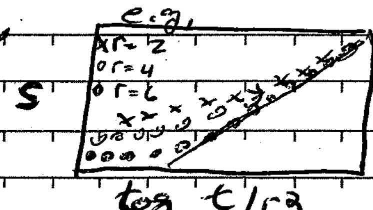
Fracture $K_F \gg$ matrix K_{por}

- Indications of fractured reservoirs from pump test response:

1) Fast response of observation well to pumping, even when widely separated.

2) "slower" pressure-time curves compared with homogeneous formations, in homogeneous, these lines should be on top of eachother.

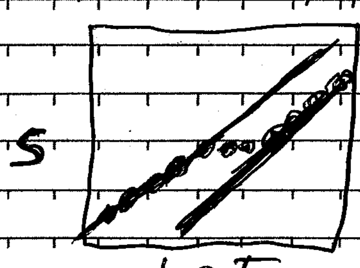
e.g.



s = drawdown

3) Parallel asymptotic lines on semilog paper.

e.g.



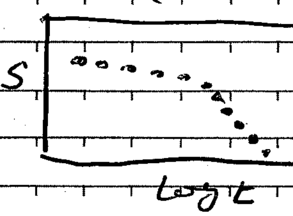
see Kruseman & deRidder for interpreting this type of response

To Page No.______

From Page No.___ 6-9-98 (cont'd) (Stretsova-Adams)

4) An initial rise in "pore pressure" may take place near withdrawal well such that drawdown far from pumped well could temporarily exceed that near the pumped well.

5) increased rate of drawdown after matrix dewatering occurs. Noticeable as a kink in semilog plot of time-drawdown e.g.: s



6) ? not sure what she means here. (another plot showing kinked line

- Fractured medium as "double-porosity"

Assuming: (1) no flow in matrix
(2) no storage in fractures
we can use Barenblatt (1960) continuity model with type curves in Table 1

↓

further assume
(3) confined aquifer
(4) drainage from block prop. to pressure difference in F-Mtx.
(5) large t

$B_1 = \sqrt{\frac{k_1 h H}{k_2}}$ ← could use h and H to derive "Block size" and "fracture aperture") see Fig 12.

- Type curves for Confined Aqfer in Table II & III
- Type curves in Table II are for fracture
- For Table III are for blocks (i.e. matrix)

These are used by Geldon to interpret C-wells

To Page No.______

From Page No. 7-10-98 Pump Test at C-Holes from 6/12 to 6/29, 1995 (pumping stopped on 6-16-95)

* Pumping well C#3 data:

- Pump test data - drawdown vs. time on log-log plot have Flat late-time response typical of delayed yield
- These data fit well to Neuman-type A curve (Neuman, 1975), but not enough late-time data to run into "type B" response
  - Q ≈ 356 gpm ± 2gpm
    $356\ gpm \times 0.1337\ \frac{FT^3}{gal} \times 1440\ \frac{min}{day} = 68530\ \frac{FT^3}{d}$
  - saturated thickness - assume full penetrated depth of sat zone by well c#3
    b = 1700 Ft
    (this assumption will probably be tested later when I look at partially penetrating well theory)
  - Borehole radius: r ≈ 11" to 1 Foot
- Match to type A curve on opposite page
- $T = \frac{1}{4\pi} \cdot \frac{Q\ s_D^*}{s^*}$ (Neuman, 1975 eqn (6))

$$T = 0.0796 \cdot \frac{68530\ FT^3/d \cdot (1.0)}{(12.8\ FT)}$$

$$\boxed{T = 426\ FT^2/d}$$

JRW 7-13-98 error in storativity calc, corrected on pg 29!

JRW 7-10-98

$$S = \frac{T\,t^*}{r^2\,t_s^*} = \frac{0.23 \cdot 426\ FT^2/d \cdot 1.\cancel{0}}{1.0 \cdot 0.84 \cdot \cancel{0.23}}$$ JRW 7-10-98

$\boxed{\cancel{S = 116}}$ → ~~Does not make sense! S should be less than 1.0~~

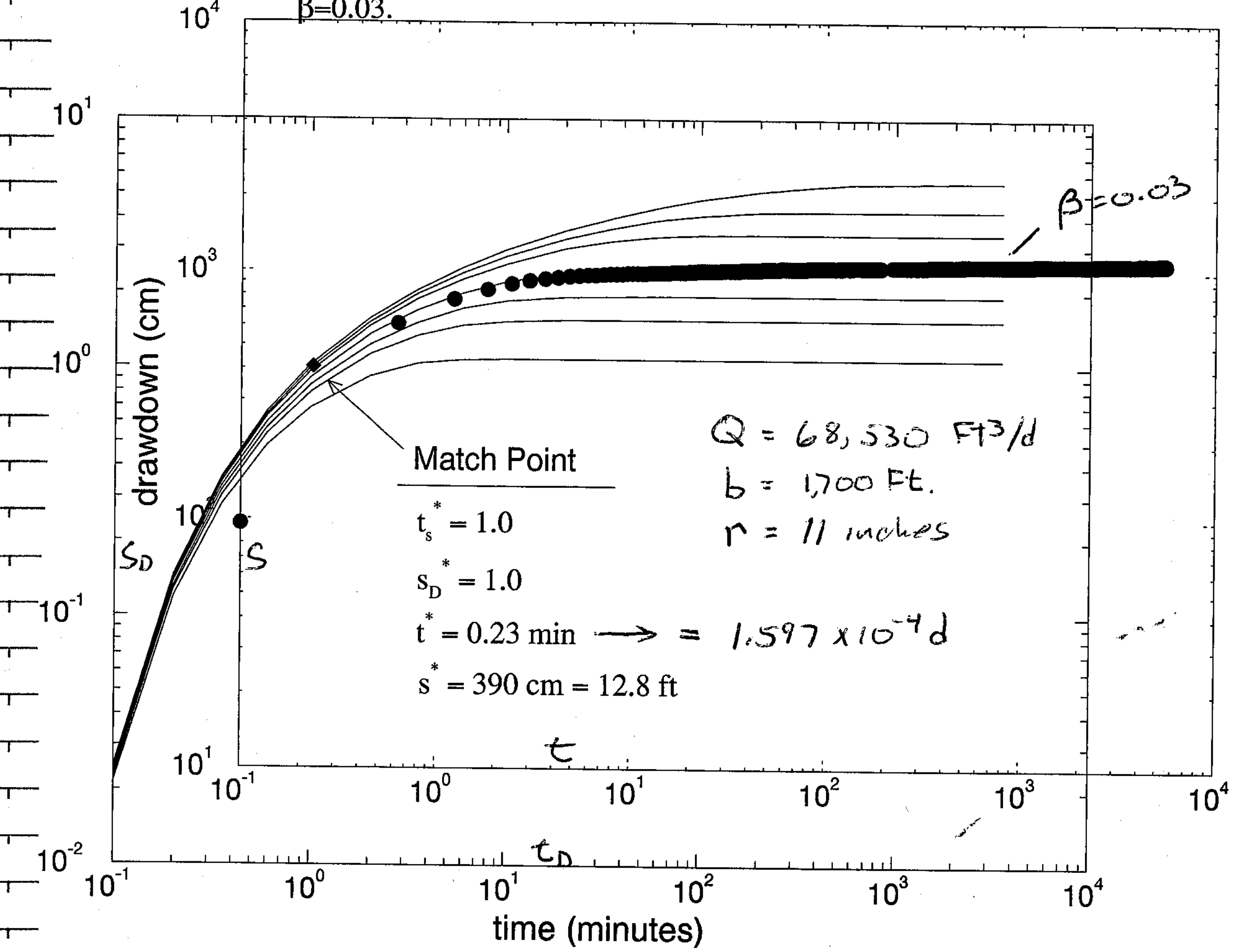
To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. White	7-10-98

From Page No. 7/10/98

JRW 7/10/98

Well c#3 response to pump-test from June 12-16, 1995 is matched well by a Neuman (1975) Type A curve with β=0.03.



Using Theiss method:
match of above data to Theiss curve gives match point
W(u) = 1
1/u = 1
t* = 0.1 min =
s* = 422 cm = 13.8 ft

$T = \frac{1}{4\pi} \frac{Q\,W(u)}{s^*}$ $S = \frac{4 T t^*}{r^2} \cdot u$ JRW 7-13-98 error in calc (see pg 29 30)

$T = 395 \frac{FT^2}{D}$ → ~~S = 188~~ ~~Nonsense!~~

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. White	7-10-98

From Page No.___ 7-13-98 Well C#3 correction to calculations.

$$S = \frac{T t^*}{r^2 t_s^*} = \frac{0.23\ \text{min} \cdot 426\ \text{ft}^2 \text{d}^{-1}}{0.84\ \frac{\text{ft}^2}{\text{ft}^2} \cdot 1} \times \frac{1\ \text{d}}{1440\ \text{min}}$$

- $\boxed{S = 0.081 \quad T = 426\ \text{ft}^2\ \text{d}^{-1}}$ Neuman 1975 'TYPE A' curve match to single well drawdown data for pumped well C#3. Fo test conducted June 12-29, 1995

- From ~~Geldon~~ JRW 7-13-98 Theis-curve analyses of single well pump test data for C#3 from test conducted June 12-29, 1995

$\boxed{T = 395\ \text{ft}^2\ \text{d}^{-1} \quad S = 0.13}$

- Similar pump test conducted in C#3 ~~and~~ JRW 7-13-98 from May to June, 1984 and interpreted by Geldon give:

$T = 300\ \text{ft}^2\ \text{d}^{-1}$ using Cooper (1963) Fissure-block curve

$T = 270\ \text{ft}^2\ \text{d}^{-1}$ using Theiss assumptions

Geldon did not estimate storage but from the match points he selected in his (1996) report I calculate S below

t^* 0.72 min $\rightarrow S = \frac{4 \cdot 0.72}{1440} \cdot \frac{270}{0.84} = 0.6$

However, this method of Cooper (1963) assumes no storage, according to Geldon so, probably shouldn't use this estimate.

To Page No.______

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by [signature] 7-13-98

From Page No.___ Well ONC-1 response to long-term pump test conducted from May 7, 1996 – March 26, 1997.

$\bar{Q} = 29{,}100\ \text{ft}^3/\text{d}$ on average } ref Geldon, 1997
$r = 843\ \text{m}$

from curve match shown below,

$$T = \frac{Q\,W(u)}{4\pi\, s^*} = \frac{29100 \cdot 1}{\cancel{0.0996} \cdot 0.11} \cdot 0.796 = 21{,}100\ \frac{\text{ft}^2}{\text{d}}$$

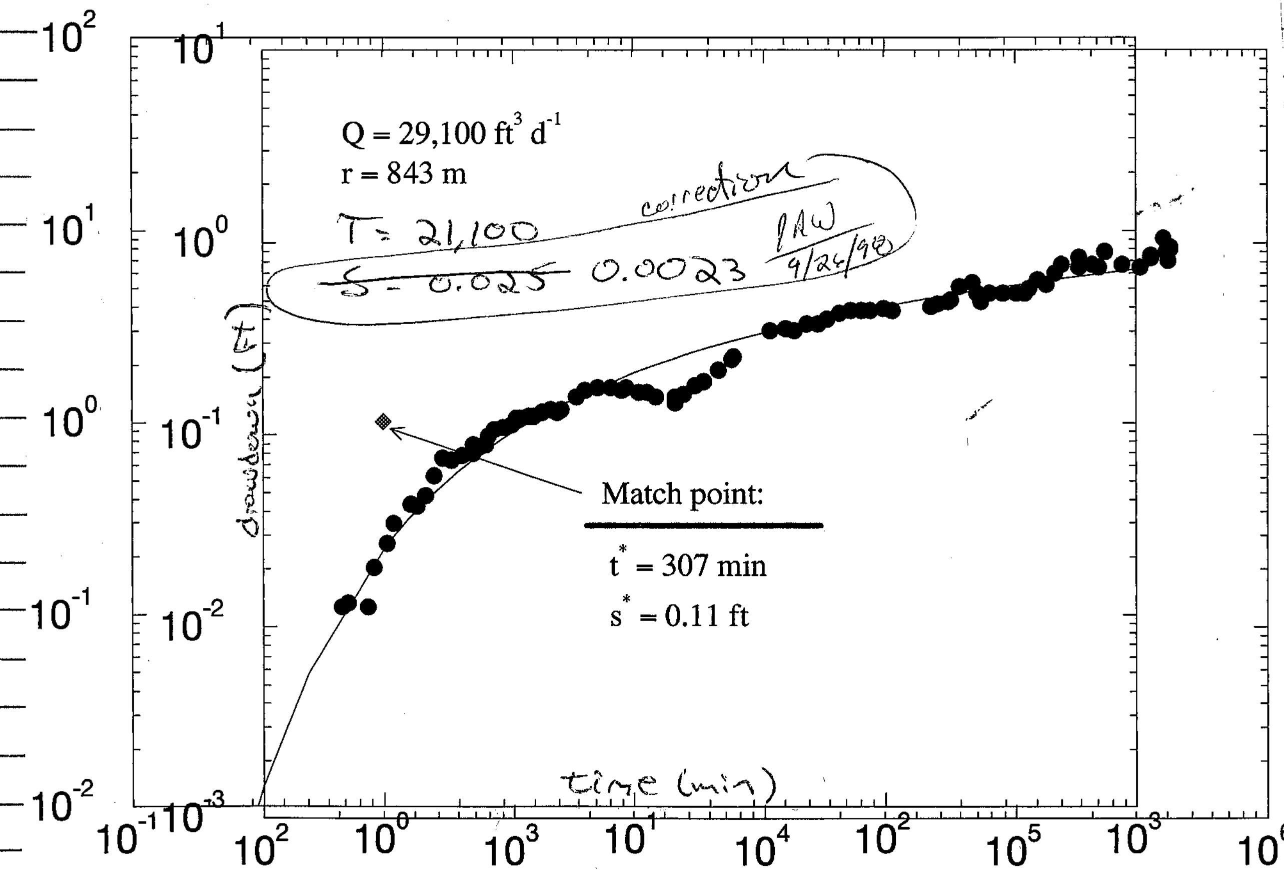
JRW 7-13-98

$$S = \frac{4 T t^*}{r^2} \cdot \frac{1}{u} = \frac{4 \cdot 21100 \cdot 307\ \text{min}}{(843\ \text{m})^2 \cdot 1440\ \frac{\text{min}}{\text{day}}} = \frac{0.025}{10.76\ \text{ft}^2/\text{m}^2} = 0.00232$$

correction JRW

JRW 7/13/98

Fit of ONC-1 drawdown data from long-term pump test to Theis curve.



This transmissivity estimate to be used in following interpretation of regional anisotropy.

To Page No.______

Witnessed & Understood by me, | Date | Invented by | Date 7-13-98
Recorded by [signature]

From Page No.__ Fitting Horizontal Anisotropy Ellipse to region encompassed by C-well Long-Term pump test.

Well Locations

	Lat - lon	Lon - Lat ?	
C#1	~~JRW 7-14-98~~	569,682.71	757,095.49
C#2	~~756,840.59~~	569,634.94	756,844.74
C#3	~~756,904.2, 569,562.29~~	E 569,553.75	N 756,909.22
H-4		563,906.50	761,644.88
ONC#1		568,094.64	759,198.19
WT-3		573,381.87	745,993.95
WT-14		575,206.20	761,651.28

In GIS Data-base, x-y coordinates are given.

