Engineering Notebook

Chilco™

Vincent Childress

March 7 - _____

TABLE OF CONTENTS

DATE: WITNESS:

TABLE OF CONTENTS CONTINUED

ACTIVITY TITLE & PROJECT **PAGE**

DATE: WITNESS:

PROJECT: IRRIGATION

ACTIVITY: <u>IDENTIFICATION OF NEED</u>

IRRIGATE 500 TREES W/1 GAL. OF WATER EACH.

COMMUNITY OWNED OLIVE GROVE.

GOVERNMENT GRANT PROVIDES UP TO $45,000 FOR CONSTRUCTION WATER TOWER SUPPORT STRUCTURE ONLY. LEFTOVER FUNDS MUST BE RETURNED.

COMMUNITY PAYS WORKER'S WAGE

WATERING W/BUCKETS IS NOT WORKING.

COMMUNITY WANTS TO USE A TANK IN THE SOLUTION BECAUSE IT CAN BE USED FOR WATER STORAGE WHEN NO IRRIGATION IS NEEDED.

DATE: WITNESS:

ACTIVITY: **DEFINITION OF THE PROBLEM**

CRITERIA: WATER 500 TREES; 1 GAL./TREE
HOSE MUST REACH 500 m
HOST MUST BE FLEXIBLE
OPTIMIZE FOR COST

USE "APPROPRIATE TECHNOLOGY" THAT IS LOW COST, LOW MAINTENANCE MINIMAL TRAINING, LOW ENERGY…

CONSTRAINTS: 7 HOURS TO WATER 500 TREES
MUST BE GRAVITY FED/NO PUMP
TOWER STRUCTURE = $1,000/VERT. FT.
TOTAL TOWER BUDGET = $45,000
TERRAIN SLOPES 1˚ TOWARD TOWER

MOTOR & PUMP TO FILL TANK IS SEPARATE JOB.

SPECIFICATIONS: TANK CAPACITY = 500 GAL. MIN.
TOWER & TANK HEIGHT = ?
HOSE LENGTH = 500 m
HOSE DIA. = ?

REVISION TO SPECS AFTER OPTIMIZATION: SEE PAGES 10 – 13.

HOSE DIA. = ¾"

TOWER & TANK HEIGHT = h_{min} + (h=(500) tan(1˚)+ TANK

54.44' = 0.32' + 28.65' + 25.47'

DATE: WITNESS:

ACTIVITY: SEARCH

EXISTING SOLUTION COMPONENTS:

HOSE: ½" I.D. $0.50/M
¾" I.D. $1.00/M
1" I.D. $10.00/M

PIPE: PIPE & MANIFOLD SYSTEM TO DISTRIBUTE WATER = $1.00/$m^2$

TOWER STRUCTURE: WELDED STRUCTURAL PIPE = $1,000/VERT. FT.

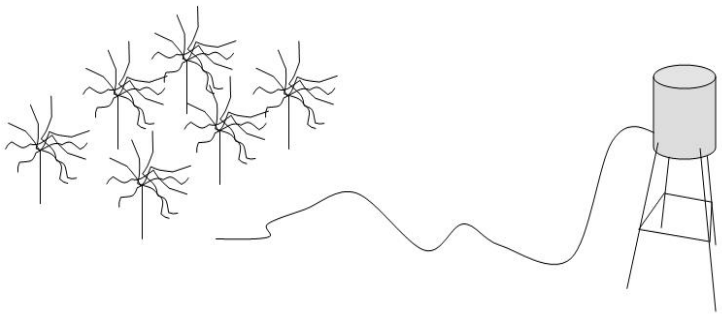
TANK: WELDED STEEL SHEET; @ SALVAGE = $200/VERT. FT.

