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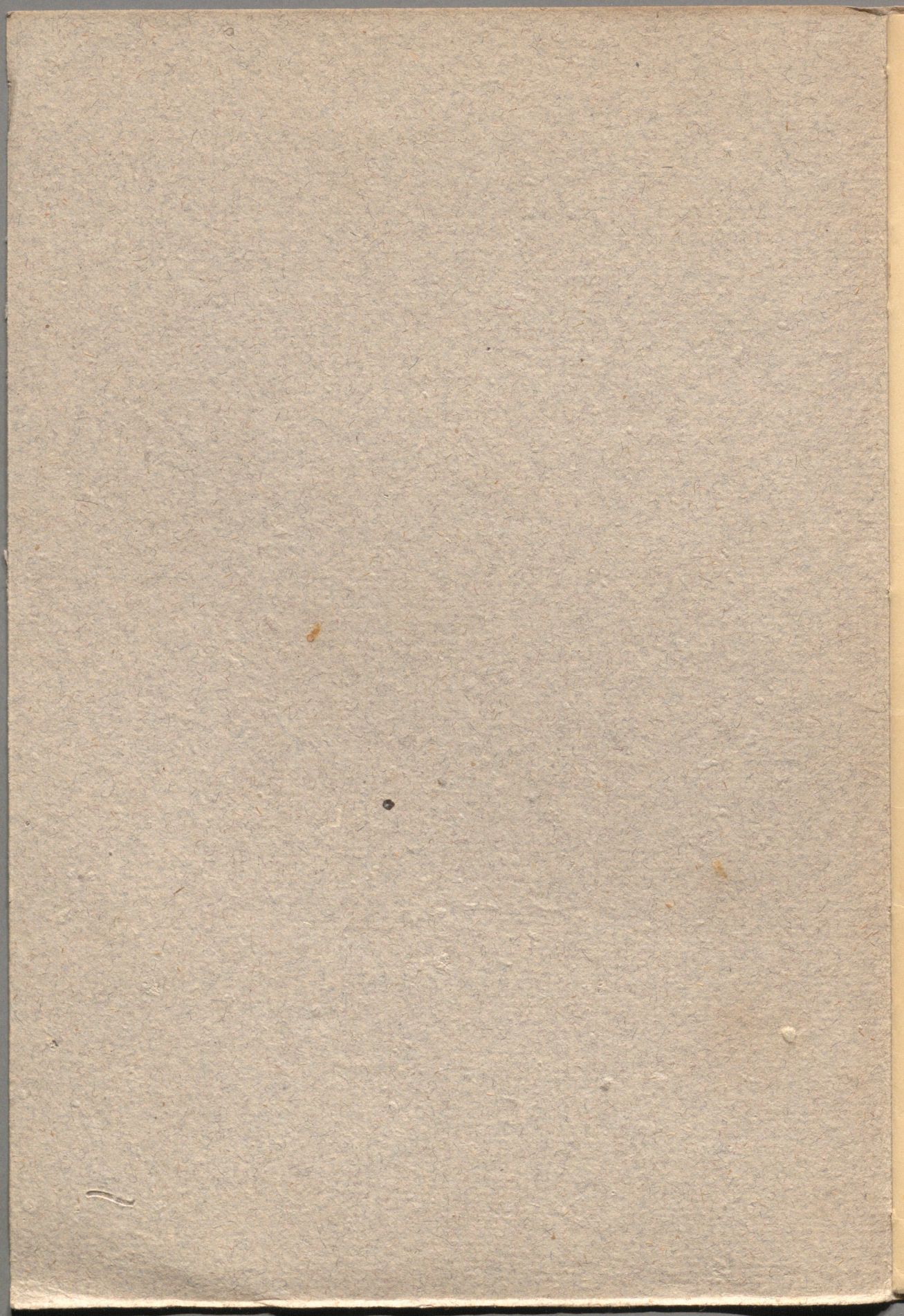
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WATERFALLS OF SWEDEN

BY

F. V. HANSEN



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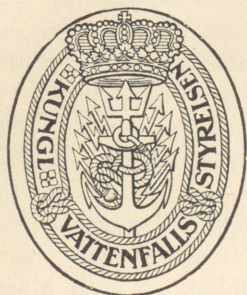
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KONIGL. FATH. VERMÄSSNINGSBUREAU

WATERFALLS OF
SWEDEN

R. W. HANSEN



Waterfalls of Sweden.

Sweden is, with regard to the supply of water power, one of the countries in Europe which Nature has most favoured. It is true that reliable data as to the measure of Sweden's water-power are still lacking, but a rough estimate has given the result of 10 million horse-power, available during from six to nine months of the year. Another estimate has led to a final figure of $6\frac{3}{4}$ million turbine horse-power, available during nine months of the year. Full certainty in this respect can obviously not be gained except by a thorough registration based on detailed investigations. This work has in fact been started in the shape of the "*Register of Waterfalls*" (*vattenfallsförteckning*), which, in conformity with the resolution of the Riksdag of 1910, is being drawn up by the Board of Waterfalls and by the Hydrographic Bureau, the first pages of which issued from the press at the beginning of the year 1913. This work, however, will take many years. An approximate estimate of the measure of the water-power in Sweden, based on certain assumptions, has recently been made by M. Serrander, Lieutenant in the Royal Engineering Corps and will be found as an appendix to part V of "*Finansstatistiska Utredningar, utgivna genom Kungl. Finansdepartementet*" (Financial and Statistical Investigations published by the Royal Finance Department), published in 1912 and prepared under the direction of I. Flodström. The exact title of the said part V is "Sveriges nationalförmögenhet omkring år 1908 och dess utveckling sedan mitten av 1880-talet" (The National Wealth of Sweden about the year 1908 and its Development since the middle of the eighties). In this work the water-power of Sweden is estimated at 6.2 million turbine horse-power, which can be utilized for about 9 months in the year.

For the purpose of comparison with these figures, it may be mentioned that Norway, from where also there are no exact data forthcoming, is stated to possess about $7\frac{1}{2}$ million turbine horse-power available during nine months in the year, and that Finland has 2.6 millions at average water level. Austria is said to possess 6.1 millions, France 5.9, and Italy 5.6 millions. Next come Switzerland with 1.5, Germany with 1.4, and Great Britain with 1 million; all in turbine horse-power, in round numbers and available during nine months of the year.

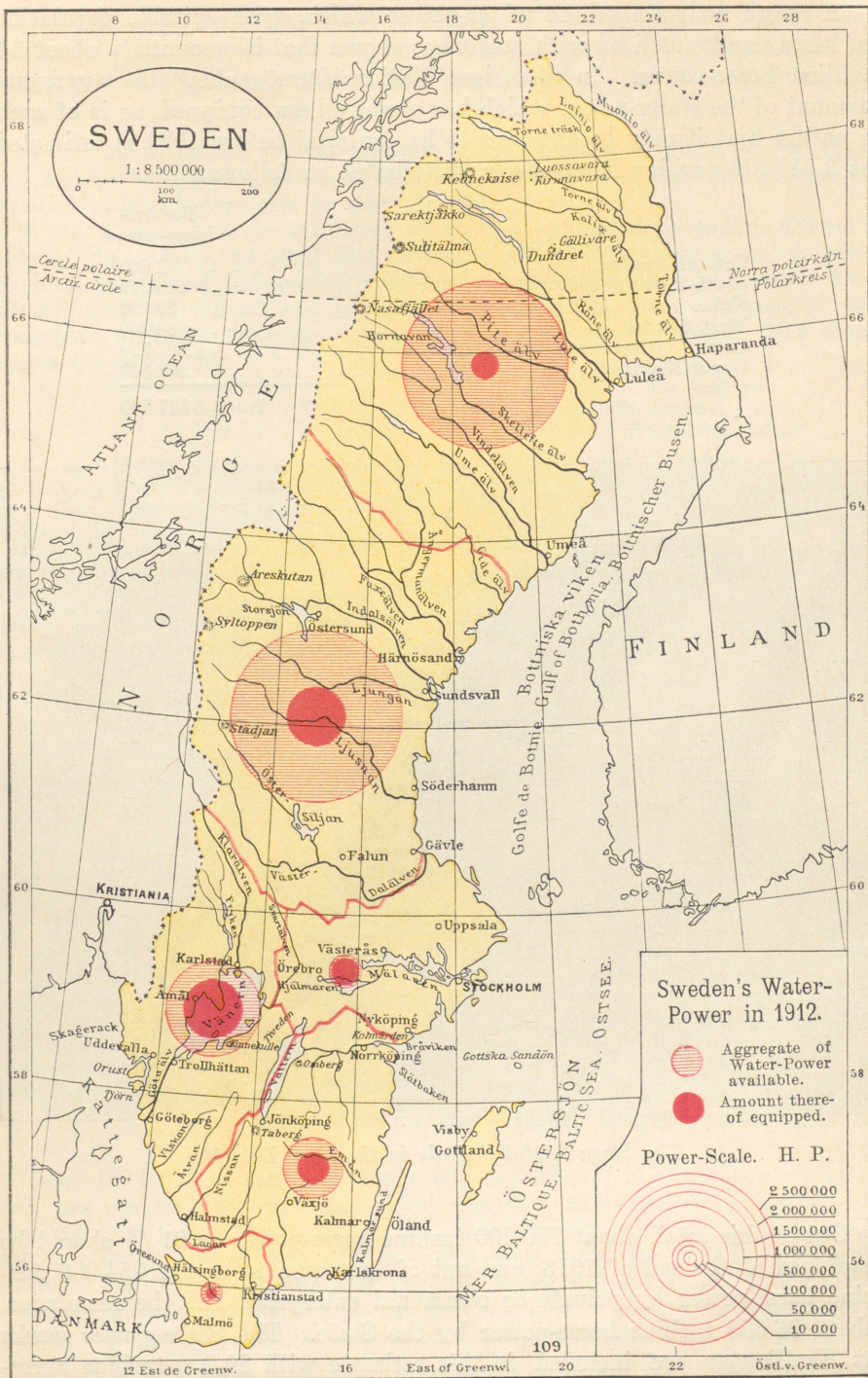
If Sweden has thus a very considerable supply of water-power, that power, however, has not as yet possessed a very high value. Most of it is to be found in the interior of the country, where the population is sparse, communications but little developed, and the prospects for industrial enterprise as a rule not very great.

On the other hand, *the abundance of lakes* in Sweden constitutes an extremely favourable factor in the rational utilization of water-power. For not only does the accumulating and regulating action of the lakes render the natural flow much less fluctuating than in other countries not so well supplied with lakes, but this action of the lakes can as a rule be still further utilized at moderate expense by the erection of regulating dams at the outlets of the lakes. The out-of-the way situation of the waterfalls, moreover, is not a matter of so much consequence as heretofore, when the utilization of the water-power was restricted in consequence of the impossibility or the difficulty of *transmitting energy over long distances from the source of power*. Especially the discoveries of recent years have produced a revolution in this respect, since it has been proved that electric power transmissions can work at tensions hardly dreamt of a few years ago. What a solution of the storage battery problem would signify for Sweden will at once be realized. In this connection it may be pointed out that several of the modern electro-chemical branches of industry are not very dependent on their locality and can often utilize even that part of the water-power which is only available during certain parts of the year.

The *Distribution of Waterfalls*. How the waterfalls are distributed over Sweden will be seen from the following figures, taken from the work cited above, "Sveriges nationalförmögenhet":

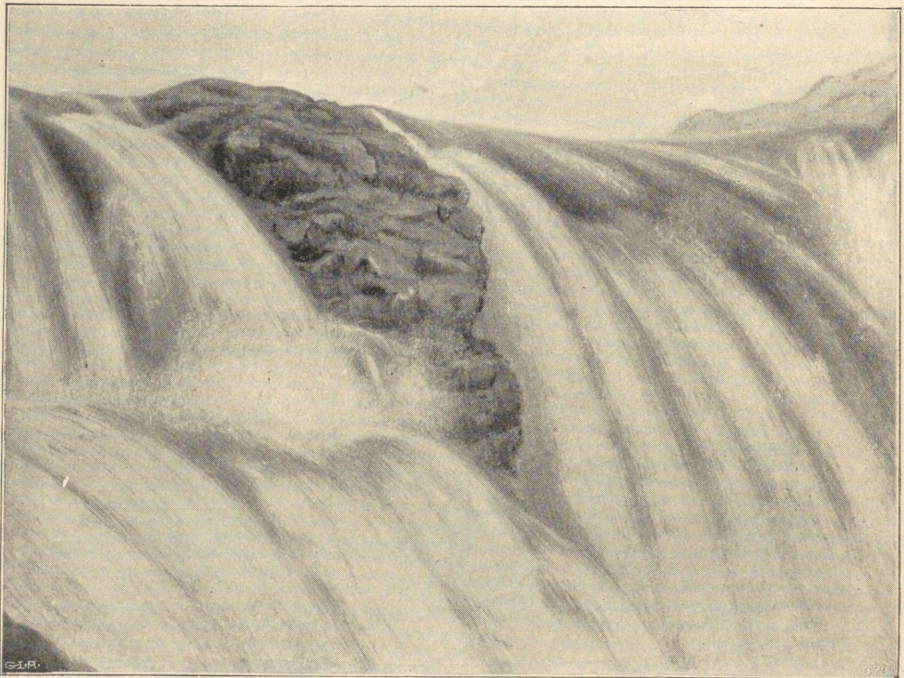
	Turbine horse-power.		
	State	Private	Total
Central Sweden	6 610	80 390	87 000
South-East Sweden	28 150	278 850	307 000
Skåne	380	36 620	37 000
West Sweden	258 240	545 760	804 000
Lower Norrland and Dalarne	100 620	2 459 380	2 560 000
Upper Norrland	646 330	1 763 670	2 410 000
Total	1 040 330	5 164 670	6 205 000

The water-power owned by the State thus forms 16.7 % of the total. Among State waterfalls have been included those entered in the register issued by the Royal Committee on Waterfalls of 1903, with the modifications necessitated by purchases subsequently made and by other circumstances. On the other hand, for obvious reasons, consideration has not been paid to the changes of proprietary rights which may result from the legal actions instituted in recent years by the State, with the object of establishing the State ownership of a large number of waterfalls which have hitherto been regarded as the private property of the riparian owners.



A rough estimate of the water-power which, with suitable regulation of lakes, can be utilized with profit has shown that it amounts to about 3·8 million horse-power. In "Sveriges Nationalförmögenhet" the aggregate amount of the water-power which has already been equipped, or is of such a nature that it may be expected to be equipped before 1959 is estimated at 3 511 540 turbine horse-power, distributed as follows:

	Turbine- horse-power
Central Sweden	83 600
South-East Sweden	280 270
Skåne	27 120
West Sweden	680 000
Lower Norrland and Dalarne	1 537 710
Upper Norrland	902 840
	Total 3 511 540



The Stora Sjöfallet Falls in the river Lule älv.

Out of this total, about 750 000 turbine horse-power or 21 % should be equipped at the end of 1913, and out of that amount again, 654 000 turbine horse-power by private or communal enterprise, and the remainder, about 96 000 turbine horse-power by the State. The State power works at Trollhättan are included in this estimate with 80 000 turbine horse-power.

If we include the works now in process of construction at Porjus and Älvkarleby and the works being constructed by the City of Stockholm at Untra, the corresponding figures will be: 870 000 — 25 % — 692 000 — 178 000.

In the above figures are not included a great number of plants of less than 100 turbine horse-power, which, if included, might increase the total amount of installed turbine horse-power by some 50 000.

If we observe how the utilization of water power has developed in different parts of the country, we shall find obvious proofs of the influence that the geographical position of the sources of power has exerted on their utilization. The relation between utilized and available water-power (the latter according to assumptions made in "Sveriges Nationalförmögenhet") at the end of 1912 then figures out as follows:

	At the end of 1913	Do., incl. of Trollhättan, Porjus, Älvkarleby, Untra ¹
Central Sweden	74.0 %	74.0 %
South-East Sweden	29.0 »	29.0 »
Skåne	13.5 »	13.5 »
West Sweden	40.0 »	40.0 »
Lower Norrland and Dalarne	9.5 »	12.5 »
Upper Norrland	1.0 »	2.7 »

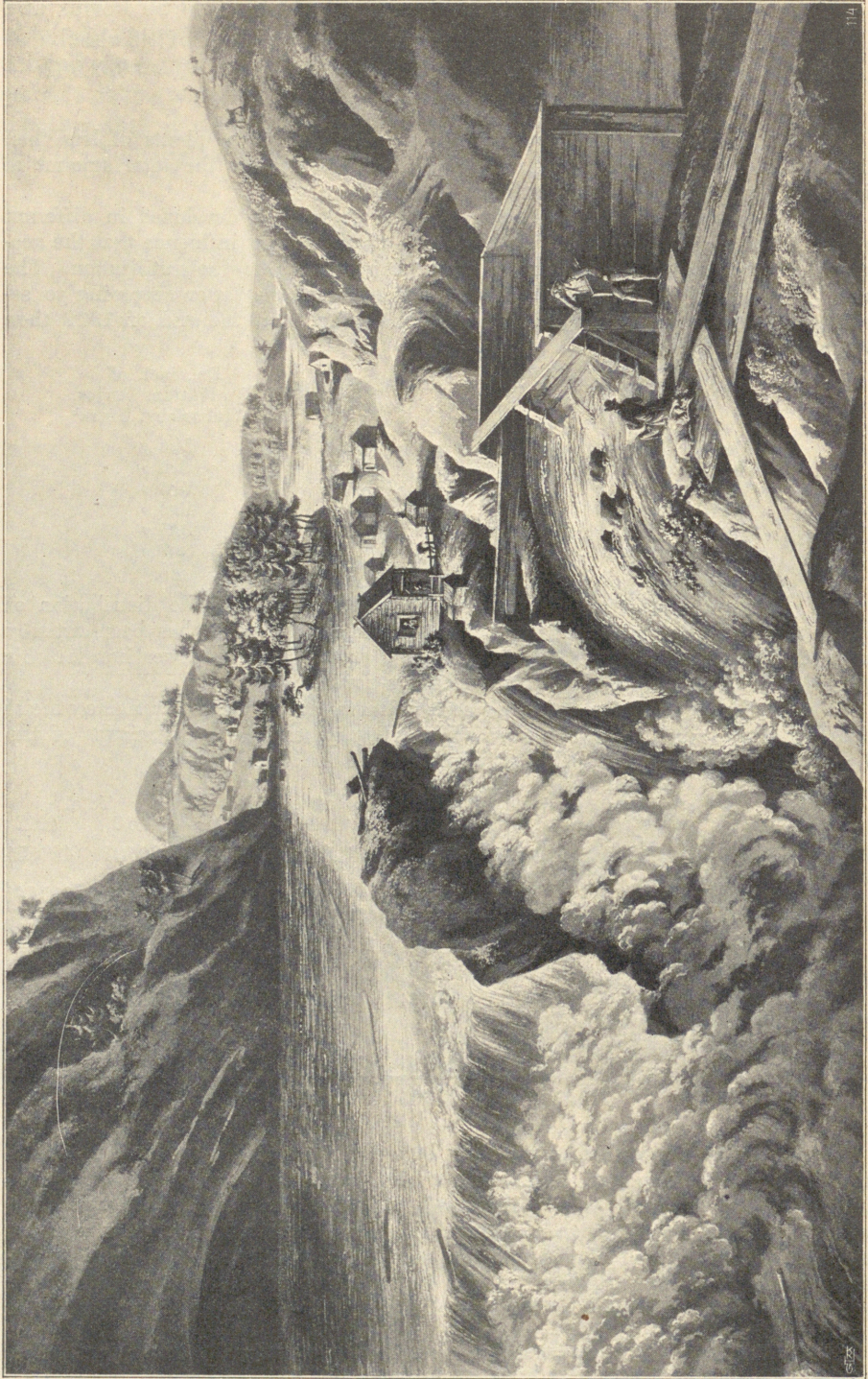
The accompanying map should furnish a clear idea of the distribution of water-power in Sweden, and also of that portion of it which has been actually utilized. The total supply of economically available water-power has for this purpose been assumed to be 6 200 000 horse-power.

It may also be of interest in this connection to give the latest available official data as to *power consumption for industrial purposes*. In the statistics of the Board of Trade for 1910 and 1912 we find the following figures:

	Mines		Factories		Total	
	1910	1912	1910	1912	1910	1912
Total power for direct running	68 422	78 280	417 873	410 571	486 295	488 851
Total power for running electric generators	31 173	33 222	393 911	579 519	425 084	612 741
Total	99 595	111 502	811 784	990 090	911 379	1 101 592
Amonunt generated by water-power for direct running	46 421	48 741	207 001	200 635	253 422	249 376
Amonunt generated by water-power for running electric generators	20 005	19 194	272 236	429 137	292 241	448 331
Total	66 426	67 935	479 237	629 772	545 663	697 707

These figures show that respectively 60% and 63% of the total power consumed was by water-power. They show also that, while during the year 1910 about 46 % of the total water-power used, was still consumed by direct shafting without electric transmission of power, this same figure for 1912 has declined to 36%. There is no doubt that the near future will see a still more remarkable change in this respect, as by far the greater part of the water-power recently equipped or now in process of equipment — the latter amounting to

¹ The Älvkarleby and Untra plants are here (according to assumptions made in "Sveriges nationalförmögenhet") reckoned as belonging to Lower Norrland and Dalarne.



Alter copperplate by J. F. MARTIN.

The Toppö Fall at Trollhättan about 1800.

about 100 000 turbine horse-power — will apparently be transformed into electric energy for transmission over shorter or longer distances.

One may classify the water-power plants equipped at the end of 1913 as follows:

Size of equipment in turbine HP	Number of plants	Total number of turbine HP
50 000 or more	1	80 000
25 000—50 000	2	68 000
10 000—25 000	6	109 000
5 000—10 000	18	116 000
1 000—5 000	126	245 000
200—1 000	296	132 000
	Total 449	750 000

The utilization of the water-power for different purposes is given approximately in the following table:

	Number of turbine HP	%
Iron-industry	215 000	29
Paper and pulp industries	240 000	32
Textile industry	40 000	5
Electro-chemical industry	90 000	12
Power-distribution, ¹ and various	165 000	22
	Total 750 000	100

The value of Swedish Water-Power. It would seem to be a very delicate matter to estimate aright the *value* represented by Swedish water-power. However, in "Sveriges Nationalförmögenhet" an attempt has been made. In this preliminary estimate the basis for calculation has been partly the prices actually paid on the sale of certain waterfalls, partly statements as to the profit made by certain water-power enterprises which may be assumed to have come into normal working order. The results yielded by this estimate are a capital value for the north of Sweden of, on an average, 75 kronor, and for the south of Sweden of, on an average, 90 kronor per turbine horse-power for the waterfalls which in 1908 had been equipped or were in process of equipment. Further, the estimate has been extended to the corresponding value of the waterfalls which it may be assumed will be equipped in the course of the next fifty years, distributed in different groups, and this value has been reduced to the year 1908 at 6% interest for private enterprises and 4½% for State enterprises.

The outcome of this preliminary computation is that Sweden's water-power "fit to be equipped" may be assumed to represent in 1908 a total value of 138.6 million kronor, out of which 21% fall to State enterprises, and 79% to private enterprises.

This figure is surprisingly low. But, in the first place, the rate at which the utilization of water-power is assumed to take place during the term of 50 years in question seems to have been rather cautiously estimated, since the basis of calculation has been that 3 million horse-power would be equipped during this period of fifty years, that is, on an average, 60 000 horse-power per annum, or about the same amount of power as was added in each of the years 1912 and 1913. However, as far as can be judged at present, the immediate prospects for Sweden's water-power lie in its appropriation to electro-chemical and electro-thermic industries, and those industries require very great amounts of power. Thus for instance, at Svaelfos and Rjukan in Norway, no less than

¹ The larger industrial subscribers for energy from the electric generating stations are not included, as they have been included under their respective groups.

290 000 horse-power are consumed almost entirely for a single industrial establishment of this kind, and the 18 000 horse-power output of the recently built Ljunga Works is taken by a single lime-nitrogen factory. Nor has consideration been paid to what the development of electro-technics can and must achieve half a century onwards.

The direct valuation is not of so much consequence. The main importance in estimating the value of water-power must be laid not on the direct earnings but in a very special degree on the *indirect profit*. For the increased use of water-power signifies increased independence of foreign fuel, increased industrial progress, and increased economic strength, and increased self-reliance. And from this point of view the water-power of Sweden constitutes a very material portion of her national wealth.

In Sweden, with her dearth of coal, water-power has been used for centuries: at first for the small, but very numerous mills, saws, and hammers, afterwards for big industrial plants, for iron works and for mines, textile and cellulose industry. Even before electric transmission of power had proved to be a practicable possibility, which was in the nineties, the energy of the waterfalls was transmitted over considerable distances. We need only remind the reader of Polhem's famous rod-and crank transmissions (*stånggångar*), which are still in use in some places, as for instance Grängesberg. The technical success of electric power-transmission opened up new possibilities for the use of water-power, and these possibilities

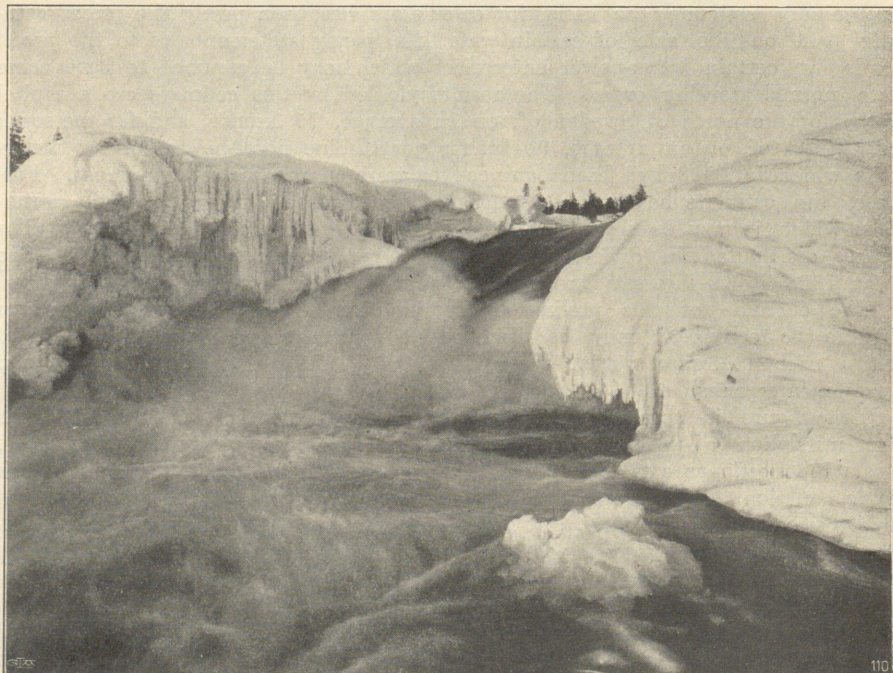
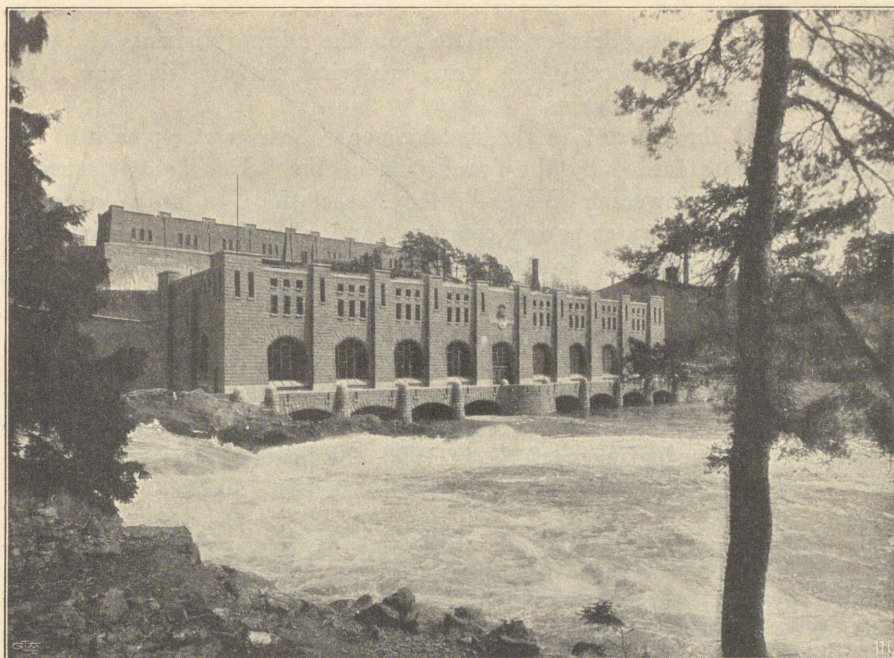


Photo. L. WESTFELT, Porjus.

The Porjus Falls.



The Trollhättan Power Station.

were soon seized upon by far-sighted men in Sweden. The first water-power works, whose mission it was to transmit electric energy over greater or smaller areas and vend it to different consumers, so-called överlandscentraler (over lands central stations), were constructed by private enterprise. Those that were first in the field were The Builders of Hissmoforsen and Skråmforsen, further Yngered's Kraftaktiebolag, Hemsjö Kraftaktiebolag, Gullspångs Kraftaktiebolag, and Sydsvenska Kraftaktiebolaget.¹ Later on the State herself appeared on the scene and built the big power works at Trollhättan, the first section of which was completed in 1910, those at Porjus, and those at Älvkarleby, the former of which is to be finished and in working order in 1914, and the latter in 1915.

A considerable amount of energy is now disposed of for electro-chemical and electro-metallurgical purposes. Electric furnaces are thus working for different purposes:

For pig iron at Domnarvet, Hagfors and Trollhättan, for zinc at Trollhättan, for ferrosilicium and ferromanganese at the same place, as well as at Vargön and Gullspång, for chlorates at Månsbo and Alby, for carbide and cyanamide at Alby and Ljunga-works.

(See, further, sections on iron-manufacturing and other industries.)

For several years plans have been rafted for the electrification of the

¹ *Kraftaktiebolag* = Power Company. *Fors* = Falls. *Syd-svenska* = South Swedish.

State railway system. An important section of it, "Kiruna—Riksgränsen", carrying the large iron-ore traffic from the mining districts of Lapp-land will be run electrically this year, receiving energy from the State water-power station at Porjus.

Evidence of the interest in the development of the water-power of the country is also afforded by the foundation of the "Svenska vattenkraft-föreningen" (the Swedish Water-Power Association), a union of communal and private water-power concerns, and of private persons. The aim of the Association is to promote the utilization of Sweden's water-power by the spread of technical, economic, and legal information in the matter.

Symptomatic of the interest evinced by the State in the exploitation of water power is the creation of two new Government offices: **Hydrografiska Byrån**, the Hydrographical Bureau, in 1908, and **Vattenfallsstyrelsen**, the Board of Waterfalls, in 1909, the latter replacing the Trollhätte Canal and Water-Works Board, established in 1905.

The Hydrographical Bureau. It devolves on the Hydrographical Bureau to collect and work up all such data as may be necessary for an exhaustive and practical working knowledge of the hydrography of the Swedish fresh water lakes, rivers, etc, and to make observations and measurings for that purpose. The Bureau shall make its results accessible to the public by the publication of year-books, monographies on rivers, treatises, and essays. Above all, the Bureau is responsible for the editing and publication of the above-mentioned "Register of Waterfalls". This Register contains information on the flow of water in the rivers at different water-levels, heights of falls, geological data, and so forth, and should prove to be of great benefit for the development of the water-power industry. The Hydrographical Bureau also, insofar as its time allows, undertakes, investigations and surveys for communes and private persons for which certain fees are charged.

The Board of Waterfalls. The principal duties of the Board of Waterfalls, in regard to water-power in Sweden, are to adopt measures calculated to encourage its exploitation. For this purpose it constructs and manages the State's own power works and is entitled to utilize the waterfalls which are not equipped for the State, by leasing them to private persons or concerns. The planning and advancement of lake-regulation works also falls within the work of the Board. The Board is composed of a Chairman and Director, "Vattenfallsdirektören", who devotes all his time to the business of the Board, and four members who take an active part only in the treatment of more important matters. These members act in the capacity of expert advisers in various practical spheres, such as technique, commerce, industry, and law, and place the Board in intimate communication with the needs of practical life. In the treatment of special questions, such as those coming within the sphere of activity of the Board of Agriculture, the Crown Lands Board and the Railway Board, representatives of those bodies shall take part in the deliberations, but not in decisions. However, in case one of these delegates records an opinion at variance with the decision of the Board, that decision shall be submitted for the consideration of Government. Thus, it is intended that the Board of Waterfalls shall as far as possible see matters from the practical point of view, moreover, in virtue of the regulations of December 31, 1908, and of other resolutions, the Board is armed with powers as to the conclusion of contracts, etc.

which are less restricted than is the case generally within the State Administration.

It is under the superintendence of the Board of Waterfalls that the big State power stations have been erected or are in process of erection, notably those at Trotthättan for 80 000, those at Porjus for 50 000, and those at Älvkarleby for 45 000 turbine horse-power.

Especially in the case of the two first-named stations there will be great possibilities of further development, when the two sources of water-supply, Lake Vänern and the Luleälv, have been regulated, while the Älvkarleby station has been planned with a view to the regulation of Lake Siljan. The Board have such regulation-problems under consideration.

The leasing of State waterfalls, on the other hand, has proceeded rather languidly; partly because the State waterfalls are, as a rule, less suitably located than a number of those in private hands; partly because it is more difficult to procure credit, as mortgages on the property cannot be given as security. An attempt has been made to remove the last-named difficulty by a Resolution of the Riksdag of 1911, which amplifies the leasing conditions with regard to certain Crown waterfalls as laid down by the Resolution of the Riksdag of 1910; the added clauses introduce a new legal right, "*waterfall rights*" (*vattenfallsrätten*), which is similar to ground rights and allows of the conveyance being mortgaged. In devising these forms for the conveyance of the State waterfalls, the chief object kept in view was to mitigate the effects of the legal actions alluded to above, and that in such a wise that the proprietor of a waterfall in dispute should be enabled to conclude a conditional contract for the conveyance of the waterfall at a small rental and for a long period of time, which contract was only to come into force in case the Crown was awarded the proprietary rights. In this manner the present proprietor would be secured in the right to use the water-power for a considerable time to come, even if the finding of the court went against him. However, in actual practice these "*waterfall rights*" have not hitherto been made use of, the reason apparently being the novelty of the legal form, and the fact that lenders prefer to take an ordinary mortgage on real property.

One way of encouraging the conveyance of waterfalls with such rights would be, obviously, that the State itself should step forward as a lender. In fact, in the Riksdag of 1912 a bill was introduced to investigate the question of the *creation of a loan fund* for users of State waterfalls with waterfall rights, and the Riksdag passed the bill. In the following year, a supplementary bill was brought forward proposing that the investigation thus called for might likewise be extended to a loan fund for the users of waterfalls in private hands.

In conclusion, as a step in the waterfall policy of the State, it may be pointed out that the Crown has purchased several large waterfalls from private persons and concerns, partly in order to hold them in reserve for a future electrification of the State railways, partly in order to complete its property in certain river areas. Among the latter purchases are to be

noted those in virtue of which the State has acquired practically sole ownership of all the water-power in the River Göta älv between Lake Vänern and the Sea.

But the State can and should encourage the utilization of water-power even in other ways than those just indicated, namely by framing its *legislation* in such a spirit that the least possible obstacles shall be encountered and the greatest possible promptitude effected in the legal treatment of questions relating to the construction of power works and dams. In this respect much remains to be done.

True, Sweden posses a Water Act of such a recent date as the Royal Ordinance "concerning the landowner's right to the water on his land", of December 30, 1880, supplemented by Royal Proclamation of October 20, 1899 "concerning regulations to be observed by those desirous of acquiring a license from the King to build on a Crown water-course (*kungsådra*)¹". But the regulations of that act do not by any means satisfy the legitimate demands of the modern water-power industry. Not only is the legal and administrative procedure far too cumbrous and slow and leaves too little scope for expert knowledge, but the law actually places obstacles in the way of a rational utilization of water power, and in many cases renders it impossible. In the last respect it is specially to be noted that the law does not concede the right of expropriating ground for the actual power station, and that it does not provide facilities for a water-power user to effectuate the regulation of a lake or the damming up of water, supposing damage thereby to be caused to a building, waterfall, or the like, belonging to another, no matter how great the public benefit accruing from the enterprise. On the other hand, by the Electric Installations Act of June 27, 1902, the water power industry has been tolerably well provided for, with reference to the right to carry over another ground the electric power lines often imperatively necessary for modern power works.

A revision of the Water Act was set on foot in 1906, when the Government appointed a committee to draft proposals for new legislation with regard to a landowner's rights over the water in his ground. That committee, jointly with another committee of same year appointed to draw up proposals for amendments in the law relating to the drainage of ground, brought forward on the December 17, 1910, a scheme for an amended Water Act. This extensive scheme, which contains many new and remarkable suggestions, is at present being considered by the authorities. Furthermore, of late a scheme for a new floating law, as well as a new bill providing for greater security with regard to agreements for delivery of electrical energy, etc., have been worked out. It is to be hoped that the Riksdag will soon see its way to decide this very important question, and that the new law will be framed in such a spirit that it will not impede, but facili-

¹ The purpose and definition of the term "Kungsådra" ("Kings artery") will be found in the second section of paragraph 7 of the said Royal Proclamation. Cf. also the article on Fishing.

tate and encourage the speedy and scientific exploitation of Sweden's water power.

The formal stumbling-blocks once removed, there is no doubt whatever that the people of Sweden will contrive, within a not too far distant future, to turn to account the national wealth which lies in her magnificent supplies of water-power, and which, utilized in the right way, should give her an extremely favourable position in the competition going on between the nations.