	X	Y
JRW 7-14-98 ~~C#1~~	~~563911.11~~	~~761,643.62~~
C#2	569633.80	756848.80
C#3	569554.90	756909.90
ONC-1	568097.70	759188.70 JRW 7-14-98
JRW 7-14-98 ~~H-4~~ H-4	563,911.11	761,643.62
WT-3	573384.41	745995.09
WT-14	575210.10	761650.60
C#1	569680.44	757095.85

Well Locations with respect to C#3 at 0,0 in Cartesian Coordinates. X (ft) Y (ft) (in Feet)

	X (ft)	Y (ft)	
C#1	125.4	185.95	T = 28000 ft²/d
C#2	78.9	-61.1	T = 28000
ONC-1	-1457.2	2288.8	T = 11000 *
H-4	-5643.2	4733.7	T = 7,000
WT-3	3829.5	-10,914.8	T = 28,000
WT-14	5655.2 1724m	4740.7 1445m	T = 14,000

* ONC-1 T = 11,000 w/ Fissure-block type curve per Gellon (1997). I reinterpreted it with Thies curve and estimate 21,100 ft²/day

To Page No.____

Witnessed & Understood by me, | Date | Invented by | Date 7-14-98

Recorded by [signature]

From Page No.__ Use PEST code to optimize Transmissivity ellipse fit to regional pump test results

1. Oservation 1 — wells WT3, WT14, ONC1, H4
T = 28000; 14000; 11000; 7000

optimized values of a, b, c define an elipse with $r = \sqrt{T}$ with angle, θ = zero at due north and origin at C#3.

a = 1.566 ; b = -0.470 ; c = 0.10 *

* (c-parameter is limited by range that I specified [0.1 < c < 2] to prevent ellipse from becoming a hyperbola.

These parameters can be plugged into eqn for an ellipse

$$ax^2 + bxy + cy^2 = 1$$

calculate rotation necessary to align principal axes (N-S) with ellipse.

to find $\theta \Rightarrow \cot 2\theta = \frac{A-C}{B} = -3.119$

$$\frac{\text{arcot}(3.119)}{2} = \boxed{\theta = -8.9^\circ} \rightarrow \text{neg = clockwise}$$

That is, ellipse major axis is aligned N 8.9°E

2. wells WT3; WT14; ONC1*; H4
T (ft²/d) = 28000; 14000; 21100*; 7000

* ONC1 Re interpreted using Theis to be consistent w/ other data from other wells.

a = 1.280 ; b = -0.174 ; c = 0.172

~~θ =~~

$\boxed{\theta = -4.46^\circ}$

[signature]

To Page No.____

Witnessed & Understood by me, | Date | Invented by | Date 7-14-98

Recorded by [signature]

From Page No.____ Continue determination of axis rotation.

3. wells ONC-1, H4, WT3, WT14, c#1, c#2
T (FT²/d) 21100, 7000, 28000, 14000, 28000, 28000

a = 0.9706 ; b = -0.2011 ; c = 0.2384

4. same wells as (3) with T_{ONC-1} = 11000 FT²/d

a = 0.804 ; b = -0.086 ; 0.263

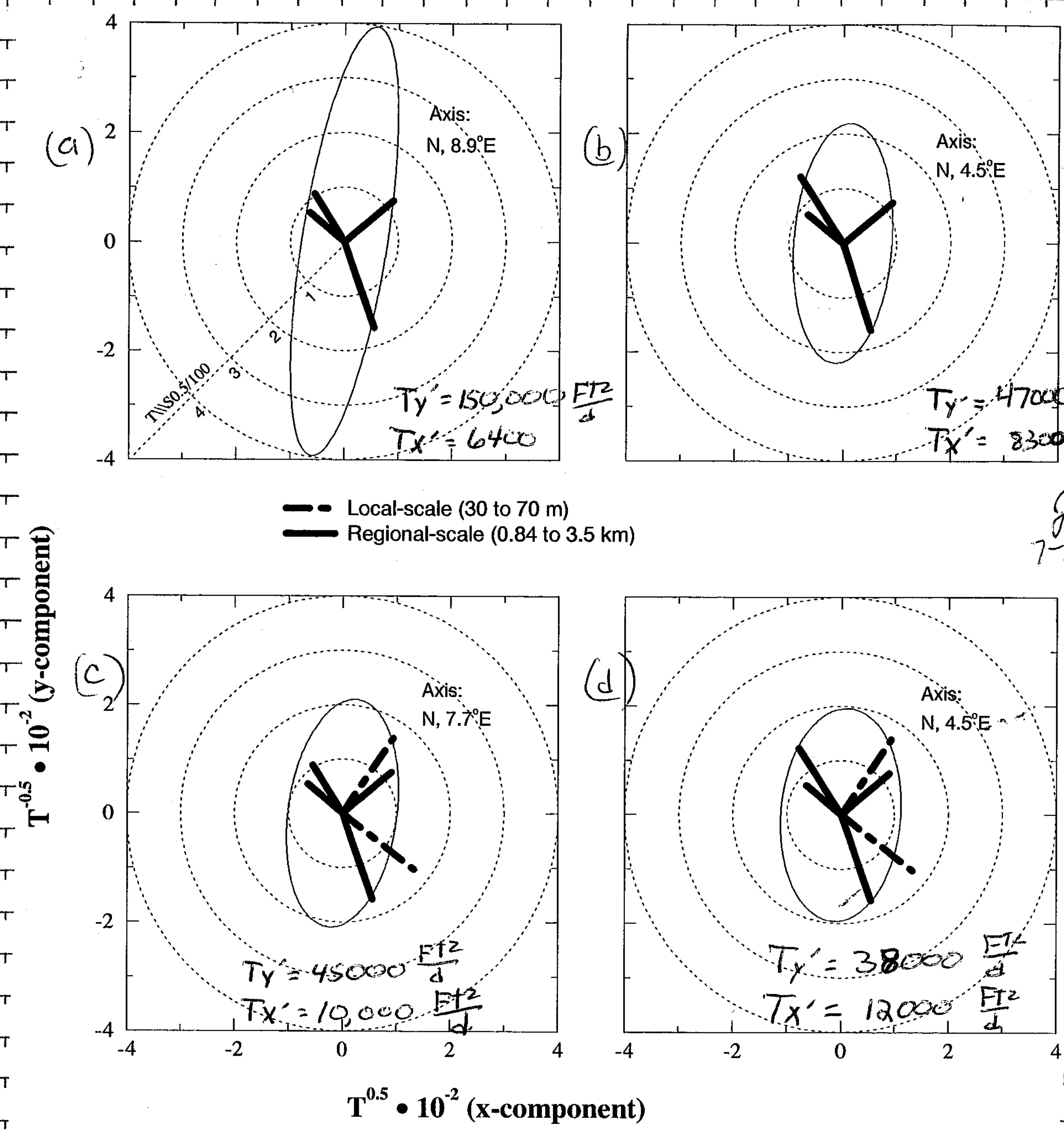
$\boxed{\theta = -4.5°}$

Plots show results on opposite page.
* Regional wells provide good fit to an ellipse, indicating that on a scale of several km a conceptual model of a homogenous continuum with horizontal anisotropy is reasonable for vicinity of c-wells.
Major axis of anisotropy is oriented between 4.5° to 8.9° NNE depending on which T-values are used. This angle is consistent with the strike of the local fault system.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	7-15-98

From Page No.____



The length of rays extending from origin represents the square-root of transmissivity (ft²/d); the angle of the rays represents the direction of the observation well with respect to the pumped well, UE-25 c#3. When the endpoints of many such rays approximate an ellipse, then the assumption of a homogenous porous medium is valid. If the ellipse is a circle (or sphere in 3-D) then the aquifer is also isotropic. Plotted transmissivity values are based on a pumping test conducted from May 9, 1996 to March 26, 1997. Plots represent: (a) transmissivity estimates of Geldon (1997) for distant observation wells (0.84 to 3.5 km from pumped well); (b) same as graph (a) with transmissivity for well ONC-1 reevaluated using Theis (1935) method, which Geldon (1997) used for all wells except ONC-1; (c) same as (a) with added transmissivity values from two local wells (30 to 70 m); and (d) same as (b) with local transmissivity values.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	7-15-98

From Page No. Analyses of Pumping Tests conducted in well c#3 & Starting w/ Single hole tests methods.

Q. Can we observe dual-Porosity behavior from derivative plots? We'll get back to that later perhaps.

8-11-98 conducted analyses of Pumping tests at C-Holes conducted from June 12-29, 1995

- Pump rate Q ≈ 355 gpm on average with about +- 2 gpm
- Well c#3 was pumped → open hole (no packers) radius of well variable, but about 1.0 ft
- well c#1 had 3 transducers in packed-off intervals in

Prow Pass @ 552.1 m depth
Upper Bullfrog @ 610.0 m
Lower Bullfrog @ 703. m
} r ≈ 95 ft (8-11-98 JRW)

only Prow Pass gave a good quality data set, the other Transducers had gaps or questionable, behavior not seen in other tests. However, from what I can tell, responses are not very different, so Prow Pass is taken to represent entire well.

- Well c# ~~1~~ 2 packed off at several intervals (JRW 10-2-98)

Calico Hills @ 519.8 m → analysed
Prow Pass @ 536.3 m
upper Bullfrog @ 610.7 m
Lower Bullfrog @ 701.6 m → analysed
Lower Bullfrog @ 796.4 m
upper Tram @ 871.6 m
} r ≈ 270 ft

Results Plotted on opposite page

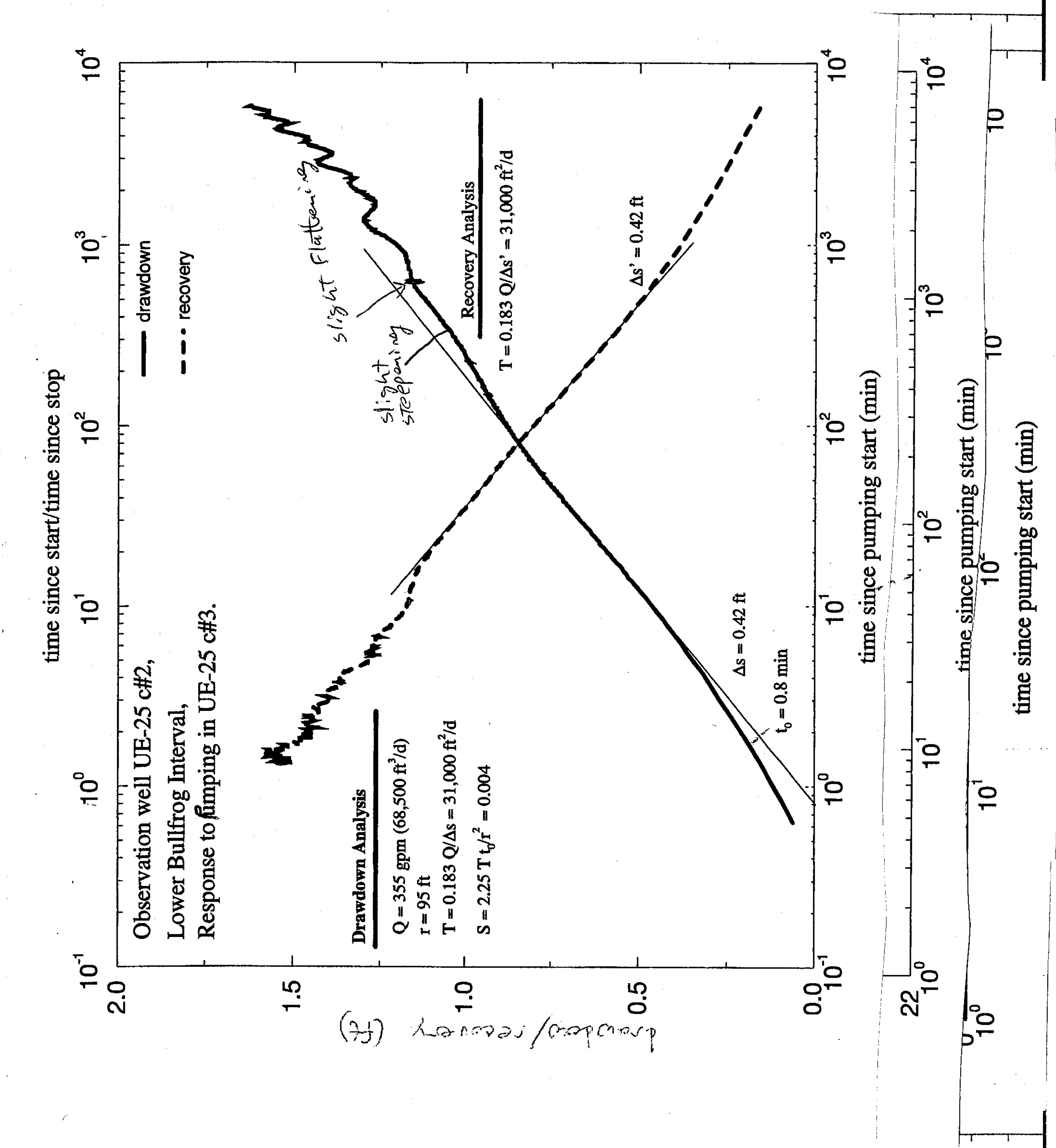
To Page No.

Witnessed & Understood by me, Date | Invented by | Recorded by [signature] | Date 8-11-98

From Page No. 3 plots, Taped to page, represent interpretation of June 12-29, 1995 Pump Test.

8-11-98 JRW

Pump-Tests/Jun12-29-95/C2_obs/C2t4-semilog.xy



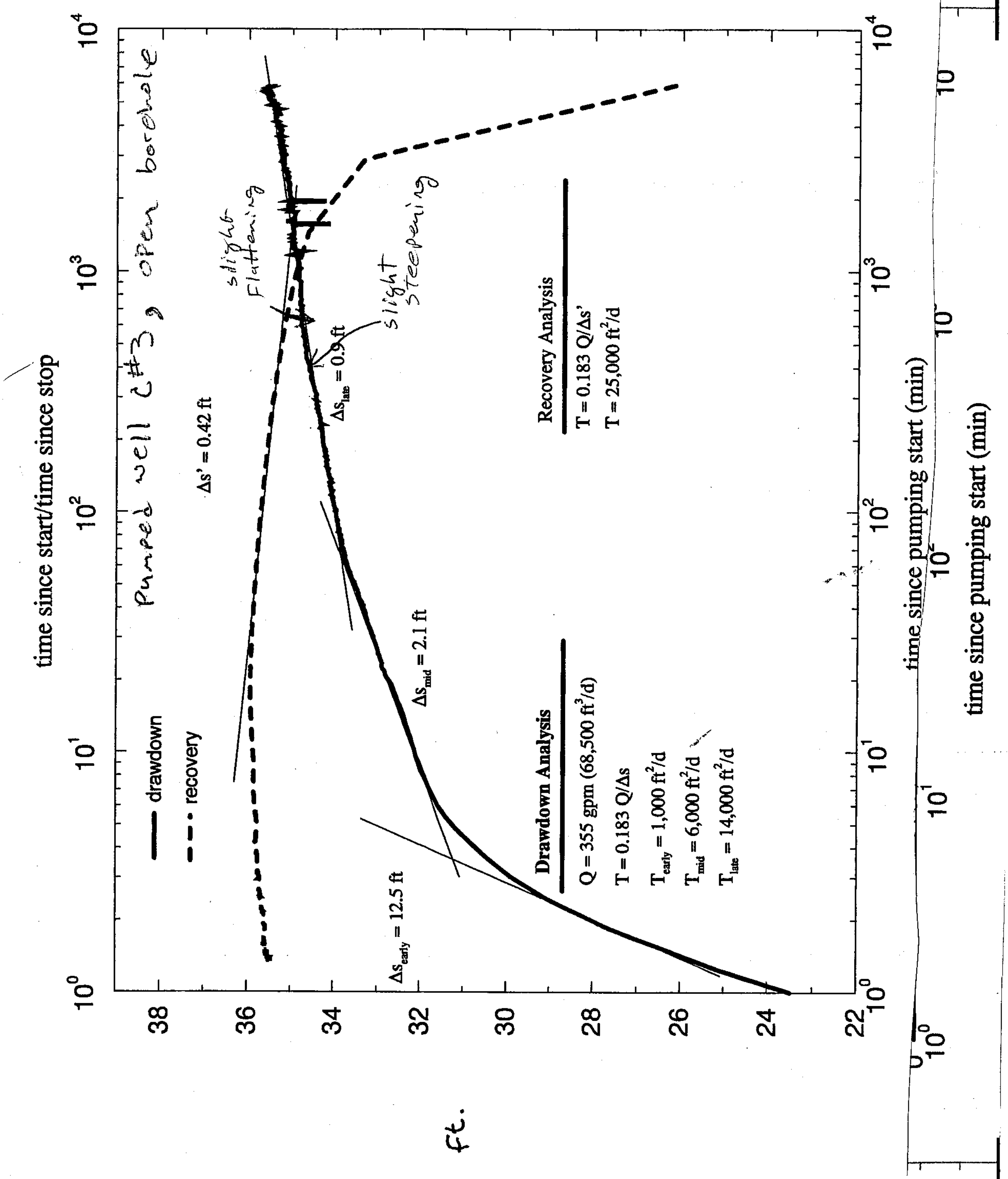
To Page No.