DATE: WITNESS:

ACTIVITY: <u>DEVELOP DESIGNS</u>

<u>BRAINSTORM ALTERNATIVE SOLUTIONS</u>

DESIGN A: TOWER, TANK, & HOSE ONLY

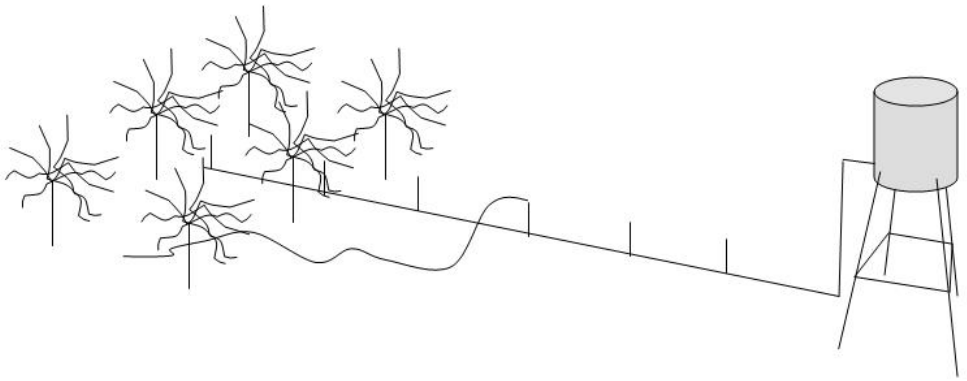


<u>DESIGN A1</u>: ½" HOSE

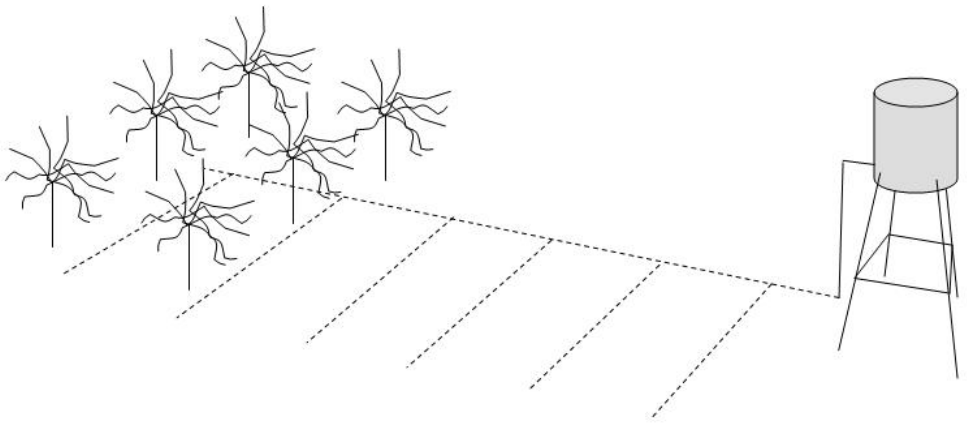
<u>DESIGN A2</u>: ¾" HOSE

<u>DESIGN A3</u>: 1" HOSE

DESIGN B: TOWER, TANK, & PIPE MANIFOLD W/ ROUTED PLUMBING TO HOSES



DESIGN C: SPRINKLER HEADS DISPERSED THROUGH FIELD



DATE: WITNESS:

ACTIVITY: **DEVELOP DESIGNS**

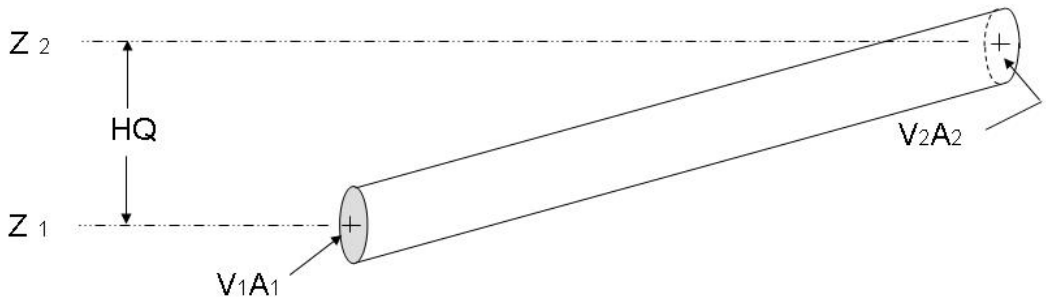
MUST GET ENOUGH WATER TO FLOW IN 7 HRS. AT LOWEST COST

DESIGN A:

