OUTLINE PROPOSAL

FOR EXTENDING

ELECTRIC RAILWAY OPERATION

OF THE

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

BY NEW POWER CONTRACTS

WITH

MONTANA POWER COMPANY

PUGET SOUND POWER & LIGHT COMPANY

WASHINGTON WATER POWER COMPANY

NOVEMBER, 1969

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MILWAUKEE ROAD ELECTRIFICATION

We have reviewed the literature on railroad electrification and observed the operations of the Milwaukee Railroad through Central and Western Washington. These observations have indicated that the Milwaukee's 656 miles of electrified track are worth far more today than the original cost or book value.

The addition of 212 miles of electrified route through Eastern Washington would provide a continuous electrified railroad for 868 miles from Harlowton, Montana to Seattle - Tacoma, Washington. This electrification crosses five mountain ranges with grades as steep as 2.2% and with some of the worst weather in North America.

Our studies have indicated that there is more to the choice between AC catenary and power supply and DC catenary and power supply. For a railroad that operates over mountainous territory in severe winter conditions, operational advantage seems to lie with DC electrification. This advantage is in the operating characteristics of large electric locomotives with DC series motors.

Locomotives with DC series motors when operating on mountain grades will have either 4, 6, or 8 motors connected in series depending on the grade and the wheel arrangement of the locomotives. The advantage of DC series motors lies in their electrical connection for low speed, high torque operation. Motor torque depends on the current through the motor while the motor speed depends on the voltage across the motor.

A locomotive with 8 motors connected in series will have the same torque on each axle. If one axle should start to slip, the increased speed of the rotor will tend to increase the back EMF of the motor increasing the voltage applied to the other 7 motors and increase the speed of these motors until all wheels are again rotating at the same speed.

Having satisfied ourselves that DC was a good operating method for a Railroad in mountainous country and hoping to encourage the Milwaukee to continue and extend its electric operations, we were left with the problem of manufacturer to supply 3300

Volt DC electric locomotives. This problem was solved last July when the General Electric Company offered to sell the Milwaukee Railroad 30 or more, 5400 Hp, 8 axle 3300 Volt DC locomotives for a cost on a rail horsepower basis equal to the cost of diesel locomotives. We have been informed that these locomotives were offered at $90 per rail horsepower or $485,000 each. With the barrier of motive power overcome, it appeared to the utilities that the Railroad load would be desirable if some means could be found to finance the 212 mile "gap" in Eastern Washington and to increase the capability of the presently electrified 656 route miles of electrification.

To this end, we have laid out an electrification scheme from the power utilities' engineers point of view. New substations in the area of the "gap" are supplied by rectifiers with silicon diodes. Increased substation capacity is made available on the Coast Division and the Rocky Mountain Division by installing four new rectifiers to replace motor generator sets in existing stations. These displaced motor generator sets are proposed to be moved to 9 substations where increased power appears to be required.

Following the pattern established by the Railroad Company's electrical engineers, it is proposed to replace all copper feeders in the Coast and Rocky Mountain Divisions with aluminum feeders of approximately the same weight thus doubling the equivalent copper cross section of all feeders replaced. This change will introduce a new size of wire to the Railroad, namely, 2250 Mcm Al. "Sagebrush". This is equivalent to 1415 Mcm copper. Second and third steps developing the Rocky Mountain Division to carry heavier traffic are proposed by installing two additional rectifiers and moving the displaced motor generator sets to areas where they may be required and may absorb regenerated power.

AVERY - OTHELLO

THE FIRST LOOK

The cost of providing facilities for electric operation of trains through the "gap" from Avery, Idaho to Othello, Washington was estimated to be $9,935,000 in July, 1969.

Fixed charges for this project were estimated to be 15% for transmission and substation cost, 17.5% for rectifier equipment cost and 12.0% for the catenary system.

The breakdown of costs is tabulated below.

	1971 Installed Cost	Annual Fixed Cost
Seven substations and associated line work	$ 841,800	$ 126,300
Seven transformer/rectifier stations	2,013,200	352,300
Sub-Total	$2,855,000	$ 478,600
Catenary & Feeder System	7,080,000	849,600
Total to Fill Gap	$9,935,000	$1,328,200

Estimated revenue to be derived from sales of electricity to the Milwaukee Road for electric operation of trains through the "gap" was projected through the year 1985 from data supplied by Mr. T. B. Kirk for the years 1960 through 1968.

At presently existing rates, Table I shows energy projections and Table II, cost of electricity at present growth and power rates. Revenue projections grow from $309,811 in 1970 to $681,000 in 1985. This revenue is less than half the fixed charges on the project. From this study, it became apparent that trolley and substation facilities through the "gap" could not be financed by the serving utility at any reasonable power rate.

Some new approach was required. An inspection of the projected use of electric power to move trains through Montana, Idaho and Washington indicated that if the utilities serving the total length of the electrified route could cooperate in a proposal to the Railroad Company, electrification of the "gap" might be feasible if all four parties, the three utilities and Milwaukee, cooperated in the project.

HARLOWTON - PUGET SOUND
THE UNIFIED LOOK

The energy projections shown on Table I and the associated revenue of Table II appeared to have a growth rate higher than could be maintained for more than a few years into the future.

The energy growth in megawatthours at a growth rate of 2/3 the historical rate from 1960 through 1968 is shown on Table III.

With these potential energy sales in view, the various possible economics that could be realized from electric operation of the Railroad in the northwest were investigated in depth.

The electric power supply system and the electric locomotives were considered as one. The trolley system and substations are useless without electric locomotives to use the electric energy the trolley can supply. On the other hand, an electric locomotive is helpless without an electric trolley system to bring power to it.

A new and modern electric supply system between Avery and Othello must be supported by the existing electrified sections of the Railroad in Montana and Washington.

With the idea in mind of supplying an efficient modern electric supply system for the Milwaukee Road from Harlowton to Seattle-Tacoma a plan was prepared and estimates made of the cost to electrify the "gap" and to reinforce the existing electrifications. These plans were based on the principal assumptions which follow.

PRINCIPAL ASSUMPTIONS

Financing of improvements to the Milwaukee's electrified sections and filling in the "gap" in Eastern Washington can only be done if the cost of fixed facilities of power lines and substations are considered together with mobile equipment of motive power. Proposals contained in this report are based on the following assumptions:

1. The three utilities will purchase Milwaukee's 115 Kv transmission lines as follows:

Montana	350 Miles in Montana
Washington	16 Miles in Idaho and Montana
Puget	138 Miles in Washington

2. The three utilities will purchase oil circuit breakers and transformers now owned by Milwaukee:

Puget	3 Oil circuit breakers
	15 Transformers
Washington	1 Oil circuit breaker
	3 Transformers
Montana	10 Oil circuit breakers
	31 Transformers

3. Milwaukee will enter into new power contracts with three utilities. Each utility will supply power to Milwaukee substations and to electric operations as follows:

Montana	Substations in the State of Montana
Washington	Substations in the State of Idaho and in the State of Washington east of the Columbia River
Puget	Substations west of the Columbia River in the State of Washington

4. Milwaukee will order locomotives for delivery in 1970 and thereafter in 1971 and 1972 so that electric operation may be reestablished over the Othello to Seattle-Tacoma section of the Railroad as soon after July 1, 1970 as possible.

5. Milwaukee will order 30 locomotives at a cost of $485,000 each or a total cost of $14,550,000 from the General Electric Company.

6. Copper for new 4/0 grooved trolley wire to be installed in the "gap" will be obtained by replacing 500 Mcm and 700 Mcm feeders between the Columbia River and Cedar Falls as follows:

   700 Mcm Cu with 2,250 Mcm Sagebrush Aluminum
   500 Mcm Cu with 1,590 Mcm Coreopsis Aluminum

   at no cost to the project. See Coast Division Feeder Replacement Schedule.

7. Electrification cost estimates are those supplied by Washington updated to November, 1969 with independent estimates for increased substation capacity in the existing electrified sections.

8. Proposed construction can be completed in two years.

9. Interest is assumed at 8%.

10. Fixed charges are assumed to be 17%

    8% Interest
    3% Depreciation
    3% Profit
    3% Federal Income Tax

11. The power contracts between Milwaukee and the three power companies will provide that the Railroad Company's demand at the time of each utilities' annual peak will be limited. There will be no demand charge and at times other than the utilities' annual peak, there will be no limit to the Railroad Company's demand.

12. Payment for Milwaukee's facilities purchased by the three power companies to be made by refunding a portion of the monthly power bill to the Railroad Company.

13. From Ernest P. Foley article "Motive Power Economics in the United States"

    (A) Energy ratio 10 Kwh = 1 Gal. Diesel Fuel

    (B) Diesel Fuel Cost = 9¢ per Gal.

    (C) Life of Diesel Locomotive,15 Years

    (D) Life of Electric Locomotive, 30 Years

    (E) "Contract system maintenance cost are just about equal in magnitude to the cost of diesel lubricants, which today, are about 8 per cent of diesel fuel cost".

    (F) Electric locomotive maintenance is from 1/3 to 1/2 the cost of maintaining diesel power. Use median or 41%.

14. The three utilities will pay for and own the 115 Kv facilities and transformer in the new rectifier substations.

15. Annual maintenance cost for Road freight diesel locomotives is $15,741 from Moody's Manual

16. One 5400 Hp electric locomotive is equivalent to two average diesels

17. Wire costs and salvage value were estimated as follows:

Copper Scrap	52¢/lb.
4/0 Cu Trolley	91¢/lb.
1,590 Mcm Al.	40.5¢/lb.
2,250 Mcm Al.	44¢/lb.

ELECTRIFICATION

EXPANSION AND IMPROVEMENT

COST SUMMARY

AVERY - OTHELLO EXTENSION		
Poles, etc.		$ 1,530,000
Trolley and Feeders		3,016,000
Labor,		2,454,000
	Trolley Total	$ 7,000,000
Substation Transformers		$ 875,000
Rectifiers, Switches, etc.		1,595,000
	Substation Total	$ 2,470,000
	Total Avery - Othello	$ 9,470,000
COAST DIVISION IMPROVEMENTS		
3 Substation Rectifier Transformers		$ 349,000
Other Substation Costs		689,000
Feeder Increase		187,000
	Total Coast Division	$ 1,225,000
ROCKY MOUNTAIN DIVISION IMPROVEMENTS		
1 Substation Rectifier Transformer		$ 122,000
Other Substation Costs		771,000
Feeder Increase		425,000
	Total Rocky Mountain Div.	$ 1,318,000
	Total Project	$12,013,000
COPPER CREDITS		
Coast Division	$100,000	
Rocky Mountain Division	140,000	$ 240,000
	Net Project	$11,773,000

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SAVINGS FROM ELECTRIC OPERATION

The savings from electric operations are found in three areas, 1) lower cost of energy, 2) lower cost of locomotive maintenance, and 3) lower capital requirements for locomotives. These savings from operating 868 miles of electrified railroad will pay the fixed charges on the extension and improvements to Milwaukee's electrified operations when the three serving utilities take over the responsibility for power supply to the 2400 volt bus in the Railroad Company's substations.

COST OF ENERGY SAVING

The growth of energy use has been projected on a straight line for this study.

1,000 Mwh/Year for the Coast Division
2,000 Mwh/Year for Avery - Othello
5,000 Mwh/Year for Rocky Mountain Division

These projections are shown on Table IV assuming an energy ratio of 10 Kwh to one gallon of diesel oil and a price for diesel oil at 9¢ a gallon and a price for electricity of 0.7¢/Kwh. There is an energy cost saving of 0.2¢ Kwh. It was assumed that diesel lubricants cost would equal the trolley maintenance cost. Estimated savings on energy through the year 1985 are shown on Table V.

LOCOMOTIVE MAINTENANCE SAVING

One 5400 electric locomotive is equivalent to two average diesel locomotives in tractive effort. Electric maintenance costs are between 1/3 and 1/2 the cost of diesel maintenance. We have used 41% as the ratio of electric to diesel maintenance.

Equivalent Annual Diesel Cost	$ 31,482
Electric Maintenance @ 41%	12,908
Annual Saving Per Electric Locomotive	$ 18,574
Annual Savings on 30 Electric Locomotives	$ 557,220

LOCOMOTIVE CAPITAL SAVINGS

Diesel locomotives have an average life of 15 years while electric locomotives have an average of 30 years or more. For this study comparison a life of 25 years

has been assumed.

30 Electric Locomotives @ $485,000	$14,550,000
Annual Amortization on 15 year Life of Diesel Locomotive	970,000
Annual Amortization on 25 year Life of Electric Locomotive	582,000
Annual Amortization Savings	$ 388,000

The foregoing savings are shown on Table VI for the years 1970 through 1985. It was assumed that full electric operation would begin in 1972 and that all new locomotives would be delivered and in operation by that year.

MILWAUKEE ELECTRIFICATION

FINANCING

Estimated Cost of Project	$ 11,773,000
Less Utilities Contribution	3,122,500
Net Cost to Milwaukee	$ 8,650,500
Annual Fixed Charges @ 17%	$ 1,470,585

@ 11% $952.000

Referring to Table VI, it may be seen that these estimated fixed charges are exceeded by savings from electric operation each year after 1972.

It should be remembered that the fixed charge of 17% is made up as follows:

8% Interest

3% Depreciation

3% Profit

3% Federal Income Tax

Considering only interest and depreciation as necessary expenses, the cost of ownership is per year, $951,550.

Referring again to Table VI, it may be seen that Milwaukee will make a small profit on its electrification investment as soon as total electric operation begins.

UTILITIES CONTRIBUTION

The utilities contribution to the project will be represented by notes for the price of existing facilities purchased and for new equipment to be purchased and installed by the Railroad Company but to be owned by the serving utilities. Current rate of interest will be paid on the note. Payment of principal and interest on the note to be by refunding a portion of the Milwaukee's electric bill.

AVERY - OTHELLO

SCOPE OF EXTENSION

To provide facilities for electric operation of trains will require a complete new trolley and feeder system, together with seven (7) new 115 Kv AC to 3300 DC - 4400 Kw substations. The following are the major items required.

RECTIFIER SUBSTATIONS

Roxboro
Ralston
Revere
Malden
Tekoa
Plummer
St. Maries

The trolley will consist of 2 - 4/0 grooved trolley wires over the main track for 212 miles and one (1) 4/0 grooved trolley wire over side tracks and in yards.

Feeders parallel to the main line will consist of 170 miles of 1,590 Mcm Al from Othello to St. Maries and 45 miles of 2,250 Mcm Al from St. Maries to Avery. The feeders will be run on the trolley poles. An estimated cost detail of this construction is shown on the following pages.

AVERY - OTHELLO

CATENARY AND FEEDER COST

POLES, GUYS AND ANCHORS		
11,000 35' Poles @ $50 ea.		$ 550,000
20,000 Mast Arms @ $13 ea.		260,000
10,000 Anchors @ $11 ea.		110,000
16,000 Pulloffs @ $9 ea.		144,000
11,000 Guy Wires @ $14 ea.		154,000
1,250 Span Wires @ $28 ea.		35,000
Miscellaneous Material		127,000
Stores Expense		150,000
	Total Poles, etc.	$1,530,000
TROLLEY AND FEEDERS		
265 Miles 1/2" Messenger @ $570		$ 151,050
460 Miles 4/0 Cu Trolley @ $3140		1,440,400
172 Miles 1590 MCM Al @ $3240		557,280
43 Miles 2250 MCM Al @ $5020		515,860
460 Miles Catenary Hangers @ $220		101,200
25 Switches @ $160		4,000
Miscellaneous Material		266,210
Stores Expense		250,000
	Total Trolley	$3,016,000
Engr. & Supt.		$ 100,000
Labor @ $9,000 Mile		1,908,000
Equipment		150,000
Contingencies		296,000
	Total Labor, etc.	$2,454,000
	Total Overhead	$7,000,000

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AVERY - OTHELLO

SUBSTATION COST

7 - 115 Kv Substation Facilities @ $30,000		$ 210,000
Fence and Grading @	$ 3,000	
Steel Structures @	5,100	
115 Kv Disc. Sw. @	2,800	
115 Kv Fuses & Mtg. @	2,900	
Lightning Arresters @	4,000	
Foundation @	1,000	
Buswork & Insulators @	1,000	
Ground Mat @	500	
Miscellaneous Material	700	
Labor and Overhead	9,000	
7 - Rectifier Transformers @	95,000	665,000
7 - Rectifiers & DC Switchgear	185,000	1,295,000
7 - DC Terminals & Cables @	4,000	28,000
7 - Supervisory Remote Stations	10,000	70,000
7 - Labor and Overhead @	2,400	168,000
TOTAL SEVEN SUBSTATIONS		$2,436,000
MASTER SUPERVISORY FOR SEVEN STATIONS		21,000
SPARE RECTIFIER DIODES & FUSES		13,000
TOTAL SEVEN SUBSTATIONS		$2,470,000
AVERY - OTHELLO TOTAL PROJECT		$9,470,000

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WASHINGTON WATER POWER COMPANY

SUPPLY FACILITIES

FOR

RAILROAD SUBSTATIONS

1. ROXBORO - WEST	
1 Mile of 115 Kv Line	
2-115 Kv Switches	$ 35,000
2. RALSTON - WEST	
1¼ Miles of 115 Kv Line	
2-115 Kv Switches	41,000
3. REVERE	
½ Mile of 115 Kv Line	
2-115 Kv Switches	23,000
4. MALDEN	
1¼ Mile of 115 Kv Line	
1-115 Kv Switch	36,000
5. TEKOA	
1 Mile of 115 Kv Line	
1-115 Kv Switch	30,000
6. PLUMMER	
½ Mile of 115 Kv Line	
1-115 Kv Switch	18,000
7. ST. MARIES	
1½ Mile of 115 Kv Line	
1-115 Kv Switch	54,000
Total Supply Facilities	$237,000
TELEMETERING	
From eight (8) Railroad substations	
to Spokane and to Malden	$ 50,000