Witnessed & Understood by me, Date | Invented by | Recorded by [signature] | Date 8-11-98

From Page No.____

3-plots, Taped to page, represent interpretation of June 12-29, 1995 Pump Test.

JRW 8-11-98



To Page No.______

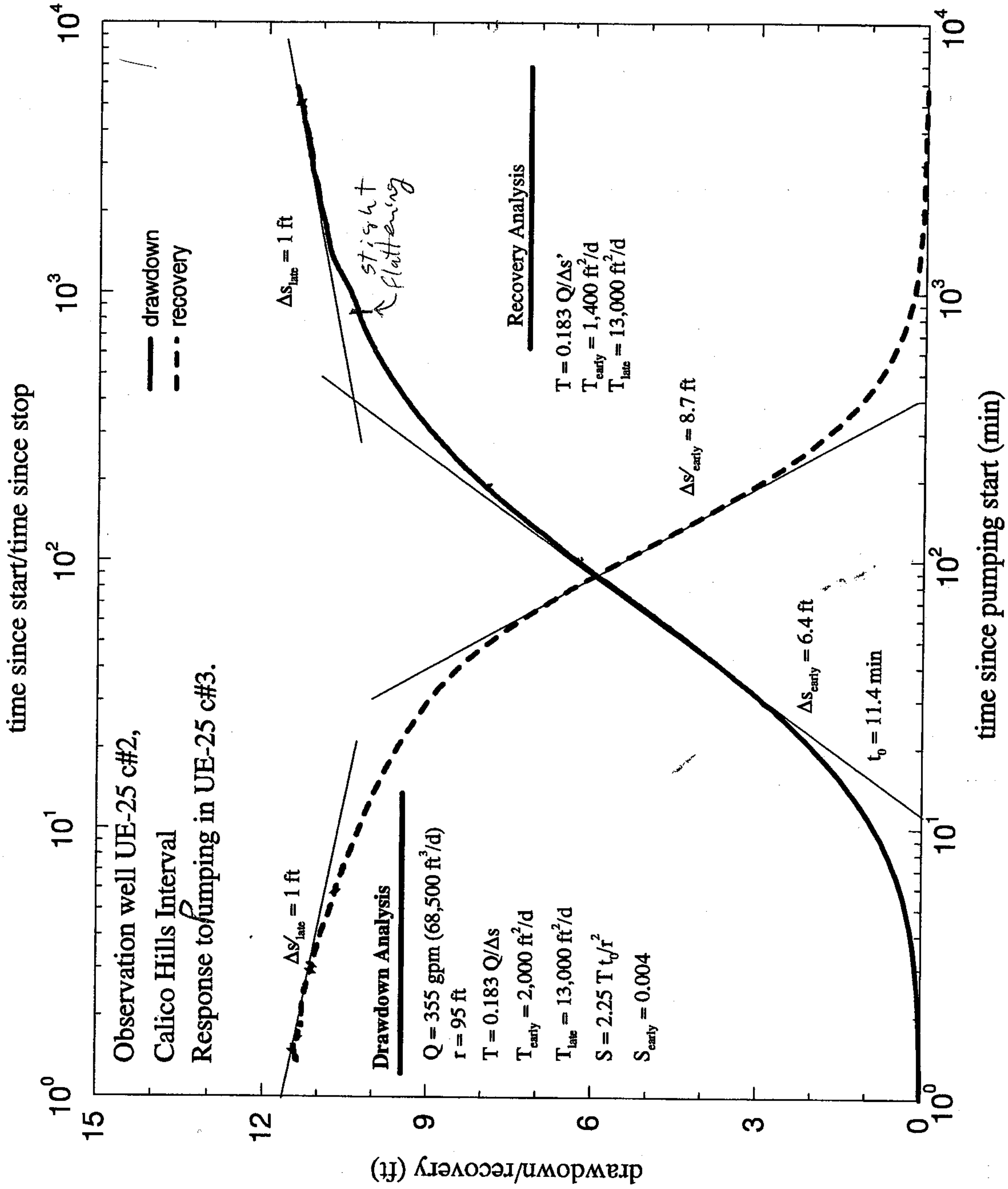
Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. R. White	8-11-98

TITLE	Project No.	Book No.	

From Page No. ___ 3 - plots, Taped to page, represent interpretation of June 12-29, 1995 Pump Test.

~~YRW 4/11/98~~

Pump-tests / June12-29_95 / C2_obs / C2&1-semilog.xvg

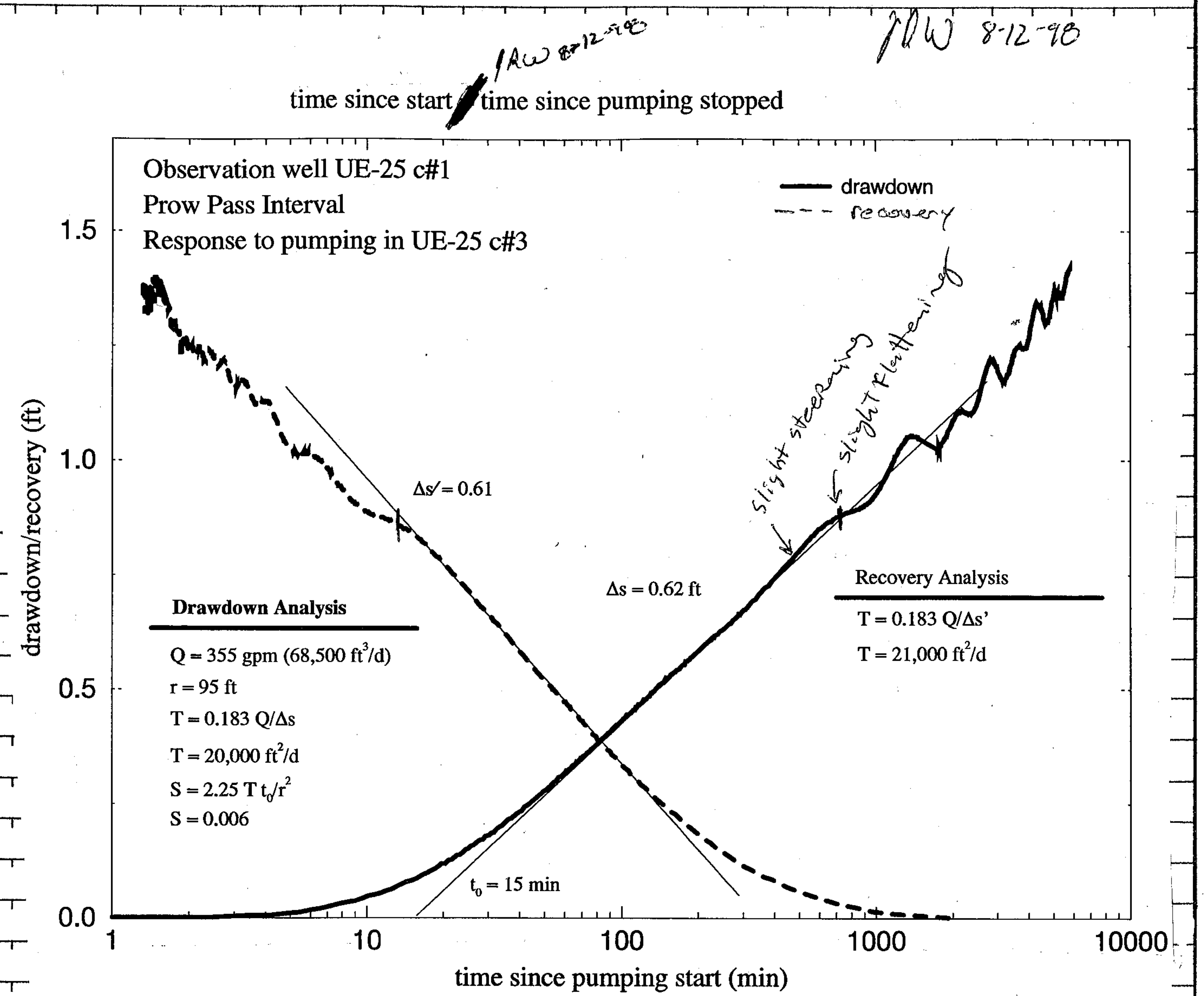


Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. R. White	8-11-98

To Page No. ___

Project No.
Book No.
TITLE 8-12-98

From Page No. More results from June 12-29, 1995 Pump Test.



note: slight steepening at ~ 400 min followed by slight flattening at ~ 700–800 min is observed on nearly all plots for other observation & pumped well. These features are likely the begining of where earth-tide effects become important.

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	8-12-98

TITLE
Project No.
Book No.

From Page No. 8-12-98 Pump test interpretation (cont'd)

- Calico Hills interval in both pumped well c#3 and obs. well c#2 show "two-limbed" response on semilog plot. This has been previously interpreted as typical of an unconfined response. Estimates of Transmissivity based on an unconfined (delayed yield) response are as follows: (for pumped well c#3)

estimate	source
T = 426 ft²/d	• pg. 30 of this notebook using Neuman Type A curve.
T = 270 ft²/d	• Gelbar (1996) using early part of Semilog plot (theis solution)
T = 300 ft²/d	• using leaky, confined sol'n of cooper 1963.

- These T-values are <u>much</u> lower than those estimated from observation wells (Factor of 100), which causes me to have reservations about this interpretation. Consider the following Regarding use of unconfined and leaky response curves
- For Neuman type curve matches, as shown on pg. 29 of this notebook, β-values of about 0.03 are used. To estimate β assume CHn interval behaves as porous medium, isotropic, homogeneous (water table is in CHn)

$$\beta = r^2 K_z / (K_r b^2) \rightarrow \text{isotropic} \rightarrow \frac{K_z}{K_r} = 1$$

$$\beta = \frac{r^2}{b^2} \approx \frac{0.5^2}{3000^2} \rightsquigarrow 10^{-8}!.$$

A value of β this low would basically result in a Theis-Type curve. For obs well c#2: $\beta \approx \frac{r^2}{b^2} \approx \left(\frac{95}{3000}\right)^2 = 0.001$ Which could be reasonable but is still pretty low and would result in later-time data being affected by delayed yield.

- If we were getting large releases from storage response at distant wells wouldn't be so fast.

To Page No.

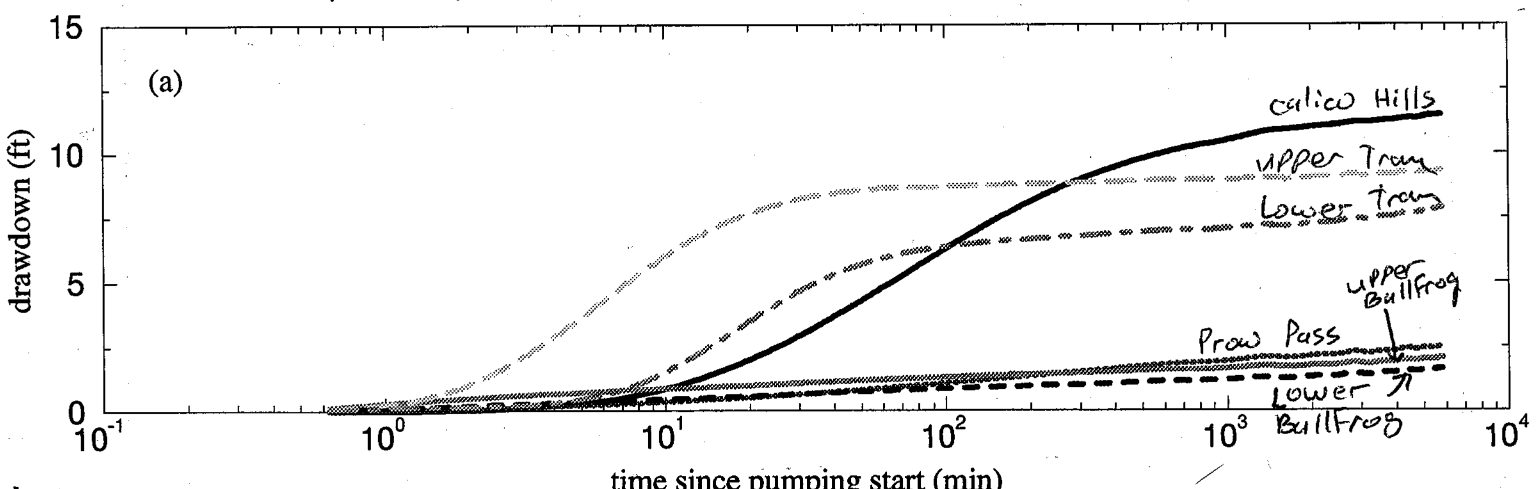
Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	8-13-98

From Page No.____ 8-13-98 C-well Pumptest of June 12-29, 1995.

- leaky aquifers could cause results seen at C-holes (i.e., dual-limbed semilog response).
- However, rather than leaky aquifer consider underlying high transmissive zones as a recharge boundary of sorts. Then, rather than estimating T for calico hills only from early time, the flattend limb of semilog curve may reflect Transmissivity of "outer" - transmissive zones.
- This is supported by C#2 observations that show 2-limb semilog plot on calico hills interval, but "ideal" behaviour in Bullfrog interval. It takes awhile for drawdown in calico Hills to be affected by Bullfrog, but eventually it is.
- Furthermore - the slopes of the semilog plot lines approach similar values for all of the drawdown curves for ~~fig~~ well C#2 (see below)

JRW 8-18-98

/Jun12-29-95/C2_obs/c2-ddn-rev-all.xvg



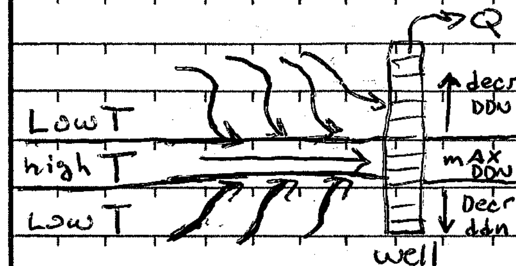
Q: What sort of vertical flow do we expect from layering where drawdown is much less in some layers than in others?

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J R Winterle	8-18-98

From Page No.____ 8-18-98

If the transmissive fracture network (where drawdown in C#2 is less) were connected to the pumped well we would expect max drawdown to be felt in the transmissive intervals, with flow from less transmissive intervals going toward more transmissive as shown below. This would require lower drawdown in less transmissive intervals. However, in fig on pg 40, lowest drawdown occurs in welded-fractured rock. Also, during the May, 1995 pump test, the same well were used w/o packers, and it seems the drawdown in well C#2 was dominated by the



JRW 8-18-98 "Low drawdown [illegible] intervals", suggesting that is where the water comes from.

