REPORT ON THE PROPOSED DEVELOPMENT OF THE STURGEON RIVER POWER FOR USE BY THE COPPER RANGE CONSOLIDATED COMPANY

By

F.W.Denton.

STURGEON RIVER WATER POWER PROJECT, NOV. 1911

Estimate of Amount and Cost of Power used at Mines & Mills last year, (1910) and of Theoretical Water Power Required

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	Mines		Mills	
Coal used	47,963 tons	$152,015	47,848 tons	$155,008
Firemen's wages		26,117		12,750
Coal passers & all other labor		12,347		7,432
Supplies, etc.		7,931		1,927
		$198,410		$177,117

Assume 48,000 tons of coal consumed annually at the mines and the same amount at the mills:-

At both mines and mills an evaporation of 7½ lbs. of water per lb. of coal is a fair assumption:-

For the mines it is assumed that 30 lbs. of water are evaporated per horsepower hour and for the mills 35 lbs.

On this basis 24,000,000 H. P. hours are developed at the mines,
and 20,600,000 " " at the mills.
Total Mines & Mills 44,600,000

At the mines this gives 4 lbs. coal per H. P. H.
" " Mills " " 4.17 " " " " "

The cost per H. P. hour at the mines then is $.0083 and at the mills $.0086.

Assuming that power is consumed continuously for 24 hours per day for 300 days per year the annual cost of a H. P. is, Mines $59.54, Mills $61.92

Converting to K. W. H. basis these figures would give:

Mines $.0110 per K. W. hour

Mills .0114 " "

or

Mines $79.38 per K. W. H. per year

Mills $82.56 " " "

These costs indicate that the assumptions made are about right.

Therefore it seems safe to assume that 44,600,000 H. P. hours per year would be sufficient on last years basis provided this power is furnished in as efficient form as now.

At the mills there would be required 20,600,000H. P.H. annually. Assuming this power to be delivered in the form of compressed air and that the efficienty of motor and air compressor together is 80% there would have to be delivered to the mills 25,750,000 H. P. hours, or say, 19,300,000 K. W. hours.

At the mines assume half the power to be used for hoisting and that this power is to be supplied in the form of compressed air and that the efficiency of motor and compressor combined is 80%. The other half of the mines' requirements we assume can be delivered in electric energy.

One-half mine power = 12,000,000 H. P. H. At 80% efficiency there would be required to deliver this in compressed air = 15,000,000 H. P. H., or 11,500,000 K. W. H. annually

	9,000,000 " " "	" for rest of mine/ power
Total	20,500,000 " " "	"
For Mines	20,500,000 K. W. H.	
For Mills	19,300,000 "	
Total	39,800,000	

If we assume 75% combined efficiency of water wheels and generators and 15% loss in transmission we have about 64% of the theoretical water power delivered to the mines and mills. On this basis, to deliver 39,800,000 K. W. Hours there would be required a water power of, say, 62,000,000 K. W. H. annually, or 83,000,000 H. P. hours. Since the water power plant would result in centralising the generation of power at the mines for hoisting a decided saving in power should result, sufficient at least to offset the extra power assumed to be required to produce compressed air. If we grant this, the total requirements for mines and mills would be reduced to 59,500,000 K. W. H. annually, of theoretical water power. This equals a continuous water power of 9056 H. P. It would seem safe, therefore, to assume that 10,000 theoretical horse power at the Sturgeon River would be sufficient to operate our present mines and mills, with the probability of there being a surplus, or at 80% efficiency of water wheels and generator, 8,000 actual H. P.

COMPARISONS

Annual Cost of H. P. at our mines	$59.54	(300 days, 24 hours per day)
Average Cost of Oliver Iron Mng.Co. for Iron Mountain district, including air power	$60.48	" " " " " "
For steam operated machinery only	70.87	" " " " " "
For all mines except Chapin	93.08	" " " " " "

These tests at Iron Mountain show 3.8 lbs. of coal per H. P. Hour including compressed air power.

Steam power alone would show higher.

Norrie-Aurora Group, Oliver Iron Mining Co.

Cost I. H. P. continuous excluding pumping -------- $76.28

Report of J. C. White for Iron Mountain district confirms above figures in a general way.

It is safe to assume, therefore, that our present power at the mines is costing $60.00 per continuous H. P. year, not including interest and depreciation charges.

At the mills, slightly more.

WATER POWER

Drainage Area

The reports on the Sturgeon River give 320 and 322 square miles of drainage area. This estimate is based on township plats, etc. and not on actual surveys, as stated in a letter from Viele, Blackwell & Buck. Checking over the drainage area as thus given and using the topographical map just issued by the U. S. Geological Survey covering the Perch Lake area, I have reduced the estimate of Viele, Blackwell & Buck as follows:

Perch Lake area from 90 sq. mi. to 79 sq. mi.

Upper Sturgeon " 160 " " "154 " "

My estimate of the drainage area is:-

Upper Sturgeon- - - - - - - - - - - - - - - - -	154	Sq.Mi.
Perch Lake - - - - - - - - - - - - - - - - - - -	79	" "
Total tributary to the Upper Power Plant- -	233	" "
Additional area on Sturgeon - - - - - - - - -	67	" "
Total tributary to Lower Power Plant- - - -	300	" "

In the computation of horse power given in the table and in the diagram the drainage area of the upper Sturgeon and of the Perch was taken at a total of 220 sq. miles and that for the lower plant 300 sq. miles. The figures,233 sq. miles,given above would be more accurate and would increase the power obtained proportionately, or about 6%.

FLOW OF STREAM

Orbison and VonSchon in their reports quote measurements of the Dead and Iron Rivers, which are two rivers of smaller watersheds than the Sturgeon, located near Marquette. These are the only records of actual measurement of flow of streams in this region available and therefore they have been applied to the Sturgeon, using the rainfall record of the Government Weather Bureau Service at Marquette.

The records for the Dead and Iron rivers are for the six year period, 1899 to 1904 inclusive, which was a period of high average rainfall, being 34.30 inches, as compared with a mean annual for 20 years of 32.36 inches. There was, however, one year of low rainfall in this period. The drainage areas of those rivers being so small also injures the value of the records as applied to the Sturgeon. These records have been worked up in two ways, and tables and diagrams have been prepared for each method.

First Method

From the records of actual measurements of flow for the Dead and Iron Rivers the following were determined:-

1st. The mean annual discharge of the stream in cubic feet per sq. mile per second.

2nd. The ratio between the monthly discharge and the monthly mean discharge.

3rd. The percentage of the total year's rain that reached the stream.

After each of the above was determined for each year, averages for the six year period were made.

Flow of Stream, Cont'd.

The average percentage of annual rainfall reaching the streams was about 60%

To be on the safe side it was assumed in applying these results to the Sturgeon that 50% of the rainfall reached the stream. The rainfall record of the Marquette Station was then taken and 50% of the rainfall for each year was assumed to be the annual run-off, and one-twelfth of this was the monthly mean discharge. The average ratios of monthly to mean monthly discharges as determined from the records of the Dead and Iron Rivers were then applied, and the actual discharge of the Sturgeon for each month for the 20 year period covered by the Rainfall record computed.

After the actual discharges were thus estimated a table (VII) was compiled on the assumption that a discharge of one cubic foot per square mile per second was to be utilized, and on this assumption the effect on the contents of the storage reservoir is compiled.

Also the horsepower is figured and the results shown graphically in diagram No. _____. (This was not made. F. W. D.)

Second Method

From the records of the Dead and Iron Rivers the following were determined:

1st. The average actual discharge of these rivers for the same month for the six year period, i. e. average actual discharge for the six Januarys, etc.

2nd. The average actual rainfall for the same month for the six year period

3rd. The ratio between the above averages.

Flow of Streams, Cont'd

This gave as the average run-off in the streams for the six-year period about 60% as before, and the ratios of monthly discharge to monthly rainfall were reduced proportionately so as to show a total discharge for the year of 50% as in the first method.

The difference in the two methods then is:

In the first we have the ratio between the monthly discharges and the monthly mean discharge as computed by dividing 50% of the annual rainfall discharge by 12.

In the second we have the ratio between the monthly discharge and the discharge as given by 50% of the average rainfall for each month.

Tables and diagrams are given for the second method prepared in the same manner as for the first.

I am inclined to think that the second method is more apt to check with actual experience than the first.

It often happens that a year's rainfall will be up to the average and yet during that year there may be several specially dry months. In such cases the first method would show a normal flow for those dry months, while the second would not. On the other hand there are ojections to the second method.

What these Figures Show

First;- that without storage the power of the river would be too variable to be considered.

Second;- that additional storage would be valuable and increase the power delivered by the river very materially.

The question of additional storage can be left for the future, Flow of Streams, Cont'd

as there is apparently sufficient to make a fairly uniform delivery possible.

Third:- Shortage of water shown can be partially offset by using the lower dam storage.

The horsepower diagram shows that with small amounts of steam power supplied in twenty years (a total of 46 H. P.) 9500 continuous H. P. output from the generators at the river could have been maintained on the assumptions made. The H. P. output is taken at 80% of the theoretical.

Allowing for difference in drainage areas these figures confirm the estimate of Viele, Blackwell & Buck.

Attached to this report are abstracts from Engineering reports on several water powers in this region, together with notes compiled by myself on a recent trip.

The following table has been compiled from these sources:

The Sturgeon compares favorably with the other powers listed, when storage is considered, but unfavorably without storage.

Although the estimated cost for construction per K. W. H. or per H. P. is high.

The tremendous advantage given by the storage dam at the upper plant more than offsets the higher cost as it should make possible much more satisfactory operating conditions than can exist at the other developments.

COMPARISON OF POWERS

(See Appendix)

Data taken from reports.

	Drainage area	Head	Product of Drainage area and head	H.P.* actual at generator for lowest water	Aver.* H. P. actual at generator	H. P. of Equipment	Cost of Power Plant
Sturgeon	320	180 220 400	128,000	1860	3345 ⊖	10,236	$1875324
Penn Iron Company	2929	25	73,225	1070 Actual Lowest in 3 yr for 2 weeks only	1920 Actual	1,000 1,200 ?	$276007
Peninsula Power CO. Twin Falls	1790	40	71,600	1040	1871	1,000 1,000 1,000	$293788
Carp River C.C.I. Co.	80	580	46,400	676	# 1212	3200 3200	$742970

⊖ Storage neglected

* Figures from Penn Iron Co. are from operating record for 3 years. Others are based on Penn Co.'s figures being made in proportion to product of drainage area and head.

Special reasons for expecting much more flow than elsewhere. Drainage from Mines & Towns of Ishpeming and Negaunee goes into Carp.

COMPARISON OF POWERS, Cont'd

	Cost of Lands	Cost of Aver. K.W. Plant & Lands	Transmission Line Cost	Total Cost of Plant	Total Cost per Av. K.W.	Estimate of Total yearly output in K. W. Hours at Plant	Cost per K.W.H. per yr. $
Sturgeon	$400,000	$907	$344,000	$2619724	$1044	Storage included 66,500,000 In dry years 3,000,000 to come from steam	.0394
Penn Iron Co.	$51,781	$227	$12,187	$339,975	$236	1500 K. W. H. continuous for 350 days 12,640,000	.0284
Peninsula Power Co. Twin Falls	$65,000	$255	$128,000	$486,788	$347	24,570,000 except for 10 or two months per year estimate	.0197
Carp River C.C.I.Co.	$100000 Estimated	$927	$124,125	$967,095	$1064	With storage 33,000,000 of which 3,000,000 from steam auxiliary in dry years	.0293

COMPARISON OF POWERS. Cont'd

	K. W. H. available at place of consumption 15% loss	Equipment cost per K. W. H.	Equipment Cost of continuous KWH for 350 days	Equipment Cost of Continuous H.P.	
Sturgeon	56,500,000 of which an average 1,500,000 from steam	.0463	$389	$292	
Penn Iron Co.	10,744,000	.033	$277	$208	
Peninsula Power Co. Twin Falls	20,874,500	.023	$193	$145	
Carp River C.C.I. Co.	26,050,000	.034	$285	$244	

COMPARISON OF POWERS Cont'd

	Operating Cost	Total ⊕ ⊕	Per K. W. Hour	Per K.W.H. Continuous for 350 days	Per Continuous Horse Power for 350 Days
Sturgeon	Fixed charges 209,580 (15,000 (Steam Operating 22,400	246,980	$.00447	$37	$28
Penn Iron Co.	Fixed charges 27,200 Operating 10,000	37,200	$.0034	$29	$22
Peninsula Power Co. Twin Falls	Fixed charges 39,000 Operating 15,000	54,000	$.0026	$22	$17
Carp River C.C.I. Co.	Fixed chg 77,400 (16,300 (Steam Operating 12,000	105,700	$.0037	$31	$23

⊕⊕ Interest on investment 5%
Depreciation 2%
General expense, taxes 1%
Fixed charges 8%

TRANSMISSION SYSTEM

Upper Plant to Lower Plant - - - - - -	6 Miles	
Power Plant to Faleston - - - - - - - -	24 "	
Faleston to Riccdale - - - - - - - - -	13.3 "	43.3 miles
Riccdale to Painesdale - - - - - - - -	1.5 "	
Total to Painesdale - - - - - - - - -	44.8 "	
Riccdale to Mill Mine Junction - - - - - - - - - - - -		5.1 "
M. M. Junction to Freda - - - - - - - - - - - - - - - - -		10.7 "
Total to Freda -		59.1 "

Upper Plant to Lower Plant- - - - -	6 Miles	
Lower Plant to Toivola - - - - - - -	29 "	
Toivola to Riccdale - - - - - - - - -	3.9 "	38.9 "
Riccdale to Painesdale - - - - - - -	1.5 "	
Total to Painesdale - - - - - - - - -	40.4 "	
Riccdale to Freda -		15.8 "
Total to Freda -		54.7 "

Upper Plant to Lower Plant- - - - -	6 Miles
Lower Plant to Painesdale - - - - - - (straight Line)	27 "
Total to Painesdale - - - - - - - - -	33 "
Painesdale to Mill Mine Jct. in straight line ---	3 "
From last point to Freda along Copper Range R.R.- -	10 "
Total to Freda - - - - - - - - - - - -	46 "

An estimate of 48 miles of transmission line as made in Viele, Blackwell & Buck's report would seem sufficient for reaching our properties. If a longer line is selected it would be for the purpose of following the Copper Range R. R. right-of-way and in that case the extra length would be largely offset by cheaper construction cost per mile.

SAVINGS TO BE HOPED FOR

Present power Expense omitting interest on investment and depreciation on last year's record.

Mines - - - - - - - - - - -	$198,410.00
Mill - - - - - - - - - - - -	177.117.00
Total - - - - - - - - - - -	$375,527.00

Assuming River Power

would be required

Total Expense, including

Interest & Depreciation- - - - - - - $246,980.00

Saving- - - - - - - - - - - - - - - -$128,547.00

It is probable that $500,000.00 would have to be invested at mines and mills to utilize electric power supplied.

At 5% interest this would reduce the estimated saving to say ,$103,000.

If we estimate profits to the Copper Range Ry. on hauling and unloading coal at $33,000.00 the balance is further reduced to $70,000.00.

Other facts favorable to the water power project should be considered:

1st. Our boiler plants are depreciating more rapidly than other machinery and replacement would have to begin in a very few years.

2nd. No interest on investment is charged against present plants.

3rd. There is every probability of a considerable water power in excess of our present requirements.

4th. The water power is a perpetual source of power and should increase in value with time, probably enough to offset the depreciation charge of 2%.

5th. If additional storage can be had, as seems highly probable, further power could be developed at much lower cost per H. P.

6th. It is proper to expect an increase in the cost of coal.

7th. The large surplus power available in the Spring could be utilized for special work.

If the low pressure turbines are as economical as figured, and it appears they are nearly so, then the saving at the mills would not be as large as figured. For our proposed extension of regrinding plants at the mills additional power will be required. With low pressure turbines this additional power it is estimated would be obtained with only 10% more steam consumption, whereas with electric power the additional requirements would all be an added burden on the Hydro-electric plant. This results in making the cost per steam H.P. much less than at present

The cost of motor-driven compressor plants to furnish power to the mills would be large. Compressor capacity for each mill would be required as large as now in use at all the mines combined.

If the modern tendency to increased fine grinding continues until the development of fine grinding machinery permits all material to be ground fine then the substitution of rolls for stamps becomes a practical certainty. In which event all mill machinery could be directly motor-driven, making the water power figure out to great advantage.

At the mines the cost of applying the electric power would not be great. The main expense would be in supplying compressed air to the the hoists, which I do not think would exceed $100,000.00.

A total of $200,000.00 would, I think, apply the power to the mines, though this matter has not been investigated thoroughly. Experience elsewhere has demonstrated the practicability of such an application.

DISCUSSION OF THE WATER POWER

The Power Diagram shows with a small amount of auxiliary power supplied, a uniform output of 9500 continuous horsepower, assuming 80% combined efficiency of water wheel and generator. I think this efficiency is probably too high for average operating conditions, and that 75% is nearer right. A total loss of 15% in transmission would seem to be sufficient, so that a total efficiency to point of consumption of the power of 64% is, I believe, fair. At a total of 64% efficiency the power at the mines would be 7600. H. P.

My estimate of the total power used last year at mines

was	24,000,000 H. P. Hours per year or	2731	H. P.	continuous	
at mills,	20,000,000 "" " " " "	2351	"	"	
	Total	5082	"		
	Surplus on these figures	2518	"	"	to

overcome losses in transfer of power and other sources.

This would seem to be a liberal margin and it is a fair assumption that the water power would operate our present plants without any auxiliary power.

The average rainfall for the 20 year period was 32.36 inches as given by the Marquette Station, for the Houghton station the average is given as 32.98, compiled from Houghton records since 1890 and data from surrounding points going back 33 years.

If now we assume that additional storage can be had to utilize 50% of the annual rainfall over the 300 sq. miles of water shed, we would have an average discharge from 32.4 inches of rain of about 1.2 cu. ft. per sec. per sq. mile, or an additional amount of power above that given in the diagram of about 20%, or in place of 7600 continuous H.P. as just estimated, about 9100 H.P.

ASSUMING A PARTIAL DEVELOPMENT OF THE RIVER POWER ONLY

Assume the storage dam at the upper falls to be built and the lower development only.

Estimated Cost From Viele, Blackwell & Buck.

Lower development		$696,524
Upper Dam		
Roads and bridges	$15,000	
Construction Plant, etc.	35,000	
Dam and intake	228,000	
Engineering & Contingencies 20%	55,600	
Interest during construction	10,000	343,600
Transmission System direct to		
Painesdale from lower plant	$193,725	
Less saving on copper	13,500	180,225
Property rights		400,000
Administration & Miscellaneous		30,000
		$1,650,349

At 64% net efficiency to the mines and 300 sq. miles of drainage area and 1 cu. ft. per sec. per sq. mile discharge, there would be delivered to the mines 3,927 continuous H. P.
The estimated requirements for the mines alone are 2731 continuous H. P. and therefore there would be a surplus of about 1200 H. P. which would be sufficient to run the regrinding mills, etc.

We could easily use all of the 3927 H. P. in places where power is now costing us most and where the application of electric power could be cheaply made.

The cost of electric power on this plan would be:

Estimated cost		$1,650,349
Total delivered continuous H. P.	3927	
Interest on $1,650,000 @5%	$82,500	
Depreciation 2%	33,000	
Taxes, etc. 1%	16,500	
Labor & Supplies	12,000	
	$144,000	
Cost per continuous H. P. per year	$36.60	
K. W. hours delivered annually	25,732,890	
Cost per K. W. hour delivered	$.0056	

Assuming this electric power would be used to replace steam power costing us $60.00 only the saving would be:

3927 H. P. @$60.00	$235,620
Cost of Water Power	144,000
Profit	$91,620

To which should be added interest and depreciation charges on present equipment and allowance made for the fact that an equal amount of additional power would be partially provided for.

NO. 2 PARTIAL DEVELOPMENT PLAN

Assuming Upper Storage Dam and Upper Power House

with Perch Creek Development to be built

Total estimated Cost, V. B. & B.	$1,128,800.00
Transmission System direct to Painesdale (35 miles)	214,775.00
Property	400,000.00
Administration & Miscellaneous	30,000.00
	$1,773,575.00

At 64% efficiency to the mines, 233 sq. miles drainage area and 1 cu. foot per second per sq. miles discharge, there would be delivered to the mines 3728 continuous H. P.

Since the storage of water is larger in proportion to drainage area in this case than in the first it is probable that a higher discharge could be maintained increasing the H. P. proportionately. The power obtained by the two developments, therefore, may be considered identical.

NO. 2 PARTIAL DEVELOPMENT PLAN

Assuming Upper Storage Dam and Upper Power House with Perch Creek Development to be built

Total estimated Cost, V. D. & B.	$1,128,800.00
Transmission System direct to Palmdale (55 miles)	214,775.00
Property	400,000.00
Administration & Miscellaneous	30,000.00
	$1,773,575.00

At 64% efficiency to the mines, 255 sq. miles drainage area and 1 cu. foot per second per sq. miles discharge, there would be delivered to the mines 3728 continuous H. P.

Since the storage of water is larger in proportion to drainage area in this case than in the first it is probable that a higher discharge could be maintained increasing the H. P. proportionately. The power obtained by the two developments, therefore, may be considered identical.

LANDS DEDUCTED FROM VIELE, BLACKWELL & BUCK'S ESTIMATE

OF DRAINAGE AREAS

Perch Creek Area- T.47 - R.34- Sections, 5,8,17,20,2,- T.48 - R. 34- Sections 32,33,34,35, 1/2 of 28, 27, 1/2 of 26. Total 11 sq. miles. Upper Sturgeon Area- T.49 - R.33- Sections 12,13,24- T.49-R.32- Sections 7, 18, 1/2 of 19, 1/2 of 6 - Total 6 sq. miles.
Lower Sturgeon- about a total of 3 sq. miles was taken off in a narrow strip where the boundary line was doubtful.

Estimate of Viele, Blackwell & Buck

Upper Sturgeon	160 sq. miles
Perch Creek	90 " "
	250 " "
Lower Sturgeon	70 " "
Total	320 " "

With Above Changes

Upper Sturgeon	154 Sq. Miles
Perch Creek	79 " "
Lower Sturgeon	67 " "
Total	300 " "

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COST OF STEAM AND AIR HORSEPOWER FOR THE CHAPIN, ARAGON, DOVER, MANSFIELD AND MICHIGAN MINES OF THE OLIVER IRON MINING COMPANY ON THE MENOMINEE RANGE AS GIVEN BY THE O. I. M. CO. OCTOBER 1911

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RATED BOILER HORSEPOWER	DEVELOPED BOILER H. P. AVERAGE	MAX. PEAK LOAD FOR 1 MINUTE	AVERAGE LOAD I.H.P.
5715	2390	9966	3272

Total I.H.P. Hours per year	Coal, tons per year	Total cost, coal & power per year	Cost per I.H.P. Hour	Cost per aver. I.H.P. per year	
24,964,006	47,228*	$209,782.00	$.0084	Chapin	$37.00#
				Aragon	80.00
				Dover	118.00
				Mans.	146.00
				Michigan	181.00

* Coal figured at $4.00 per ton fired

\# Covers cost of water power and steam. The Chapin operates a plant at Quinnesec Falls which compresses air that is transmitted to mine.

Average cost per H. P. year based on average load $64.00

" " " " " " " maximum peak ld. 13.20

" " " " " " " 1 minute " load 21.00

For air operated machinery only, for all mines, average cost per H.P. year based on average load $35.00

Steam operated machinery for all mines except the Chapin, average cost per H. P. year based on average load $98.50

Included in the above costs are, coal, firemen, maintenance of boilers.

No depreciation and interest on investment are included

Above figures give 3.8 lbs. of coal per I.H.P. which probably includes compressed air power.

SUMMARY OF POWER COSTS NOT INCLUDING FIXED AND DEPRECIATION CHARGES FOR THE NORRIE, AURORA, GROUP OF MINES OF THE OLIVER IRON MINING CO. ON THE GOGEBIC RANGE, OCTOBER 1911

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	Hrs. per Yr.	Av. I.H.P.	Total Cost.	Cost per I.H.P. Yr.
Aver. Continuous I.H.P. Pumping	8760	199	$52,735	$265.00
" " " Compressing	6740	460	16,303	36.00
" " " Electrical	7370	167	9,340	56.00
" I.H.P. Hoisting	6100	127	66,092	105.00
" H. P. Miscellaneous	6100	12	3,940	237.00
	35070	1465	147,510	100.00
Without pumping	26310	1266	94,575	76.28

Total cost of power for hoists for the year from above table is $66,092.00

The ore hoisted during this same period was 1,826,691 tons

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NOTES OBTAINED FROM MR. McCLURE, MASTER MECHANIC,

CLEVELAND-CLIFFS IRON COMPANY, NOVEMBER, 1911

650 continuous horsepower requires 12,000 tons of coal per year. This gives about 4.2 lbs. of coal per horsepower.

A five day test showed that the foot pounds of useful work done by a motor driven engine hoisting ore were 32% of input. No allowance was made for hoisting men and timber. Load of ore was 3 tons. Horsepower of motor 150, geared hoisting engine driven directly using friction clutch.

4,000 H. P. of motors are being driven by an average of 600 H.P. output.

Consist of the following:

Continuous-----(4)	50 H. P. Pumps
10 hours daily (1)	400 " "
Continuous-----(1)	150 " Compressor
12 hours ------(1)	250 " "
As needed------(4)	400 " Hoists
As needed------(2)	150 " "
As needed------(1)	75 " "
2 Shifts-------(4)	100 K.W. motor-generator sets
1 " -------(1)	125 H. P. Crusher
1 " -------(2)	25 " "
2 " -------(5)	25 " Tramming Motors
" -------(1)	50 " "

In addition, power is furnished for shops, lighting, etc.

Present Stations contain two 1,000 K. W. Steam Turbines driving 1500 K. W. Generators.

Both plants required for peak loads.

Cost is 1½¢ per K. W. H. including all losses, operating, maintenance and depreciation.

New water power plant is expected to furnish current for .5¢ figured on same basis.

The AuTrain river power plant now furnishes purrent for .1¢ per K.W. H., covers operation and maintenance only.

Efficiency of Water Wheels at Au Train plant:

Full to 3/4 load	82%
Generator	94%
Combined=	77%

Transmission losses and unaccounted for current = 15%

From Report of John C. White on Iron Mountain Power Census, Aug. 18, 1909.

At Iron Mountain about 10,000 H.P. of boilers of horizontal tubular type. With evaporation ranging from five lbs. to seven and one-half pounds of water per lbs. of coal, and coal taken to cost $3.25 per ton.

Cost at Pewabic Mine estimated to range from 3/4 to 1 1/8¢ per K. W.H. For Compressor condensing units, including auxiliaries two boiler H. P will furnish about three I. H.P. For simple non-condensing units, ratio is about 1 to 1, including auxiliaries and losses. Above fair for entire district.

Minimum discharge in cu. ft. per second per Square Mile at base of Twin Falls based on Flow at river near Iron Mountain.

Minimum figures as given by the hydrographs of Report

Year	Jan.	Feb.	March	December
1903	.47	.42	.5	.5
1904	.6	.8	.6	.5
1905	.5	.5	.5	.4 to .7 to .5
1906	.5 plus	.7	.6 plus	no record
1907	.7-	.75	.8-	.58
1908	.5	.5 plus	.5 plus	.4 plus

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SOME FIGURES TAKEN FROM FANNING'S "TREATISE ON HYDRAULICS"

(25 years old)

Ratios

Ratio of mean annual rainfall- - - - - - - - - - - - -	1.00
" " " rainfall of lowest 3 yr. cycles -- - -	.80
" " minimum annual rainfall - - - - - - - - - - -	.70
" " mean annual flow in streams (of the given year's rain) - - - - -	.60
" " mean summer flow in stream (of given year's rain)- - - - - - -	.25
" " low " " " " - - - - - - - --	.05
" " annual available flow in stream (of given year's rain) - - - - - --	.50
" " Storage necessary to make available 50% of annual rainfall	.15

These ratios are given for streams along the Atlantic coast, and are based on many records of actual flow.

In general, assumptions on the Sturgeon agree with these ratios closely.

A storage of 2,100,000,000 cu. ft. in the upper reservoir is about 10% of the average annual rainfall for the whole drainage area of 300 sq. miles, or 12.6% for that on 220 sq. miles.

FANNING'S HYDRAULICS

ESTIMATES OF MINIMUM, MEAN AND MAXIMUM FLOW OF STREAMS.

Area of Watershed	Minimum in cu. ft. per second per sq. mile.	Mean in cu. ft. per second per sq. mile.	Maximum in cu. ft. per second per sq. mile.
1 sq. mile	.083	1.00	200
10 " "	.1	.99	136
25 " "	.11	.98	117
50 " "	.14	.97	104
100 " "	.18	.95	93
250 " "	.25	.90	80
500 " "	.30	.87	71

Minimum refers to 15 days of least summer flow

Mean " " 120 " usually July, August, September & October.

Maximum " " floods

Mean Annual flow = 50% of annual rainfall, or for the low cycle years = 40%.

Ordinary flow of New England streams on an average = about 92 cu.ft. per minute per sq. mile. For low cycle years .8 of this, or 72 cu.ft. per sq. mile and 1/4 of this, or 18 cu.ft. per sq. mile per minute = minimum monthly flow.

In the case of the Sturgeon the large amount of snow fall and consequent floods in the Spring make conditions different from those of the Atlantic Coast. However, extra storage offsets this difference largely.

_ NOTES ON PENN IRON MNG.COMPANY'S WATER POWER DEVELOPMENT_

Drainage Area	2929 Sq. miles
Head	25 feet

19.47% of rainfall is ordinary flow

Rainfall equals	31.15 inches

76,000 cu.ft.per min. is the ordinary low water run-off equals

0.43 sec. ft. per sq. mile

2303 H. p. at ordinary low-water with 20 ft. head

2760 " " " " " 25 " "

Blue print shows average output at the falls generator to be as follows: 1908:- 1316 K.W. 1909:- 1497 K.W. 1910:- 1505 K.W. The same diagram shows when steam auxiliary power was required.

Cost with an output of 1500 K. W. is given as $.0025 which includes operation and interest charges. Formerly before this plant was in operation, about 51,200 tons of coal were consumed per year. It is estimated that now more work is being done than formerly.

A 1500 K. W. Westinghouse-Parsons Steam turbo-generator set has been established to take care of low water periods. This steam plant is estimated to furnish current at $.009 perK.W.H. not including interest and depreciation, but only operating costs. The plant uses 23 pounds of steam per K. W. Hour.

Transmission Line consists of six 000 wires, generators furnish current at 6600 volts with 180 r.p.m. directly to the transmission line. At the mines this is reduced to 2200 volts, Compressors are being driven with two 6600 volt motors, but this is not recommended. On the hoists one 500 H.P. motor is used, one 350 H.P. and one 200 H.P. On the first the net load is 7 tons of ore and the cage load is sometimes thrown on at the same time. On the 200 H.P. motor the net load is 5½ tons of ore.

#2 Notes on Penn. Iron Mng. Co.'s Water Power Development

The 350 H.P. motor is being placed on a new hoist where the load will be the same as on the 500 H.P. motor. These motors are connected by rope drive to large fly-wheel pulleys. When starting from rest it requires 20 seconds to speed up these fly-wheel pulleys before throwing in the friction clutches. Enough inertia is left in moving parts to carry load one level after current is cut off. Speed of hoisting is 800 ft. per min. This hoisting is apparently giving entire staisfaction.

Investment in the water power plant and machinery and line, and including cost of application at the mine is given as follows:

Machinery	$76,478.00	
Land	51,781.00	
Construction	199,529.00	$327,788.00
Transmission Line	$ 12,187.00	
East Vulcan Mine quipment	40,977.00	
West " " "	87,947.00	141,111.00
Grand Total		$468,899.00

A description of this plant was published in the proceedings of Lake Superior Mining Institute.

ABSTRACT OF A REPORT ON A PROPOSED HYDRO-ELECTRIC DEVELOPMENT AT TWIN FALLS ON THE MENOMINEE RIVER NEAR IRON MOUNTAIN, MICH.
DANIEL W. MEAD, MADISON, WISCONSIN, APRIL 1910

April 25, 1910

The Peninsula Power Company

INTRODUCTION

States that he has made detailed top survey of the river from below the lower Twin Falls to Island Rapids, a total distance along the river of about seven and one-half miles.
Has had a careful investigation made by J. C. White of the probable amount and cost of power at their mines, etc. and reports as follows:

Available Head

Survey shows head water can be raised to elevation 1115
This necessitates raising of certain roads, etc. Deducting 3 ft. for possible contingencies leaves elevation of 1112, at which it is proposed to construct crest of spillway.
Elevation of ordinary tail water equals 1070 ft. leaves 42 as gross available head. Allowing 2 feet for losses, through races, racks, etc. and for drawing down head, there remains a net head of 40 ft. which is head used in estimated power.

Amount of Power

Drawings N-204 to N 209 inclusive, are hydrographs showing flow and actual H. P. for years 1903 to 1908, inclusive.
Based on flow of river as determined by gage readings a C. M. & St.P. Ry. Bridge below Iron Mountain. Drainage area above gaging station-2415 Sq. miles and above Twin Falls drainage area equals 1790 Sq.Mi. Estimated flow based on this proportion, Drawing #198 shows these areas.

Hydrographs on left show discharge in cubic feet per second per square mile and on right total amount of continuous H. P. that could have been developed at Twin Falls, without storage. Turbines efficiency estimated equals 80%.

Hydrographs shows that with head of 40 feet 3900 continuous H.P. could have been developed by the turbines each day for the entire period, except for about two months in 1903, one month in 1905, one month in 1907 and 4 months in 1908, when the power would have been somewhat less. It will also be noted that for a period of eight months of nearly every year at least 5000 continuous Hydraulic H.P. could have been developed. The following estimated earnings of the plant are based upon 3900 continuous H. P. at the turbine shaft. Allowing for generator and line losses 3500 continuous H.P. can be delivered to any point within a radius of 16 miles.

Available Pondage.

Surveys above Twin Falls show proposed dam would make a pond of about 1000 acres. Sufficient to store entire night flow at low water when level of pond lowered during day.

Proposed Plan of Development

Proposed to instal 10 steel tainter gates which will provide ample capacity for extreme floods. In addition a spillway section provided to pass over ice and drift.

It is proposed to instal at first five 1200 K. W. generators. Head Works and Head race estimated on ultimate capacity of seven 1200 K. W. units. Fishway and logway provided.

Estimated Cost of Development

Based on a machine equipment of 6000 K.W. including hydraulic and electric equipment and necessary transmission lines.

Rock excavation, 38650 yd. @$2.25		$86,960.00
Concrete in entire plant		
Head gates 1200 yds. @$8.00	$9,600.00	
Tainter Gate 4590 yds. @$8.50	42,015.00	
Wall between head & tainter gates, 1270 yds. @$7.00	8,890.00	
Spillway, 3030 yds. @$7.00	21,210.00	
Concrete in Power House @$10.00	53,000.00	134,715.00
		$221,675.00
Tainter Gates hoist, etc.		11,000.00
Racks, gate hoist & gates		12,000.00
Building above concrete walls		47,000.00
Turbines, five 2100 H. P. units		52,500.00
Generators, five 1200 K. W. "		66,000.00
Penstocks		5,000.00
Switchboard & Wiring		18,000.00
Fishway		2,000.00
Log Chutes		1,000.00
Cofferdam and pumping		20,000.00
Transmission Line		75,000.00
Iron Mountain Electric Plant (It is proposed to buy out this company)		40,000.00
Flowage & water rights		65,000.00
Road Improvement & Railway		35,000.00
		$671,175.00

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Estimated cost of Development(Continued)

Amount brought forward		$671,175.00
Engineering	5%	
Interest during construction & general expense	5%	
Contingencies	5%	
Discount on Bonds	10%	
	25%	167,795.00
		$838,970.00

Estimated Gross Income

At conservative figure estimates power can be sold @0.75 cents per H. P. hour or 1.00 cent per K. W. Hour. On this basis, for 312 days per year 3500 H. P. will yield an annual income of $196,560.00 There would also be a demand for pumping and other purposes for the reamaining 50 days (Sundays) which would yield an added income of $15,750.00.

Total income therefore $212,310.00

This estimate conservative for no value has been placed upon the extra 1000 H. P. that can be furnished for eight months of each year.

Estimated Annual Cost of Power

On the basis of total estimated cost of $838,970.00

Interest @6%	$50,340.00
Depreciation & Repairs 1% of physical values	6,710.00
Taxes 1% of total estimate	8,390.00
Operating Expense	15,000.00
Total annual cost	$80,440.00

On the basis of 3500 continuous electric H. P. delivered this is equiva-

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Estimated Annual Cost of Power, Continued

lent to about $25.00 per H. P. per year.

Estimated Net Earnings

Gross Annual Income	$212,310.00
Charges & Operating expenses	80.440.00
Net earnings	$131,870.00

equals 15.7% on total estimated cost

or 13.2% on capitalization of $1,000,000.00

Proposed Market

Census of Power Used

Mr. White estimates this power is costing the mines from ¾ to 1 1/8 cents per H. P. hour, not including fixed charges.

This could be sold at from 0.6 to 1.0 cents per H. P. hour. Power used for furnishing water and light to City probably costs four cents per H. P. hour and could probably be sold for 2 cents or 3 cents.

Water Power Rights

Appended copy of Wisconsin law taken from the Session Laws of 1907 and those of Michigan were furnished by Mr. Stirling.

Wisconsin rights obtain under a law published June 27, 1907, and are printed in Chapter 409 of the Session Laws of 1907.

Michigan Rights

There is a special act, apparently intended to cover this development which is included in the local Acts of 1907, No. 647. Right to construct this plant is however covered by Local Act No.443 of the laws of 1905 which is a general act to "authorise and empower the construction,etc. of dams on the Menominee River, etc."

Report Concludes.

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SUPPLEMENTARY REPORT TO PENINSULA POWER CO.
MAY 16, 1911 BY DANIEL MEAD

****

Supplementary report on proposed hydro-electric development at Lower Twin Falls, Menominee River. Since date of 1st report, April 25, 1910, there has been organized the Peninsula Power Co., a Wisconsin Corporation, Capital $750,000.00

Present Plans for Development

Proposed to construct first a plant of three 1000 K. W. units, one as a reserve unit. Additional units may be added as business warrants.

Estimated Cost of Development

Since 1st report about $900.00 has been spent on dam construction. Test Pits put down showed 1st estimates of rock excavation were too large.

The following table shows our estimated cost on the basis of final plans and also on basis of unit prices of lowest and best bidder. The total cost of initial development should not exceed $500,000.00. $550,000 assumed as conservative.

	QUANTITY	Unit prices EST.	BID	TOTAL PRICES based on estimated quantity ESTIMATE	BID
Cement					17,500.00)
Concrete Work	10,125 Cy.yd.	$836	$3.50	$84,600.00	35,437.50) }*
Mortar Finish	1,300 Sq. "		.27		351.00)
Reinforcement	120,000 lbs.		.03		3,600.00)
Brick Building				16,600.00	18,050.00
Rock Excavation	15,140 Cu.Yd.	$2.00	1.50	30,280.00	22,710.00
Earth "	2,000 " "	0.35	0.80	700.00	1,600.00
" Fill	12,200 " "	0.40	0.45	4,880.00	5,490.00
Timber Work	70 M	50.00	50.00	3,500.00	3,500.00
Coffer Dam & Pumping				10,000.00	3,600.00
Rip-Rap	240 Cu.Yd.	1.25	1.65	300.00	396.00
Turbines-- 3 units 1750 H.P. each				25,500.00	28,000.00
Generators, exciters--1000 K. W. each				35,400.00	32,500.00
Pen Stocks				4,100.00	4,100.00
Concrete Dam including camp, etc.				8,000.00	10,000.00
Total on which bids have been received				225,860.00	136,834.50

Structural Steel (Not including Pen stocks) 250,000# @4¢	$10,000	
Hoist for penstock gates	1,200	
" " Tainter "	800	
Switchboard, oil switches, etc.	9,700	
Conduits, cables, ? treating outfit, etc.	4,000	
Crane	2,000	
		$27,700
Road Improvement	15,000	
Land & Water Rights	65,000	
		107,700
Transmission Line, 40 miles @3200 dol.per miles	128,000	
	235,700	
Bids already received brought forward	223,860	
	$459,560	
Interest during construction	7,500	
General Expenses, 10% engineering & contingencies	42,956.00	
	$510,016	

Bids.

Bids already received	$186,834.50
Estimate as above up to and through Transmission line	235,700.00
	$422,534.50
Interest during Construction	7,500.00
General Expense	12,500.00
	$442,534.50
10% Engineers Conveyances	44,253.50
Total Cost	$486,788.00

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Annual Fixed Charges

On basis of bond issue of $300,000.00 the annual cost of power is estimated as follows:

Interest, 5%	$18,000.00
Depreciation	3,500.00
Taxes	4,500.00
Operating Expenses	15,000.00
Total Fixed charges	$41,000.00

Net Earnings from Minimum Flow

Hydrographs of stream flow for years 1903-1910 inclusive show(except for short period in 1908-10)

2500 continuous H. P. per day could have been delivered to turbines. This is equivalent to 2000 continuous H.P. (Electrical) to customer. Assuming Average Selling price of 1¢ per K. W. Hour, gross income equals $133,000 per year return of $92,000.00 per year. This is equivalent to a little over 12% on capital stock of $750,000.00.

This is extremely conservative because based on minimum flow, not average flow. Also on 3 machines (1 spare) plant 3000 K.W. or 4,000 H. P.

Net Earnings with Auxiliary Steam Plant

The hydrographs shows that when demand for power warrents the plant should be increased to 3500 K. W, or 4,700 H. P. delivered to customer.

The following table shows additional annual expense for steam power with additional fixed charges, also added net income which would have resulted for each year by use of steam in addition to hydraulic power.

Estimated Net Earnings from Combined Steam & Hydraulic Plant

YEAR	K.W. HOURS FROM STEAM MILLIONS	% of TOTAL	ANNUAL FIXED CHARGES	ANNUAL OPERATING EXPENSES AT 1¢ K.W.	TOTAL AMOUNT OPERATING EXPENSES	INCREASED PROFIT WITH INCOME OF $175,200.00	TOTAL INCOME STEAM & HYDRAULIC
1903	3.996	13.0	$52,500	$39,960	$92,460	$82,740	$174,740
1904	3.108	10.1	"	31,080	83,580	91,620	183,620
1905	4,400	14.3	"	44,000	96,500	78,700	170,700
1906	3,552	11.6	"	35,520	88,020	87,180	179,180
1[illegible]7	5.772	18.8	"	57,720	110,220	64,980	156,980
1908	9.768	31.8	"	97,680	150,180	25,020	117,020
1909	8.880	29.0	"	88,800	141,300	33,900	125,900
1910	12.432	40.5	"	124,320	176,820	1,620	90,380
Aver	6,439	21.1	"	64,885	117,385	57,815	149,815

CARP RIVER DEVELOPMENT, C. C. I. CO.

Abstract of Report of Viele, Blackwell & Buck,

May 10, 1910.

It is proposed to deliver all the power generated over a 15 mile transmission line to the Brownstone Substation of the Cleveland-Cliffs Iron Co. at Ishpeming, Mich., the power being distributed from this plant over existing lines to the various mines in Ishpeming, Negaunee and Princton Districts.

Discharge of Stream.

Drainage area above proposed site of dam about 80 sq. miles and average flow during a dry month estimated at 0.4 sec. ft. per sq. miles of drainage area, or 32 sec. ft.

On account of receiving the drainage of the Ishpeming and Negaunee districts including the water pumped from the mines, the flow of the Carp is higher than that of other streams in Northern Michigan, which go down to 0.3 of a second ft. per sq. mile.

For six months out of every year the stream flow will be more than it would be practicable to utilize, so that during this period water would be wasted.

Our investigations indicate that it will be desirable to design the Carp plant so as to utilize a stream flow that can be relied upon for at least seven months in the year, your Mass and Princeton steam plants being used as auxiliaries during dry seasons. Later storage may be developed to equalize the flow.

Continuous records of the daily flow of the Carp River for more than eight months are not available which is too short to give a reliable indication of the average discharge.

The Dead River lying immediately to the north of the Carp

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has been measured by U. S. Geological Survey for '99 to 1902, incl. and it is assumed Carp run-off similar per sq. mile for the four years referred to . Average rainfall '99 to '02 = 32.2 in somewhat less than normal, the lowest year, 1902, having 26.77 in. and the highest, 1899, having 37.75 in. The year 1902 was the lowest rainfall recorded at Marquette for the period 1888-1908 inclusive. In our opinion the Dead River flow records for '99-'02 should be a conservative indication of the average discharge of the Carp, particularly as the latter may have a somewhat higher flow on account of receiving the drainage from the mines.

During the 48 months in question there were 29 in which the discharge was equivalent to 1.25 sec. ft. per sq. mile of drainage area, or an average of more than seven months per year and we have therefore estimated on the Carp plant being capable of utilizing continuous stream flows up to 100 sec. ft. the waterways and hydraulic apparatus, being designed for a maximum discharge of 152 sec. ft. and permitting of operating the plant @66% L. F.

Power Developed

Total fall = 622 ft. aver. working head = 580 ft. so with low water flow of 32 sec. ft. 1680 H. P. can be generated continuously. The demand for power will not be uniform and we have estimated that the ratio between the average and peak loads of the plant will be 66%, water being stored at the intake reservoir during the periods of light loads for use during periods of heavy demand.

At low water, therefore, a peak load of 2560 H. P. might be generated at the power house. The extreme low water flow will probably not occur in an average of more than 30 days per year and for two-thirds of the

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time, when the discharge is equivalent to 100 sec. ft. ore more, 5250 H. P. can be generated constantly, or 8000 H. P. @ 66% L. F.

The transmission loss should not exceed 15%, which would allow a peak load of 6800 H.P. to be delivered at the Brownstone Sub-Station. This @66% L. F. and for 330 days per year is equivalent to 26,500,000 K. W. hours, of which we estimate an average of 15% would have to be supplied in steam power, or nearly 4,000,000 K. W. hours annually.

A steam plant of 3000 K. W. capacity would be necessary in order to deliver the full capacity of the development during extreme low water periods.

STORAGE

Available storage back of intake dam will be 10,000,000 cu. ft. which is suffcicient to average up the daily and weekly discharge of the stream and to allow the plant to operate at low load factors.

Six miles above proposed intake there is apparently a good reservoir site which preliminary surveys indicate a dam 18 feet above low water level of the river and 650 ft. long would store 1055.55 acres and contain 275,000,000 cu. ft. acres [redacted] With this storage the flow at the intake might be regulated so that at extreme low water the continuous output of the plant could be increased 100% which would give 5100 H. . constantly @66% L. F. The average amount of steam power required annually at the Brownstone Sub-station would be reduced from 4,000,000 K. W. Hours without storage to 1,300,000 K. W. H., which is about 5% of the total annual combined delivered output of 26,500,000 K. W. H. from the water and steam plants. The capacity of th auxiliary steam plant necessary would be reduced by 50% or to 1500 K. W.

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PLAN OF DEVELOPMENT

Dam to consist of concrete retaining section 125 feet long, concrete spillway, 140 feet long and concrete retaining section 120 ft. long. Maximum height would be in spillway section equal 52 ft. above bed of river.

Three feet of flash boards across spillway and with water to top of these or at 1230 fet. elev. the pond would be about one mile long and cover approximately 320 acres.

A 66" riveted steel pipe varying in thickness from 1/4" to 1/2" would conduct water a distance of 1900 feet to a standpipe consisting of a 48" pipe running up the side of the Mt. Mesnard and terminating in a 10 ft. steel surge tank.

Two 46" riveted steel penstocks, each about 2000 ft. long would be carried from the foot of the standpipe to the power house at the river, the tail race being excavated for a distance of 1500 ft. to elev. 608.

The power house would be a fire-proof structure and would contain two 4000 H. P. 1200 R.P. M. Francis type turbines with governors, each direct connected to a 2500 K. W. 3-phase 60 cycle 2300 volt alternator, with direct-coupled exciter.

There would also be 4 single phase 1700 K. W. water-cooled 2300-30000/60000 volt step-up transformers and a complete switchboard equipment.

From the generating station a steel tower double circuit transmission line would be run for 15 miles to the Brownstone Sub-station, where the necessary step-down transformers and switchboards would be intalled.

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Plan of Development

Each of the line circuits would consist of three No. 8 B. & S. wires and the towers would carry also a steel guard wire and a telephone circuit.

ESTIMATED COST

Construction Plant, camp, tools, etc.			$25,000.00
Reservoir Dam			20,000.00
Main Dam and intake			45,000,00
Water Ways			
18,700 ft. 66" Steel Pipe	,4,834,600#		
Surge Tank	296,000		
4000 ft. 44" Steel Penstock	864,800		
	5,995,400#		
	@ .05		
	$299,770.00		
Grading, foundations, etc.	57,500.00		357,270.00
Power House & Tail race			34,000.00
Hydraulic apparatus, two 4000 H.P. Wheels			40,000.00
Electrical equipment, 2 2500 K.W. Alter.		$32,500.00	
Exciters		2,000.00	
Four 1700 K. W. Transformers		27,200.00	
Switchboards, wiring, etc.		15,000.00	76,700.00
			$597,970.00
Engineering contingencies, incidentals, etc.			120,000.00
Int. during construction			25,000.00
			$742,970.00
Cost per H. P. (8000 H.P. 66% Load Factor)			$93.00

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ESTIMATED COST TRANSMISSION LINES

Length of Line	15 miles	
Two #2 B. & S. Circuits		
Potential	30,000 volts	
Loss 6800 H. P. delivered 85% Power factor 5.5%		
Copper, 100,000 lbs. @16¢		$16,000.00
Insulators & pins 1000 @$2.50		2,500.00
Towers, 150 @$165.00 erected		24,750.00
Guard Wire		500.00
Telephone system		1,125.00
Stringing Wire		2,250.00
Special works		5,000.00
Camp, tools, etc.		3,000.00
		$55,125.00
Step down transformers 5000 K. W.		25,000.00
Switchboards & Station equipment		20,000.00
		$100,125.00
Engineering & Contingencies		20,000.00
Interest during construction		4,000.00
		$124,125.00

SUMMARY

Generating Plant	$742,970.00
Transmission System	124,125.00
Water power rights & properties, costs assumed	100,000.00
	$967,095.00

Cost per H. P. delivered, 6800 H.P. @66% Load Factor) equals $142.00

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ANNUAL COST OF OPERATION
WITH STORAGE OF 275,000,000 CUBIC FEET

Interest on $1,000,000.00 @5%		$50,000.00
Depreciation at 2½%		27,500.00
Labor & Supplies		12,000.00
General Expenses & Taxes		10,000.00
		$99,500.00
Steam Power, 1,300,000 K. W. H. @1¼¢		16,300.00
		$115,800.00
Average K. W. Hours delivered annually		
at Brownstone Substation, Water Power	25,200,000	
Steam "	1,300,000	
	26,500,000	
Average cost per K. W. H. delivered	$.00437	
Average cost per H. P. delivered (6800 H. P. @66% L. F.)		$17.10

ESTIMATED COSTS CARP RIVER DEVELOPMENT WITHOUT STORAGE RESERVOIR.

Total with Storage		$967,095.00
Deduct for storage dam	$20,000.00	
" " Land & water rights	50,000.00	
" " Engineering, contingencies and interest	5,000.00	75,000.00
Total Estimated Cost		$892,095.00

Annual Charges

Intest on $900,000.00		$ 45,000.00
Depreciation 2½%		22,500.00
Labor & Supplies		11,400.00
General Expense & Taxes		9,000.00
		$ 87,900.00
Steam power 4,000,000 K. W. H. @1¢		40,000.00
		$127,900.00
Average K. W. H. delivered annually at Brownstone Substation Water Power	22,500,000	
Steam "	4,000,000	
	26,500,000	
Average Cost per K. W. H. delivered	$.00485	
Aver. cost per H. P. year delivered (6800 H. P. @66% Load Factor)	$18.85	

CONCLUSION

Recommends investment, etc. Says plant can be built in 12 to 18 months.

Believe estimates conservative.

Cost of power with modern steam plant of same capacity in the Ishpeming District would cost not less than 1¢ per K. W. H., or more than twice the cost of this development, either with or without storage reservoirs.

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AIR REQUIRED TO OPERATE STAMPS

Indicator Cards from Simple Stamps show a mean effective pressure

of	102.1 lbs. for Top
Vacuum by card =	8.0
Total M.E.P. for down stroke =	110.1 lbs.
Stroke	22.59"
Cut Off	82%
Initial Pressure	131 lbs.

- -

In another case:

M. E. P. is	109.4 lbs.
Vaccum by card	9.0 "
Total M.E.P. for down stroke	118.4 for 21.78" Stroke
	86% cut off
	138 lbs.steam pressure

$$\begin{array}{r} 110.1 \\ \underline{118.4} \\ 2\ )\ \underline{228.5} \end{array}$$

Or an average of 114.25 lbs.

By using air instead of steam, stamp will then operate with a back pressure on down stroke of probably 1 lb. which would be required to expel bottom air.

$$\begin{array}{r} 114.25 \\ \underline{1.00} \end{array}$$

When operating with air M.E.P.'s required = 115.25 lbs.

Average stroke for above = 22.5 inches.

By Extending table on page 503 in Kent, carrying out to a pressure of 150 lbs.(and this by the way I assume is air compressed Isothermal) a mean effective pressure of 117 lbs. is obtained with a 50% cutoff. With a clearance of 2½ inches as a mean the cylinder clearance for 20" diameter

diameter	705 cu. inches	
additional clearance for valve ports	775 " "	
Total of	1480 " "	

With a 50% cutoff on 22.5 inches

the volumetive displacement = 3530 cu.in.

plus clearance 1480 " "

Therefore 5010 " " of

air at 150 lbs. pressure required per down stroke.

1 cu. ft. of air compressed Isothermally from 1 atmos.to 150#= .0892 cu.ft

1 " " " " " Adiabatically " " " " 150#= .1796 " "

Ideal Isothermal compression would not be obtained, so will assume the volume of a cu. ft. of air/compressed under our conditions to be .11 cu. ft. Required $\frac{5010}{1728}$ = 2.890 cu. ft. of air at 150 lbs. pressure per down stroke but since 1 cu. ft. of free = .11 cu. ft. of air at 150 lbs, it will require $\frac{2.890}{.11}$ = 26.3 cu. ft. free air per stroke, or 26.3 x 108 = 2840 cu. ft. free air per minute, compressed to 150 lbs.----for down strokh only.

For up stroke M.E.P. from steam cards= 27.1 lbs.

In second case = 28.2 "

2) 55.3 "

or an average of 27.7 "

In addition to this, vacuum on top of piston was respectively 8 & 9 lbs., or an average of 8.5 lbs. When operating with air assume back pressure of 1 lb. or a total M.E.P. required with air of 37.2 lbs.

On up strokes instead of admitting air at 150 lbs. pressure it is better to reduce to about 65 lbs.

From table (503) Kent)a M. E. P. of 37 lbs. is obtained when <u>cut off</u> is at 35% of stroke with 65 lb. air pressure.

Volumetric displaycement of piston at point of

cut off = .35 x 314 x $22\frac{1}{2}$ = 2475 cu. in.

Total bottom clearance 3" = 1095 " "

Or 3570 " "

of air at 65 lbs. pressure required per up stroke.

1 cu.ft. of air compressed Iso. from 1 atmos.to 65 lb.= .184 cu. ft.

1 " " " " " Adiab. " 1 " " 65 " = .301 " "

Under our conditions it will probably be .22 cu. ft.

Required $\frac{3570}{1728}$ = 2.07 cu. ft. of air at 65 lbs. pressure,or $\frac{2.07}{.22}$ = 9.42 cu. ft. of free air at a pressure of 65 lbs.

But since this pressure of 65 lbs. is to be obtained by expanding down from 150 lbs. the 9.42 cu. ft. of free air will also have to be compressed to 150 lbs. pressure, which will mean a waste of power of about 12%, or 9.42 x 108 = 1020 cu. ft. of free air per minute at 150 lbs. pressure will be required for up stroke.

2840
1020

or a total of 3860 cu. ft. free air at 150 lbs. required per minute per simple stamp.

APPROXIMATE TOTAL AMOUNT OF AIR REQUIRED AT BALTIC MILL

For 4 simple heads @ 3860 equals	15,440 cu. ft.
" 2 compound " @ 85% of 3860 equals	6,560 " "
For 400 H. P. Engine equals	3,200 " "
	25,200 " "

of free air at 150 lbs. pressure will be required to operate six heads and mill engine. In addition to this it will require 500 electrical H. P. for regrinding motors, and lighting.

Note:- A reduction in stamping rate of 15 to 20% will result by using air in compounds unless pressure on L. P. Piston will be increased to 40 lbs. guage instead of 28 lbs.

The following shows the excessive clearance

volume in steam stamp practice

- -

Clearance top end for valves, etc.	775
Unfinished stroke, cylinder clearance	600
For top - total clearance	1375

Full air pressure will be taken during a volumetric displacement of 3530 cu. in.

- -

Bottom clearance = 1089 cu. in.

Air at 65 lbs. will be taken during a volumetric displacement of 2475 cu. in.

- -

Additional air at 150 lbs. pressure is required

$\frac{1375}{3530}$ = 39.1% to fill clearance volume on top.

$\frac{1089}{2475}$ = 44.2% " " " at 65 lbs. on bottom.

Top takes $\frac{2820}{3840}$ or 73.4% of total air consumed.

39.1 X 73.4% = 28.6% of total

Bottom takes 26.6% of total air

44.2 X 26.6 = 11.7

40.3% of total air at 150 pounds pressure is required to fill cylinder clearances.

This accounts greatly for low effinciencies.

REGARDING STURGEON RIVER POWER

DEVELOPMENT

Data taken from the report of T. W. Orbison.

This report assumes the minimum flow of the river as 8,816 cubic feet per minute. This amount was determined by measuring the stream for a brief period. His estimated minimum was a little larger than this. The report states that Dam No. 4 at the head of Tibbetts Falls can be made to store 1,500,000,000 cubic feet. Orbison estimates that a storage of 5,293,000,000 cubic feet would furnish a continuous flow for 366 days per year of 31,893 cubic feet per minute. Since the minimum flow is 8,816 cubic feet per minute then 31,893 less 8,816, or 23,077 cubic feet per minute, represents the flow which must be added during the time of minimum water. Assuming that the continous flow of the river above the minimum is proportional to the amount of storage, then if Dam No. 4 stores 1,500,000,000 cubic feet the flow that this could furnish would be 15 divided by 53 X 23,077, equal to 6,530 cubic feet per minute of total flow.

$$\text{H. P.} = 62.5 \times \frac{\text{Head}}{190} \times 15{,}000 \div 33{,}000 = 5{,}398 \text{ H. P.}$$

Multiplying by 80%, 4,318 H. P. Effectual.

Effectual without storage 2,537 H. P.

Gained by storage, 1,781 H. P.

Assuming this power to be required only 18 hours per day, there would be available 5,757 H. P. at the generating station, but with 81% transmission loss, at place of consumption, 4,663 H. P. The lower power dam, which covers 785 acres could be made to deliver 200 additional H. P. for 60 days by dropping the water level two feet. It is probable that Storage Dam No. 4 might be assumed to be filled one and one half times per year instead of only once as in the above computation.

REPORT OF VIELE BLACKWELL & BUCK

By a short time measurement in August, 1910, the flow of the river at Tibbetts Falls was found to be only 21 cubic feet per second, and at the lower falls 75½ cubic feet per second, or respectively 1,260 and 4,530 cubic feet per minute, whereas in Orbison's report the minimum flow at the lower falls was found to be 8,816 cubic feet. The flow diagram given shows that one cubic foot per second per square mile may be assumed for six months of the year without using the storage. Drainage Area above Tibbetts Falls equals 160 Sq. Miles and on the Perch 90 Sq. Miles, therefore, we should have for six months without storage from the upper Sturgeon, 160 x 60 = 9,600 cubic feet per minute and from the Perch. 90 x 60 = 5,400 cubic feet per minute, or a total of 15,000 cubic feet per minute. For the remaining six months of the year the discharge of the river would be much less, down to a minimum of 1,260 cu. ft. per minute for the Upper Sturgeon and 1,260 Cu. ft. per minute for the Perch, making the total minimum flow 2,520. This report states that a storage dam at Tibbetts Falls can be built to hold 2,100,000,000 cu. ft. This amount of storage would be sufficient to increase the minimum flow to 15,000 cu. ft. per minute for about four months. It is not at all probable, however, that the river would be at its minimum flow for such a long period. It is fair to assume that the average low water flow would be a mean between 15,000 and 2,520, or 8,760 cu. feet per minute.

```
15,000
 8,760
------
 6,240
```

6,240 equals the average to be supplied from storage for six months in the year. The storage assumed would supply this amount for eight months in the year, so that there are two months leeway.

The average available head, allowing for drawing down the the reservoir, equals 220 feet, and the H. P. equals 6,250. Assuming 80% available at the development and 81% of this at the mines, the net available at the mines would be 64.8%, or 4,050 H. P. As above, it is probable that the storage dam could be filled more than once and the benefit of this obtained in extra power above what has been assumed.

AT THE LOWER POWER PLANT

The flow for six months at one cu. ft. per second per Sq. mile equals 320, or 19,200 cu. ft. per minute. Storage at the upper dam, 2,100,000,000; lower dam, 350,000,000, total 2,450,000,000 Minimum flow is given as 4,530 cu. ft. per minute.

19,200
4,500

14,700 cu. ft. per minute required from storage at the lowest stage of the river. Assuming the average low water flow to be a mean between 19,200 and 4,500 we have 11,850 cu. ft. per min. as the average low water flow. The total storage assumed would increase this flow to 19,200 for almost eight months, or two months more than is likely to be necessary. Effective head equals 180 feet, and the H. P. equals 6,545.

6,545 x 64.8 = 4,241 H. P. at the mines supplied from the lower plant and using all storage.

Upper Plant	4,050
Lower Plant	4,241
Total	8,291

Regarding Sturgeon River Power Development

If we assume the power used continuously only 18 hours per day, then there would be a total of 11,055 H. P. available at the mines.

H. P. NOW USED AT MINES & MILLS.

Consumption of coal at mines per year~~s~~, 54,000 tons, or 108,000,000 pounds. Assuming an average evaporation of eight pounds of water per pound of coal, that would evaporate per year 864,000,000 pounds of water. If now we assume that 30 pounds of steam are consumed per H. P. Hour, and that this power is used in 310 days of the year that would give as the H. P. used at all three mines 3,871. If it is assumed that 40 pounds of steam are required per H. P. Hour then the total H. P. at the mines would be 2,903. I think that the first figure is most nearly correct.

At the mills the coal consumption is about the same, and the steam used per H. P. is more. If we assume steam consumption to be 40 pounds per H. P. Hour then the total equals 2,903 H. P.

mines – 3871 HP
Mills – 2903 "
6774 Total HP mines + Mills

Vele Blackwell + Buck NY
O'Keefe + O'Brien appleton Wis.

STURGEON RIVER POWER DEVELOPMENT

Upper Power Plant	1,128,800
Trans. System	344,400
Property	400,000
Admin. & General Expense	50,100
	1,923.200

Omitting Lower Plant would further reduce above

Trans. Line	
Copper	25,000
	4,000
2	3,000
	5,
	22,500
	12,500
	10,000
	5,000
	2,000
	89,000

Or to 1,834,200

	Per H. P.
1,834,200 will produce 4000 H. P. at mines	458
2,619,724 " " 8241 " " "	318
at 66% load factor these figures become	
6000 H. P.	305
12360 "	212
Annual charges estimated equal 236,600 equal	$19.00 per H. P.

Assume all above expense for our own use only

saving 108 thousand tons coal @3.00	324,000
" 40 men @ 700	28,000
	352,000
	236,600
Profit	115,400

STURGEON RIVER POWER DEVELOPMENT

The Elevation Flow Line upper dam equals	1247	V.B.&Buck
" " " " Lower " "	968	figures
Maximum possible head	279	
Total head as designed equals	267	
Total head at lower dam "	196	
Height of Dam over stream " at lower dam	84	

Possible to build 40 foot dam and have crest not over 100 feet long

With this, total head equals 152 feet

Power 190:146: :4241: X

$X = \frac{146 \times 4241}{190} = 77\%\ 4241 = 3265$ H. P. at Mines

```
190 )146.00
       77%

     4241
       77
    -----
    29687
   29687
   ------
  3265.57
```

Estimated cost full development of lower plant equals	$696,524
Above reduction in dam would reduce cost, say	100,000
	$596,524.

STURGEON RIVER POWER DEVELOPMENT

Profit	115,400
@5% Investment of 300,000 at mines & mills to apply power	15,000
Net Gain	100,000

Our present H. P. equals about 6000 to 7000 H. P., so should have 5000 to 6000 H. P. surplus available.

Coal per year. 108,000 tons @3.00	324,000
60 men @700	42,000
Supplies	6,000
	372,000

@ 7000 H. P. this equals $53.00 per H. P.

No allowance for interest on investment or depreciation

Orbison gives @66% load factor about $60.00 as total cost

Annual cost of water power H. P. equals	19.00
Leaving a margin of	41.00

Therefore surplus should bring at least $39.00 per H. P. giving $20 per H. P. profit equals $100,000 to $120,000 per year.

STURGEON RIVER POWER DEVELOPMENT

4500 tons coal per month at mines
12

54000 per year
2000

108,000,000 lbs.

8 Evaporation

30)864,000,000 Lbs. of water

28,800,000 H. P. hours with 30 lbs. steam per H. P. Hour.

7440)28,800,000 (3871 H. P.

310 days per year
24

7440 Hr. per year.

If 40 lbs. of steam required per H. P. then total at mines equals 3871 - 968 = 2903 H. P.

At Mills = coal consumption about the same and are 40 lbs. of steam per H. P. Hour = 2903 H. P., or total mines and mills of 5,806 H. P.

Say total investment equals 2,000,000 @ 5% = 100,000

Operation will cost less than at present which will offset interest on investment at the mines and mills made necessary to use power.

Coal at present 108,000 tons @3.00	324,000.00
Interest charge	100,000.00
Saving per year	224,000.00

on 2000,000 tons equals 11.2¢

Say present H. P. equals 6000 then cost equals for coal alone $54.00
Interest charge alone on 6,000 H. P. equals $16.66.

Much more power than above available for six months in the year, and perhaps for 12 months.

Capacitors

Price

no enclosure $1260

with " $1615

Saving in power bill each month $945

see attached sheet

JMcM

9/19/67

U S G S has no
flow figure on the
Iron or Mineral
Rivers; but the Aliigen
region is similar in
character

Nov. 1911.

fuel cost M. 198.410
inc labor 177117
$375.527

May 1916.

est cost of power 286,230
C.R. portion 185.655

Complete

/

ESTIMATED ELECTRICAL POWER REQUIREMENT AT MINES
EXPRESSED IN H.P.H.
PER YEAR.

	Champion	Trimountain	Baltic	% of Total	Total
Rpck crushers	752,500	414,480	545,000	4.95	1,711,980
Rockhouse Hammer & Timber Hoists	48,000	21,600	32,000	.29	101,600
Locomotives	480,000	80,000	168,000	2.10	728,000
U.G. pumps	352,000	123,000	780,000	3.63	1,255,000
Compressors with air @ 80# go.	10,351,000	4,383,800	5,645,800	58.80	20380,600
Hoists	4,873,000	1,964,000	2,313,000	26.40	9,150,000
Lights	308,000	188,200	131,400	1.81	627,600
Shops	136,800	36,300	48,000	.64	221,100
	416,000			1.20	416,000
Water Works	832,500				832,500
Fans	76,900				76,900
	17,717,300	7,211,380	9,663,200	99.8	34,591,880

Note:- Red figures show present consumption which will change with electrical conversion, and are not added in totals.

ESTIMATED ELECTRICAL POWER REQUIREMENT AT MILLS
EXPRESSED IN H.P.H.
PER YEAR.

Present Consumption for Mills, shafting, lighting		8,640,000
Additional requirements for " " " equipment now being installed		3,084,000
Dredging Pump @ Champion operating 6 mo., 8hrs. per day		120,000
Pumping for additional mill Supply	Probable	360,000
	Total	12,204,000
Generating capacity of both turbines operating @ full load 300 days		28,800,000

above without hoists comps. 5.061.000
present consump + ads 12.204000
Electrolytic 7.776000
25.041.000

Brought Forward:- (Total 1000 H.P.H. per yr.) 34,591

Electrolytic Plant at 750 H.P. continuous & 80% effic. 7,776

Total 42,367

Above includes work to be done at mines by mill turbines, so water power becomes spare for turbines and vice versa.

	Tons of Coal	Saving in coal at $3.30	Boiler H. & Coal Passing Labor 1915 record.	Feed water pumping cost.	Total Savings.	Total 1000 H.P. Hours required at mines.	Cost of Electric power charged at 1¢ KWH or ¾¢ per H.P.Hour.
Champion	25,000	82,500	$22,500	2,700	107,700	17,717	$132,870.00
Baltic	16,000	52,800	17,500	2,100	72,400	7,211	69,090.00
Trimt.	11,000	33,300	10,000	1,200	44,500	9,663	72,480.00
	52,000	168,600	50,000	6,000	224,600	34,591	$274,440.00
Electrolytic Plant at 750 H.P.continuous & 80% effic. = 900 H.P.						7,776	58,320.00
Grand Totals						42,367	$332,760.00
							or 31,775 K.W.H.

Under development proposed, there will be a surplus above the 42,367,000 H.P. hours,

Summary.

	Savings.	Income for Electric Power @ 1¢
Hoisting & Compressing	$224,600.	$274,440.
Electrolytic plant	58,320.	58,320.
(Assuming steam plant could) (generate current @ 1¢ KWH)	$282,920.	$332,760.

- -

Water Power.

Drainage Area.

V. B. & B.'s Estimate		Mine.
90 sq. Miles	Perch Lake Area	79 sq. miles
160 " "	Upper Sturgeon	154 " "
250		233
70 " "	Lower Sturgeon	67 " "
320 " "		300 " "

	Total Fall	Effective Head.	Storage above intake.(27 ft.)
Upper dam	267	220	2,100,000,000.
Lower dam	196	180	350,000,000.

(Up to 1910)

Average Annual rainfall 20 years, Marquette records 32.36"
" " " 33 " Houghton " 32.98"
(Government Station at Houghton since 1890)
Taken = 32.4 inches.
Over 1 sq. mile = 75,271,280 cu. ft.

An average flow of 1 cu. ft. per sec. per sq. mile of drainage area for the year may be assumed. To maintain this average flow storage equal to 15% of the annual rainfall is required, or 75,271,280 x 15% = 11,290,692 cu. ft. per sq. mile.

Upper storage reservoir holds 2,100,000,000 cu. ft. and is,

therefore, sufficient to maintain a flow of 1 sec. ft.

$$\text{over } \frac{2,100,000,000}{11,290,692} = 186 \text{ sq. miles.}$$

Assume development of both Upper and Lower powers but <u>without</u> Perch Creek.

Drainage area Upper Sturgeon = 154 sq. miles.

Storage will maintain flow of 1 sec. ft.

$$\text{H.P.} = \frac{154 \times 62.5 \times 220}{550} = 3850 \text{ theoretical H.P.}$$

Combined efficiency of water wheels and generators = 75% - Transmission and unaccounted for loss = 15%
Therefore, net efficiency = 75% x 85% = 63.75% taken at 64%.

Delivered H.P. = 3850 x 64% = 2464 say <u>2500 H.P.</u>

Drainage area of Lower power = 300 sq. miles.
Storage of upper dam will maintain 1 sec. ft. flow over 186 sq.miles

Records seem to show that .2 sec. ft. is about the lowest flow to be expected.

H.P. at lower dam on above basis =

$$\underset{(3805)}{\frac{186 \times 62.5 \times 180}{550}} + \underset{(466)}{\frac{(114 \times .2) \times 62.5 \times 180}{550}} = 4271 \text{ H.P. (theoretical)}$$

At 64% net efficiency = <u>2733</u> H.P. delivered. @1 sec. ft. over 300 sq. mi = 39?? [illegible]

(Without Perch Creek) Upper development = 2500 H.P. delivered.
Lower " = 2733 " "
5233

or 45,841,080 H.P. hours annually or 34,380,810 K.W.H.

V. B. & B. ESTIMATES OF COSTS.

LOWER POWER PLANT.

Roads, bridges, etc.	$35,000.	
Construction plant, tools, etc.	25,000.	
Dam and intake	141,000.	
Pipe line (7300' of 108" wooden stave pipe)	124,000.	
Steel Surge Tank (40' diameter, 55' high)	9,750.	
Penstocks (2 - 520' of 72" diam.steel pipes)	22,120.	
Power house and tailrace	60,000.	$416,870.
Hydraulic machinery (2 - 5000 H.P. wheels with governors, etc.		57,500.
Electrical Equipment:		
2 - 3000 K.W. alternators with exciters	$38,000.	
2 - 3000 K.W. transformers,	20,000.	
Switchboards, etc.	15,000.	
Freight, Hauling & Eredtion	16,000.	89,000.
		$563,370.
Engineering and Contingencies, 20%,		112,674.
Interest during construction,		20,000.
		$696,044.

V. B. & B. ESTIMATES OF COST.

UPPER POWER PLANT.

WITHOUT PERCH CREEK DEVELOPMENT.

Roads and Bridges,		$ 15,000.
Construction plant, tools, camp, etc.		35,000.
Sturgeon dam and intake		228,000.
Sturgeon pipe line, 24,000' of 84" diam. wood stave		275,000.
Steel surge tank, 30' diam., 90 ft. high		13,500.
Penstocks 2 - 800 ft. 60" steel pipes		28,800.
Power house and tailrace		50,000.
Hydraulic machinery (2 - 3500 H.P. wheels, governors, etc.)		43,000.
Electrical Apparatus:		
2 - 2200 K.W. alternators with exciters	$24,200.	
2 - 2200 K.W. transformers	15,500.	
Switchboard, Wiring, etc.	12,000.	
Freight, Hauling, Insulation, etc.	7,500.	59,200.
		747,500.
Engineering and Contingencies, 20%		182,300.
Interest during construction		35,000.
		$ 964,800.

Transmission Line Upper dam to Lower dam to Painesdale = 33 miles.

At $7,000 per mile, which is twice the cost of Lake Shore Line, total cost = $231,000.00

Assume lands and all rights = $650,000.00

SUMMARY.

Lower Development	....	$696,044.
Upper "	....	964,800.
Transmission Line	....	231,000.
Lands, etc.,	....	650,000.
	=$486.00 Per H.P.	$2,541,844.

ANNUAL CHARGES.

Int. on cost @ 5%	.................................$	127,092.
Labor & Supplies	....	24,000.
Gen.'l Exp. & Taxes	....	15,000.
	Total........	166,100.

5233 continuous H.P. = $31.74 per H.P.

45,841,080 H.P. hours = $.00362 per H.P.H.

34,380,810 K.W.hours = $.00483 per K.W.H.

Lower development & upper dam only

gives - - - - 696,044
upper dam - - 343,600
Trans. line - - 189,000
650,000
1,878,644 for 33,929,000 H.P.H. per yr.
with same stream

30,421,000 K.W.H. sold @ 1¢ ....$304,210.

Total annual charges .... 166,100.

Profit ....$138,110.

Estimated Cost of Power. -		C.R.Co. Portion.		Estimated Savings		C.R.Co. Portion.
Champion	132,870	61,435	Loss	25,170		12,585
Baltic	44,880	44,880	Saving	3,310		3,310
Trimountain	50,160	50,160	Loss	28,000	Loss	28,000
Electro. Plant	58,320	29,160		---		---
	286,230	185,635	Net Loss	$49,860	Net Loss	$ 37,275

Water Power Profit . . . . $138,110.

Net loss to C.R. Co. in changing . . . . 37,275.

Total gain . . . . $100,835.

In addition, there would be available

34,380,810
30,421,000
3,959,810 K.W.H. for use in heating or other purposes,

making an additional saving of say - $40,000.

By developing Perch Creek there would be added

$$\frac{79 \times 62.5 \times 180}{550} = 1616 \text{ H.P. annually}$$

or at 64% - - - - - - - - - - - - - - - - - 1034 H.P. delivered

at an additional expenditure - - $164,000.

All of previous figures are further assured and an increased output obtained 80% of the time by utilizing steam auxiliaries, which are already established or may be instituted at small outlay.

ESTIMATED COST OF CONVERTING HOISTS AND COMPRESSORS TO ELECTRIC DRIVE

Hoist Motors.

On account of the relatively small generating capacity of Power Station, some motor generator sets for flywheel equalization will be necessary. But in order to restrict windage losses of flywheels, two generators would be used with each flywheel and motor, each generator to serve one hoist motor. All motor generator sets would be duplicate and parts interchangeable and provided for flywheel attachment. Where tonnage is light sets operate without flywheels. The G. E. Co.'s estimate of 1912 is used as a basis, in which they give $24,080 as cost of a complete 850 KVA motor and 650 K.W. generator set, including direct connected 850 H.P. hoist motor, exciter, switchboard, lightning arresters, etc., but without flywheel. For an equipment as above mentioned, the cost per hoist would probably be increased slightly for flywheel, and is estimated at $2500 per set.

Compressor Motors.

The air demand is variable, and the use of turbo-compressors may not prove as economical as the present machines equipped with auxiliary governing valves to open for a portion of the stroke on light loads, and operated by motors through silent chain or Herringbone gears. These machines would be so coupled to permit disengagement when steam auxiliary power is necessary. The use of synchronous motors for this work would be desirable for power factor correction. The following estimates are based on this method of conversion at a cost of $9.00 per H.P. for motors and necessary switchboard equipment.

For Champion:----

The hoisting at this mine will be done for the present through four shafts, but to be dropped to three later. The tonnage would permit the use of two flywheel motor generatorsets, each with two generators, giving a spare motor and generator when a shaft is dropped.

Hoist Equipment:

Two flywheel motor generator sets with four hoist motors	$101,000.
Foundation, frt. & couplings $2,000 ea.	8,000.
2500 K.V.A. transformers @ $3.00 ea.	7,500.
Connecting cable from generator to hoist motor	5,000.
Erection & Incidentals	5,000.
	$ 126,500.

Compressor Equipment.:

1500 H.P. Motor for "F" @ $9.00 per H.P.	13,500.
600 H.P. " " "B" @ " " "	5,400.
Gears & Coupling cost @ $2.00 " "	4,200.
Foundation, frt. & incidentals	1,500.
Transformer 2000 K.V.A. @ $3.00	6,000.
	$ 30,600.
Estimated total cost for conversion	$ 157,100.

For Trimountain:

Hoisting Equipment.

One flywheel motor generator set and two hoist motors complete with exciter, switchboard, etc.	$ 50,050.
Foundation frt. & couplings	4,000.
Use Mill transformers	- - - -
Connecting cable from generator to hoist	5,000.
Erection and incidentals	2,500.
	$ 61,550.

Compressor Equipment.

750 H.P. Motor for #3 @ $9.00	$6,750.
375 H.P. " " #2 @ $9.00	3,375.
Gears & coupling cost @ $2.00 per H.P.	2,250.
Foundation, frt. & incidentals	800.
Transformers 1125 KVA @ $3.00	3,375.
	$ 16,550.
Estimated total cost for conversion	$ 78,100.

For Baltic:

Hoisting Equipment.

Two motor generator sets without, flywheel	$48,000.
Foundation, frt. & coupling	4,000.
1300 KVA of transformers @ $3.00	3,900.
Erection and incidentals	2,500.
	$ 58,400.

Compressor Equipment.

Two 750 H.P. motors @ $9.00 per H.P.	$ 13,500.
Gear & Coupling cost @ $2.00 per H.P.	3,000.
Foundation, frt. & incidentals	1,000.
Transformers 1500 KVA @ $3.00	4,500.
	$ 22,000.
Estimate total cost of conversion	$ 80,400.
Conversion cost for the three mines	$315,600.

REQUIRED IN THE NEW FUTURE UNDER PRESENT METHODS.

Spare turbine at Mills - - - - - - - - - - - - - - - - - -

Baltic Mine.

Within 5 yrs. new hoist No. 2	$50,000	
" 5 " " " No. 5	50,000	
Renewal of coal trestles	10,000	$110,000.

Trimountain Mine.

Renewal of coal trestles	$10,000	
Avoid turbine installation in rebuilding mill	80,000	90,000.

Champion Mine.

Within five years new hoist No. 4.......	$50,000	
New boiler plant F	50,000	
Coal trestles	10,000	110,000.

Electrolytic Plant.

Boiler house not wanted	75,000.
Greater coal handling facilities will be needed at C.R. dock, Houghton	
Total	

Generating capacity at Mills per hour = 4000 H.P.

Total H.P.H. at the mines for 300 days = 34,591,880
or 115306 H.P.H. per day.

Since this power will be required in about 16 hours the rate per hour will be 7206 H.P.

Surplus from mill turbines =	2,306 H.P.
A steam central station to make up the balance would output	4,900 H.P.
	7,206 H.P. or 5405 K.W.

Plant should have say 4 - 2000 K.W. generators, one being spare.

Such a plant will cost at least $750,000.00, anf in addition a coal dock and storage equipment will be necessary ..

Mill turbine output	28,800,000	H.P.H per
Required for Mill work	12,204,000	Year.
Surplus	16,596,000	
Needed for Mines for other than hoisting & Compressing	5,061,280	
Surplus	11,534,720	
Needed for Electrolytic work	7,776,000	
Surplus	3,758,720	

This plan requires transmission line to Smelter and installation of spare turbine at Lake Shore somewhere.

Power Schemes.

(1) Use entire output of L.P. turbines at mills. This would do all but hoisting and compressing, including Electrolytic work. Establish one H.P. 2000 K.W. turbine somewhere, preferably at mills, Cost $250,000 to $300,000. This assumes stamps will be used for a long time to come, which is more doubtful than ever before.

(2) Take Up Water Power.--
Requires cash of $700,000 to $1,000,000.
Present equipment becomes auxiliary.
Makes a future permanent power supply and provides greatest flexibility.
Power plant ~~of~~ independently and permanently valuable and value likely to increase and more than offset depreciation.
Will reduce the cost of power as a whole.

(3) Use one of present turbines as spare for the other, keeping "F" electric plant and R.H. engines ready for service.
Electrolytic plant to furnish its own power.

TABLE I

Run off of Dead River During 1899 & 1900

Month	Total Cu.Ft. per Min. 1899	Total Cu.Ft. per Min. 1900	Average Cu.Ft. per Min. 1899	Average Cu.Ft. per Min. 1900	Average Cu.Ft. per Min. per Sq. Mile 1899	Average Cu.Ft. per Min. per Sq. Mile 1900
Jan	95,583	230,203	3,083	7,426	24.276	58.472
Feb.	57,656	172,216	2,059	5,938	16.212	46.756
Mar	64,911	157,569	2,094	5,083	16.488	40.023
Apr.	1575,361	1348,426	52,512	44,947	413.480	353.913
May	743,452	454,071	23,982	14,647	188.834	115.330
June	502,925	255,368	16,764	8,512	132.000	67.023
July	241,304	231,298	7,784	7,461	61.291	58.748
Aug.	213,938	200,645	6,901	6,472	54.338	50.960
Sept.	435,154	542,467	14,505	18,082	114.212	142.378
Oct.	574,660	264,326	18,538	8,526	145.968	67.133
Nov.	281,056	275,384	9,368	9,179	73.763	72.276
Dec.	274,621	203,625	8,859	6,569	69.756	51.724
Totals	5,060,621	4,335,578	166,449	142,842	1310.618	1124.736
Average			13870.75	11903.50	109.218	93.728

TABLE II

6 Years Run off of Dead & Iron Rivers

Cu. Ft. per Sec. per Sq. Mile

Month	1899	1900	1901	1902	1903	1904	Average
Jan.	0.404	0.974	0.940	0.772	0.910	1.05	0.83
Feb.	0.270	0.779	0.627	0.653	0.80	1.05	0.71
Mar.	0.275	0.667			1.17	0.86	0.99
Apr.	6.891	5.898			1.59	1.26	4.10
May	3.147	1.922			3.12	2.03	2.77
June	2.200	1.117			1.14	1.25	1.42
July	1.021	0.979			1.51	1.01	1.14
Aug.	0.905	0.849			1.73	1.01	0.98
Sept.	1.903	2.370			2.64	1.20	1.63
Oct.	2.433	1.119			1.41	1.35	1.35
Nov.	1.229	1.204			1.01	1.00	1.12
Dec.	1.162	0.862			1.02	0.81	0.94
Totals	21.840	18.740			18.05	13.88	17.98
Average	1.82	1.561			1.50	1.16	1.50

TABLE III

Ratios of Actual Mo. Run off ÷ Mean Mo. Run Off

Month	Dead River 1899	Dead River 1900	Dead River 1901	Iron River 1902	Iron River 1903	Iron River 1904	Average
Jan.	0.222	0.623	0.643	0.485	0.606	0.905	0.5807
Feb.	0.148	0.498	0.470	0.438	0.533	0.905	0.4987
Mar.	0.151	0.427	0.500	1.490	0.780	0.741	0.6815
Apr.	3.780	3.770	3.184	3.030	1.060	1.086	2.6517
May	1.729	1.230	2.202	2.128	2.030	1.750	1.8531
June	1.208	0.715	0.863	1.053	0.760	1.080	0.9465
July	0.561	0.626	0.952	0.625	1.006	0.871	0.7735
Aug.	0.497	0.544	0.470	0.462	1.153	0.871	0.6661
Sept.	1.046	1.619	0.571	0.550	1.760	1.034	1.0800
Oct.	1.337	0.716	0.744	0.490	0.940	1.164	0.8985
Nov.	0.675	0.771	0.893	0.637	0.673	0.862	0.7519
Dec.	0.638	0.552	0.554	0.643	0.680	0.698	0.6275

Average Figured by Total Run off & Rainfall for the 6 Year Period = 59.4%

TABLE IV

Ratios, of Actual Mo. Run off to 50% of Actual Mo. Rainfall

Month	1899	1900	1901	1902	1903	1904	Total	Average (Ratios of Actual Mo. Run off to Actual Mo. Rainfall)
Jan.	0.56	1.10	1.19	1.07	1.52	1.03	6.47	0.414
Feb.	1.15	0.70	2.15	1.37	1.46	1.61	8.44	0.487
Mar.	0.22	0.85	0.70	8.61	1.08	0.54	12.00	0.394
Apr.	5.89	4.62	10.70	3.61	1.00	3.20	29.02	1.582
May	1.50	1.51	1.73	3.95	1.41	0.83	10.83	0.607
June	1.06	1.12	0.84	1.37	1.19	0.91	6.49	0.410
July	0.82	0.48	0.61	1.13	0.50	0.76	4.30	0.248
Aug.	0.48	0.98	0.77	0.82	0.84	0.75	4.64	0.288
Sept.	1.11	0.81	0.49	1.77	2.04	1.02	7.24	0.406
Oct.	0.80	1.92	0.91	0.96	1.39	0.86	6.84	0.468
Nov.	4.98	1.69	0.89	0.73	0.49	1.28	10.06	0.391
Dec.	0.60	1.07	1.03	0.66	0.93	0.78	5.07	0.305

Average for Whole Period Figured from Total Flow for All Years and Total Rainfall for each Month, and then Averaging These Monthly Ratios = 64.6%

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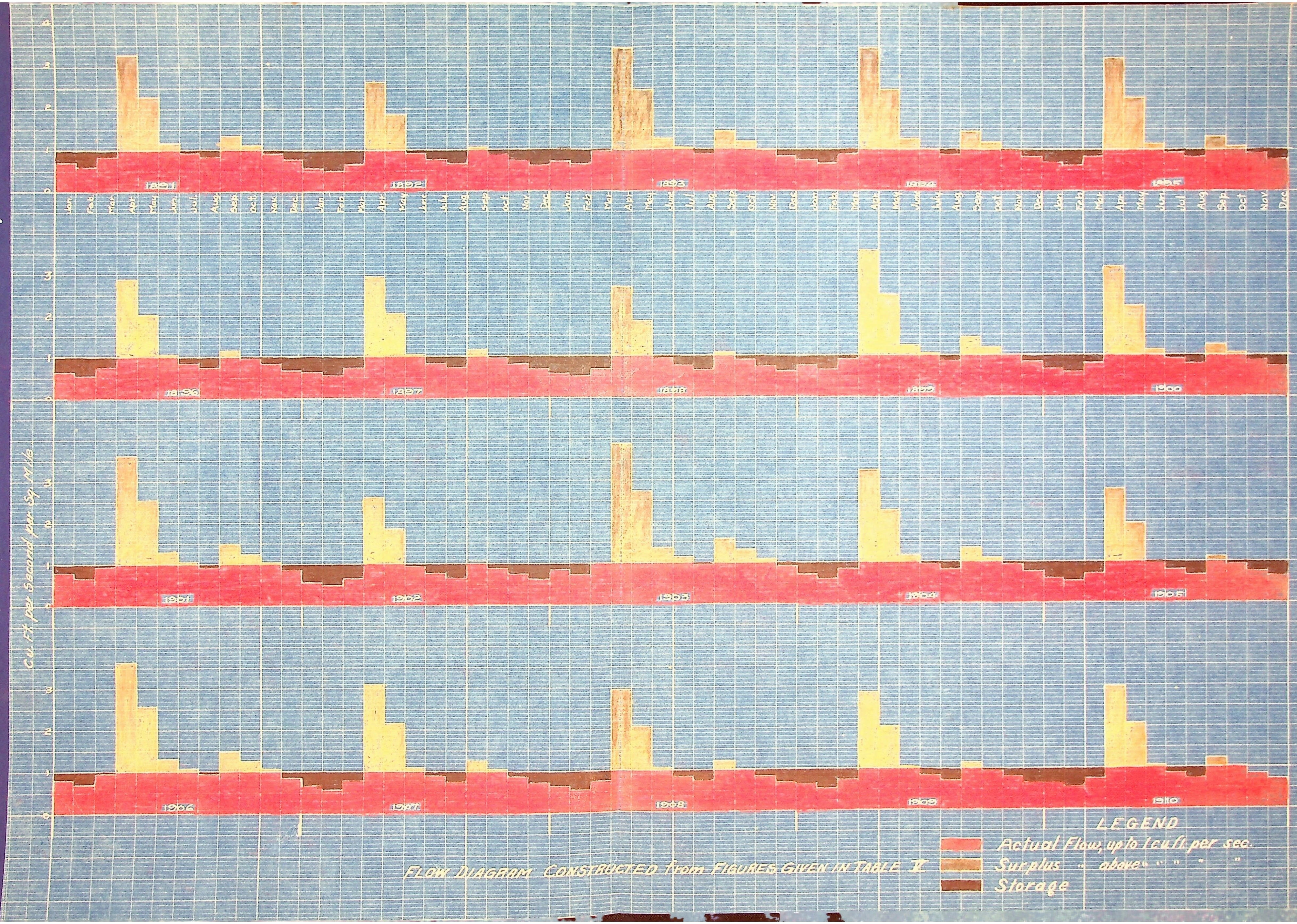

FLOW DIAGRAM CONSTRUCTED from FIGURES GIVEN IN TABLE V

STURGEON RIVER WATER POWER PROJECT.
Capacity Table, Upper Reservoir
TABLE IX

Contour	Total Area	Sum of 2 Adjacent Areas	Average Area	Volume for Contour Interval	Volume for Each Ft. in Contour Interval		Vol. Drawn from Reservoir and Vol. Left after Each Ft. Drop: Cu.ft. Drawn	Feet	Cu.ft. Left	
1247	156727575								2,100,000,000	Full
		289,534,825	144,767,412	289,534,824	1 st.	150,747,494	150,747,494	1 st.	1,949,252,506	
					2 nd	138,787,331	289,534,824	2 nd	1,810,465,176	
1245	132,807,250									
					1 st.	129,896,130	419,430,954	3 rd.	1,680,569,046	
					2 nd.	124,073,890	543,504,844	4 th.	1,556,495,156	
		236,503,300	118,251,650	591,258,250	3 rd.	118,251,650	661,756,494	5 th.	1,438,243,506	
					4 th.	112,429,410	774,185,904	6 th.	1,325,814,096	
					5 th.	106,607,170	880,793,074	7 th.	1,219,206,926	
1240	103,696,050									
					1 st.	100,522,370	981,315,444	8 th.	1,118,684,556	
					2 nd.	94,175,010	1,075,490,454	9 th.	1,024,509,546	
		175,655,300	87,827,650	439,138,250	3 rd.	87,827,650	1,163,318,104	10 th.	936,681,896	
					4 th.	81,480,290	1,244,798,394	11 th.	855,201,606	
					5 th.	75,132,930	1,319,931,324	12 th.	780,068,676	
1235	71,959,250									
					1 st.	69,539,725	1,389,471,049	13 th.	710,528,951	
					2 nd.	64,700,675	1,454,171,624	14 th.	645,828,376	
		119,723,250	59,861,625	299,308,125	3 rd.	59,861,625	1,514,033,249	15 th.	585,966,751	
					4 th.	55,022,575	1,569,055,824	16 th.	530,944,176	
					5 th.	50,183,525	1,619,239,349	17 th.	480,760,651	
1230	47,764,000									
					1 st.	45,587,000	1,664,826,349	18 th.	435,173,651	
					2 nd.	41,233,000	1,706,059,349	19 th.	393,940,651	
		73,758,000	36,879,000	184,395,000	3 rd.	36,879,000	1,742,938,349	20 th.	357,061,651	
					4 th.	32,525,000	1,775,463,349	21 st.	324,536,651	
					5 th.	28,171,000	1,803,634,349	22 nd.	296,365,651	
1225	25,994,000									
					1 st.	25,044,400	1,828,678,749	23 rd.	271,321,251	
					2 nd.	23,145,200	1,851,823,949	24 th.	248,176,051	
		42,492,000	21,246,000	106,230,000	3 rd.	21,246,000	1,873,069,949	25 th.	226,930,051	
					4 th.	19,346,800	1,892,416,749	26 th.	207,583,251	
					5 th.	17,447,600	1,909,864,549	27 th.		Empty
1220	16,498,000									

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STURGEON RIVER WATER POWER DEVELOPMENT

Estimated Actual Flow in Cu. Ft per sec per Sq Mile for 20 Years

TABLE V

	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
JAN	.72	.58	.77	.76	.70	63	.64	.59	.78	.69	.80	.57	.85	.71	.60	.80	.68	.65	.63	.65
FEB	.62	.50	.66	.66	.61	.54	.55	.51	.67	.60	.68	.49	.73	.61	.51	.69	.58	.55	.54	.56
MAR	.85	.68	.96	.89	.82	74	.75	.69	.91	.81	.93	.67	1.00	.83	.71	.94	.80	.76	.74	.77
APR	3.30	2.65	3.49	3.47	3.22	2.88	2.93	2.68	3.55	3.16	3.62	2.61	3.89	3.24	2.75	3.65	3.10	2.95	2.85	2.98
MAY	2.31	1.87	2.43	2.41	2.25	2.02	2.04	1.85	2.48	2.20	2.53	1.83	2.72	2.27	1.92	2.56	2.15	2.06	2.00	2.08
JUN	1.18	.95	1.25	1.24	1.15	1.04	1.04	.96	1.27	1.13	1.30	.93	1.39	1.16	.98	1.30	1.10	1.05	1.02	1.07
JUL	.96	.77	1.02	1.01	.93	.84	.85	.78	1.04	.92	1.06	.77	1.13	.94	.80	1.07	.90	.86	.83	.87
AUG	.83	.67	.89	.88	.82	.73	.74	.67	.89	.80	.91	.65	.98	.81	.69	.92	.77	.74	.72	.75
SEP	1.34	1.08	1.42	1.42	1.31	1.17	1.19	1.09	1.45	1.28	1.48	1.07	1.58	1.32	1.12	1.49	1.26	1.21	1.16	1.22
OCT	1.12	.90	1.19	1.18	1.09	.98	.99	.91	1.21	1.07	1.23	.89	1.32	1.10	.94	1.24	1.03	1.00	.97	1.01
NOV	.93	.75	.99	.99	.91	.82	.83	.76	1.01	.90	1.03	.74	1.10	.92	.78	1.04	.88	.84	.81	.85
DEC	.78	.63	.83	.82	.77	.68	.70	.62	.84	.74	.86	.62	.92	.77	.65	.87	.73	.70	.68	.71
TOTALS	14.94	12.03	15.90	15.73	14.58	13.07	13.25	12.11	16.10	14.30	1643	11.17	17.61	14.68	12.45	1657	13.98	13.37	12.95	13.52
Average	1.25	1.00	1.33	1.31	1.22	1.09	1.10	1.01	1.34	1.19	1.37	.93	1.47	1.22	1.04	1.38	1.16	1.11	1.08	1.13

For Table V, Actual Mo. Flow $= f \times \frac{50\% \text{ Annual Rainfall}}{12}$

f = Ratio Taken from Table III

For Table VI, Actual Mo. Flow $= f' \times$ Actual Mo. Rainfall

f' = Ratio Taken from Table IV

TABLE VI

JAN	.93	.92	.83	1.01	1.88	.75	1.10	.74	.60	.73	.76	.64	.49	.84	.64	1.73	.64	.77	.39	.74
FEB	1.46	1.19	.83	.87	.57	.76	.70	1.68	.23	1.09	.36	.53	.53	.54	.28	.65	.76	1.57	1.15	1.20
MAR	1.56	1.10	1.05	1.45	.46	.64	1.51	.81	.97	.62	.95	.23	.85	1.27	.92	1.16	.47	1.15	.71	.07
APR	3.03	2.33	3.30	2.42	2.02	4.36	2.88	2.40	3.63	4.14	1.59	4.67	5.03	1.24	1.71	1.50	5.32	4.36	4.74	5.44
MAY	1.12	1.44	2.09	4.30	2.61	1.33	1.03	1.69	2.54	.77	2.60	1.15	2.81	2.96	1.93	1.38	.61	1.67	.84	1.37
JUN	.84	.57	.50	.69	1.53	.83	1.33	1.40	1.70	.82	1.41	1.08	.78	1.13	1.30	1.81	1.53	1.26	.60	.29
JUL	.60	.33	1.14	.34	.24	.33	.66	.56	.62	1.01	1.31	.47	1.49	.66	.44	.38	.47	.64	1.00	.54
AUG	1.20	.11	.65	.45	.43	.49	.72	.29	1.09	.25	.59	.55	.55	.77	.50	.82	.56	.27	.34	.85
SEP	.44	.42	.19	.98	1.27	.48	.71	.53	1.40	2.37	1.59	.44	1.05	.95	.94	1.14	2.04	1.25	.61	.63
OCT	1.06	1.64	1.21	.83	1.05	1.74	1.11	1.41	1.43	.55	1.29	.81	.95	1.48	.90	1.53	.97	.44	.73	1.47
NOV	1.16	1.29	1.36	1.58	.98	2.23	.42	.62	.19	.56	1.32	1.17	1.60	.61	.87	1.40	.86	.66	1.42	1.19
DEC	.70	.38	1.54	.61	.81	.37	.48	.41	1.19	.49	.55	1.02	.66	.63	.84	.91	.36	.49	.92	.99
TOTALS	14.10	11.72	14.69	15.53	13.85	14.31	12.65	12.54	15.59	13.40	14.32	12.76	16.79	13.08	11.27	14.41	14.59	14.53	13.45	14.78
Average	1.18	.98	1.22	1.28	1.15	1.18	1.05	1.04	1.28	1.12	1.18	1.06	1.38	1.09	.94	1.20	1.22	1.21	1.12	1.23

TABLE VIII

STURGEON RIVER WATER POWER DEVELOPMENT
Flow and Storage Estimates
Based on Figures Given in Table VI.
1891 – 1894 incl.

YEAR	MONTH	Cu.Ft per Sec. per Sq. Mile Surplus	Def.	Cu.Ft. per Sq. Mi. Added to or Drawn from Upper Reservoir	Cu.Ft. in Storage Upper Reservoir	Deficiency for 300 Sq. Miles	Upper Reservoir Total Lost Head	Total Flow H.P.	Surplus Above Storage in Upper Reservoir 220 Sq. Miles
1891	Jan.		.07	- 183,859	2,100,000,000	55,157,700	0.30	8800	
	Feb	.46			2,044,842,300				
	Mar	.56							
	Apr.	2.03						17000	
	May	.12							
				+ 8,326,200					1,776,600,100
	June		.16		2,100,000,000		0.00		
	July		.40					6600	
				- 1,470,900		441,261,000	3.00		
	Aug	.20		+ 525,300	1,658,739,000			12000	
	Sept		.56	- 1,470,900	1,774,307,200	441,262,000		4100	
	Oct.	.06			1,333,045,200		6.00		
	Nov.	.76						19600	
				+ 577,800			5.00		
	Dec		.30	- 788,000	1,460,170,900	236,391,000		7600	
1892	Jan.		.08	- 210,100	1,223,779,900	63,037,500	7.00	7600	
	Feb	.19			1,160,742,400		7.50		
	Mar	.10						10600	
	Apr.	1.33							
	May	.44							
				5,410,700			0.00		251,099,000
	June		.43		2,100,000,000				
	July		.67						
	Aug		.89					3400	
	Sept.		.58						
				6,750,300		2,025,078,600			
	Oct.	.64			74,921,400		26.70		
	Nov.	.29						13100	
				2,442,700			14.50		
	Dec.		.62	1,628,500	612,316,300	488,541,300		3500	
1893	Jan.		.17		123,775,000		26.50		
	Feb.		.17					7400	
				- 893,000		267,909,000			
	Mar.	.05			-144,134,000		27.00		
	Apr.	2.30						19500	
	May	1.09							
				- 9,035,300			1.75		
	June		.50	1,313,300	1,843,642,600	393,984,000		4700	
	July	.14		367,719	1,449,658,600		4.75	10700	
	Aug.		.35		1,530,556,800		4.35		
	Sept.		.81					3900	
				- 3,046,800		914,044,200			
	Oct.	.21			616,512,600		14.25		
	Nov.	.36							
	Dec.	.34						11800	
1894				2,915,500			6.50		
	Jan.	.01		26,300	1,257,922,600				
	Feb.		.13	341,500	1,263,701,100	102,435,900	6.50	8100	
	Mar.	.45			1,161,265,200		7.50		
	Apr.	1.42						25600	
	May	3.30							
				+ 13,579,300					2,042,932,700
	June		.31		2,100,000,000		0.00		
	July		.66						
	Aug		.56					6300	
	Sept		.02						
	Oct.		.17						
				4,491,400		1,347,427,200			
	Nov.	.58		1,523,400	752,572,800		12.50	14600	
	Dec.		.39	1,024,400	1,087,721,900	307,308,000	8.50	5700	
					780,413,900		12.00		

TABLE VIII. cont'd.
1907 - 1910 incl.

YEAR	MONTH	Cu. Ft. per Sec. per Sq. Mile Surplus	Cu. Ft. per Sec. per Sq. Mile Def.	Cu Ft per Sq. Mi. Added to or Drawn from Upper Reservoir	Cu. Ft. in Storage Upper Reservoir	Deficiency for 300 Sq Miles	Upper Reservoir Total Lost Head	Total Flow H.P.	Surplus Above Storage in Upper Reservoir 220 Sq. Miles
1907	JAN.		.36		1,447,255,500		4.75		
	FEB.		.24					6500	
	MAR		.53						
	/			2968000		890403900			
	APR.	4.32		11,346,700	556,851,600		15.50	48700	953128800
	MAY		.39	1,024,400	2,100,000,000	307308000	0.0	5800	
	JUNE	.53		1,392,100	1,792,692,000		2.50	14300	
	JULY		.53		2,098,948,900		0.0		
	AUG.		.44					4800	
				2,547,800		764328000			
	SEP.	1.04		2,731,600	1,334,620,900		6.00	19100	
	OCT.		.03		1,935,577,500		1.00		
	NOV.		.14					7000	
	DEC.		.64						
				2,127,500		638,255,700			
1908	JAN.		.23	604,100	1,297,321,400	181,232,100	6.25	7000	
	FEB.	.57			1,116,089,300		8.0	12600	
	MAR	.15			1,445,429,300		5.0	72600	
	APR.	3.36			1,532,029,300		4.0	40800	[illegible]
	MAY	.67			2,100,000,000		6.0	13800	
	JUNE	.26						13800	
				13,159,100					1,911,089,500
	JULY		.36		2,100,000,000		0.0		
	AUG.		.73					4300	
				2,862,900		858885,000			
	SEP.	.25		656,600	1,241,115,000		6.75	11700	
	OCT.		.56		1,385,575,400		5.50		
	NOV.		.34					4600	
	DEC.		.51						
				3,703,500		1,111,035,600			
1909	JAN		.61	1,602,200	274,539,806	480,661,800	23.00	4600	
	FEB	.15		394,000	-206,122,000		27.00	10200	
	MAR		.29	761,700	-119,445,500	228,510,300	27.00	6300	
	APR.	3.74		9,823,400	-347,955,800		27.00	42900	
	MAY		.16		1,813,181,600		2.00		
	JUNE		.40						
	JULY		0.00						
	AUG.		.66					6500	
	SEP.		.39						
	OCT.		.27						
				4,937,900		1,481,379,900			
	NOV.	.42		1,103,200	331,801,700		20.50	13100	
	DEC.		.08	210,100	574,494,900	63,037,500	15.25	7500	
1910	JAN.		.26	682,900	511,457,400	204,871,200	16.25	7500	
	FEB.	.20		525,300	306,586,200		21.75	10800	
	MAR.		.93	2,442,700	422,154,400	732,809,100	18.50	640	
	APR.	4.44			-310,654,700		27.00	48900	
	MAY	.37						12900	
				12,633,700					368,763,900
	JUNE.		.71		2,100,000,000		0.0		
	JULY.		.46						
	AUG.		.15					5500	
	SEP.		.37						
				4,438,900		1,331,667,000			
	OCT.	.47			768,333,000		12.25		
	NOV.	.19						12300	
				1,733,500					
	DEC.		.01	26,300	1,149,708,500	7,879,800	7.50	9200	
					1,141,828,700		7.75		

TABLE VIII cont'd.
1903 - 1906 incl.

YEAR.	MONTH	Cu. Ft. per Sec per Sq. Mile Surplus	Cu. Ft. per Sec per Sq. Mile Def.	Cu. Ft. per Sq. M. Added to or Drawn from Upper Reservoir	Cu. Ft. in Storage Upper Reservoir	Deficiency for 300 Sq. Miles	Upper Reservoir Total Lost Head	Upper Reservoir Total Flow H.P.	Surplus Above Storage in Upper Reservoir 220 Sq. Miles
1903	JAN.		.51		864,606,600	401,850,000	10.75	4700	
	FEB.		.47		462,757,000	370,350,000	17.00	4700	
	MAR.		.15		92,407,000	118200000	26.50	7500	
				2,968,000	- 25,793,000	890402700	27.00		
	APR.	4.03			- 43,796,100		27.00		
	MAY	1.81						35800	
				15339,100					230800000
	JUNE		.22	577800	2,100000000	173352300	0.00	7400	
	JULY	.49		1,287,000	1926647700		1.00	14100	1097[illegible]9900
	AUG.		.45	1,181,900	2,100,000000	354584400	0.00	5200	
	SEP.	.05		131,300	1,745415600		2.50	14100	
	OCT.		.05	131,300	1774307800	39398400	2.50	8900	
	NOV.	.60		1,575,900	1,734909400		2.50	15000	
	DEC.		.34	893,000	2,081,015500	267909600	0.00	6500	
1904	JAN.		.16		1,813,705,900		2.00		
	FEB.		.46					6500	
				1,628,500		488,539,200			
	MAR.	.27			1,325,166,700		6.00		
	APR.	.24							
	MAY	1.96						15500	
	JUNE	.13							
				6,829,000					727,557,500
	JULY		.34		2,100,000,000		0.00		
	AUG.		.23					7500	
	SEP.		.05						
				1,628,500		488,540,100			
	OCT.	.48		1,260700	1,611,459,900		3.50	13900	
	NOV.		.39		1,888823800		1.50		
	DEC.		.37					5800	
				1,996,200		598856700			
1905	JAN.		.36		1,289,967,100		6.50		
	FEB.		.72					5800	
	MAR.		.08						
				3,046,800		914,042,700			
	APR.	.71			375,924,400		19.50		
	MAY	.93						15100	
	JUNE	.30							
				5,095,500					
	JULY		.56		1,496,941,000		4.50		
	AUG.		.50						
	SEP.		.06						
	OCT.		.10					7000	
	NOV.		.13						
	DEC.		.16						
				3939,100 ~~[illegible]~~		1,181,732,100			
1906	JAN.	.73		1,917,400	315,208,900		21.25	15700	
	FEB.		.35	919,300	737,034,000	275789400	12.50	6000	
	MAR.	.16			461,245,600		17.50		
	APR.	.50							
	MAY	.38						13400	
	JUNE	.81							
				4,859,100					
	JULY		.62		1,530,256,600		4.25		
	AUG.		.18					5600	
				2,101,300		630375600	10.25		
	SEP.	.14			899,881,000				
	OCT.	.53							
	NOV.	.40						12700	
				2,810,400					
	DEC.		.09	236,390	1,518,172,500	70917000	4.25	6500	
					1,447,255,500		4.75		

TABLE VIII cont'd.
1895 - 1898 Incl.

YEAR	MONTH	Cu.Ft. per Sec. per Sq. Mile Surplus	Cu.Ft. per Sec. per Sq. Mile Def.	Cu.Ft. per Sq. Mi. Added to or Drawn from Upper Reservoir	Cu.Ft. in Storage Upper Reservoir	Deficiency for 300 Sq. Miles	Upper Reservoir Total Lost Head	Total Flow H.P.	Surplus Above Storage in Upper Reservoir 220 Sq. Miles
1895	JAN	.88		2311400	780413900		12.00	17400	
	FEB		43		1,288,916,600		6.50		
	MAR		54					4800	
				2547800		764328000			
	APR.	1.02			524588600		16.00		
	MAY	1.61							
	JUNE	.53						18900	
				8299900					250572800
	JULY		76		2,100,000,000		0.00		
	AUG.		.57					3100	
				3493300		1047997200			
	SEP	27			1052002800		8.75		
	OCT.	.05						10800	
				840500					
	NOV.		.02		1,236,912,100		6.75		
	DEC.		.19					7400	
				551600		165473100			
1896	JAN		25		1,071,439,000		8.50	[illegible]	
	FEB		.24					7400	
	MAR		.36						
				2232600		669772200			
	APR.	3.36			401666800		18.75		
	MAY	.33						26200	
				9692000					433913400
	JUNE		.17		2,100,000,000		0.00		
	JULY		67						
	AUG.		51					5000	
	SEP.		52						
				4937900		1,481,381,400			
	OCT.	.74			618618600		14.50		
	NOV.	1.23						18400	
				5174300					
	DEC.		.63	1654700	1756968300	496421100	2.50	3500	
1897	JAN	.10		262700	1,260547200		6.75	10300	
	FEB		30	788000	1,318,331,500	236391000	6.25	6600	
	MAR	51			1,081,940,500		8.75		
	APR.	1.88							
	MAY	.03						15800	
	JUNE	.33							
				7,223,000					571,010,000
	JULY		34		2,100,000,000		0.00		
	AUG.		.28					6600	
	SEP.		.29						
				2390200		717050400			
	OCT.	.11		288900	1382949600		5.50	10400	
	NOV.		.58		1,446,512,400		4.75		
	DEC.		.52					5200	
				2915500		874644600			
1898	JAN.		.26	682900	571,867800	204871200	15.25	5200	
	FEB.	.68		1786100	366996600		19.80	15300	
	MAR.		.19	499000	758830900	149713800	12.25	7500	
	APR	1.40			609,117,100		14.25		
	MAY	.69						16900	
	JUN.	.40							
				6540100					
	JULY	~~44~~	44		2,047,948,100		0.00		
	AUG.		.71					4400	
	SEP.		.47						
				4255000		1,276,507,500			
	OCT.	41		1,076,900	771,440,600		12.25	13000	
	NOV.		.38		1008355500		9.25		
	DEC.		.59					5200	
				2547800		764329800			
					244025700		24.00		

TABLE VIII contd.
1899 - 1902 incl.

YEAR	MONTH	Cu.Ft. per Sec. per Sq. Mile Surplus	Def.	Cu.Ft. per Sq. Mi. Added to or Drawn from Upper Reservoir	Cu.Ft. in Storage Upper Reservoir	Deficiency for 300 Sq. Miles	Upper Reservoir Total Lost Head	Total Flow H.P.	Surplus Above Storage in Upper Reservoir 220 Sq. Miles
1899	JAN		.40		244,025,700		24.00		
	FEB		.77					5200	
	MAR		.03						
				3,151,900		945,560,100			
	APR.	2.63			-701,534,400		27.00		
	MAY	1.54						23800	
	JUNE	.70							
				12,791,300					12,559,500
	JULY		.38	998,100	2,100,000,000	299,428,500	0.00	5800	
	AUG	.09			1,800,571,500		2.00		
	SEP	.40							
	OCT.	.43						12400	
				2,416,400					232,185,400
	NOV.		.81	2,127,500	2,100,000,000	638,254,800	0.00	1800	
	DEC.	.19		499,000	1,461,745,200		4.75	11200	
1900	JAN.		.27	709,200	1,571,535,300	212,750,700	3.75	6900	
	FEB.	.09		236,400	1,358,784,600		5.75	10300	
	MAR.		.38	998,100	1,410,790,400	299,428,500	5.25	5800	
	APR.	3.14		8,247,400	1,111,361,900		8.00	38800	825,794,700
	MAY		.23		2,100,000,000		0.00	7500	
	JUNE		.18						
				1,076,900		323,066,400			
	JULY	.01		26,300	1,776,933,600		2.50	9500	
	AUG.		.75	1,969,900	1,782,712,100	590,975,400	2.34	2300	
	SEP.	1.37		3,598,400	1,191,736,700		7.25	22300	
	OCT.		.45		1,983,382,300		0.50		
	NOV.		.44					5800	
	DEC.		.51						
				3,677,200		1,103,153,100			
1901	JAN.		.24		880,229,200		10.75		
	FEB.		.64						
	MAR.		.05					5800	
				2,442,700		732,811,200			
	APR.	.59			147,418,000		26.30		
	MAY	1.60							
	JUNE	.41						15600	
	JULY	.31							
				7,643,300					
	AUG.		.41	1,076,900	1,828,942,500	323,065,800	1.75	5600	
	SEP.	.59			1,505,876,700		4.50		
	OCT.	.29							
	NOV.	.32						12900	
				3,151,900					99,288,800
	DEC.		.45	1,181,948	2,100,000,000	354,584,400	0.00	4600	
1902	JAN.		.36		1,745,415,600		2.50		
	FEB.		.47						
	MAR.		.77					4600	
				4,202,500		1,260,747,600			
	APR.	3.67			484,668,000		17.00		
	MAY	.15						21100	
	JUNE	.08							
				10,243,600					638,259,600
	JULY		.53		2,100,000,000		0.00		
	AUG.		.45						
	SEP.		.56					5400	
	OCT.		.19						
				4,543,900		1,363,183,500			
	NOV.	.17			736,814,500		12.50		
	DEC.	.02						10000	
				499,000					
					864,606,600		10.75		