WATERFLOOD EVALUATION

PROPOSED VIRDEN ROSELEA UNIT NO. 2

VIRDEN ROSELEA FIELD

MANITOBA

PRODUCING, CALGARY DIVISION
JUNE 1965

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PROPOSED VIRDEN ROSELEA UNIT NO. 2

VIRDEN ROSELEA FIELD, MANITOBA

SUMMARY:

I. INTRODUCTION

The purpose of this study was to investigate the feasibility of secondary recovery of oil by waterflooding the Mississippian limestone reservoir in a proposed portion of the Virden Roselea Field. See Figure 1.

II. FINDINGS

1. The estimated original oil-in-place from volumetric calculations within the proposed waterflood area was 13,200,000 barrels.

2. * The indicated ultimate primary production from the proposed area is 1,700,000 barrels or 12.9% of the original oil-in-place. The estimated cumulative production for the area to January 1, 1966 will be 1,000,000 barrels or 7.6% of the original oil-in-place.

3. The bottom hole pressure in the developed area has declined to an estimated average pressure of less than 400 PSI.

4. Waterflood calculations indicate a total ultimate primary plus secondary recovery of 4,600,000 barrels or 35% of the original oil-in-place in the proposed waterflood area. This is an increase of 2,900,000 barrels over the ultimate primary recovery.

III. CONCLUSION

The area outlined in Figure 1 should be waterflooded as increased ultimate recovery and increased production rates can be realized.

* Estimated Remaining Primary Oil on Leases 1 to 13 incl.
as at 10/31/65 = 874,000 bbls.

Cumulative Production " " " = 1,054,000

PROPOSED VIRDEN ROSELEA UNIT NO. 2

WATERFLOOD EVALUATION

This report is a waterflood evaluation of the proposed Virden Roselea Unit No. 2 area. The area of proposed waterflooding is outlined on Figure 1. For greater detail in methods used, reference can be made to a report entitled "Waterflood Evaluation - Virden Roselea Field - Manitoba" dated September 1963, which was prepared for the Virden Roselea Unit No. 1.

GENERAL:

The majority of the wells in the proposed waterflood area were drilled during 1960, with the final completion being 8-36-10-26 during September 1961. This well is currently a salt water disposal well.

There are 34 wells in the proposed waterflood area of which 23 belong to The California Standard Company; 5 to Paradise Petroleums Ltd., 2 to Continental Leaseholds Ltd., 2 to K & N Oil Development; and 2 to Shannon Oils Ltd. Most of the wells were completed by cementing 4½" production casing at the top of the Crinoidal zone leaving the Crinoidal, Oolitic and Cherty zones open. The wells were initially completed with an acid wash and squeeze. Only one of the wells was hydraulically fractured.

Due to a depleted reservoir condition, re-stimulation in recent years has generally proved ineffective.

ISOPACHS:

In the evaluation the reservoir was treated as three separate zones for oil-in-place determination. The three zones considered are the Crinoidal, Oolitic and Cherty zones. The Sandhill member is considered ineffective within the proposed area. Ten of the wells in the proposed waterflood area have core analyses although they are not all complete.

Separate pay isopachs, based on core analyses, core descriptions, and log interpretations have been prepared for each of the three zones. These are presented in Figures 2, 3 and 4 for the Crinoidal, Oolites and Cherty zone respectively. Figure 5 represents a total pay isopach.

ORIGINAL OIL-IN-PLACE:

The isopachs were planimetered to give the average pay thickness for each zone. An average footage weighted porosity was obtained for each zone from available core analyses in the area. The values used for the initial water saturation were those obtained for the Virden Roselea Unit No. 1. A formation volume factor of 1.05 bbl./bbl. was also used.

The results are as follows:

Zone	Average Pay Thickness	Average Porosity	Subsurface Area(Acres)	Initial Water Saturation
Cherty	13.9 feet	13.2%	1,360	52%
Oolitic	5.4	11.8	1,240	52
Crinoidal	4.0	9.1	1,200	52
TOTAL	23.3		1,360	

The original oil-in-place calculations for each of the three zones are as follows:

Cherty Zone:

$$N = 7758\ (.132)(18850)(0.48)(1/1.05)$$
$$= 8{,}800{,}000 \text{ barrels,}$$

or using average figures:

$$N = 7758\ (.132)(40)(.48)(1/1.05)$$
$$= 18{,}700 \text{ barrels/ft./40 acre lease,}$$

$$\text{or } N = 7758\ (.132)(.48)(1/1.05)$$
$$= 467 \text{ bbls/acre-foot.}$$

Oolitic Zone:

$$N = 7758\ (.118)(6650)(0.48)(1/1.05)$$
$$= 2{,}800{,}000 \text{ barrels,}$$

$$\text{or } N = 7758\ (.118)(40)(.48)(1/1.05)$$
$$= 16{,}700 \text{ bbls/ft./40 acre lease,}$$

$$\text{or } N = 7758\ (.118)(.48)(1/1.05)$$
$$= 417 \text{ bbls/acre-foot.}$$

Crinoidal Zone:

$$N = 7758\ (.091)(4820)(0.48)(1/1.05)$$
$$= 1{,}600{,}000 \text{ barrels,}$$

$$\text{or } N = 7758\ (.091)(40)(0.48)(1/1.05)$$
$$= 12{,}900 \text{ bbls/ft./40 acre lease,}$$

$$\text{or } N = 7758\ (.091)(.48)(1/1.05)$$
$$= 322 \text{ bbls/acre-foot.}$$

A summary of the original oil-in-place and their relative amounts are as follows:

	Oil-in-Place	Percent of Total
Cherty Zone	8,800,000	67%
Oolitic Zone	2,800,000	21%
Crinoidal Zone	1,600,000	12%
TOTAL	13,200,000	100%

PRIMARY PERFORMANCE:

An estimate of primary performance was made employing a rate versus time plot for the total proposed waterflood area (see Figure 6). The indicated ultimate primary recovery is 1,700,000 barrels or 12.9% of the original oil-in-place. The indicated remaining primary recoverable reserves will be 700,000 barrels as of January 1, 1966, which is the assumed date of waterflooding. The estimated cumulative production for the area to January 1, 1966, will be 1,000,000 barrels or 7.6% of the estimated original oil-in-place.

WATERFLOOD RECOVERY PREDICTION:

The waterflood recovery prediction was based on a combination of Welge's[1] displacement efficiency concept, Dykstra and Parsons[2] vertical sweep efficiency or permeability variation efficiency, and the concept of areal sweep efficiency in pattern flood as explained by Caudle, Erickson and Slobod[3] and Dyes, Caudle and Erickson[4]. The various efficiencies were found as functions of the water-oil ratios and were combined to yield the effective recovery of the waterflood.

Assumptions made in the prediction are that the economic limit will be 7 BOPD/well and that the area will be produced to a water-oil ratio of 10.5:1. It was assumed that the recovery efficiency within the Crinoidal and Oolitic zones would be the same as the calculated recovery efficiency for the Cherty zone.

Assuming that waterflooding is initiated on January 1, 1966, the remaining oil-in-place at start of flood is 12,200,000 barrels. The predicted recovery to breakthrough is 1,650,000 barrels or 12.5% of the original oil-in-place or 13.5% of the oil-in-place at the beginning of the flood. The ultimate oil recovery under waterflood operation is estimated at 3,600,000 barrels or 27.4% of the original oil-in-place. The predicted total recovery would be composed of 1,000,000 barrels of primary oil production to January 1, 1966 and 3,600,000 barrels of oil recovered under waterflood operations for a total of 4,600,000 barrels or 35% of the original oil-in-place.

INJECTIVITY AND FLOOD PATTERN:

The proposed flood pattern for the area is indicated on Figure 7. It consists of a five-spot pattern with some modification in the southern portion of the area. The average well injectivities in the north are considerably lower than in the south, thus in the northern portion, a denser injection pattern is proposed.

The water injectivity rates were calculated using a formula derived from Darcy's flow formula. The formula employed is presented below:

$$Q = \frac{0.003541\ K_w h \Delta P}{\mu \beta (\ln d/r_w - 0.6190)}$$

where

- Q = injection rate in barrels per day.
- K_w = reservoir permeability to water, millidarcies.
- h = vertical section, feet.
- ΔP = pressure differential ($P_{surface} + P_{well\ bore} - P_{reservoir}$).
- μ = viscosity of injection water at reservoir conditions, centipoise.
- d = distance from injection well to producing well in flood pattern, feet.
- r_w = effective well bore radius, feet.

By assuming the following values the formula reduces to the simplified form shown below:

- P_{wb} = 0.433 PSI/ft. x 2100 ft. = 900 PSI.
- P_{inj} = 1100 PSI (not to exceed overburden pressure).
- P_{res} = 500 PSI (average over flood life)

- $\therefore \Delta P$ = 1100 + 900 - 500 = 1500 PSI.
- μ = 0.864 cp at reservoir temperature.
- d = 1320 feet between injector and nearest producer.
- r_w = 25 feet (radius of acidizing and fracturing assumed).

$$Q = 1.84\ K_w h$$

Where core analyses were available, they were employed in the injectivity determinations. Where core analysis were not available, the average values for the proposed waterflood area were used.

The following are the average parameters by zone for the area:

	K_{MAX}(AIR)	K_{MAX}(WATER)	INJECTIVITY(BWPD/FT)
Crinoidal	33.85	4.25	7.82
Oolites	28.78	3.50	6.44
Cherty Zone	19.55	1.95	3.59

Table 1 presents estimates of injectivities for the eleven proposed injection wells. Satisfactory injectivity for waterflooding is indicated for the proposed waterflood area.

REFERENCES:

1. WELGE, H. J.:

"A Simplified method for Computing Oil Recovery by Gas or Water Drive". Journal of Petroleum Technology, April 1952, P. 91.

2. DYKSTRA, H. and PARSONS, R. L.:

"The Prediction of Oil Recovery by Water Flood". Secondary Recovery of Oil in the United States, American Petroleum Institute 1950, P. 160.

3. CAUDLE, B. H., ERICKSON, R. A., and SLOBOD, R. L.:

"The Encroachment of Injected Fluids beyond the Normal Well Pattern". Journal of Petroleum Technology, May 1955, P. 79.

4. DYES, A. B., CAUDLE, B. H. and ERICKSON, R. A.:

"Oil Production after Breakthrough as Influenced by Mobility Ratio". Journal of Petroleum Technology, April 1954, P. 27.

ECONOMIC EVALUATION:

The economic evaluation was based on the Canadian Tax System. The major assumptions made were:

1. Reservoir response would be similar to that predicted for and currently being experienced at the North Virden Scallion Unit.
2. Waterflooding would be initiated January 1, 1966, with a peak production of 1000 BOPD reached in 1969 and maintained to 1972.
3. The secondary recovery life would be 20 years at which time production would decline to an economic limit of 240 BOPD or 7 BOPD per well.

The calculated economics based only on additional oil due to waterflooding are:

Payout	2.9 years
Rate of Return	80%
Cumulative Net Profit	$3,250,000

The estimated waterflood investment used in the evaluation was $150,000.

Figure 8 represents the cash flow for the proposed waterflood based only on additional oil due to waterflood operations.

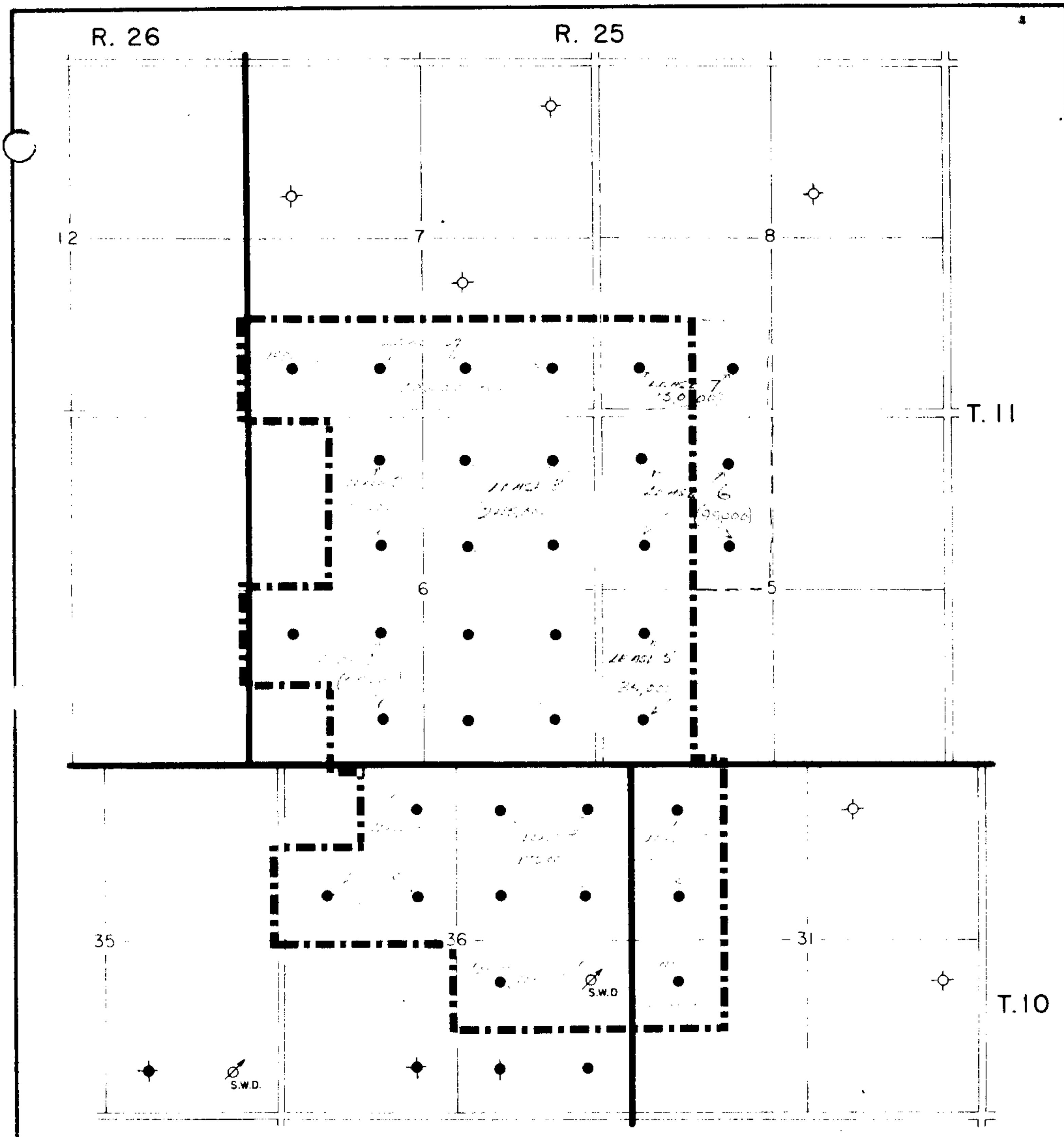


FIGURE 1

PROPOSED VIRDEN ROSELEA UNIT No. 2

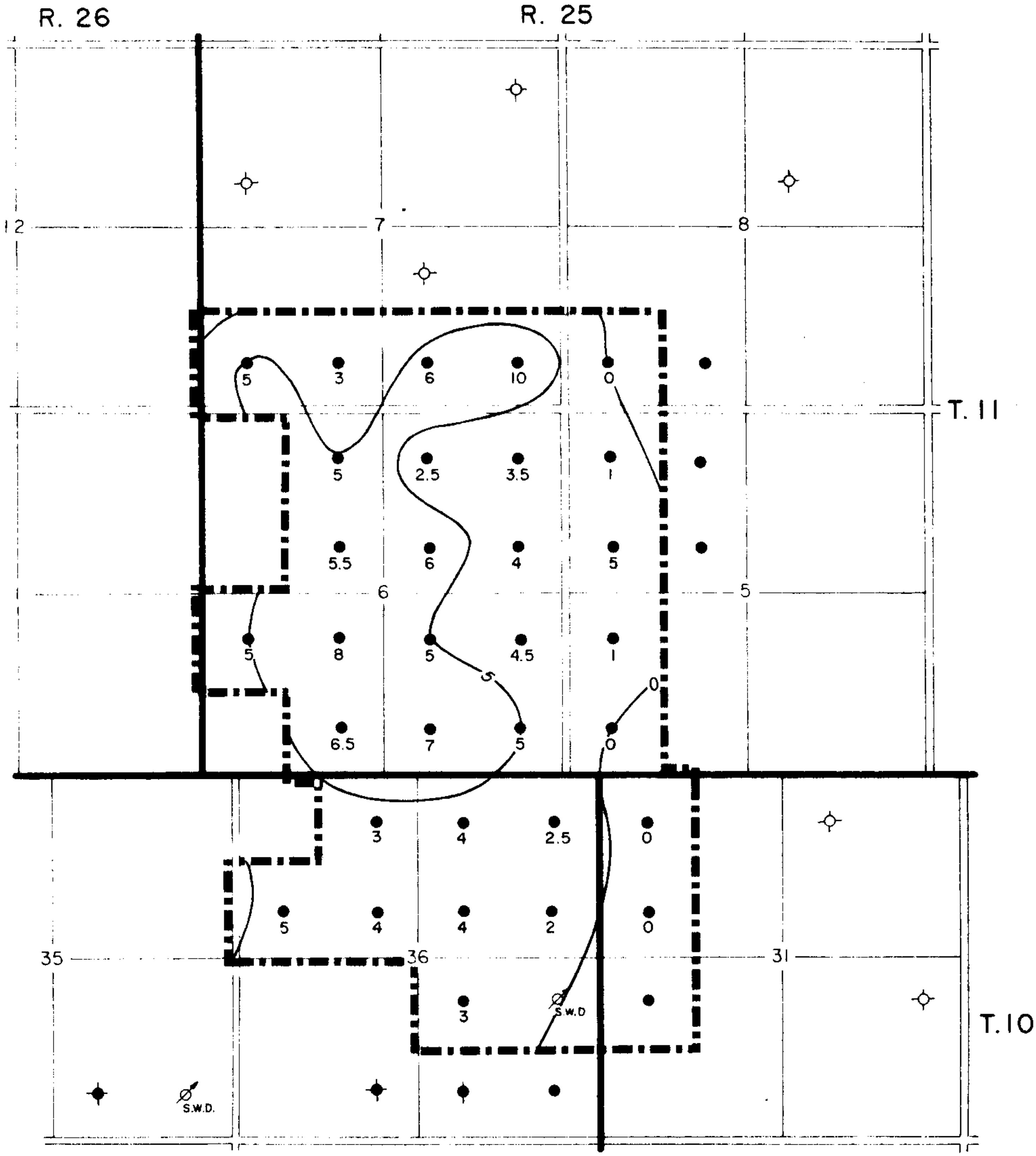


FIGURE 2

PROPOSED VIRDEN ROSELEA UNIT No. 2

CRINOIDAL ZONE PAY ISOPACH

C.I.= 5'

UNIT BOUNDARY

Scale: 1" = 2000'

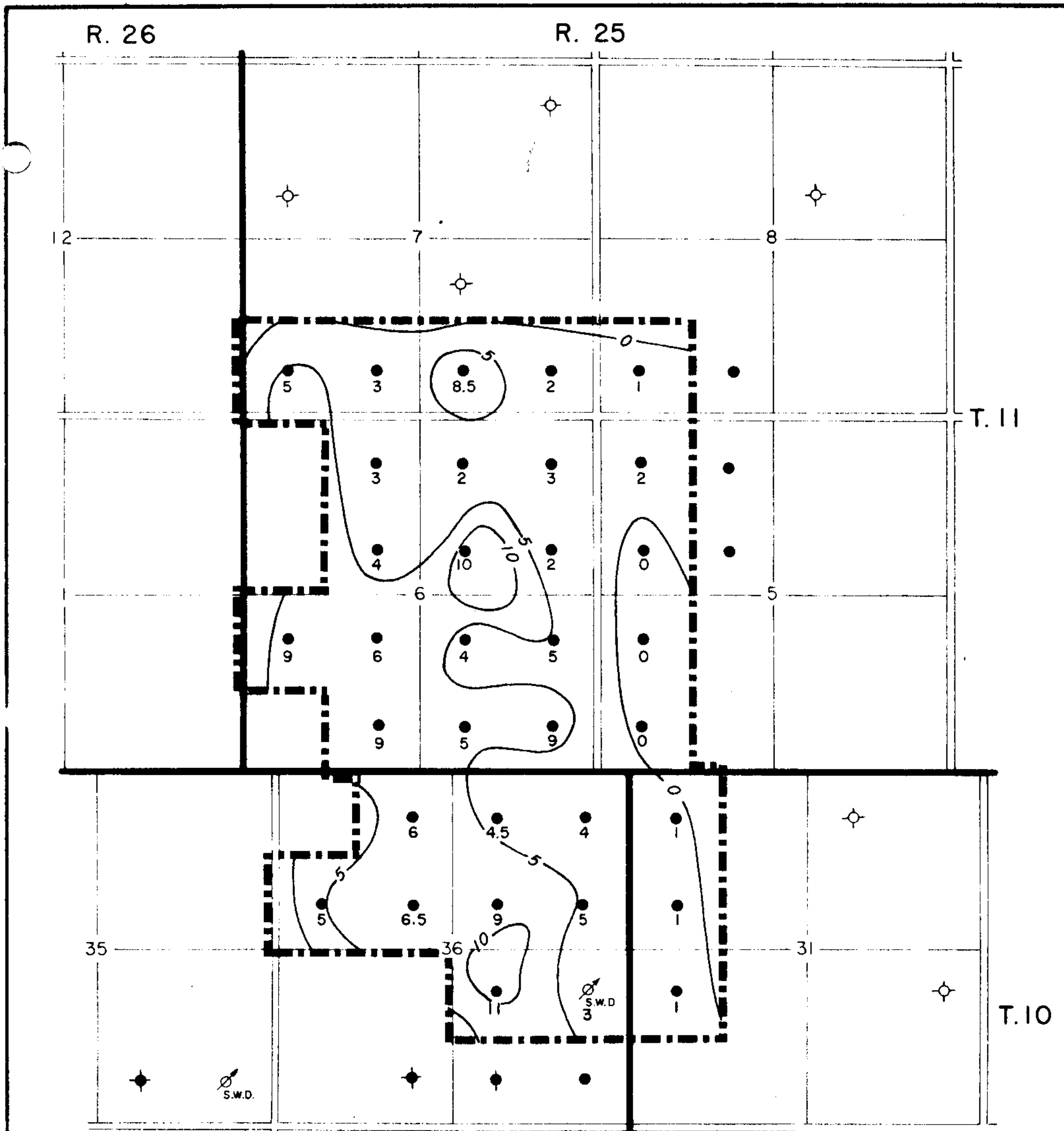


FIGURE 3

PROPOSED VIRDEN ROSELEA UNIT No. 2

OOLITIC ZONE PAY ISOPACH

C.I. = 5'

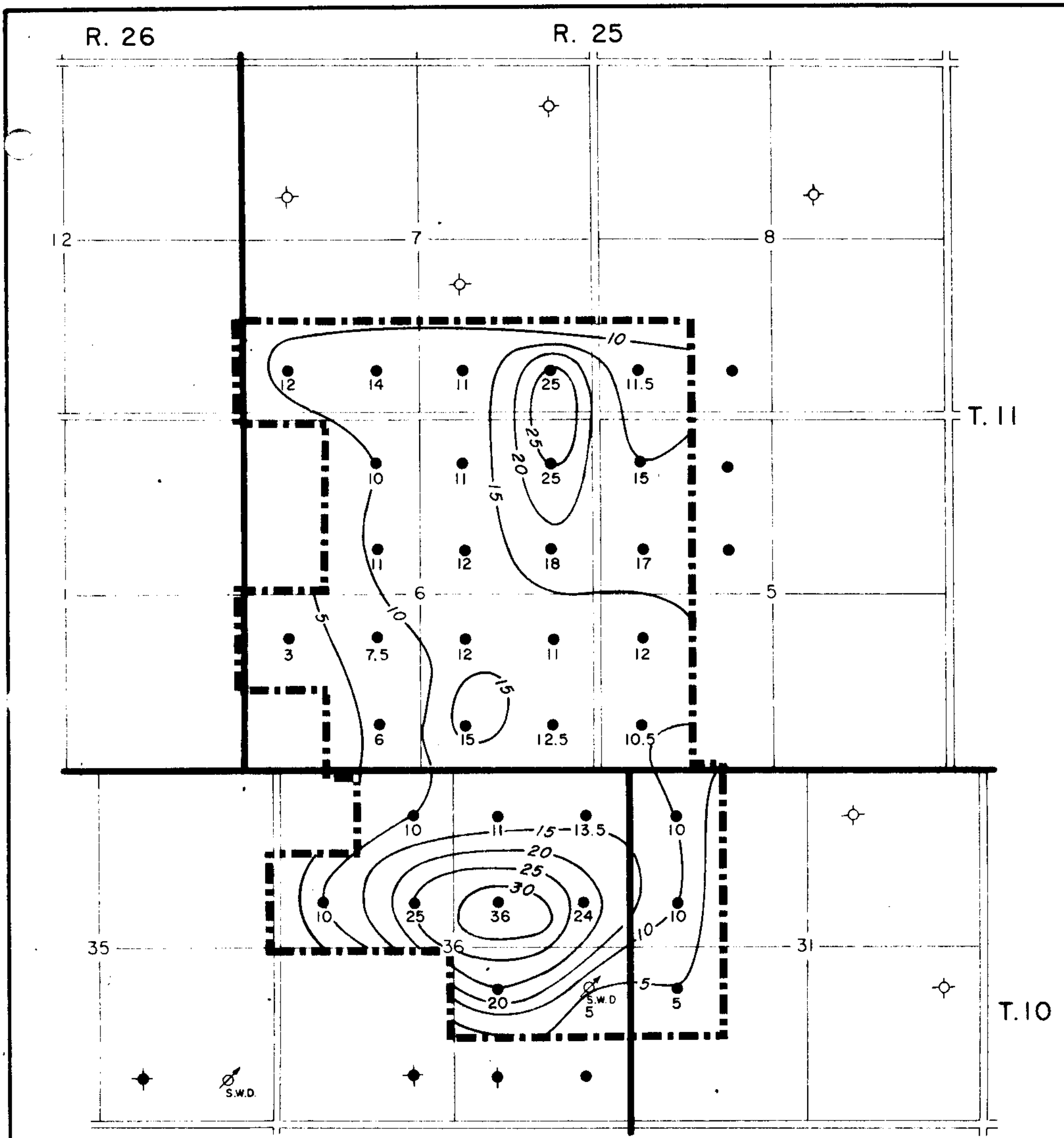


FIGURE 4

PROPOSED VIRDEN ROSELEA UNIT No. 2

CHERTY ZONE PAY ISOPACH

C. I. = 5'

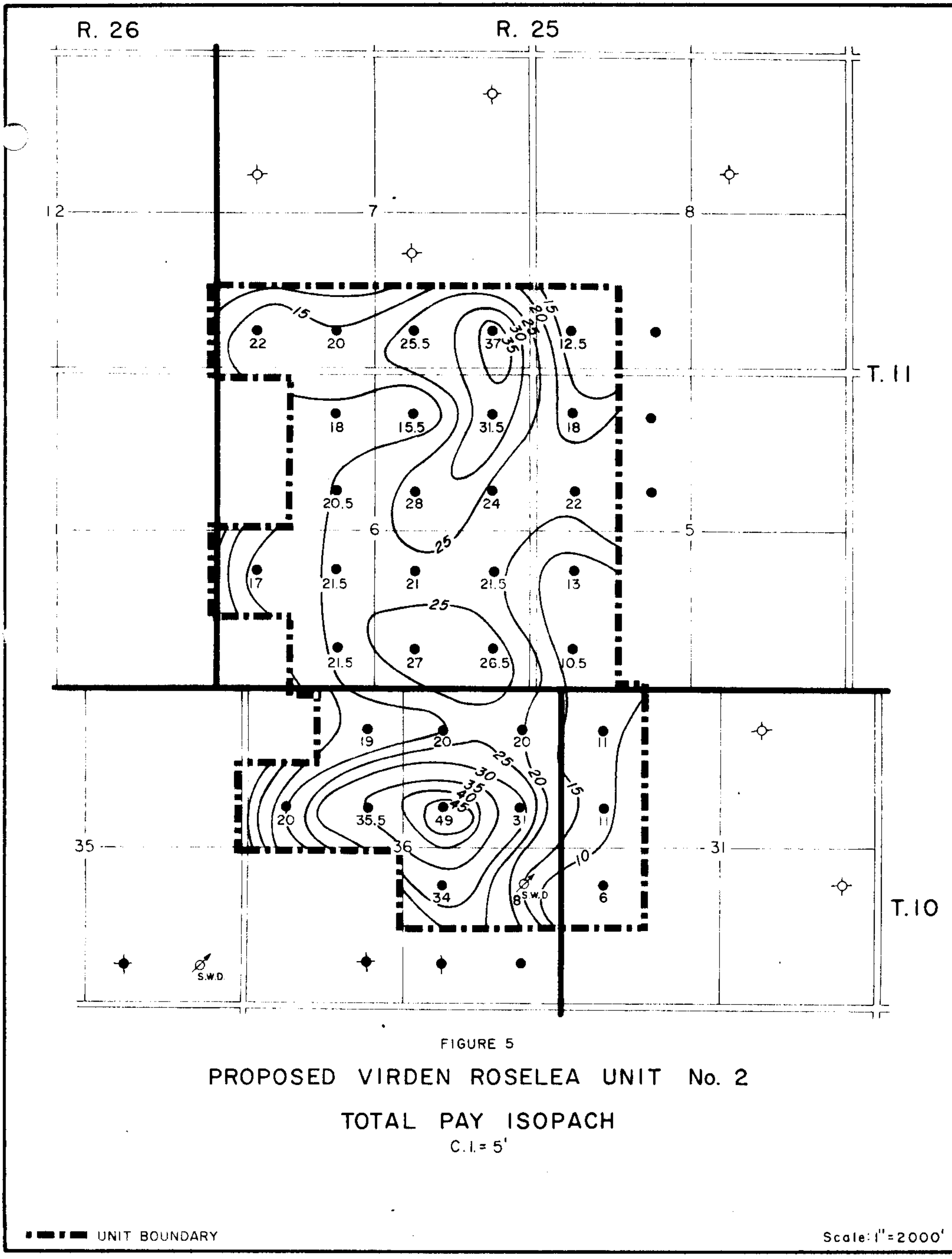


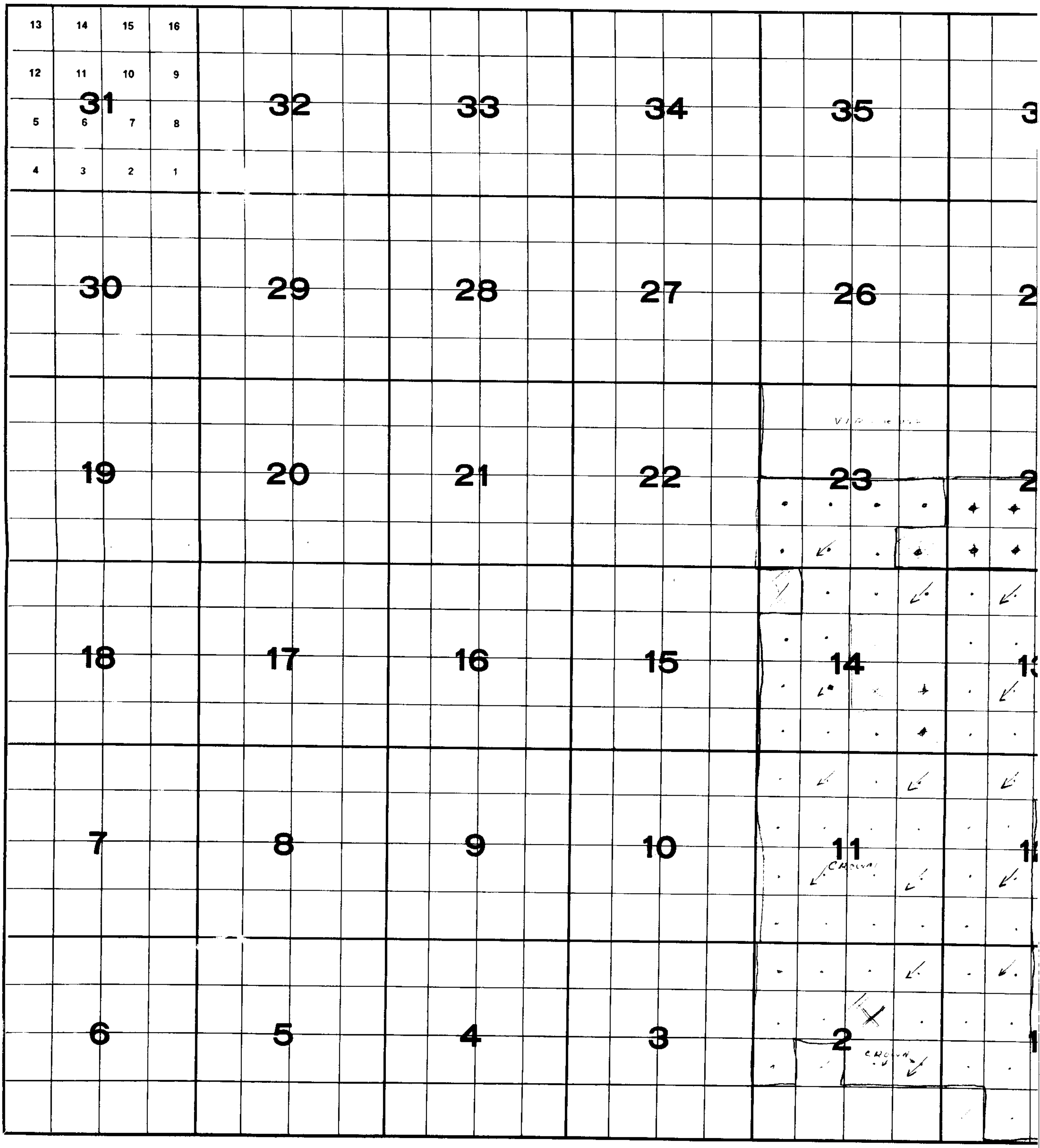
FIGURE 5

PROPOSED VIRDEN ROSELEA UNIT No. 2

TOTAL PAY ISOPACH

C.I. = 5'

Tp. 10 **Rge.** 20 **P.M.**



Tp. 10 Rge. 26 P.M.

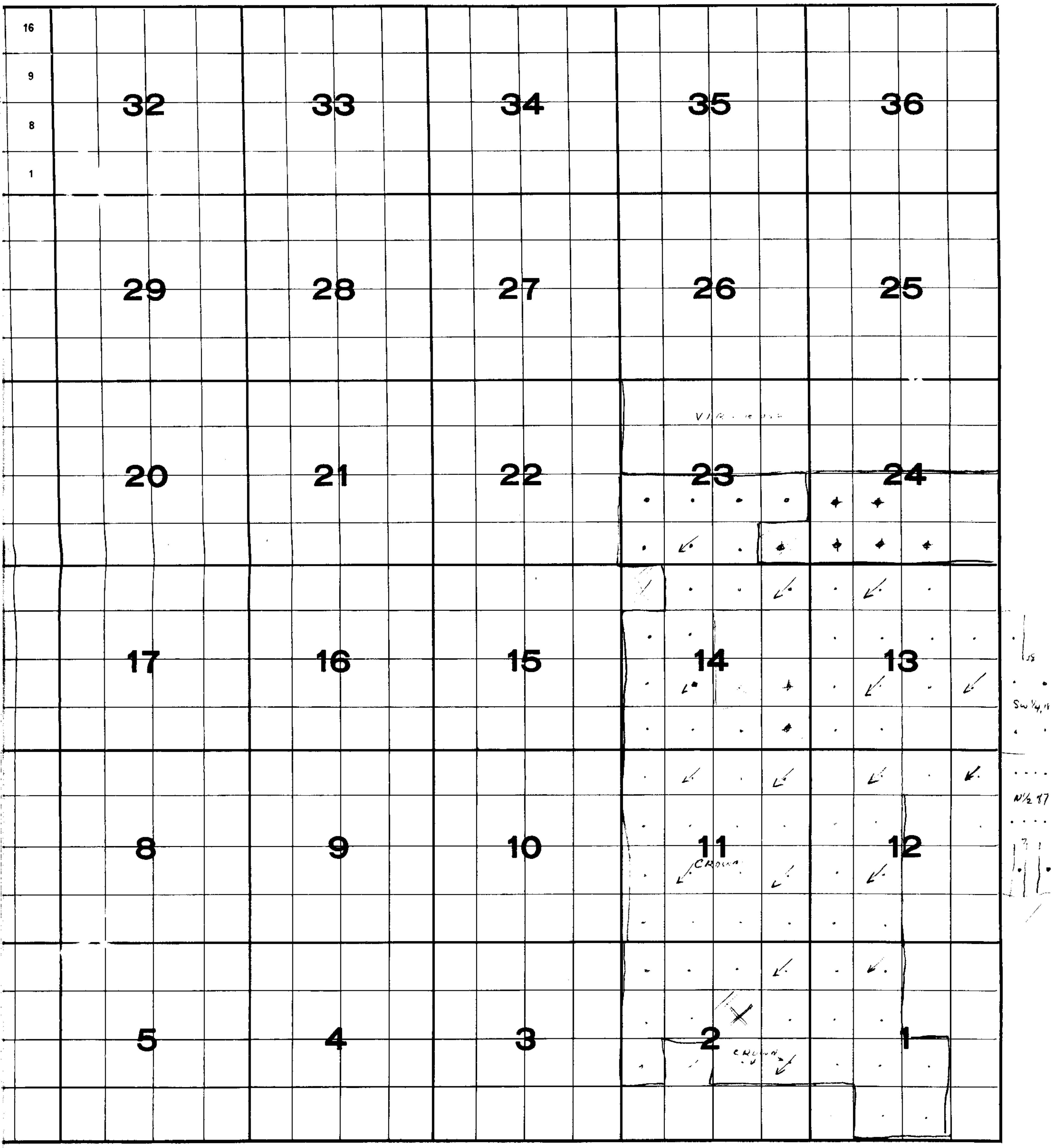


FIGURE 6

PROPOSED VIRDEN ROSELEA UNIT No. 2
PREDICTED PRIMARY AND WATERFLOOD PRODUCTION

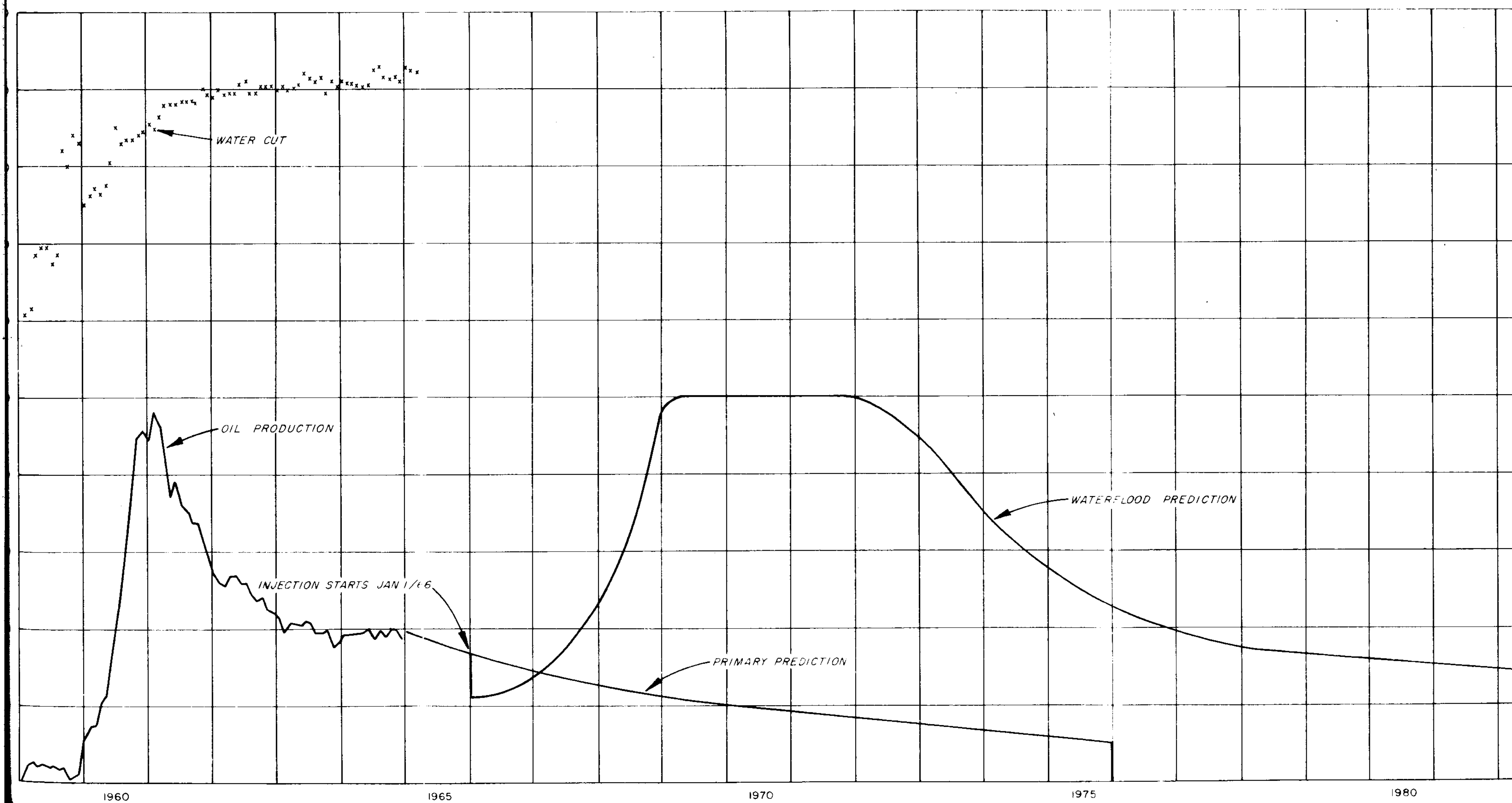


FIGURE 6

PROPOSED VIRDEN ROSELEA UNIT No. 2

PREDICTED PRIMARY AND WATERFLOOD PRODUCTION

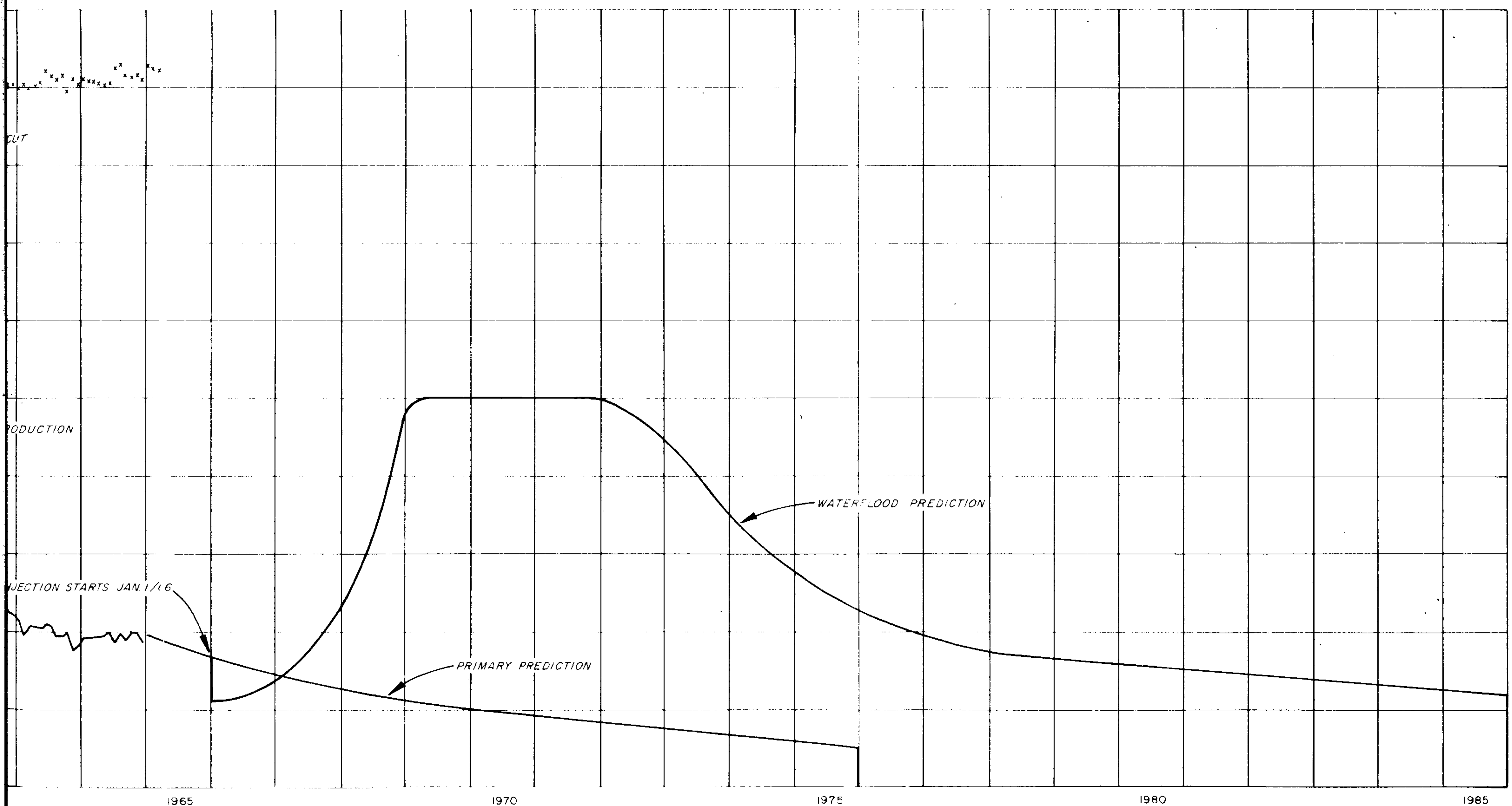
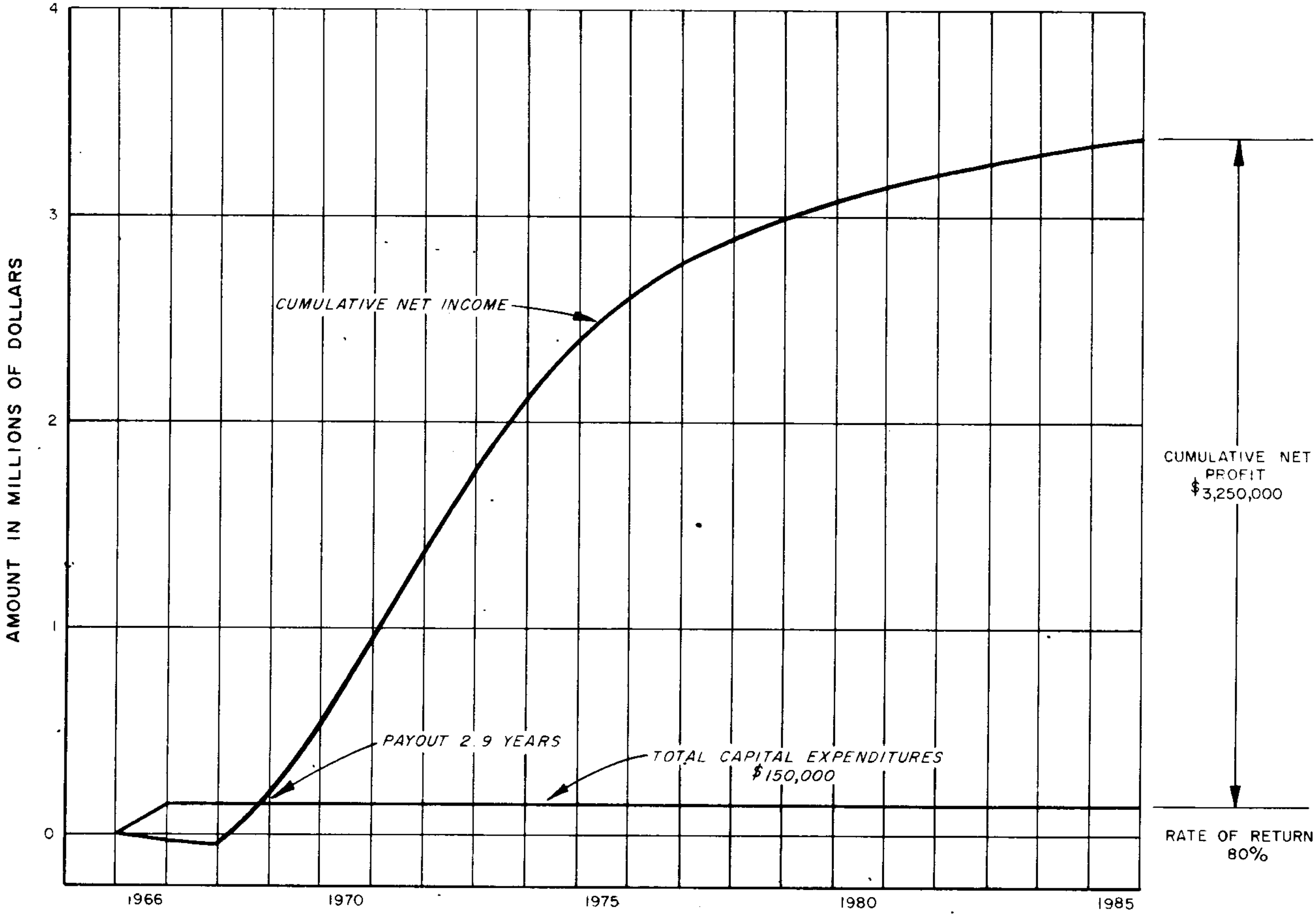


FIGURE 8

VIRDEN ROSELEA UNIT No. 2

CASH FLOW DIAGRAM



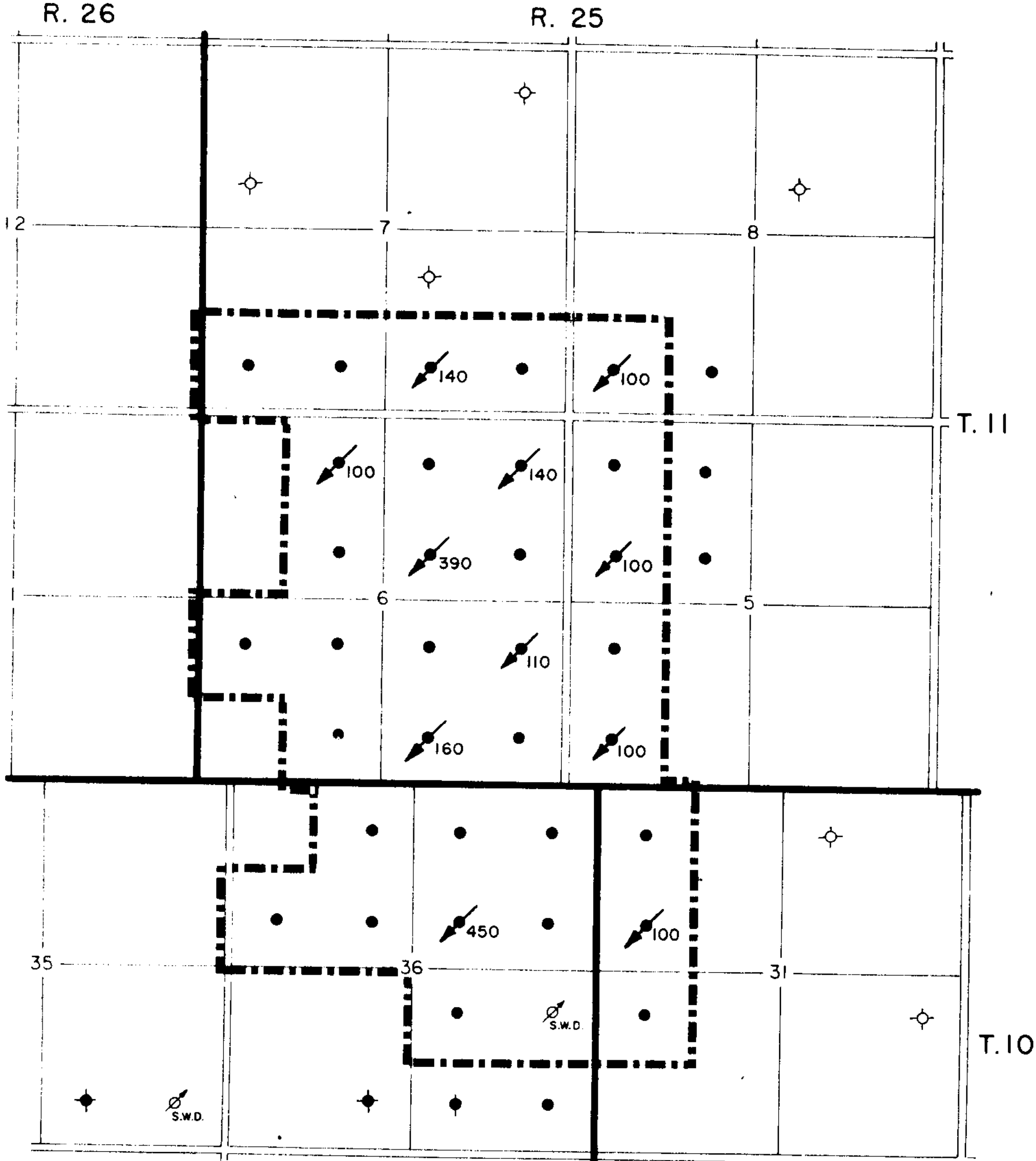


FIGURE 7

PROPOSED VIRDEN ROSELEA UNIT No. 2

100 INJECTION WELL & RATE

UNIT BOUNDARY

Scale: 1" = 2000'

(PROPOSED #3)

TWP 10 - RGE 25

	CRINOIDAL (PAY)	SANDHILL	OOLITES	CHERTY	TOTAL PAY
6-7-10-25			4.0	6.	10.
8-7			3.0	3.	6
9-7			6.	13	19
10-7		1.0	8.	12	21.
11-7		2.0	6.	10	18.
12-7		2.0	9	7	18.
13-7	5.0	2.0	9.	16.	32 (32)
14-7 (W/W)	3.0	2.0	8.	14.	27 (27)
15-7		1.0	6.	17.	24
16-7 (W.W)		3.0	6.	18.	27
3-18-10-25		2.0	10.	—	12
4-18	7.0	4.0	12.	18.	41 (41)
5-18	10.0	4.0	12.	12.	38
(CUT) SECD 5-18					
6-18	6.0	3.0	8	9.	26.
12-18	8.0	3.0	11	6.	28

TWP 10 - RGE 26

	CRINOIDAL	SANDHILL	OOLITES	CHERTY	TOTAL PAY
2-1-10-26			8.	5.	13
3-1			1.	5.	6
5-1			6.	3	9
6-1 (W/W)	1.5	2.0	6.	13.	22.5
7-1		1.0	6	13	20.
11-1		4.0	9.	11	24
12-1	2.5	5.0	8.	15	30.5
13-1	7.0	6.0	8.	12	33
14-1 (W.W)	3.0	4.0	8.	13.	28
5-2-10-26	5.0	7.0	7.	1.	20
7	4.0	6.0	5.	6	21
8 (W/W)	1.5	4.0	3.	7.	15.5
9	8.0	6.0	9.	5.	28
11	6.0	7.0	3.	3	19.
12	5.0	7.0	7.	3	22
13	8.0	2.0	6.	4	20.
14	4.0	5.0	3.	5	17
15	8.0	9.0	6.	10.	33
16 (W/W)		6.0	10.	17.	33

		CRINOIDAL	SANDHILL	OOLITES	CHERTY.	Total Pay
TWP 10 - RGE 26						↓
1-11-10-26			7.0	8.	11.	26.
2-11			4.0	12	15	31
(OUT) SUN 2-11						
3-11		3.0	9.0	11.	13.	36
(OUT) SUN 3-11						
4-11		6.0	3.0	10.	5.	24.
5-		13.0	6.0	9.	12	40.
6-	(h.w.)		7.0	9.	12	28
7-			7.0	11.	14	32
8-	(h.w.)	~~7.0~~	5.0	11.	10.	26
9-		7.0	6.0	8	14	35
10-		~~[illegible]~~	4.0	9.	17	30
11-		15.0	7.0	8.	8.	38.
12-		20.0	7.0	11.	20.	58
13-		8.0	4.0	8.	10.	30
14-	(h.w.)	10.0	5.9	8.	8.	31.9
15-		10.0	9.0	8.	9.	36
16-	(h.w.)	10.0	6.0	7.	8.	31
3-12-10-26		1.0	4.0	9.	9	23.
4-12			10.0	7.	11	28
5-12		2.0	7.0	8.	9.	26
6-12	(h.w.)		7.0	9.	9	25
9-12			4.0	5.	0	9. ✓
11-12		5.0	2.0	3.	11	21.
12-12		4.0	10.0	8	14	36.
13-12			9.0	8	7	24
14-12	(h.w.)		8.0	9.	7	24
15-12			5.0	7.	3.	15
16-12	(h.w.)	5.0	7.0	4.	3.	19.
1-13-10-26		5.0	2.0	10	7.	24.
3		5.0	8.0	10	5.	28
4		18.0	10.0	8	5.	41
5		8.0	10.0	4		22.
6	(h.w.)	9.0	9.0	7	5	30.
(OUT) SUN 6						
7		10.0	5.0	12.	15.	42
8	(h.w.)	10.0	4.0	11	15.	40
9		8.0	7.0	9.	17	41
10		5.0	8.0	9.	17	39
11		11.0	7.0	6.	10	34
12.		6.0	10.0	7.	5.	28
13		9.0	11.0	9.	10.	39
SUN 14	(h.w.)	5.0	9.0	10.	20.	44
15		7.0	8.0	10.	15.	40

CRINOIDAL	SANDHILL	OOLITES	CHERTY	TOTAL PAY
TUPIC RGE 26.				

		CRINOIDAL	SANDHILL	OOLITES	CHERTY	TOTAL PAY
2-14-10-26		9.0	9.0	10.	5	31.
3		15.0	6.0	9.	9	39
4		10.0	4.0	9.	10	33
5		12.0	2.0	6.	10	30.
6	(W.I.W.)	10.0	3.0	6.	7.	26
11		13.0	2.0	8.	5	28
SUSP 12		8.0		4.	9	21
14		10.0	1.0	8	5	24.
15		9.0	2.0	8.	5	24
16	(W.I.W.)	9.0	7.0	9.	7.	32
2-23-10-26		10.0		10.	10.	30
3	(W.I.W.)	10.0	2.0	10.	10.	32
4		10.0	2.0	5.	5.	22
5			5.0	9	15.	29
6		1.1		12	10.	23.5
7		3.2	3.0	13	2.	21.2
8				10.	1.	11
						2493 /

TOTAL WELLS = 92
INJECTION (19)
PRODUCERS (73)

Ave Pay T. = 27' ϕ 11.6
Area = 3680 acres C_s = .48 FVF 1.05
7758 × 3680 × 27' × (.48) × $\frac{1}{1.05}$ = 41 MM. bbls.

O.I.P.

CRINOIDAL	7.1 MM.	= 16%
SANDHILL	10.5	= 23.6 %
OOLITIC	11.5	= 25.9 %
CHERTY	15.3	= 34.5 %
	44.4 M bbls	

Primary recoverable (est.) = 5.9 MM.

Primary & Secondary estimate = 15.5 million
Primary estimate to Jan, 1967 = 4.9
~~[illegible]~~ "
Remaining Primary & Secondary 10.6 MM
" Secondary only. 9.6

TABLE 1

PROPOSED VIRDEN ROSELEA UNIT NO. 2

SUMMARY OF

PROPOSED INJECTION WELL INJECTIVITIES

WELL	INJECTION RATE (BWPD)
12 - 31 - 10 - 25	100
10 - 36 - 10 - 26	450
4 - 5 - 11 - 25	100
12 - 5 - 11 - 25	100
2 - 6 - 11 - 25	160
8 - 6 - 11 - 25	110
10 - 6 - 11 - 25	390
14 - 6 - 11 - 25	100
16 - 6 - 11 - 25	140
2 - 7 - 11 - 25	140
4 - 8 - 11 - 25	100
TOTAL	1,890