8-19-98

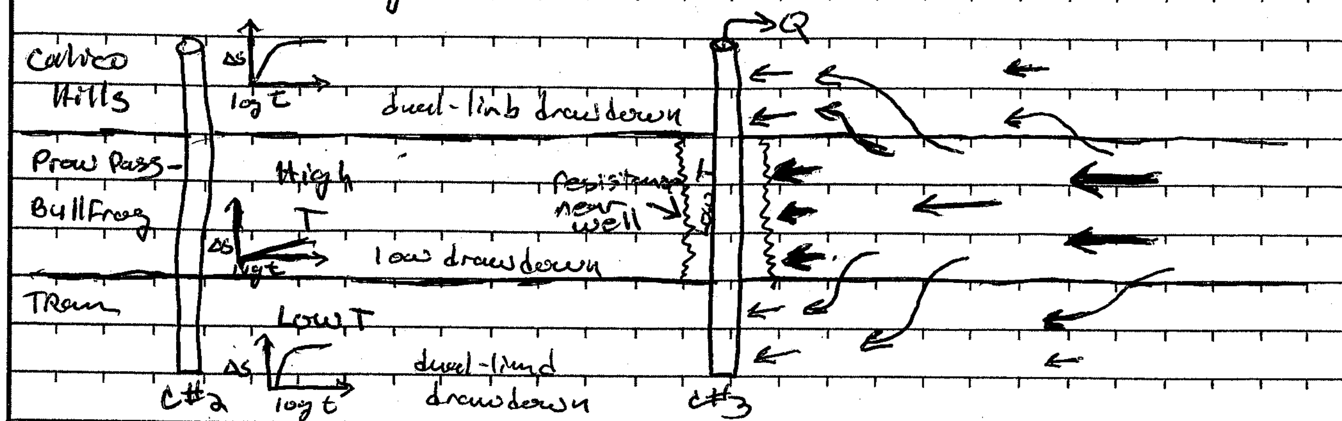
- What I think is happening:
  - Where fractures intersect well (High T zone) the "ramming effect" (Winograd & Thordarsson, 1975) creates a ~~high~~ large head drop in the high T layer that dissipates very rapidly away from the well. JRW 8-19-98
  - This large head drop is "felt" through the entire well casing (ie, no packers) and transmitted to the "Low T" layers where flow is mainly through matrix.
  - Thus the large drawdown is transmitted away from the wells in these Low T layers.
  - now we have a situation where horizontal layers are at different head potentials
  - we already know from (Geldon et al 1997) that horiz. layers are not hydraulically isolated (ie, leaky)
  - Thus pumping in un-packed C#3 induces vertical flow from High-T zone to Low T zones ⟶ cont'd

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J R Winterle	8-19-98

From Page No.____ 8-21-98

- If the "ramming effect" causes the high T zone to behave like a low T zone only very close to the well then we can conceptualize the effects as drawn below:



- Some might argue that large initial head drop is due to turbulent flow - But this effect seems to prevail at low as well as high pump rates. (Winograd & Thordarson, 1975, give a good discussion of Ramming effect on page C-21 of ~~OFR~~ Professional Papers 712-C, USGS)

8-24-98

- the above explanation explains the observation of dual-limbed behavior in single well pump tests and in the "matrix flow" layers in observation wells

9-1-98

Looking at Report from USGS testing of UE25b#1

- Fit Neuman 1975 Type curves to Data from observation well UE25-a#1

TypA match point (31 min, 0.61 m) for $\beta = 0.2$

$$s = \frac{Q}{4\pi T} W(u_a, u_b, \beta) = 0.61 = \frac{35.7\ L/s}{4\pi T} \cdot 1$$

$\boxed{T = 400\ \frac{m^2}{d}}$ $\beta = 0.4$

To Page No.______

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by [signature] | 9-1-98

From Page No.____ $r = 107\ m$

$$1/S_A = \frac{r^2}{4T\, u_a \cdot t} = \frac{(107)^2}{4 \cdot 400 \cdot 1 \cdot 31/1440)}$$

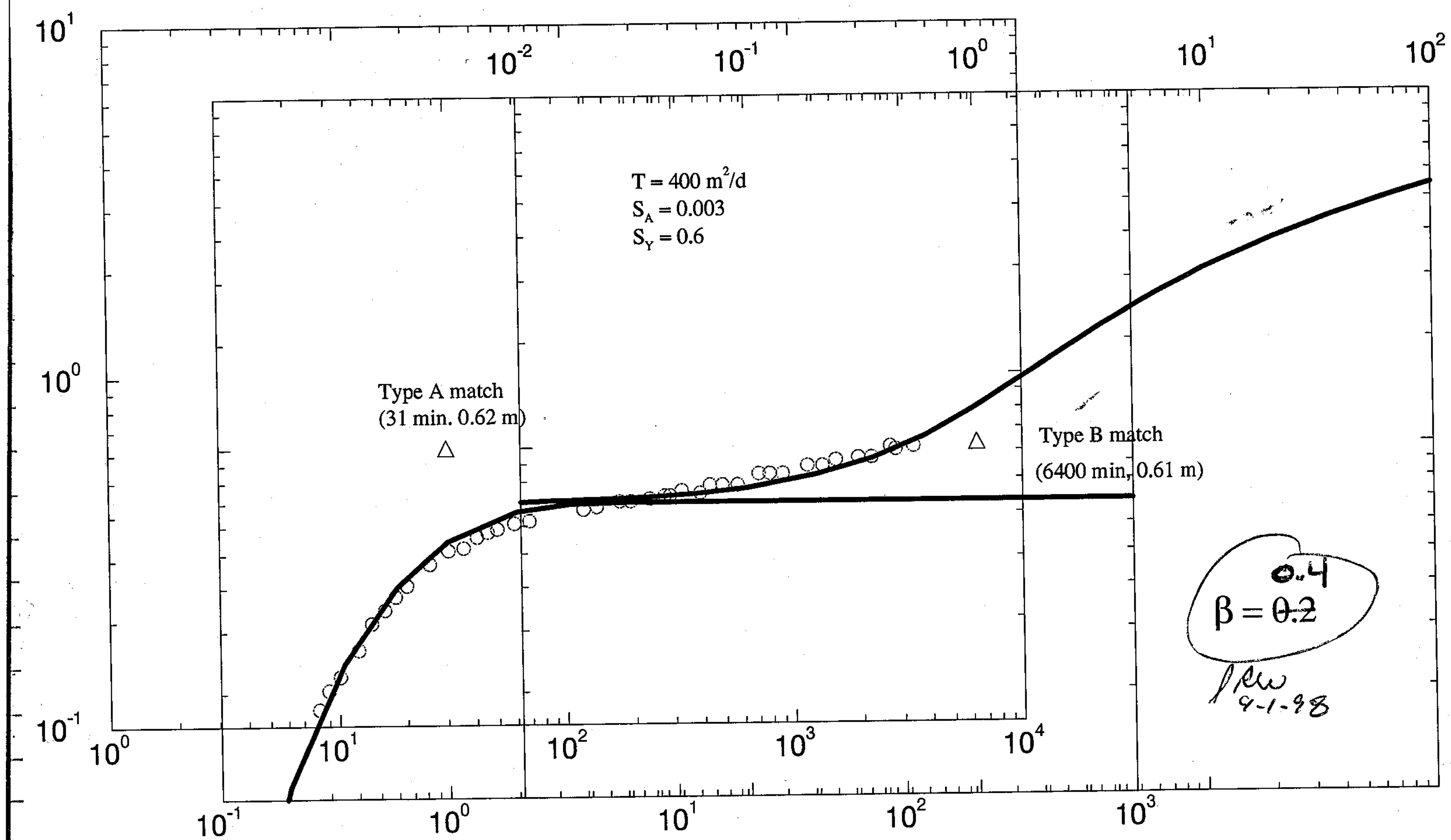
$\boxed{S_A = 0.003}$

Type B match point (6359 min, 0.61 m) $\beta = 0.4$

$$S_y = \frac{4Tt}{r^2 u_B} = \frac{4 \cdot 400 \cdot 6359}{(107)^2 \cdot 1 \cdot 1440}$$

$S_y = 0.62 \rightarrow$ very high!

JRW 9-1-98



To Page No.______

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by [signature] | 9-1-98

Project No._______
Book No._______ TITLE_______

From Page No.___ 9-1-98 UE25b#1 interpretation

for match to $\beta = 0.2$ type curve

$\boxed{T = 650\ \frac{m^2}{d}}$

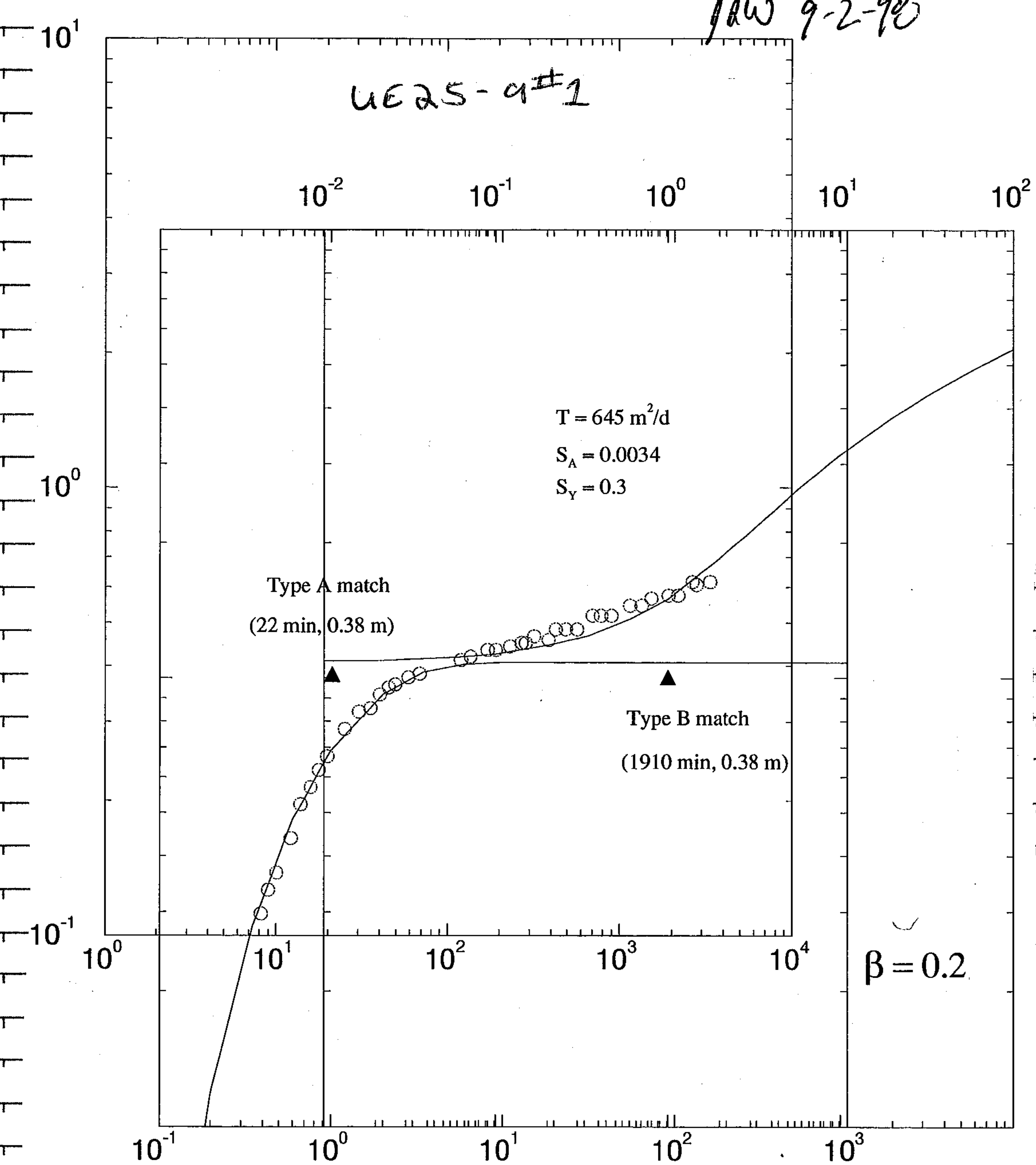
Type A match (22 min, 0.38 m)

Type B match (1910 min, 0.38 m)

$S_A = 0.0034$

$S_y = 0.3$ → still a tad high!

JRW 9-2-98



To Page No._______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	9-2-98

TITLE_______
Project No._______
Book No._______

From Page No.___ 9-2-98 still interpreting UE-25 b#1

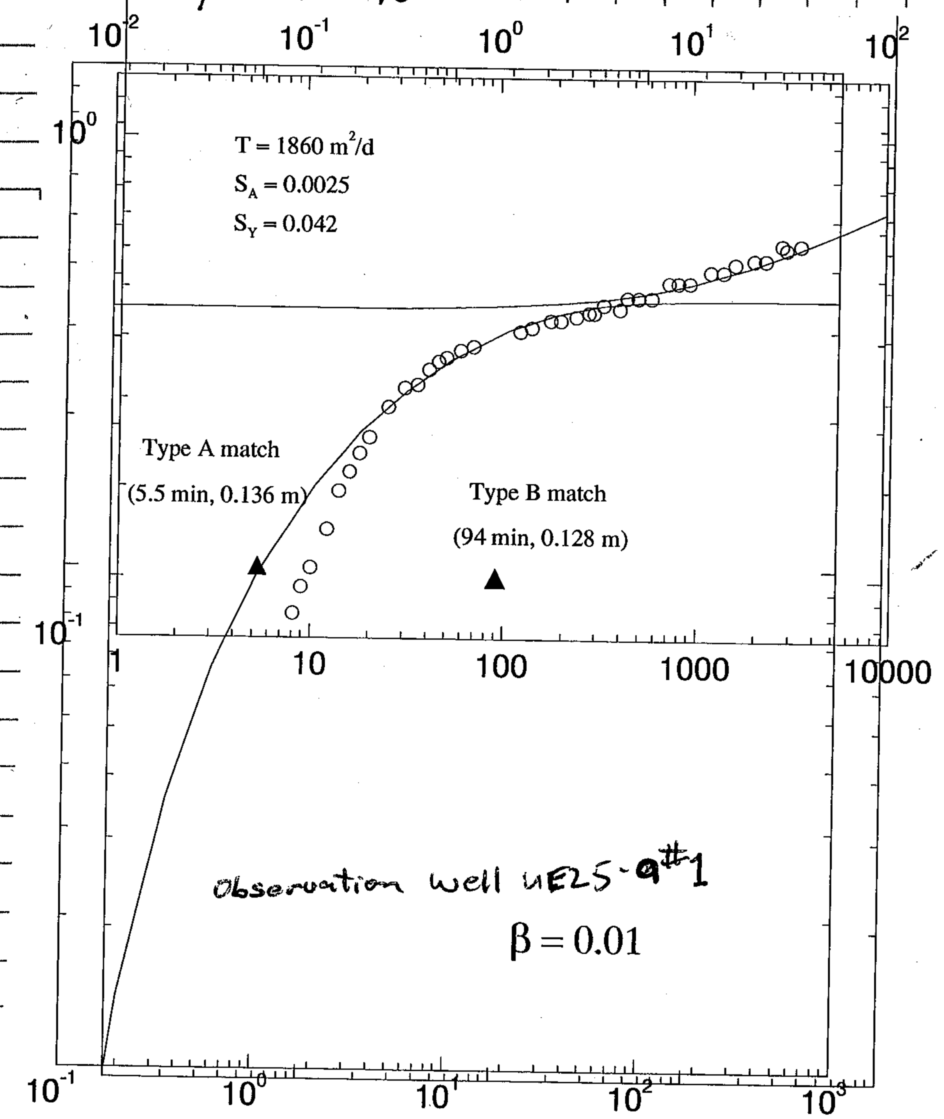
Pump test #3. Lets try data fit to late-time first (Type B curve), Then fit type A:

$T = \frac{Q}{4\pi s} = \boxed{1860\ \frac{m^2}{d}}$

$S_A = 0.0025$

$S_y = 0.042$ → (more in line w/ S_y for unconf. aquifer)

JRW 9-2-98



$K_v = \frac{\beta b^2 K_h}{r^2}$

$= \frac{\beta T \cdot b}{r^2}$

$= \frac{0.01 \cdot 1860 \cdot 749}{(107)^2}$

$\boxed{K_v = 1.2\ \frac{m}{d}}$

$K_H = \frac{T}{b}$

$\boxed{K_H = 2.5\ \frac{m}{d}}$

Note:
I like that K_H and K_v are of same order of magnitude!

