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DEPARTMENT OF THE NAVY

ATLANTIC DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORFOLK, VIRGINIA 23511-6287

TELEPHONE NO.
(804) 444-9566

IN REPLY REFER TO:
6280
1143CFB

DRAFT

MEMORANDUM FOR CODE 09A21

Subj: CONTRACT N62470-83-C-6106, NACIP PROGRAM, CONFIRMATION STUDY, MCB, CAMP LEJEUNE

1. Second round sampling and testing under subject contract is required. In addition, based on results from round one, a characterization effort is needed for sites in the Hadnot Point Industrial area. Request you solicit from ESE Incorporated, a proposal for a change order, to accomplish the following:

a. Site 1, French Creek Liquids Disposal Area: Sample and test surface water and sediments in two locations on Cogdels Creek; sample and test the six shallow wells. Add o,m,p-xylene, MEK, MIBK, EDB, and hexavalent Cr to the analytical parameters for round one.

b. Site 2, Former Nursery/Day Care Center: Sample and test Well 2GW1. Sample soil at four locations in the vicinity of sample 2S4; sample surface water and sediment from the drainage ditch in two locations; install four shallow two-inch wells in locations directed by the EIC. Sample new wells twice at an interval of 60 days. Analyze each sample for OCP, OCH, dioxin, and VOA.

c. Site 6, Storage lots 201 and 203: Install eight shallow two-inch wells in locations directed by the EIC. Sample wells twice at a 60-day interval. Sample surface water and sediment from Bearhead and Wallace Creeks adjacent to the site. Analyze all samples for DDT-R and VOA.

d. Site 9, Fire Fighting Training Pit: Resample and test the two shallow wells. Install a third well in a location directed by the EIC and sample twice at a 60-day interval. Analyze all samples for o,m,p-xylene, MEK, MIBK, EDB and hexavalent Cr in addition to round one parameters.

e. Site 21, Transformer Storage Lot 140: Sample soil at eight locations around perimeter of site, including two samples from drainage ditch. Sample four depths at each location (0-1', 1-3', 3-5,' and at 5') and analyze for OCP, OCH, PCB, dioxin. Resample well GW21-1 and analyze for VOA, OCP, OCH, PCB, dioxin, xylene, MEK, MIBK, EDB, and oil and grease.

f. Site 24, Industrial Area Fly Ash Dump: Install two downgradient wells in locations directed by the EIC. Sample new wells twice at a 60-day interval. Sample five shallow wells, existing surface water locations and two new surface water/sediment locations on tributaries to Cogdels Creek and analyze all samples for metals A, VOA, and hexavalent Cr.

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g. Site 28, Hadnot Point Burn Dump: Install new upgradient well and sample twice at a 60 day interval. Sample three existing shallow wells, New River surface water and sediments in four locations, and one new surface water/sediment location in Cogdels Creek near new upgradient well. Analyze all samples for round one parameters, dioxin, o,m,p-xylene, MIBK, MEK, and hexavalent Cr.

h. Site 30, Combat Town Training Area: Install another well downgradient and sample twice at a 60-day interval. Sample shallow well, surface water/sediment in French Creek and analyze all samples for same parameters as listed for round one plus xylene, MEK, MIBK, and EDB.

i. Site 35, Camp Geiger Area Fuel Farm: Install three shallow two-inch wells in locations directed by the EIC. Sample twice at a 60-day interval. Sample surface water and sediments from Brinson Creek in two locations; analyze all samples for Pb, VOA, EDB, and O&G.

j. Site 36, Camp Geiger Area Dump: Install new upgradient well; sample twice at a 60-day interval. Resample four shallow wells; sample surface water and sediments from Brinson Creek and unnamed creek south of site in two locations. Analyze all samples for parameters listed in round one, o,m,p-xylene, MEK, MIBK, EDB, and hexavalent Cr.

k. Site 41, Camp Geiger Dump: Resample four shallow wells. Add new upgradient well and sample twice within 60-day period. Sample surface water and sediment from Tank Creek in two locations and unnamed creek in two locations and analyze all samples for parameters listed in round one plus dioxin o,m,p-xylene, MEK, MIBK, and hexavalent Cr.

l. Site 45, Campbell Street Underground Fuel Storage Area: Install new well south of fuel farm; sample twice at 60-day interval. Resample three shallow wells and surface water/sediment from the drainage ditch in two locations. Analyze water samples for Pb, O&G, VOA, EDB, and xylene. Sample soil in six locations along perimeter of fuel farm and avgas storage. Composite 5' borings into 3 samples, 0-1', 1-3', and 3-5', analyze soil and sediment samples for Pb, O&G.

m. Site 54, Crash Crew Fire Training Burn Pit: Install one upgradient and one downgradient well at site and sample twice at 60-day interval. Resample Well 54GW1, drainage ditch surface water and sediments in three locations and analyze for round one parameters, o,m,p-xylene, MEK, MIBK, EDB, and hexavalent Cr.

n. Site 68, Rifle Range Dump: Resample three shallow wells and analyze for round one constituents plus o,m,p-xylene, MEK, MIBK, and EDB.

o. Site 69, Rifle Range Chemical Dump: Resample eight shallow wells and three surface water locations. Sample surface water and sediments from two unnamed guts southeast of site. Analyze all samples for parameters listed in round one plus dioxin, o,m,p-xylene, MEK, MIBK, and EDB.

p. Site 73, Courthouse Bay Liquid Disposal Area: Relocate Well 73GW4 closer to Courthouse Bay to allow for construction activities in that area. Install new upgradient well and sample twice at a 60-day interval. Resample four shallow wells and sample Courthouse Bay surface water and sediments in three locations. Analyze all samples for parameters listed in round one, o,m,p-xylene, MEK, MIBK, EDB, and hexavalent Cr.

q. Site 74, Grease Pit and Pest Control Area: Install a third well west of site; sample twice at a 60-day interval. Resample two shallow wells and analyze all samples for OCP, OCH, PCBs, dioxin, and VOA.

r. Site 75, MCAS Basketball Court: Resample three shallow wells and analyze for VOA, chloropicrin, and dioxin.

s. Site 76, MCAS Curtis Road: Resample two shallow wells and analyze for VOA, chloropicrin, and dioxin.

t. For all existing wells: Install two additional protective bollards and fill with concrete. Pour 5' x 5' concrete pad around well and bollards; paint well bollards day-glo orange. Use monitoring well construction specifications, Attachment A, for installation of new wells.

u. Sample all potable wells on MCB Camp Lejeune and MCAS New River (approx. 100). Composite samples from a maximum of ten wells serving the same water treatment plant (except for "contaminated" wells listed below) and analyze for priority pollutants, all the Safe Drinking Water Act (SDWA) parameters and xylene, MEK, MIBK, and EDB. If any parameter(s) from the composite exceed(s) regulatory limits or suggested guidelines for potable water, analyze samples for only that (those) parameters from the individual wells in the composite to pinpoint the source of contamination. These "contaminated" wells have been shut down by MCB Camp Lejeune: 601, 602, 603, 634, 637, 651, 652, 653, TT26, and TT New. Sample these wells individually and analyze for priority pollutants, SDWA parameters, xylene, MEK, and MIBK.