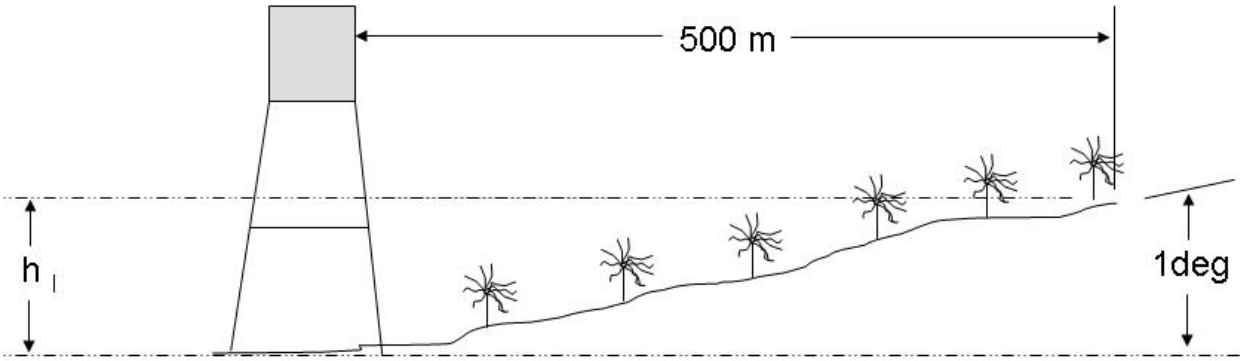
GIVEN: IN A PERFECT SYSTEM, FLOW RATE BY VOLUME (Q) IS EQUAL AT ANY 2 POINTS (1,2) SO LONG AS THE CROSS SECTIONAL AREA (A) IS THE SAME AT BOTH POINTS ($A_1 = A_2$). THIS ALSO MEANS THAT THE AVERAGE VELOCITY (V) IS EQUAL AT POINTS 1 & 2 ($V_1 = V_2 = V_0$)

$\therefore \quad Q = A_1V_1 = A_2V_2$

GIVEN: THE DIFFERENCE IN THE HEIGHT OFTHE 2 POINTS (Z) IS THE "HEAD" OR HYDRAULIC GRADIENT ($HG = Z_2 - Z_1$)



HEIGHT CONSUMED BY BACK SLOPE (h_l)



h_l = 500m x tan (1˚) = 8.73m or 28.65 ft.

DATE: WITNESS:

ACTIVITY: DEVELOP DESIGNS

ACCOUNT FOR TIME WHEN NOT WATERING & MOVING FROM TREE TO TREE: ESTIMATE = 2 HRS.

7 HRS. – 2 HRS. = 5 HRS. OF FLOW

TIME IN SEC. = 5 HRS. x 60 $^{MIN}/_{HR}$ x 60 $^{S}/_{MIN}$ = 18,000 s

NEEDED FLOW RATE: Q = 500 GAL./18,000 s

Q = .028 GALS./s

CONVERT GAL. TO CUBIC FT.

CONVERSION FACTOR = .13368 X 500 GAL = 66.84 ft^3

Q = 66.84 ft^3/18,000 s

Q = .0037 ft^3/s

CROSS SECTIONAL AREA OF HOSE: = (πr^2)

HOSE SIZE	R	R^2	π*	CROSS SECTIONAL AREA
⅛" I.D. = .125	.0625	.0039	3.14	**.012246 in^2 = .000085 ft^2 **
¼" I.D. = .25	.125	.0156	3.14	.0489 in^2 = .00034 ft^2
½" I.D. = .5	.25	.0625	3.14	.19625 in^2 = .0014 ft^2
¾" I.D. = .75	.375	.141	3.14	.44274 in^2 = .0031 ft^2
1" I.D. = 1.0	.5	.25	3.14	.785 in^2 = .00545 ft^2

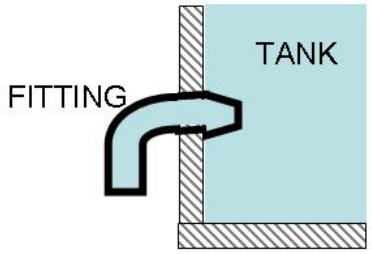
*π = 3.14 **CONVERT in^2 TO ft^2 = X^X.