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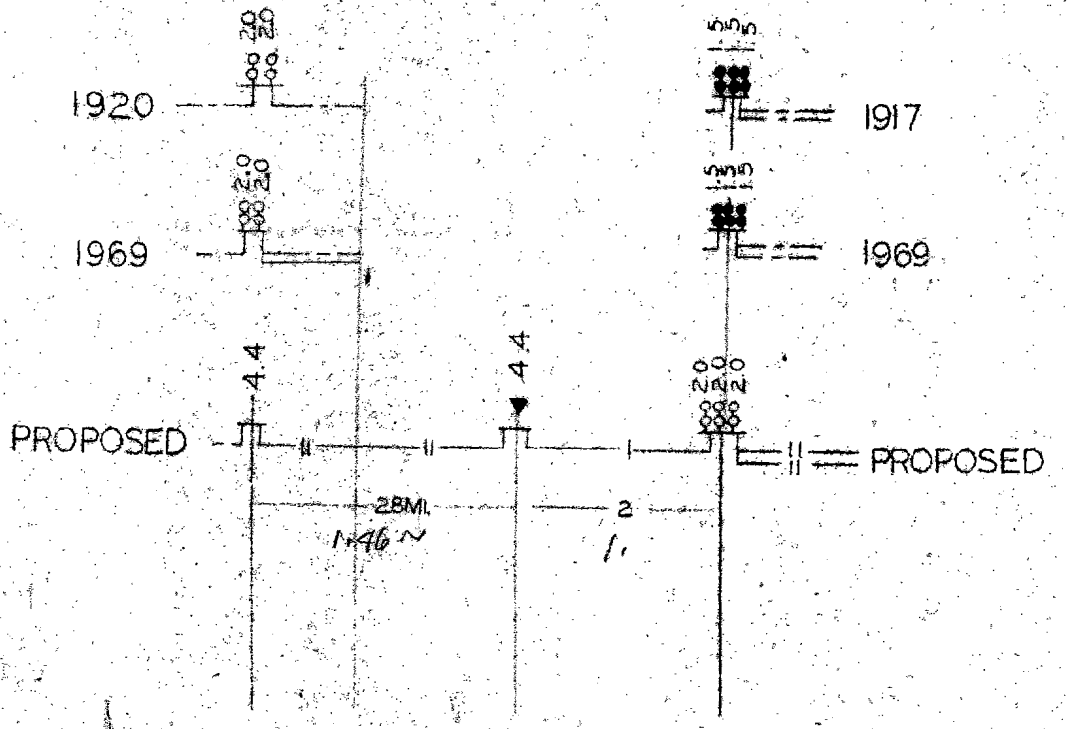

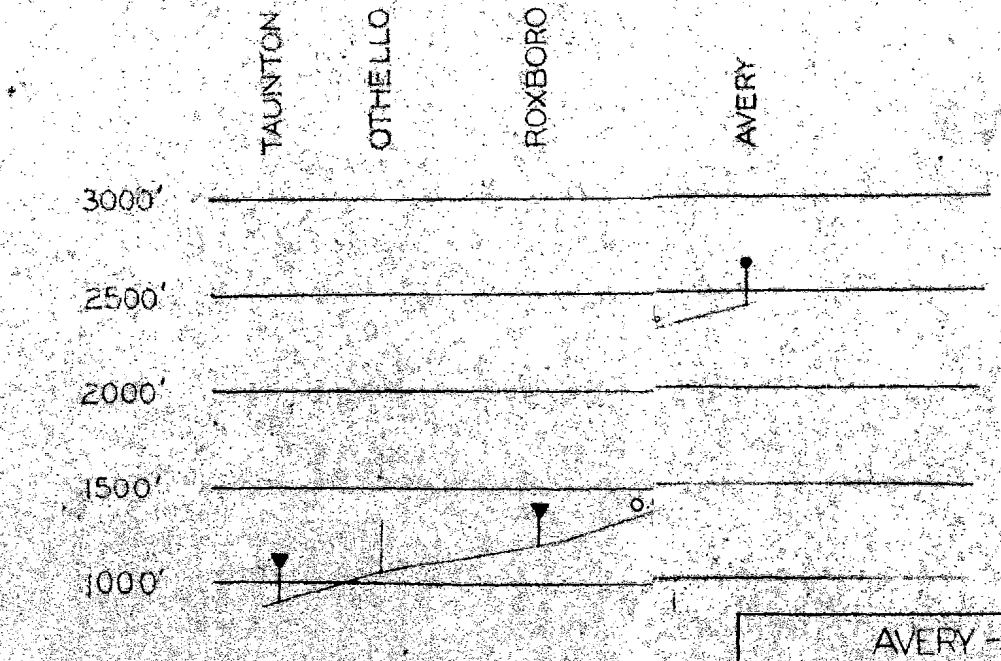

AVERY - OTHELLO
MILWAUKEE RAILROAD ELECTRIFICATION

PUGET SOUND POWER & LIGHT COMPANY
GENERAL ENGINEERING DEPARTMENT BELLEVUE

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COAST DIVISION

AND

ROCKY MOUNTAIN DIVISION

IMPROVEMENTS

To bring the existing Coast Division and Rocky Mountain Division electrification up to the standards of the proposed Avery - Othello electrification, the following improvements are proposed:

Four (4) new 115 Kv AC to 3300 V DC - 4400 Kw Rectifier Substations at:

Black River Junction
Cle Elum
Taunton
Eustis

Motor-generator sets from the substations replaced by these rectifier substations will permit increase of M-G capacity at locations where it is desirable to absorb regenerated power from trains descending the mountains.

The changes in motor-generator capacity and the additional rectifiers proposed are given below:

Substation	Existing Capacity	Proposed Capacity
Tacoma Junction	2,000 Kw	2,000 Kw M-G
Renton	4,000 Kw	4,400 Kw R
Cedar Falls	4,000 Kw	6,000 Kw M-G
Hyak	4,000 Kw	6,000 Kw M-G
Cle Elum	3,000 Kw	4,400 Kw R
Kittitas	4,000 Kw	6,000 Kw M-G
Doris	6,000 Kw	8,000 Kw M-G
Taunton	4,000 Kw	4,400 Kw R
Avery	4,500 Kw	6,000 Kw M-G
East Portal	6,000 Kw	7,500 Kw M-G
Drexel	4,000 Kw	4,000 Kw M-G

Substation	Existing Capacity	Proposed Capacity
Tarkio	4,000 Kw	4,000 Kw M-G
Primrose	4,000 Kw	4,000 Kw M-G
Ravenna	4,000 Kw	4,000 Kw M-G
Gold Creek	4,000 Kw	4,000 Kw M-G
Morel	4,000 Kw	4,000 Kw M-G
Janney	7,500 Kw	8,000 Kw M-G
Piedmont	4,500 Kw	6,000 Kw M-G
Eustis	4,000 Kw	4,400 Kw R
Francis	4,000 Kw	4,000 Kw M-G
Loweth	4,000 Kw	6,000 Kw M-G
Two Dot	4,000 Kw	4,000 Kw M-G

Feeder capacity will be increased by replacing:

500 Mcm Cu with 1,590 Mcm Al.

700 Mcm Cu with 2,250 Mcm Al.

The copper replaced on the Coast Division will be reprocessed into 4/0 grooved trolley wire for use between Avery and Othello. This will provide a saving of almost $200,000 over purchasing new 4/0 grooved trolley wire.

Two additional steps at power supply improvement are proposed for the Rocky Mountain Division for future years as the load growth in the Rocky Mountain Division is greater than in the Coast Division.

Estimated costs for these improvements are shown on the following pages.

COAST DIVISION

IMPROVEMENTS

BLACK RIVER JUNCTION NEW SUBSTATION		
Fence & Grading	$ 3,000	
115 Kv Facilities	27,000	
Rectifier Transformer	95,000	
Rectifier & DC Switchgear	185,000	
DC Terminals & Cables	6,000	
3rd DC Feeder Breaker	10,000	
Supervisory Control	10,000	
Labor and Overhead	24,000	$ 360,000
CLE ELUM SUBSTATION RECTIFIER		
Fence & Grading	3,000	
115 Kv D.E. Tower & Lightning Arresters	10,000	
Rectifier Transformer	95,000	
Rectifier & DC Switchgear	185,000	
DC Terminals & Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	23,000	330,000
TAUNTON SUBSTATION RECTIFIER		
Fence & Grading	3,000	
115 Kv Facilities	27,000	
Rectifier Transformer	95,000	
Rectifier & DC Switchgear	185,000	
DC Terminals & Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	24,000	348,000
TACOMA JUNCTION SUBSTATION		
Supervisory Control		10,000

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DORIS M-G SETS		
Replace 2 - 2000 Kw West. M-G Sets with 2 - 2000 Kw G.E., M-G Sets from Hyak and add a 4th 2000 Kw G.E. M-G Set from Renton		
Replace 2 M-G Sets	$ 30,000	
Building Expansion	20,000	
Install 4th M-G Set	35,000	
Supervisory Control	10,000	$ 95,000
KITTITAS ADD M-G SET		
Install 3rd 2000 Kw West. M-G Set on Existing Foundation from Taunton	22,000	
Supervisory Control	10,000	32,000
HYAK M-G SETS		
Replace 2 - 2000 Kw G.E. M-G Sets with 2 - 2000 Kw West. M-G Sets from Doris and Install 3rd 2000 Kw West. M-G Set from Taunton		
Replace 2 M-G Sets	30,000	
Add 1 M-G Set	22,000	
Supervisory Control	10,000	52,000
CEDAR FALLS ADD M-G SET		
Install 3rd 2000 Kw G.E. M-G Set from Renton	22,000	
Supervisory Control	10,000	32,000
MASTER SUPERVISORY FOR EIGHT STATIONS		23,000
TOTAL SUBSTATION		$1,050,000

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FEEDER INCREASE

DORIS TO THE COLUMBIA RIVER	
Replace 4 Miles of 2 - 500 Mcm Cu Feeders with 2 - 1590 Mcm Al.	$ 8,000
KITTITAS TO DORIS	
Replace 23.6 Miles of 2 - 700 Mcm Cu Feeders with 2 - 2250 Mcm Al.	57,000
HYAK TO KITTITAS	
Replace 60 Miles of 1 - 500 Mcm Cu Feeder with 1 - 1590 Mcm Al.	60,000
CEDAR FALLS TO HYAK	
Replace 21.8 Miles of 2 - 700 Mcm Cu Feeders with 2 - 2250 Mcm Al.	52,000
TAUNTON TO OTHELLO	
Replace 9.4 Miles of 1 - 500 Mcm Cu and 1 - 4/0 Cu Feeders with 1 - 1590 Mcm Al.	10,000
TOTAL FEEDER LABOR	$ 187,000
TOTAL COAST DIVISION	1,225,000

MILWAUKEE ELECTRIFICATION

COAST DIVISION

FEEDER REPLACEMENT

CEDAR FALLS - HYAK 21.8 MILES

Remove 2 - 700 Mcm Cu 497,476# Install 2 - 2250 Mcm Al. 491,023#

HYAK - KITTITAS 60.0 MILES

Remove 1 - 500 Mcm Cu 489,060# Install 1 - 1590 Mcm Al. 472,980#

KITTITAS - DORIS 23.6 MILES

Remove 2 - 700 Mcm Cu 538,552# Install 2 - 2250 Mcm Al. 531,566#

DORIS - COLUMBIA RIVER 4 MILES

Remove 2 - 500 Mcm Cu 65,208# Install 2 - 1590 Mcm Al. 63,064#

TAUNTON - OTHELLO 9.4 MILES

Remove 1 - 500 Mcm Cu 76,619# Install 1 - 1590 Mcm Al. 74,100#

Remove 1 - 4/0 Cu 32,430#

COPPER REMOVED

90.8 Miles 700 Mcm @ 11,410#	=	1,036,028#
77.4 Miles 500 Mcm @ 8,150#	=	630,887
9.4 Miles 4/0 @ 3,450#	=	32,430
Total Cu Removed		1,699,345#

ALUMINUM INSTALLED

90.8 Miles 2250 Mcm @ 11,262#	=	1,022,589#
77.4 Miles 1590 Mcm @ 7,883#	=	610,114
Total Al. Required		1,632,733#

COPPER TROLLEY WIRE REQUIRED

460 Miles @ 3,450# = 1,587,000#

Copper Removed = 1,699,345#
Copper Trolley Req. = 1,587,000#

Net Excess of Cu 112,345#

Cost of 460 Mile 4/0 Trolley Wire from Estimate 91¢/lb - 3450#/Mile $ 1,440,400

Cost of Aluminum Feeder 91 Miles 2250 Mcm @ 44¢/lb and 11,262#/Mile $ 450,931

75 Miles 1590 Mcm @ 40.5¢/lb and 7,883#/Mile 239,446 $ 690,377

Credit for Feeder Wire 750,023

Coast Division Feeder Labor 187,000

Credit After Feeder Replacement 563,023

Cost of Remanufacturing Cu Salvage to 4/0 Trolley Wire 1,587,000# @ 33¢/lb 523,710

Net Saving on Trolley Wire 39,313

Surplus Cu 112,345# @ 52¢/lb 58,419

Credit to Project from Cu Feeders 97,732

Coast Division Round To 100,000

PUGET SOUND POWER & LIGHT COMPANY

ADDED FACILITIES REQUIRED

FOR

COAST DIVISION IMPROVEMENTS

115 KV LINE TO BLACK RIVER JUNCTION

2 Miles of 115 Kv line from Milwaukee's Renton Substation west to Black River Junction	$ 60,000

TELEMETERING

Telemeter Railroad load from six (6) Railroad substations to Redmond and from Redmond to Tacoma	45,000

CLE ELUM REARRANGEMENTS

Underground 33 Kv Getaway	$12,000	
Reroute 115 Kv West	5,000	
Reroute 115 Kv East	5,000	
Reroute 115 Kv from Cascade	3,000	
Relocate Oil Circuit Breaker	10,000	
Install New Oil Circuit Breaker	15,000	
Tap to New Rectifier Substation	5,000	55,000

TOTAL PUGET	$160,000

Rev.11/14/69

ROCKY MOUNTAIN DIVISION

IMPROVEMENTS

FIRST STEP

EUSTIS SUBSTATION RECTIFIER

Fence and Grading	$ 3,000	
115 Kv Facilities	27,000	
Rectifier Transformer	95,000	
Rectifier & DC Switchgear	185,000	
DC Terminals and Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	24,000	$ 348,000

JANNEY REPLACE M-G SETS

Replace 3 - 1500 Kw G.E. and 1 -3,000 Kw G.E. M-G Set with		
2 - 2000 Kw G.E. M-G Sets from Eustis		
2 - 2000 Kw G.E. M-G Sets from Loweth		
4 - M-G Sets @ 20,000	80,000	
Supervisory Control	10,000	90,000

PIEDMONT ADD M-G SET

Add 1 - 1500 Kw G.E. M-G Set from Janney to 3 - 1500 Kw G.E. M-G Sets		
Building Expansion	25,000	
Install M-G Set	35,000	
Supervisory Control	10,000	70,000

LOWETH REPLACE M-G SETS

Replace 2 - 2000 Kw G.E. M-G Sets with 1 - 3000 Kw G.E. M-G Set from Janney and 1 - 3000 Kw G.E. M-G Set from Cle Elum		
2 - M-G Sets @ 30,000	60,000	
Rewind 1 Transformer	10,000	
Supervisory Control	10,000	80,000

EAST PORTAL REPLACE M-G SETS

Replace 3 - 2000 Kw G.E. M-G Sets with 5 - 1500 Kw G.E. M-G Sets, 2 from Janney and 3 from Avery		
Extend Building	$ 35,000	
High Voltage Switchgear	45,000	
Install M-G Sets in New Building Addition @ 22,500	45,000	
Replace Existing M-G Sets 3 @ 20,000	60,000	
Supervisory Control	10,000	$ 195,000

AVERY REPLACE M-G SETS

Replace 3 - 1500 Kw G.E. M-G Sets with 3 - 2000 Kw G.E. M-G Sets from East Portal @ 20,000	60,000	
Supervisory Control	10,000	70,000

SUPERVISORY CONTROL AT SUBSTATIONS

Install Supervisory Control at the Following Substations:

Drexel	10,000	
Tarkio	10,000	
Primrose	10,000	
Ravenna	10,000	
Gold Creek	10,000	
Morel	10,000	
Francis	10,000	
Two Dot	10,000	80,000

DEER LODGE SUPERVISORY MASTER

Install Supervisory Control Master at Deer Lodge Dispatchers Office		30,000
TOTAL SUBSTATIONS		$ 893,000

FEEDER INCREASE

(Labor Only)

AVERY TO EAST PORTAL	
Replace 23.8 Miles of 2 - 500 Mcm Cu with 2 - 1590 Mcm Al	$ 50,000
EAST PORTAL TO DREXEL	
Replace 14.7 Miles of 2 - 500 Mcm Cu and 9 Miles of 1 - 500 Mcm and 1-4/0 Cu with 23.7 Miles of 2 - 1590 Mcm Al.	44,000
DREXEL TO TARKIO	
Replace 38.1 Miles of 1 - 500 Mcm Cu and 24 Miles of 1-4/0 Cu with 38.1 Miles of 1 - 1590 Mcm Al.	38,000
TARKIO TO PRIMROSE	
Replace 36.7 Miles of 1 - 500 Mcm Cu and 24 Miles of 1-4/0 Cu with 36.7 Miles of 1590 Mcm Al.	38,000
PRIMROSE TO RAVENNA	
Replace 37.0 Miles of 1 - 500 Mcm Cu and 8 Miles of 1-4/0 Cu with 1 - 1590 Mcm Al.	37,000
RAVENNA TO GOLD CREEK	
Replace 33.3 Miles of 1 - 500 Mcm Cu with 1 - 1590 Mcm Al.	34,000
MOREL TO JANNEY	
Replace 23.4 Miles of 1 - 500 Mcm Cu with 1 - 1590 Mcm Al.	24,000
JANNEY TO PIEDMONT	
Replace 14 Miles of 2 - 700 Mcm Cu with 14 Miles of 2 - 2250 Mcm Al.	34,000

FRANCIS ADD M-G SET		
Add 1 - 2000 Kw G.E. M-G Set from Tarkio to 2 - 2000 Kw G.E. M-G Sets		
Building Expansion	$ 25,000	
Install M-G Set	35,000	$ 60,000
MOREL ADD M-G SET		
Add 1 - 2000 Kw G.E. M-G Set from Tarkio to 2 - 2000 Kw G.E. M-G Sets		
Building Expansion	25,000	
Install M-G Set	35,000	60,000
TOTAL SUBSTATIONS		$ 468,000
FEEDER INCREASE (Labor and Material)		
FRANCIS TO LOWETH		
Run second 1590 Mcm Al. Feeder 30.4 Miles Parallel to Existing 1590 Mcm Al. Feeder		140,000
FRANCIS TOWARD EUSTIS		
Run second 1590 Mcm Al. Feeder 15 Miles West Toward Eustis, Paralleling Existing 1590 Mcm Al. Feeder		70,000
MOREL TO JANNEY		
Run second 1590 Mcm Al. Feeder 24 Miles East from Morel, Paralleling Existing Feeder		107,000
TOTAL FEEDERS		$ 317,000
TOTAL SECOND STEP		$ 785,000