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v. In accordance with the original scope of work, conduct Step IB, Characterization, for the Hadnot Point industrial area (bounded by Sneads Ferry Road, Codgels Creek, the New River, and Wallace Creek) and for the deep potable water aquifer influenced by wells serving the Hadnot Point treatment plant. The pump houses for these wells are numbered:

601	613	633	642
602	614	634	651
603	615	635	652
606	616	636	653
608	620	637	654
609	621	638	655
610	626	639(2)	LCH-4006
611	627	640	LCH-4007
612	632	641	

The objectives of the characterization step are as follows:

1. Locate source of VOCs detected in deep water supply wells 601, 602, 603, 608, 634, 637, and 642.

2. Determine concentration of detected analytes in source area(s).

3. Determine aquifer characteristics: transmissivity, hydraulic conductivity, permeability, storage coefficients and degree of confinement for both deep and shallow aquifers.

4. Determine rate and direction of groundwater and contaminant flow for the deep potable water supply aquifer influenced by wells listed above, and for the shallow aquifer in the Hadnot Point industrial area.

Conduct an extensive physical survey and document review for activities within the industrial area to identify potential sources of contamination. Perform a soil gas investigation to delineate the source areas; install additional wells to verify findings. We estimate fourteen additional shallow wells may be required in this area, including seven which will form pairs with potable wells 601, 602, 603, 608, 634, 637, and 642. Perform a minimum of two rounds of sampling at the seventeen Site 22 shallow wells; add xylene, MEK, MIBK, and EDB to the round one verification step parameters.

Perform aquifer testing to determine aquifer characteristics and rate and direction of ground water and contaminant flow. Potable water wells shall be evaluated for various well pumping combinations. Access holes will be drilled, threaded and removable plugs installed in the tops of all potable wells to provide a means of logging the depths of the water levels in the wells. The elevations of these plug holes above mean-sea-level shall be accurately determined by surveying. The method described in Attachment B or another commonly used method/model, as approved by the EIC, shall be used to determine the flow characteristics and contaminant profiles of the aquifers under study.

w. Conduct Step II Feasibility for the Hadnot Point industrial area. Specify and evaluate five each interim and long-term feasible alternatives for cleanup of contaminated aquifers; include projected effectiveness and cost estimate for each alternative in your evaluation.

x. For the contaminated wells TT26, TTNew, 651, 652, and 653, conduct an extensive physical survey and document review to identify potential sources of contamination. Perform a soil gas investigation within a one-mile radius of each well to delineate the source areas; install additional shallow wells (up to six per potable well) to verify findings. Perform two rounds of sampling at these wells; analyze samples for volatile organics, xylene, MEK, and MIBK.

y. Forward a report on the results of this additional work to the Government for review, in accordance with the original scope of work effort. Raw data, pertinent facts and conclusions shall be provided in this report.

2. A milestone chart with projected completion dates for this additional effort is forwarded as Attachment C. The Government fee estimate is being prepared by Code 114 and will be forwarded to you as soon as possible.

3. Please change the EIC for this contract to Cherryl Barnett, Phone 444-9566.

J. R. BAILEY, P.E.
Head, Environmental Quality Branch
Utilities, Energy and Environmental
Division

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MONITORING WELL CONSTRUCTION AND FIELD OPERATIONS

All confirmation study monitoring wells will be drilled. The borings are estimated to have drilled depths of no more than 25.0 feet.

Well construction is shown in Figure A-1. At least one drill should be mounted on an All-Terrain-Vehicle (ATV) for access to remote areas. Each rig will use necessary tools, supplies and equipment and supplied by the contractor to drill at each site. Drill crews consist of an experienced driller and a driller assistant for work on each rig. A geologist, experienced in hazardous waste site investigations, shall be on-site to monitor the drillers efforts and for air monitoring/safety control. Additional contractor personnel will transport water to the rigs, clean tools, assist in the installation of the security and marker pipes, construct the concrete aprons and use a portable water pump to activate the wells. Unless otherwise specified, all water used/removed in this effort shall be allowed to seep back into the ground at each drill site.

Supplies and equipment will be transported to the lay-down area designated on-station by the Government. Any office space, trailers, etc., required for drilling, subsequent sampling and shipping shall be arranged and provided by the contractor.

The test borings will be drilled using 3-1/4 inch I.D. hollow stem auger flights (O.D. approximately 7-1/2 inches). Standard penetration test will be performed in accordance with ASTM D-1586. Standard penetration tests will be performed at the following depths: 0.0'-1.5'; 1.5'-3.0'; 3.0'-4.5', and five-foot centers thereafter. Each soil sample will be sealed in eight-ounce glass bottles or as required for follow-on laboratory analysis. A boring log of the soil type, stratification, consistency and groundwater level will be made.

After completion of the soil sampling and drilling to the specified depth, the hollow stem auger flights will be removed and a 6-inch I.D. PVC flush threaded pipe installed in the bore hole. If cave-in occurs, these soils will be removed by jetting through the 6-inch casing using potable water transported and supplied by the contractor. Water sources for refilling the tanks will be designated on base.

Two-inch I.D. flush threaded Schedule 80 PVC monitoring well slotted screen and well casing will be installed within the 6-inch PVC casing. A sand pack will be placed around the slotted well screen extending to 2 feet above the top of the screen. A 15-20 foot section of 0.01 inch slotted PVC well screens should be used in each well. A 12-inch seal of bentonite clay pellets will be placed over the sand pack and the 6-inch PVC casing will be removed to the bottom level of the seal using a hoist plug and sand line on the drill rig. A grout mixture of 2 parts sand and 1 part cement will be placed and blended in with the specified amount of potable water and then be thoroughly mixed. The grout will be placed in the 6-inch PVC casing and rodded to insure a proper seal. A 4-inch security pipe with a hinged locking cap will be installed having an embedment depth of 2.5 feet into the grout. The security pipes will extend a minimum 2.5 feet and maximum of 4.0 feet above the ground surface. A concrete apron measuring 5'x5'x0.5' will be constructed around each well. This apron will be constructed of 3000 psi ready mixed concrete. The concrete will be crowned to provide positive runoff. The concrete pads can be constructed within 5 days after all of the wells have been installed.