To Page No._______

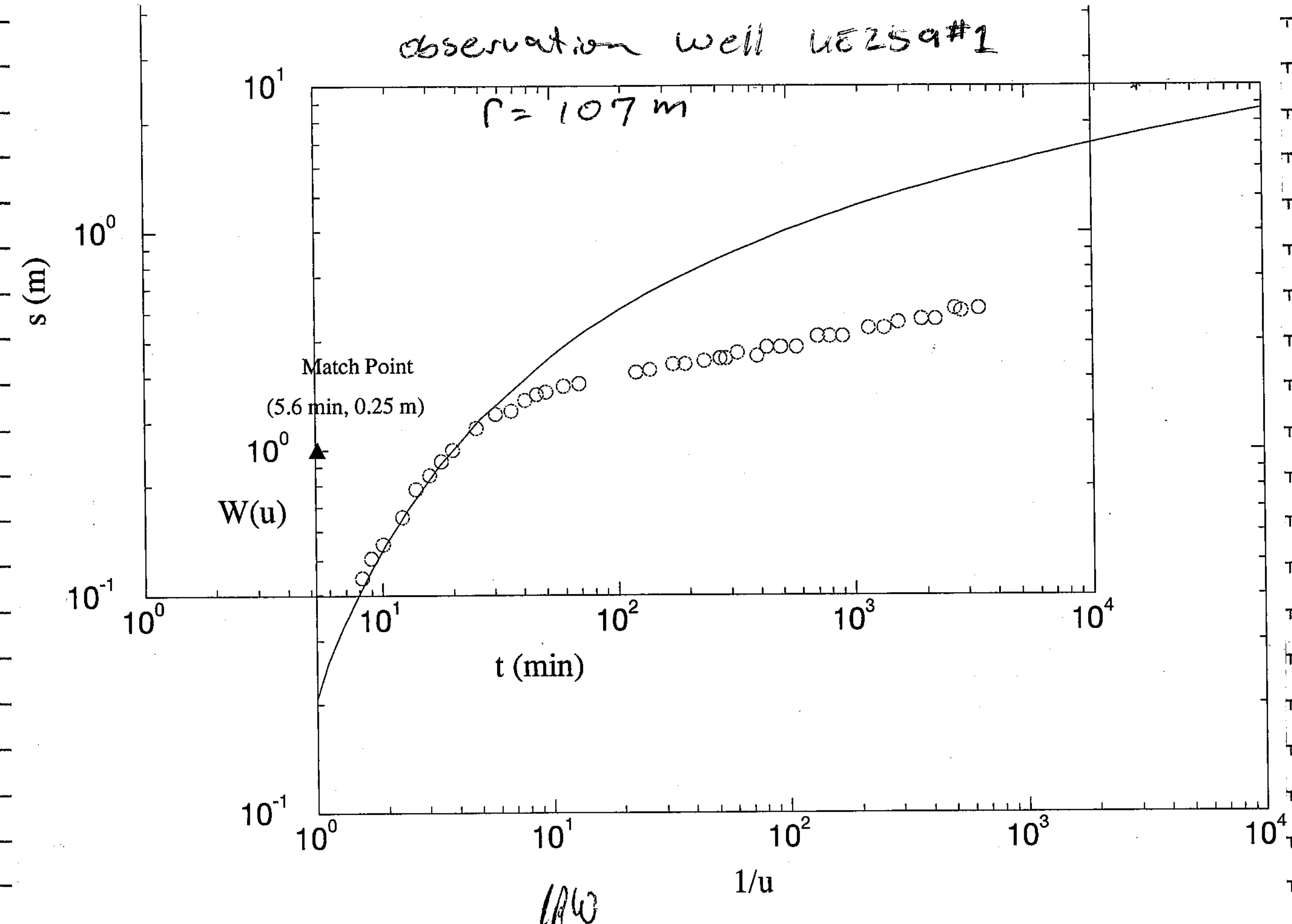
Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	9-2-98

From Page No.____ UE-25b#1 analysis.

Theis-curve fit to early-time data gives Transmissivity value of: (match point: 5.6 min, 0.25 m)

$T = \frac{1}{4\pi}\frac{Q}{s}W(u) = \boxed{981 \frac{m^2}{d}}$ obs. well → r = 107 m

$S = \frac{u4Tt}{r^2} = 0.0013$



This is not an estimate of transmissivity that I would use, but could be an upper-end estimate.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	9-2-98

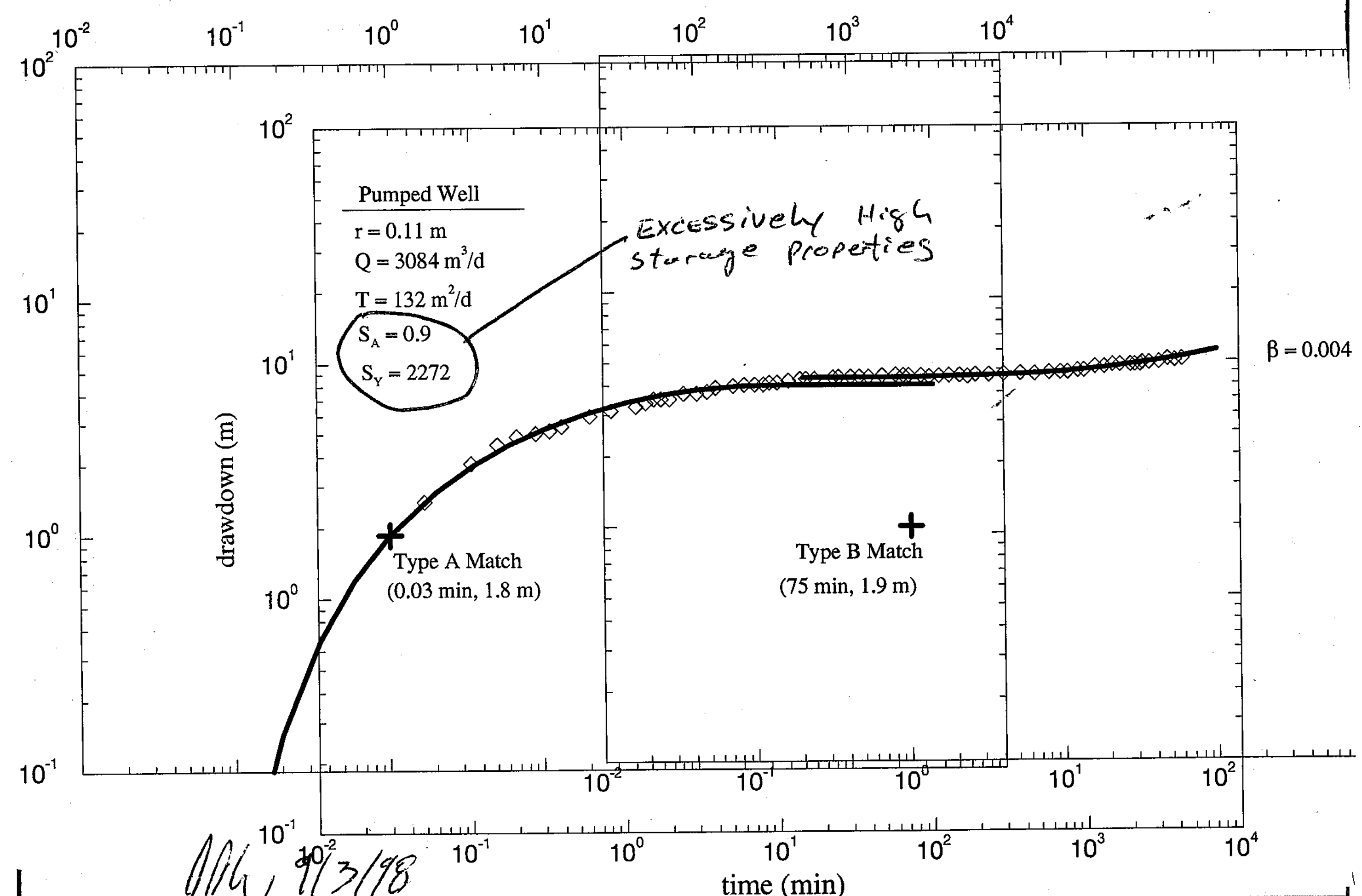
From Page No.____ 9-3-98

Neuman Type curve fit to UE25b#1 (shown below) yields a good fit, but the Specific yield estimate is completely unrealistic! overall, based on inconsistency between a#1 and b#1 results I'd say Neuman method is not appropriate.

MOENCH - (1984) WRR 20(7) used double porosity to fit both wells simultaneously.

$T = 350\ m^2/d$ $S' = 0.12$ (matrix)
$S = 0.0006$ (Fractures)

Nueman (1975) type curves for unconfined response fit to pump test data for Pump Test 3 in well UE-25b#1



9/3/98

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	9-3-98

From Page No.___ Evaluation of Anisotropy from C-wells

Well ID	Trans (Te)	$T_d(\theta)/S$	Notes
ONC 1	1960 m²/d	845,244	see pg 31 of notes
WT#3	2600 m²/d	1,300,000	Geldon
WT#14	1300 m²/d	650,000	
H-4	650 m²/d	325,000	H4 may be low due to ~~boundary~~ of Fault.

Ellipses should be plotted as $(T_d/S)^{1/2}$, however, those shown on pg 35 of these notes were plotted using only Te. Now I go back and estimate approx Td for each well, assuming constant S

9-29-98 Re interpret Long-term pump test data: Using method of Papadopulous (1965)

Well ONC 1 - from pg 31 of notes.

$$\boxed{T_e = 1960\ \frac{m^2}{d} \qquad \sqrt{T/S} = 920\sqrt{\frac{m^2}{d}}}$$

Well USW H-4 - from curve match on following pg.

match pt = 1145 min (0.795 day), 0.046 m

$$T_e = \frac{1}{4\pi}\frac{Q}{s^*}W(u) = \frac{823\ \frac{m^3}{d}}{4\pi\ 0.046}\cdot 1.0$$

$$\boxed{T_e = 1423\ \frac{m^2}{d}}$$

$$\frac{T_d(\theta)}{S} = \frac{r^2}{4t^*}\frac{1}{u} = \frac{(2245\ m)^2}{0.795\ d} = \frac{6.34\times10^6}{2.2}$$

correction: JRW 9-30-98

$$\sqrt{T/S} = \frac{\cancel{2520}}{2}\ \frac{m}{\sqrt{d}} = 1260$$

UE25 - WT#14 see match on pg 50: r = 2249 m

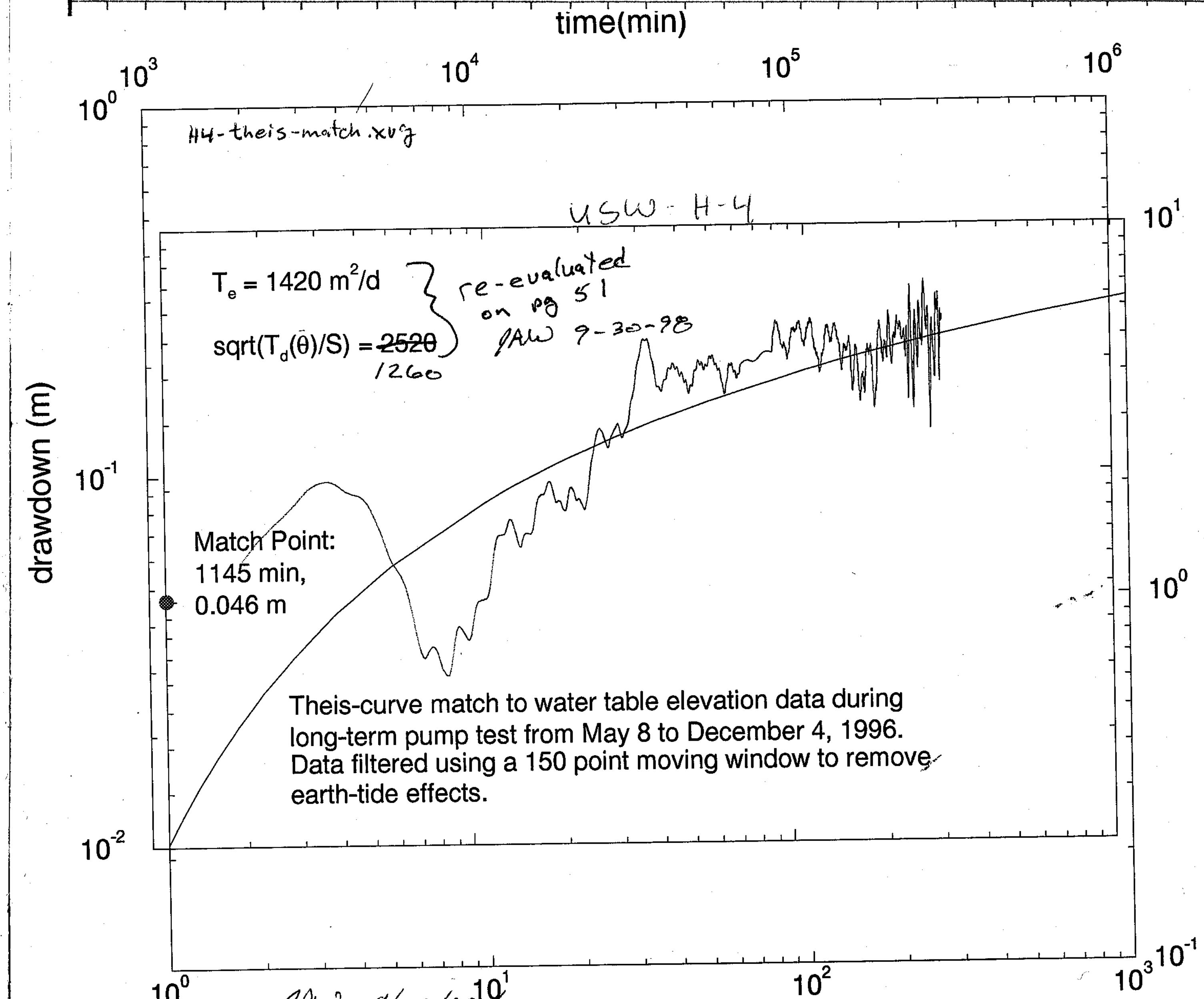
match point = 1300 min (0.90 d); 0.043 m from transparency

$$\boxed{T_e = 1500\ \frac{m^2}{d} \qquad \sqrt{T_d(\theta)/S} = \cancel{2370}\ 1185\ \frac{m}{d^{0.5}}}$$

To Page No.___

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. R. Whitney	9-29-98

From Page No.___ 9-29-98



JRW 9/29/98

UE 25 - WT#3 - see pg 51

To Page No.___

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. R. Whitney	9-29-98

From Page No. 9-29-98

Interpretation of WT#14 during longterm pumptest

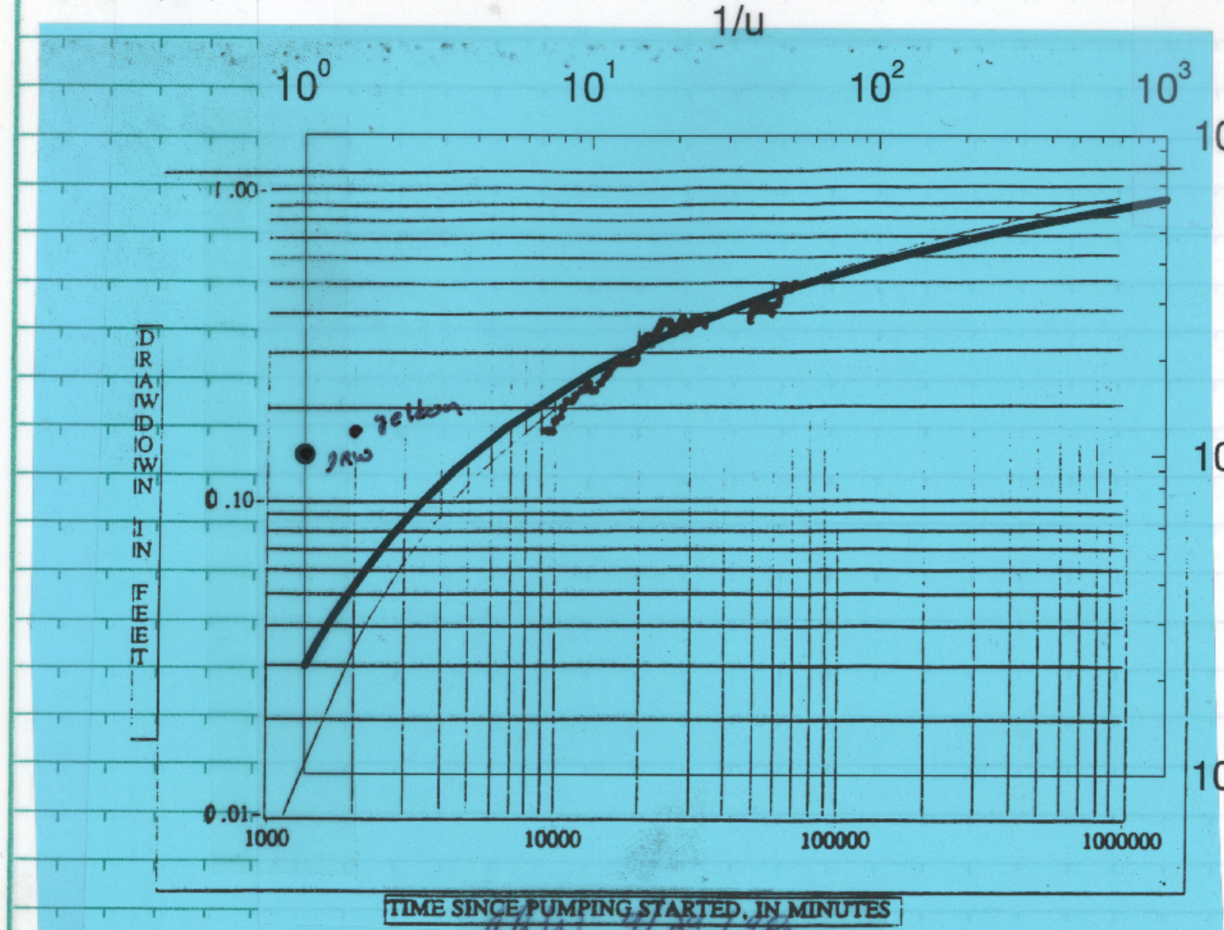
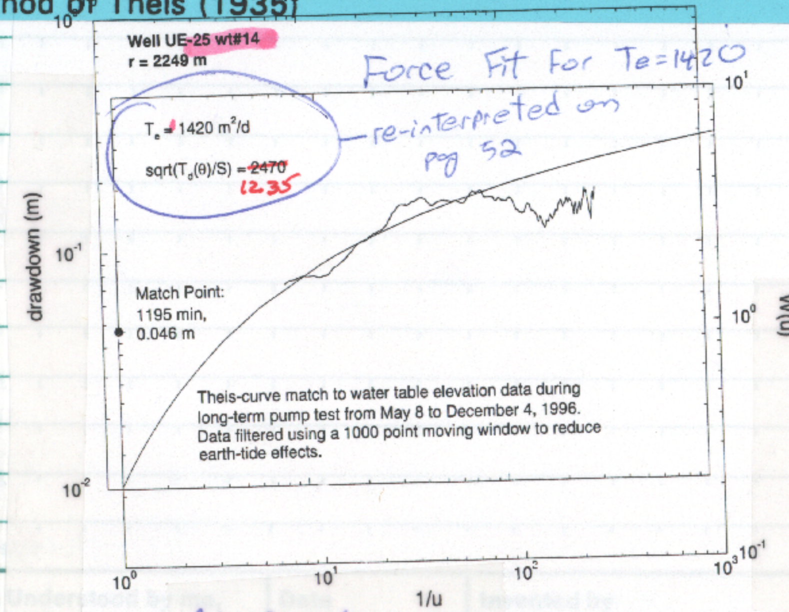
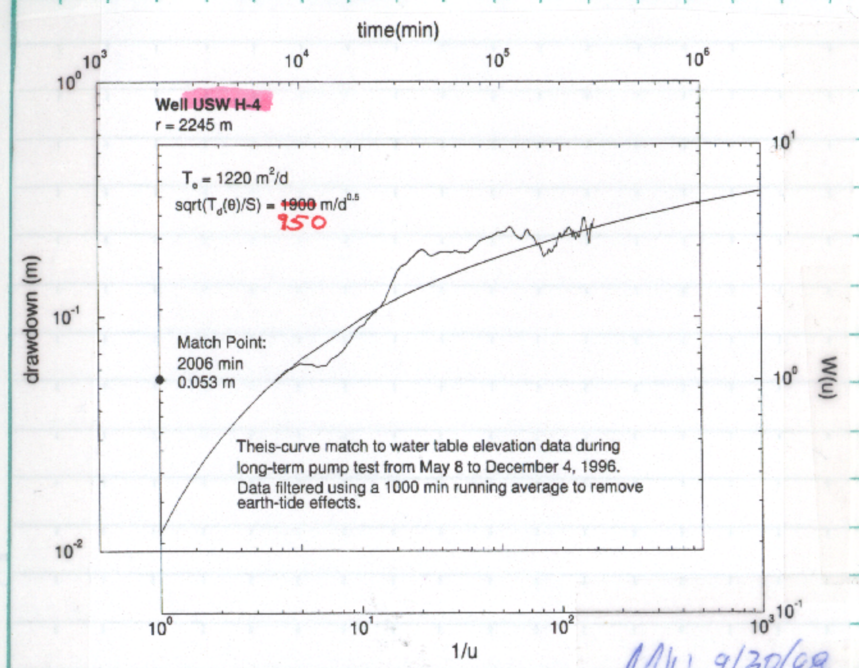


Figure 34 - Analysis of drawdown in UE-25 WT#14, May 8 to June 27, 1996 by the method of Theis (1935)

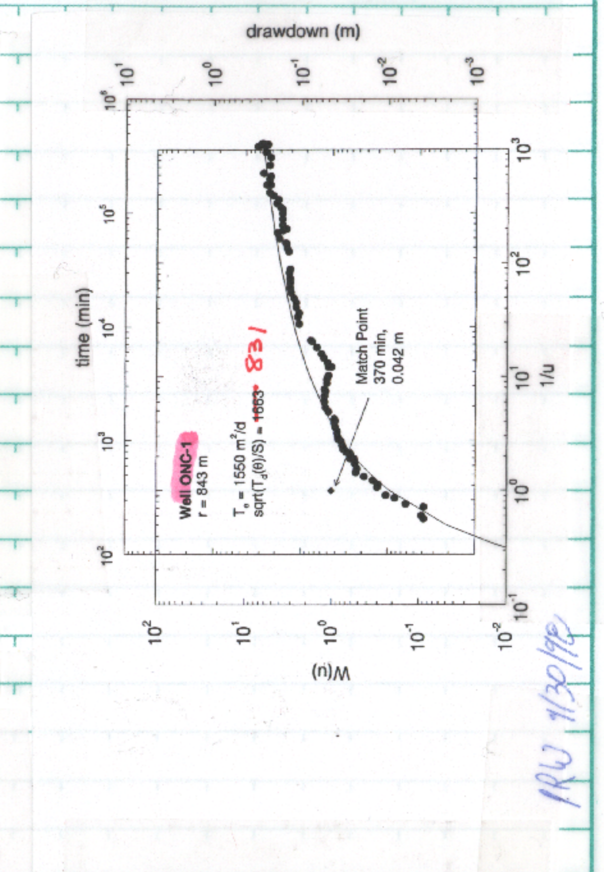
JRW 9/29/98



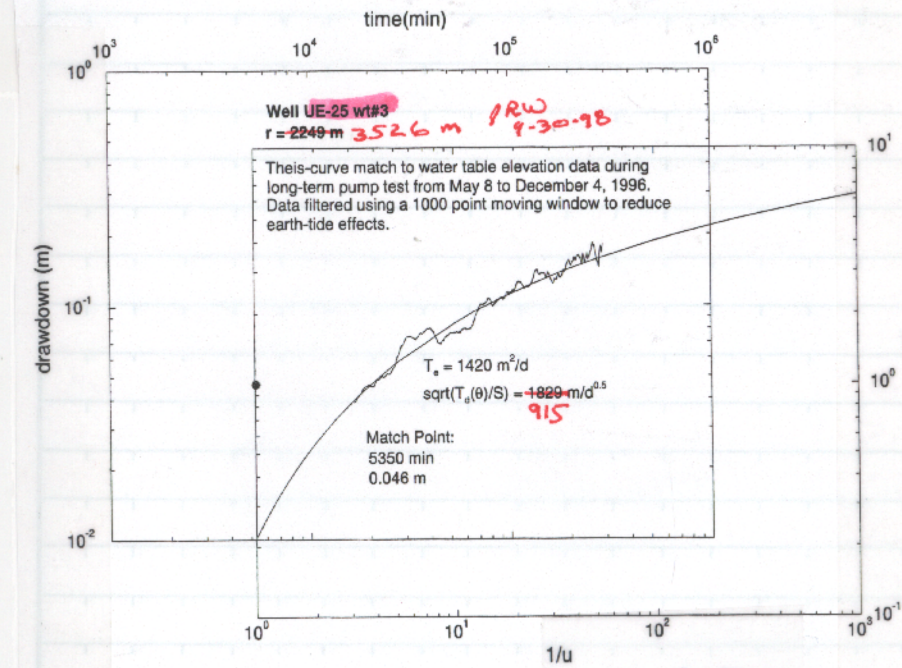
From Page No.



JRW 9/30/98



JRW 9/30/98



9/30/98 JRW

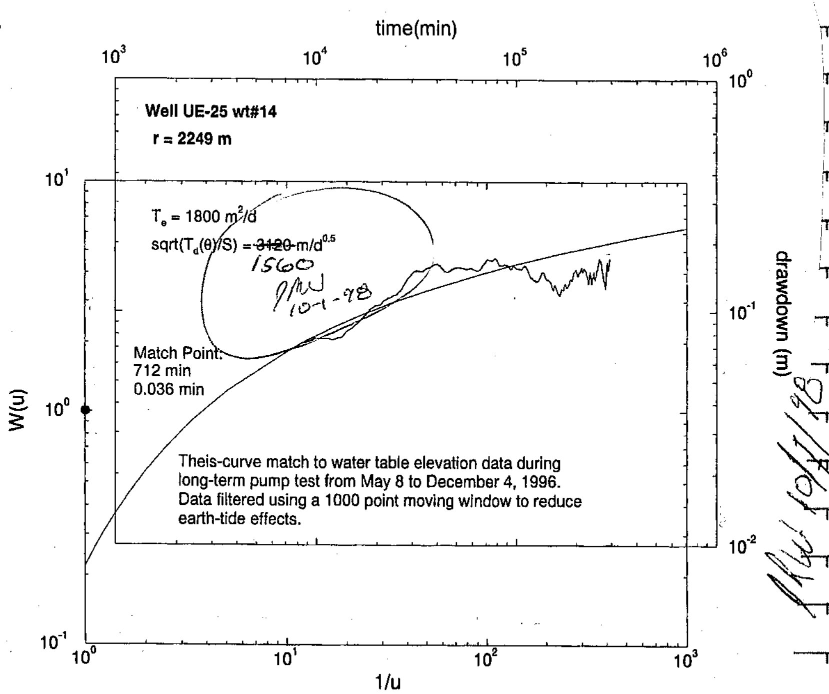
These Theis-fits (on this pg) are all off by factor of 2 on estimate of $\sqrt{T_d(\theta)/S}$; corrected values shown in red

JRW 9-30-97

Well	r	θ	Te	$\sqrt{T_d(\theta)/S}$
ONC1	843		1550 $\frac{m^2}{d}$	1660 $\frac{m}{d^{0.5}}$
H-4	~~1220~~ 2245		~~1900~~ 1220	1900
WT3	~~2249~~ 3526		1420	1829
WT14	2249		1500	2370 ? Fit Geldon's data

JRW 9/30/98

From Page No.____



O.K. - now after all this type-curve confusion, lets see what we have. We basically did two sets of analyses: a set of fits where Te was forced to be as close as possible to $1420 \frac{m^2}{d}$; and a set where this restriction was relaxed. Tables below summarize results

1. Forced Fits to $T_e \approx 1420 \frac{m^2}{d}$

well	Te	$\sqrt{T/S}$	θ from North	
ONC1	1550 $\frac{m^2}{d}$	831	327.5°	
H-4	1420	1260	~~320.0°~~ 310.0°	JRW 10-1-98
WT14	1420	1235	~~40.0°~~ 50.0°	JRW 10-1-98
✱ WT3	1420	915	160.67	
Best Fit to individual wells				
2. ONC1	1960	920	327.5°	
H4	1220	950	310.°	
WT14	1800	1560	50°	
✱ WT3	1420	915	161°	

✱ Need to check location of WT #3 ✓ good

To Page No.____

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	10-1-98

From Page No.____ 10-1-98

Used PEST code to obtain best fit of ellipse to $\sqrt{T/S}$ data from "Best Fit" data.

- After multiplying $\sqrt{T/S}$ by 10^{-3}, ellipse parameters are

$$\left.\begin{aligned} A &= 0.7480 \\ B &= -0.4125 \\ C &= 0.9812 \end{aligned}\right\} \quad ax^2 + bxy + cy^2 = 1$$

- To find rotation of ellipse axis from principle coordinate system (N-S = y; E-W = x)

$$\cot 2\theta = \frac{A-C}{B} = 0.5653 \longrightarrow \theta = 30°$$

- Rotation of major axis from North $\boxed{(\alpha) = 60°}$

✱ Calculate Storativity

$$\hat{T_e} = \sqrt[4]{T_{ONC1} \cdot T_{H4} \cdot T_{WT3} \cdot T_{WT14}}$$

$$\hat{T_e} = 1570 \frac{m^2}{d}$$

$$\frac{T_e}{S} = \sqrt{\frac{T_{major}}{S}} \cdot \sqrt{\frac{T_{minor}}{S}}$$

where T_{major} and T_{minor} are max & min Trasmissivity.

$$\sqrt{\frac{T_{major}}{S}} = \cancel{1750}\ \cancel{2200} = 1260$$ JRW 10-1-98

$$\sqrt{\frac{T}{S}}^{minor} = 960$$

$$S = \frac{T_e}{\sqrt{maj}\sqrt{min}} = \boxed{0.0013}$$

To Page No.____

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	10/1/98

From Page No.___ 10/19/98 Correct well data for atmos pressure variations.

Awk script used to process raw wsl data

```
#! /bin/sh
# nawk script to filter atmospheric signal from water level data
# by Jim Winterle, 10/19/98
# Usage: cnvt.sh arg1 arg2 arg3 arg4
#   arg1 is file with raw water level data
#   arg 3 is weighting factor for atmo signal
#   arg3 is  mean value for atmo signal
#   arg4 is offset used to plot atmos signal on same scale as wsl
# Example: cnvt.sh wt14.raw 0.5 12.85 729.5

echo $2 $3 $4 > temp1
cat temp1 $1 atmo.dat > temp

nawk '
 BEGIN { i=1; j=1}
 NR==1 {factor=$1; const=$2; offset=$3}
 /\#begin-data/, /\#end-data/  {
if($0 !~ /\#/){ t[i]=$1; h[i]=$2; i++}
}
 /\#begin-atmo/, /\#end-atmo/  {
  if($0 !~ /\#/ && $1>=t[j] && $1<=t[i-1]){
  print t[j],h[j],(h[j]+(($2-const)*factor)~~+offset~~)~~/2~~,$2-const+offset; j++
              }
}' < temp > $1.out
 xvgr -nxy -param correct.parms $1.out &
 rm temp temp1
```

JRW 10/19/98

correction JRW 10-19-98

Raw data files, xvgr files (plots) and .out files are in directory "jwinterle/cwells/Pump-Tests/LTPT/Atmo correct" and associated subdirectories

On facing page, shows plot of a portion of corrected data for wt#14.

Similar plots were made for wells H-4 and WT#3. Next step is to convert to Time-drawdown plots.

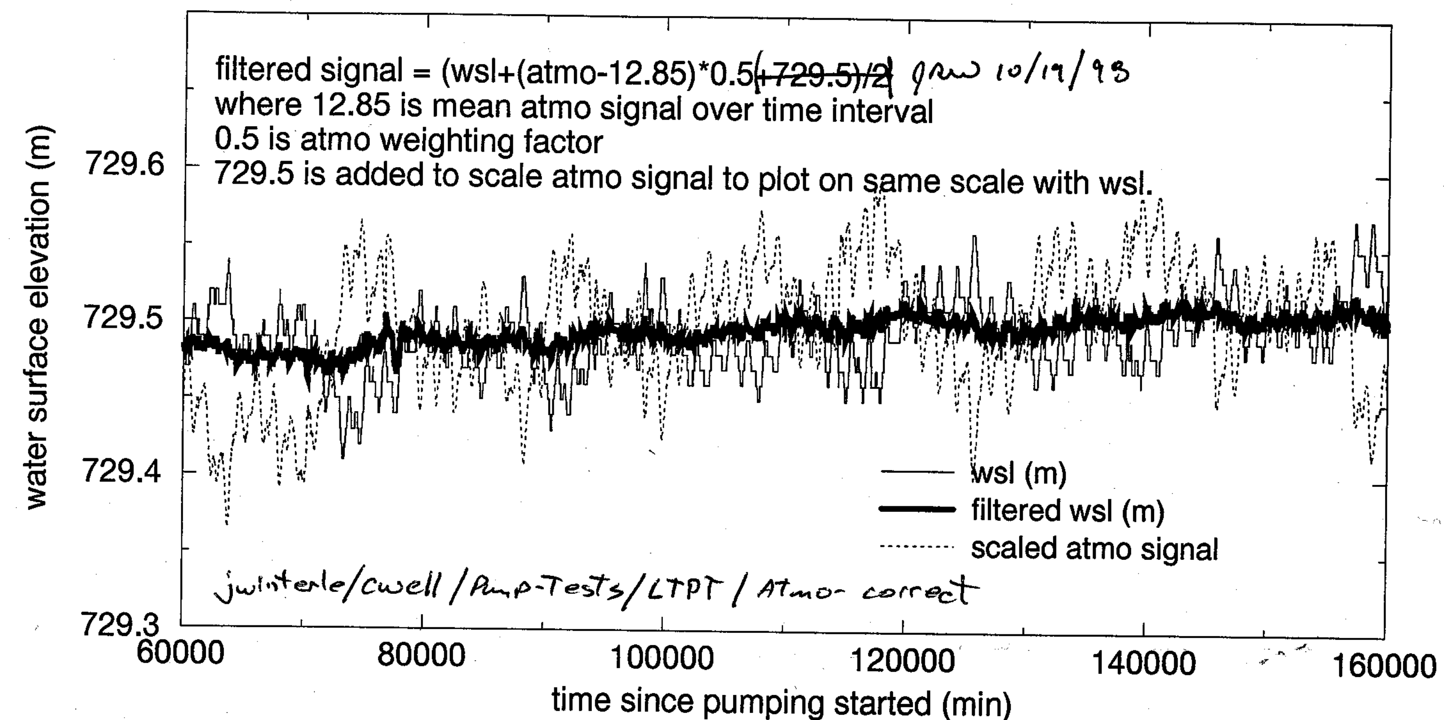
To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	10/19/98

From Page No.___ 10/19/98

JRW 10/19/98

Water level data filtered to remove atmospheric signal
for well UE-25 wt#14



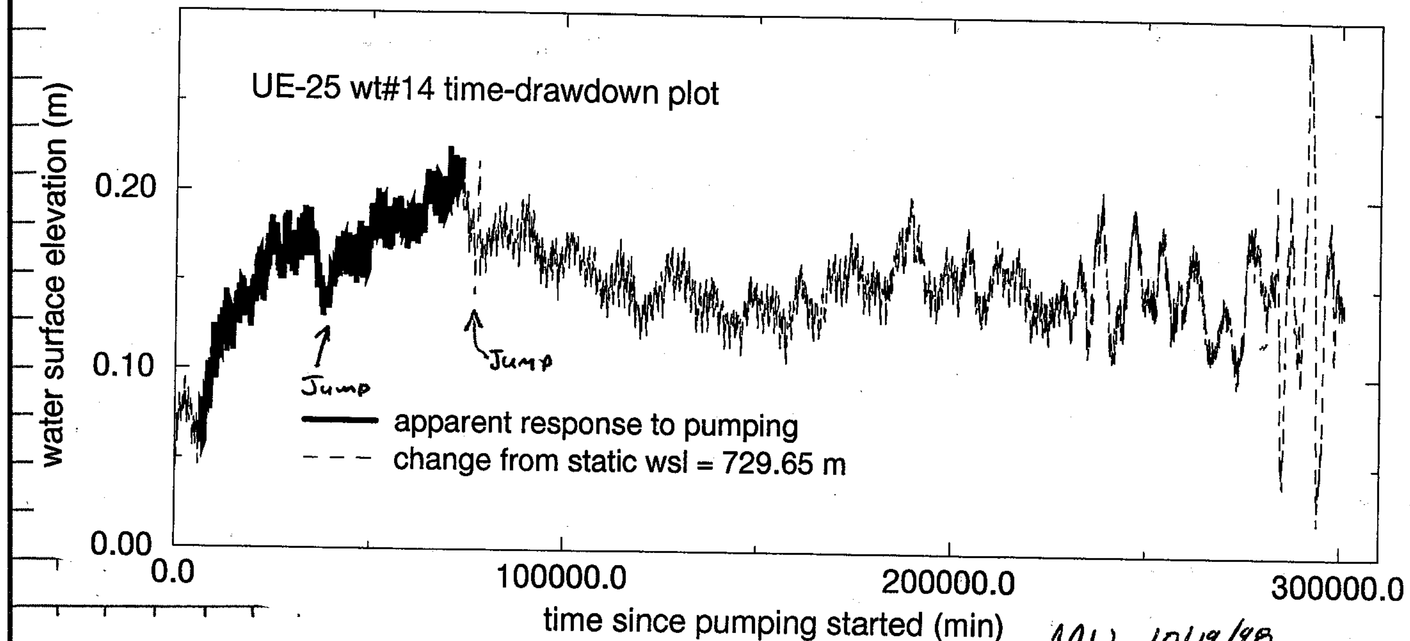
After filtering to remove atmo, data are converted to time-drawdown, by subtracting static water level and multiplying by Neg 1
* Note: found mistake in program and fixed it, see red corrections, (above and opposite).

Data for WT-14 converted to time-drawdown plot by subtracting 729.65 m from wsl, based on static water level reported by Graves et al (1998, USGS OFR 98-169), and then multiplying by -1. See plot on facing page (pg 56). Note that early time data (before drawdown response) and late-time data (after boundary effects (?)) are cut from data.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	10/19/98

From Page No.____ 10/19/98



JW 10/19/98

Note the jumps in pressure response at about t = 40,000 and t ≈ 75,000 on above plot. These jumps are also present on atmo signal

10-27-98 –
At this point I am deeply suspicious regarding USGS correction of barometric efficiency. It appears that USGS subtracted atmos. pressure from well pressure transducer data in order to obtain guage pressure, then added it back in to correct for what they called response to atmospheric pressure. It seems to me that since transducers were packed-off they should have been isolated from the atmospheric pressure. Thus there was no need to subtract out atmo. pressure. Of course, this rant only applies to packed-off intervals of c-wells — wells wt3, wt14, JW 10/28/98 WT H-4, ~~and ONC~~ JW 10-28-98 are water table elevation data that are not corrected for atmo.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	10/27/98

From Page No.____ 10/28/98 correcting data for Barometric pressure. Message below confirms that ONC1 is packed off from direct atmosheric pressure. J Winterle 10/28/98

Date: 10/26/98
Sender: <METLASVEGA@aol.com>
To: jwinterle@swri.edu
cc: StellaNick@aol.com
bcc: Jim Winterle
Priority: Normal
Subject: Re: Transducer pressures in ONC1

Mr. Winterle:

Nick Stellavato of Nye County forwarded your e-mail regarding data at ONC#1 to me. I am assuming that you have been successful in obtaining the data from www.nyecounty.com.
The raw data in the zip files are transducer pressures in absolute psi. There is no correction for earth-tides no for barometric effect. The zones, where pressure is monitored, are packed off; therefore, your assumption of shut in is correct. The only atmospheric connection is through the unsaturated zone. Please let me know if you have any further questions. Thank you.

Perry Montazer
Multimedia Environmental Technology, Inc.

12/16/98
Hypothesis:
Low-freq (days to weeks) oscillations in atmoshperic pressure are felt by water table after a lag period which gives appearance of reduced barometric efficiency compared to daily higher freq. fluctuations. This is evidenced by looking at ONC1 data which was packed-off from atmospheric effects (see fig on next page): after smoothing it can be seen that peaks in water pressure signal lag peaks in atmo pressure signal. Below is a comparison of times of obvious peaks in atmo and water pressure signals:

Atmo pk (min)	Water press. pk (min)	lag (min)
-18160	-17630	530
-13759	-12720	1039
35770	37310	1340
77110	77810	700
97340	100720	3380 (outlier?)
133110	133810	700
180420	181064	640
239450	240410	960

To Page No.______

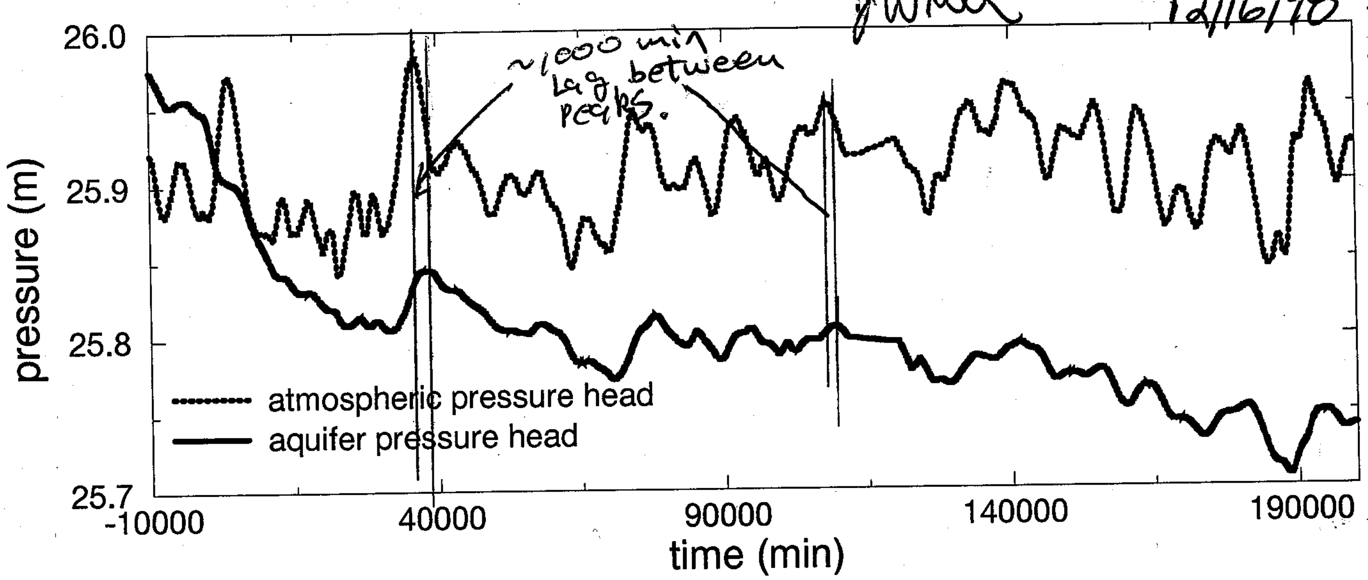
Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by J. Winterle	12-16-98

From Page No.___ 12/16/98

atmo pk (min)	water press. pk (min)	lag (min)
244570	245690	1120
274860	276100	1240
292010	292950	940
317770	318890	1120
327430	328490	1060
330560	331800	1240

Mean lag = 970 min
Std Dev. = 260 min

JWinter 12/16/98

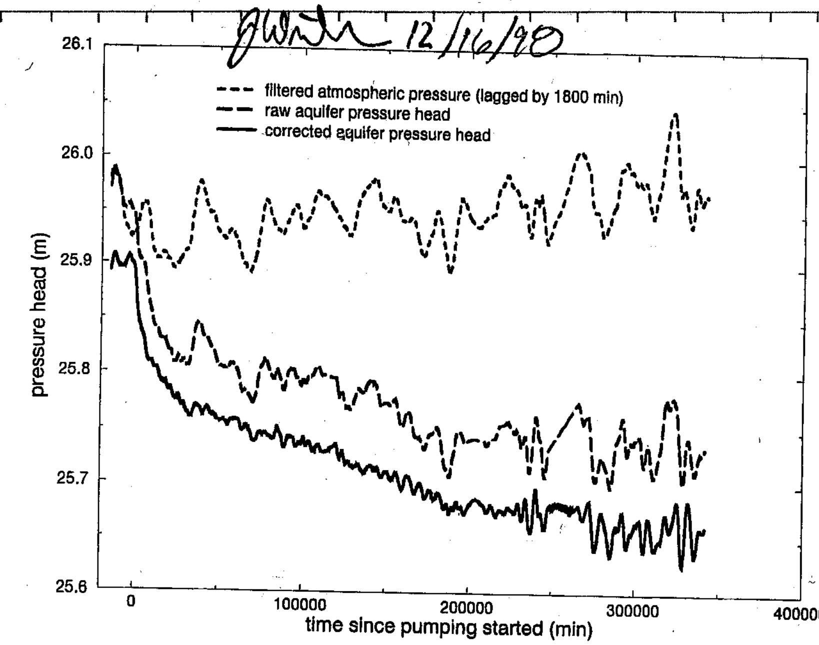


After playing with this idea awhile, I found that filtering atmo signal with a 500 pt running average makes it look qualitatively like water pressure signal. I then found that an 1800 min lag results in good correllation with peaks of both data sets (see Fig on opposite page). Regression of prepump atmo & baron signal gives atmo-water ~~corr~~ regression coeff. of 0.56. Corrected water pressure head curve reflects subtraction of atmo signal after scaling by 0.56. I'm a genius!