PIEDMONT TO EUSTIS

Replace 41.6 Miles of 1 - 500 Mcm Cu and 26 Miles of 1-4/0 Cu with 41.6 Miles of 1 - 1590 Mcm Al. $ 42,000

EUSTIS TO FRANCIS

Replace 29.9 Miles of 1 - 500 Mcm Cu and 13 Miles of 1-4/0 Cu with 29.9 Miles of 1 - 1590 Mcm Al. 30,000

FRANCIS TO LOWETH

Replace 30.4 Miles of 1 - 500 Mcm Cu and 25 Miles of 1-4/0 Cu with 30.4 Miles of 1 - 1590 Mcm Al. 32,000

LOWETH TOWARD TWO DOT

Add second 1590 Mcm Al. Feeder East from Loweth for 8 Miles 10,000

TWO DOT TO HARLOWTON

Replace 12.0 Miles of 1 - 500 Mcm Cu and 1-4/0 Cu with 1 - 1590 Mcm Al. 12,000

TOTAL FEEDERS	$ 425,000
TOTAL FIRST STEP	$1,318,000

SECOND STEP

TARKIO SUBSTATION RECTIFIER

Fence and Grading	$ 3,000	
115 Kv Facilities	27,000	
Rectifier Transformer	95,000	
Rectifier & DC Switchgear	185,000	
DC Terminals & Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	24,000	$ 348,000

THIRD STEP

PRIMROSE SUBSTATION RECTIFIER

Fence and Grading	$ 3,000	
115 Kv Facilities	27,000	
Rectifier Transformer	95,000	
Rectifier & DC Switchgear	185,000	
DC Terminals & Cables	4,000	
Supervisory Control	10,000	
Labor and Overhead	24,000	$ 348,000

DREXEL ADD M-G SET

Add 1 - 2000 Kw G.E. M-G Set from Primrose to 2 - 2000 Kw G.E. M-G Sets		
Building Expansion	25,000	
Install M-G Set	35,000	60,000

TWO DOT ADD M-G SET

Add 1 - 2000 Kw G.E. M-G Set from Primrose to 2 - 2000 Kw G.E. M-G Sets		
Building Expansion	25,000	
Install M-G Set	35,000	60,000

TOTAL SUBSTATION	$ 468,000

FEEDER INCREASE

(Labor and Material)

DREXEL TOWARD TARKIO

Run second 1590 Mcm Al. Feeder 10 Miles East Toward Tarkio, Paralleling Existing 1590 Mcm Al. Feeder	50,000

TWO DOT TO LOWETH

Run second 1590 Mcm Al Feeder 25.2 Miles West Toward Loweth, Paralleling Existing 1590 Mcm Al. Feeder	130,000

TOTAL FEEDERS	$ 180,000
TOTAL THIRD STEP	$ 648,000
TOTAL ROCKY MOUNTAIN DIVISION	$2,751,000

MILWAUKEE ELECTRIFICATION

ROCKY MOUNTAIN DIVISION

FEEDER REPLACEMENT

AVERY - EAST PORTAL 23.8 Miles

Remove 2 - 500 Mcm Cu 387,988# Install 2 - 1590 Mcm Al. 375,231#

EAST PORTAL - DREXEL 23.7 Miles

Install 2 - 1590 Mcm Al. 373,654#

Remove 1 - 500 Mcm Cu 14.7 Miles 119,820#

Remove 2 - 500 Mcm Cu 9.0 Miles 146,718

Remove 1 - 4/0 Cu 9.0 Miles 31,050

DREXEL - TARKIO 38.0 Miles

Remove 1 - 500 Mcm Cu 309,738 # Install 1 - 1590 Mcm Al. 299,554#

Remove 1 - 4/0 Cu 24.0 Miles 82,800#

TARKIO - PRIMROSE 36.7 Miles

Remove 1 - 500 Mcm Cu 299,142#

Remove 4/0 Cu 24 Miles 82,800 Install 1 - 1590 Mcm Al. 289,306#

PRIMROSE - RAVENNA 37.0 Miles

Remove 1 - 500 Mcm Cu 301,587# Install 1 - 1590 Mcm Al. 291,671#

Remove 1 - 4/0 Cu 8 Miles 27,600#

RAVENNA - GOLD CREEK 33.3 Miles

Remove 1 - 500 Mcm Cu 271,428# Install 1 - 1590 Mcm Al. 265,504#

GOLD CREEK - MOREL 35.5 Miles

Existing 1 - 1590 Al. Feeder

MOREL - JANNEY 33.5 Miles

Remove 1 - 500 Mcm Cu 23.4 Miles 190,733# Install 1 - 1590 Mcm Al. 184,462#

JANNEY - PIEDMONT 28.4 Miles

Remove 2 - 700 Mcm Cu 14 Miles 319,480 Install 2 - 2250 Mcm Al. 315,336#

PIEDMONT - EUSTIS 41.6 Miles

Remove 1 - 500 Mcm Cu 339,082#

Remove 1 - 4/0 Cu 13 Miles 44,850# Install 1 - 1590 Mcm Al. 327,933#

EUSTIS - FRANCIS 30 Miles

Remove 1 - 500 Mcm Cu 244,530# Install 1 - 1590 Mcm Al. 236,490#

Remove 1 - 4/0 Cu 13 Miles 48,850#

FRANCIS - LOWETH 30.4 Miles

Remove 1 - 500 Mcm Cu 247,790# Install 1 - 1590 Mcm Al. 239,643#

Remove 1 - 4/0 Cu 25 Miles 86,250#

LOWETH - TWO DOT 33.2 Miles

Existing 1 - 1590 Al. Feeder

East from Loweth 8 Miles Install 1 - 1590 Mcm Al. 63,064#

TWO DOT - HARLOWTON 12.0 Miles

Remove 1 - 500 Mcm Cu 97,812# Install 1 - 1590 Mcm Al. 94,596#

Remove 1 - 4/0 Cu 41,400#

COPPER REMOVED

28 Miles 700 Mcm	@ 11,410#	=	319,480#
363 Miles 500 Mcm	@ 8,150#	=	2,960,368
128 Miles 4/0	@ 3,450#	=	441,600
Total Cu Removed			3,721,448#

ALUMINUM INSTALLED

28 Miles 2250 Mcm	@ 11,262#	=	315,336#
386 Miles 1590 Mcm	@ 7,883	=	3,041,108
Total Aluminum Required			3,356,444#

Salvage Value of Copper 3,721,448# @ 52¢/lb		$ 1,935,153
Cost of Aluminum		
315,336# 2,250 Mcm @ 44¢/lb	$ 138,748	
3,041,108# 1590 Mcm @ 40.5¢/lb	$1,231,649	
Total Aluminum		1,370,397
Credit for Cu Conductors		564,756
Rocky Mountain Feeder Labor		425,000
Credit to Project		139,756
Rocky Mountain Credit Round To		140,000

MONTANA POWER COMPANY

ADDED FACILITIES REQUIRED

FOR

ROCKY MOUNTAIN DIVISION IMPROVEMENTS

TELEMETERING

Telemeter Railroad load from thirteen (13) Railroad substations to Butte and from Butte to Deer Lodge	$ 85,000

OUTLINE OF CONTRACT REQUIREMENTS

BETWEEN

PUGET SOUND POWER & LIGHT COMPANY

AND

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

TERM OF CONTRACT. Contract to be effective January 1, 1970 and to run for thirty (30) years to December 31, 1999 and thereafter until terminated by two years written notice given by either party.

ELECTRIC POWER SUPPLY. Puget will supply electric power to all Milwaukee substations in Puget's service area west of the Columbia River in the State of Washington at a nominal voltage of 115 Kv.

PAYMENT. (A) Payment to Puget for power delivered to Milwaukee to be at the rate of per Kwh for all Kwh supplied from January 1, 1970 to April 30, 1976.

(B) Payment for power delivered to Milwaukee from May 1, 1976 to the end of the contract to be at the rate of per Kwh plus an energy cost adjustment. The energy cost adjustment will be a multiplying factor to be determined from time to time as agreed between Milwaukee and Puget. This factor to continue in effect until a new factor is agreed upon by Milwaukee and Puget.

DEMAND LIMITATION. In consideration of the rates hereby granted, Milwaukee agrees that the Railroad's electric power demand at the request of Puget's Power dispatcher will be limited to a value not to exceed one (1) Kw for each 10,000 Kwh delivered to Milwaukee by the Power Company in the previous twelve month period. This limitation to be applied upon two hours notice to Milwaukee's dispatcher by Puget Power's dispatcher. Such interruptions shall not exceed four consecutive hours in duration.

EXTENSION OF ELECTRIC OPERATION. Both Puget and Milwaukee desire to see the Railroad Company continue and extend its electric operation in the State of Washington. To this end and to enable the Railroad Company to make the maximum use of its assets to continue and extend electric operation of trains in the States of Washington, Idaho and Montana, Puget will purchase from the Railroad Company the following facilities all located in the State of Washington.

(A) 115 Kv transmission line extending from Cedar Falls to Taunton

(B) 115 Kv oil circuit breakers located at the Railroad Company's substations at Cedar Falls, Hyak and Kittitas. One oil circuit breaker at each substation

(C) Power transformers located at the following Railroad substations:

Tacoma Junction	2 transformers
Renton	2 transformers
Cedar Falls	2 transformers
Hyak	2 transformers
Kittitas	2 transformers
Doris	3 transformers
Taunton	2 transformers

In addition to the foregoing existing lines and equipment, Puget will pay the Railroad Company for new rectifier transformers to be installed in a new Railroad Company substation at Black River Junction and at a new rectifier installation at Cle Elum. Puget will own these transformers and the Railroad Company will own the balance of the rectifier substations. Puget will, at its own expense, extend its 115 Kv line west from the Railroad Company's Renton Substation to its new Black River Junction Substation on right-of-way to be supplied by the Railroad Company.

PAYMENT FOR FACILITIES PURCHASED. Puget will pay the Railroad Company $ plus 8% interest on the unpaid balance by refunding to the Railroad Company fifty (50) percent of its monthly power bill.

RELOCATION OF FACILITIES. If the Railroad Company desires to relocate motor-generator sets that are supplied by transformers purchased by Puget from the Railroad Company, the Railroad Company shall pay the cost of moving and connecting said transformers.

BILLING. The Power Company shall render the Railroad Company on or before the tenth day of each montn a bill for electric power delivered under this contract during the preceding calendar month and the Railroad Company shall pay such bill on or before the last day of the month the bill was presented.

METERING. Metering equipment to measure electric energy shall be supplied by the Power Company.

(A) Metering will be on the low tension side of the Railroad Company's transformers

(B) Metering will be provided to record all electric energy delivered to the Railroad Company and all electric energy regenerated by the Railroad Company's locomotives and returned to the Power Company.

(C) Recording demand meters shall be installed at each of the Railroad Company's substations to indicate the maximum demand of the Railroad Company and to indicate the maximum energy returned to the Power Company by regeneration in those substations equipped for regeneration.

(D) The demand meter readings shall be telemetered to the Power Companies' dispatchers where the readings will be totalized. Puget's Power Dispatcher's Office is located at Redmond, Washington. The totalized demand for the Railroad Company's substations in Puget's service area shall be telemetered to the Railroad Company's Dispatcher's Office in Tacoma, Washington.

(E) Power Company representatives shall have access at all times during the normal working day to its apparatus used to measure electric energy and to telemeter such measurements.

OUTLINE OF CONTRACT REQUIREMENTS

BETWEEN

WASHINGTON WATER POWER COMPANY

AND

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

TERM OF CONTRACT. Contract to be effective January 1, 1970 and run for thirty (30) years to December 31, 1999 and thereafter until terminated by two years written notice given by either party.

ELECTRIC POWER SUPPLY. Washington will supply electric power to all Milwaukee substations to be built and to two (2) existing substations in Washington's service area east of the Columbia River in the State of Washington and in the State of Idaho at nominal voltage of 115 Kv.

PAYMENT. (A) Payment to Washington for power delivered to Milwaukee to be at the rate of $ per Kwh for all Kwh supplied from January 1, 1970 to April 30, 1976.

(B) Payment for power delivered to Milwaukee from May 1, 1976 to the end of the contract to be at the rate of $ per Kwh plus an energy cost adjustment. The energy cost adjustment will be a multiplying factor to be determined from time to time as agreed between Milwaukee and Washington. This factor to continue in effect until a new factor is agreed upon by Milwaukee and Washington.

DEMAND LIMITATION. In consideration of the rates hereby granted, Milwaukee agrees that the Railroad's electric power demand at the request of Washington's power dispatcher will be limited to a value not to exceed one (1) Kw for each 10,000 Kwh delivered to Milwaukee by the Power Company in the previous twelve month period. This limitation to be applied upon two hours notice to Milwaukee's dispatcher by Washington's power dispatcher. Such interruptions shall not exceed four consecutive hours in duration.

EXTENSION OF ELECTRIC OPERATION. Both Washington and Milwaukee desire to see the Railroad Company continue and extend its electric operation in the States of Idaho and Washington. To this end and to enable the Railroad Company to make the maximum use of its assets to continue and extend electric operation of trains in the States of Washington, Idaho and Montana, Washington will purchase from the Railroad Company the following facilities:

(A) 115 Kv transmission line extending from East Portal, Montana to Avery, Idaho

(B) Power transformers (3) located in the Railroad Company's substation in Avery, Idaho

(C) 115 Kv oil circuit breaker located at the Railroad Company's substation at Taunton

In addition to the foregoing lines and equipment, Washington will pay the Railroad Company for eight (8) new rectifier transformers to be installed in seven new Railroad Company substations located at St. Maries and Plummer, Idaho and at Tekoa, Malden, Revere, west of Ralston and west of Roxboro in the State of Washington. Together with a rectifier at Taunton replacing existing motor-generator sets, Washington will own these transformers and the Railroad Company will own the balance of the rectifier substations. Washington will, at its expense, extend its 115 Kv lines to serve the Railroad Company's new rectifier substations at St. Maries and Plummer, Idaho and at Tekoa, Malden, Revere, west of Ralston and west of Roxboro in the State of Washington.

PAYMENT FOR FACILITIES PURCHASED. Washington will pay the Railroad Company plus 6% interest on the unpaid balance by refunding to the Railroad Company fifty (50) percent of its monthly power bill.

RELOCATION OF FACILITIES. If the Railroad Company desires to relocate rectifier equipment supplied by transformers owned by Washington, the Railroad Company shall pay the cost of moving and connecting said transformers.

BILLING. The Power Company shall render the Railroad Company on or before the tenth day of each month a bill for electric power delivered under this contract during the preceding calendar month and the Railroad Company shall pay such bill on or before the last day of the month the bill was presented.

METERING. Metering equipment to measure electric energy shall be supplied by the Power Company.

(A) Metering will be on the low tension side of the Railroad Company's transformers

(B) Metering will be provided to record all electric energy delivered to the Railroad Company and all electric energy regenerated by the Railroad Company's locomotives and returned to the Power Company

(C) Recording demand meters shall be installed at each of the Railroad Company's substations to indicate the maximum demand of the Railroad Company and to indicate the maximum energy returned to the Power Company by regeneration in those substations equipped for regeneration

(D) The demand meter readings shall be telemetered to the Power Company's dispatchers where the readings will be totalized. Washington's Power Dispatcher's Office is located at Spokane, Washington. The totalized demand for the Railroad Company's substations in Puget's service area shall be telemetered to the Railroad Company's Dispatcher's Office in Malden, Washington.

(E) Power Company representatives shall have access at all times during the normal working day to its apparatus used to measure electric energy and telemeter such measurements

OUTLINE OF CONTRACT REQUIREMENTS

BETWEEN

MONTANA POWER COMPANY

AND

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

TERM OF CONTRACT. Contract to be effective January 1, 1970 and run for thirty (30) years to December 31, 1999 and thereafter until terminated by two years written notice given by either party.

ELECTRIC POWER SUPPLY. Montana will supply electric power to all Milwaukee substations in the State of Montana at a nominal voltage of 115 Kv.

PAYMENT. (A) Payment to Montana for power delivered to Milwaukee to be at the rate of $ per Kwh for all Kwh supplied from January 1, 1970 to June 30, 1975.

(B) Payment for power delivered to Milwaukee from July 1, 1975 to the end of the contract to be at the rate of $ per Kwh plus an energy cost adjustment. The energy cost adjustment will be a multiplying factor to be determined from time to time as agreed between Milwaukee and Montana. This factor to continue in effect until a new factor is agreed upon by Milwaukee and Montana.

DEMAND LIMITATION. In consideration of the rates hereby granted, Milwaukee agrees that the Railroad's electric power demand at the request of Montana's power dispatcher will be limited to a value not to exceed one (1) Kw for each 10,000 Kwh delivered to Milwaukee by the Power Company in the previous twelve month period. This limitation to be applied upon two hours notice to Milwaukee's dispatcher by Montana's power dispatcher. Such interruptions shall not exceed four consecutive hours in duration.

EXTENSION OF ELECTRIC OPERATION. Both Montana and Milwaukee desire to see the Railroad Company to continue and expand its electric operation in the State of Montana. To this end, and to enable the Railroad Company to make the maximum use of its assets to continue and extend electric operation of trains in the States of Montana, Idaho and Washington. Montana will purchase from the Railroad Company the following facilities all located in the State of Montana.

(A) 115 Kv transmission lines extending east from East Portal to Two Dot

(B) 115 Kv, 600 A - 1000 Mva oil circuit breakers located at the following Railroad Company's substations in Montana.

East Portal	2 OCB
Gold Creek	1 OCB
Morel	1 OCB
Piedmont	3 OCB
Francis	1 OCB
Two Dot	2 OCB

(C) Power transformers located at the following Railroad substations:

Cle Elum	1 transformer
East Portal	3 transformers
Drexel	2 transformers
Tarkio	2 transformers
Primrose	2 transformers
Ravenna	2 transformers
Gold Creek	2 transformers
Morel	2 transformers
Janney	4 transformers
Piedmont	3 transformers
Eustis	2 transformers
Francis	2 transformers
Loweth	2 transformers
Two Dot	2 transformers

In addition to the foregoing existing lines and equipment, Montana will pay the Railroad Company for one (1) new rectifier transformer to be installed at the Railroad Company substation at Eustis. Milwaukee will own the balance of the rectifier substation equipment at Eustis.