DATE: WITNESS:

ACTIVITY: <u>DEVELOP DESIGNS</u>

COEFFICIENT OF VELOCITY (C_V) = .98

(C_V DESCRIBES FLOW THRU. FITTING)



<u>IGNORING FRICTION</u>

<u>REQUIRED HEAD</u> (h_W) PER HOSE DIA.: $h_W = V_0/2gC_V^2$

$V_0 = Q/A$ $2gC_V^2 = (2)(32.17)(.961) = (64.34)(.961) = 61.8$

HOSE	$Qft^3/s\ /Aft^2$	=	V_0	$V_0^2/2gC_v^2$	=	H_w
⅛"	.0037 / .000085	=	43.53	1894.9 / 61.8	=	30.66 ft.
1/4"	.0037 / .0034	=	10.88	118.4 / 61.8	=	1.9 ft.
1/2"	.0037 / .0014	=	2.64	6.9 / 61.8	=	.111 ft.
¾"	.0037 / .0031	=	1.19	1.4 / 61.8	=	.022 ft.
1"	.0037 / .00545	=	.679	.46 / 61.8	=	.007 ft.

<u>HEAD LOSS DUE TO FRICTION</u> (h_f) <u>& TOTAL HEAD</u> (h_{min})

$h_f = f(L_e/D \times V_0^2/2g) = f \times f_{tube} = \underline{f(L_e/D \times h_w)}$

f IN CHART BELOW IS GIVEN.

HOSE	$f \times (L_e/D^* \times h_w)$	=	$h_f + h_w$	=	H_{min}
⅛"	.014 x (4000 x 30.66)	=	1716.96 + 30.66	=	1747.62 ft.
1/4"	.016 (2000 x 1.9)	=	60.8 + 1.9	=	62.7 ft.
1/2"	.018 (1000 x .111)	=	1.998 + .111	=	2.1 ft.
¾"	.02 (666.6 x .022)	=	.293 + .022	=	<u>.032 ft.</u>
1"	.021 (500 x .007)	=	.0735 + .007	=	.08 ft.

*L_e = HOSE LENGTH = 500m D = HOSE DIA.

DATE: WITNESS:

ACTIVITY: <u>ANALYSIS OF ALTERNATIVES</u>

<u>PREDICTIVE ANALYSIS</u>: 5 HR. WATERING TIME

FLOW RATE AS WATER LEVEL DROPS

$$\text{TIME} = \frac{2A_t\,(\sqrt{h_1} - \sqrt{h_2})}{C_d\, a_0\, \sqrt{2g}}$$

TANK DIM.

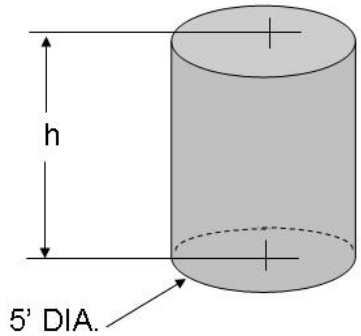
DIA.= 5 ft.
R = 2.5 ft.

TANK VOLUME = $\pi r^2 h$

HEIGHT (h) = 25.47 ft.

v = (3.14)(6.25)(25.47)

v = 500g.



A_t = CROSS SECTIONAL AREA OF TANK = πr^2 = 78.5 ft^2

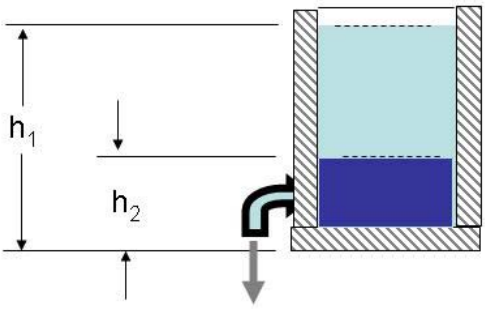
h_1 = 25.48 ft.

h_2 = 1 ft.

A_o = CROSS SECTIONAL AREA OF HOSE (ft^2)

C_d = FLOW COEF. OF FITTING = .97

g = ACCEL. GRAVITY = 32.17



<u>¼" HOSE</u>:
A_0 = .0034

$$\text{TIME} = \frac{2A_t\,(\sqrt{25.48} - \sqrt{1})}{(.97)(.0034)\sqrt{(2)32.17}} = \frac{635.85}{.0026}$$

TIME = 244557s

TIME = **<u>67 hrs.</u>**

DATE: WITNESS:

ACTIVITY: ANALYSIS OF ALTERNATIVES

PREDICTIVE ANALYSIS:

½" HOSE TIME = $\frac{635.85}{(.97)(.0014)(8.02)}$ = 63585 s
A_0 = .0014

TIME = **17.66 Hrs**

¾" HOSE TIME = $\frac{635.85}{(.97)(.0031)(8.02)}$ = 26493 S
A_0 = .0031

TIME = **7.3 HRS**

1" HOSE TIME = $\frac{635.85}{(.97)(.00545)(8.02)}$ = 15193 s
A_0 = .00545

TIME = **4.2 hrs**

DATE: WITNESS:

ACTIVITY: DECISION

OPTIMIZE FOR COST DESIGNS A1, A2, A3

TOWER: (28.65 ft + .32 ft) = 28.97 ft. x $1,000 = $28970

DESIGN A3: HOSE, 1": $10/m x 500m = $5,000

DESIGN A3: HOSE, ¾": $1/m x 500m = $500

DESIGN A1: HOSE, ½": $.50/M X 500M = $250

TANK: $200/vert. ft. x 25.48 ft. = $5096

IMPORTANCE OF CRITERIA (WEIGHT)

COST = 50%
TIME = 35%
EASY USE = 10%
MAINTENANCE = 5%

RATING = 1 TO 10

DESIGNS B & C ARE OUT: HIGH COST & HIGH MAINTENANCE

DECISION MATRIX

CRITERIA	WEIGHT	DESIGN A1	**DESIGN A2**	DESIGN A3
COST	50 x R	R = 9 450	R = 7 350	R = 2 100
TIME	35 x R	R = 2 70	R = 7 245	R = 9 315
EASE	10 x R	R = 8 80	R = 7 70	R = 6 60
MAINTENANCE	5 x R	R = 9 45	R = 9 45	R = 9 45
TOTAL	100	Σ = 645	**Σ = 710**	Σ = 520

DESIGN A2 IS BEST W/ SOME TRADE OFF.

DATE: WITNESS:

ACTIVITY: <u>TEST & VERIFY PROTOTYPE</u>

<u>SCALE MODEL</u> TO 1:100 SCALE (DESIGN A2)

500 TREES REDUCES TO <u>5</u> TREES

500G REDUCES TO <u>5G</u>

TOWER HEIGHT = h_{min} + HEIGHT OF SLOPE

= 54.44' REDUCES TO 5.44'

IF 12"/10 = 1.2"
THEN 1.2" = .1' 1.2" x 5.4 = 6.48" = **<u>6 ½"</u>**

TIME = 7.3 HRS. /100 = .073 HRS. x 60 = 4.38 min
4.38 min x 60 = <u>262.8 sec</u> TOTAL

GAL./TREE = 1G/100 = 1/100 g = ? oz.
CONVERSION FACTOR = 153.721
= .01G x 153.721 = **<u>1.5 oz.</u>**

HOSE LENGTH REDUCES TO <u>5m</u>.

FILL CUP TO 7.5 OZ. (5 TREES x 1.5 OZ.)

IN 260s.

USE 5 GAL. BUCKET W/h_{min} @ 6 ½"

HOSE: SMALLEST POSSIBLE
(CANNOT REALLY SCALE HOSE @ 1:100)

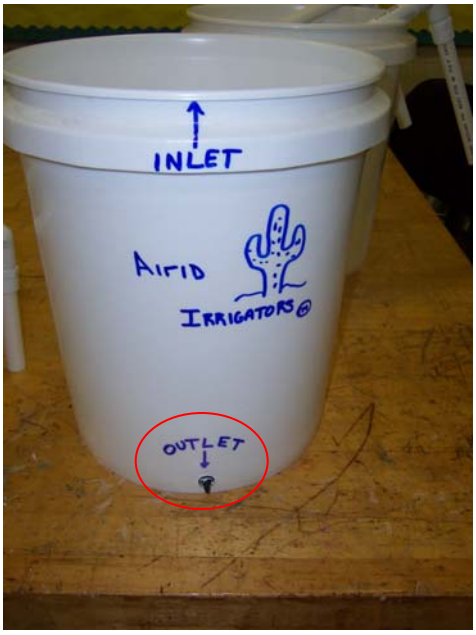
DATE: WITNESS:

ACTIVITY: <u>TEST & VERIFY PROTOTYPE</u>

MAKE TOWER W/ PVC PIPE & FITTINGS & TUBING

6.5”

TOWER STRUCTURE



TANK

SUPPLIES

DATE: WITNESS:

ACTIVITY: <u>COMMUNICATION PLAN</u>

EXPLAIN TO COMMUNITY: CRITERIA
CONSTRAINTS
SPECIFICATIONS
DECISION MATRIX
TRADE-OFFS

DATE: WITNESS: