CHAPTER 5

Legal and Constitutional Aspects

The Problem of the South Saskatchewan River Development Project. A memorandum by John J. Connolly, Q.C.

THE purpose of this memorandum is to set out the scope of the Commission's responsibilities having regard particularly to legal questions that may arise. The South Saskatchewan River is an interprovincial river and in its upper reaches some of its tributaries cross the international boundary. It is proposed to discuss the existing condition of the law which touches problems connected with its development. It is also proposed to consider problems with reference to legislative competence.

The three Prairie Provinces acquired the right to control the bulk of their natural resources by agreements with the Dominion Government in December 1929 and March 1930. These agreements were confirmed by legislation of the Parliament of Canada in 1930, and the Canadian legislation was ratified later by the Imperial Parliament. It is important to understand the effect of these agreements.

Before these three provinces were constituted certain lands, including, of course, waters and water powers in that area, were owned by the Crown in right of Canada. When the Prairie Provinces were established, these lands, water powers and so forth were not handed over to the administration of the provincial authority but were retained by the federal Crown. In summary, the effect of the agreements in 1930 was merely to transfer the lands and properties still held by the Crown and administered by the federal authority, to the administration of the provincial authorities. The 1930 federal legislation conferred no new sources of legislative jurisdiction upon the legislatures of any of the provinces concerned. All that the 1930 legislation accomplished was to transfer to the several provincial authorities concerned, additional Crown assets to be administered by them, subject to the provisions of the several agreements, and administration by the federal authority came to an end.

It is to be borne in mind that the federal government had granted lands prior to 1930 to private individuals. These grants, of course, were not disturbed by the 1930 agreements. As regards the ownership of lands and water powers in the Prairie Provinces, the position prior to 1930 was that they were owned, to some extent, by private individuals who had acquired the lands under grants from the Crown, the C.P.R., the Hudson's Bay Company or other private individuals, and there were lands and water powers owned by the Crown and administered by the federal authority. The lands owned by

the Crown in right of the provinces and administered by them were comparatively insignificant. After 1930 certain lands and water powers continued to be held by private individuals, but virtually all the remaining lands owned by the Crown came under the administration of the several provincial governments. The 1930 legislation, therefore, gave to the governments of each of the three Prairie Provinces new assets to administer but it did not give them any new sources of legislative powers.

There may be a misunderstanding arising out of the use of the term "natural resources". It appears to be considered that the agreements of 1930 transferred to the provinces all the natural resources in the provinces as a matter of ownership and all legislative power in relation to them. In fact, as already indicated, they transferred only certain assets and did not change the distribution of legislative power. The confusion arises in the use of the term "natural resources" in two ways. In a political sense, the Natural Resources Agreements of 1930 transferred from the federal Crown to the provincial Crown the right or power of administration over all natural resources in the said provinces then still unalienated by the federal Crown. The effect of the legislation was to give the Prairie Provinces the same power with respect to the natural resources within their boundaries as the original provinces to Confederation acquired by virtue of Section 109 of the B.N.A. Act. In the political sense, therefore, the provinces acquired their natural resources in 1930. In a legal sense, however, as already indicated, it was merely a transfer of the administrative rights over the remaining assets without affecting legislative power.

Following the depression and the drought of the early Thirties, the federal government decided that some special action was required for the relief of people in the Prairie Provinces. Accordingly in 1935 the federal Parliament enacted the Prairie Farm Rehabilitation Act as Chapter 23 of that year. The Act was amended in 1937 by Chapter 14 of the Statutes of that year. The purpose of the legislation is best expressed by the following excerpts from the Act as amended.

"4. The Advisory Committees shall consider and advise the Minister as to the best methods to be adopted to secure the rehabilitation of the drought and soil drifting areas in the Provinces of Manitoba, Saskatchewan and Alberta, and to develop and promote within these areas systems of farm practice, tree culture, water supply, land utilization and land settlement that will afford greater economic security, and to make such representations thereon to the Minister as the Advisory Committees may deem expedient.

10. The Minister may,

(*a*) subject to section four of this Act, undertake the development, construction, promotion, operation and maintenance of any project or scheme under or by virtue of this Act, or enter into agreements with any province, municipality or person with respect thereto.

(*b*) pay all necessary administrative expenses incurred under the Act

and all necessary travelling and living expenses incurred by officials or employees in performance of their duty.

(2) No single project or scheme under this section involving an expenditure in excess of ten thousand dollars in any fiscal year shall be undertaken without the consent of the Governor in Council.

11. The Minister may, for the purposes of this Act, and with the approval of the Governor in Council, purchase, lease or otherwise acquire, or sell, lease or otherwise dispose of, any lands or premises which may be required for or included in any project or scheme, upon such terms or conditions as he may deem desirable."

Under date of June 19, 1947, P.C. 2298 was passed by the federal government. This order in council laid down certain principles to govern the policy of the federal government in connection with the construction of large water development projects by the P.F.R.A. organization if the same were approved by the Governor in Council. The pertinent parts of P.C. 2298 are as follows:

"1. Before Canada undertakes the construction and operation of a project it will be necessary for the province in which the project is located to enter into an agreement:

(1) to transfer any water rights required for the construction and operation of such project;

(2) to make available to Canada any Provincial Crown lands which may be required for dam site, reservoir or canal right-of-way purposes in connection with such project.

(3) under which the water will be utilized by the Province or some other authority or organization on the terms set out in such agreement.

2. Canada will operate any project constructed pursuant to this policy in such a way as to maintain so far as possible the minimum flow determined by the Prairie Provinces Water Board for the stream upon which the project is constructed;

3. Canada will make a legal survey of any lands necessary for the construction, operation and maintenance of the portion of any project to be constructed by Canada pursuant to this policy and will file a plan or plans of such survey in the appropriate Land Titles Office and in the Water Resources Office of the Province.

4. In the construction of an irrigation project hereunder Canada will undertake and assume responsibility for the construction of the main reservoirs and any connecting canals, and will be responsible for the maintenance and operation of such works; Canada will deliver to the Provinces such water as it is agreed the Province will utilize at such place and for such fee as may be agreed upon between Canada and the Province. If the Province does not desire to utilize all of such water Canada may enter into

arrangements with others for the delivery and use of any water not taken by the Province."

Many agreements have been concluded between the Dominion on the one hand, and each of the four Western Provinces on the other, to carry out recommendations made under the P.F.R.A. Some of these agreements were made prior to the passage of P.C. 2298. Some projects were very small. Others like the St. Mary River Irrigation project were very substantial undertakings. I think it proper to say that projects undertaken under the P.F.R.A. have all been special projects designed to afford relief and assistance in the light of circumstances existing at the time. It does not appear that any special attention was paid to the legal rights of riparian owners downstream to the location of the project in question. In any event, the projects proposed and developed, do not appear to have been part of an overall plan designed to be in the best interests of all the Prairie Provinces or of Canada as a whole. This is not to say that the projects planned and completed were not in the interests of the Prairie Provinces at large and of Canada. It is to say, however, that the approach to the various schemes of development under the P.F.R.A. was not made from this point of view as set out in the Order in Council establishing this Royal Commission and which must govern the recommendations which the Commission is to make.

At this point it is perhaps important to consider the Prairie Provinces Water Board. P.C. 2297 of June 19, 1947, is an Order in Council authorizing the Dominion Minister of Agriculture to execute an agreement with the Governments of Alberta, Saskatchewan and Manitoba to establish the Prairie Provinces Water Board. It will be convenient to outline here the recitals contained in that Order in Council.

"WHEREAS the construction of water development projects in the Provinces of Alberta, Saskatchewan and Manitoba involves the use of inter-provincial waters;

AND WHEREAS no provision has been made for determining the allocation of the said waters between the provinces;

AND WHEREAS it is desirable that the most beneficial use be made of the available water resources of the three Prairie Provinces;

AND WHEREAS it is considered desirable by agreement with the Governments of the Prairie Provinces to establish a Board for the purpose of allocating the said waters and making recommendations as to their beneficial use;"

The agreement which the Minister of Agriculture was authorized to complete under P.C. 2297 was dated July 28, 1948. The following are extracts from that agreement which bear upon the questions herein discussed.

"1. Manitoba, Saskatchewan and Alberta and Canada agree to establish and there is hereby established a Board to be known as the Prairie Provinces Water Board to consist of five members to be appointed as follows:

(a) two members to be appointed by the Governor General in Council, one on the recommendation of the Minister of Mines and Resources, and one, who

shall be Chairman of the Board, on the recommendation of the Minister of Agriculture;

(b) one member to be appointed by the Lieutenant Governor in Council of each of the Provinces of Manitoba, Saskatchewan and Alberta.

"2. *Functions*

The functions of the Board shall be to recommend the best use to be made of interprovincial waters in relation to associated resources in Manitoba, Saskatchewan and Alberta and to recommend the allocation of water as between each such province of streams flowing from one province into another province.

"3. *Composition of Board*

The members of the Board shall be chosen from those engaged in the administration of water resources or related duties for Manitoba, Saskatchewan, Alberta or Canada, as the case may be, and shall serve as members of the Board in addition to their other duties.

"4. *Duties of Board*

The duties of the Board shall be as follows:

(a) to collate and analyse the data now available relating to the water and associated resources of interprovincial streams with respect to their utilization for irrigation, drainage, storage, power, industrial, municipal, navigation and other purposes;

(b) to determine what other data are required from time to time in order to reach decisions on questions referred to it and to make recommendations to the appropriate governmental organizations concerned for the carrying out of such field surveys, power investigations, soil surveys, establishment of gauging stations, economic studies relating to drainage and flood control and all similar work which the Board considers necessary to supply information required for the proper performance of its duties;

(c) upon the request of any one of the three Provinces or the Dominion to recommend the allocation of the waters of any interprovincial stream among the respective Provinces;

(d) to report on any questions relating to specific projects for the utilization or control of common river or lake systems at the request of one or more of the Ministers or authorities charged with the administration of such river or lake systems.

"5. *Confirmation of Board's Recommendations*

A recommendation of the Board with respect to any matters referred to it under Subsections (*c*) and (*d*) of Section 4 hereof shall become effective when adopted by Orders in Council passed by Canada and by each of the Provinces affected thereby.

"9. *Reports*

The Board shall submit an annual progress report outlining work done and work contemplated in the agreed program to each of the responsible Ministers of the parties hereto and such other reports as may be required by any one of such Ministers.

"11. Each of the parties hereto agrees that it will not within the limits of its jurisdiction construct or permit the construction of any project that will interfere with the allocation

of waters resulting from a recommendation of the Board duly adopted pursuant to Section 5 hereof.

"12. Any water development project already constructed or to be constructed by any one of the parties hereto shall be so operated as to maintain as far as possible the allocation of water determined by the Board."

It is apparent that the functions of the Prairie Provinces Water Board are advisory. The members of the Board are public servants employed by the various interested governments. As a result of the terms of section 5 of the agreement, the proposals of the Board become effective only after each of the governments who are parties to the agreement implement the recommendations. Thus each government interested has a veto power under the agreement for every recommendation.

I understand that there has been some discussion before the Prairie Provinces Water Board on the merits of the South Saskatchewan River project as outlined in the report of the P.F.R.A. dated April 2, 1951. No decision has been reached.

It is now important in the light of this background to consider P.C. 4435, dated August 21, 1951, which is the federal Order in Council appointing this Commission. The terms of reference are as follows:

> ". . . to conduct an inquiry into the following matters, namely:
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> Whether the economic and social returns to the Canadian people on the investment in the proposed South Saskatchewan River Project (Central Saskatchewan Development) would be commensurate with the cost thereof;
>
> Whether the said project represents the most profitable and desirable use which can be made of the physical resources involved."

The following paragraph is of importance.

> "6. That the Commissioners be further authorized to include in their examination and to report upon all matters which the Commissioners may consider pertinent or relevant to the general scope of the inquiry."

These terms of reference are very broad. Under them, the Commission is charged with making a report to the Federal authorities on the "most profitable and desirable use" which can be made of the resources in question, in the interests not only of the people of the Prairie Provinces, but of the Canadian people as a whole. This work might have been done by the P.F.R.A. organization. It might have been done by the P.P.W.B.

The findings of the Commission do not commit the Federal Government to implement the report. It might be accepted, rejected or modified. Likewise, of course, the report would not commit any Province to any action.

If there is disagreement among the authorities of the various Provincial Governments concerned, as to their several rights to the consumptive use of the water of the South Saskatchewan River, that disagreement must not deter the Commission from making its report as P.C. 4435 demands. "The most profitable and desirable use which can be made of the resources involved" will take into account such factors as economics, costs, engineering, best land uses, hydro-electric power, alternative sources of power available, up and down river interests and the effect of varying these in the interests of the community as a whole, and the like. When this report is made the parties concerned would be in a position to consider its implementation.

The Commission, however, should be aware of the position in law.

In view of the fact that some of the tributaries of the South Saskatchewan River have their origin in the United States, there is an international aspect to the problem. Through the International Joint Commission the American authorities have claimed a certain quantity of the water in the resource as their own. The amount is relatively small. However, it should be pointed out to this Commission that all the water in the system is not available for use in Canada, and accordingly any allocation made in Canada should respect an allocation made by the International Joint Commission for consumption in the United States.

The allocation of water from the resource among the three Prairie Provinces raises legal questions and questions of jurisdiction. Expressions like "Provincial Rights", "The Rights of the Provinces to control their own natural resources", "The Rights of the Provinces to legislate in respect of 'Property and Civil Rights in the Province' " coupled with the 1930 Federal Legislation which returned to each of the three Prairie Provinces control over the great bulk of their natural resources, may engender the opinion that each of these provinces has certain vested rights in the resources in question which could forestall their development in the interests of the Prairies and of the country at large. To understand the position on this point it is important to know what the Provinces are before the law.

Provinces are not sovereign states, they are not legal persons. In one sense they are geographical areas defined by statute. In another sense the term "province" is applied to the governments established by statute for those areas, and having certain legislative, executive and administrative functions. Among their other powers these governments have authority to administer certain Crown property, and the right to administer this property has been conferred upon them by appropriate legislation. Other Crown property is administered by Federal authorities. For example, when the Crown in the right of the Province transfers land to the Crown in the right of Canada, there is no real conveyance of property since Her Majesty remains the owner in either case. What takes place is merely a change in administrative control.

It is elementary to say that the Crown is still the same person in Alberta, Saskatchewan and Manitoba. The properties owned by the Crown, however, in each of these Provinces are administered by different authorities. In some cases the authority is Provincial, in other cases the authority is Federal. For example, the Crown is the owner of the beds of navigable streams, also of the foreshore thereof. Such property of the Crown is administered by the provincial authorities. The Crown may be the owner of harbours which were in existence in 1867, of lands for post offices, and the like. Such Crown property, also owned by Her Majesty, is administered by Federal authorities. The Crown in the right of Canada or in the right of the Province can be and no doubt is, the owner of land bordering on interprovincial streams, i.e. a riparian owner.

All property is owned either by the Crown or by other legal persons. The fact that the

province as such is not the owner of Crown property administered by the province, but that it is owned by Her Majesty establishes certain legal premises and raises certain legal difficulties. For example there can be no rights between the provinces with reference to Crown property, because the owner in each case is Her Majesty, and she cannot have rights against Herself.

There is ample authority for the statement that the rules of common law apply to the Crown except as varied by Statute. It is equally clear that the rules of common law, except as varied by Statute, govern rights asserted by riparian owners other than the Crown to the consumptive use of water in streams.

The common law rules as to the rights of riparian owners are not complex. It has been settled that the right to the enjoyment of a natural stream of water on the surface, ex jure naturae, belongs to the proprietor of the adjoining lands, as a natural incident to the right to the soil itself, ... he has the right to have it come to him in its natural state, in flow, quantity and quality, and to go from him without obstruction; upon the same principle that he is entitled to the support of his neighbour's soil for his own in its natural state. These riparian owners rights are not founded on the ownership of the bed of the river but upon right of access to the water. No riparian proprietor has any property in the water itself except in that particular portion which he may choose to abstract from the stream to take into his possession, and that during the time of his possession only. Under certain circumstances, and provided no material injury is done, the water may be used and may be diverted for a time by the upper owner for the purpose of irrigation. The lower riparian owner is entitled to the accustomed flow of the water for the ordinary purpose for which he as a riparian owner can use the water. The Latin maxim covering the right to water is stated "sic utere tuo ut alienum non laedas".

This is a summary of the common law position. This is the position apart from Statute.

As between say Saskatchewan and Alberta, or as between Manitoba on the one part, and Alberta and Saskatchewan on the other, it can well be argued apart from Statute that the rights with reference to the use of the water are covered by the common law as aforesaid. In this background John Smith living in Manitoba could at common law succeed on an application for an injunction and on a claim for damages, if proved, arising out of a diversion for consumptive use by a riparian owner in Alberta who had diminished the natural flow of the South Saskatchewan River in front of his property. It might well be asked if the common law doctrine of riparian rights runs beyond the Provincial boundary. There would appear to be no authoritative decision on the precise point. Statutory law, however, can change the common law rules, and specifically, valid statutory law can change the common law rules to confer a right of diversion of water for consumptive use.

If a diversion for consumptive use in any of the three Prairie Provinces from the South Saskatchewan River is to be authorized, and the common law rule abrogated, the question arises as to what legislative body is competent to enact the required legislation. By

subsection 13 of Section 92 of the British North America Act a provincial legislature may make laws respecting "Property and Civil Rights in the Province." Thus Alberta may legislate to prevent an action by an Eastern Alberta riparian owner against a Western Alberta authority which would diminish riparian rights of the Eastern Albertan.

However, it is not competent for a provincial legislature to legislate with reference to property and civil rights "outside" the province. The Privy Council has held that the legislature of the Province could not legislate validly in derogation of a civil right outside the province. In other words, it can be argued that such legislation as above mentioned by the Province of Alberta would not be effective to deprive a Saskatchewan resident of his riparian rights against an Alberta authority which infringed them.

While it cannot be determined with any great certainty what legislative body, Federal or Provincial, is competent to enact suitable legislation to vary the common law, in certain circumstances the Federal government could assert jurisdiction.

For example, the Federal parliament might declare a project for the development of the resource in question to be a work "for the general Advantage of Canada or for the Advantage of two or more of the Provinces", under Section 92 (10) (*c*) of the B.N.A. Act. Such a declaration would give the Federal authority jurisdiction. In certain circumstances it might be possible for the Federal authority to claim jurisdiction under the general powers contained in Section 91 of the B.N.A. Act. This enables the Federal authority to make "laws for the Peace, Order, and Good Government of Canada, in relation to all Matters not coming within the Classes of Subjects by this Act assigned exclusively to the Legislatures of the Provinces." It is to be noted that this is not a matter assigned exclusively to the legislatures of the Provinces by the B.N.A. Act.

It should be pointed out also that the Federal Government in certain circumstances would have authority under Sections 56 and 90 of the B.N.A. Act to disallow legislation by one provincial authority if that legislation is in derogation of rights existing in another province.

At the hearings in Saskatchewan it was contended on behalf of the Government of that Province, that the doctrine of "equitable apportionment" which applies in certain jurisdictions in the United States, should be the doctrine to be applied to this interprovincial river. It was admitted, however, by Counsel for the Government of Saskatchewan that the doctrine in question is not the law in Canada. It was proposed that it should be the principle used and that this condition should be brought about through agreements with the various Governments concerned.

In addition I should point out that it was part of the agreements concluded between the Dominion and the four Western Provinces when the administration of their assets was handed over to the provincial authorities, that all contracts and leases for the alienation of resources made by the Dominion prior to the transfer should be honoured. This is a factor which should receive appropriate consideration.

It is obvious from the above that there is great uncertainty as to the legal position

and as to jurisdiction. Perhaps this is not unusual in a new country. There may be further complications arising from conditions of land tenure in the West e.g. the rights of the Hudson's Bay Company, of the Crown in the right of the Dominion, of the rights acquired by the C.P.R. and others. The position of the Federal authorities with reference to navigation rights is a further possible complicating factor. There may be others.

I therefore suggest that the Commission make its finding as required by P.C. 4435. Such findings should touch upon problems of economics, costs, engineering, irrigation, and other matters. I think it might be stated the Commission is advised that to carry out its recommendations may involve the solution of complex legal problems and problems of jurisdiction about which there is at present considerable uncertainty. It might be added that it is thought the scope of the Commission's terms of reference do not include the making of suggestions to solve these problems, but that if the Commission's findings are to be implemented, no doubt such legal and jurisdictional obstacles can be overcome. I think it should then be left to the authorities concerned to solve the legal and jurisdictional problems if they could agree on the report of the Commission as made or as they might agree to vary it.

Legal Aspects of the South Saskatchewan River Development Project. A memorandum by H. Carl Goldenberg, Q.C.

THE proposed development of the South Saskatchewan River for irrigation and power purposes in the Province of Saskatchewan invites consideration of the respective rights of the three Prairie Provinces in the waters of this interprovincial river. These rights are subject to such rights as the United States may have in the headwaters of the river and to the rights of Canada under the Navigable Waters Protection Act, which are not here considered.

The South Saskatchewan, with its headwaters in Montana and southern Alberta, flows into Saskatchewan where, north of Saskatoon, it joins with the North Saskatchewan to form the Saskatchewan River which flows into Lake Winnipeg, in Manitoba, and by the Nelson River empties into Hudson Bay. Works erected on the South Saskatchewan for irrigation or power purposes within the boundaries of one province may, therefore, affect the flow of water into another province.

Before 1930 control of the water resources of the Prairie Provinces vested in the Government of Canada and such waters were under a single administration. With the transfer of the natural resources to these provinces in 1930, the single control and administration was replaced by divided control in that Manitoba, Saskatchewan and Alberta acquired jurisdiction over the waters within their respective boundaries. Each of the provinces established a separate water administration office.

Having regard to the common interest of the three provinces in the waters of the river system and to avoid interprovincial disputes which might arise from water diversions in any one province, the formation of an interprovincial board to recommend the best uses of the water and its allocation was discussed shortly after the transfer of the resources to

the provinces, but a satisfactory agreement could not then be reached. Some years later Manitoba became concerned with the possible effects of large water diversions in Alberta upon lake levels and water power possibilities in the lower regions of the drainage basin and an agreement for the creation of an interprovincial board was reached in 1945. As this agreement failed to give recognition to participation by the Government of Canada in financing irrigation projects, the interprovincial board was in 1948 replaced by a Federal-Provincial board under the name of the Prairie Provinces Water Board.

The agreement of July 28, 1948, between the governments of Canada, Manitoba, Saskatchewan and Alberta, which provided for the establishment of the Prairie Provinces Water Board consisting of representatives of each of these governments, declared that:

> "The functions of the Board shall be to recommend the best use to be made of interprovincial waters in relation to associated resources in Manitoba, Saskatchewan and Alberta and to recommend the allocation of water as between each such province of streams flowing from one province into another province."

Among the duties of the Board are the following:

> "upon the request of any one of the three Provinces or the Dominion to recommend the allocation of the waters of any interprovincial stream among the respective Provinces;
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> "to report on any questions relating to specific projects for the utilization or control of common river or lake systems at the request of one or more of the Ministers or authorities charged with the administration of such river or lake systems."

A recommendation of the Board on any of the matters referred to it under the two foregoing sections of the agreement becomes effective when adopted by Orders in Council passed by Canada and by each of the provinces affected thereby.

A number of projects submitted for the recommendation of the Board affecting waters allocated by the governments of Canada and of the provinces prior to the formation of the Board have been approved and duly confirmed. When, however, an allocation of water for the South Saskatchewan project was requested by Saskatchewan in 1951, Alberta's representative presented an alternative project for consideration and supported by Manitoba's representative, submitted that it was the function of the Board not merely to allocate water having regard to the available supply, as submitted by Saskatchewan, but also to take into consideration the economics of the proposed projects having regard to the most beneficial use of the water. The resulting disagreement as to the functions of the Board has been referred to each of the governments for its consideration.

In its submission to the Royal Commission on the South Saskatchewan River Development the Government of Alberta has drawn attention to this interprovincial problem as it affects the proposed development. Manitoba, pointing out that its share of the Saskatchewan River is "the residue remaining after approved appropriations are made effective in other provinces", has also drawn attention to the possible adverse effec s of the proposed development upon its resources through a decline in the potential capacity of the power sites on the Dauphin and Nelson Rivers.

With the assertion by each of the provinces of its rights to the use of the surface waters of the river system, and a reference by the Government of Alberta to possible legal disputes similar to those which have arisen in connection with the use of interstate waters in the United States, it becomes necessary to consider the nature of the rights thus asserted. These rights, as such, do not appear to have been adjudicated by the Canadian courts but the corresponding rights of the States have given rise to considerable litigation in the United States. It may, therefore, be useful to examine the jurisprudence in cases arising from the diversion and use of waters in interstate streams.

The decisions of the Supreme Court of the United States have been based upon the principle of "equitable apportionment" of interstate waters. "On the basis of equality of rights, this doctrine fits the decision to the facts of the controversy, without adherence to any particular formula. The doctrine stems from the 1907 opinion in Kansas v. Colorado.[1] Kansas claimed the right to have the water of the Arkansas River flow into Kansas undiminished in quantity and unimpaired in quality. On the other hand, Colorado denied that it had in any substantial manner diminished the flow of the Arkansas River into Kansas. The Court found that, while Colorado had diminished the flow into Kansas by appropriation for irrigation purposes, the result had been reclamation of large areas in Colorado and that the ensuing diminution in flow had caused little if any detriment in Kansas".[2] Accordingly, the Court refused to enjoin Colorado, saying that:

> "We must consider the effects of what has been done upon the conditions in the respective States and so adjust the dispute upon the basis of equality of rights as to secure as far as possible to Colorado the benefits of irrigation without depriving Kansas of the like beneficial effects of a flowing stream."[3]

In delivering the opinion of the Court, Mr. Justice Brewer said that notice must be taken that the local law of Kansas governing water rights was the Common Law doctrine of riparian rights and, further, that it recognized the right of appropriating waters for irrigation subject to the protection of the equal rights of other riparian proprietors. The Court therefore held that:

> "As Kansas thus recognizes the right of appropriating the waters of a stream for the purposes of irrigation, subject to the condition of an equitable division between the riparian proprietors, she cannot complain if the same rule is administered between herself and a sister State."[4]

In the case of Wyoming v. Colorado (259 U.S. 419) the State of Wyoming sued the State of Colorado to prevent a proposed diversion in Colorado of the waters of the Laramie River, a non-navigable interstate stream, for purposes of irrigation. In both states the law governing water rights was not the Common Law doctrine of riparian rights but the statutory doctrine of "prior appropriation" under which priority of appropriation gives superiority of right. In

[1] 206 U.S. 46.
[2] Water Resources Law: Report of the President's Water Resources Policy Commission, Vol. 3, 1950, pp. 59-60.
[3] 206 U.S. 100 [4] 206 U.S. 104-105.

delivering the opinion of the Court, Mr. Justice Van Devanter said, at p. 466:

> "The contention of Colorado that she as a State rightfully may divert and use, as she may choose, the waters flowing within her boundaries in this interstate stream, regardless of any prejudice that this may work to others having rights in the stream below her boundary, can not be maintained. The river throughout its course in both States is but a single stream wherein each State has an interest which should be respected by the other."

And at p. 484:

> "The question here is not what one State should do for the other, but how each should exercise her relative rights in the waters of this interstate stream. Both are interested in the stream and both have great need for the water. Both subscribe to the doctrine of appropriation, and by that doctrine rights to water are measured by what is reasonably required and applied. Both States recognize that conservation within practicable limits is essential in order that needless waste may be prevented and the largest feasible use may be secured. This comports with the all-pervading spirit of the doctrine of appropriation and takes appropriate heed of the natural necessities out of which it arose. We think that doctrine lays on each of these States a duty to exercise her right reasonably and in a manner calculated to conserve the common supply."

The rule of equitable apportionment was followed in the case of New Jersey v. New York (283 U.S. 336). In delivering the opinion of the Court, Mr. Justice Holmes said, at p. 342:

> "A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it. New York has the physical power to cut off all the water within its jurisdiction. But clearly the exercise of such a power to the destruction of the interest of lower states could not be tolerated. And on the other hand equally little could New Jersey be permitted to require New York to give up its power altogether in order that the River might come down to it undiminished. Both States have real and substantial interests in the River that must be reconciled as best they may be. The different traditions and practices in different parts of the country may lead to varying results, but the effort always is to secure an equitable apportionment without quibbling over formulas."

In Hinderlider v. La Plata River and Cherry Creek Ditch Co. (304 U.S. 92) the Supreme Court again applied the principle of equitable apportionment. In this case the Court had to consider a compact between the States of Colorado and New Mexico providing for an equitable apportionment of interstate waters to secure the greatest beneficial use thereof. In delivering the opinion of the Court, Mr. Justice Brandeis spoke favourably of such interstate compacts, pointing out, at p. 105, that "resort to the judicial remedy is never essential to the adjustment of interstate controversies, unless the States are unable to agree upon the terms of a compact, or Congress refuses its consent."

In New York v. New Jersey (256 U.S. 96) the Court also suggested that interstate water disputes might be better solved by interstate compacts:

> "We cannot withhold the suggestion inspired by the consideration of this case, that the grave problem of sewage disposal presented by the large and growing populations living on the shores of New York Bay is one more likely to be wisely solved by cooperative study and by conference and mutual concession on the part of representatives of the States so vitally interested in it than by proceedings in any court however constituted."

In its decisions on the rights of States to divert and use waters in interstate streams, the United States Supreme Court has thus established that:

(a) The waters of a non-navigable stream rising in one State and flowing into an

adjoining State may not be disposed of by the upper State as it may choose regardless of any injury or prejudice to the lower State;

(b) Each State has an interest in the common stream which must be respected by the other and such interests must be reconciled as best they may be;

(c) Each State is entitled to an equitable apportionment of the waters of the common stream;

(d) Equitable apportionment does not necessarily imply an equal division of the water but is to be determined by the facts of the case and not by adherence to any particular formula;

(e) It is not unreasonable to enforce against a State its own local rule governing water rights, although in Connecticut v. Massachusetts (282 U.S. 660) the Court pointed out that "while the municipal law relating to like questions between individuals is to be taken into account, it is not to be deemed to have controlling weight" in suits between States.

The Supreme Court has also suggested resort to interstate compacts as a more satisfactory means of settling disputes arising from the use of waters in interstate streams.

In the absence of Canadian precedents, the rules laid down by the United States Supreme Court may usefully be considered, in so far as they may be applicable, in determining the rights of the three Prairie Provinces to use the surface waters of an interprovincial river.

[5] e.g., Groat v. City of Edmonton, 1928 S.C.R. 522.

The law governing water rights in the Provinces of Manitoba, Saskatchewan and Alberta is the Common Law doctrine of riparian rights.[5] In 1930 and 1931, following the transfer of the natural resources to the Prairie Provinces, each of these provinces enacted legislation on water rights, as follows:

Manitoba: The Water Rights Act (1940 Revised Statutes of Manitoba, cap. 230).

Saskatchewan: The Water Rights Act (1940 Revised Statutes of Saskatchewan, cap. 41).

Alberta: The Water Resources Act (1942 Revised Statutes of Alberta, cap. 65).

The basic rights of riparian proprietors are protected by each of these Acts. Section 6 (3) of the Manitoba Act reads as follows:

> "Nothing contained in this Act or the regulations shall interfere with or be understood as intended to interfere with the right of any person owning or occupying any land which adjoins any river, stream, lake or other body of water referred to in this section to use such quantity of its waters as he may require for domestic or industrial purposes on the land but he shall not be entitled to the right of impounding or diverting nor shall he impound or divert from any such body of water by any dam, pipe, flume, channel, ditch, or other means used in the impounding or diversion of water any water he may require unless authority therefor has been obtained under the provisions of this Act."

Section 7 (2) of the Saskatchewan Act and section 5 (3) of the Alberta Act contain the same provision with the exception that the protection of the riparian right is restricted to the use of water for domestic purposes.

"Domestic purposes" is defined in the same way in each of the Acts as including household and sanitary purposes and all purposes connected with the watering of stock and the working of agricultural machinery.

"Industrial purposes" is also defined in each of the Acts in substantially the same way as meaning the operation of railways and factories.

Appropriation of water rights otherwise than under the provisions of the statutes is prohibited by each of the Acts. Section 8 of the Alberta Act and section 11 of the Saskatchewan Act are the same as section 8 of the Manitoba Act, which reads as follows:

> "Unless acquired by a grant made in pursuance of some agreement or undertaking existing at the time of the coming into force of this Act, no right to the permanent diversion or to the exclusive use of the water in any river, stream, watercourse, lake, creek, spring, ravine, canyon, lagoon, swamp, marsh, or other body of water shall be acquired by any riparian owner or any other person by length of use or otherwise than as it may be acquired or conferred under the provisions of this Act or the regulations."

Each of the Acts protects existing licensed rights to water granted prior to the coming into force of the Act and provides for the acquisition of rights in water which is the property of the Crown for various purposes and for the construction of necessary works therefor, upon application made under the Act. Such applications have precedence in the following order:

Manitoba: (1) domestic purposes; (2) municipal purposes; (3) industrial purposes; (4) irrigation purposes; (5) other purposes.

Saskatchewan: (1) domestic purposes; (2) municipal purposes; (3) industrial purposes; (4) irrigation purposes; (5) other like purposes; (6) mineral water purposes; (7) mineral recovery purposes.

Alberta: (1) domestic purposes; (2) municipal purposes; (3) industrial purposes; (4) irrigation purposes; (5) water power; (6) other purposes.

While in Manitoba and in Alberta applications for water rights have precedence according to the respective dates of their filing, an amendment to the Saskatchewan Act in 1951 provides that precedence of application does not entitle the applicant to a prior right to water.

Section 11 of the Manitoba Act further protects the rights of riparian proprietors, as follows:

> "No application for any purpose shall be granted where the proposed use of the water would deprive any person owning lands adjoining the river, stream, lake or other source of supply of whatever water he requires for domestic and industrial purposes."

Section 15 of the Saskatchewan Act contains a similar provision but only with respect to water required for domestic purposes.

The Common Law rights of the riparian proprietor were set out in the leading case of Miner v. Gilmour (12 Moore's P.C. Reports 131) as follows:

> "By the general law applicable to running streams, every riparian proprietor has a right to what may be called the ordinary use of the water flowing past his land; for instance, to the reasonable use of the water for his domestic purposes and for his cattle, and this without regard to the effect which such use may have, in case of a deficiency, upon proprietors lower down the stream. But, further, he has a right to the use of it for any purpose, or what may be deemed the extra-

> ordinary use of it, provided that he does not thereby interfere with the rights of other proprietors, either above or below him. Subject to this condition, he may dam up the stream for the purpose of a mill, or divert the water for the purpose of irrigation. But, he has no right to interrupt the regular flow of the stream, if he thereby interferes with the lawful use of the water by other proprietors, and inflicts upon them a sensible injury."

The legislation governing water rights in each of the Prairie Provinces asserts and preserves the Common Law right of the riparian proprietor to the ordinary use of the water flowing past his land, that is, its use for domestic purposes and for his cattle (and in Manitoba for industrial purposes) but restricts such "extraordinary use" of it as the right to impound or divert water, unless he has received authority therefor under provincial statutes.

If a rule, such as that laid down by the United States Supreme Court,[6] that it is not unreasonable to enforce against a State its own local law governing water rights, is applied, it is submitted that the respective legal rights of the Provinces of Manitoba, Saskatchewan and Alberta in the surface waters of interprovincial rivers are the Common Law rights of riparian proprietors, in so far as these provinces are riparian proprietors.

> "The law relating to the rights of riparian proprietors," said Lord Macnaghten, in Young & Co. v. Bankier Distillery Co.,[7] "is well settled. A riparian proprietor is entitled to have the water of the stream, on the banks of which his property lies, flow down as it has been accustomed to flow down to his property, subject to the ordinary use of the flowing water by upper proprietors, and to such further use, if any, on their part in connection with their property as may be reasonable under the circumstances. Every riparian proprietor is thus entitled to the water of his stream, in its natural flow, without sensible diminution or increase and without sensible alteration in its character or quality. Any invasion of this right causing actual damage or calculated to form a claim which may ripen into an adverse right entitles the party injured to the intervention of the Court."[8]

If the rule, as set out above, is applicable, it is submitted that each of the Provinces of Manitoba, Saskatchewan and Alberta has legal rights to the reasonable use of the surface waters of the Saskatchewan River system, which rights must be respected; that none of these provinces may dispose of such waters within its boundaries to the injury or prejudice of one or both of the other provinces; and, that a major diversion of such waters in one province which has the effect of diminishing the quantity or affecting the quality of the flow into another province may injuriously affect the rights of the latter province.

It does not follow that every diversion of water would be wrongful. The right to flowing water is a right incident to property in the land entitling each proprietor to a just and reasonable use of such water as it passes through his land. It has been pointed out that:

> "What is such a just and reasonable use, may often be a difficult question, depending on various circumstances. To take a quantity of water from a large running stream for agriculture or manufacturing purposes, would cause no sensible or practicable diminution of the benefit, to the prejudice of a lower proprietor; whereas, taking the same quantity from a small running brook passing through many farms, would be of great and manifest injury to those below, who need it for domestic supply or watering cattle; and therefore it would be an unreasonable use of the water,

[6] Kansas v. Colorado, 206 U.S. 46
[7] 1893 A.C. 691, 698.
[8] Per Lord Sumner in Stollmeyer v. Trinidad Petroleum Co., 1918 A.C. 485, 491.

and an action would lie in the latter case and not in the former. It is therefore, to a considerable extent a question of degree . . ."[9]

The natural rights of a riparian proprietor being rights incidental to the ownership of property are not primarily rights of user.[10]

"All persons having lands on the margin of a flowing stream, have, by nature, certain rights to use the water of that stream, whether they exercise those rights or not; and they may begin to exercise them when they will."[11]

It follows that under the strict riparian doctrine, the owner of riparian rights who makes no use of the water may, nevertheless, enjoin interference with those rights by other proprietors. In the leading English case of Mason v. Hill,[12] Lord Denman said:

"The proposition of the defendant is that the right to flowing water is *publici juris*, and that the first person who can get possession of the stream and apply it to a useful purpose, has a good title to it against all the world, *including* the proprietor of the land below, who has no right of action against him unless such proprietor has already applied the stream to some useful purpose also, with which the diversion interferes; and in default of his having done so, may altogether deprive him of the benefit of the water. The position that the first occupant of running water for a beneficial purpose has a good title to it, is perfectly true in this sense, that neither the owner of the land below can pen back the water, nor the owner of the land above divert it to his prejudice . . . But it is a very different question whether he can take away from the owner of the land below, one of its natural advantages, which is capable of being applied to profitable purposes, and generally increases the fertility of the soil even when unapplied, and deprive him of it altogether by anticipating him in its application to a useful purpose. If this be so, a considerable part of the value of an estate, which, in manufacturing districts particularly, is much enhanced by the existence of an unappropriated stream of water with a fall, within its limits, might at any time be taken away . . ."

The rule that the first occupant of running water who appropriates such water for a useful purpose does not by the mere fact of such prior appropriation acquire a right to a permanent diversion or to the exclusive use of the water, is embodied in the water rights legislation of each of the Prairie Provinces.[13] The fact that a lower proprietor may have made no beneficial use of his riparian rights does not affect the case. If the rule is applied to the provinces, it follows, for example, that if Manitoba has not as yet applied to a useful purpose its rights in the surface waters of the lower reaches of the Saskatchewan River system, it has not thereby forfeited such rights in favour of one or both of the other provinces which may have made beneficial use of the waters within their boundaries.

While it has been submitted that if rules such as those applied by the United States Supreme Court in controversies between States arising from the use of interstate waters, are applied to similar controversies between the three Prairie Provinces, each province, to the extent that it is a riparian proprietor, may assert riparian rights in interprovincial waters, it is essential to note that in asserting such rights a State is constitutionally in a different position from a

[9] Shaw, C. J., in Elliott v. Fitchburg Railroad Co., 10 Cush. 191, 193, 196.

[10] Cotton, L. J., in Kensit v. Great Eastern Railway Co., 27 CL.D. 122.

[11] Sampson v. Hoddinot, (1857) 1 C.B. (N.S.) 590.

[12] (1833) 5 B. & A.1.

[13] Water Rights Act (Man.) sec. 8; Water Rights Act (Sask.) sec. 11; Water Resources Act (Alta.) sec. 8.

Canadian province. The United States Constitution (Art. III, sec. 2) extends the judicial power of the United States "to Controversies between two or more States" and confers original jurisdiction upon the Supreme Court in all cases in which a State is a party. There is no corresponding provision in the British North America Act for the adjudication of controversies between provinces. Parliament has, therefore, provided for such adjudication but with due regard to the constitutional position of the provinces. The Exchequer Court Act (1927 R.S.C., cap. 34, sec. 31) provides as follows:

> "When the legislature of any province of Canada has passed an Act agreeing that the Exchequer Court shall have jurisdiction in cases of controversies,
>
> (a) between the Dominion of Canada and such province;
>
> (b) between such province and any other province or provinces which have passed a like Act;
>
> the Exchequer Court shall have jurisdiction to determine such controversies.
>
> 2. An appeal shall lie in such cases from the Exchequer Court to the Supreme Court."

In the case of the Province of Ontario v. the Dominion of Canada (42 S.C.R. at pp. 118-119), Mr. Justice Duff, of the Supreme Court, said, with respect to this provision:

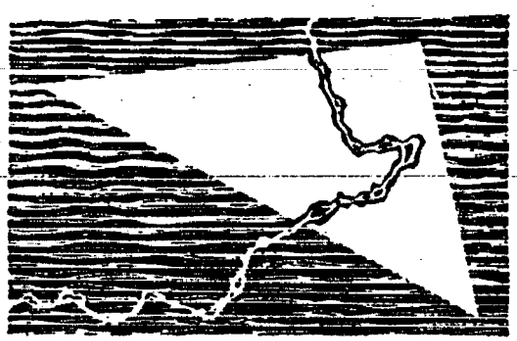
> "The 'Exchequer Court Act' confers upon that court jurisdiction to decide a controversy such as this. It says nothing about the rule to be applied in reaching a decision; but it is not to be supposed that (acting as a court) that court is to proceed only upon such views as the judge of the court may have concerning what (in the circumstances presented to him) it would be fair and just and proper that one or the other party to the controversy should do. I think that in providing for the determination of controversies the Act speaks of controversies about rights; pre-supposing some rule or principle according to which such rights can be ascertained; which rule or principle could, it should seem, be no other than the appropriate rule or principle of law. I think we should not presume that the Exchequer Court has been authorized to make a rule of law for the purpose of determining such a dispute; or to apply to such a controversy a rule or principle prevailing in one locality when, according to accepted principles, it should be determined upon the law of another locality. This view of the functions of the court under the Act does not so circumscribe those functions as greatly to restrict the beneficial operation of the statute. Whatever the right of the Dominion in such a case as the present it is difficult to see how the province could (apart from the statute and without its consent given in the particular case) be brought before any court to answer the Dominion's claim. The statute referred to and the correlative statute of the province once for all give a legal sanction to such proceedings, and provide a tribunal (where none existed) by which, at the instance of either of them, their reciprocal rights and obligations touching any dispute may be ascertained and authoritatively declared."

Accordingly, a controversy between two or more provinces affecting rights, such as rights in interprovincial waters, may be adjudicated on the basis of the appropriate principles of law, but only with the consent of each of the provinces concerned expressed by an Act of its legislature. Without its consent so expressed, a province cannot be brought before the courts to answer the claim of another province. Failing adjudication by the courts, the provinces must have recourse to an interprovincial agreement for the protection of their respective rights. It has been pointed out that with respect to the rights of States in interstate waters, the Supreme Court of the United States has expressed a preference for the apportionment of such waters by interstate compacts rather than by judicial determination.

In the light of the foregoing, it is important to note the 1948 agreement setting up

the Prairie Provinces Water Board, already referred to, under which the three provinces, recognizing their respective rights in interprovincial waters, departed from a strict application of the doctrine of riparian rights by accepting the principle of allocation of such waters in accordance with the most beneficial use thereof "in relation to associated resources in Manitoba, Saskatchewan and Alberta". Riparian rights, as has been pointed out, may be asserted without regard to beneficial use and even if the water cannot apparently be applied to a useful purpose. In effect, therefore, the 1948 agreement set out the principle of equitable apportionment of the waters on the basis of their most beneficial use in relation to the resources of the provinces.

Notwithstanding the principle underlying the agreement, differences have arisen between the provinces as to the proper basis for determining allocations of water in the river system of which the South Saskatchewan forms a part. It is argued, on the one hand, that allocations should be governed only by the available supply of water, and, on the other hand, that regard must be had not only to the available supply but also to its most beneficial use. It is clear that if available supply alone is taken into account, most beneficial use in the wider sense may have to give way to beneficial use in a more local sense. Considering the rights of each of the Prairie Provinces in the interprovincial waters and the importance attached to financial participation by the Government of Canada in the development of these waters, it is submitted that major allocations of water must have regard to the requirements of a reasonably integrated development of the entire system. Such development cannot be contemplated without agreement by the three provinces to subordinate their rights to the principle of the most beneficial use of the waters properly determined.



CHAPTER 6

The South Saskatchewan River Project

THE South Saskatchewan River Project proposes to utilize the water of the South Saskatchewan River and its tributaries, to irrigate lands in Central Saskatchewan.

By means of a dam constructed at a site near Outlook, Saskatchewan, 80 miles upstream from the City of Saskatoon, it is possible to create a resevoir 140 miles long. This reservoir will be adequate to irrigate nearly a half a million acres of land and as well provide the source for generating electrical energy for domestic, irrigation and industrial uses. In addition, the reservoir will permit the diversion of water down the Qu'Appelle Valley, provide a source of water supply for the cities of Moose Jaw and Regina, and regulate the river flows below the damsite.

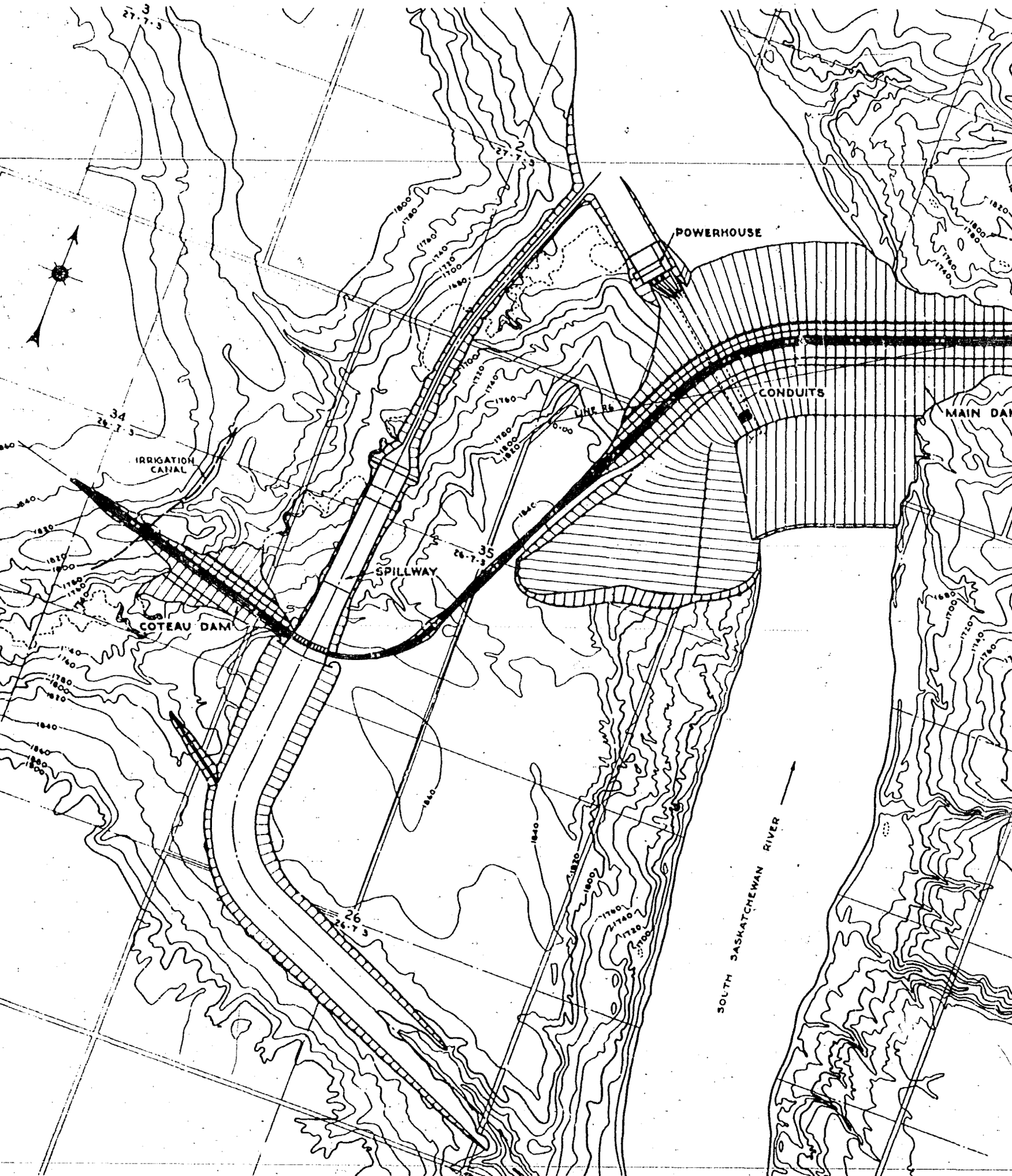
The project will require the construction of:

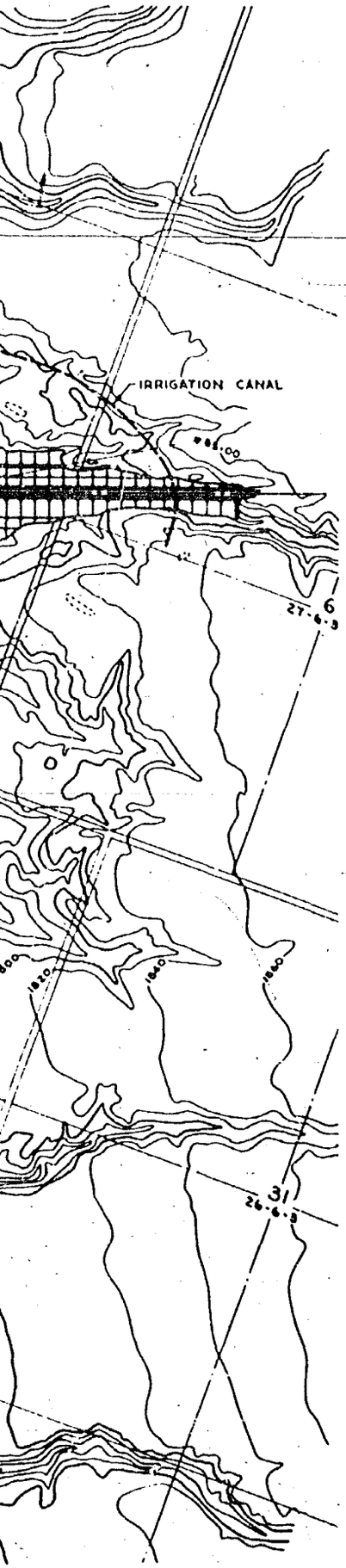
1. An earth dam on the South Saskatchewan River, 205 feet high and 8,500 feet long;
2. An auxiliary earth dam in the Qu'Appelle Valley to prevent the impounded waters from escaping down the valley;
3. A spillway channel, about three miles long, with a concrete control structure;
4. A reinforced concrete outlet works through the dam to provide for river diversion, the generation of power, and river regulation;
5. A powerhouse with an installed capacity of 150,000 horsepower, for generating power;
6. Five hundred miles of main canals and laterals, and 12 pumping stations to transport water to the lands to be irrigated;
7. A high level railway crossing of the Qu'Appelle Valley to provide for C.N.R. and C.P.R. rail transportation in that vicinity.

The following section will describe the main engineering features of the Project, as far as they have been defined by the engineering services of the P.F.R.A. Then it will set out the main agronomic aspects of the Project, as they have been analyzed in reports prepared for the P.F.R.A.

General Engineering Features

Selection of Site: The first location to be investigated for the proposed diversion from the South Saskatchewan River was in the reach of river between Saskatchewan Landing, north of Swift Current, and the Cabri Ferry, about 20 miles upstream. The purpose of this general location was to utilize


POWERHOUSE
CONDUITS
MAIN DAM
IRRIGATION CANAL
SPILLWAY
COTEAU DAM
SOUTH SASKATCHEWAN RIVER
LINE 26
3
27-7-3
2
27-7-3
34
26-7-3
35
26-7-3
26
25-7-3



PLAN OF STRUCTURES

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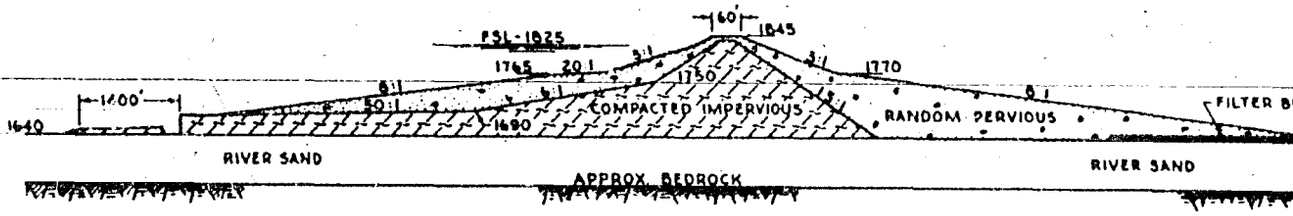
SCALE OF FEET



DAM CROSS SECTION

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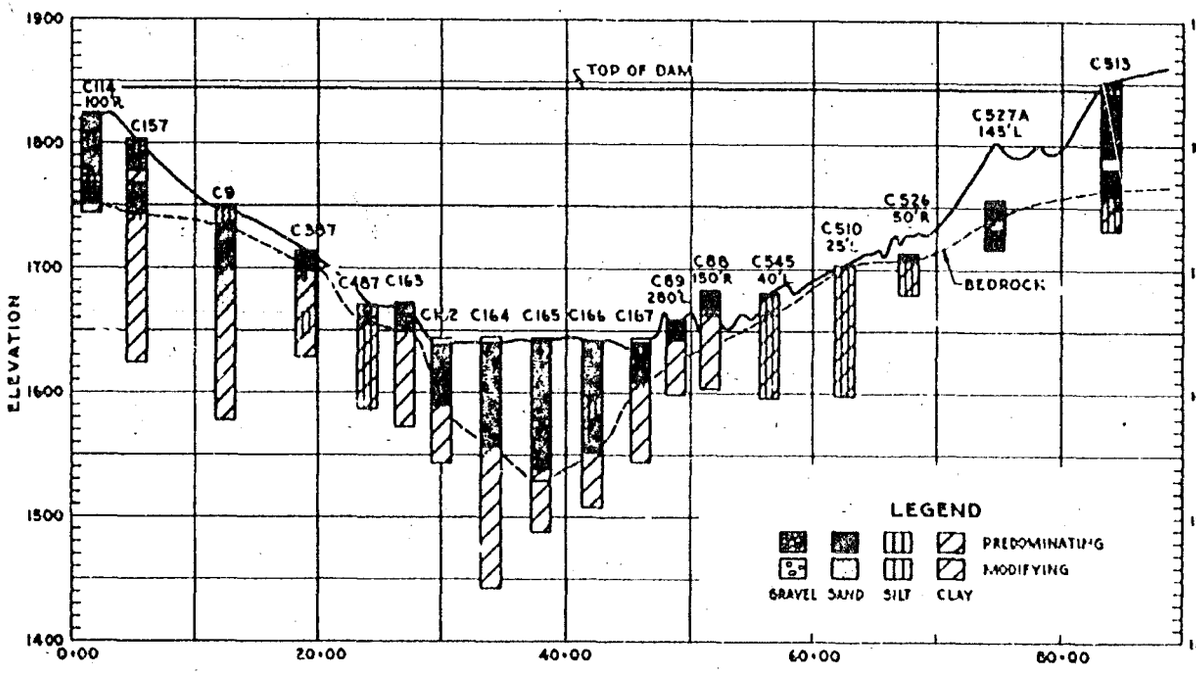
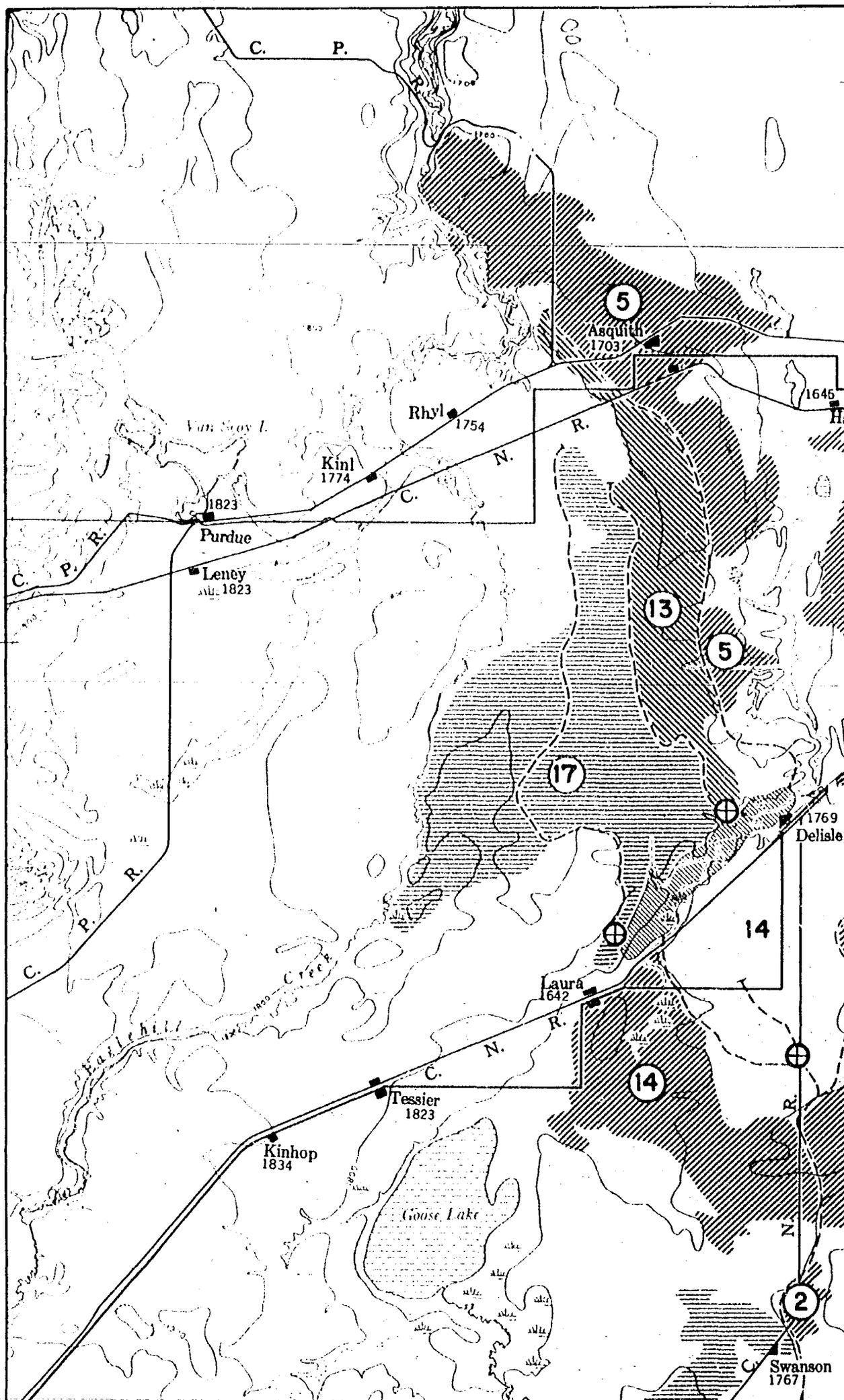


PROFILE OF LINE R6 SHOWING TEST BORINGS

PROPOSED
SOUTH SASKATCHEWAN RIVER DAM

GENERAL LAYOUT AND SECTIO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N.
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17
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14
C. P. R.
Laura
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N.
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Kinhop
1834
Goose Lake
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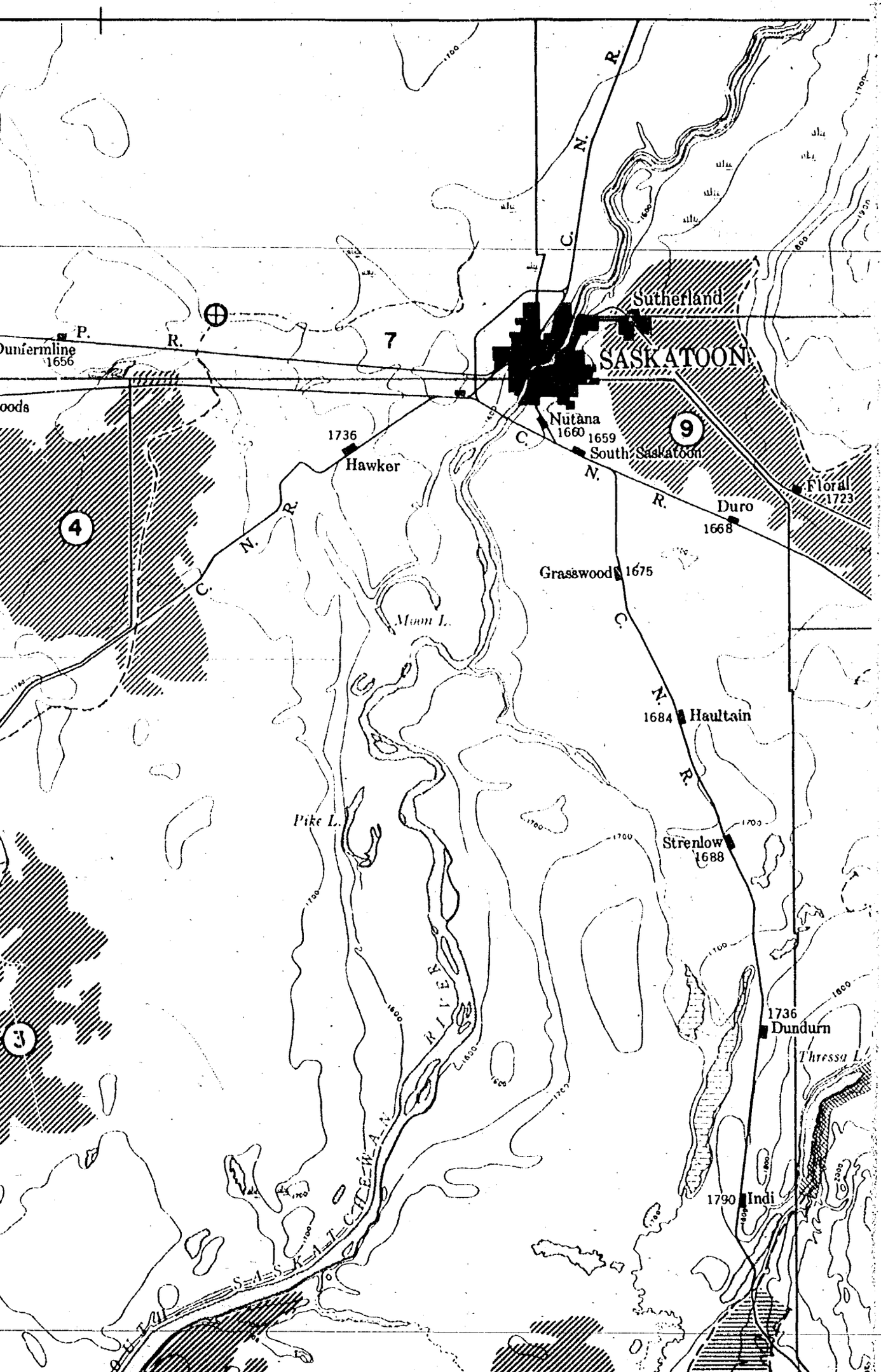
Swanson
1767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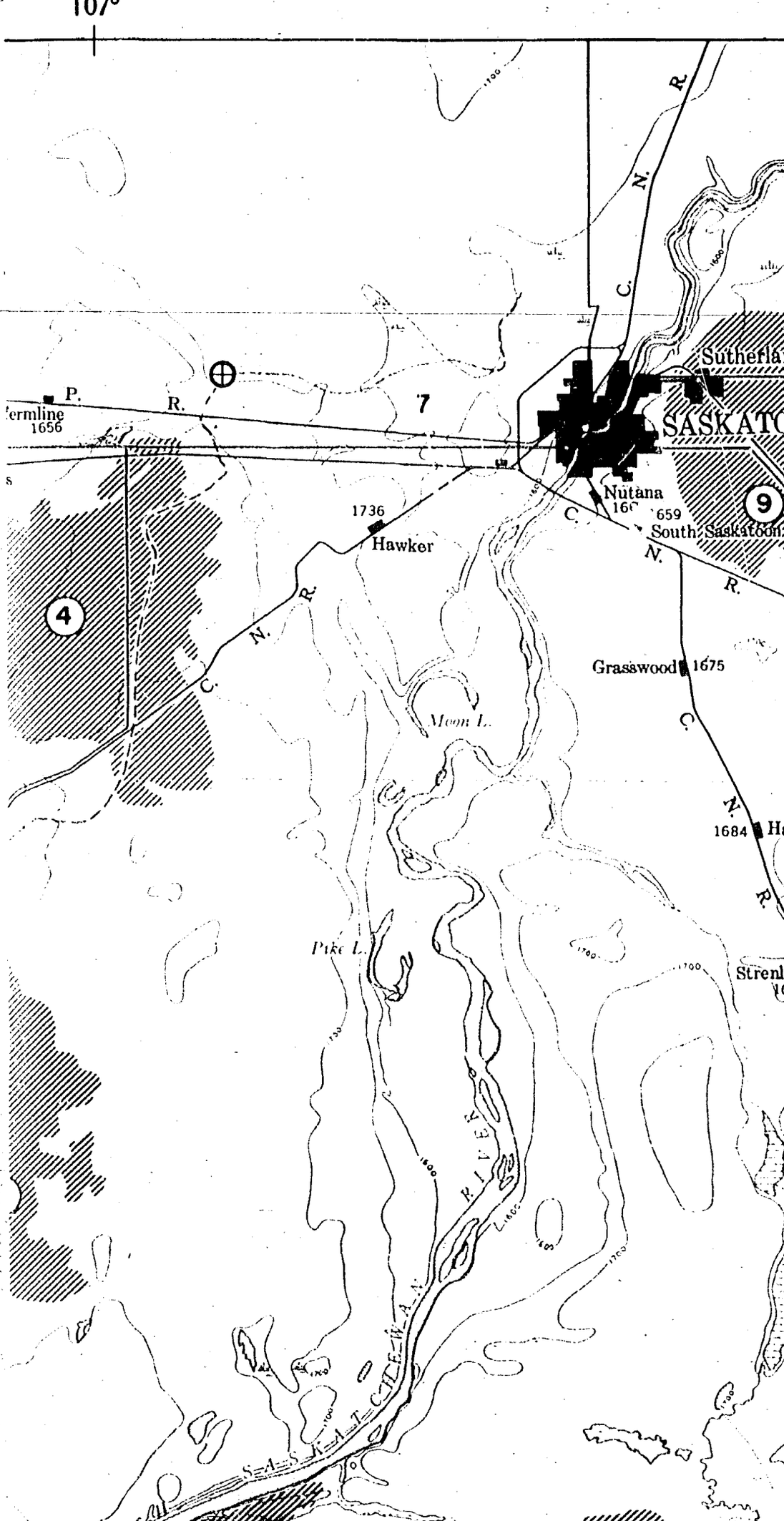
RIVER
S A S K A T C H E W A N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RIVER
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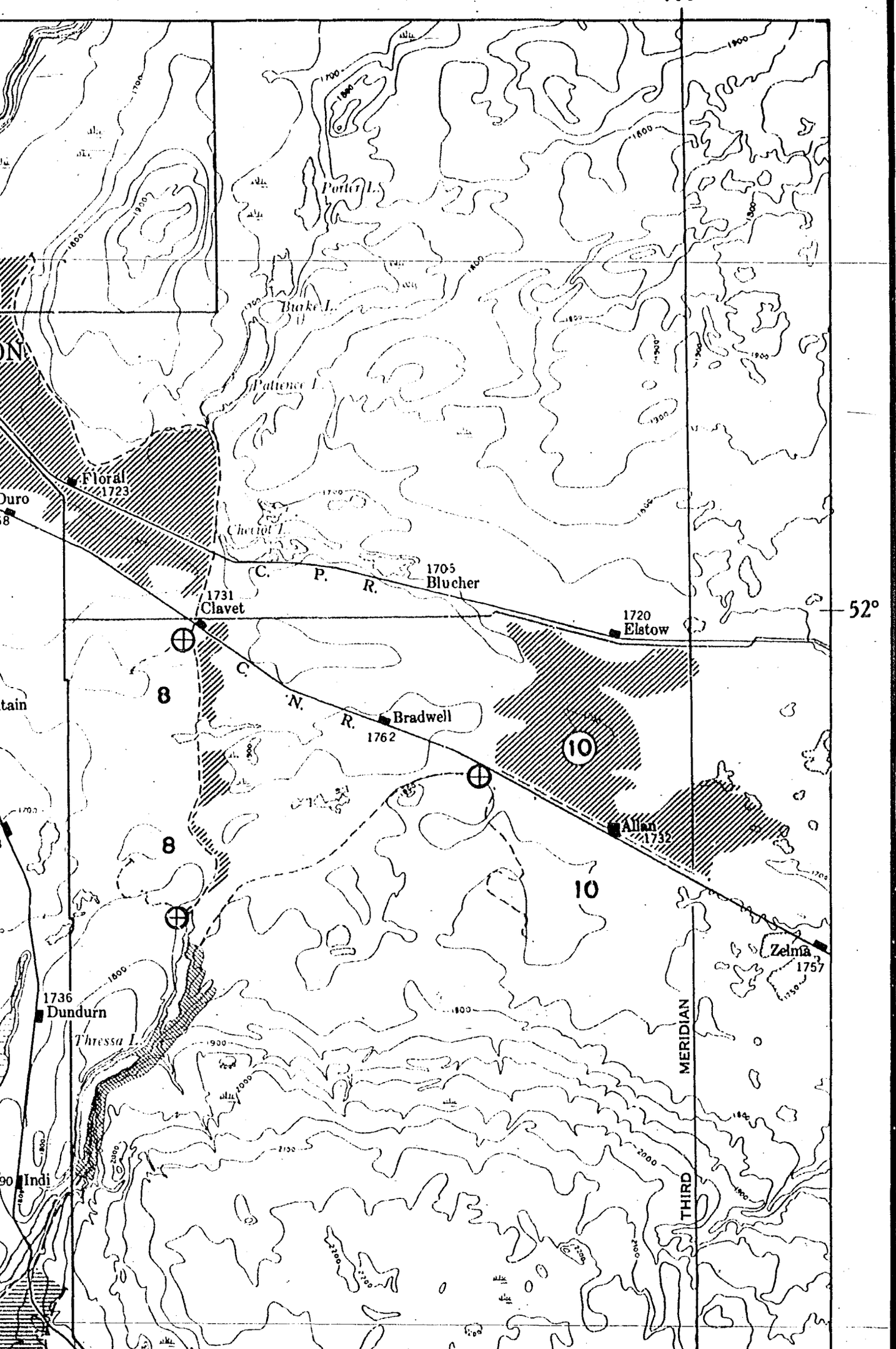
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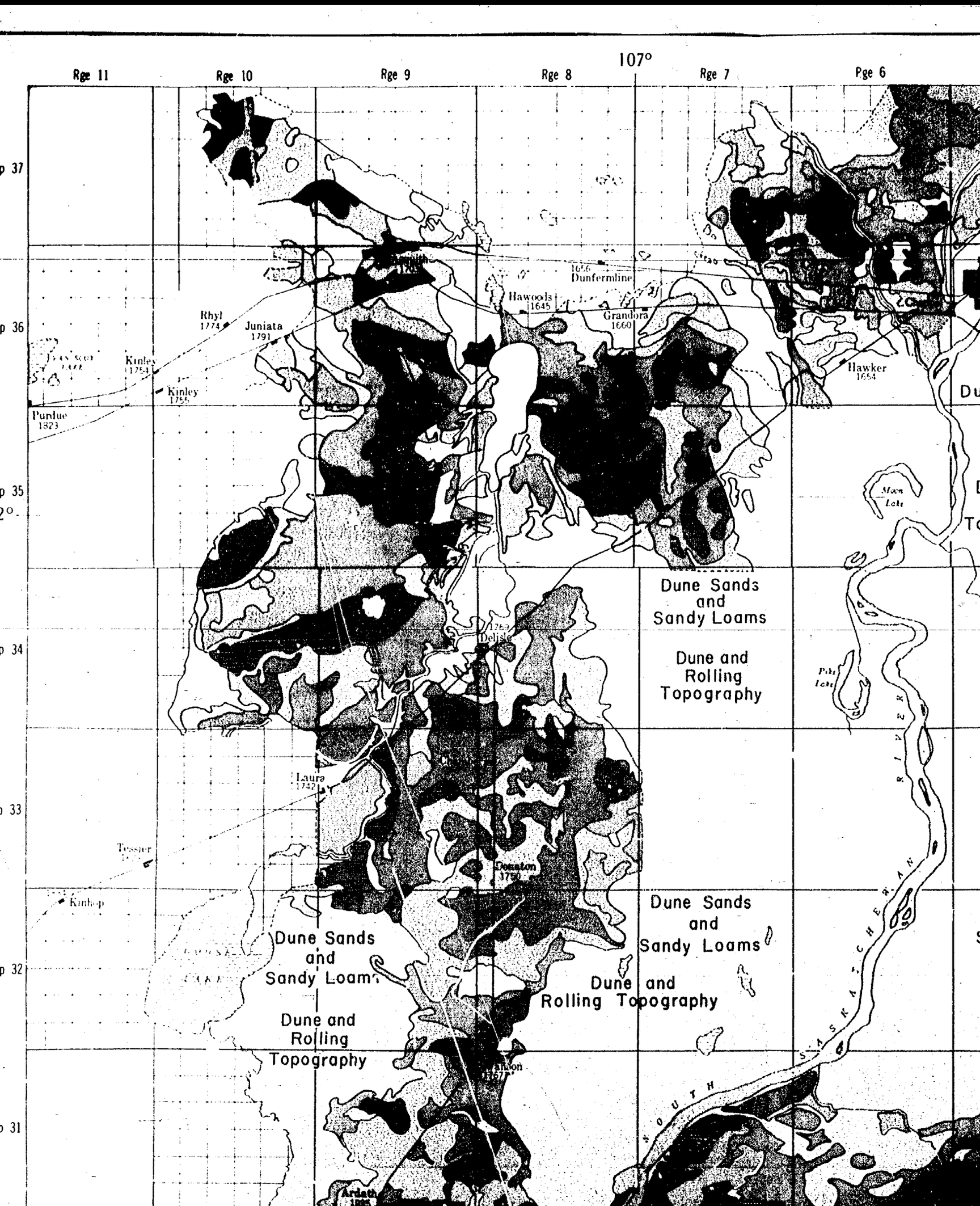
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Rge 7
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Grandora
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Rhyl
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Juniata
1791
Kinley
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Kinley
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Purdue
1823
Hawker
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Moon Lake
Delisle
1763
Laura
1742
Tessier
Donaton
1750
Kinbep
Dune Sands
and
Sandy Loams
Dune and
Rolling
Topography
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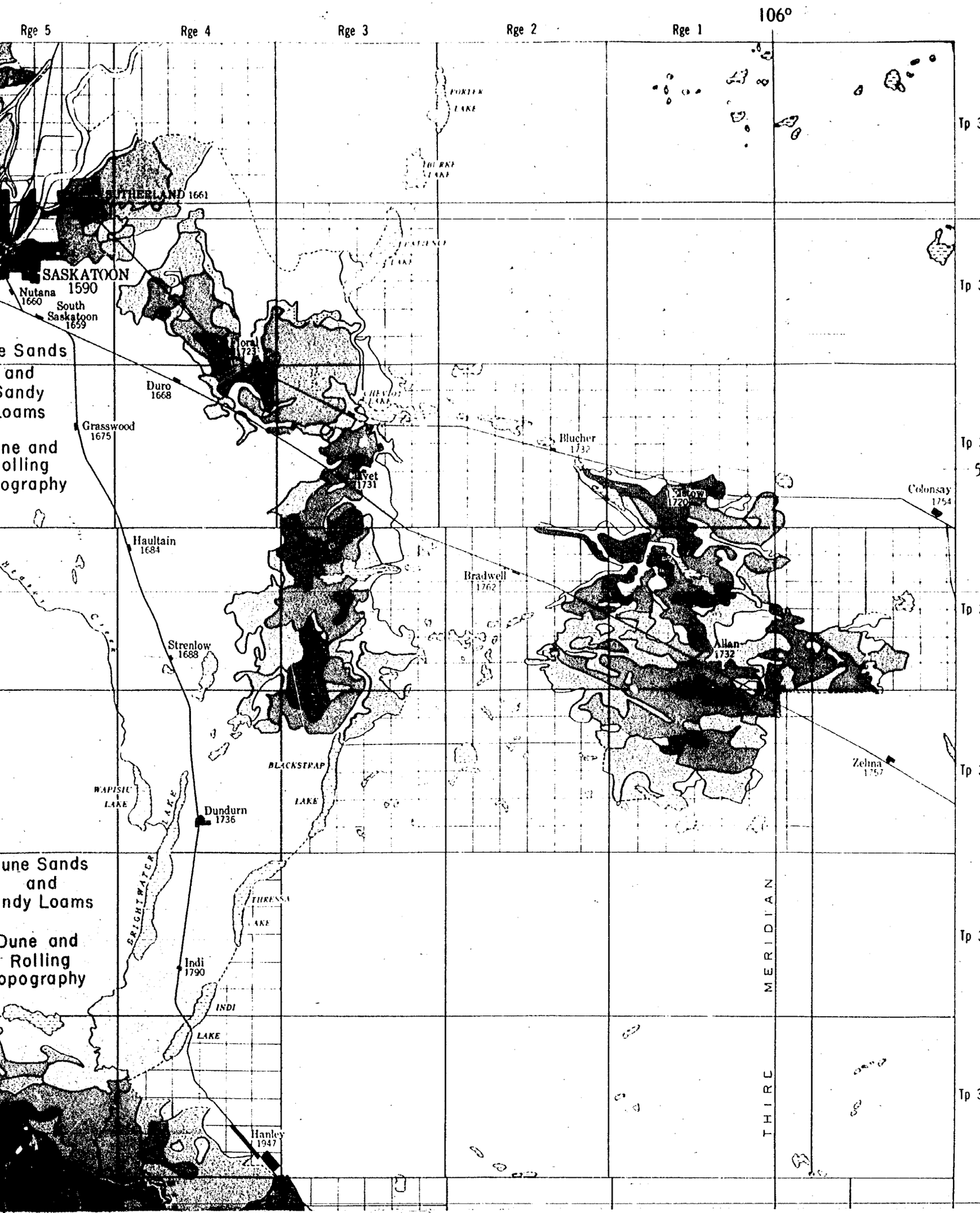
106°
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SASKATOON 1590
Nutana 1660
South Saskatoon 1659
Duro 1668
Grasswood 1675
Haultain 1684
Strenlow 1688
Dundurn 1736
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Bradwell 1762
Colonsay 1754
Allan 1732
Zelma 1757
Indi 1790
Hanley 1947
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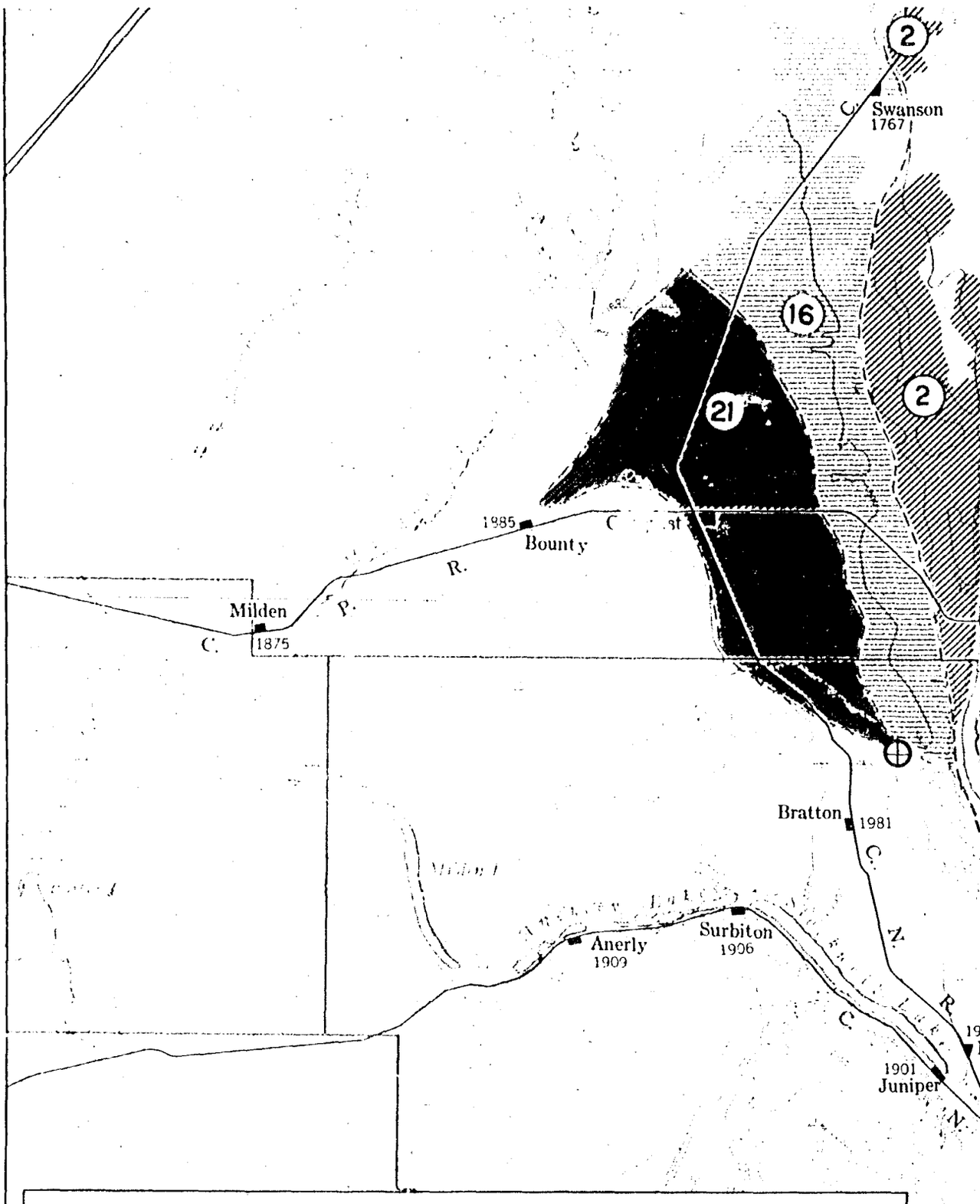


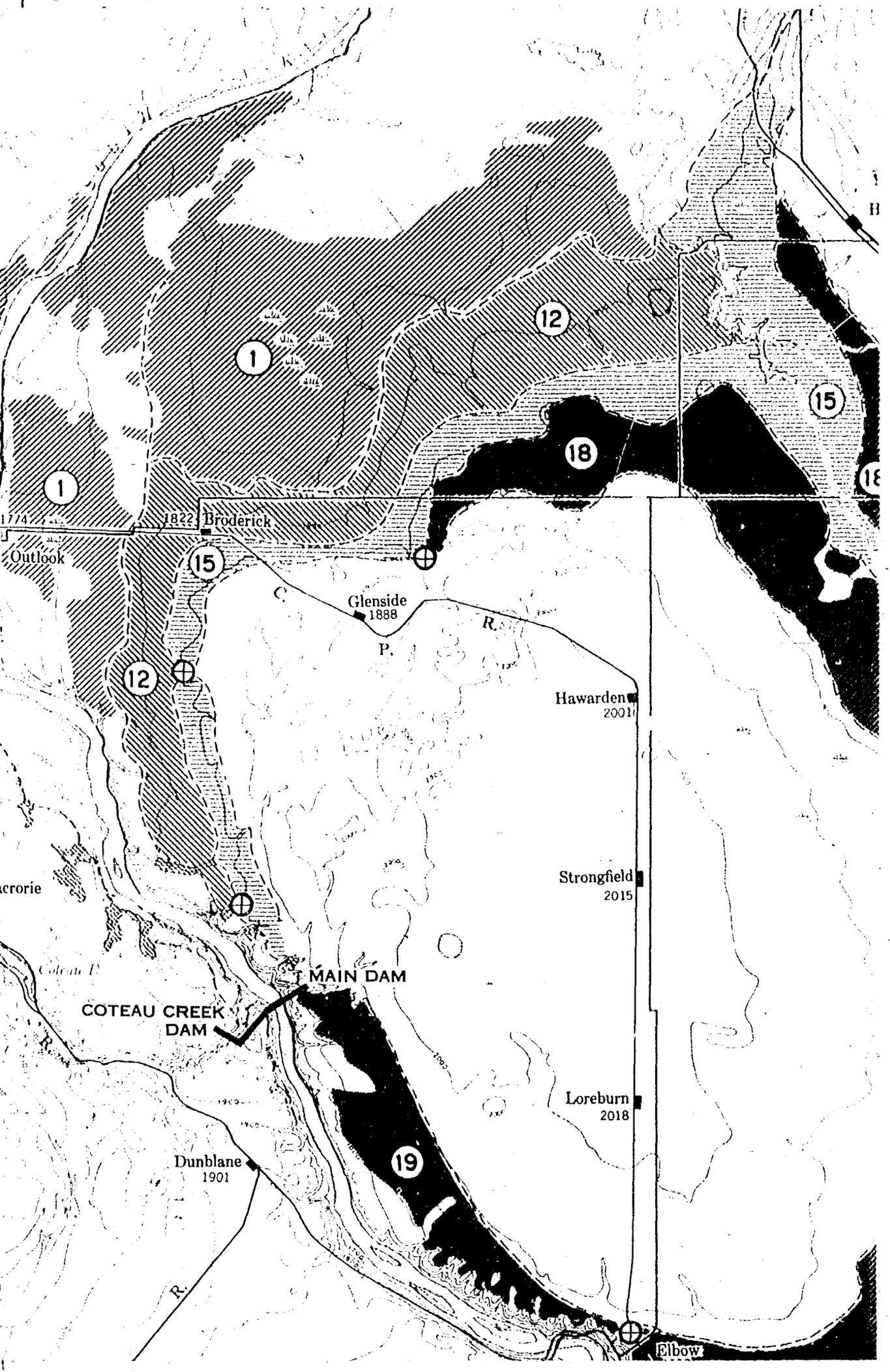
IRRIGABLE AREAS
OF
SOUTH SASKATCHEWAN RIVER PROJECT

LEGEND

Irrigation Blocks 19

Areas Irrigated by Gravity.....

Areas Irrigated by Lift


12
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15
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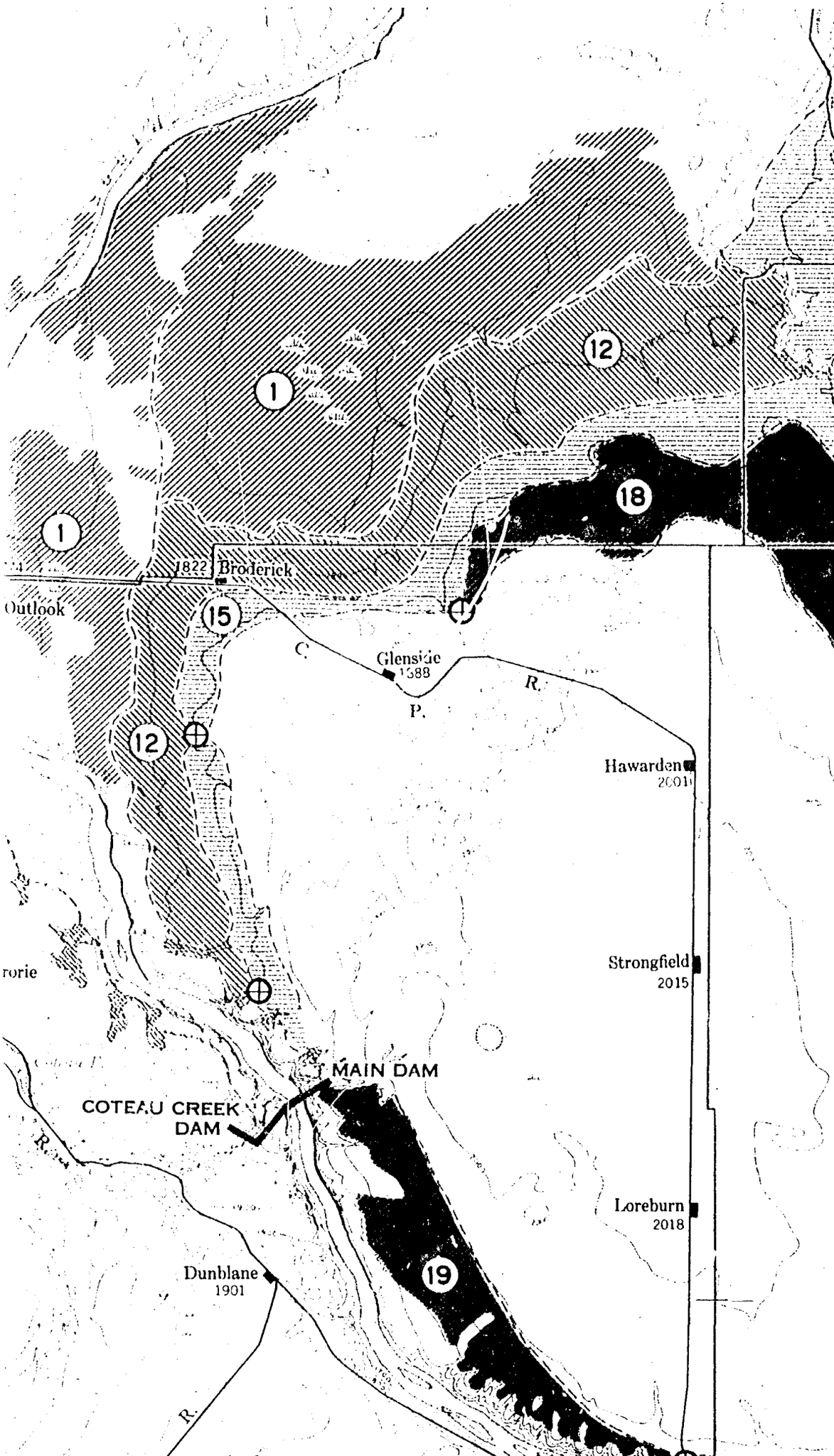
1774
1822
Broderick
Outlook
15
C.
Glenside
1888
R.
P.
12
Hawarden
2001
Strongfield
2015
MAIN DAM
COTEAU CREEK
DAM
Loreburn
2018
19
Dunblane
1901
R.
Elbow


12
1
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MAIN DAM
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Loreburn
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Dunblane
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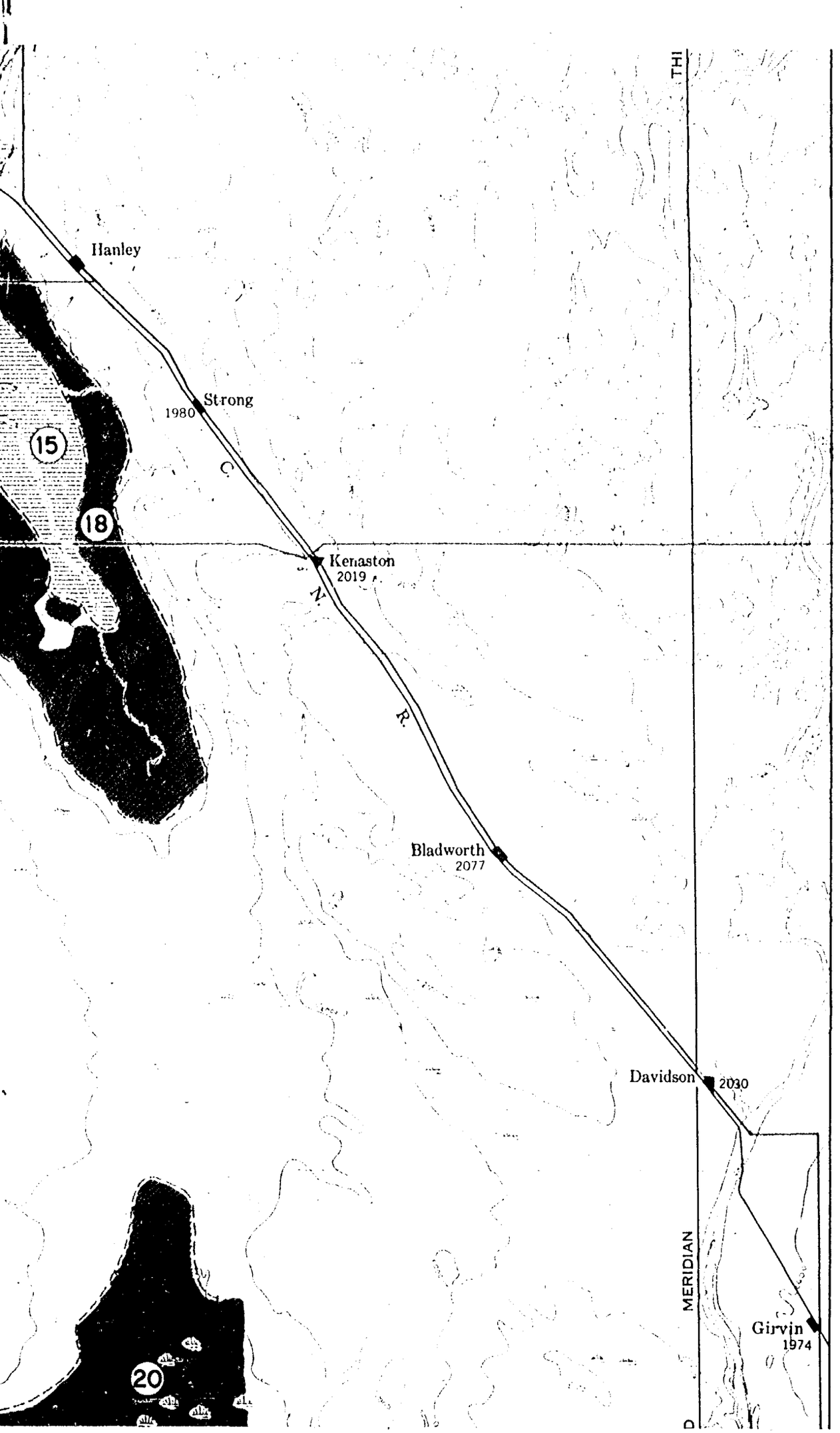
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Kenaston
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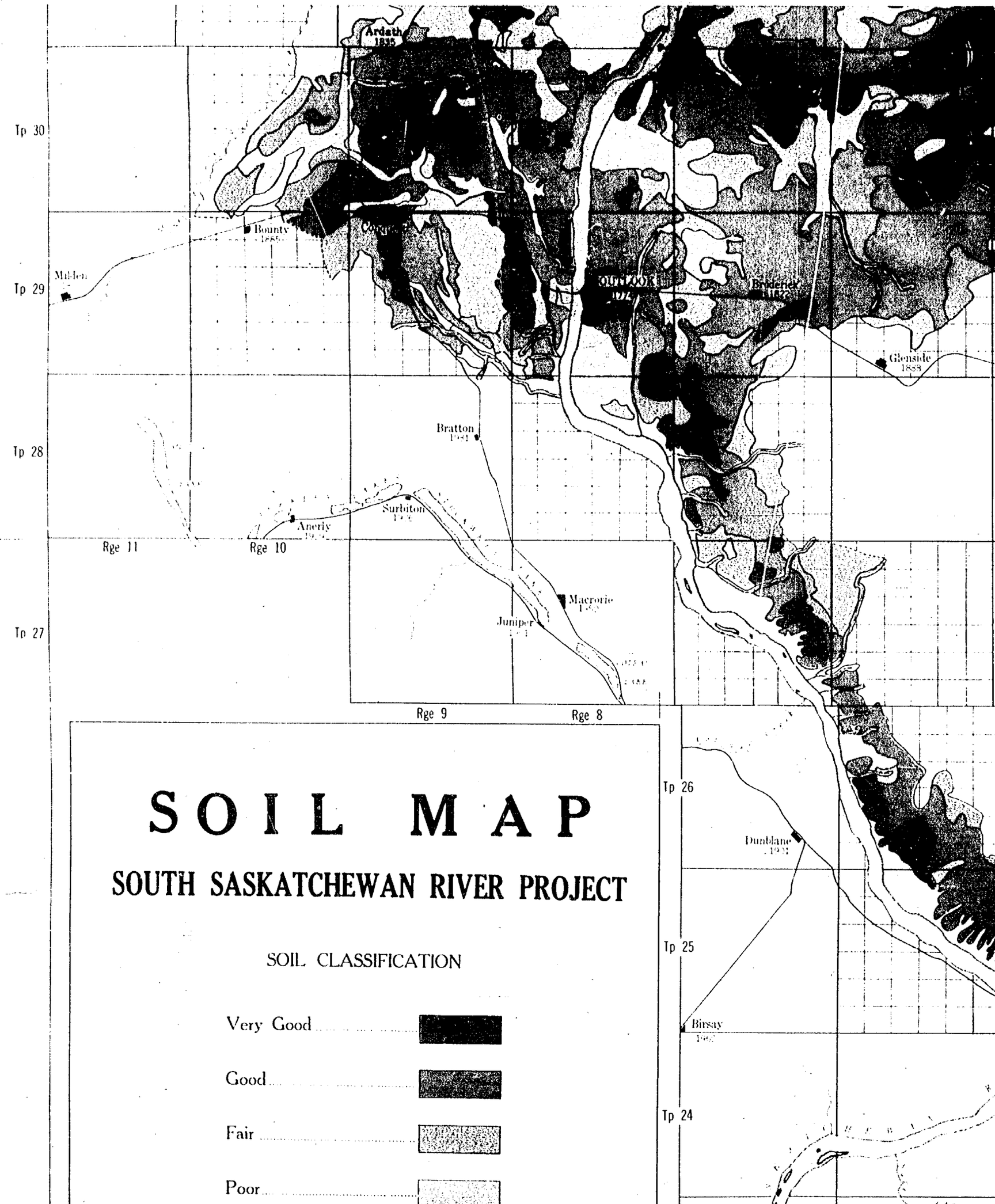
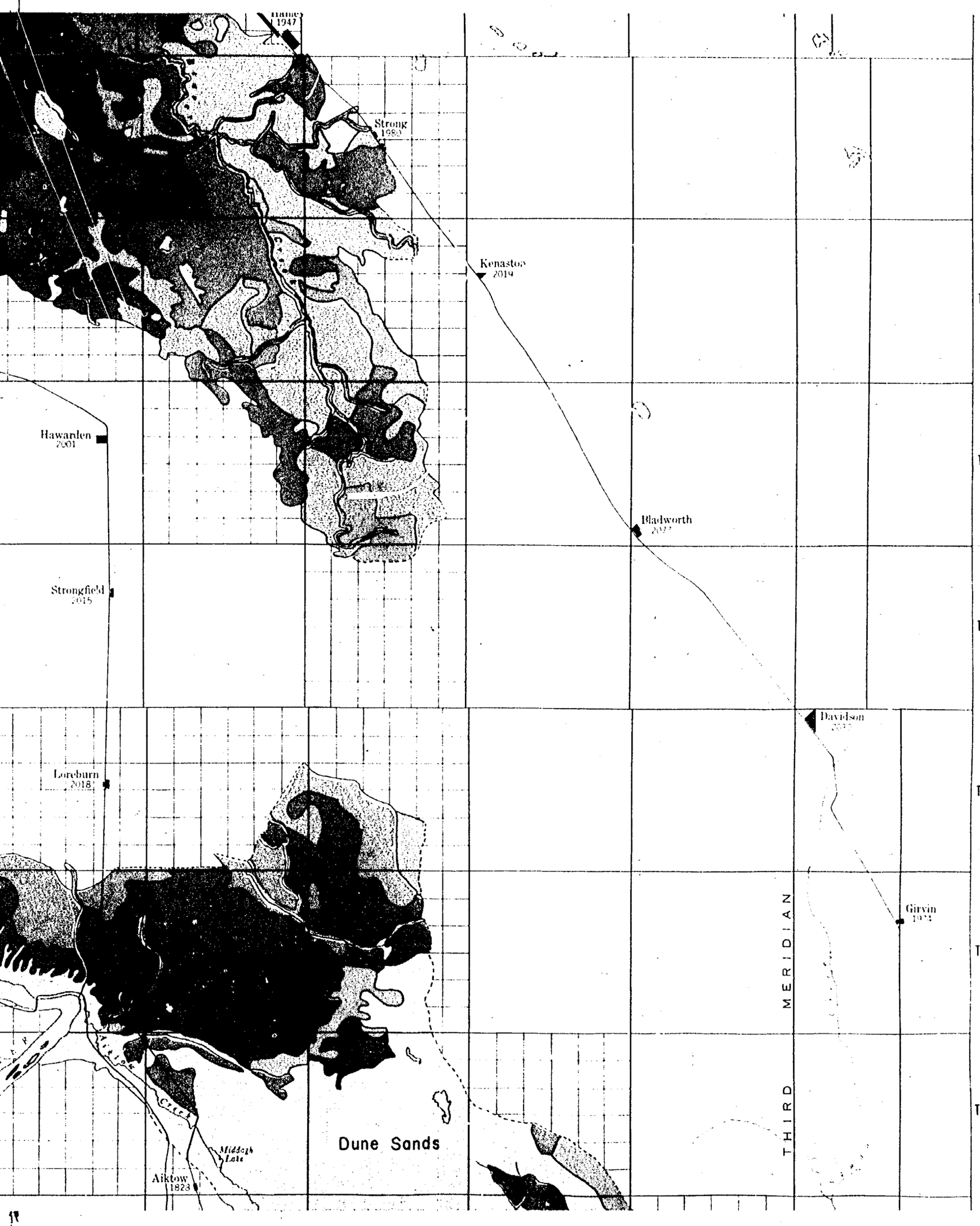
Bladworth
2077
Davidson
2030
MERIDIAN
Girvin
1974
20


Ardath
1895
Bounty
1885
Colgate
Mullen
Tp 30
Tp 29
Tp 28
Tp 27
Tp 26
Tp 25
Tp 24
Rge 11
Rge 10
Rge 9
Rge 8
Bratton
1881
Surbiton
Anerly
Macrorie
Juniper
Glenside
1883
Dunblane
1903
Birsay
1907
SOIL MAP
SOUTH SASKATCHEWAN RIVER PROJECT
SOIL CLASSIFICATION
Very Good
Good
Fair
Poor


Strong
1980
Kenaston
2019
Hawarden
2001
Bladworth
Strongfield
2015
Davidson
Loreburn
2018
Girvin
MERIDIAN
THIRD
Dune Sands
Aiktow
1823

Junipe

IRRIGABLE AREAS
OF
SOUTH SASKATCHEWAN RIVER PROJECT

LEGEND

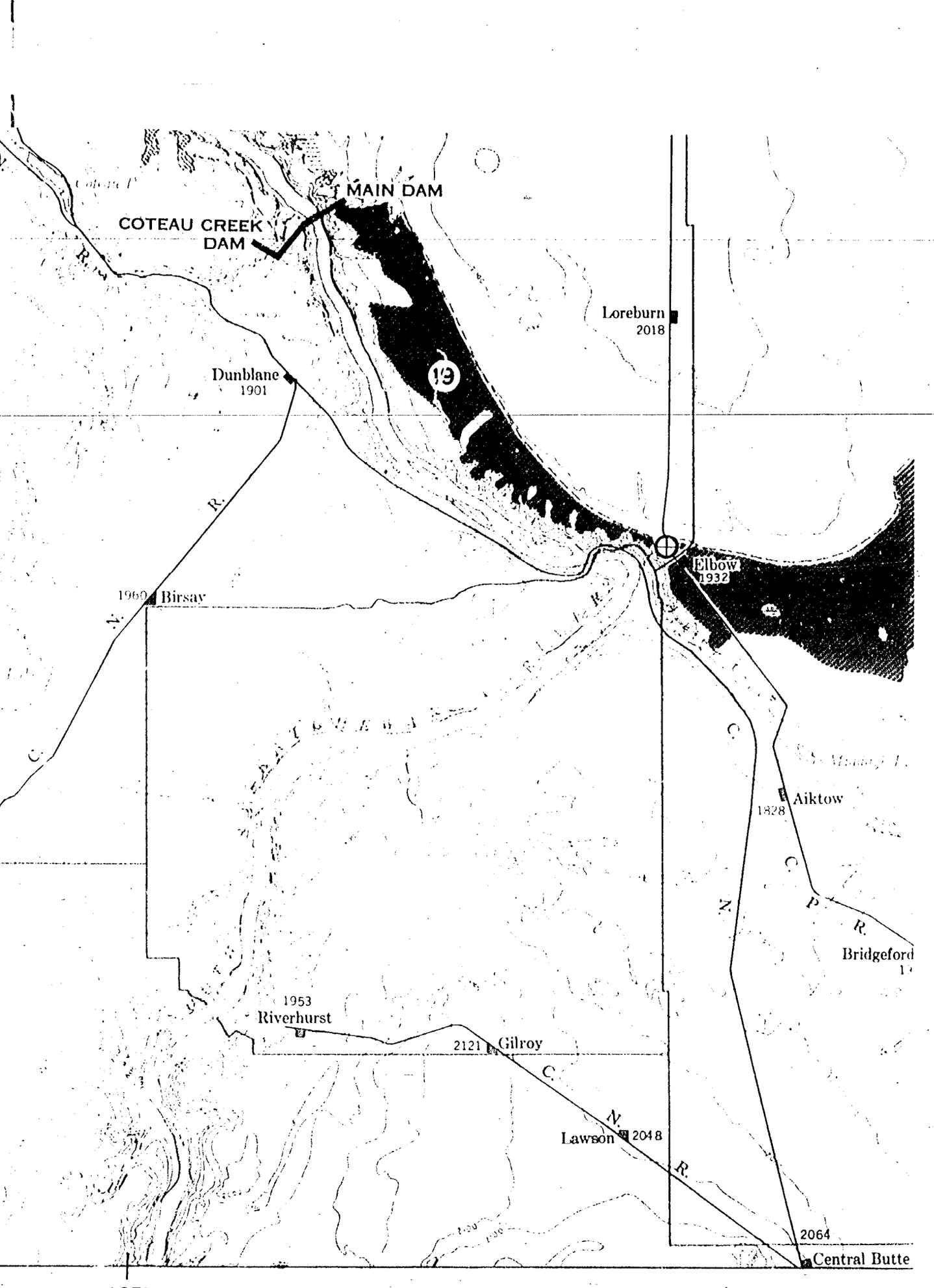
Irrigation Blocks 19
Areas Irrigated by Gravity .....
Areas Irrigated by 15′ Lift .....
Areas Irrigated by 30′ Lift .....
Areas Irrigated by 60′ Lift .....
Areas Irrigated by 120′ Lift .....
Pumps .....
Canals .....
Main Dam .....
Permanent Lakes and Rivers .....
Intermittent Lakes and Rivers .....
Ponds .....
Marshes .....
Lake Bed .....
Contour Intervals .....
Spot Elevations 1879
Roads .....
Railroads ..... C. N. R.
Cities and Towns ..... SASKATOON
..... Sutherland
..... Hanley

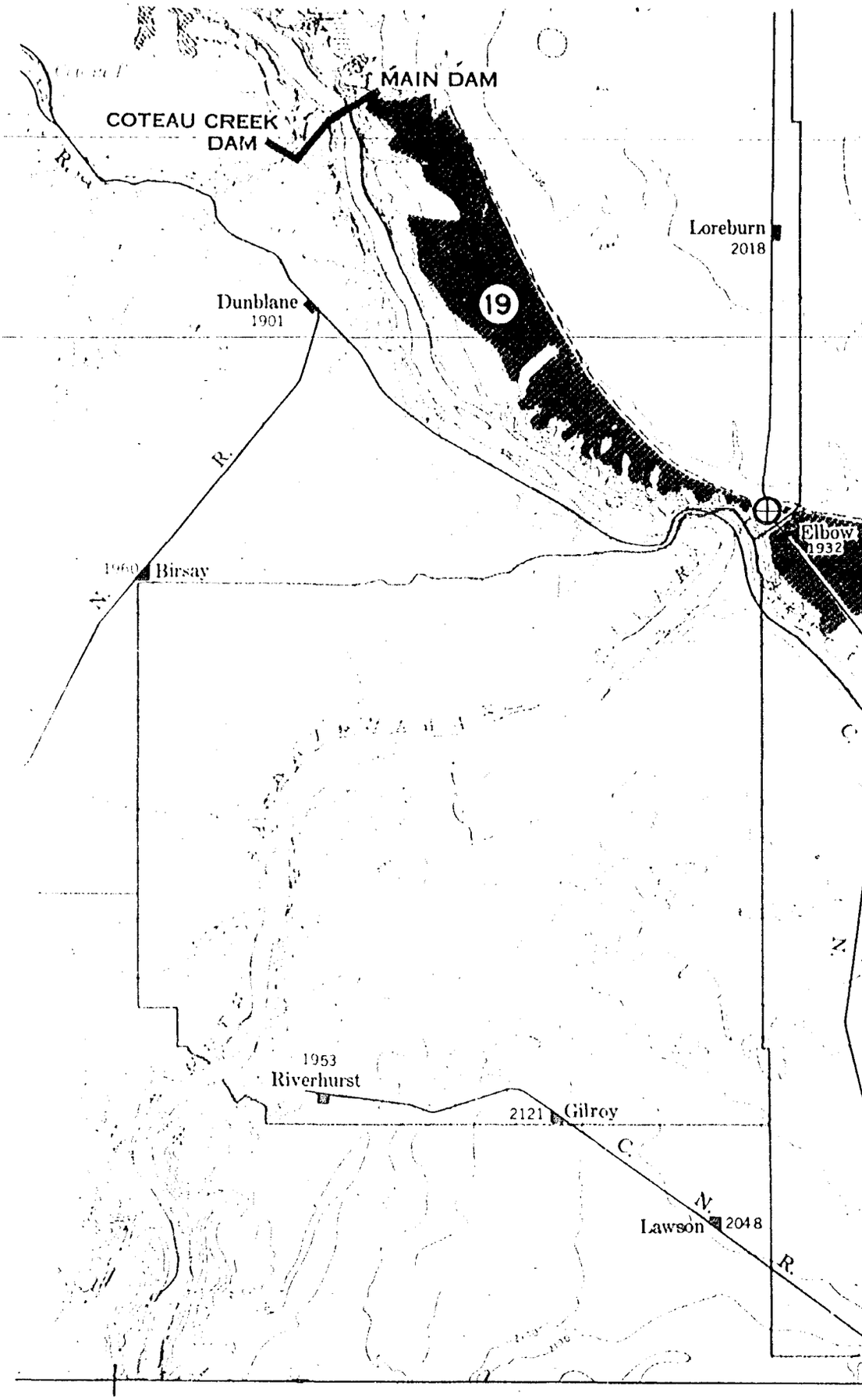
51°

Scale in Miles

4 3 2 1 0 4 8 12 16

Map planning, compilation, drafting and editing by Paul-H. Laurendeau, geographer-cartographer, assisted by Martin H. Sinclair, geographer, and Gilles Morin, draftsman.


MAIN DAM
COTEAU CREEK DAM
Loreburn
2018
Dunblane
1901
19
Elbow
1932
1960 Birsay
Aiktow
1828
Bridgeford
1953
Riverhurst
2121 Gilroy
Lawson 2048
2064
Central Butte
107°


MAIN DAM
COTEAU CREEK DAM
Loreburn
2018
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Dunblane
1901
Elbow
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Riverhurst
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Gilroy
Lawson
2048
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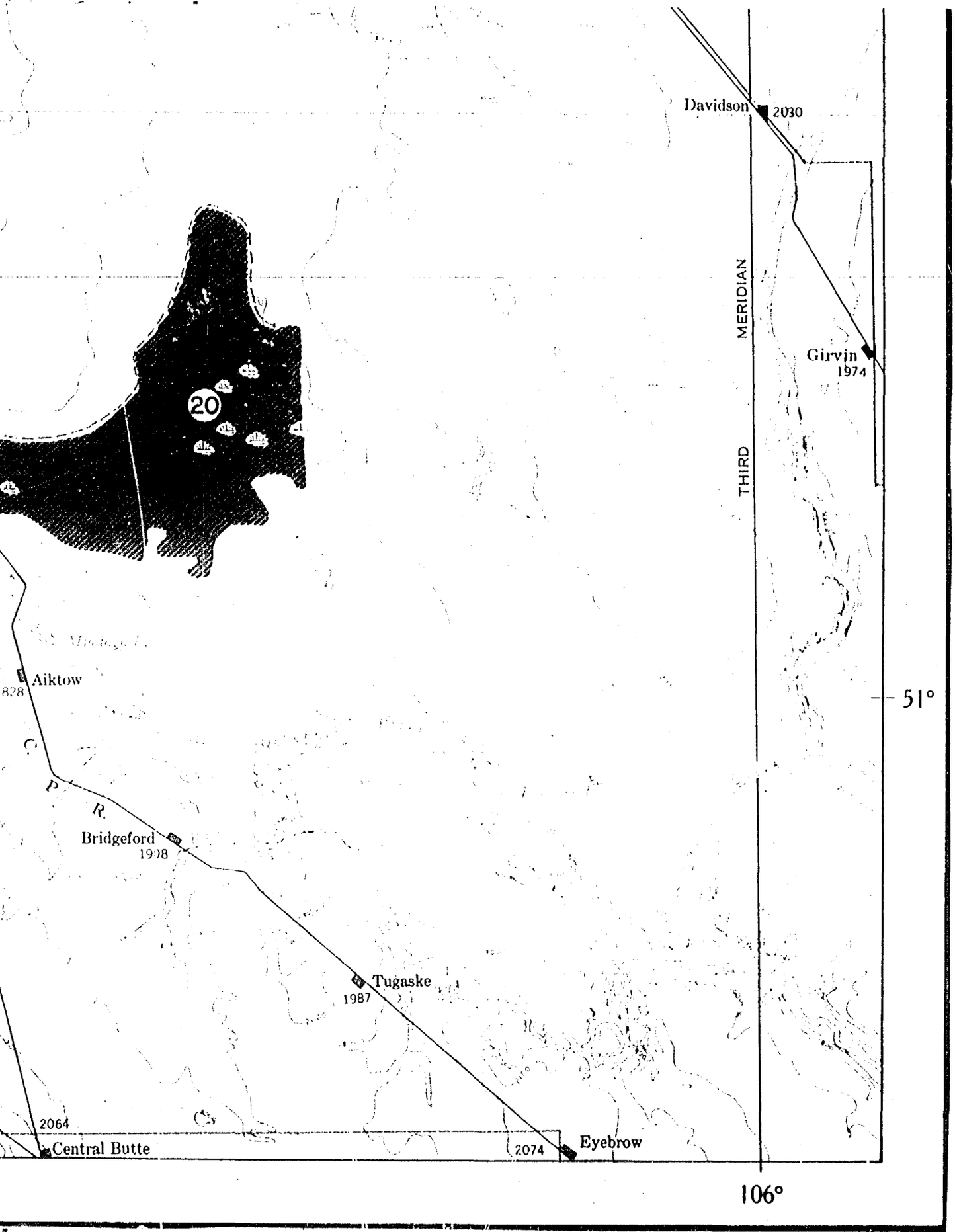

Davidson
2030
MERIDIAN
THIRD
Girvin
1974
20
51°
Aiktow
828
C
P
R
Bridgeford
1908
Tugaske
1987
2064
Central Butte
2074
Eyebrow
106°

SOIL MAP

SOUTH SASKATCHEWAN RIVER PROJECT

SOIL CLASSIFICATION

Very Good

Good

Fair

Poor

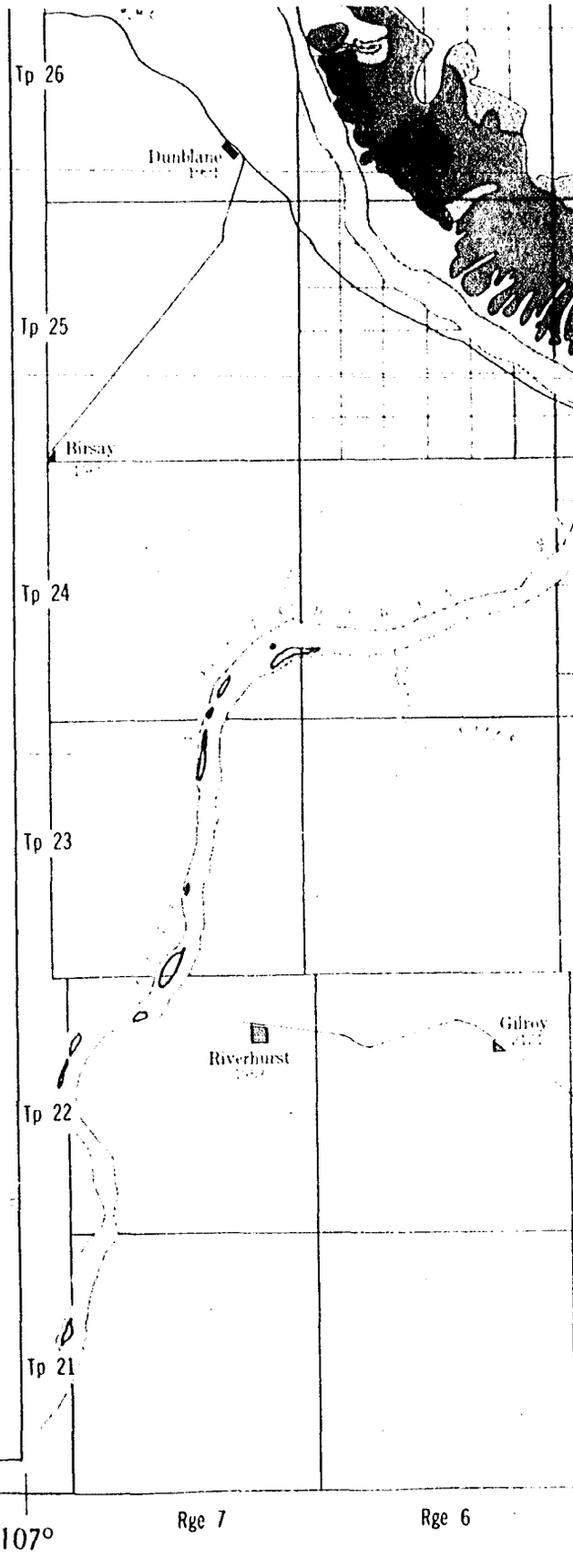
Very Poor

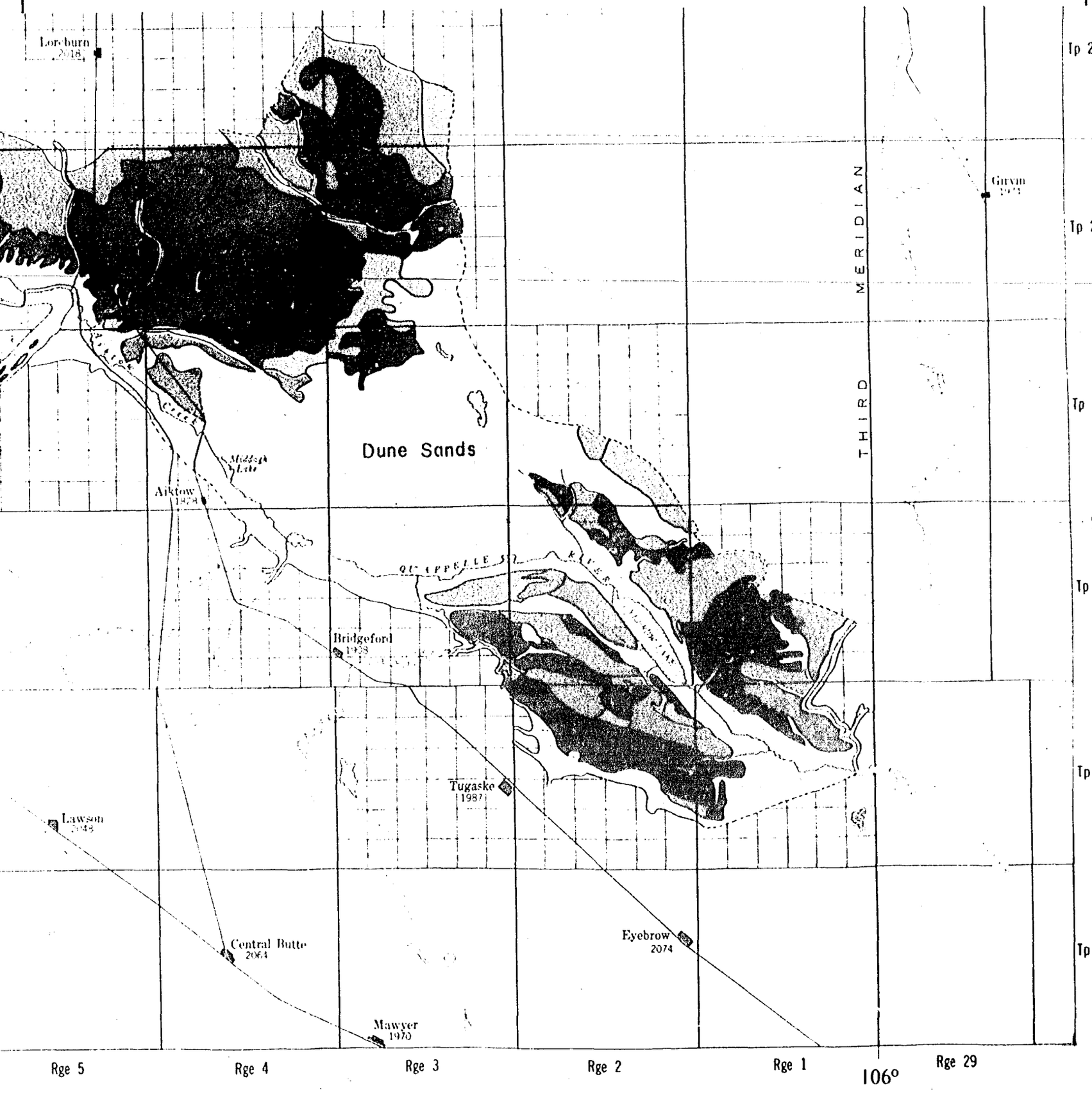
Scale in Miles

4 3 2 1 0 4 8 12

Data from field surveys undertaken for the Administration of the Prairie Farm Rehabilitation Act.

Map planning, compilation, drafting and editing by Paul-H. Laurendeau, geographer-cartographer, assisted by Martin H. Sinclair, geographer, and Gilles Morin, draftsman.




Lor·burn
2048
Girvin
Dune Sands
THIRD MERIDIAN
Aiktow
1978
Bridgeford
1988
Tugaske
1987
Lawson
2048
Central Butte
2064
Eyebrow
2074
Mawyer
1970
Tp 2
Tp
Tp
Tp
Tp
Tp
Rge 5
Rge 4
Rge 3
Rge 2
Rge 1
106°
Rge 29

a depression in the north bank, known as the White Bear Depression, through which to convey water to most of the lands originally included in the North Saskatchewan project investigated by the Department of Reclamation and lying generally between Elrose and Rosetown on the west, and Outlook and Saskatoon on the east.

Six profiles were surveyed and drilled. This brought out the following facts:

(a) The dam required would have been between 110 and 150 feet high and it would have had provisions for some power.

(b) The project was feasible from a topographic point of view.

(c) The foundations were not as good as had been hoped for, and materials for construction were inferior.

(d) The reservoir would have flooded a large area of valuable lands in the vicinity of Lacadena, Saskatchewan.

(e) The reservoir capacity would not have been large enough to make best use of the flow of the river.

(f) Agricultural and soils reports on the lands which would have been served from this location, reduced the area suited to irrigation to a small fraction of the acreage originally estimated.

It was found that there was a large area of excellent irrigable land to the east of the Saskatchewan River and in the Qu'Appelle River Valley. However, the Qu'Appelle area could not be reached with water from this point of diversion, and the area east of the river could be reached only by means of an expensive syphon crossing of the South Saskatchewan River. At the same time, an urgent need for domestic water had developed in the Qu'Appelle Valley.

Attention was therefore directed to the reach of river between Elbow and Outlook. Three general sites were explored in this reach—one just above the junction with the Qu'Appelle Valley, another close to the town of Outlook called Site 8, and another at Coteau Creek called Site 10. The site above the Qu'Appelle Valley junction would serve most of the objectives aimed at, and would avoid the railway damages associated with any site downstream. However, foundations proved the poorest yet investigated and further consideration was dropped. Of the remaining two sites, careful investigation showed Site 10 at Coteau Creek to be superior. The advantages of this site are:

1. The possible reservoir capacity which can be developed by a dam in this reach is the greatest on the river, because of the huge side-channel volume in the Qu'Appelle Valley.
2. This reservoir site is close to the irrigable area on both sides of the river.
3. A reservoir in this section will permit casual diversion of water down the Qu'Appelle Valley as required for irrigation and domestic uses.
4. Because of Qu'Appelle Valley storage, the reservoir is more efficient for power than any upstream site.
5. The side-channel storage in the Qu'Appelle cannot accumulate silt from bed load or suspended load movement in the main river.
6. Suitable earth materials of the classes required for construction are found in abundance on both banks.
7. All the required gravel for concrete aggregates is available on the site.

Main Dam.—The proposed South Saskatchewan dam, spillway and appurtenant

works are located adjacent to the North boundary of Township 26, Range 7, west of the Third Meridian, about 15·5 miles downstream from the Elbow.

The dam will be a rolled earth fill 205 feet high with a crest length of 8500 feet, and a crest at elevation 1845. The crest width will be 60 feet and the maximum base width in the River channel will be 2600 feet, exclusive of a 1200-foot upstream blanket. Embankment slopes will vary from 2 to 1 at the top to 8 to 1 at the bottom. A roadway will be constructed across the crest and tentative plans make provisions for carrying a railway across the dam. The upstream and downstream portions of the dam will consist of pervious fill material; the core will be impervious rolled earth fill. The upper 40 feet of the upstream slope will be protected by riprap.

The area under the dam is underlain by Bearpaw shale. The shale in turn is underlain by Belly River sandstone. The overburden consists principally of sand in the river bed, with clay, sand and gravel in the abutments. To prevent seepage under the dam through the overburden, a 1200-foot blanket varying in thickness from 34 to 10 feet will be constructed in the river bed, and a cutoff trench will be excavated to the Bearpaw shale under the abutments.

A detailed sub-surface exploration has proven that ample quantities of material suitable for the rolled earth-fill and pervious zones of the dam are available in the immediate vicinity. This material has a good distribution on both sides of the river and sufficient impervious and pervious fill can be obtained within easy haul distance. Riprap surveys have been made which indicate that all the material required for riprap and closure rock could be obtained within 40 miles of the site.

Spillway.—A gated, reinforced concrete chute spillway will be located southwest of the main fill about a mile away from the west abutment. This location utilizes a natural depression to reduce the approach channel excavation. The over-all length is 17,000 feet, of which 8,000 feet is approach channel, 3,000 feet is reinforced concrete control structure and 6,000 feet is exit channel.

The drainage area of the South Saskatchewan River above the proposed damsite is 48,800 square miles. The spillway is designed to pass a flood with a peak discharge of 400,000 c.f.s., a total volume of 4,000,000 acre-feet in 16 days. This design flood when routed through the spillway indicated a maximum spillway discharge of 265,000 c.f.s. with the reservoir rising to elevation 1830, five feet above full supply level. The largest flood on the river during the period of record was 131,000 c.f.s. in June, 1923.

The approach channel is 600 feet wide with 3 to 1 side slopes and a bed elevation of 1775. A pilot channel 100 feet wide with 3 to 1 side slopes at elevation 1650 will be excavated for the exit from the stilling basin. The crest of the concrete chute is 520 feet wide and its elevation is 1797·5. There are eleven 40-gate openings with ten eight-foot thick concrete piers to support roadway and railroad bridges. The chute section is tapered from a 520-foot width at the crest to a 400-foot width about 600 feet below the crest, this section being continued to the stilling basin. The stilling basin is the same width as the chute and 300 feet long at elevation 1608. The control gates selected

for the spillway are 40 x 29 metal tainter gates. This size has been standardized by the U.S. Corps of Engineers.

The spillway will be founded on materials varying from pervious sands and gravels to impervious clays and shales. No difficulty is expected in placing the spillway on sand, gravel and clays but special precautions must be taken where the structure will be on or close to the shale formation. Where the structure is located on shale it will be designed so that the weight of the structure will balance the weight of the material excavated wherever this is practical, in order to eliminate the upward heave due to elastic rebound and swelling of the shale. The spillway will be constructed on a schedule which will allow differential settlements due to uneven reloading of the foundation to take place before the structure is complete.

Outlet Works.—A multi-barrelled conduit of reinforced concrete 2750 feet long with four 25-foot diameter barrels has been tentatively selected for diversion purposes. This conduit must be able to pass the design diversion flow without excessive head under initial closure conditions, and must in addition be capable at a later date of passing the maximum probable June flow during the construction period.

The conduit will be used as a reservoir outlet works after completion of the dam. Twenty-foot diameter penstocks will be installed in three of the conduit barrels to supply water to the powerhouse, and the fourth barrel will provide for river regulation.

The conduit as presently proposed will be located in the west abutment. This location was chosen because it provided a suitable bench where foundation conditions were uniform and there was no indication of any movement having occurred. This also eliminates the necessity for any deep cuts in the shale at the inlet, outlet and powerhouse areas. The slopes adjacent to these structures are very gradual and therefore will be stable under any conditions to which they might be subjected.

The conduit in cross-section will be a reinforced concrete block 152 feet wide and 45 feet high with four 25-foot diameter openings through it. Wall thicknesses are 10 feet between barrels and eight feet outside. A tapered section of low strength unreinforced concrete will be placed adjacent to the sides of the block for most of their length. This will permit a gradual change of fill height from the depth of fill over the conduit to the depth of fill beside the conduit, with a view to obtaining a gradual transition in differential settlements. These sections will also reduce any draping effect which would tend to increase the vertical load on the conduits proper.

The control tower will be located near the upstream end of the conduit, about 700 feet from the dam centreline. This tentative location has resulted from a compromise between keeping it as near the inlet as possible and minimizing the length of an access bridge to the dam crest. The tower will be 50 feet by 152 feet, and will rise 210 feet above the conduits. Tentative plans are to provide two tractor-type gates for each conduit opening, 10 feet wide and 25 feet high for both emergency and operating sections.

During the preliminary planning of the project, the possibility of using tunnels at various sites was considered. In order to restrict the tunnels to an economical length, deep approach and exit channels cut into

the shale abutment would have been necessary. Although deep cuts in shale may pose a difficult stability problem during both construction of the dam and operation of the reservoir, the possibility of using tunnels for diversion is still being considered. At present the relative merits of tunnels and conduits are still being studied and the final decision as to which will be adopted will depend on the relative safety and economy of the alternatives.

Reservoir.—The reservoir created by the construction of the dam will impound 8,400,000 acre-feet of water, of which about 2,650,000 acre-feet will be live storage for irrigation purposes, between full supply levels in reservoir and irrigation canals, and a total of about 4,000,000 acre-feet for river regulation. This reservoir will extend from Saskatchewan Landing to the Coteau damsite, and 30 miles down the Qu'Appelle Valley, at which point a secondary dam will be located. The flooded area at full supply level will be 116,000 acres of land, 11 per cent of which is under cultivation; the remainder is land immediately adjacent to the river which has little agricultural value.

Flooding of the Qu'Appelle Valley will make it necessary to raise or relocate a portion of the C.P.R. line from Moose Jaw to Outlook. The C.N.R. line from Central Butte to Dunblane will have to be relocated as both the portion in the Qu'Appelle Valley and the bridge crossing on the South Saskatchewan River will be flooded by the reservoir.

Qu'Appelle Valley Dam.—In selecting the locations for a dam across the Qu'Appelle Valley, many economic factors must be considered aside from topographic and foundation conditions. In all, five sites have been explored as possible embankment location. These sites are known as the Elbow Crossing site, C.P.R. Crossing site, Summit site, Ridge Creek site and the Third Meridian site.

The most important factor in selecting a site, other than topographic and foundation conditions, is that the further east the dam is constructed, the greater the reservoir capacity of the project will be. However, there is a limit to how far east the dam can be placed as beyond the Third Meridian the Qu'Appelle Valley widens appreciably, and also the height of dam increases rapidly. Another factor to be considered is the problem of providing railway crossings for the C.P.R. and C.N.R. lines which will be flooded in the Qu'Appelle area.

In order to provide the extra storage which will be available in the Qu'Appelle Valley, it is proposed to construct the embankment at the Third Meridian site, which is considered to be as far east as is practicable. This embankment will be 4300 feet long and 130 feet high. Preliminary drilling has indicated an abundance of suitable borrow material available at the site, as well as an adequate source of pervious and semi-pervious material. Surveys by aerial photographs indicate the presence of an adequate supply of riprap on adjacent valley slopes.

A second embankment will be constructed at the Elbow Crossing site for railroad relocation purposes. The embankment will be 6700 feet long and 135 feet high. Provision will be made for conduits through the embankment of a capacity, such that the depth of water will remain very nearly the same on both sides of the fill. Foundation conditions appear favourable at the site of the proposed embankment. Both abutments and the valley

bottom are composed of glacial till overlying the bedrock material, Bearpaw shale. The limited amount of drilling to date in search of borrow materials indicates there are ample quantities of first class pervious and impervious materials present for construction purposes. Aerial photograph studies indicate an ample supply of riprap on the valley slopes adjacent to the site.

Hydrology.—The South Saskatchewan River receives most of its water from eight major tributaries, which rise on the eastern slope of the Rocky Mountains in the Province of Alberta and the State of Montana. This river actually starts where the Oldman River with its tributaries, the St. Mary, Belly and Waterton, and the Bow River, with its tributaries, the Highwood and Elbow flow together, midway between the cities of Lethbridge and Medicine Hat in southern Alberta. The Red Deer River joins the main stream at the Alberta-Saskatchewan boundary, near Empress. The river flows from the boundary, in an easterly direction, through southern Saskatchewan to Elbow, then northerly through the City of Saskatoon, to the junction with the North Saskatchewan River 30 miles east of the City of Prince Albert.

The drainage area of the river contains about 65,500 square miles. The portion of this area upstream from the proposed damsite contains 48,800 square miles.

Flow in the South Saskatchewan River is subject to a wide seasonal variation. Base flow is derived from ground water and melting glacial ice. The snow-melt in the foothills and on the prairies usually causes an early spring flood, and larger floods occur in June, when run-off from snow-melt in the mountains is supplemented by heavy spring rainfall. Continuous heavy rainfall during September and October has caused appreciable rises in the normally low fall flow. The flow in the river is subject to some regulation by power and irrigation works on tributaries in Alberta, and although this effect is negligible during the flood season, the diversions for irrigation appreciably reduce the total annual discharge.

Diversion of water for irrigation and urban water supply, and storage for power, has varied considerably during the period for which hydrometric records on the South Saskatchewan River are available. To get a picture of the water available for the South Saskatchewan River project, it is necessary to assemble complete data on recorded flows, and then reconstruct the natural flows, by taking into account the historical upstream uses of water. By allowing for the water requirements of all the existing and planned projects upstream, it is possible to obtain an estimate of the water available for the project in the future.

Fairly complete hydrometric records for the South Saskatchewan River have been kept at Medicine Hat and Saskatoon since 1911. The average annual recorded flow at Saskatoon for the period 1911-1948 was 7,128,000 acre-feet, varying from a maximum of 14,610,259 acre-feet in 1915-1916 to a minimum of 3,440,000 acre-feet in 1940-1941.

Water from the watershed has been used in the past by Saskatchewan, Alberta and United States irrigationists. In order to determine the net water diversion by

historical users, it is necessary to study the operation of the following projects:

*Milk River Project	United States
St. Mary-Milk River Project	Alberta
Leavitt Irrigation District	Alberta
Mountain View Irrigation District	Alberta
United Irrigation District	Alberta
Lethbridge Northern Irrigation District	Alberta
Canada Land and Irrigation Company	Alberta
Eastern Irrigation District	Alberta
Western Irrigation District	Alberta
Swift Current Irrigation District	Saskatchewan
City of Calgary Water Supply	Alberta

The existing and planned irrigation projects with acreages to be irrigated are tabulated in Table I. All of these projects are in Alberta with the exception of the Swift Current Irrigation Project, which is in Saskatchewan.

TABLE I

Project	Acreage Area Under Irrigation 1952	Ultimate Irrigated Acreage Allowed for
Western Irrigation District.....	50,000	50,000
Eastern Irrigation District.....	200,000	281,000
Bow River (Canada Land) and Irrigation Co.....	50,000	240,000
Lethbridge Northern Irrigation District.....	75,000	96,135
United Irrigation District.....	21,000	34,000
Mountain View Irrigation District...	3,600	3,600
Leavitt Irrigation District.....	2,500	4,400
Aetna Irrigation District.....	50	7,300
St. Mary-Milk River River Project..	150,000	495,000
Red Deer Project.....	Planned only	350,000
Macleod Irrigation District.....	500	5,000
Small Projects(1).....	Planned only	64,000
Swift Current Irrigation Project.....	7,500	21,000
Private projects.....	50,000	70,000
	610,150	1,721,400

(1) Possible small projects are:

	acres
Carmangay.....	12,000
Macleod Extension.....	20,000
Pincher Creek.....	16,000
Oldman projects.....	16,000
	64,000

Estimates of the future upstream requirements of these projects have been based on the assumption of an eighteen-inch duty of water and an 80 per cent irrigation factor, with varying allowances for conveyance losses and return flows. It has also been assumed that the Clearwater River, tributary of the North Saskatchewan River, will be diverted into the South Saskatchewan watershed to help irrigate the Red Deer Project. No allowance need be made for the 15,000 acres that will be irrigated on the St. Mary-Milk River Project from the Milk River.

Hydro-electric power developments in the watershed are limited to those in operation on the Bow River by the Calgary Power Ltd. The regulation of flow from its storage reservoirs of 536,000 acre-feet is taken into account.

TABLE II

Average Annual Flow of South Saskatchewan River (1911-48) Ac. ft.

Type of Flow	U.S. Water*	At Alberta-Saskatchewan Boundary	At Saskatoon	At Damsite
Recorded.....	Included	6,947,000	7,128,000	7,115,000
Historical Canadian Use....	.....	616,000	618,000	618,000
Natural.....	Excluded	7,427,000	7,610,000	7,597,000
Future Canadian Use....	.....	2,140,000	2,180,000	2,165,000
Available.....	Excluded	5,287,000	5,430,000	5,432,000

* Unused portion of United States share of the flow of St. Mary River.

The water available to the South Saskatchewan River Project is tabulated in Table II. This water study indicates that the

*By order of the International Joint Commission in 1921, the United States has the right to use a certain portion of the St. Mary River.

average annual flow available at the damsite, based on records from 1911-1948, is 5,432,000 acre-feet. Some consideration should be given to the fact that upstream projects will not be developed to the extent allowed for in these studies for several years, and in the interim, all the additional water would be available for the production of additional commercial energy at this Project.

Water Utilization

The reservoir created by a dam on the South Saskatchewan River, will provide live storage for 4,000,000 acre-feet of water, enough to allow beneficial use of all the flow in the river, during all but the very high flow years. Creating a reservoir of this size in the prairie region would provide a source of water which could remedy many of the water deficiencies in the immediate area.

1. *Irrigation.*—The primary purpose of the project is irrigation. It is estimated that 455,000 acres of land can be irrigated by water from the South Saskatchewan Reservoir. Several compact blocks, which are spread out from Saskatoon to Elbow in the north and south direction, and from Colonsay to Asquith in an east and west direction, make up 431,000 acres of this area. In addition, some small parcels of land, 24,000 acres in all, can be irrigated along the Qu'Appelle Valley.

Topographical surveys have not been completed to the stage where all the irrigation works can be designed. Sufficient information is available, however, to make a preliminary layout of these works.

All of the irrigable lands cannot be reached by gravity canals. It is planned, by the use of hydro-electric energy generated at the damsite, to pump water from the reservoir to irrigate lands which lie as much as 120 feet above the gravity canals. A summary of the gravity areas, and those requiring pump irrigation, is given in Table III.

TABLE III

South Saskatchewan River Project

Area	Static Lift ft	Area to be Irrigated acres	Main Canal			Pumping Plants		
			Section	Capacity cfs	Length miles	Pump No.	Capacity cfs	Lift ft
1	0	69,300	Canal 1					
			Main	2,909	3·9			
			Sec A	1,360	16·2			
			Sec B	1,050	21·9			
			Sec C	230	10·5			
			Sec D	200	6·0			
2	0	15,300	Canal 2					
			Main	2,137	16·8			
			Sec A	1,711	16·2			
			Sec B	1,371	7·5			
3	0	11,900	Canal 3					
			Sec A	1,326	4·3			
			Sec B	132	6·7			

TABLE III—*Con.*

South Saskatchewan River Project

Area	Static Lift ft	Area to be Irrigated acres	Main Canal			Pumping Plants		
			Section	Capacity cfs	Length miles	Pump No.	Capacity cfs	Lift ft
4	0	28,800	Canal 4	793	16·2			
5	0	22,500	Canal 5	404	18·0			
6 and 11	15 and 30	24,100	Qu'Appelle River					
7	15	18,750	Canal 7	343	15·6	XI	340	15
8	15	7,000	Canal 8	335	10·8			
8*(a)*	10	2,100	Sec A	57	3·9	IV	100	10
			Sec B	100	2·7	VI	57	15
9	0	11,900	Canal 9	245	19·5			
			Canal 10					
10	18	5,000	Sec A	315	11·7			
10*(a)*	0	10,000	Sec B	200	8·4			
			Sec C	110	8·4	V	100	18
			Canal 12					
12	39	39,600	Sec A	1,550	8·1	I	1,550	39
			Sec B	600	24·6			
13	30	11,700	Canal 13	230	12·0	X	250	30
			Canal 10					
14	0	10,000	Sec A	1,131	1·3			
14*(a)*	15	8,000	Sec B	1,006	7·2			
			Sec C	156	3·3	VIII	150	15
			Canal 15					
15	73	34,200	Sec A	130	9			
			Sec B	1,050	9·6	II	1,150	34
			Sec C	430	39			
16	60	19,600	Canal 16	354	14·6	VII	350	60
17	60	26,600	Canal 17	466	18·9	IX	450	60
18	123	33,700	Canal 18	640	45	III	650	50
19	120	10,800	Canal 19	232	14	XII	575	120
20	120	23,100	Canal 20	439	18	XII	575	120
21	120	11,000	Canal 21	232	21·6	VII	200	120

Totals: Gravity	179,800	30′ lift	70,400	120′ lift	78,600
15′ lift	45,750	60′ lift	80,400		455,000

To supply water to all of the area it will be necessary to construct nearly 500 miles of canals and main ditches, and 12 pumping stations. The capacity of these canals will vary from 2900 cubic feet per second at the reservoir, to 100 cubic feet per second near the end of the system. Pumping plants will be required with capacities varying from 1550 cubic feet per second on the larger canals, to 100 cubic feet per second on the smaller lateral ditches.

A soil survey, covering 1,328,800 acres of this general region, has been completed. The soils were classified as to their suitability for irrigation in five soil classes. These were designated as "very good soils", "good soils", "fair soils", "poor (doubtful) soils", and "very poor (unsuitable) soils". The lands included in the irrigation plans have been selected from the first three soil grades. However, class four soil will be irrigated in some cases because of its proximity to the distribution ditches.

The development of the irrigation system could be carried on at any rate which seems desirable and practical. No water could be made available for irrigation until the dam has been practically completed. Therefore, it would not be necessary to start work on the irrigation system until three or four years before the scheduled completion of the dam. A reasonable program would plan to be ready to serve all the gravity lands by the time the dam was completed.

2. *Maintenance of Lake Levels.*—The development will permit diversion of the water down the Qu'Appelle Valley, and in addition to providing a water supply for irrigation there it can be used to maintain water levels in Long Lake and the six Qu'Appelle Valley lakes. This valley has been developed extensively as a recreation and resort area to serve a large part of the population of Saskatchewan and lowering of the lake levels during successive dry years in the past has seriously deteriorated these resorts.

3. *Urban Water Supply.*—The Government of Canada has agreed to maintain levels in Buffalo Pound Lake for a water supply for the cities of Regina and Moose Jaw. Water for this purpose will be obtained by pumping from the South Saskatchewan River. This obligation could be met with water by gravity flow from the large reservoir, which would result in saving the annual pumping costs.

4. *Power.*—Details of the power development, for the purpose of this section, have been drawn from the General Engineering Report issued by the P.F.R.A., March, 1952.

A study of stream flow characteristics and the distribution of energy demands in the power grid in Saskatchewan indicates that the generating station at the Coteau damsite should have an installed capacity of about 150,000 KW. Tentative plans are to install six 24,000 KW and two 4,000 KW units, which would give a total installed capacity of 152,000 KW. Water will be carried to the turbines by three 20-foot diameter steel penstocks inside the 25-foot diameter conduit openings. Each penstock will feed water to two units through Y-branches.

The approximate over-all dimensions of the powerhouse building, allowing for clearance between units, working space, office space and storage, will be 118 feet high, 88 feet wide and 365 feet long. The powerhouse will be founded on the hard shale and the location has been chosen so that the excavation required at the desired elevation will be

such that the weight of the excavated material will balance the weight of the structure and avoid either heaving or settlement.

The pumping of the irrigation water will utilize a portion of this energy, but large amounts of commercial energy will also be available. It is estimated that 325,000,000 KWH will be produced annually, 50,000,000 KWH of which will be required for pump irrigation at full development.

The generating plant would be ideally located to fit into the power grid of Saskatchewan. It is estimated that 53 per cent of the population of the province live within a radius of 125 miles of the dam, and 69 per cent within a radius of 150 miles of the dam.

5. *River Regulation.*—The wide variation of seasonal flow of this river has made power developments without large storage facilities impractical. The reservoir will provide almost complete regulation of the river flows and will increase the power potential of those downstream power sites where storage cannot be provided at the plant.

There are five potential power sites which would benefit from this regulation. Two 75-foot head sites exist between Saskatoon and the junction of the North and South Saskatchewan Rivers, and two 120-foot and one 50-foot head plants on the Saskatchewan River below the Forks. They are

Batoche	75-foot head
Coxby	75-foot head
Fort a la Corne ..	120-foot head
Nipawin	120-foot head
Squaw	50-foot head

The Fort a la Corne site has been studied in detail by the Saskatchewan Power Corporation. With an installed capacity of 125,000 HP this plant would be capable of producing 598,400,000 kilowatt hours of energy annually. The regulation provided by the reservoir will increase the annual output by nearly 100,000,000 kilowatt hours.

Studies have not been made of the other sites mentioned. However, the potential of these sites would be increased to a degree proportionate to that indicated for the Fort a la Corne site.

The Dauphin River site and those sites located on the Nelson River would not benefit materially by this regulation because of the large storage provided by Cedar Lake, Lake Winnipegosis, Lake Manitoba, and Lake Winnipeg.

6. *Floods.*—The Pike Lake area in the vicinity of Saskatoon, and the Carrot River area near The Pas, Manitoba, have been subjected to periodic flooding in the past. Creating this large reservoir on the river would virtually eliminate the flood hazard at Pike Lake, and materially decrease the magnitude of the floods in the Carrot River area.

Pertinent Data of Dam and Reservoir

Main dam, including conduit and spillway, Coteau Creek Dam, Third Meridian Dam and Elbow Railway Crossing.

Fill (including dredge fill)	57,509,000 cu. yd.
Riprap	702,000 cu. yd.
Concrete	989,010 cu. yd.
Cement	1,497,000 bbls.
Reinforcing steel	30,535 tons
Structural steel and steel plate	22,606 tons

Hydraulic

(a) *Drainage Areas* (Gross)

Stream	Gauging Station	Drainage Area
Bow	Bassano	7,610 sq. mile
Oldman	Lethbridge	6,710 sq. mile
Red Deer	Empress	18,160 sq. mile
South Saskatchewan	Medicine Hat	20,600 sq. mile
South Saskatchewan	Damsite	48,800 sq. mile

(b) *Reservoir*

—	Elevation	Total Reservoir Storage acre-ft.	Area of Reservoir acres
Maximum Water Surface	1,830·1	9,210,000	110,000
FSL	1,825·0	8,570,000	104,600
Spillway Crest	1,797·5	5,780,000	78,100
Maximum Drawdown	1,785·0	4,700,000	68,100

(c) *Recorded Flow at Saskatoon*

The following are the flows for the climatic year from October 1st to September 30th.

Average Annual (24 yr.)	7,127,000 acre-ft.
Maximum year (1915-1916)	14,610,000 acre-ft.
Minimum year (1940-1941)	3,440,000 acre-ft.
Maximum mean month (June, 1948)	59,830 c.f.s.
Minimum mean month (December, 1936)	997 c.f.s.
Maximum mean daily (June 6, 1923)	131,000 c.f.s.

(d) *Spillway Design Flood Data*

The spillway design flood is a synthetic flood.

Peak rate, inflow to reservoir	400,000 c.f.s.
Duration of Flood	16 days
Total volume of run-off	4,000,000 acre-ft.
Pool elevation at start of flood	1,825
Maximum pool elevation reached	1,830
Maximum spillway discharge	260,000 c.f.s.

(e) *Freeboard*

Computed	12·5 ft.
Provided (above FSL)	20 ft.

(f) *Outlet Works*

Size of Conduits	25 ft.
Number of Conduits	4

General Agronomic Aspects

In general the method of study of the agricultural features of the South Saskatchewan River Project has been to compare the proposed irrigated area in Saskatchewan with well established irrigated districts in Alberta. Many years of experience with irrigation agriculture in Alberta together with some knowledge of the Saskatchewan area have been drawn upon in this appraisal of the material contained in the P.F.R.A. report.

The two major irrigation developments in Alberta are in the vicinities of Brooks and Lethbridge respectively. Hence weather and crop data from these two points must be taken as applicable to the surrounding irrigated farm land. However, it should be pointed out that the immediate environs of the City of Lethbridge constitute only a fairly good irrigation area. The suitability of the area improves rapidly as one proceeds eastward from Lethbridge. The Taber district, 35 miles east, is much more successful in the production of heat-loving crops such as tomatoes, cucurbits, and corn. All authorities are agreed, and considerable experience

TABLE IV

Annual precipitation in inches at points in Alberta and Saskatchewan and in two irrigated districts of the United States.

Station	Years of Record	J	F	M	A	My	J	Jy	Au	S	O	N	D	Total
Brooks	(25)	·57	·50	·72	1·03	1·69	1·85	2·38	1·20	1·37	·65	·50	·60	13·06
Lethbridge	(42)	·62	·67	·94	1·11	2·32	2·72	1·75	1·52	1·73	·90	·75	·66	15·75
Medicine Hat	(49)	·72	·64	·74	·82	1·74	2·36	1·60	1·37	1·25	·71	·69	·67	13·27
Outlook	(34)	·64	·52	·50	·62	1·13	2·52	1·78	1·32	1·07	·65	·48	·38	11·61
Saskatoon	(46)	·59	·52	·57	·67	1·39	2·69	2·34	1·71	1·42	·80	·56	·47	13·69
Salt Lake City (Utah)	(40)	1·31	1·55	2·00	1·85	1·94	·74	·57	·91	·95	1·43	1·28	1·26	15·79
Fort Collins (Colorado)	(40)	·27	·64	1·08	2·13	2·82	1·56	1·64	1·32	1·52	1·17	·49	·56	15·20

indicates, that the Medicine Hat area will be much superior to Lethbridge district for irrigation farming. The main advantages for Medicine Hat are: (1) lower altitude, (2) less wind, (3) higher temperatures, (4) longer growing season, (5) somewhat lighter soil type.

In an appraisal of the various climatic factors, the data from Brooks, Lethbridge and Medicine Hat in Alberta, and Elbow, Outlook, and Saskatoon within the proposed irrigated area of Saskatchewan were used. Data for Elbow were not available on all climatic factors studied.

Long term weather records are available for Medicine Hat, and although extensive irrigation in the immediate district must await construction of the distributory system (the water is available from the St. Mary Dam), it was thought advisable to include weather data from Medicine Hat in this study.

Table IV shows the annual precipitation for these several points in Alberta and Saskatchewan, together with data from two irrigated areas of the United States.

TABLE V

Crop season precipitation (May to September inclusive) and percentage of total precipitation in the form of snow.

—	Crop Season Precipitation	Percentage of Annual Precipitation Provided by Snow
	in.	
Brooks	8·49	26
Lethbridge	10·04	31
Medicine Hat	8·32	27
Elbow	9·14	26
Outlook	7·82	31
Saskatoon	9·55	31

Thus Outlook has annual rainfall of 11·61 compared to 13·06, 15·75 and 13·27 for Brooks, Lethbridge and Medicine Hat respectively. Crop season rainfall shows Outlook with 7·82, Saskatoon with 9·55 and Lethbridge, Medicine Hat and Brooks with 10·04, 8·32 and 8·49 respectively.

The figures for the average evaporation from a free water surface for the period May to September are available for only two

locations, viz., Lethbridge—24·60 inches and Saskatoon—27·69 inches.

The potential evapo-transpiration according to the Thornthwaite method* for the six points is as follows:

Brooks—22·50, Medicine Hat—23·08, Lethbridge—22·18, Outlook—21·25, Elbow —21·82 and Saskatoon—21·04.

Saskatoon has more annual rainfall and more crop season rainfall but less evaporation than Outlook or Elbow. Thus from the point of view of moisture and moisture efficiency, Saskatoon would have less need for irrigation than either Outlook or Elbow.

In summary, the Outlook-Elbow district appears to be poorer dry farm area than Lethbridge. Outlook has less rainfall but also much less evapo-transpiration than Medicine Hat. The seasonal deficiencies of moisture (potential evapo-transpiration minus the rainfall) for the two points are: Outlook 12·01 and Medicine Hat 13·16. Thus Medicine Hat must be considered drier than Outlook.

Saskatoon must be considered much more favourable as to moisture conditions than Medicine Hat or Brooks, perhaps approaching Lethbridge in this respect.

The average yield of wheat (1920-48) in municipalities 345, 346, 375 and 376, which are in the proposed irrigation area near Saskatoon, varied from 11·6 bu. per acre to 13·3 bu. with an average of 12·5 bu. The six municipalities near Outlook, Nos. 283 284, 285, 313, 314 and 315 showed an average acre yield of 11·0 bu. with variation from 10·1 to 12·1 bu.

Long term records indicate that the Lethbridge district has slightly higher yield than either Outlook or Saskatoon and that the yields in the Medicine Hat and Brooks districts are poorer than in either of the Saskatchewan districts.

Prevailing Temperatures and Frost Free Season

The prevailing temperatures and the length of the growing season exert a decided influence on the suitability of an area for irrigation development. If ample moisture is available to good soil through irrigation, then temperature and length of growing season become the limiting factors in crop production.

Table VI indicates the mean monthly temperatures during the growing season at three points in the Southern Alberta area and three in the proposed irrigated area of Saskatchewan.

TABLE VI

Mean monthly temperatures during the growing season at Lethbridge, Brooks and Medicine Hat, Alberta, and at Elbow, Outlook and Saskatoon, Saskatchewan.

Station	Apr.	May	June	July	Aug.	Sept.	Oct.
Brooks.....	42	52	61	66	64	53	43
Lethbridge.....	43	51	59	65	63	54	45
Medicine Hat..	45	55	63	69	67	56	46
Elbow.....	39	53	60	68	64	53	42
Outlook.....	38	52	60	67	64	53	40
Saskatoon.....	37	51	60	65	62	51	39

A comparison of the highest average daily maximum temperatures and the lowest aver-

* Thornthwaite, an eminent U.S. climatologist, has made use of the term "evapo-transpiration". This numerical value for any given area can be calculated from records of mean temperature, giving due consideration to latitude. Evapo-transpiration is defined as the amount of water that would be lost from the soil to the atmosphere by evaporation and transpiration if water were continually available in optimum quantity.

age daily minimum temperatures shows Outlook to be very slightly warmer than Lethbridge but cooler than Medicine Hat during the months of May to September. Saskatoon is slightly cooler than Lethbridge in May and August, decidely cooler in April, but warmer in June; in July the temperatures are the same. Elbow is slightly warmer than Outlook.

A comparison with the mean July temperatures of some irrigated areas in United States is interesting; Havre and Chinook, two points in the irrigated Milk River Valley of northern Montana, have mean July temperatures of 68 and 70 respectively; the comparable figure for Salt Lake City is 77 and for Fort Collins, Colorado, 69. The decidedly lower temperatures at all Canadian points is quite apparent.

Growing Season and Frost Free Period

In Dr. Currie's report (*) the length of the vegetative period at various Alberta and Saskatchewan points is set forth. The vegetative period is defined as the number of days between the average dates when the mean daily temperature rises to 42°F. in the spring and falls to 42°F. in the fall. The appropriate data for three Stations in each of the two provinces are reproduced in Table VII, also included in this table are the median lengths of the frost free period, these latter figures were obtained by calculation from Dr. Currie's report.

TABLE VII

Number of days in the vegetative period and the median frost free period at Lethbridge, Brooks and Medicine Hat in Alberta, and Elbow, Outlook, and Saskatoon in Saskatchewan.

Station	Vegetative Season	Median Frost Free Period
	days	days
Brooks	187	118
Lethbridge	189	114
Medicine Hat	196	125
Elbow	177	
Outlook	173	115
Saskatoon	163	112

The superiority of the Alberta over the Saskatchewan stations in length of vegetative season is striking. However, in median length of frost free period Elbow and Outlook are quite similar to Lethbridge and Brooks. In actual practice the length of the vegetative period is the more important criterion since many crop plants will withstand a few degrees of frost and will thus make some growth during the early spring period if the days are warm enough, even though frosts may occur occasionally at night.

Dr. Currie's report shows a calculation of the "day-degrees" which is a value related to the number of days during the year when the temperature rises above 42°F., thus inducing growth of common crop plants. The data for the three pertinent stations in each of the provinces are as follows:

Alberta		*Saskatchewan*	
Brooks	2655	Outlook	2595
Lethbridge ..	2590	Elbow	2660
Medicine Hat	3342	Saskatoon	2231

* The Climate of the South Saskatchewan Irrigation Project, B. W. Currie, Ph.D., University of Saskatchewan, 1949.

Thus Outlook and Elbow compare favourably with Lethbridge which is a fair irrigated area. Once again the superiority of Medicine Hat is striking. Saskatoon has a decidedly lower number of heat units, even lower than Cardston in Alberta. Some small irrigation projects near Cardston have not proved to be well adapted to irrigated crop production.

Hours of Sunshine

The possible hours of sunshine during the summer months increase as the latitude increases. Thus Saskatoon has a possible total of 2313 hours of sunshine from May to September, whereas Lethbridge has a possible total of 2271. However, Lethbridge has received a long term average of 1386 hours for the period and Saskatoon has received an average of 1332. Dr. Currie has pointed out that the earlier onset of spring rains in Alberta brings about more cloud cover to this area in May and June than occurs in the Saskatchewan area.

In final summary with regard to temperature and frost free period, it would appear that the Elbow-Outlook area would be at least equally as suitable as the Lethbridge area, but inferior to the Medicine Hat district. The area around Saskatoon must be considered as somewhat inferior to the immediate environs of Lethbridge.

Soils.—The soils of the proposed irrigation area belong to the Dark Brown Soil Zone of the Province of Saskatchewan. In its native state the land supported a mixed prairie vegetation of short and medium-tall grasses. Some of the more dominant species were: blue grama grass, spear grass, western whe grass, pasture sage, northern wheat gras rough fescue, sedges, rose bushes and buck brush.

These dark brown soils are generally high fertility and regularly produce goo yields of grain when rainfall is ample.

The soil survey conducted by Moss *et* has rated the soils as to their suitability fo irrigation. This rating follows the method outlined by Bowser and Moss.*

Texture.—The texture of the soil is gener ally quite satisfactory for irrigation. Les than six per cent of the total land is classifie as clay. About 80 per cent of the propose irrigated land is included in the textura classes, Fine Sandy Loam, Sandy Loam Loam, Silt Loam, Silty Clay Loam an Clay Loam.

Topography.—A very large proportion o the proposed irrigated land exhibits nearly level, gently undulating to moderately undulating topography. There are also som areas with rolling topography but these ha presently been considered unsuitable for irri gation along with sand dune areas, poorly drained depressional areas and the cut-up lands adjacent to the streams and coulees.

Drainage.—The general area is well drained. The lands are of the upland prairie type and generally lie 200 feet or more above the level of the water in the streams. The water table of the area is generally quite deep, seldom above 20 feet. In the course of the soil survey 80 borings were made to study the permeability of the lower soil strata. A stratum of lower permeability was frequently encountered below the depth of 12 feet although in two cases such a layer w

* A Soil Rating and Classification for Irrigation Lands in Western Canada—W. Earl Bowser and H. C. Moss. Sci. Agr. 30: 164-171, 1950.

encountered at seven feet. In the opinion of the soil surveyors, "no special difficulty should arise in the soils overlying the impervious strata". The solonetz soils generally exhibit impeded drainage and require some care in handling in order to make successful irrigated farm land.

Salt Content.—Chemical analyses indicate that a proportion of the soils have soluble salts within the upper six-foot profile. Generally these salts are below a depth of 18 inches and are not of high concentration, generally well below one per cent in the upper three feet of soil, usually entirely absent in the upper two feet.

Marshall and Palmer (*) have reported on salt movement in an irrigated solonetz soil in Alberta. After 20 years of cropping the concentration of salts was generally reduced throughout the profile and there was apparently a gradual downward movement. The soils successfully produced crops for the 20-year period discussed (1917-37) and are currently (1952) in crop production. The authors state "that no harmful effects from these salts have been observed, although the concentrations in the lower depths remain moderately high and might cause deterioration of the soil should a rise in position take place." None of the analyses quoted in the Soil Survey report of the Saskatchewan soils is as high in concentration of soluble salts as were the Alberta soils studied by Marshall and Palmer. With normal care in the application of water, alkali salts should not become a problem in the proposed irrigated area. Normal care must include discreet location of canals and surface drainage ditches to prevent seepage and a rising water table, both of which tend to bring the alkali salts to the surface layers where they will limit crop production.

General Appraisal of Soils.—After considering soil texture, topography, alkali salt content, degree of stoniness, and degree of wind and water erosion, Moss *et al* indicate in the Soil Survey report that 25 per cent of the 450,000 acres which are suitable for irrigation is of Grade 1—very good irrigated land; 53 per cent is classified as Grade 2—good irrigated soil, and 22 per cent is Grade 3 or fair irrigated land.

The climate and soils of the proposed South Saskatchewan River area seem suitable for irrigation development. The need for irrigation and the probable success of it is greater in the southern portion of the area (near Elbow and Outlook) than in the northern segment (near Saskatoon). Experience in Alberta and elsewhere indicates that irrigation farming is rarely successful in areas where natural rainfall is sufficient to permit fair crop production. This fact would seem to urge caution in the extension of irrigation northward into the parkland belt.

In the Elbow-Outlook area it appears that irrigation could be established on a sound agronomic basis. The climate and soils of the area seem favourable for production of usual irrigated crops. Thus the question of ultimate success of the development seems to shift to economic and sociological considerations.

* Marshall, J. B. and A. E. Palmer. Changes in the nature and position of the soluble salts in certain Alberta soils after twenty years of irrigation, Sci. Agr. 19: 271-278, 1939.

Water Supply*

The purpose of the South Saskatchewan River Project is to irrigate an estimated 454,700 acres of land in Central Saskatchewan by constructing a dam across the South Saskatchewan River near Outlook. Associated with the plans for irrigation, it is proposed to develop hydro-electric power of which a part would be used to pump water to heights ranging from 15 to 120 feet to irrigate approximately 307,000 acres of the total area. In addition, it is proposed to create power for municipal and industrial uses. The Commission is requested to ascertain whether the economic and social returns are commensurate with the cost thereof.

Review of Physical and Economic Features

The economic feasibility of the proposed project depends upon various conditions and factors which may be briefly summarized as follows:

(a) The need for irrigation of the lands for increased crop production as compared with crops grown under the existing dry farming practice.

(b) The suitability of the soils for good crop production under irrigation within the limits imposed by climatic conditions.

(c) The topographic features with respect to roughness, steep or flat slopes which will permit irrigating the land by practical and economical methods.

(d) The volume and rate of flow of water with attending unavoidable losses, required for irrigation and power for pumping and other uses in relation to the available supply.

From various reports on climate, soil and crop production under dry farming methods during the past, it is indicated that conditions generally for a large part of the project would justify a conversion to irrigation farming if it is economically possible to do so. It is also apparent that a supply of water for domestic uses would meet an urgent need in municipalities and towns, and that power production would enhance domestic and industrial uses within limits of its economic production.

The largest and most costly part of the proposed project is the dam, the location of which is fixed by topography along the Saskatchewan River and by the geological formations necessary to the security of a very large dam. Aside from the dam there remains the cost of main and branch canals, lateral distributary systems with appurtenant structures and, in this case, provisions for a large amount of mechanical equipment for pumping water.

Irrigation Requirements

The volume of water supply and rate of flow for irrigation is based on certain definable but varying factors. The variations are the result of climate as influenced by temperature, length of growing season and rainfall; by soil condition; by kind of crops grown, and the average results of unregimented farm operations as related to land preparation; time of planting crops, and the efficiency of individual farm management.

* This section was prepared as a memorandum respecting requirements and water supply by D. W. Hays.

The effect of these many influences on irrigation requirements is not definitely predictable. The most influential factor is the volume and date of occurrence of rainfall. In wet years little or no irrigation is required whereas in dry years an abundant supply of water is needed. If a project is to be successful, the size of irrigation works and water requirements must be based on a reasonable assurance of fulfilment in dry years, not the driest year, but for a period of average dry years. Conversely, it is equally important that large and expensive works should not be built if years of sufficient to ample rainfall for crop growth will preclude continued practical irrigation.

Before proceeding to a review of the use of water, it is perhaps pertinent to the problem to give a brief description of irrigation factors and to explain the reasons for a considerable variation in the measure of these factors.

Irrigation Factor

This factor is the percentage of the gross irrigable area irrigated in one irrigation season. It will vary with climatic conditions, the progress of land development and in changes in crop production from growing grain to mixed farming and on to specialty crops. It will be affected by the areas of land summer-fallowed or left idle.

Duty of Water

This represents the quantity of water in depth on the land needed to produce the optimum growth of crops. It is legally fixed for administrative purposes by the "Irrigation Act" and "Water Resources Acts" at 1·5 feet depth on the land and is expressed at 1·5 acre feet for the irrigation season May 1 to September 30. The Duty of Water will vary with the seasons, particularly with the date and amount of rainfall in relation to the requirements for the kind of crops grown.

Irrigation Period, Depth of Application and Ditch Head

These factors are inter-related in irrigation practice.

The average depth of water applied for one irrigation will approximate 6 inches on fairly well-prepared land but may exceed this amount on poorly prepared land particularly during stages of early farming practice. It may be reduced to 4 inches for well-prepared land and the method used for irrigating.

The length of irrigation period depends on the rate of flow of water supply or "ditch head".

These factors all combine to provide sufficient depth of irrigation within a period of from 12 to 20 days which will preclude deterioration and unequal growth of crops in a farm unit, and also prevent unnecessary waste of the irrigator's time. The usual request for water varies from 2·0 to 3·5 c.f.s. Too small a flow results in over-soaking land near the source of supply and inability to spread water. Too large a flow may result in waste and possible damage to the farmer's own or his neighbour's crops. A sufficient ditch head is a highly valued asset to the irrigator about which he will vigorously complain in the event of short supply. In

these respects, however, there is a tendency to over-irrigate or demand more water than is actually needed, particularly by inexperienced and careless irrigators.

These conditions result in an irrigation demand and, under proper use, constitutes good irrigation practice in the best interests of the farmer which governs the purpose of the project.

Demand Factor

This is the aggregate of all ditch heads to be supplied in one irrigation period. The demand factor will vary largely with wet and dry years and be at its maximum in a dry year. If the maximum is assumed at 100% then the maximum canal supply, in theory, could be determined as follows:

Assume an area (A) of 5,000 acres, that the irrigation factor (I.F.) is 80%; that the average depth of irrigation (d) is 0·5 feet to be supplied in a period (p) of 16 days during a dry year of maximum use of water at 100%, then:—

$$(A)\ \frac{5{,}000 \text{ acres} \times \text{I.F.}80\% \times (d)\ 0{\cdot}5}{(p)\ 16 \text{ days} \times 2 \text{ (to reduce to c.f.s.)}} = \frac{2000}{32} = 62{\cdot}5 \text{ c.f.s.}$$

Since, however, none of the above factors is definitely predictable, an over-all factor based on known conditions of flow in operated projects may supply the best answer.

Flow Ratio

This is a ratio expressed as that part of the gross irrigable area which could be supplied by 1 c.f.s. In the above case it would be $\frac{5000}{62{\cdot}5}$=1 c.f.s. to 80 acres gross irrigable area.

The use of this ratio is a convenient and practical method for determining the required size of main and branch canals. It is applicable to areas of sufficient size, 5,000 acres or more, to provide for average conditions for a number of farm units.

Seepage

Additional capacity must be made in all irrigation works to provide for seepage losses in the course of transportation of water from source of supply to the point of furthermost delivery. Seepage losses vary with soil texture. In theory, for canals in prairie soils, it is frequently estimated at 6 c.f.s. per million square feet of the wetted area of the canal. This would be an intermediate factor between losses for clay loam and losses for sandy loam according to tests made many years ago by the United States Reclamation Service. No reliable information is available for canals operated in Canada.

Evaporation from reservoirs in the open prairie may be assumed at 2·5 feet depth per year varying from practically nothing in winter months to a maximum during July and August. Long days, high temperatures and dry winds increase evaporation losses.

It is perhaps pertinent to say that no branch of engineering work for which large amounts of money are spent, is subject to so many variable and unpredictable factors. In face of these conditions some of the large irrigation projects in Alberta were first built undersize as evidenced by enlargements made since the original construction. The possible exception lies in erroneous early judgment of the sustained need for irrigation wherein rainfall in excess of early expectations

resulted in sporadic use of irrigation and the utimate conversion of the project largely to the needs for stock water. In these respects a fine line of demarcation may exist in the varied conditions of climate and soil conditions within a short distance or even within the limits of the project itself.

The degree of success of an irrigation project or part thereof depends on the yearly need and use of irrigation with a minimum of exceptions and not in the reverse order to the ultimate failure of its original purpose.

Review of Use of Water in Large Projects

The first large irrigation project in Canada was started about 1910. In the following few years three more large projects were under construction by private companies. In the early 1920's several irrigation districts were formed and works built. Except for small project extensions no new irrigation developments were undertaken until the starting of work in recent years by the P.F.R.A.

These older projects provide a history of irrigation developments in Canada and some measure of irrigation factors relative to the use of water. Unfortunately, they are not consistent each with another due partly to the method used in supplying water and procedure in keeping records. Data from some of the large projects have been obtained for the past ten years, 1941 to 1950 inclusive, as shown by Schedules 1a, 1b, etc. attached.

Table No. 1 is a summary of the average factors for the ten-year period.

Variation of Factors

The principal reason for differences in the foregoing summary is due to a common and convenient practice in some projects of turning more water into the main supply canal than is actually needed for crops, except possibly at maximum demand, and allowing the excess water to return to the rivers as waste water. Some variations occur due to the size of the project for which water is turned into the canals in anticipation of demands at remote parts of the project. Variations are expected due to local climatic conditions and kind of crops.

The Eastern Irrigation District, Schedule 1a, includes the irrigation of summer-fallow as a part of the irrigated area although water supplied is probably less than required for the cropped area. The area has been deducted in the summary in relation to Irrigation Factor to correspond with other projects. If the quantity of water used for summer-fallow were deducted, the Duty of Water for the cropped area would be higher. The Flow Ratio as shown is very high, being based on the diversion of 2600 c.f.s. from the river plus diversion from four reservoirs and therefore includes reservoir storage served to the lands under them. The Manager states:

> "If the farmer will irrigate early, before the rush is on, the ditchrider will encourage him to take 4 to 5½ feet of water and finish his irrigation as soon as possible before the peak. We try to give each man 2 c.f.s. for each irrigation head during peak deliveries, allowing for topography of the area in which he lives.
>
> The extensive distance of most all farm lands from our intake supply necessitates us keeping a constant stream in our canals and filling our reservoirs in anticipation of irrigation demands that could reach an intense peak in 36 to 48 hours. Quite often

TABLE NO. 1

Use of Water in Large Irrigation Projects Operated in Alberta

Year	Irrigation Factors				Duty of Water				Flow Ratio l.c.f.s. to gross irrg. area				Project	Miscellaneous Data						
	E.I.D.	L.N. I.D.	St. M. and M.R.	C.L. and I. Co.	E.I.D.	L.N. I.D.	St.M. and M.R.	C.L. and I. Co.	E.I.D.	L.N. I.D.	St. M. and M.R.	C.L. and I. Co.		Aver. farm units acres	Depth per Irrig.	Ditch head c.f.s.	No. Irrigations			
																	Grain	Hay and Past.	Beets	Canning
1941	84·2	75·9	75	69·5	1·38	1·58	1·19	1·05	41	82	118	68	E.I.D.....	140	6 in.	2 to 3	2	2	.....	3½
1942	88·8	39·1	45	69·7	0·76	1·78	1·22	·82	50	115	137	94	L.N.I.D...	160	6 "	2	2	2	3	3
1943	70·0	81·7	88	72·2	1·57	1·85	1·33	1·18	41	113	104	81	St. M. and M.R.....	110-120	6 "	2 to 3	2	3	3	2
1944	83·8	93·2	80	71·8	1·47	1·60	1·33	1·11	43	128	121	105	C. L. and I. Co.....	120	6" to 4"	2 to 3·5	2	2	.....	.....
1945	82·0	70·6	75	68·9	1·29	1·48	1·16	1·09	40	95	112	81								
1946	87·7	85·2	90	75·5	1·30	1·47	1·36	1·07	40	98	107	102								
1947	85·7	72·3	85	78·1	1·13	1·34	1·13	·90	42	96	104	82								
1948	83·6	73·0	35	74·7	·92	1·10	1·22	·88	42	105	134	80								
1949	88·1	90·4	80	76·7	1·59	1·58	1·18	1·35	43	102	117	73								
1950	84·7	96·5	80	74·6	1·25	1·36	1·25	1·08	46	111	98	76								
Mean	83·8	77·8	73·3	73·2	1·27	1·51	1·24	1·05	42	104	115	84								

Length of irrigation period for Grain and Hay varies according to size of ditch head from 12 to 20 days for 160 acres.

Irrigation of any crop will approximate 4 acres for each 1 c.f.s. of ditch head.

NOTES:

Irrigation Factors—exclude Summer-fallow.

Duty of Water—E.I.D. includes irrigation of summer-fallowed land.
L.N.I.D. includes seepage in canal and excess water.
St. M. & M. R. includes seepage and is short of water in some years.
C.L. & I. Co. shows net delivery to land.

Flow Ratio—E.I.D. not comparable with other projects as it includes total water diverted from Bassano Dam plus draft from four reservoirs without reference to reservoir inflow from Dam versus outflow of reservoir.
St. M. & M. R. to some extent may have low supply due to shortage of water. C. L. & I. Co. limited by canal size and could have used larger flow in some years.

an unexpected heavy rain forces us to spill water in the Bow or Red Rivers. During the customary three weeks' irrigation period, there is no extra water in our District and no water being spilled in any of our divisions."

The Lethbridge Northern Irrigation District operates on the principle of diverting more water than needed for crops with surplus water returned to the river of which a part, however, may be used on a rental basis.

The St. Mary and Milk River Project has to some extent been short of water for all periods of the irrigation season for which provisions are made in the construction of the St. Mary dam. There has been a tendency to irrigate early in anticipation of a shortage later in the season.

The Canada Land & Irrigation Co. Ltd. was under gradual and continued enlargements of its main canal with capacity barely sufficient to meet demands. There were no provisions for taking care of excess water, hence the operation of the canal was closely adjusted to actual crop needs with daily inspections at farm headgates. The data is therefore not comparable with projects where a surplus of water could be diverted. The crops in this project were largely grain with limited areas of hay and pasture crops.

For the Western Irrigation District (not shown in Table No. 1) the Manager states:

"Since the District was formed in 1944 there has been very little record of the irrigating done in the project. The farmers are largely wheat growers and do not wish to irrigate, but there is a tendency to go into livestock raising and mixed farming which will no doubt increase the use of water. In most years a fairly good crop can be grown without irrigation and irrigation is largely just an insurance against crop failure from drought."

The project has been in operation over 30 years and is still in a prospective stage in relation to irrigation needs as a result of borderline climatic conditions and the farmer's attitude toward irrigation where average rainfall will produce fair to good grain crops in most of the years.

Proportionate Use of Water in the Irrigation Season

Data to show the proportionate use of water during the irrigation season will vary with the seasons and kind of crops grown. Where grain is the major crop, large quantities are required, usually in the period of 15th June to 15th July, with little or no irrigation in August and September when grain crops mature and are harvested. With the inclusion of hay, pasture and vegetable crops, more irrigations are required extending into the late summer and fall.

Where diversions of water from the natural flow of a stream are made without storage regulation, the proportionate use by months is a matter for close attention in relation to water supply.

In the case of the South Saskatchewan River Project with a large reservoir planned for immediate and direct supply of water, the proportionate use of irrigation in the limited time of maximum demands will have little general effect on the reservoir supply, except in the matter of reservoir evaporation.

It is generally agreed that the maximum demands occur within a thirty-day period, June 15 to July 15, with variations in the succeeding months according to character

of crops. In order to correlate irrigation demands with the conventional records of stream flow and power load factors, the requirements for irrigation are herein adjusted to calendar months.

A summary of data obtained is as follows

Percentage of Use of Water by Months

—	April	May	June	July	Aug.	Sept.	Oct.	Total
								%
Lethbridge Ex. Station	.....	10	20	30	20	10	10	100
St. Mary's and Milk River	03	17	19	24	16	12	09	100
C.L. & I. Co. (a)	.....	3·9	41·0	47·2	3·9	1·1	2·9	100
C.L. & I. Co. (b)	.....	5·3	32·2	38·5	10·0	6·5	7·5	100

(a) Delivery of water at farm unit headgates at Vauxhall.

(b) Flow of water at Drop No. 3 on Main Canal 20 miles above District and includes seepage to headgates and flow for summerflow and stock water in months August to October.

The records of the Lethbridge Experimental Station relate to use of water on a variety of crops grown and irrigated under careful supervision.

Records for the St. Mary and Milk River Project, years 1941 to 1950, are measurements at farm unit headgates for grain, hay, pasture and vegetable crops, and reflect the use of water for the latter crops in August and September. Early irrigations in April and relatively large amounts in May are partly attributed to the practice of farmers to irrigate when water is available in anticipation of a shortage of water later in the season which has occurred during the past for this Project. Excluding this condition, it is probable that less water would be used in May and more in June.

In the Canada Land & Irrigation Company Project at Vauxhall, where grain is the major crop, irrigation reaches its maximum in the period June 15 to July 15, shifting according to seasons, with little water used after July 20 except for stock water or summer-fallow land.

Early irrigation in May is largely for alfalfa and pasture. Grain crops are not usually planted and ready for irrigation before the latter part of May. Except where required for germinating seed, it is not practical to irrigate grain before the grain is well sprouted in order to avoid washing the soil surface and channelling in the process of irrigation.

Estimated Use of Water for South Saskatchewan River Project

The use of water as related to all irrigation factors must be predicated on an estimate of future development in the proposed project.

Like all projects, it is probable that agriculture under irrigation for some time will be confined to growing grain with gradual transition, in part, to hay and pasture for growing and fattening livestock with some areas in vegetable crops. It is not expected that a project of its size can be soon con-

verted to a highly developed project for growing sugar beets, canning crops and other specialty crops, which can be commercially produced in Canada, pending a very large increase in Canada's population and improved market facilities.

With respect to various factors the following suggestions are made:—

Irrigation Factor

In view of the probable production of grain crops for some years and concurrent need for summer-fallow, the Irrigation Factor will approximate 80 per cent.

Duty of Water

For actual use on grain crops it is probable that a "Duty of Water" of 1·3 feet would be sufficient in average dry years, no water being required for fall irrigations. Upon including hay and pasture crops with limited areas in vegetables requiring late summer and fall irrigations, the Duty of Water will increase. Taken together it is estimated that 1·5 acre feet may be required in average dry years.

Depth of application, period of use and ditch head are factors relative to size of lateral works required by farmers to irrigate crops without loss or waste of the irrigator's time. Provision should be made to deliver 3 c.f.s. to each farm unit subject to probable demands on the lateral system varying from 100 per cent for one farm unit to 70 per cent for an area up to 5,000 acres. This will provide for some leeway in ditch capacity for one lateral ditch system in relation to the average for several lateral ditch systems to be supplied by the main canal.

Percentage of Use during Irrigation Season

There will be some variations in the percentage of use of water by calendar months according to crops grown. It is anticipated for the South Saskatchewan River Project that grain will be the major crop for many years with gradual transition to livestock and mixed farming for a part of the area in due time.

Having regard to all conditions the following percentages of use are suggested:

May	June	July	Aug.	Sept.	Oct.	Total
						%
10	30	30	15	10	5	100

Small variations in percentage by months will not affect the reservoir supply except for minor changes in evaporation.

Flow Ratio

Regardless of any or all factors pertaining to irrigation, if the size of works will meet peak demands, then all other conditions can be fulfilled limited only by the available reservoir supply. Referring to flow ratios for operated projects, as shown by Table 1, it is suggested that 1 c.f.s. net delivered at farm unit headgates to 90 acres gross irrigable area should meet requirements. To the maximum rate of flow so determined provision must be made for seepage for which 6 c.f.s. per million square feet of wetted area is suggested.

Power Requirements

Power is required for pumping water from 15 to 120 feet above gravity supply level for approximately 307,000 acres. For this purpose average monthly requirements for power will approximate 25,000 H.P. during June and July. The remaining available water supply in the reservoir may be used for commercial power for which average monthly load factors as a percentage of peak loads in December, typical of operated plants, is estimated as follows:—

November	54%	March ..	46%	July	43%
December	58%	April ...	44%	August ..	45%
January	50%	May	43%	September	48%
February	49%	June	43%	October .	51%

Relation of Water Requirements to Water Supply

Table No. 2 attached shows available water supply in South Saskatchewan River for a period of 25 years which include seven successive years, 1934-35 to 1940-41, when the flow of water averaged less than any other corresponding period of record. The flow is taken from data compiled by the Prairie Province Water Board, Report No. 3. dated March, 1951, showing flow of South Saskatchewan River at boundary after Alberta's request for Red Deer and small irrigation (with Clearwater diversion) Condition B.

Table No. 3 is an estimate of water required for 454,700 acres at 80 per cent I.F. plus estimated seepage losses at 60 per cent from reservoir to land served. The estimated seepage is a mere guess pending data on the length and size of supply canals.

Table No. 4 shows estimated average power per month required to pump water for the areas of land to be served by pumps with estimated seepage losses reduced to 40 per cent to provide for that part of the canal losses from pumps to lands served. The quantity of water required for irrigation as per Table No. 4 is provided for in the estimates as per Table No. 3.

Tables Nos. 5a, 5b, etc. These Tables show the effect on the reservoir with dam in the Qu'Appelle Valley at Elbow for seven successive years in the relation of available reservoir supply to required outflow to meet demands under condition of the various factors used for irrigation and power.

The rate of flow of water from the reservoir for generating power will vary within the limits of the available power head between the maximum water surface elevation of the reservoir and the required supply level of water in the canal for irrigation. The maximum elevation of water surface in the reservoir is El. 1825, the full supply level of the canal El. 1800, and the bed of the canal El. 1787·5.

Preliminary trials have been made to ascertain whether or not the water supply in the reservoir, during the cycle of dry years 1933 to 1940, would provide for irrigation, pumping and the typical commercial power loads for a plant of 150,000 H.P. Another trial was made for a plant capacity of 120,000 H.P. In both cases the available water supply from the reservoir was insufficient to an extent that the reservoir drawdown depleted the water surface in the reservoir below the required elevation to supply the canal.

TABLE NO. 2

Showing flow of South Saskatchewan river at boundary after Alberta's request, Red Deer and small Irrigation (with Clearwater Diversion) condition B, as shown by records by Prairie Province Water Board Report No. 3, dated March 1951, Table 27

Years	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Totals C.F.S. Mos.	Totals Ac. Ft.
1923–24	4,671	3,817	3,646	4,072	3,962	1,259	7,497	13,506	7,586	9,531	4,558	3,603	67,708	4,062,480
24–25	4,363	4,095	3,908	4,250	8,445	13,527	11,692	14,614	6,767	7,330	7,750	9,242	95,983	5,758,980
25–26	6,005	4,676	4,064	4,026	9,280	7,285	2,100	4,939	5,673	3,771	20,080	13,894	85,793	5,147,580
26–27	7,793	5,352	4,622	4,473	6,365	13,836	16,878	39,008	21,417	15,381	17,747	10,800	163,672	9,820,320
27–28	6,594	5,425	8,429	5,738	13,203	9,632	12,739	36,512	30,023	7,264	5,211	5,942	146,712	8,802,720
28–29	5,620	4,060	4,614	4,140	6,712	3,041	8,894	24,053	1,859	1,621	1,831	3,723	70,438	4,226,280
29–30	4,025	4,325	3,879	6,438	6,014	5,850	6,946	7,830	6,080	1,982	2,288	4,278	59,935	3,596,100
30–31	4,286	4,482	4,048	3,811	3,831	2,023	1,495	3,416	2,144	1,039	2,064	4,601	37,242	2,234,520
31–32	3,630	3,329	3,443	3,486	4,686	5,094	8,303	29,297	7,472	2,304	4,560	4,025	79,629	4,777,740
32–33	4,525	4,277	3,913	3,993	4,819	4,265	18,552	16,120	5,667	1,105	1,504	2,820	71,860	4,311,600
33–34	6 228	4,866	4,941	5,321	4,699	6,496	14,800	16,406	2,896	798	1,601	4,491	73,543	4,412,580
34–35	6,102	4,185	4,356	5,288	4,794	5,338	4,468	9,553	8,155	6,733	2,486	3,668	65,121	3,907,260
35–36	3,932	3,547	3,114	3.491	6,510	10,696	5,853	7,290	1,033	1,016	1,313	2,465	50,260	3,015,600
36–37	3,193	2,552	2,738	3,109	3,982	3,533	1,697	9,168	1,439	1,005	1,857	3,437	37,710	2,262,600
37–38	4,587	4,452	4,201	3,645	5,734	6,891	9,394	13,076	9,221	3,461	4,527	4,679	73,868	4,432,080
38–39	4,525	4,115	3,647	3,389	5,549	3,822	2,906	12,001	6,485	1,529	2,367	3,533	53,868	3,232,080
39–40	4,326	3,578	3,574	3,539	5,483	9,582	8,203	3,894	2,456	2,148	3,783	5,495	56,061	3,363,660
40–41	4,977	4,120	3,619	3,809	5,987	3,862	1,600	2,447	2,031	1,344	3,206	5,038	42,040	2,522,400
41–42	4,415	3,702	3,594	3,221	3,892	3,672	15,193	23,041	19,866	11,728	9,004	6,712	108,040	6,482,400
42–43	4,919	3,956	3,815	4,548	6,755	21,050	5,208	14,369	12,142	3,853	1,782	3,259	85,926	5,155,560
43–44	3,647	3,806	3,740	3,636	3,585	2,349	251	7,164	5,166	7,452	3,167	2,813	46,776	2,806,560
44–45	3,523	3,659	3,431	3,486	5,467	2,365	6,192	19,401	8,421	3,160	4,624	6,351	70,080	4,204,800
45–46	4,192	4,520	4,443	4,024	7,032	6,670	5,389	19,989	8,748	2,415	6,909	5,588	79,919	4,795,140
46–47	5,049	5,155	4,649	5,039	13,385	13,770	17,023	17,228	10,010	4,676	6,706	10,005	113,295	6,797,700
47–48	6,977	4,530	4,297	3,983	6,261	25,338	48,653	48,938	12,496	10,736	3,470	.....	175,679	10,540,740

TABLE No. 3

Estimated water for 454,700 acres at 80% I.F. plus estimated seepage losses at 60% from reservoir to land

—	Pump Lift	Area—Acres	Net Area at 80% I.F.	May	June	July	Aug.	Sept.	Oct.	Totals	Totals ac. ft.
Percentage of Use				10%	30%	30%	15%	10%	5%	100%	
Depth per acre on land—ft.				·15	·45	·45	·225	·15	·075	1·5 a.f.	
Assumed Losses at 60%				·09	·27	·27	·135	·09	·045	·9 a.f.	
Total depth per acre				·24	·72	·72	·36	·24	·12	2·4 a.f.	
Water Requirements—											
To land by gravity, Div. 1 to 5		147,700	118,160	473	1,418	1,418	709	473	287	4,778	286,680
To be Pumped—											
Divs. 6, 7 and 8	15′	42,850	34,280	137	411	411	206	137	69	1,371	82,260
Divs. 9 to 14	30′	106,150	84,920	340	1,019	1,019	510	340	170	3,398	203,880
Divs. 15 to 17	60′	79,400	63,520	254	762	762	381	254	127	2,540	152,400
Divs. 18 to 21	120′	78,600	62,880	251	755	755	378	251	125	2,515	150,900
Totals to lands to be pumped		307,000	245,600	982	2,947	2,947	1,475	982	491	9,824	589,440
Totals—All Lands		454,700		1,455	4,365	4,365	2,184	1.455	778	14,602	876,120

TABLE No. 4

Estimated H.P. required to pump water for 307,000 acres at 80% I.F. plus estimated seepage at 40% from site of pump to land assuming pump efficiency at 75% and transmission at 90% ef.

—	Pump Lift	Area—Acres	Net Area at 80% I.F.	May	June	July	Aug.	Sept.	Oct.	Totals	Totals ac. ft.
Percentage of Use				10%	30%	30%	15%	10%	5%	100%	
Depth per acre on land—ft.				·15	·45	·45	·225	·15	·075	1·50 a.f.	
Assumed Loss at 40%				·06	·18	·18	·09	·06	·03	·60 a.f.	
Total depth per acre				·21	·63	·63	·315	·21	·105	2·10 a.f.	
Water to be pumped—											
Divs. 6, 7 and 8	15′	42,850	34,280	120	360	360	180	120	60	1,200	72,000
Divs. 9 to 14 incl.	30′	106,150	84,920	297	892	892	446	297	148	2,972	178,320
Divs. 15 to 17 incl.	60′	79,400	63,520	222	666	666	333	222	111	2,220	133,200
Divs. 18 to 21 incl.	120′	78,600	62,880	220	660	660	330	220	110	2,200	132,000
Totals		307,000	245,600	859	2,578	2,578	1,289	859	429	8,592	515,520
Divs. 6, 7 and 8	15′			303	908	908	454	303	151	3,027	
Divs. 9 to 14	30′			1,498	4,495	4,495	2,247	1,498	749	14,982	
Divs. 15 to 17	60′			2,240	6,720	6,720	3,360	2,240	1,120	22,400	
Divs. 18 to 21	120′			4,440	13,320	13,320	6,660	4,440	2,220	44,400	
Total H.P. (a)				8,481	25,443	25,443	12,721	8,481	4,240	84,809 =	45,552,600 KW Hrs

(a) H.P. at Power Plant $= \frac{\text{c.f.s. x h}}{\cdot 75 \times \cdot 90} = \frac{\text{c.f.s. x h}}{5 \cdot 947}$

TABLE No. 5a—1933-34

Service of Coteau reservoir for irrigation of 454,700 acres and water required for power to pump water for 307,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. × 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1933-34 c.f.s.	Reservoir		Bal. in reservoir, end of Mo. c.f.s.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1																50,000	
Nov.	54	54,000	594,000	178·0	3,337				96,200			3,337	6,228	2,891		52,891	
Dec.	58	58,000	638,000	178·5	3,574				96,700			3,574	4,866	1,292		54,183	
Jan.	50	50,000	550,000	179·0	3,072				97,400			3,072	4,941	1,869		56,052	
Feb.	49	49,000	539,000	180·5	2,986				99,000	·10	166	3,152	5,321	2,169		58,221	
Mar.	46	46,000	506,000	181·5	2,799				100,100	·15	250	3,049	4,699	1,650		59,871	
Apr.	44	44,000	484,000	183,5	2,637				102,500	·20	342	2,979	6,496	3,517		63,388	
May	43	43,000	473,000	185·0	2,556	1,455	504	1,959	104,000	·25	433	4,948	14,800	3,279		66,667	6,573
June	43	43,000	473,000	185·0	2,556	4,365	1,512	5,877	104,000	·30	520	8,953	16,406			66,667	7,453
July	43	43,000	473,000	184·0	2,571	4,365	1,521	5,886	103,000	·50	858	9,315	2,896		6,419	60,248	
Aug.	45	45,000	495,000	180·0	2,750	2,184	777	2,961	93,500	·50	821	6,532	798		5,734	54,514	
Sept.	48	48,000	528,000	177·0	2,983	1,455	527	1,982	95,000	·30	475	5,440	1,601		3,839	50,675	
Oct.	51	51,000	561,000	177·0	3,170	778	263	1,041	95,000	·20	316	4,527	4,491		36	50,639	
Totals	47·8%	574,000			34,991	14,602	5,104	19,706		2·5	4,181	58,878	73,543	16,667	16,028		14,026

Col. 7. Amount of water under given head (h) required to produce power to pump water as shown by Table 4, i.e., cfs = $\frac{HP \times 11}{h}$

TABLE No. 5b—1934-35

Service of Coteau Reservoir for irrigation of 454,700 acres and water required for power to pump water for 307,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. × 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1934-35 c.f.s.	Reservoir		Bal. in reservoir, end of Mo.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres.	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1	Forward from Oct. 31st, 193															50,639	
Nov.	54	54,000	594,000	178·0	3,337				96,200			3,337	6,102	2,765		53,404	
Dec.	58	58,000	638,000	178·5	3,574				96,700			3,574	4,185	611		54,015	
Jan.	50	50,000	550,000	179.0	3,072				97,400			3,072	4,356	1,284		55,299	
Feb.	49	49,000	539,000	180·0	3,000				98,500	·10	164	3,164	5,288	2,124		57,423	
Mar.	46	46,000	506,000	181·5	2,799				100,100	·15	250	3,049	4,794	1,745		59,168	
Apr.	44	44,000	484,000	182·5	2,652				101,500	·20	338	2,990	5,338	2,348		61,516	
May	43	43,000	473,000	182·5	2,592	1,455	511	1,966	101,500	·25	423	4,981	4,463		518	60,998	
June	43	43,000	473,000	184·0	2,571	4,365	1,521	5,886	103,000	·30	515	8,972	9,553	581		61,579	
July	43	43,000	473,000	184·0	2,571	4,365	1,521	5,886	103,000	·50	858	9,315	8,155		1,160	60,419	
Aug.	45	45,000	495,000	183·5	2,697	2,184	762	2,946	102,500	·50	854	6,497	6,733	236		60,655	
Sept.	48	48,000	528,000	181·0	2,917	1,455	515	1,970	99,800	·30	499	5,386	2,486		2,900	57,755	
Oct.	51	51,000	561,000	180·5	3,108	778	258	1,036	99,000	·20	330	4,474	3,368		806	56,949	
Totals	47·8	574,000			34,800	14,602	5,088	19,690		2·5	4,231	58,811	65,121	11,694	5,384		

Column 7. See note Table 5a.