PAYMENT FOR FACILITIES PURCHASED. Montana will pay the Railroad Company plus 8% interest on the unpaid balance by refunding to the Railroad Company thirty-three and one third (33-1/3) percent of its monthly power bill.

RELOCATION OF FACILITIES. If the Railroad Company desires to relocate DC supply equipment supplied by transformers owned by Montana, the Railroad Company shall pay the cost of moving and connecting said transformers.

BILLING. The Power Company shall render the Railroad Company on or before the tenth day of each month a bill for electric power delivered under this contract during the preceding calendar month and the Railroad Company shall pay such bill on or before the last day of the month the bill was presented.

METERING. Metering equipment to measure electric energy shall be supplied by the Power Company.

(A) Metering will be on the low tension side of the Railroad Company's transformers

(B) Metering will be provided to record all electric energy delivered to the Railroad Company and all electric energy regenerated by the Railroad Company's locomotives and returned to the Power Company.

(C) Recording demand meters shall be installed at each of the Railroad Company's substations to indicate the maximum demand of the Railroad Company and to indicate the maximum energy returned to the Power Company by regeneration in those substations equipped for regeneration.

(D) The demand meter readings shall be telemetered to the power companies' dispatchers where the readings will be totalized. Montana's Power Dispatcher's Office is located in Butte, Montana. The totalized demand for the Railroad Company's substations in Montana's service area shall be telemetered to the Railroad Company's Dispatcher's Office in Deer Lodge, Montana

(E) Power Company representatives shall have access at all times during the normal working day to its apparatus used to measure electric energy and to telemeter such measurements

MILWAUKEE ELECTRIFICATION
TABLE I
KILOWATT HOURS USE ACTUAL AND PROJECTED

	COAST DIVISION		OTHELLO - AVERY		ROCKY MOUNTAIN DIVISION	
	Actual	Est. Total Elec. Oper.	Actual	Est. Total Elec. Oper.	Actual	Est. Total Elec. Oper.
1960	37,037,720	39,759,000		32,200,000	75,660,887	101,453,000
1961	31,190,010	37,073,000		30,200,000	68,675,617	94,903,000
1962	26,829,690	41,712,000		33,250,000	76,981,627	104,332,000
1963	29,629,710	42,285,000		35,600,000	74,792,849	109,208,000
1964	25,591,840	44,461,000		38,300,000	65,938,438	116,708,000
1965	28,428,860	46,415,000		40,400,000	78,700,771	127,518,000
1966	28,247,627	46,191,000		43,739,000	82,112,574	134,329,000
1967	25,889,240	47,307,000		44,549,000	77,775,179	131,652,000
1968	14,929,940	50,286,000		47,262,000	69,390,084	143,373,000
	3.34% Growth	PROJECTED	5.79% Growth	PROJECTED	5.17% Growth	PROJECTED
1969		51,570,000		50,306,000		150,681,000
1970		53,289,000		53,218,000		158,475,000
1971		55,066,000		56,298,000		166,672,000
1972		56,903,000		59,557,000		175,294,000
1973		58,800,000		63,005,000		184,361,000
1974		60,761,000		66,652,000		193,897,000
1975		62,787,000		70,510,000		203,926,000
1976		64,881,000		74,591,000		214,474,000
1977		67,044,000		78,909,000		225,568,000
1978		69,280,000		83,476,000		237,235,000
1979		71,590,000		88,308,000		249,506,000
1980		73,978,000		93,420,000		262,412,000
1981		76,445,000		98,827,000		275,985,000
1982		78,998,000		104,549,000		290,253,000
1983		81,637,000		110,602,000		305,260,000
1984		84,363,000		117,006,000		321,041,000
1985		87,181,000		123,781,000		337,639,000

MILWAUKEE ELECTRIFICATION
TABLE II
POWER COST ACTUAL AND PROJECTED

	COAST DIVISION		OTHELLO - AVERY		ROCKY MOUNTAIN DIVISION	
	Actual	Est. Total Elec. Oper.	Actual	Est. Total Elec. Oper.	Actual	Est. Total Elec. Oper.
1960	$ 217,863	$ 233,862		$ 177,000	$ 405,542	$ 543,788
1961	182,331	216,655		166,000	368,101	508,680
1962	156,503	243,306		183,000	412,622	559,220
1963	171,555	244,830		196,000	400,890	585,355
1964	150,393	261,786		211,000	353,430	625,555
1965	166,964	272,456		222,300	421,836	683,496
1966	166,426	271,602		240,565	440,123	720,004
1967	154,092	276,746		245,020	416,875	705,657
1968	79,948	294,171		259,940	361,211	768,478
	3.35% Growth	PROJECTED	5.79% Growth	PROJECTED	5.17% Growth	PROJECTED
1969		302,170		276,815		807,611
1970		312,304		292,848		849,378
1971		322,778		309,811		893,307
1972		333,603		327,755		939,507
1973		344,792		346,740		988,096
1974		356,355		366,823		1,039,199
1975		368,307		388,071		1,092,943
1976		380,659		410,549		1,149,469
1977		393,426		434,328		1,208,917
1978		406,620		459,485		1,271,440
1979		420,258		486,100		1,337,196
1980		434,353		514,255		1,406,352
1981		448,920		544,042		1,479,087
1982		463,914		575,542		1,555,556
1983		479,409		608,866		1,635,978
1984		495,421		644,119		1,720,558
1985		511,968		681,414		1,809,511

MILWAUKEE ELECTRIFICATION
TABLE III
MEGAWATTHOURS PROJECTED YEARS 1969 THROUGH 1985
LOW GROWTH RATE

Year	Coast Division 2.2%	Othello - Avery 3.8%	Rocky Mountain 3.4%	Total Electrification
1969	51,570	50,306	150,681	252,557
1970	52,756	52,218	155,955	260,929
1971	53,970	54,202	161,413	269,585
1972	55,211	56,262	167,063	278,536
1973	56,481	58,400	172,910	287,791
1974	57,780	60,619	178,962	297,361
1975	59,109	62,922	185,225	307,256
1976	60,468	65,313	191,708	317,489
1977	61,856	67,795	198,418	328,069
1978	63,282	70,371	205,362	339,015
1979	64,373	73,045	212,550	349,968
1980	66,226	75,821	219,990	362,037
1981	67,749	78,702	227,690	424,141
1982	69,307	81,693	235,659	386,659
1983	70,901	84,797	243,907	399,605
1984	72,461	88,019	252,120	412,600
1985	74,055	91,364	260,775	426,194

JJD:mro
General Engineering Department
11/13/69

MILWAUKEE ELECTRIFICATION
TABLE IV
MEGAWATTHOURS PROJECTED YEARS 1969 THROUGH 1985
ON A STRAIGHT LINE

Year	Coast Division	Othello - Avery	Rocky Mountain	Total Electrification
1970	20,000		80,000	100,000
1971	50,000		155,000	205,000
1972	55,000	55,000	160,000	270,000
1973	56,000	57,000	165,000	278,000
1974	57,000	59,000	170,000	286,000
1975	58,000	61,000	175,000	294,000
1976	59,000	63,000	140,000	302,000
1977	60,000	65,000	185,000	310,000
1978	61,000	67,000	190,000	318,000
1979	62,000	69,000	195,000	326,000
1980	63,000	71,000	200,000	334,000
1981	64,000	73,000	205,000	342,000
1982	65,000	75,000	210,000	350,000
1983	66,000	77,000	215,000	358,000
1984	67,000	79,000	220,000	366,000
1985	68,000	81,000	225,000	374,000

Straight Line Growth

Coast Division	1,000 MWH/year
Avery - Othello	2,000 MWH/year
Rocky Mountain	5,000 MWH/year

MILWAUKEE ELECTRIFICATION
TABLE V
ENERGY COST SAVINGS

Year	Total MWH.	Dollar Savings
1970	100,000	200,000
1971	205,000	410,000
1972	270,000	540,000
1973	278,000	556,000
1974	286,000	572,000
1975	294,000	588,000
1976	302,000	604,000
1977	310,000	620,000
1978	318,000	636,000
1979	326,000	652,000
1980	334,000	668,000
1981	342,000	684,000
1982	350,000	700,000
1983	358,000	716,000
1984	366,000	732,000
1985	374,000	748,000

Based on energy ratio of 10KWH = 1 gal. of diesel fuel
Diesel fuel $0.09 per gal.
Electricity $0.007 per KWH.
For energy saving of $0.002 per KWH.

MILWAUKEE ELECTRIFICATION
TABLE VI
PROJECT SAVINGS FROM ENERGY,
LOCOMOTIVE OPERATIONS AND AMORTIZATION

Year	Energy	Operations	Amortization	Total
1970	200,000	92,870	-0-	292,870
1971	410,000	278,610	129,330	817,940
1972	540,000	557,220	258,670	1,355,890
1973	556,000	557,220	388,000	1,501,220
1974	572,000	557,220	388.000	1,517,220
1975	588,000	557,220	388,000	1,533,220
1976	604,000	557,220	388,000	1,549,220
1977	620,000	557,220	388,000	1,565,220
1978	636,000	557,220	388,000	1,581,220
1979	652,000	557,220	388,000	1,597,220
1980	668,000	557,220	388,000	1,613,220
1981	684,000	557,220	388,000	1,629,220
1982	700,000	557,220	388,000	1,645,220
1983	716,000	557,220	388,000	1,661,220
1984	732,000	557,220	388,000	1,677,220
1985	748,000	557,220	388,000	1,693,220

VOLTAGE REQUIREMENTS
AND
CONTROL

To operate electric locomotives efficiently, the voltage supplied to the trolley must be as near constant as possible. Railroads using DC to operate trains, use one of three means to control DC voltage depending on the type of conversion equipment employed.

1. Motor-generator sets control voltage by changing the field current of the DC generator

2. Rectifier DC voltage may be controlled by phase control

3. Rectifier DC voltage may be controlled by changing the AC voltage supplied to the rectifier

Voltage supplied to the nominal 3300 volt trolley of the electrified divisions of the Milwaukee should be under control at the Railroad's dispatcher. The voltage range required is from a maximum of 3600 volts to a minimum of 2,000 volt at the DC terminals of the conversion equipment.

This range of voltage can be delivered by the motor-generator sets now in use by the Railroad Company. Extension of the electrified sections of Milwaukee through eastern Washington and northern Idaho contemplates the use of solid state rectifiers to supply 3300 volt DC current to the trolley. Voltage output of these rectifiers could be controlled by phase control but this control has two undesirable features.

1. At reduced voltage with phase control, a great many harmonics of large magnitude are introduced into the AC supply system.

2. At reduced voltage, the power factor of the AC load is reduced.

Considering the voltage characteristics of the heavy traction type rectifiers proposed for use by Milwaukee, a rectifier with load tap changing on its supply transformer appears to be the most effective way to control voltage.

Heavy traction type rectifiers have about a 6% droop in voltage as load is applied.

To supply 3300 volts of rated load, a rectifier will have the following voltage variation:

Percent Load	DC Voltage
0	3500
100	3300
150	3200
200	3100
300	2900
450	2600

To control this voltage from a maximum of 3600 volts to a minimum of 2,000 volts, load tap changing equipment on the rectifier transformer should use the standard 32 step tap changing equipment with 50 volts change on each step. With neutral voltage at 3300 volts, the voltage range with this combination of LTC equipment and a 6% rectifier droop are listed below.

Percent Load	Maximum Voltage	Minimum Voltage
0	4100	2500
100	3900	2300
150	3800	2200
200	3700	2100
300	3500	1900
450	3200	1600

Although the no load voltage can only be reduced to 2500 volts, as soon as locomotives begin drawing current from the rectifier, the voltage will droop to the desired level.

A similar range of voltage control may be secured by using standard range 32-5/8% step LTC equipment and an Amplistat. This combination of equipment will cost approximately the same as extended range load tap changing equipment. The voltage range possible with these facilities and 3700 volts no load output from the rectifier are listed below.

Percent Load	Maximum Voltage	Minimum Voltage
0	4070	2630
100	3870	2430
150	3770	2330
200	3670	2230
300	3470	2030
450	3170	1730

SUBSTATION EQUIPMENT

Milwaukee Road electrical engineers have determined that rectifier ratings should have a continuous rating of 4400 Kw with standard heavy traction rating as follows:

Load Duration	Percent Load	Output Kilowatts	Amperes
Continuous	100	4400	1333
2 hours	150	6600	2000
1 minute	450	19800	6000

Rectifiers operating with six (6) phases should satisfy the Railroad's requirements. This can be done by using a three phase bridge rectifier connection in conjunction with a 115 Kv delta to 2520 V wye LTC secondary with 36 volt taps on the secondary which will supply a 50 volt charge to the rectifier output.

change

RECTIFIER TRANSFORMER

5000 Kva outdoor, 55 Kv rise continuous with fan rating of 6250 Kva delta, 115 Kv primary with rated Kva taps arranged

2 - 2½% taps above rated voltage

2 - 2½% taps below rated voltage

wye secondary with 32 steps load tap changing to provide 50 volt step changes of DC output

RECTIFIER

4400 Kw 3300 volt continuous silicon rectifier, inherent regulation from no load to full load of approximately 6%. Power factor at rated load 95%.

The rectifier transformers included under these specifications are designed to carry the equivalent of two 2-hour overloads in a 24 hour period, subject to the following conditions:

(A) Subsequent to each 2 hour overload, the load is reduced to 100% or less for a sufficient time to allow the liquid temperature to drop to at least the 100% level.

(B) The RMS load over the entire 24 hour period does not exceed 100%.

DC overloads and short circuits will be cleared by the d-c breaker without operation of cell isolating fuses or failure of silicone cells.

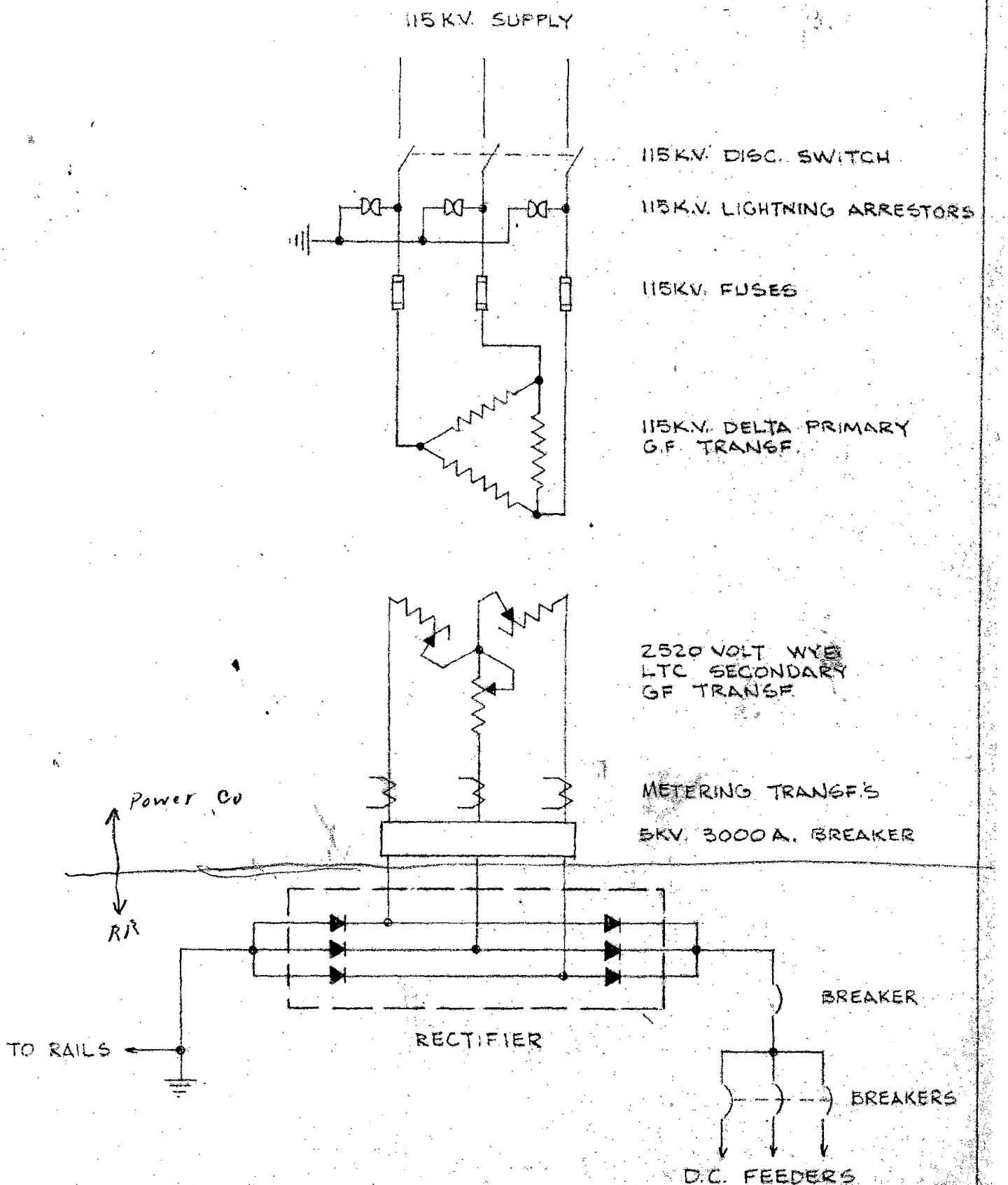
A failed silicone cell will be disconnected by its isolating fuse without damage to other cells or isolating fuses, and without operation of the d-c breakers.

Possible substation arrangements are shown on the following three drawings.

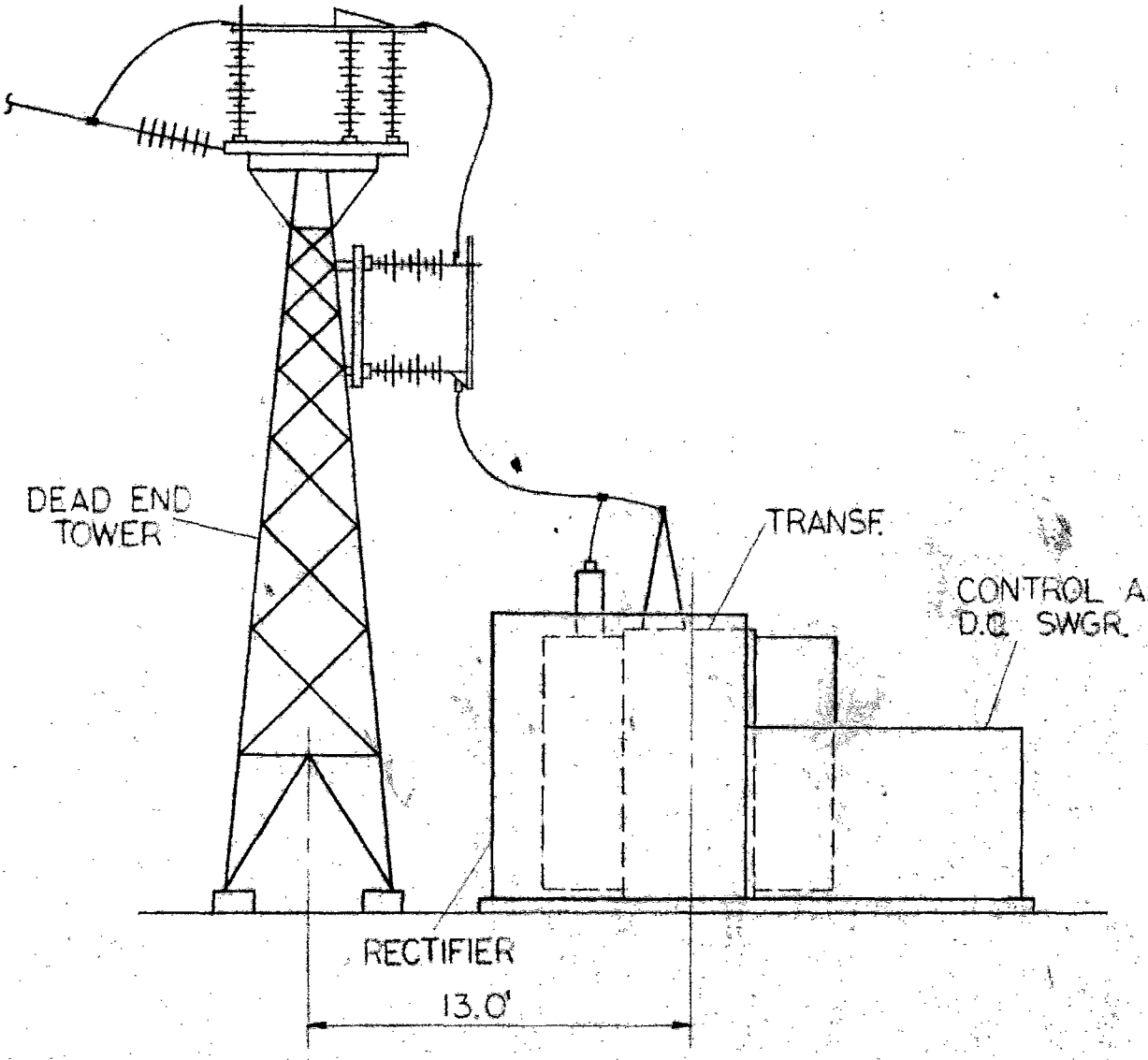
M - 2847 Rectifier Substation - Simplified Diagram

M - 2845 Rectifier Substation - Elevation

M - 2844 Rectifier Substation - Plan



MILWALKEE ELECTRIFICATION RECTIFIER SUBSTATION SIMPLIFIED DIAGRAM				
PUGET SOUND POWER & LIGHT COMPANY GENERAL ENGINEERING DEPT. BELLEVUE WASH.				
SCALE. NONE	DRAWN	CHECK'D	APPROV'D	M-2847
DATE 11-14-69	R.L.K.			
IR				



ELEVATION A-A

TYPICAL RECTIFIER SUBSTATION FOR MILWAUKEE RAILROAD ELECTRIFICATION

PUGET SOUND POWER & LIGHT COMPANY
GENERAL ENGINEERING DEPARTMENT BELLEVUE

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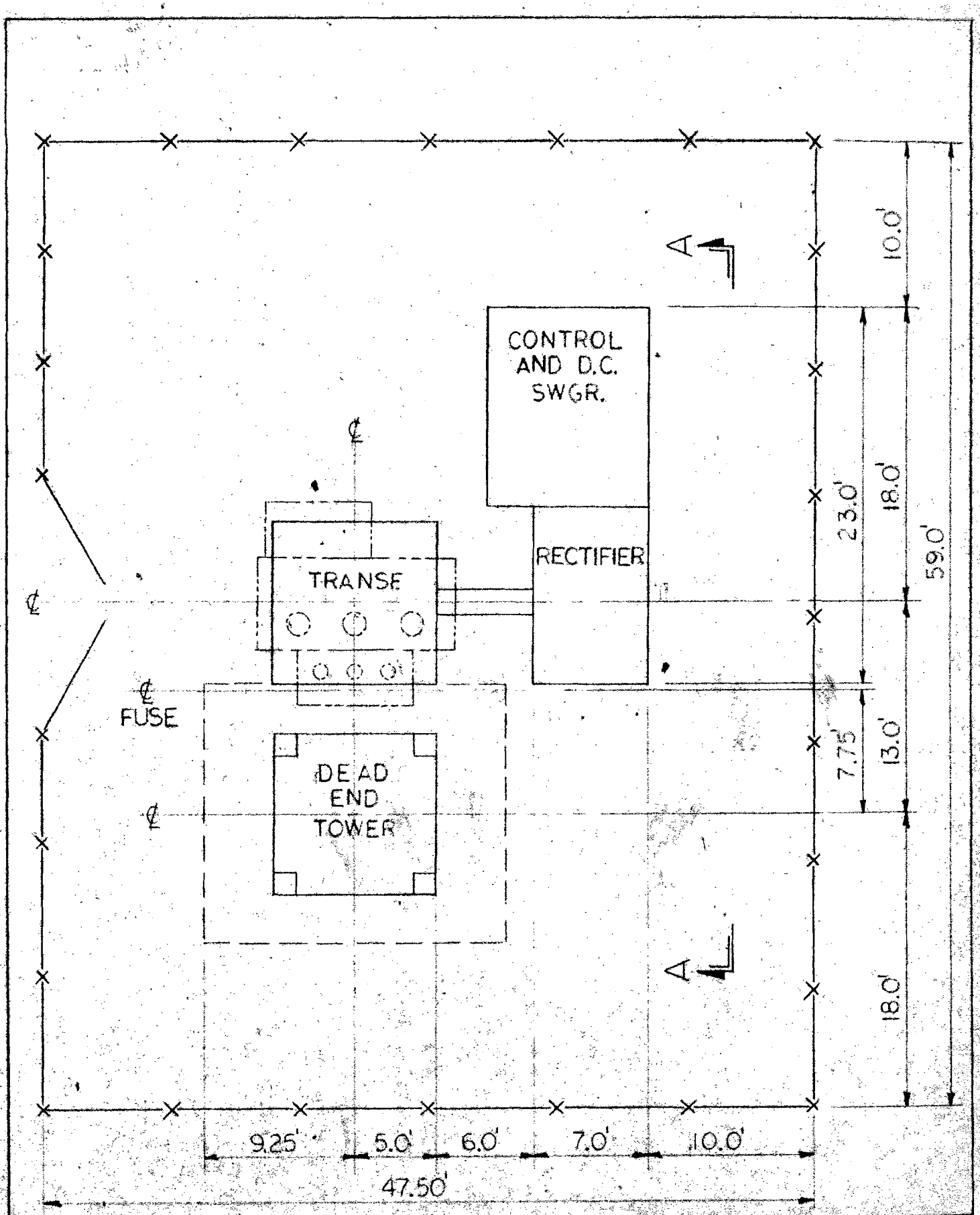
DATE: 11-14-69	T.D.A.			
1R				



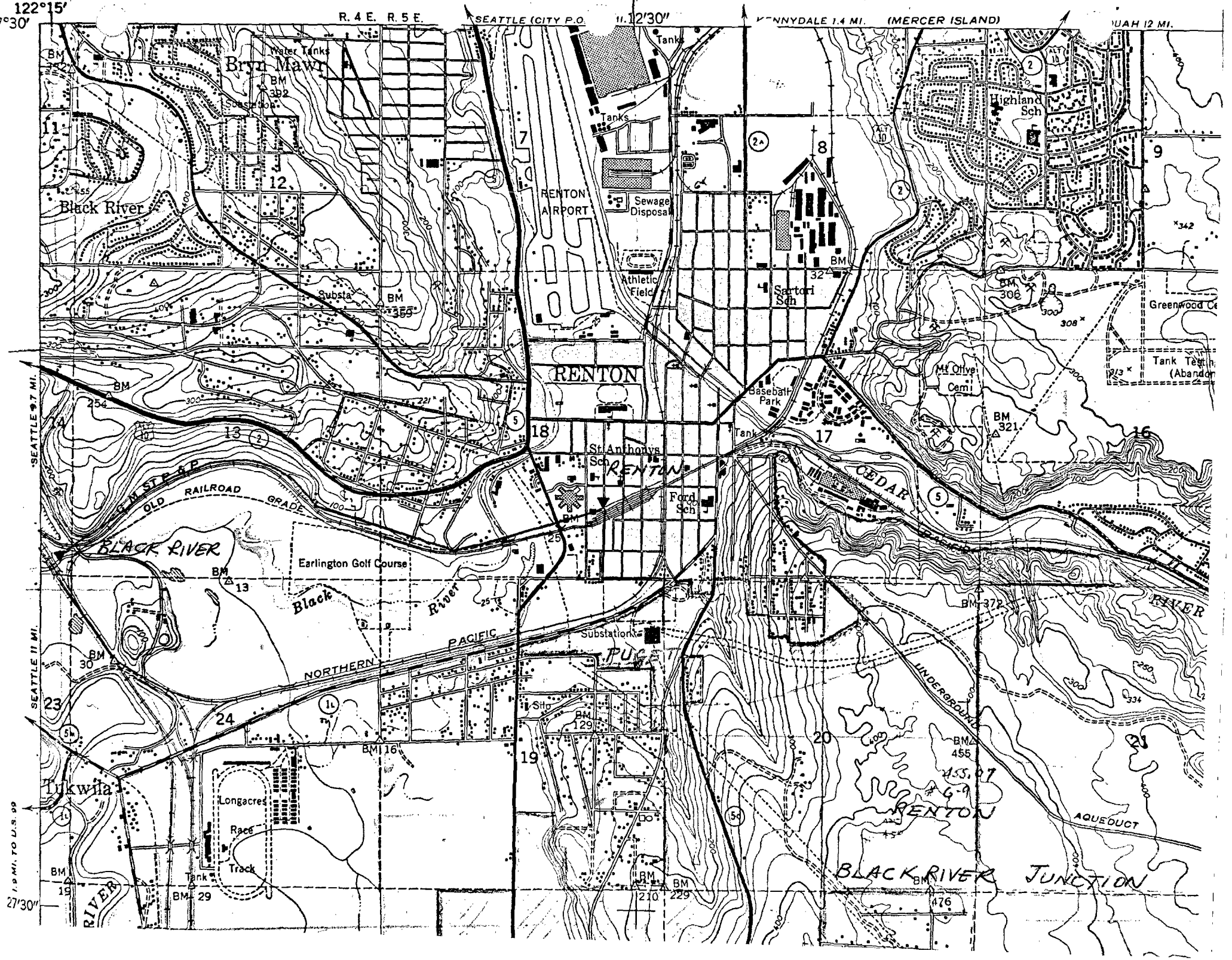
PLAN

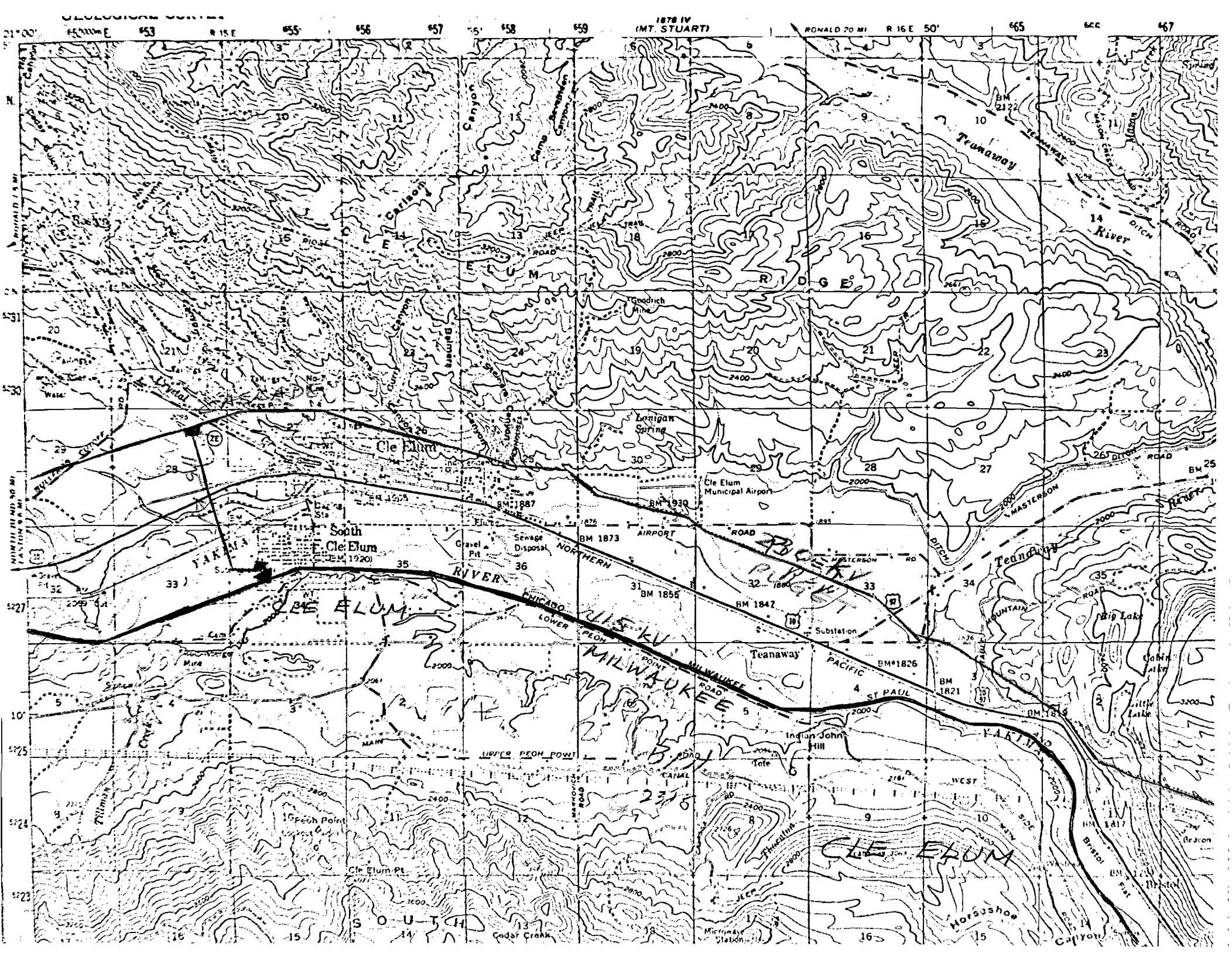
TYPICAL RECTIFIER SUBSTATION FOR MILWAUKEE RAILROAD ELECTRIFICATION

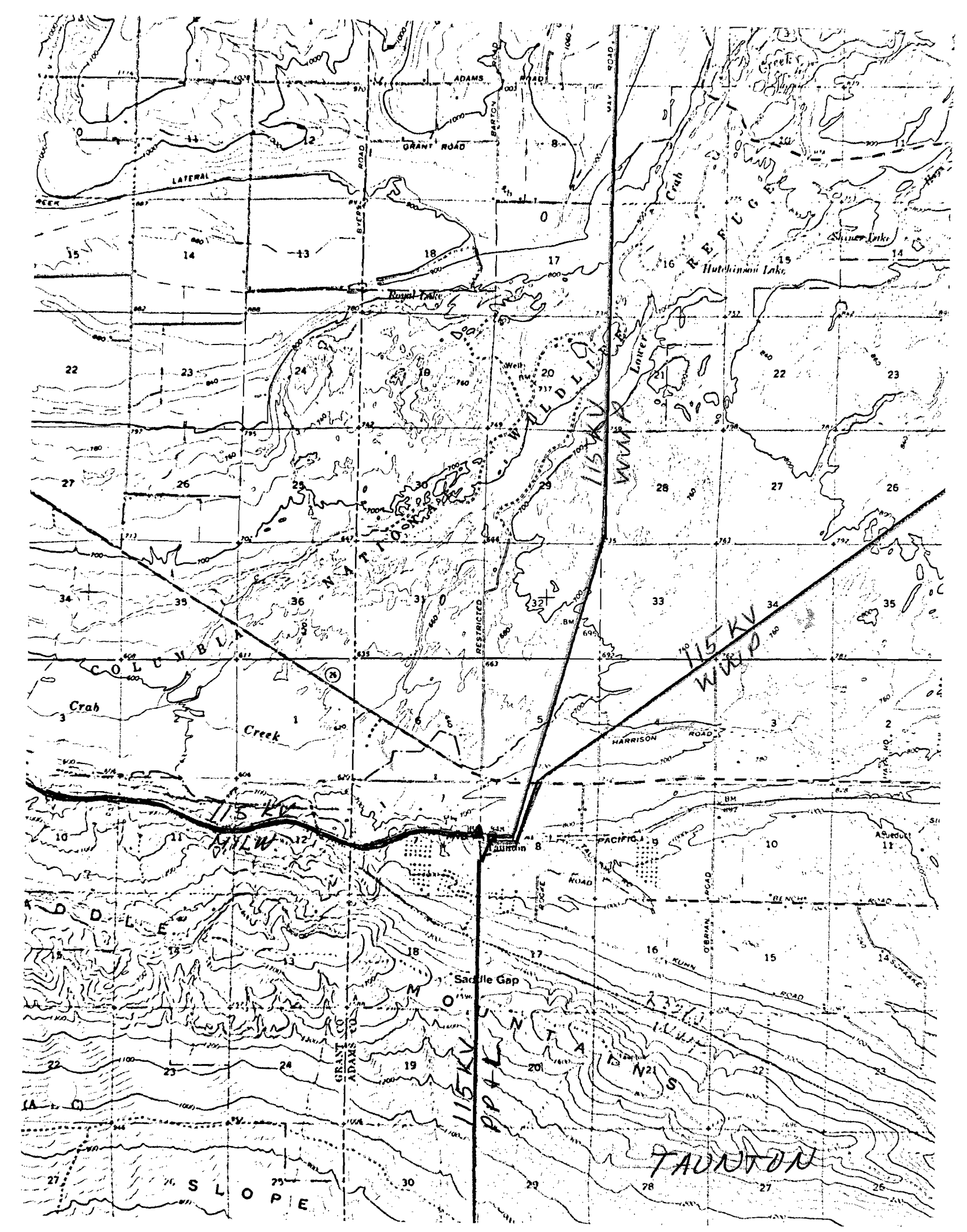
PUGET SOUND POWER & LIGHT COMPANY
GENERAL ENGINEERING DEPARTMENT BELLEVUE

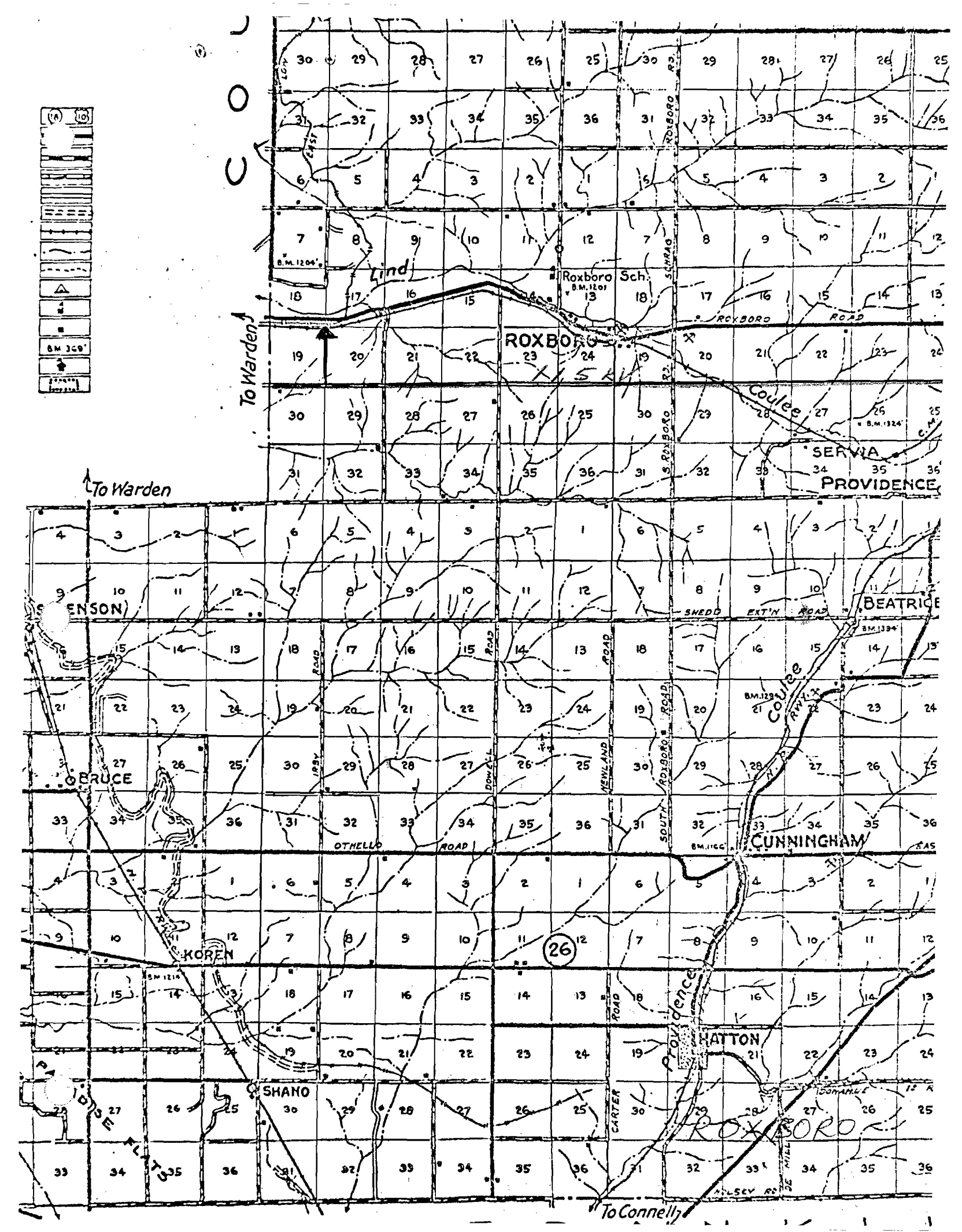
SCALE: 1/8"=1'-0"	DRAWN	CHK'D.	APP'D.
DATE: 11-14-69	T.D.A.		
IR			

M-2844


GEOLOGICAL SURVEY
122°15'
47°30'
R. 4 E.
R. 5 E.
SEATTLE (CITY P.O.
11.12'30"
(MERCER ISLAND)
Water Tanks
Bryn Mawr
BM 392
Substation
Tanks
Highland Sch
Black River
RENTON AIRPORT
Sewage Disposal
Athletic Field
Sartori Sch
BM 324
BM 306
Greenwood Ce
Tank Testin
(Abandon
Mt Olive Cemi
Baseball Park
BM 321
RENTON
St Anthonys Sch
Tank
CEDAR
RIVER
Ford Sch
BM 372
BLACK RIVER
Earlington Golf Course
Black River
OLD RAILROAD GRADE
C.M.St.P.&P.
PACIFIC NORTHERN
Substation
TPUGE
Silo
BM 129
UNDERGROUND
BM 455
455.07
RENTON
AQUEDUCT
Tukwila
Longacres
Race Track
Tank
BM 29
BM 16
BM 210
BM 229
BM 476
BLACK RIVER JUNCTION
RIVER
SEATTLE 9.7 MI.
SEATTLE 11 MI.
1.9 MI. TO U.S. 99
27'30"


1878 IV
(MT. STUART)
R 15 E
R 16 E
CLE ELUM RIDGE
Carlson Canyon
Teanaway
14 River
Goodrich Mine
Crystal
Lanigan Spring
Cle Elum
Cle Elum Municipal Airport
South Cle Elum
(EM 1920)
Gravel Pit
Sewage Disposal
AIRPORT ROAD
NORTHERN PACIFIC
YAKIMA RIVER
CLE ELUM
115 KV MILWAUKEE
LOWER PEOH POINT
UPPER PEOH POINT
MILWAUKEE ROAD
CHICAGO ST PAUL
Substation
Teanaway
Big Lake
Cabin Lake
Little Lake
Indian John Hill
Peoh Point
Cle Elum Pt
Thorp Creek
Cedar Creek
Horseshoe
Caryon
SOUTH
BM 1887
BM 1930
BM 1873
BM 1855
BM 1847
BM 1826
BM 1821
BM 2122
BM 1417
BM 25

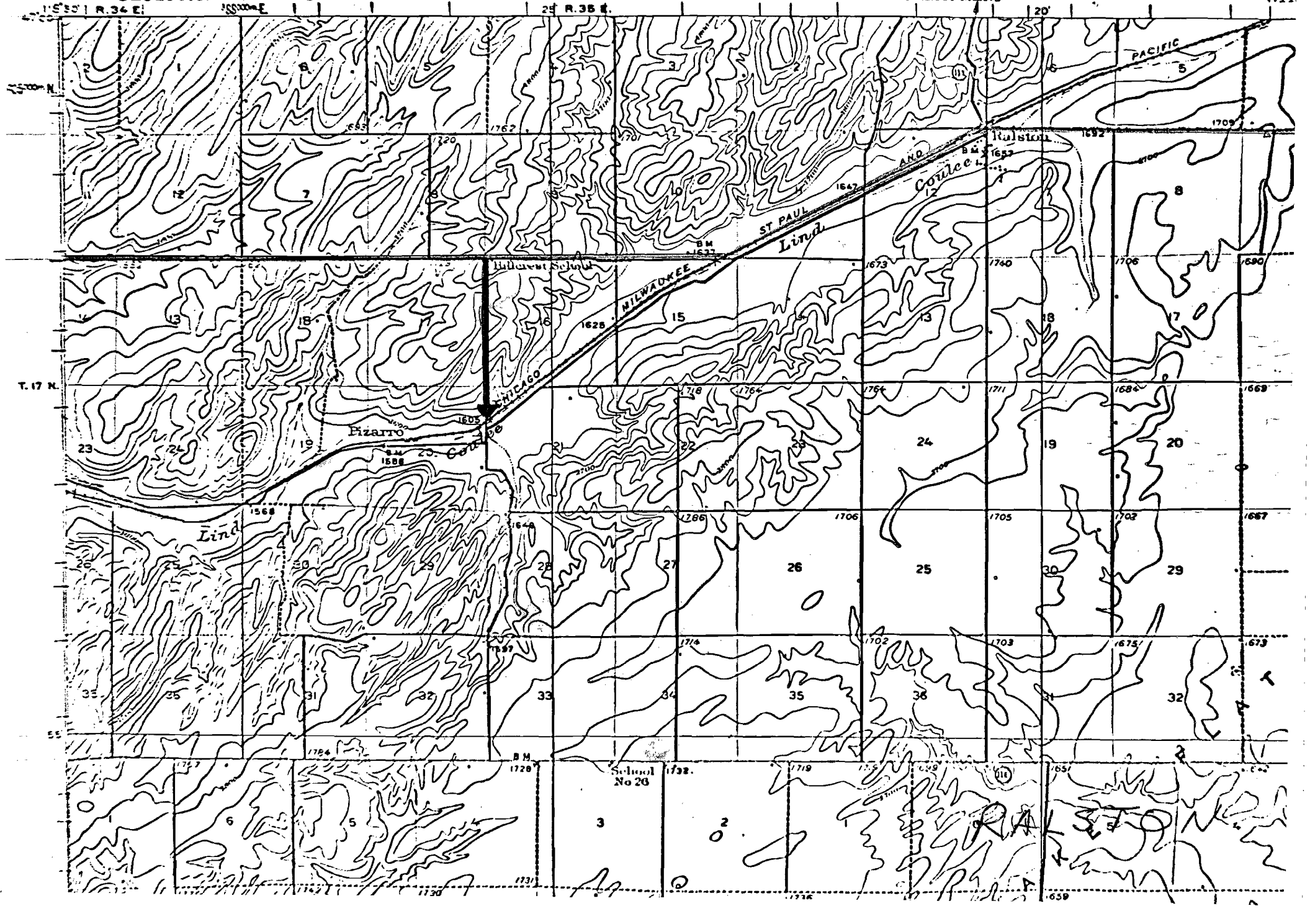

ADAMS ROAD
GRANT ROAD
BARTON ROAD
BYERS ROAD
LATERAL
Royal Lake
Hutchinson Lake
Lower Crab Creek
WILDLIFE REFUGE
NATIONAL
115 KV WWP
115 KV MWP
Crab Creek
HARRISON ROAD
PACIFIC
Taunton
Saddle Gap
MOUNTAINS
SLOPE
GRANT CO.
ADAMS CO.
TAUNTON

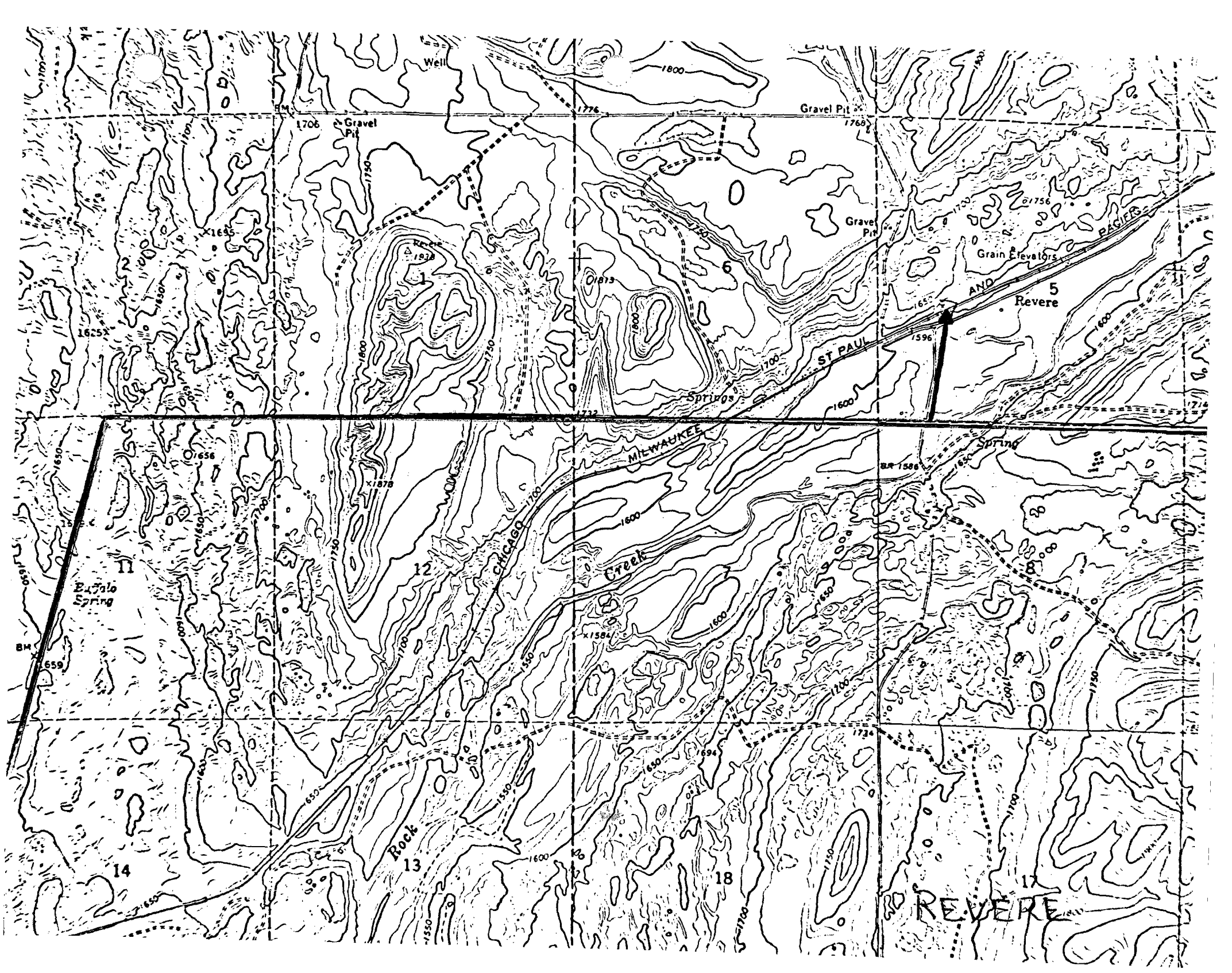

To Warden
To Warden
ROXBORO
SERVIA
PROVIDENCE
BEATRICE
CUNNINGHAM
HATTON
ROXBORO
BRUCE
KOREN
SHANO
To Connelly
Roxboro Sch.
B.M. 1204'
B.M. 1201'
B.M. 1324'
B.M. 1394'
B.M. 1236'
B.M. 1166'
B.M. 1214'
B.M. 1369'
Lind
Coulee
Providence
ROXBORO ROAD
SHEDD EXT'N ROAD
OTHELLO ROAD
SOUTH ROXBORO ROAD
NEWLAND ROAD
CARTER ROAD
DOWAGAC ROAD
IRBY ROAD
EAST ROXBORO RD.
SOUTH ROXBORO RD.
SCHRAG ROAD
ROLBORO RD.
26

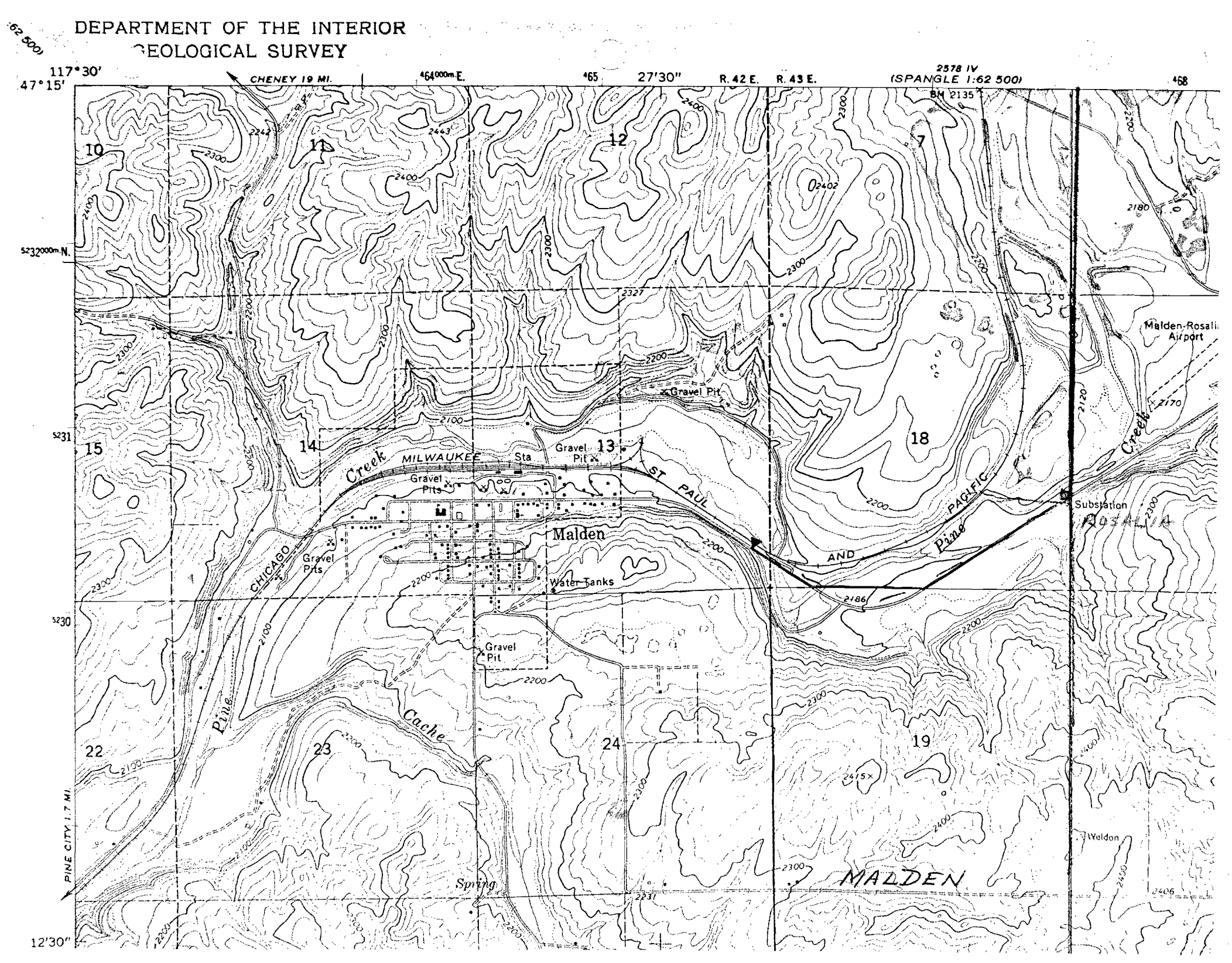
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

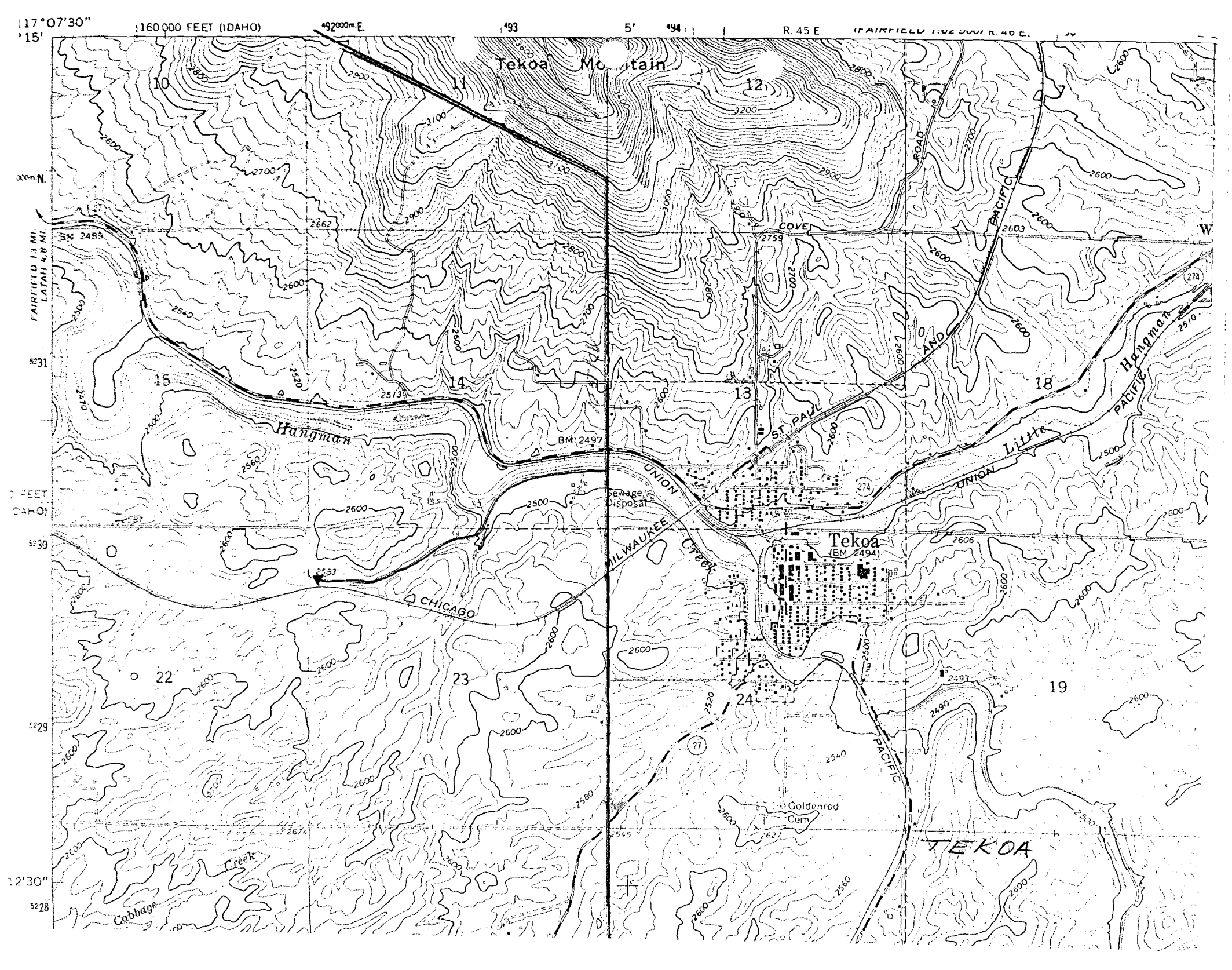
STATE OF WASHINGTON
REPRESENTED BY THE
DEPARTMENT OF CONSERVATION AND DEVELOPMENT

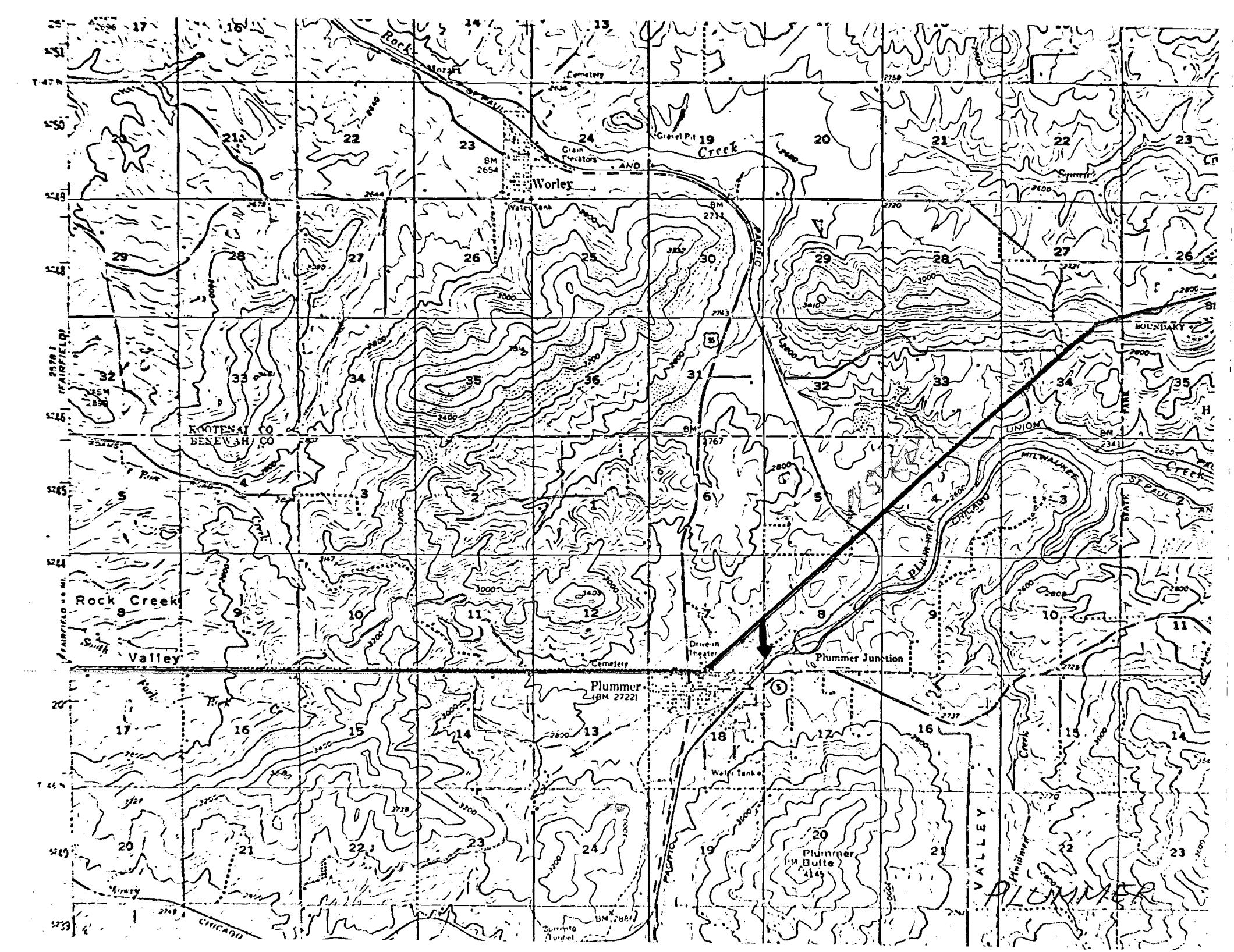
SPOKANE (CIVIC CENTER) 17 MI.
RITZVILLE (JUNC. U.S. 395) 10 MI.

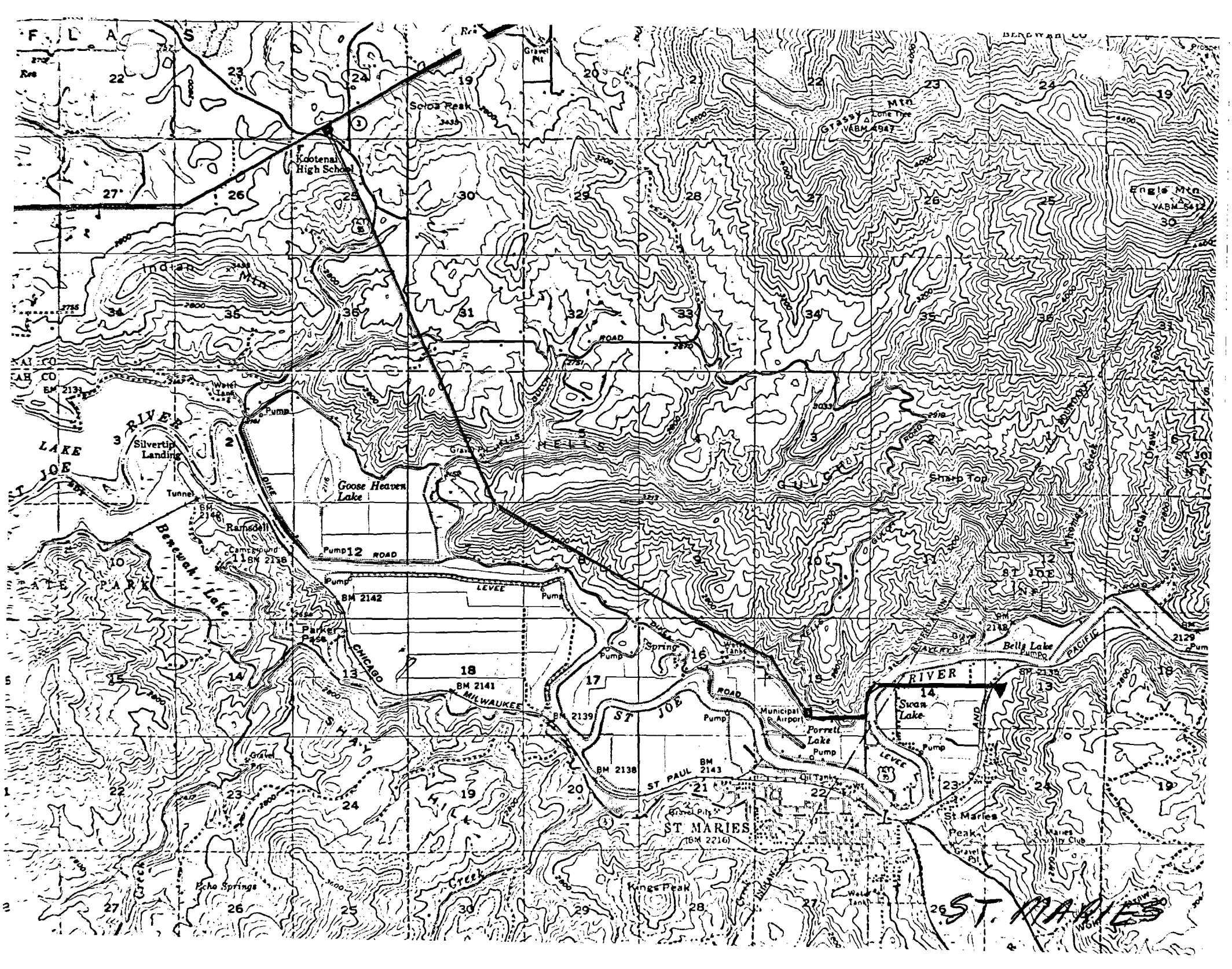


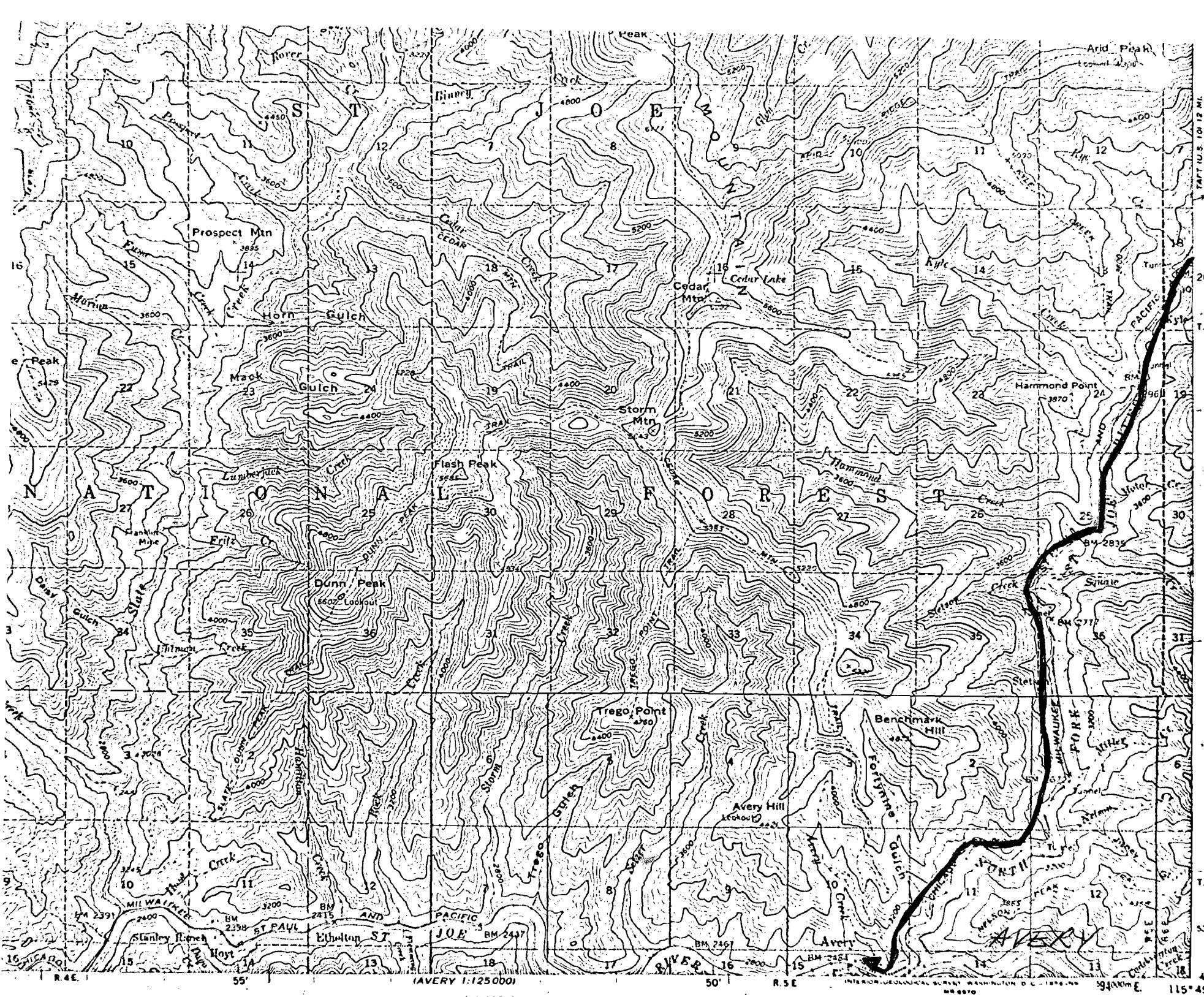

Well
Gravel Pit
Gravel Pit
Gravel Pit
Grain Elevators
AND
PACIFIC
ST PAUL
MILWAUKEE
CHICAGO
Springs
Spring
Creek
Buffalo Spring
Rock
REVERE
Revere
1
2
5
6
8
11
12
13
14
17
18


DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
117°30'
47°15'
CHENEY 19 MI.
464000m.E.
465
27'30"
R. 42 E.
R. 43 E.
2578 IV
(SPANGLE 1:62 500)
468
BM 2135
5232000m.N.
5231
5230
12'30"
PINE CITY 1.7 MI.
Malden-Rosalia Airport
Gravel Pit
Creek
MILWAUKEE
Sta
Gravel Pits
ST PAUL
AND
PACIFIC
Substation
ROSALIA
Malden
CHICAGO
Water Tanks
Pine
Cache
Spring
Weldon
MALDEN


117°07'30"
15'
1:60 000 FEET (IDAHO)
492000m.E.
493
5'
494
R. 45 E.
FAIRFIELD 1:62 500 R. 46 E.
Tekoa Mountain
10
11
12
13
14
15
18
19
22
23
24
2662
2759
2603
2513
2583
2494
2491
2490
2627
2674
2545
2540
2580
2560
2606
2510
2540
2520
2560
2530
2500
2600
2700
2800
2900
3000
3100
3200
SN 2489
FAIRFIELD 1.3 MI.
LATAH 4.8 MI.
5231
5230
5229
5228
000m.N.
12'30"
Hangman
BM 2497
ST PAUL
UNION
Little
PACIFIC
AND
ROAD
COVE
Sewage
Disposal
MILWAUKEE
Creek
CHICAGO
Tekoa
(BM 2494)
Goldenrod
Cem.
TEKOA
Cabbage
Creek
274
27


Rock Creek
Worley
Grain Elevators
Gravel Pit
Cemetery
BM 2654
BM 2711
BM 2767
BM 2341
Water Tank
Creek
AND
PACIFIC
BOUNDARY
KOOTENAI CO
BENEWAH CO
UNION
MILWAUKEE
CHICAGO
ST PAUL
PLUM HT
Rock Creek
Valley
Drive-in Theater
Plummer Junction
Plummer
(BM 2722)
Plummer Butte
4145
VALLEY
PLUMMER


Kootenai High School
Solos Peak
Grassy Mtn
Lone Tree
VABM 4947
Eagle Mtn
VABM 5412
Indian Mtn
ROAD
Water Tank
Pump
Silvertip Landing
LAKE
ST JOE
RIVER
Tunnel
BM 2148
Ramsdell
Campground
BM 2138
Goose Heaven Lake
Sharp Top
Cedar Creek
Benewah Lake
Pump
12
ROAD
LEVEE
BM 2142
Parker Pass
CHICAGO
MILWAUKEE
18
BM 2141
Spring
Water Tanks
Municipal Airport
Bells Lake
PACIFIC
Swan Lake
Pornell Lake
BM 2139
BM 2138
BM 2143
ST PAUL
Oil Tanks
ST MARIES
(BM 2216)
St Maries Peak
Gravel Pit
Kings Peak
Echo Springs
Creek
ST. MARIES


NATIONAL FOREST
ST JOE
Prospect Mtn
Horn Gulch
Mack Gulch
Cedar Mtn
Cedar Lake
Storm Mtn
Flash Peak
Dunn Peak
Lookout
Trego Point
Benchmark Hill
Avery Hill
Lookout
Hammond Point
Arid Peak
Franklin Mine
Stanley Ranch
Hoyt
Ethelton
Avery
NELSON
MILWAUKEE
PACIFIC
ST PAUL
AND
RIVER
FORK
TAFT U.S. 10 12 MI.
T. 46 N.
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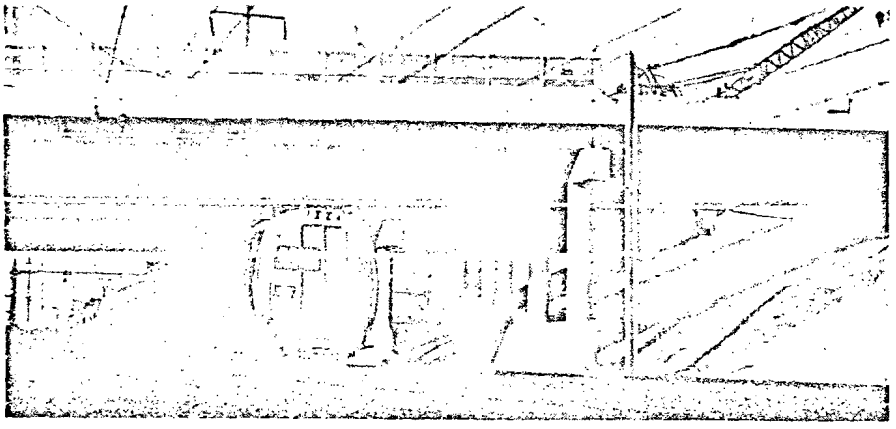


Between New York and Washington the Metroliners are showing what electric traction can do for passengers; freight can also benefit economically from higher average speeds

MOTIVE POWER ECONOMICS IN THE UNITED STATES

The point has now been reached where a firm case can be made for a major programme of electrification in North America

ERNEST P. FOLEY, *Vice-President (Transportation & Transmission) Gibbs & Hill Incorporated*

RAILWAYS IN THE UNITED STATES are experiencing an almost startling motive power investment turnover. It took 25 years (1936–60) for diesels, representing a total investment of about $4,000 million, to replace steam, which represented an investment of only $1,750 million. It is now taking no more than 14 or 15 years for this $4,000 million investment to be consumed, and to require renewal; indeed the railways are now more than halfway through the second round of diesel motive power investment. This situation makes it almost mandatory for railway managements to examine in much greater depth than hitherto the economics of electric traction as an alternative to diesel.

Although the electric locomotive is the most efficient and most economical motive power yet devised, it is not suggested that all the railways in the United States suddenly retire their 27,300 diesel units in favour of electric units. The appeal of electric motive power to railway managements must come through capital conservation, more economical railway operation, improved service to their customers, and the matching of lagging railway technology to that of modern industry.

Capital conservation

The electric locomotive, having a proven service life at least twice that of a diesel, would conserve its own capital cost every 15 years, even if its cost were on a par with that of a diesel having the same horsepower rating. Motive power manufacturers will concede that electrics, manufactured in standard sizes and in the same quantities and capacities as diesels are being made today, would cost only 70 per cent of present diesel costs on a comparative horsepower basis.

Overload capability

The electric locomotive carries no expensive prime mover but draws its energy from a source which is effectively of infinite capacity. Thus the short-time overload capability of its motors can be called upon to provide up to 75 per cent more power for acceleration after slow-downs and for climbing adverse gradients. The diesel cannot do this because the rated output of its prime mover must not be exceeded. Hence, there are often three, five, or even more diesel units included in each heavy train solely to overcome acceleration and gradient limitations. This may represent a $1 million investment in motive power for each heavy train just to maintain a high average speed.

Fuelling, lubricating and cleaning of both fuel and lubricant filters at terminal points requires much more time with a diesel than is the case with the much simpler electric, which has no moving parts other than the traction motors, air compressors and blowers common to both forms of traction. With shorter turn-round time, the availability of the electric is greater than that for the diesel.

For these reasons it is possible for 80 electric units to perform the same work as is done by 100 diesel units which deliver the same horsepower to the rail.

The capital saving represented by the purchase of 80 motive power units every 30 years instead of 100 units every 15 years, together with a 30 per cent reduction in unit cost, is very substantial.

Power supply

In the earlier electrified railway systems installed 50 to 60 years ago, many of which are still operating, it was necessary for the railway to build its own power stations, transmission lines and substations, because the small power plants built for city lighting, industrial, and tramway or inter-urban rapid transit were not adequate for the heavier railway loads.

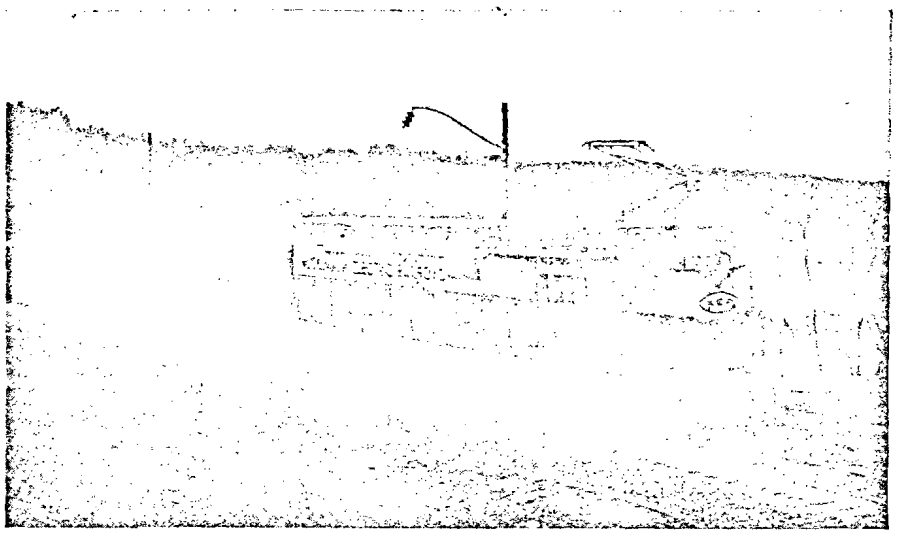
Today the power supply situation has changed completely. Large capacity and high-efficiency generating stations have been built, thermal and hydro, which are now being augmented by nuclear plants; all are interconnected by high capacity transmission networks which can easily absorb the modest degree of unbalance inherent in the use of modern high-voltage railway electrification at industrial frequency.

The high voltage grid is especially concentrated in the region north of the Ohio River, Virginia and West Virginia, and between the Mississippi and the Atlantic coast, where much of the nation's heavy industry is located. This territory is also served by the railway lines which carry the heaviest traffic flows. Many of these power transmission lines are located along the railways' right-of-way, and they cross and re-cross all railways in this area at frequent intervals. There is thus no need for railways to invest in new power stations or transmission systems.

Lower power costs

The existing power companies are able and willing to assume any railway loads offered. Power costs to industry have been steadily declining over the past three decades because of improved generating efficiency and shared capital investment in reserve and peak demand capacity, and this in the face of rising fuel and labour costs.

A recent report prepared for the Edison Electric Institute indicates that by use of modern designs of supporting wires and structures, and with the use of modern construction methods and procedures, an adequate contact system for dense traffic can be built for as little as $42,000 per track-mile, depending upon track accessibility,



Two 5,000 hp locomotives were built by General Electric last year for the Muskingum Electric Railway; these are regarded as prototypes for main line electrification schemes at 25 kV 50 c/s

nature of terrain, high speed requirements, labour costs and related problems. Research by European railways has produced substantial economies in the first cost of the catenary, and there is every indication that further savings can be expected in this sphere.

For a selected district, an average cost figure was $58,500 which can be rounded out to $60,000 per track-mile. How can this figure be related to motive power costs, and be made consistent with capital conservation?

The oldest electrified railway in the United States equipped with an overhead catenary contact system is still in operation after 62 years. It can last for many more years yet. The life of the overhead line is thus at least five times the life of the diesel locomotive.

It is well known that 50 per cent of all ton-miles on US railways, obviously requiring 50 per cent of the motive power, is carried on only 10 per cent of the present freight-carrying system, now totalling something like 211,000 route-miles.

Expand this figure of 10 per cent to 27,000 miles for the purpose of connecting short dense-traffic routes, and there will then be a present investment in diesel motive power of half a diesel unit for each mile of route. If the route is double-track, as most dense traffic routes are, the investment in diesels is a quarter of a unit for each mile of track.

Diesel unit costs

A modern diesel unit costs between $200,000 and $250,000, depending on horsepower rating, and the dense-traffic lines will require the larger ratings. At an average cost of $240,000 per unit, there is thus already an investment of $60,000 in motive power per track-mile in these dense traffic sections, requiring replacement every 15 years.

Even if the electric motive power did cost the same as diesel power, it is still good for another 15 years, whereas for continued diesel operation a new investment of $60,000 per track-mile must be made again for new motive power. That makes the total investment in motive power and contact system required for electric operation somewhat less than for diesel operation over a 30-year period.

A simple rule of thumb can thus be derived: where the investment in diesel motive power per mile of track (which would require electrification for electric operation) is approximately equal to the per-mile cost of electrification, the use of electric motive power should be carefully studied.

The investment will actually be less over a 30-year period, whereas most public utilities today plan their larger investment in plant and equipment for at least a 30-year life.

Operating economies

The principal operating economies will be in motive power repair costs. Experience both in North America and elsewhere confirms that electric motive power can be maintained for between one-third and one-half the cost of maintaining diesel power of the same age, having the same horsepower rating, and performing the same service. Contact system maintenance costs are just about equal in magnitude to costs of diesel lubricants, which today are about 8 per cent of diesel fuel costs.

The cost of electric power varies with the load factor. Much of the electric power purchased by US railways today is used for passenger commuter service which has a notoriously bad load-factor of 20 to 25 per cent and therefore costs about 1·5 to 2·0 cents/kWh. Dense freight traffic would have a load factor better than 50 per cent, thus affording a good base load for the power supply systems which would command much lower rates.

Rates for hydro power can be as low as 0·6 cents/kWh and from modern thermal plants as low as 0·8 cents/kWh; electric power at 0·9 cents/kWh is on a par with the price of diesel fuel at 9 cents/US gal.

Diesel fuel has been between 9 and 10 cents/gal since 1948, but the price of crude oil has increased recently, and the railways as well as all other users of internal combustion engines are facing increased fuel costs.

Service to customers

The inherent ability of electric motive power to maintain higher average speeds by making use of the short-time overload rating of its traction motors will lead to faster schedules and faster service to shippers. The shorter, more frequent and faster trains permitted by shorter motive power turnround time would not only augment the service improvement to shippers, but would also improve the railway load factor and tend to lower power costs to the railways.

The faster service could regain for the railways some of the traffic now lost to their competitors, and command some of the higher rates now paid by shippers to these other transport agencies.

Today's railway customers demand shorter "out of processing" time for their materials and supplies. This is not the same as higher maximum speed: rather, it is the ability to maintain the highest average speed. Electric locomotives can make full use of their inherent ability to regain maximum speed quickly after speed restrictions caused by track condition, curves, adverse gradients and bridges.

Finally, there must be an evaluation of some of the less tangible benefits of electric operation. All railway rolling stock and wayside structures will be cleaner and free from the increasing deposits of unburned fuel.

The public is becoming increasingly concerned—and rightly—about protecting the environment from air or water pollution and noise. On all three counts electrification makes a positive contribution that is especially significant in urban areas.

But the real economies of electric railway operation are in the conservation of motive power capital and the marked reduction in motive power repair costs. It is the task of railway management to seek out the dense traffic areas where such economies can be realised. They should be quite substantial. The technical skills for designing the facilities to enable the railways to share with industry the advantages of electric power are fully developed and available now.

ANACONDA WIRE AND CABLE COMPANY

607 LLOYD BUILDING, SEATTLE, WASHINGTON 98101

4/0 grooved copper
Trolley Wire
$ 40.68/cwt

206 623-4686

October 29, 1969

Puget Sound Power & Light Company
104 Puget Power Building
Bellevue, Washington 98004
Attn: Mr. J.J. Dempsey

RE: Electrification -
Chicago Milwaukee Railroad

Gentlemen:

In receiving your needs of wire and cable for the purposed electrification of the reference railroad; we have come up with the following estimates based on shipment during the second half of 1970.

460 miles of 4/0 grooved copper trolley wire based on receiving the same amount of scrap tonage"wise" that would be required to manufacturer the 4/0 grooved copper trolley wire needed - Our best estimate would be the new trolley wire - cost from $30.00 to $35.00 per cwt. 4/0 grooved copper trolley wire weights - 642 lbs per/mft. The bare all aluminum conductor needed to extend this line and replace the copper that would be taken down - the sizes requested, 1,590 MCM code, "Coreopsis"and 2,250 MCM code, "Sagebrush"; would be priced approximately as follows for delivery in last half of 1970:

275 miles - 1,590 code,"Coreopsis" 1493 lbs/mft	$40.50/CWT
90 miles - 2,250 code,"Sagebrush" 2133 lbs/mft	$44.00/CWT

Understand the the above figures are based on our best estimate of market conditions in the second half of 1970 - Anaconda Wire and Cable is well equiped to manufacturer all of these products and sell them based on receiving scrap copper as partial payment towards these products. The trolley wire would be manufactured in Hastings, N.Y.,on a newly installed equipment. The aluminum would be manufactured in Great Falls, Montana.

Any further information needed please contact us. We would be more than happy to work out any detail you might need.

Very truly yours,

David A. Gould
Branch Manager

NOTED
OCT 29 1969
J.J.D.

DAG/cjw

MORGAN

THIS SHEAVE

Can Save You Money

•

During changeover and rephasing, energize the conductor in the Sheave.

•

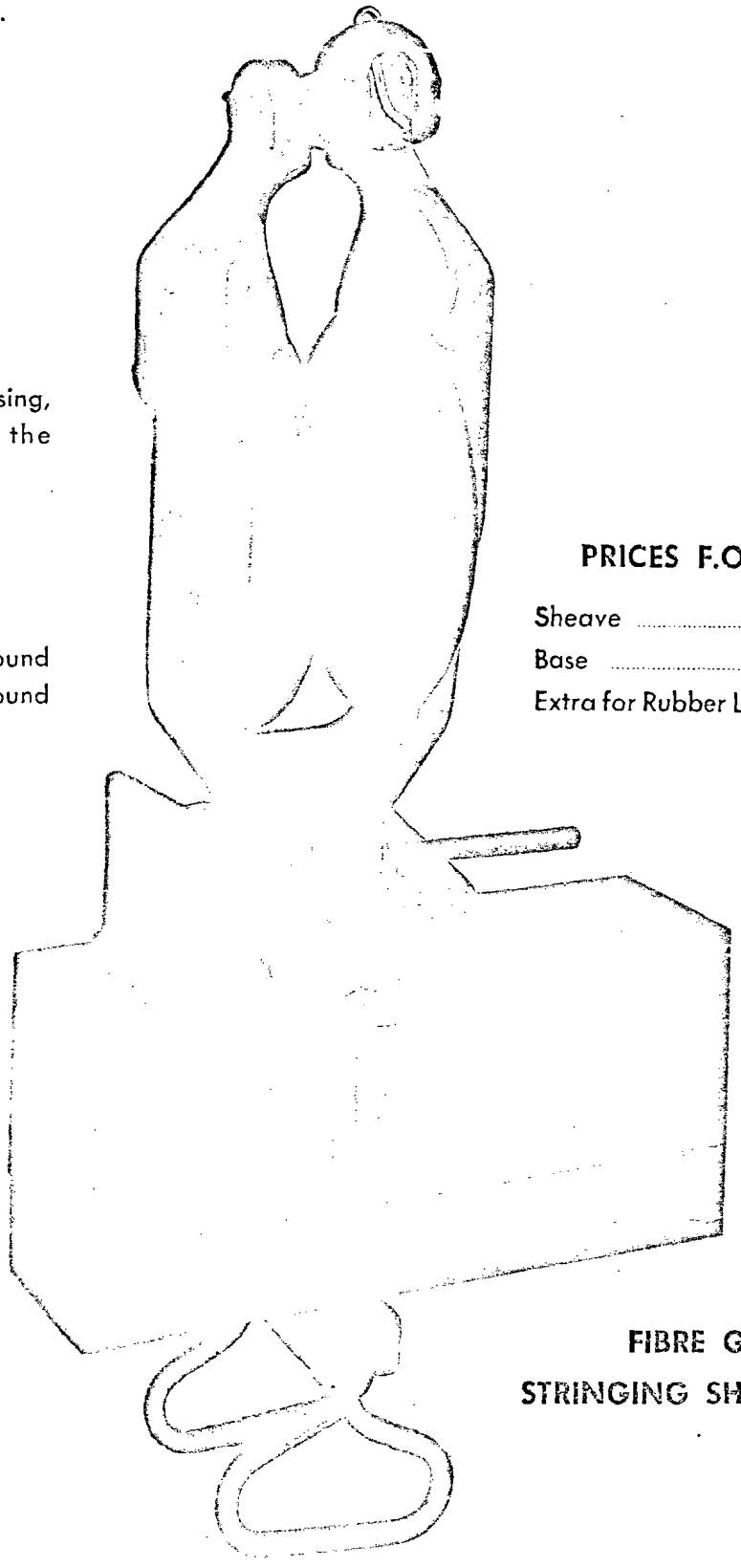
TEST DATA

Dry	26 KV to ground
Wet	16.5 KV to ground

•

FEATURES

1. Insulated Wheel.
2. Positive Hinge Lock.
3. 5,000-lb. Duty.
4. No wrench required.
5. Can be installed and worked with hot tools.



PRICES F.O.B. SEATTLE

Sheave	$25.00
Base	10.00
Extra for Rubber Lined Wheel	4.00

FIBRE GLASS
STRINGING SHEAVE LH-10