Each well will be marked with four Schedule 40 steel pipes imbedded in a minimum of 2.5' of 3000 psi concrete. The steel marker pipes will be painted black and the top 2-foot portion will be painted day-glo orange. Each well will be properly labeled by metal stamping on the exterior of the security pipe locking cap and by labelling vertically on the exterior of the security pipe with stick-on 2" high weather resistant decals. The labelling shall indicate the site and well number assigned to both new and existing groundwater monitoring wells:

SITE	TYPE OF WELL	WELL NUMBER
1	GW (New Well)	5
1	EGW (Exist. Well)	6
1	PW (Potable Well)	8

The soil removed by the augers will be piled beneath the drill rig while drilling. The drill equipment and tools will be cleaned at each well site using a portable decontamination system/operation supplied by the contractor. Wash water at the sites will not be contained, unless otherwise directed by the EIC, and may seep into the ground locally.

The concrete used to secure the four pipes will be poured at the same time and be an integral part of the 5'x5'x0.5' concrete apron described above.

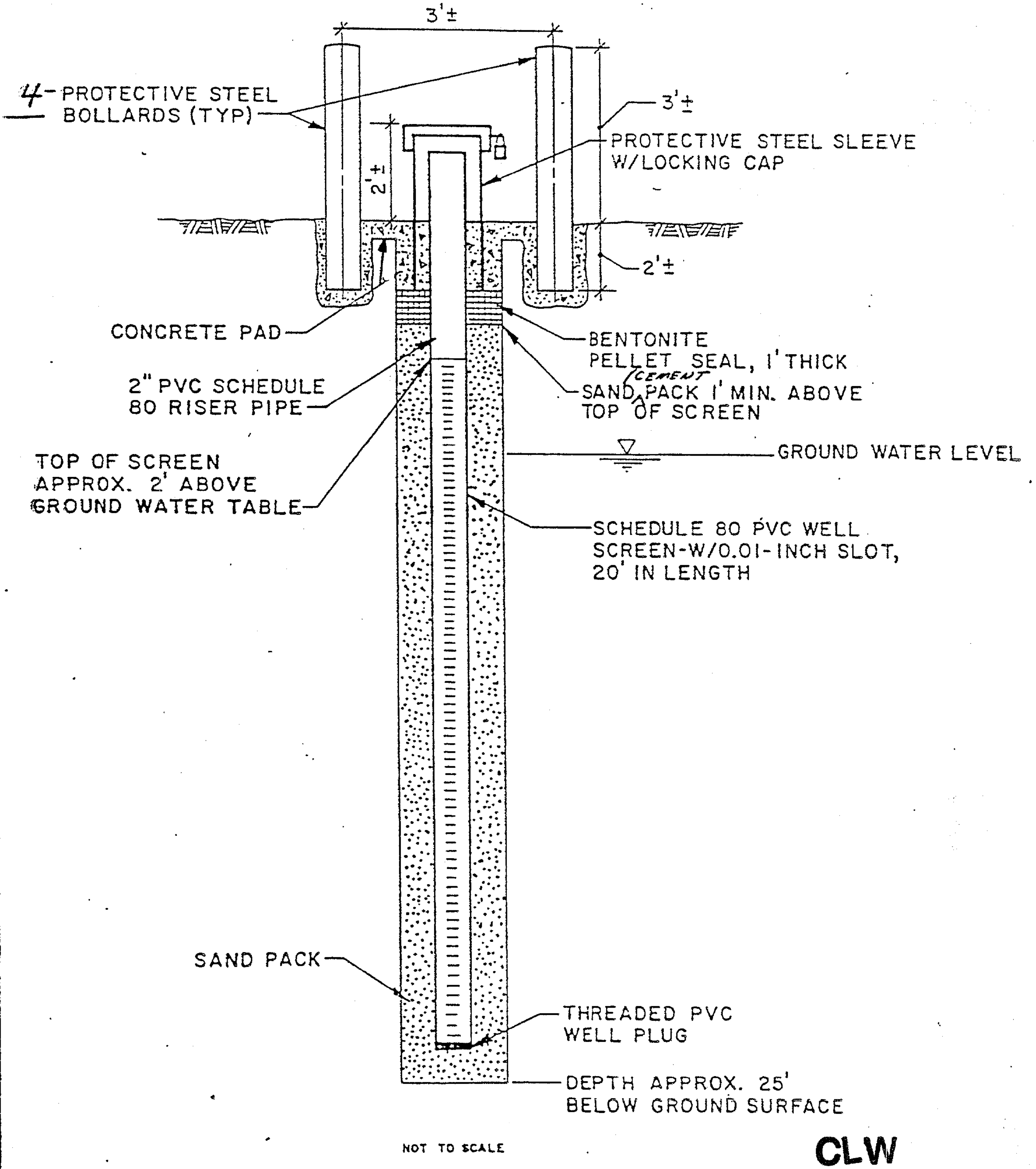

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FIGURE A-1

MONITORING WELL CONSTRUCTION

A method to determine the direction and rate of groundwater flow by the water elevations in three observation wells.

INTRODUCTION

A simple, reliable method for determining the rate and direction of groundwater flow would be helpful for groundwater studies, sampling for spill contamination and hazardous waste and sanitary landfill studies and monitoring. This article describes such a method using three wells. The wells are first used for a pumping test to determine the permeability of the soil. The permeability is thereafter used, with the water elevations in the wells, to determine the rate and direction of flow, the width of the flow path between wells, and the volume of flow between wells. A computer program written in basic is included to do the necessary computations.

DISCUSSION

For the method, the following assumptions are made:

A. Darcy's flow equation through soil is applicable (i.e., the soil flow is laminar and viscous). This condition would be true in most soils (~~eruptions~~ exceptions - heavy ~~days~~ clays or non laminar flow in rock fissures.

B. All three wells are screened in the same aquifer (withdrawal from one affects the drawdown in the others), and the pumped well penetrates the aquifer far enough to represent full penetration (≥ 70 %)

C. The groundwater surface can be represented by a tilted plane in the area of the three wells. This would be true in most soils except in the immediate vicinity of a pumped well.

D. The ground elevation differences between the well tops are insignificant compared with the distances between wells (i.e., distance measured on surface are approximately the same as their projections on a horizontal plane). If this is not the case, the horizontal projection distances must be computed from surface measured distances. This is not a problem if the distances are scaled from a map.

ret Derivation of equations

Consider (Figure 1):

Let the water plane specified by water well elevations A, B, and C be orientated so C resides in the XZ plane at coordinates (L3, 0, W3); A resides on the Z axis at coordinates (0, 0, W1); and B resides at coordinates (r, S, W2). Let the distance between A and B = L1, B and C = L2, C and A = L3.

From the Law of Cosines:

$$D = \cos^{-1} [(L1^2 + L3^2 - L2^2)/(2\ L1\ L3)] \text{ radians} \quad (1)$$

$$R = L1 \cos D \quad (2)$$

$$S = L1 \sin D \quad (3)$$

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Attachment 6

The determinate for the normal equation of the plane specified by the coordinates of the three points A, B, and C is

$$\begin{array}{c} \\ A \\ B \\ C \end{array} \begin{vmatrix} X & Y & Z & 1 \\ 0 & 0 & W1 & 1 \\ r & S & W2 & 1 \\ L3 & 0 & W3 & 1 \end{vmatrix} = 0 \qquad (4)$$

Expanding (4) by minors:

$$X \begin{vmatrix} 0 & W1 & 1 \\ S & W2 & 1 \\ 0 & W3 & 1 \end{vmatrix} = X\,[S\,(W3-W1)] \qquad (5)$$

$$-Y \begin{vmatrix} 0 & W1 & 1 \\ R & W2 & 1 \\ L3 & W3 & 1 \end{vmatrix} = Y\,[L3(W2-W1) + R\,(W1-W3)] \qquad (6)$$

$$Z \begin{vmatrix} 0 & 0 & 1 \\ R & S & 1 \\ L3 & 0 & 1 \end{vmatrix} = Z\,[-S\,(L3)] \qquad (7)$$

Equation of the plane ABC in normal form is

$$(L)\,X + (M)Y + (N)X + OP + 0 \qquad (8)$$

Where L, M and N are the direction numbers of the normal to the plane from the origin OP (Figure 2).

From (8) and (5), $L = S\,(W3 - W1)$ (9)

From (8) and (6), $M = L3(W2-W1) + R(W1-W3)$ (10)

From (8) and (7), $N = -S(L3)$ ~~S(L3)~~ (11)

From Figure (2), $G = \left(L^2 + M^2\right)^{0.5}$ (12)

and Slope (SL) of plane ABC with horizontal plane XY

$SL = G/N$ (13)

The direction or fall line of the slope of the plane is AP, which is perpendicular to the normal OP, and makes the same horizontal angle (E) with the line AC ~~as OP~~ as G makes with L in the ~~XY~~ XY plane. Then

$$E = \cos^{-1}(L/G) \qquad (14)$$

Which is the direction of groundwater flow relative to a line between Wells A and C.

If the permeability of the soil P_b is known, then from Darcy's Law the velocity of flow can be computed from the water gradient or slope of the plane (equation ~~(EQN 13)~~ and the permeability (P_b).

$$V = P_b \times SL \text{ where } P_b = \text{permeability in ft/day} \qquad (15)$$

SL ~~EL~~ = Gradient in Ft/Ft

V = Velocity of flow in Ft/Day

The aquifer permeability P_b can be measured from a well draw down test - Figure (3). If one of the wells is pumped at a known rate until the drawdown in the other two wells stabilized, the permeability Pb can be computed from the well equation

$$Pb = \frac{1055\ Q \text{ Log } (r_1/r_2)}{(h_2^{\ 2} - h_1^{\ 2})} \quad \text{(See Figure (3).} \qquad (16)$$

Where Pb = the permeability, in GPD/FT^2 or FT/DAY

Q = Pumping rate, in GPM

r_1 = Distance to the nearest observation well (feet)

r_2 = Distance to the furthest observation well (feet)

h_1 = Saturated aquifer thickness, in feet at the nearest observation well

h_2 = Saturated aquifer thickness, in feet at the furthest observation well.

The permeability Pb can then be used in the Darcy equation (15) to obtain the velocity of flow in ft/day ~~from (15)~~.

To determine the width of flow paths between the wells in the direction of flow:

From Figure (4), distances between wells A and B in direction AP is d_{ab}; wells A and C is d_{ac} and wells B and C is d_{bc}. The slope of the flow direction of the parallel lines is (M/L) in the XY plane.

Solving the point slope matrix equations for the parallel lines through the wells by expanding minors:

Pt A:

$$\begin{vmatrix} X & Y & 1 \\ 0 & 0 & 1 \\ 1 & M/L & 0 \end{vmatrix} = X\begin{vmatrix} 0 & 1 \\ M/L & 0 \end{vmatrix} - Y\begin{vmatrix} 0 & 1 \\ 1 & 0 \end{vmatrix} + 1\begin{vmatrix} 0 & 0 \\ 1 & M/L \end{vmatrix} = 0$$

$$= (-M/L)\ X + Y = 0$$

$a = (-M/L),\ b = 1,\ C = 0$

Pt B :

$$\begin{vmatrix} X & Y & 1 \\ R & S & 1 \\ 1 & M/L & 0 \end{vmatrix} = X\begin{vmatrix} S & 1 \\ M/L & 0 \end{vmatrix} - Y\begin{vmatrix} R & 1 \\ 1 & 0 \end{vmatrix} + 1\begin{vmatrix} R & S \\ 1 & M/L \end{vmatrix} = 0$$

$$= (-M/L)X + Y + R\ (M/L) - S$$

$a = (-M/L),\ b = 1,\ C = [R(M/L)-S]$

Pt C:

$$\begin{vmatrix} X & Y & 1 \\ L3 & 0 & 1 \\ 1 & M/L & 0 \end{vmatrix} = X\begin{vmatrix} 0 & 1 \\ M/L & 0 \end{vmatrix} - Y\begin{vmatrix} L3 & 1 \\ 1 & 0 \end{vmatrix} + 1\begin{vmatrix} L3 & 0 \\ 1 & M/L \end{vmatrix} = 0$$

$$= (-M/L)X + Y + L3\ (M/L) = 0$$

$a = (-M/L),\ b = 1,\ C = L3(M/L)$

Distances between parallel well lines:

$$d_{ab} = \frac{|0 - [R\ (M/L) - S]|}{[(-M/L)^2 + 1]^{0.5}} = \frac{|S - R\ (M/L)|}{[(-M/L)^2 + 1]^{0.5}} \quad (17)$$

$$d_{bc} = \frac{|R\ (M/L - S - [L3(M/L)]|}{[(-M/L)^2 + 1]^{0.5}} = \frac{|(R-L3)(M/L) - S|}{[(-M/L)^2 + 1]^{0.5}} \quad (18)$$

$$d_{ac} = \frac{|0 - [L3\ (M/L)]|}{[(-M/L)^2 + 1]^{0.5}} = \frac{|-L3\ (M/L)|}{[(-M/L)^2 + 1]^{0.5}} \quad (19)$$

If the saturated depth of the aquifer (Ad) is known, the Volume of flow between wells (cubic feet/day) will be:

Wells A and B = (V) (Ad) (dab) (20)

Wells A and C = (V) (Ad) (dac) (21)

Wells B and C = (V) (Ad) (dbc) (22)

If the concentration of pollutants ~~is~~ are known from well samples, the quantity of pollutants (lbs/day) flowing between the wells can be calculated by multiplying the concentration (mg/l) X Vol of flow (ft^3/day)/62.4 FT^3 water/lb (23)

A computer program written in basic is shown in Figure (5) which will make the necessary computations of equations (1), (2), (3), (9), (10), (11), (12), (13), (14), (15), ~~and~~ (16), (17), (18), (19), (20), (21), and (22) from program and imput data.

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Program Data Statements are:

First line of data is well field name, printer output, permeability (gal/ft^2 - day)

Second line of data is L1, L2, L3 (well distances AB, BC, CA)

Third line of data is E1, E2, E3 (well top elevations of wells A, B, C)

The program cues for the depths from the well tops to water in each well. The program then computes and displays the slope of the water table (Ft/Ft), the velocity of flow (ft/day), the direction of flow (degrees right or left of line from Well A to Well C), the flow paths widths between wells, and the volume of flow between wells.

If the permeability of the soil is not known, 0, is entered for permeability in the first line of data, and the program branches to a routine that computes the permeability from the results of a well test. This permeability is then entered at the end of the first data statement, and the program will thereafter compute groundwater flow.

CONCLUSIONS

The necessary computations can be performed by the basic computer program of Figure (5). The data inputs are: W$ = Name of the well field, P1 = the soil permeability, L1, L2, L3 the distances in feet between AB, BC, and CA respectively, E1, E2, E3 = the elevation of the well top A, B, and C.

RECOMMENDATIONS - PROCEDURE

Drill the three wells into the same aquifer around the periphery of the area to be studied 200 to 500 feet apart. They should not be arranged in an equilateral triangle. One of the wells is to be pumped for a permeability test, and the other two used as observation wells. The observation wells should be different distances from the pumped well by at least 50 percent (i.e., the furthest observation well at least 1 1/2 times the distance from the pumped well as nearest observation well. (Figure (5))

The pumped well should penetrate at least 70 percent of the aquifer and the distances (feet)between the wells measured (AB = L1, BC = L2, CD = L3). The elevation of the well tops AB and C are surveyed (E1, E2, and E3). While any datum will do, feet above mean sea level is recommended for uniformity between well fields. This information is added at the end of the program as data Lines 2 and 3. The first data line is the well field name, printer status (0 = print and display, 1 = display only), and 0 for the permeability if known

Prior to pumping, the depth of the well to the pumped and the depths from the well tops to the static water levels in all three wells are noted. The pumped well is pumped and the pumping rate is adjusted so that a significant drawdown is produced the two observations wells and the drawdowns stabilize in a reasonable length of time (i.e., less than four hours). The drawdown depths to the water in the observation wells and the pumping rate are noted for program inputs.

The program, reading "0" for permeability, jumps to the well test routine, calculates the permeability, and stops at the proper data statement so the permeability canld be copied as data.

The program is now set to compute the direction and rate of groundwater flow from the water levels in the wells. The depths measured prior to pumping can be used. Also, after pumping ceases long enough for the wells to recover, the depth's from the well tops to the water are again measured in each of the three wells. The computer program is run again, and the depth values are input when prompted. The program again uses these values to do the necessary computations.

Figure (6) is a an example of a simulated flow test and computer computations of the groundwater flow. For any questions, please contact Mr. J. J. Harwood, Code 114, LANTNAVFACENGCOM, Naval Station, Norfolk, Virginia 23511-6287, (804) 444-9557.

In the example; a profile of a contaminate level in 3 sampling wells is drawn perpendicular to the flow and the pounds of leachate from the dump per day is computed.

FIG 1

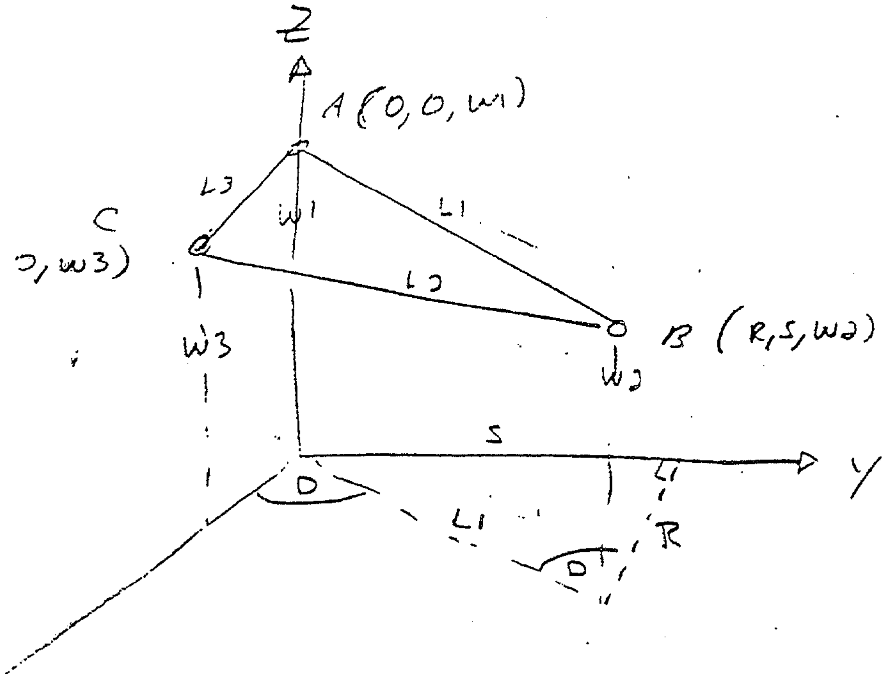

FIG 2

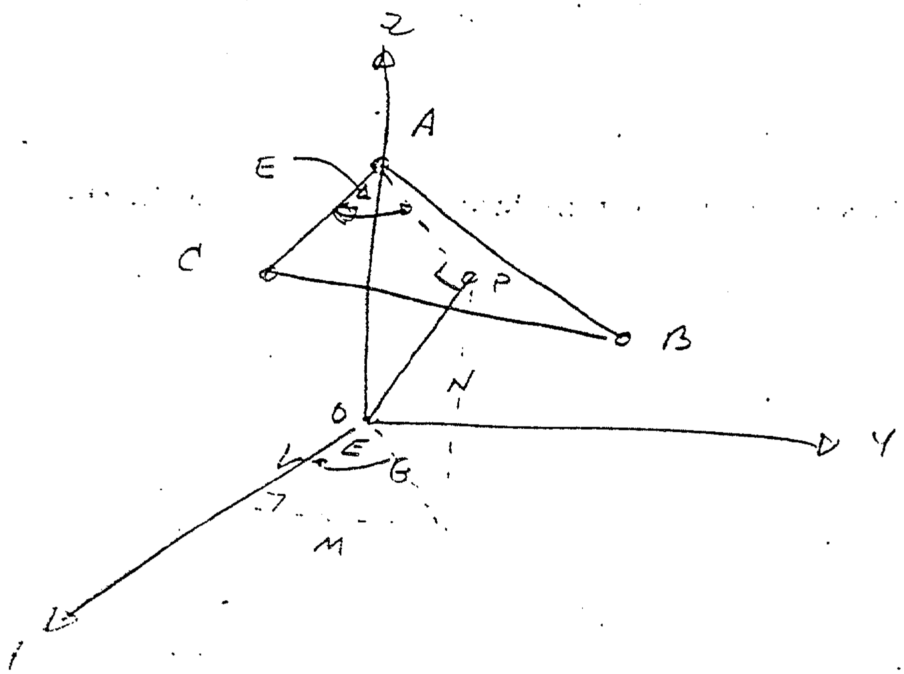

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FIG 4

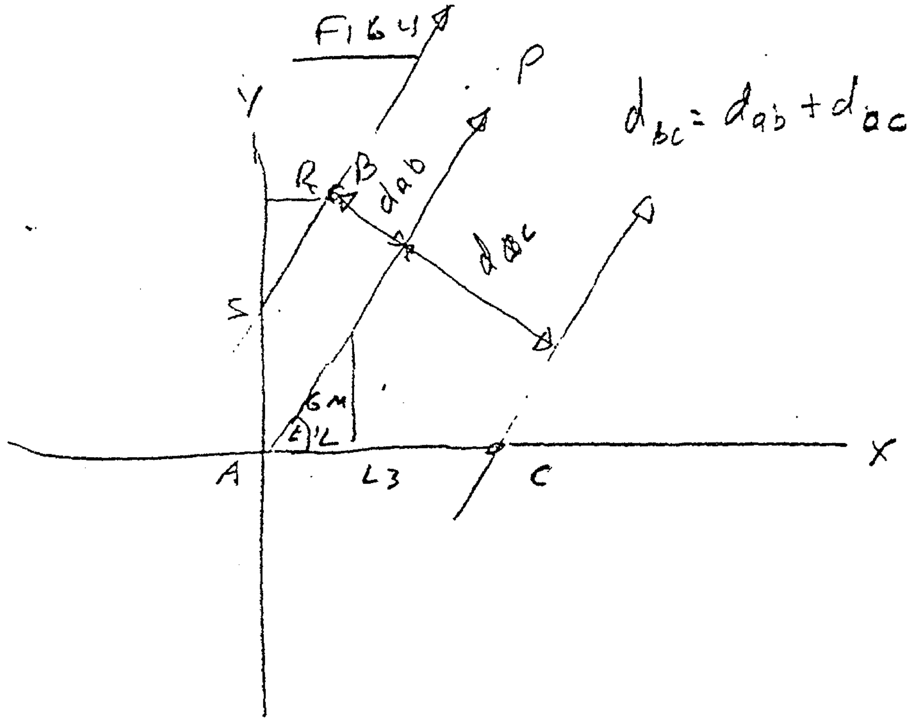
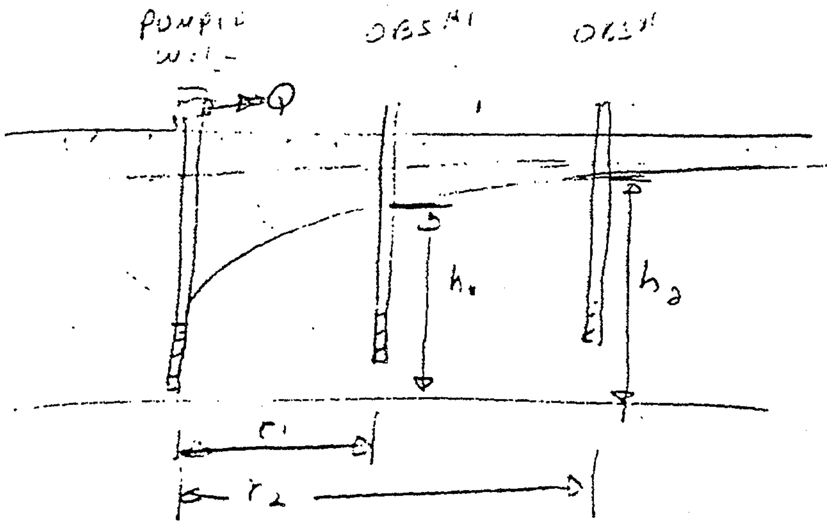


FIG 3



```
10 CLS
20 CLEAR 5000
30 READ WL$,PR,P1
35 P9=PR
40 READ L1,L2,L3
50 READ E1,E2,E3
60 'GOSUB 1720
70 IF P1=0 THEN  GOTO 1050  'PUMP TEST
80 PRINT ,"WELL A","WELL B","WELL C"
90 PRINT "ELEVATION (FT)",E1,E2,E3
100 IF PR = 1 GOTO 150
110 LPRINT ,"WELL A","WELL B","WELL C"
120 LPRINT "ELEVATION (FT)",E1,E2,E3
150 PRINT "DISTANCE","A-B","B-C","C-A"
160 PRINT "FEET",L1,L2,L3
170 PRINT : PRINT
180 IF PR/= 1 GOTO 220
190 LPRINT "DISTANCE","A-B","B-C","C-A"
200 LPRINT "FEET",L1,L2,L3
210 LPRINT : LPRINT
220 INPUT "PRESS ENTER TO CONTINUE";Z$
230 CLS
235 PR=1
240 'GOSUB 1720
245 PR=P9
250 INPUT "DEPTH TO WATER (FEET) - WELL A = ";D1
260 INPUT "DEPTH TO WATER (FEET) - WELL B = ";D2
270 INPUT "DEPTH TO WATER (FEET) - WELL C = ";D3
280 INPUT "DEPTH OF FLOW (FEET) = ";AD
290 W1 = E1-D1
300 W2 = E2-D2
310 W3 = E3-D3
320 IF PR = 1 GOTO 370
330 LPRINT "DEPTH TO WATER (FEET) - WELL A";D1
340 LPRINT "DEPTH TO WATER (FEET) - WELL B";D2
350 LPRINT "DEPTH TO WATER (FEET) - WELL C";D3
360 LPRINT "DEPTH OF FLOW = ";AD;" FEET"
370 X#=(L1*L1+L3*L3-L2*L2)/(L1*L3*2)
380 AL=-ATN(X#/SQR(-X#*X#+1))+1.5708
390 S# = L1*SIN(AL)
400 R# = L1*COS(AL)
405 K# = L3#*S#*W1
407 IF K# = 0 THEN K# = 1
410 L# = S#*(W3-W1)/K#
420 M# = (L3*(W2-W1)+ R#*(W1-W3))/K#
430 IF L#=0 AND M#=0 THEN CLS:PRINT"WATER TABLE IS FLAT, NO FLOW": GOTO 80
440 N# = -S#*L3/K#
450 G# = SQR(M#*M#+L#*L#)
460 'PRINT"L";L#;"M";M#;"N";N#;"G";G#;"M/G";M#/G#;:INPUTZ$
470 SL = -G#/N#
```

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```
480 IF L#=0 THEN BA=90:GOTO 530
490 BT# = M#/G#
500 BT = (ATN(BT#/SQR(-BT#*BT#+1)))*57.3
510 'PRINT"ANGLE =";BT:INPUTZ$
520 IF L#>0 THEN BA =180-ABS(BT) ELSE BA = BT
530 PRINT
540 PRINT  "WATER SLOPE= ";:PRINT  USING ".#####";SL;:PRINT  " FEET/FOOT"
550 V = P1 * SL
560 PRINT "FLOW RATE - ";:PRINT  USING "###.####";V;:PRINT " FEET/DAY"
570 IF M#>0  THEN  D$="RIGHT" ELSE D$="LEFT"
580 BA = ABS(BA)
590 PRINT "FLOW DIRECTION ";:PRINT  USING "###.# ";BA;:PRINT " DEGREES TO ";D
 OF LINE /A-C"
600 IF PR=1 GOTO 640
605 LPRINT
610 LPRINT  "WATER SLOPE= ";:LPRINT  USING ".#####";SL;:LPRINT  "  FEET/FOOT"
620 LPRINT "FLOW RATE - ";:LPRINT  USING "###.####";V;:LPRINT " FEET/DAY"
630 LPRINT "FLOW DIRECTION ";:LPRINT  USING "###.# ";BA;:LPRINT "  DEGREES TO
$;" OF LINE  A-C"
640 PRINT
650 IF L# = 0 THEN L# = 1E-6
660 S9# = SQR(ABS(1+M#*M#/(L#*L#)))
670 PRINT S9$
680 T1 = ABS(S#-K#*M#/L#)/S9# : F1 = V*T1*AD
690 T1 = INT(T1+.5) : F1 = INT(F1+.5)
700 T2 = ABS((K#-L3)*M#/L#-S#)/S9# : F2 = V*T2*AD
710 T2 = INT(T2+.5) : F2 = INT(F2+.5)
720 T3 = ABS(L3*M#/L#)/S9# : F3 = V*T3*AD
730 T3 = INT(T3+.5) : F3 = INT(F3+.5)
740 T1$="          "
750 T2$=T1$
760 T3$=T1$
770 F1$=T1$
780 F2$=T1$
790 F3$=T1$
800 RSET T1$ = STR$(T1)
810 RSET T2$=STR$(T2)
820 RSET T3$ = STR$(T3)
830 RSET F1$=STR$(F1)
840 RSET F2$=STR$(F2)
850 RSET F3$=STR$(F3)
860 PRINT
870 PRINT"FLOW PATHS BETWEEN WELLS"
880 PRINT  "WELLS","WIDTH BETWEEN","FLOW BETWEEN"
890 PRINT  "","WELLS (FEET)","WELLS ( CUBIC FEET/DAY )"
900 PRINT  "A & B",T1$,F1$
910 PRINT  "B & C",T2$,F2$
920 PRINT  "C & A",T3$,F3$
930 PRINT
940 PRINT
```

```
941 IF PR = 1 GOTO 1020
946 LPRINT:LPRINT
950 LPRINT"FLOW PATHS BETWEEN WELLS"
955 LPRINT
960 LPRINT "WELLS","WIDTH BETWEEN","FLOW BETWEEN"
970 LPRINT "","WELLS (FEET)","WELLS ( CUBIC FEET/DAY )"
980 LPRINT "A & B",T1$,F1$
990 LPRINT "B & C",T2$,F2$
1000 LPRINT "C & A",T3$,F3$
1010 LPRINT:LPRINT
1020 INPUT "PRESS ENTER FOR ANOTHER RUN";Z$
1030 CLS
1040  GOTO  10
1050 PRINT "WELLFIELD - ";WL$
1054 IF PR = 1 GOTO 1070
1056 LPRINT:LPRINT
1060 LPRINT "WELLFIELD - ";WL$
1070 INPUT "PUMPED WELL (A,B,C)=";W$
1080 PRINT "PUMPED WELL = ";W$
1090 IF W$<>"A" THEN 1190
1100 IF L3<L1 THEN 1150
1110 R1=L1
1120 W1$="B":W2$="C"
1130 R2=L3
1140  GOTO 1300
1150 R1=L3
1160 W1$="C":W2$="B
1170 R2=L1
1180  GOTO 1300
1190 IF W$<>"B" THEN 1290
1200 IF L1<L2 THEN 1250
1210 W1$="C":W2$="A"
1220 R1=L2
1230 R2=L1
1240 GOTO 1300
1250 R1=L1
1260 R2=L2
1270 W1$="A":W2$="C"
1280 GOTO 1300
1290 IF W$<>"C" THEN PRINT "REDO":END
1300 IF L3<L2 THEN 1360
1310 R1=L2
1320 R2=L3
1330 W1$="B":W2$="A"
1340  GOTO 1380
1350 R1=L3
1360 R2=L2
1370 W1$="A":W2$="B"
```

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```
1390 IF  (R2/R1)<1.50  THEN  PRINT  "WELL DISTANCES ARE NOT DIFFERENT ENOUGH,
Y A DIF FERENT COMBINATION": GOTO  1070
1400 INPUT "PUMPED WELL DEPTH (FT)=";WD
1410 LPRINT "PUMPED WELL (";W$;") DEPTH (FT)=";WD
1420 INPUT "                  DISCHARGE (GPM)=";Q
1430 LPRINT "                 DISCHARGE (GPM)=";Q
1440 INPUT "                  STATIC WATER DEPTH (FT)=";T
1450 LPRINT "                 STATIC WATER DEPTH (FT)=";T
1460 PRINT
1470 LPRINT
1480 PRINT "WELL # ";W1$;" (NEAREST) ";:INPUT "   STATIC WATER DEPTH (FT)=";T
1490 LPRINT "WELL # ";W1$;" (NEAREST) STATIC WATER DEPTH (FT)=";T1
1500 PRINT "WELL # ";W1$;:INPUT "   DRAWDOWN WATER DEPTH (FT)=";D1
1510 LPRINT "WELL # ";W1$;" DRAWDOWN WATER DEPTH (FT)=";D1
1520 PRINT
1530 LPRINT
1540 PRINT "WELL # ";W2$;" (FURTHEST)";:INPUT "   STATIC WATER DEPTH (FT)=";T
1550 LPRINT "WELL # ";W2$;" (FURTHEST) STATIC WATER DEPTH (FT)=";T2
1560 PRINT "WELL # ";W2$;:INPUT "   DRAWDOWN WATER DEPTH (FT)=";D2
1570 LPRINT "WELL # ";W2$;" DRAWDOWN WATER DEPTH (FT)=";D2
1580 S1=D1-T1
1590 S2=D2-T2
1600 H1=WD-T-S1
1610 H2=WD-T-S2
1620 CLS
1630 P1=(1055*Q*LOG(R2/R1))/(7.5*LOG(10)*(H2*H2-H1*H1))
1640 IF  P1<0  THEN  PRINT  "NEAREST WELL AND FURTHEST WELL DATA WERE ENTERED
PROPERLY  - REDO - ":  GOTO  1070
1650 PRINT "SOIL PERMEABILITY = ";P1;" GAL/SQ FEET-DAY "
1660 LPRINT "SOIL PERMEABILITY = ";P1;" GAL/SQ FEET-DAY "
1670 PRINT
1680 LPRINT
1690 PRINT "ENTER PERMEABILITY ";P1;" X TO END OF DATA LINE 1970"
1700 EDIT 1970
1710 END
1930 REM
1940 REM 1ST LINE OF DATA IS THE WELLFIELD NAME, THE PRINTER
1950 REM    STATUS (0 FOR PRINT & DISPLAY: 1 FOR DISPLAY ONLY),
1960 REM    SOIL PERMEABILITY (0 IF UNKNOWN)
1970 DATA ALLEN DUMP,0,2.52292
1980 REM 2ND LINE OF DATA ARE DISTANCES (FEET) BETWEEN WELLS
1990 REM    A-B, B-C, C-A
2000 DATA 475,385,282
2010 REM 3RD LINE OF DATA ARE THE ELEVATIONS OF THE TOPS OF
2020 REM   WELLS A,B,C -(FEET ABOVE MEAN SEA LEVEL)
2030 DATA 22.62,25.04,21.22
```

CLW

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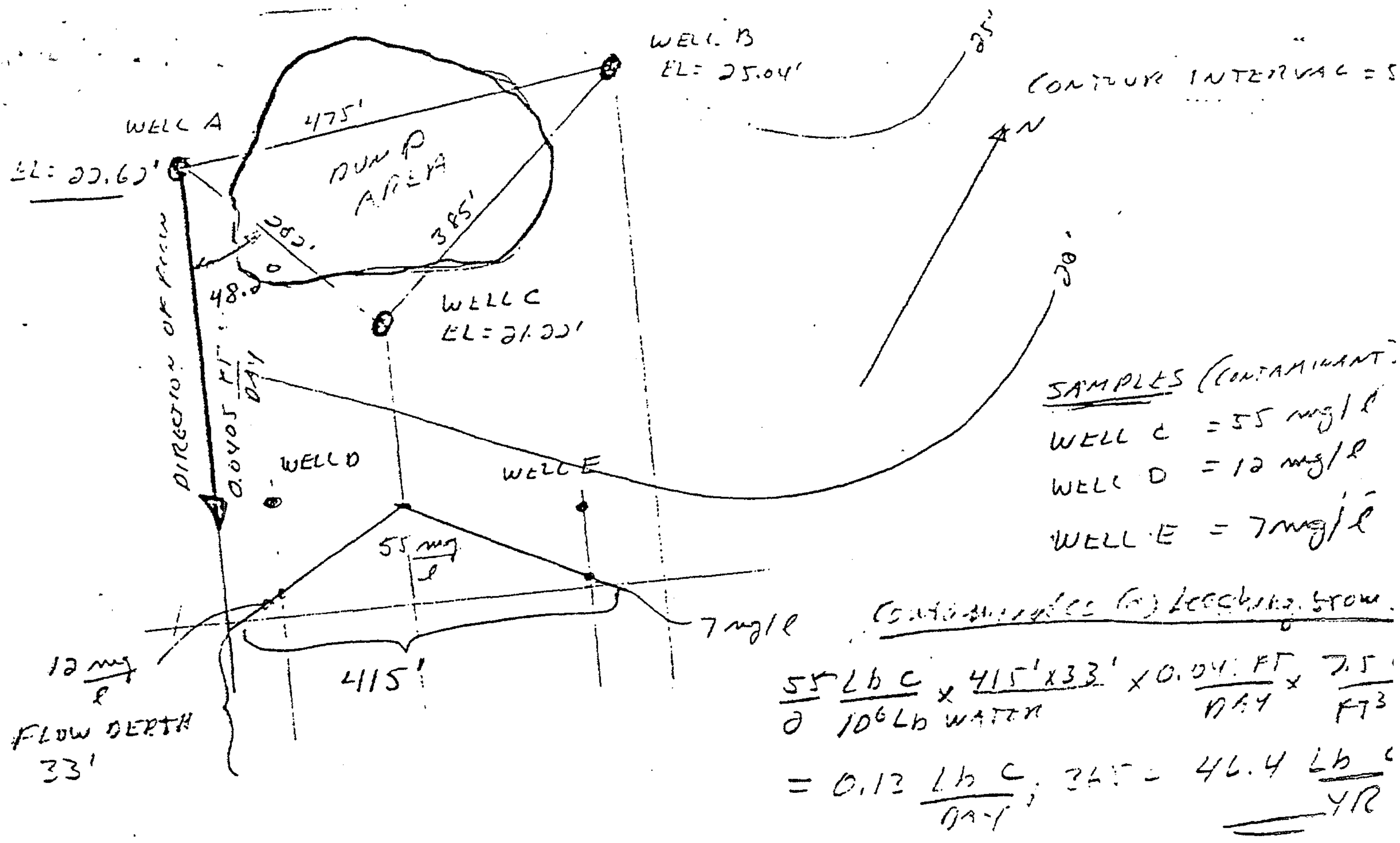

	WELL A	WELL B	WELL C
ELEVATION (FT)	22.62	25.04	21.22
DISTANCE	A-B	B-C	C-A
FEET	475	385	282

DEPTH TO WATER (FEET) - WELL A 22.25
DEPTH TO WATER (FEET) - WELL B 23.04
DEPTH TO WATER (FEET) - WELL C 23.87
DEPTH OF FLOW = 33 FEET

WATER SLOPE= .01606 FEET/FOOT
FLOW RATE - 0.0405 FEET/DAY
FLOW DIRECTION 48.2 DEGREES TO RIGHT OF LINE A-C

FLOW PATHS BETWEEN WELLS

WELLS	WIDTH BETWEEN WELLS (FEET)	FLOW BETWEEN WELLS (CUBIC FEET/DAY)
A & B	464	621
B & C	254	339
C & A	210	281

DRAFT

MILESTONE CHART

Milestone	Day
Government Issuance of Change Order	0
Submit POA&M and Safety/Contingency Plan for Characterization Effort	10
Government Approval of POA&M and Safety/Contingency Plan	17
Initiate Characterization On-Site Investigations for Contaminated Potable Wells	60
Initiate Round Two Sampling, Verification Step	60
Initiate Potable Well Sampling	60
Submit Report with Round Two Results, Potable Well Results	105
Return of Government Comments	135
Complete Characterization On-Site Investigation	150
Submit Draft Report with Characterization Step Results	180
Return of Government Comments	210
Submit Draft Feasibility Step Report	270
Return of Government Comments	300

Attachment C