To Page No.______

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by JWinter | 12/16/98

From Page No.___ 12/16/98



2/28/99 Correcting Daily well water levels from periodic network from May 22 to June 12, 1999.

- These are manual water sfc elev. readings; Date is given, but time is not, in GS96070831231.2.009
- Using atmo pressure at Choles for these dates, assume readings taken at ~ 12:00. Smooth atmo using ~~250~~ 100 pt running avg; take diff from smoothed atmo

JW 2/28/99

Day 0 = March 22, 1995

JW 2/28/99

Day	atmo change	Day	Atmo chg
0	0.0 m	7	- 0.01 m
1	0.02	8	+0.0~~37~~ JW 2/28
2	0.0	9	0.0
3	0.0	10	- 0.035
4	+0.01~~2~~	11	0.0
5	+0.00		
6	-0.01 m		

JW 2/28/99 (beside Day 1); JW 2/28/99 (beside Day 4)

On second thought, this is Bogus

To Page No.______

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by JWinter | 2/28/99

From Page No.

3/3/99 Analysis of May 22 pump test at C-Holes: a fresh look

1. C well data: corrected raw water data for atmo pressure → Raw data is in pressure, so it should not be affected by down-borehole effects of atmo pressure. → so, I only need to do stage 2 of filtering as described on pg 58 with a attenuation factor of 0.2 and a lag of 1800 min.

→ convert raw data to hourly, then filter using 20 hr running average, then go back and replace first few data points (30 min) with original data. this approach puts back early time data to interpret initial pump test response.

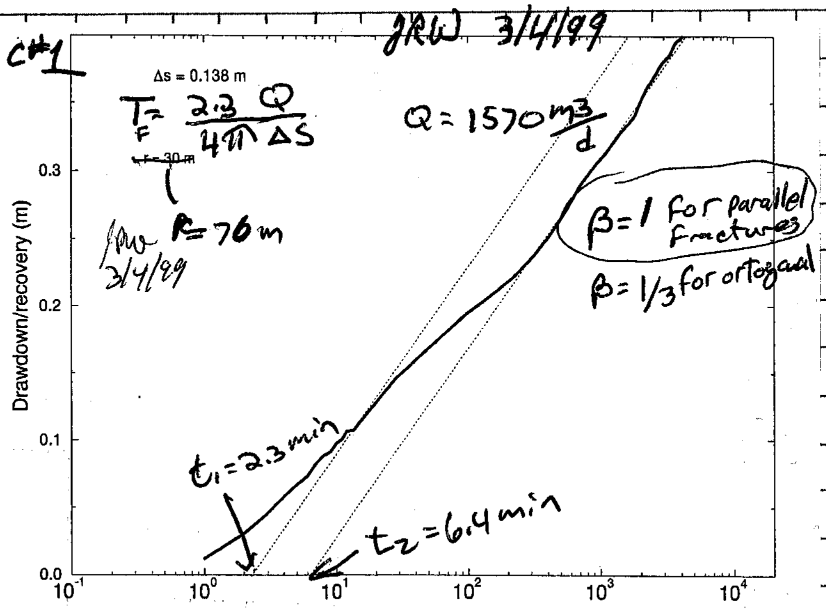
→ Final atmo conversion for all c-wells was lag of 1800 min and attenuation factor 0.18

→ Semilog analyses of Drawdown follow.

3/4/99 Plot below is used for Kazemi et al method (1969) on well c#1 following approach on page 257 of Kruseman & DeRidder.

JRW 3/4/99

c#1



This plot shows some dual-porosity effects.

$$\boxed{T_F = 2080\ m^2 d^{-1}}$$

$t_1 = 0.0016$ day

$$\boxed{S_F = \frac{T_F t_1 \cdot 2.25}{r^2} = \cancel{0.008}\ 0.0013}$$ JRW 3/4/99

$t_2 = 0.00444$ day

$$\cancel{S_F}\,S_m = \frac{T_F t_2 \cdot 2.25}{r^2} - S_F$$

$$\boxed{S_m = \cancel{0.014}\ 0.0022}$$

JRW 3/4/99

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	3/4/99

From Page No.

for well c#2: $\Delta s = 0.094$; $t_1 = 3.5E\text{-}4d$; $t_2 = 0.0033$
$T_F = 3060\ m^2/d$ — note these values will likely change in final report as I refine my atmospheric correction method.

3/16/99 Type curve fitting to May 1995 P.T. data using AQTSolve software → Version 2.12 professional

Well c#1 Moench (1984) solution for fractured aquifers. Need to make some assumptions about matrix properties. from L.Flint (1996) matrix Ksat in the Bullfrog and Prow Pass units is on the order of 10^{-5} m/d

minimum $\boxed{K' = 10^{-5}\ m/d}$ JRW 3/16/99

If we assume ~~most~~ storativity in matrix is due to compressibility of water; from standard Hydraulics text (Roberson/Crowe 5th ed.) $\frac{1}{\beta} = E_v$ = Bulk modulus of water

$$E_v \approx 2.2 \times 10^9\ N/m^2 \times \frac{1\ m^3}{1000\ kg} \times \frac{1\ s^2}{9.81\ m} \quad (E_v \cdot \rho g)$$

gives E_v in meters $\frac{1}{E_v} = \beta = 4.46 \times 10^{-6}\ \frac{m^3\ water}{m^3_{vol.} \cdot m_{Ahead}}$

$S_s' = \beta \cdot \phi \Rightarrow$ assume porosity $(\phi) \approx 0.2$

$S_s' = 4.46 \times 10^{-6} \times 0.2\ m^{-1}$

$S_s' = 8.92 \times 10^{-7}\ m^{-1}$ → round up to allow for slight formation compressibility.

$\boxed{S_s = 10^{-6}\ m^{-1}}$ → use this as minimum value

Use constant K′ and S_s' in Moench solution of AQTESolv software. see final report for outputs (Winterle — letter report 861-950, June, 1999)

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	3/16/99

From Page No.___ 8/4/99 Processing of Raw data from May 22, 1995 Pumping test.

Hourly water table levels were obtained from Kristi Lewis at USGS (303) 236-5050 x 265. These data are referenced under Yucca Mountain Data Tracking Number ~~GS97~~ GS960708312312.009
MOL.19970717.0348

The data are hourly water levels for Jan 1, 1995 Through approximately Oct. 1, 1995 (stop dates vary). Data are from wells:

USW H1 – transducer #3
USW H1 – transducer #4
USW H3 – Lower interval
USW H3 – upper interval
USW H4 – Lower "
USW H4 – upper "
USW H5 – lower " and upper
USW H6 – lower and upper
UE-25 p#1
UE-25 wt 1
UE-25 wt 10
UE-25 wt 14
UE-25 wt 3
UE-25 wt 4

- The data were not delivered in a usable format, so I had to write an algorithm to process the data into two-column, time (hours since 000 on Jan 1, 1995) and water surface elevation (meters). This algorithm is taped to facing page (63).
- The next step is to correct the data for barometric pressure effects. This required a record of atmospheric pressure in the area

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	8/4/99

From Page No.___

JRW 8/4/99

```
#! /bin/sh

nawk '
 BEGIN {NR=999}

 /PROVISIONAL/ {
    NR=0
    if($3 =="JANUARY") mhours=0
    if($3 =="FEBRUARY") mhours=31*24
    if($3 =="MARCH") mhours=59*24
    if($3 =="APRIL") mhours=90*24
    if($3 =="MAY") mhours=120*24
    if($3 =="JUNE") mhours=151*24
    if($3 =="JULY") mhours=181*24
    if($3 =="AUGUST") mhours=212*24
    if($3 =="SEPTEMBER") mhours=243*24
    if($3 =="OCTOBER") mhours=273*24
    if($3 =="NOVEMBER") mhours=304*24
    if($3 =="DECEMBER") mhours=334*24
    dhours = mhours+(int($4)-1)*24
               }
  NF==0 {NR=999}
  NR>0 && NR<=20 && NF%2==0 {
   split($1, t, ":"); print dhours+t[1]+t[2]/60, $2
   if(NF>2) {split($3, t, ":"); print dhours+t[1]+t[2]/60, $4}
   if(NF>4) {split($5, t, ":"); print dhours+t[1]+t[2]/60, $6}
   if(NF>6) {split($7, t, ":"); print dhours+t[1]+t[2]/60, $8}
   if(NF>8) {split($9, t, ":"); print dhours+t[1]+t[2]/60, $10}
   }
' < $1.raw > temp
 sort -n temp > ../$1.95
rm temp
xvgr -nxy ../$1.95 &
```

← Program used to strip data from the raw data files provided by USGS.

output is Time, water-surfase elev. Written with nawk, runs on unix OS.

Last Line, xvgr...; plots output using XVgr so it can be checked for errors qualitatively.

Program: getdata.sh

- Raw data file for atmospheric pressure at Weather station WX3, near Yucca Mtn, was obtained from www.ymp.gov, Data Tracking Number GS960808312111.003.
- Atmospheric pressure in raw data file was in kPa units: need to convert to meters of H_2O. Calculation shown on next page.

To Page No.______

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by [signature]	8/4/99

64

Project No.

Book No.

TITLE Analysis of May 22, 1995 Pump Test

From Page No. 8/5/99

Conversion of atmospheric pressure in KPa to m_{H_2O}

- density of water is temperature dependent

ρ_{H_2O} @ 35°C = 994 Kg/m³
ρ_{H_2O} @ 50°C = 988 Kg/m³
} approx. range of observed water temperatures in boreholes near YM.

$$\text{meters of pressure head} = \frac{\text{Pressure}}{\rho \cdot g}$$

$$@35°C \quad 1\,KPa \times 1000\frac{Pa}{KPa} \times \frac{1}{994\frac{Kg}{m^3} \times 9.81\frac{m}{s^2}} = 0.1026\frac{m}{KPa}$$

$$@50°C \quad 1\,KPa \times 1000\frac{Pa}{KPa} \times \frac{1}{988\frac{Kg}{m^3} \cdot 9.81\frac{m}{s^2}} = 0.1032\frac{m}{KPa}$$

both of these round out to $0.103\frac{m}{KPa}$

compare to Gelder 1998 → $0.707\frac{m}{psi} \times \frac{1\,psi}{6.894\,KPa} \rightarrow 0.1026\frac{m}{KPa}$

- over range of temperatures, error is less than 1/2 % of average conversion factor.

- Wrote program in 'nawk' language to convert raw data file to a usable format. This nawk program is taped to the facing page.

- Note problems with raw data file: ① The year 1994 was incorrectly entered as 1995 for several lines in the 10/94 area of the file. ② The month of June ("06") was in-correctly entered as "05" for several lines on June 25, 1995. I corrected these errors prior to processing raw data.

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	8/5/99

TITLE May 22 Pump Test Analysis

Project No.

Book No.

65

From Page No. 8/5/99

JRW 8/5/99

```
#! /bin/sh

# Program to process atmospheric pressure data from station
# WX3 near Yucca Mountain, Nevada. Data obtained from YMP internet site
# at www.ymp.gov data tracking no. GS960808312111.003.
# Written by Jim Winterle, 8/4/99.

nawk '
BEGIN {
  factor=0.103   # conversion factor: meters-water per kPa based on water
                 # density within a temperature range of 35-50 Celsius.
}
NR >= 21 && NF==9 && $3>0 {     # process data, which begins on line 21

 split($8, date, "/")    # split date field into an array
 split($9, time, ":")    # split time field into an array

 if(date[3]=="1995") yhours=0.0    # zero hour is Jan 1, 1995
 if(date[3]=="1994") yhours=-8760  # that makes 1994 negative

# calculate total hours since 0000 on January 1, 1995
 if(date[1]=="01") hours=0       +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="02") hours=31*24   +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="03") hours=59*24   +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="04") hours=90*24   +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="05") hours=120*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="06") hours=151*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="07") hours=181*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="08") hours=212*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="09") hours=243*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="10") hours=273*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="11") hours=304*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60
 if(date[1]=="12") hours=334*24 +yhours+(date[2]-1)*24 + time[1] + time[2]/60

 PressHead=$3*factor    # convert kPa to meter of water
 print hours, PressHead # print the results
}
' < wx3_94-95.dat
```

Nawk Script used to process raw atmospheric pressure data from weather stn. WX-3 on Yucca Crest.

- The next step is to find borehole config. info. for each of the boreholes under consideration. This will allow for ~~proper~~ JRW selection of proper correction method for barometric effects. Sources are:

* Graves et al, 1997 → USGS WRIR 96-4256
* Graves, 1998 → " OFR 98-169

To Page No.

Witnessed & Understood by me,	Date	Invented by	Date
		Recorded by	8/5/99

From Page No.____ 10/6/99

Next: need to convert time-drawdown data so that t=0 is at start of May 22, 1995 pumping test. start of test is $\boxed{3422 \text{ hrs}, 59 \text{ min}}$ since January 01, 1995, 0000hrs.
- Thus I will make the first data point from t=0 the point from hour 3423 hrs. ~~and call it t=1.0 min. Although subsequent data points will be thr + 1 min... etc. it will be sufficient to round it to the hour.~~

JRW

for use in pump Test Analyses, it is necessary to determine distance (r) from the pumping well, UE-25 c#3. The spread sheet below was used to calculate r and azimuth angle (degrees Clockwise from True North) for the hourly-monitored wells, based on well locations in GIS database: doe-wells.txt.

JRW 10/6/99

Well ID	UTM-X (m)	UTM-Y (m)	Radius (m)	Azimuth
c#3	550919.8	4075886.0	0	N/A
WT-1	549151.7	4074967.0	1993	243
WT#3	552090.0	4072550.0	3535	161
WT-4	550438.5	4079411.8	3558	352
WT-10	545964.3	4073377.6	5554	243
WT#14	552630.5	4077329.6	2238	50
USW H-1	548727.0	4079925.6	4596	332
USW H-3	547561.7	4075759.1	3360	268
USW H-4	549187.8	4077309.0	2242	309
USW H-5	547668.3	4078841.1	4394	312
USW H-6	546188.1	4077816.1	5110	292
UE-25 p#1	551501.2	4075658.7	624	111

ONC1 r = 843 θ = 327° → (see pp 32 + 52)

(Geldon et. al, 1998)

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by [signature] 10/6/99

From Page No.____ 10/11/99

- At this point we have data reduced to a time series of water-level measurements beginning 500 hrs before start of pumping test, ending 500 hrs after. t=0 at 1500 hrs, May 22, 1995.
- Each file of data contains 3-columns: time in hrs; change in Water Level from time t=0; change in atmospheric pressure from time t=0.

Note: since all of the wells in the hourly monitor network are pretty far away, it took a while for them to respond to pumping. Thus, it was a convenient approximation to make t=0 at Time 1500 hrs on May 22, 1995, even though pumping actually began a minute earlier.

- The next step is to investigate response to atmospheric pressure fluctuations.

[signature] 5/3/00

No Further Entries

Witnessed & Understood by me, | Date | Invented by | Date
Recorded by [signature] 5/3/00

Project No.

Book No. TITLE

From Page No.

Final Entry:
This notebook appears
to comply with
QAP-001.

E. C. R[illegible]
5/4/2000

To Page No.

Witnessed & Understood by me, | Date | Invented by | Date

Recorded by