TABLE No. 5c—1935-36

Service of Coteau Reservoir for irrigation of 454,700 acres and water required for power to pump water for 307,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. x 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1934-35 c.f.s.	Reservoir		Bal. in reservoir, end of Mo. c.f.s.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres.	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1 Forward from Oct. 31st, 1935																56,926	
Nov.	54	54,000	594,000	180·5	3,291				99,000			3,291	3,932	641		57,587	
Dec.	58	58,000	638,000	180·5	3,534				99,000			3,534	3,547	13		57,600	
Jan.	50	50,000	550,000	180·5	3,047				99,000			3,047	3,114	67		57,667	
Feb.	49	49,000	539,000	180·5	2,986				99,000	·10	166	3,152	3,499	347		58,014	
Mar.	46	46,000	506,000	183,0	2,765				102,000	·15	271	3,036	6,510	3,474		61,488	
Apr.	44	44,000	484,000	184·0	2,630				103,000	·20	343	2,973	10,696	5,179		66,667	2,544
May	43	43,000	473,000	185·0	2,556	1,455	504	1,959	104,000	·25	433	4,948	5,853			66,667	905
June	43	43,000	473,000	185·0	2,556	4,365	1,512	5,877	104,000	·30	520	8,953	7,290		1,663	65,004	
July	43	43,000	473,000	182·0	2,599	4,365	1,538	5,903	101,000	·50	841	9,343	1,033		8,310	56,694	
Aug.	45	45,000	495,000	178·0	2,782	2,184	786	2,970	96,200	·50	801	6,553	1,016		5,537	51,157	
Sept.	48	48,000	528,000	175·0	3,017	1,455	533	1,988	93,000	·30	465	5,470	1,313		4,157	47,000	
Oct.	51	51,000	561,000	172·0	3,261	778	291	1,069	90,000	·20	300	4,630	2,465		2,165	44,835	
Totals	47·8	574,000	.....	.....	35,024	14,602	5,164	19,766	.....	2·5	4,140	58,930	50,268	9,721	21,832	.....	3,449

Col. 7. See note Table 5a.

TABLE No. 5d—1936-37

Service of Coteau Reservoir for irrigation of 454,700 acres and water required for power to pump water for 307,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. x 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1936-37 c.f.s.	Reservoir		Bal. in reservoir, end of Mo. c.f.s.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres.	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1 Forward from Oct. 31st, 1936																44,835	
Nov.	54	54,000	594,000	172·0	3,453				90,000			3,453	3,193		260	44,575	
Dec.	58	58,000	638,000	171·5	3,721				89,050			3,721	2,552		1,169	43,406	
Jan.	50	50,000	550,000	171·0	3,216				89,000			3,216	2,738		478	42,928	
Feb.	49	49,000	539,000	171·0	3,152				89,000	.10	148	3,300	3,109		191	42,737	
Mar.	46	46,000	506,000	171·5	2,950				89,500	.15	224	3,174	3,982	808		43,545	
Apr.	44	44,000	484,000	171·5	2,828				89,500	.20	297	3,125	3,533	408		43,953	
May	43	43,000	473,000	170·0	2,782	1,455	548	2,003	88,000	.25	367	5,152	1,697		3,455	40,498	
June	43	43,000	473,000	171·5	2,758	4,365	1,632	5,997	89,500	.30	447	9,202	9,168		34	40,464	
July	43	43,000	473,000	166·0	2,849	4,365	1,685	6,050	84,500	.50	704	9,603	1,439		8,164	32,300	
Aug.	45	45,000	495,000	160·0	3,093	2,184	874	3,058	79,500	.50	662	6,813	1,005		5,808	26,492	
Sept.	48	48,000	528,000	157·0	3,363	1,455	594	2,049	77,000	.30	385	5,797	1,857		3,940	22,525	
Oct.	51	51,000	561,000	156·0	3,596	778	299	1,077	76,000	.20	253	4,926	3,437		1,489	21,063	
Totals	47·8	574,000	.....	.....	37,761	14,602	5,632	20,234	.....	2·5	3,487	61,482	37,710	1,216	24,988	.....	

Col. 7. See note Table 5a.

TABLE No. 5e—1937-38

Service of Coteau Reservoir for irrigation of 454,700 acres and water required for power to pump water for 807,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. x 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1937-38 c.f.s.	Reservoir		Bal. in reservoir, end of Mo. c.f.s.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres.	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1	Forward from Oct. 31st, 1937															21,063	
Nov.	54	54,000	594,000	155·5	3,820				75,600			3,820	4,587	767		21,830	
Dec.	58	58,000	638,000	156·0	4,090				76,000			4,090	4,452	362		22,192	
Jan.	50	50,000	550,000	156·5	3,514				76,600			3,514	4,201	687		22,879	
Feb.	49	49,000	539,000	156·5	3,444				76,600	·10	128	3,572	3,645	73		22,952	
Mar.	46	46,000	506,000	157·5	3,213				77,500	·15	194	3,407	5,734	2,327		25,279	
Apr.	44	44,000	484,000	161·0	3,006				80,500	·20	268	3,274	6,891	3,617		28,896	
May	43	43,000	473,000	165·0	2,866	1,455	565	2,020	84,000	·25	350	5,236	9,394	4,158		33,054	
June	43	43,000	473,000	170·0	2,782	4,365	1,646	6,011	88,000	·30	440	9,233	13,076	3,843		36,897	
July	42	43,000	473,000	169·5	2,795	4,365	1,651	6,016	87,500	·50	729	9,540	9,221		319	36,578	
Aug.	45	45,000	495,000	166·0	2,982	2,184	843	3,027	84,500	·50	704	6,713	3,461		3,252	33,326	
Sept.	48	48,000	528,000	164·0	3,219	1,455	569	2,024	83,000	·30	415	5,658	4,527		1,131	32,195	
Oct.	51	51,000	561,000	163·5	3,431	778	285	1,063	82,500	·20	275	4,769	4,679		90	32,105	
Totals	47·8	574,000			39,162	14,602	5,559	20,161		2·5	3,503	62,826	73,868	15,834	4,792		

Col. 7. See note Table 5a.

TABLE No. 5f—1938-39

Service of Coteau Reservoir for irrigation of 454,700 acres and water required for power to pump water for 807,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. x 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1938-39 c.f.s.	Reservoir		Bal. in reservoir, end of Mo. c.f.s.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres.	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1	Forward from Oct. 31st, 1938															32,105	
Nov.	54	54,000	594,000	164·0	3,622				83,000			3,622	4,525	903		33,008	
Dec.	58	58,000	638,000	164·0	3,890				83,000			3,890	4,115	225		33,233	
Jan.	50	50,000	550,000	164·0	3,353				83,000			3,353	3,647	294		33,527	
Feb.	49	49,000	539,000	164·5	3,276				83,500	·10	139	3,415	3,389		26	33,501	
Mar.	46	46,000	506,000	166·0	3,048				84,500	·15	211	3,259	5,549	2,290		35,791	
Apr.	44	44,000	484,000	166·5	2,970				85,000	·20	283	3,253	3,822	569		36,360	
May	43	43,000	473,000	165·5	2,858	1,455	563	2,018	84,300	·25	351	5,227	2,906		2,321	34,039	
June	43	43,000	473,000	169·0	2,800	4,365	1,656	6,021	87,100	·30	435	9,256	12,001	2,745		36,784	
July	43	43,000	473,000	166·5	2,841	4,365	1,688	6,053	85,000	·50	708	9,602	6,485		3,117	33,667	
Aug.	45	45,000	495,000	162·0	3,055	2,184	863	3,047	81,400	·50	678	6,780	1,529		5,251	28,416	
Sept.	48	48,000	528,000	159·0	3,321	1,455	586	2,041	78,600	·30	393	5,755	2,367		3,388	25,028	
Oct.	51	51,000	561,000	158·0	3,551	778	295	1,073	78,000	·20	260	4,884	3,533		1,351	23,677	
Totals	47·8	574,000			38,585	14,602	5,651	20,253		2·5	3,458	62,296	53,868	7,026	15,454		

Col. 7. See note Table 5a.

TABLE No. 5g—1939-40

Service of Coteau Reservoir for irrigation of 454,700 acres and water required for power to pump water for 307,000 acres plus commercial power up to a maximum of 100,000 H.P. plant

Month	Load factor %	H.P. produced out of 100,000 H.P.	H.P. x 11	Mean Head (h) ft	Draft for power c.f.s.	Draft for Irrigation			Evaporation			Total draft sum of 5, 8 and 11	Inflow 1938-40 c.f.s.	Reservoir		Bal. in reservoir, end of Mo. c.f.s.	Waste
						To land Table 3 c.f.s.	For pumping Table 4	Total for irrig.	Mean area acres.	Rate per mo.	Equi. c.f.s.			Net stored c.f.s.	Net draft c.f.s.		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nov. 1	Forward from Oct. 31st, 1939															23,677	
Nov.	54	54,000	594,000	157·5	3,772				77,500			3,772	4,326	554		23,231	
Dec.	58	58,000	638,000	157·5	4,051				77,500			4,051	3,578		473	23,758	
Jan.	50	50,000	550,000	157·0	3,503				77,000			3,503	3,574	71		23,829	
Feb.	49	49,000	539,000	157·0	3,433				77,000	·10	128	3,561	3,539		22	23,807	
Mar.	46	46,000	506,000	158·5	3,192				78,500	·15	196	3,388	5,483	2,095		25,902	
Apr.	44	44,000	484,000	163·0	2,974				82,000	·20	273	3,247	9,582	6,335		32,237	
May	43	43,000	473,000	166·5	2,841	1,455	560	2,015	84,300	·25	351	5,207	8,203	2,996		35,233	
June	43	43,000	473,000	163·5	2,899	4,365	1,712	6,077	82,500	·30	412	9,388	3,894		5,494	29,739	
July	43	43,000	473,000	158·5	2,984	4,365	1,766	6,131	78,300	·50	652	9,767	2,456		7,311	22,428	
Aug.	45	45,000	495,000	154·0	3,214	2,134	908	3,092	74,600	·50	621	6,927	2,148		4,799	17,649	
Sept.	43	48,000	528,000	152·0	3,473	1,455	613	2,068	73,000	·30	365	5,906	3,783		2,123	15,526	
Oct.	51	51,000	561,000	152·0	3,691	778	306	1,084	73,000	·20	243	5,018	5,495	477		16,003	
Totals	47·8	574,000			40,027	14,602	5,865	20,467		2·5	3,241	63,735	56,061	12,528	20,202		

Col. 7. See note Table 5a.

A further trial was made for a plant capacity of 100,000 H.P. It is evident by the computations that the demands for irrigation and power cannot be continued into 1940-41, a very dry year, and maintain reservoir elevations above Canal F.S.L. A rough estimate of the deficit of water and effect on production of power is as follows:—

Yearly requirements of water for irrigation, evaporation and power for a plant of 100,000 H.P. at load factors used, approximates 60,000 c.f.s. mo. Reservoir inflow for 1940-41 was only 40,040 c.f.s. mo. a deficit of 20,000 c.f.s. mo. for the year. The deficit for 1939-40 below Canal F.S.L. approximates 13,000 c.f.s. mo; total 33,000 c.f.s. mo. If this amount is distributed over the period June 1936, when reservoir is full, to October 1941, total 65 months, then the average deficit of water per month is 508 c.f.s. or 6,096 c.f.s. mo. for a year. At an estimated mean head of 170 feet this represents 94,200 H.P. The power production per year from a plant of 100,000 H.P. at load factors used is 574,000 H.P. Deducting 94,200 H.P., leaves 479,800 H.P. therefore:

574,000 : 100,000 : : 479,000 : (x)=83,600 H.P.

This represents roughly, on the basis of an estimated power head, the capacity of a plant which would prevent depleting the reservoir below Canal F.S.L. during the period June 1936 to October 1941.

Comparison Reservoir Outflow *versus* Inflow

The following is a summary of reservoir outflow in c.f.s. mos. required to meet irrigation and power requirements as determined by Tables 5a, 5b, etc. for the years 1933 to 1940 as compared with the average reservoir inflow for years 1928 to 1941.

Year	Draft for Irrigation	Draft for Pumping	Reservoir Evaporation	Draft for 100,000 H.P.	Total
1933-34	14,602	5,104	4,181	34,991	58,878
1934-35	14,602	5,088	4,231	34,890	58,811
1935-36	14,602	5,164	4,140	35,024	58,930
1936-37	14,602	5,632	3,487	37,761	61,482
1937-38	14,602	5,559	3,503	39,162	62,826
1938-39	14,602	5,651	3,458	38,585	62,296
1939-40	14,602	5,865	3,241	(a) 40,027	63,735
1940-41(b)	.....	.....	.....	.....	.....
Averages	14,602	5,437	3,749	37,206	60,994

NOTE: (a) Deficit of 13,000 c.f.s. below Canal F.S.L. and (b) insufficient inflow to restore reservoir to supply canal.

The average inflow to the reservoir for 13 years 1928-29 to 1941-42 inclusive (see Table 1) was 59,352 c.f.s. mos.

Maximum Power Plant Capacity in Relation to Peak Loads

Computations for power are based on the average monthly power load in relation to the maximum peak load in December. In

similar manner a peak load for pumping will occur for ten days to two weeks in June or July for irrigation which will be considerably in excess of the commercial peak load for those months. This peak demand for irrigation is determined by the maximum flow ratio, *i.e.* 1 to 90, plus losses. The maximum power requirement for pumping would be for a short period once a year for which, nevertheless, provision must be made from some source of power. The amount of this peak load is computed as follows:

Water for Irrig. to be supplied by pumping	Gross Irrig. Area: Acres	Max. Flow Ratio 1-90, c.f.s.	Est. Losses at 40% c.f.s.	Totals	Pump Lift: Feet	Required H.P. (a)
Divs. 6, 7 and 8.....	42,850	476	190	666	15	1,680
Divs. 9 to 14 inc.....	106,150	1,180	472	1,652	30	8,333
Divs. 15 to 17 inc.....	79,400	882	353	1,235	60	12,460
Divs. 18 to 21 inc.....	78,600	873	349	1,222	120	24,657
Totals.....	307,000	3,411	1,364	4,775	.....	47,130

(a) H.P. at power plant $= \frac{\text{c.f.s.} \times \text{h}}{8{\cdot}81 \times {\cdot}75 \times 90} = \frac{\text{c.f.s.} \times \text{h}}{5{\cdot}947}$

The above power peak load for pumping brings the maximum power requirements for a short ten days to two weeks period in June or July, viz:—

	H.P.	*H.P.*
Power for typical loads from 100,000 H.P. Plant	43,000	
Add for normal June or July peaks, say	40,000	83,000
Plus irrigation peak load as above		47,130
Maximum Capacity required		130,130
Available Capacity due to Water Supply		100,000
Deficit		30,130

On a comparable basis the peak load in June or July for 83,600 H.P. would be:—

	H.P.	*H.P.*
Power for typical loads from 83,000 H.P. plant	36,000	
Add for normal June or July peaks, say	33,000	69,000
Plus irrigation peak loads as above		47,130
Maximum Capacity Required		116,130
Available Capacity due to Water Supply		83,600
Deficit		32,530

It is indicated that the water supply would be short for peak irrigation requirements in June or July by about 30,000 H.P. and 32,500 H.P. in the respective periods for which auxiliary power must be provided.

A power plant of 130,000 H.P. or more could be maintained by the available reservoir supply in wet years. Its use, however, would be subject to the following conditions:—

(a) Insufficient water supply in dry years as in the period 1933 to 1941.

(b) The difficulty of supplying power if the irrigation peak load for ten days to two weeks in June or July creates a deficit for normal commercial load commitments, thereby resulting in shut-downs, power rationing or the need to purchase power for the short period from some other source.

It will be understood that the foregoing analysis of the use of water for irrigation is

based on the average conditions of a dry year with an Irrigation Factor at 80 per cent and Duty of Water at 1·5 acre feet. These factors may vary according to relative differences in the amount and dates of occurrence of rainfall. It also may be assumed that seepage losses might be higher due to the sandy loam texture of soils as related to length and size of canals. These variations would have some effect up and down on the power potential in some years.

Cost for Pumping Water to Land

On the basis of commercial peak loads, the annual charge for power installation and transmission lines should approximate $20.00 per H.P. per year. At this value the cost per acre for power only to pump water to lands is estimated as follows:

Land	Gross Irrig. Area	Pump Lift Ft.	H.P. at Peak Load	Annua. Jost at $20.00 per H.P.	Cost Per Acre
				$	$
Divs. 6, 7 and 8	42,850	15′	1,680	33,600	0·78
Divs. 9 to 14	106,150	30′	8,333	166,660	1·57
Divs. 15 to 17	79,400	60′	12,460	249,200	3·13
Divs. 18 to 21	78,600	120′	24,657	493,140	6·27
Totals	307,000	.....	47,130	942,600	3·07

Upon adding the above average cost per acre for power only to the estimated cost for operation and maintenance for the irrigation works, including pumping plants, at say $2.00 per acre (based on average cost for Alberta projects) brings the total to over $5.00 per acre per year. This is too much for the farmer to pay and does not include any charge for principal and interest for a water right.

Proposed Enlargement of Reservoir

Since the foregoing Memorandum was directed to the Commission, it has been found that the reservoir is to be enlarged by shifting the location of the dam in the Qu'Appelle Valley.

The enlargement is brought about by moving the site of the dam in the Qu'Appelle Valley to the 3rd Meridian some 20 miles east of the Elbow Crossing site as formerly planned. This is shown by map, profiles, etc. following Chapter 16, pages 104 to 107 in the General Engineering Report, dated March 1952, submitted by the P.F.R.A. at the meeting in Washington, D.C., April 7, 1952.

The proposed enlargement appears to be planned for the purpose of obtaining additional storage of water for power during a cycle of wet years to provide for reserve storage of water for use during a period of dry years. Aside from this it is not clear from reports and data whether other features such

as conditions of foundations for dams, railway locations, facilities for supply of water to Moose Jaw or Regina, or other features enter into the reasons for the enlargement.

An estimate of reservoir service for the enlarged reservoir, determined for inflow versus outflow worked out for monthly periods by tables and chart would involve a large amount of detailed computations. For general purposes it is hoped that a Table as shown herein will suffice to provide for an approximate estimate of power potential in excess of the use of water for irrigation, seepage and evaporation and supply of water to Regina and Moose Jaw.

Comparative Reservoir Capacities and Areas of Water Surface

In reports of the P.F.R.A., references are made to a draw-down in the operations of the reservoir of 40 feet, whereas the full supply level is at Elev. 1825 and the Canal F.S.L. at Elev. 1800, difference of 25 feet. It is indicated in computations in our earlier memorandum that difficulties would arise in a cycle of dry years should the reservoir be drawn down for winter power below Canal F.S.L. in anticipation of spring inflow replenishing the reservoir to an elevation sufficient for irrigation. It might be possible to do so if the conditions of a very wet winter indicated a forthcoming high spring inflow but this may happen only occasionally and would be hazardous for irrigation requirements. It therefore appears advisable to consider the available capacity of the reservoir within the limits of full supply level Elev. 1825 and the Canal F.S.L. Elev. 1800.

The following shows the comparative capacities and areas for an enlarged reservoir with dam in the Qu'Appelle Valley at the 3rd Meridian and Elbow site as formerly planned.

—	Capacity, acre feet	Equiv. c.f.s. mos.	Area Acres
Dam at 3rd Meridian—			
Elev. 1825	2,649,530	44,160	121,758
Elev. 1800			93,421
Mean Area			107,590
Dam at Elbow—			
Elev. 1825	2,282,251	38,037	104,000
Elev. 1800			70,031
Mean Area			91,815
Difference	387,279	6,123	16,075

Maximum Available Power

Table A is based on conjecture of possible reservoir operations under condition of having advance knowledge of inflow as shown by the records of inflow, by which the maximum power potential is determined for the period 1923-24 to 1947-48. For future use advance knowledge of inflow is not available. In practical operations there would be a tendency to draw on the reservoir excessively to supply water for a dry year assuming the next following year would be wet and refill the reservoir. This, however, does not always occur. Therefore, without advance knowledge of inflow as shown by the records on which Table A is based, it is probable that the power potential would be less than shown by Table A.

Table A is predicated on the following principles:—

(a) The reservoir will not be depleted by draft for power, ending October or

during the winter, below Canal F.S.L. and then only if there is ample evidence of an abundant forthcoming inflow for the succeeding year's operations.

(b) That the reservoir is refilled during relatively wet years as an assurance for future use in a dry year or period of dry years rather than to draw excessively on storage during a wet year and leave reservoir reserve in short supply.

(c)

	Acre Ft.	*c.f.s. mos.*
It is assumed that the maximum irrigable area is 454,700 acres for which water for irrigation plus seepage is estimated at	876,120	14,602
The average area subject to evaporation will approximate 110,000 acres at an estimated loss 2·5′ per acre including reservoir seepage	275,000	4,583
Provision is made for water for the Cities of Regina and Moose Jaw	29,000	483
Totals	1,180,120	19,668

Assume the amount at 19,670 c.f.s. mos.

TABLE A

Table showing water supply to reservoir less requirements for irrigation, seepage, evaporation and supply of water to cities of Regina and Moose Jaw, under assumed operations of reservoir with dam at 3rd meridian.

Year	Reservoir inflow c.f.s. mos.	Plus storage draft	Less to storage	Total reservoir supply c.f.s. mos.	Less for irrig., evap. and cities	Available for power c.f.s. mos.	Mean monthly flow c.f.s.	Est. average head (h) ft.	H.P. at 80% $\frac{\text{c.f.s.} \times h}{11}$	Storage reserve c.f.s. mos.
1923.....	Assumed Reservoir Storage Reserve,—			.....	.....	.....	.....	.....	.....	25,000
1923-24.....	67,708	20,000	.....	87,708	19,670	68,038	5,670	175	90,200	5,000
1924-25.....	95,983	.....	8,000	87,983	19,670	68,313	5,690	170	87,910	13,000
1925-26.....	85,703	2,000	.....	87,703	19,670	68,123	5,680	170	87,780	11,000
1926-27.....	163,672	.....	33,160	130,512	19,670	110,542	9,210	175	146,520	44,160
1927-28.....	146,712	.....	.....	146,712	19,670	127,042	10,590	185	178,100	44,160
1928-29.....	70,438	.....	.....	70,438	19,670	51,768	4,230	180	69,220	44,160
1929-30.....	59,935	12,000	.....	71,935	19,670	52,265	4,360	175	69,360	32,160
1930-31.....	37,242	32,160	.....	69,402	19,670	49,732	4,140	170	63,980	.....
1931-32.....	79,629	.....	10,000	69,629	19,670	49,959	4,160	165	62,400	10,000
1932-33.....	71,860	.....	.....	71,860	19,670	52,190	4,350	165	64,700	10,000
1933-34.....	73,543	.....	13,000	60,543	19,670	40,873	3,410	170	52,700	23,000
1934-35.....	65,121	.....	5,000	60,121	19,670	40,451	3,370	175	53,010	28,000
1935-36.....	50,260	10,000	.....	60,260	19,670	40,590	3,380	175	53,770	18,000
1936-37.....	37,710	18,000	.....	55,710	19,670	36,040	3,000	170	46,360	.....
1937-38.....	73,868	.....	14,000	59,868	19,670	40,198	3,350	170	51,770	14,000
1938-39.....	53,868	7,000	.....	60,868	19,670	41,198	3,430	165	51,450	7,000
1939-40.....	56,061	5,000	.....	61,061	19,670	41,398	3,440	165	51,600	2,000
1940-41.....	42,040	2,000	.....	44,040	19,670	24,370	1,700	165	24,590	.....
1941-42.....	108,040	.....	44,160	63,880	19,670	44,210	3,680	175	58,540	44,160
1942-43.....	85,926	.....	.....	85,926	19,670	66,256	5,520	180	90,330	44,160
1943-44.....	46,776	34,000	.....	80,776	19,670	61,106	5,090	175	80,980	10,160
1944-45.....	70,080	10,160	.....	80,240	19,670	61,570	4,960	165	74,400	.....
1945-46.....	79,919	.....	.....	79,919	19,670	60,249	5,020	165	75,300	.....
1946-47.....	113,295	.....	33,000	80,295	19,670	60,525	5,050	175	80,340	33,000
1947-48.....	175,679	.....	11,160	164,519	19,670	144,849	12,070	180	197,510	44,160

(d) Table A is based on inflow for the period November 1 to October 31. Since the bulk of inflow occurs in the spring months, April to June inclusive, maximum storage in the reservoir would occur in July with depletion as at October 31 instead of being at full capacity i.e. 44,160 c.f.s. mos. as shown by the Table. It is probable that waste would occur in wet years during the spring months and therefore the power potential may be less than the amounts shown by Table A in such years. Irrigation requirements occur in the period May to October inclusive at variable amounts with very high peaks in June or July, which, however, in some relative degree, coincide with variations in reservoir inflow. In similar manner, water required for pumping varies with irrigation requirements, provisions for which are deduced from the total power potential as shown by Table B to obtain the net potential commercial energy. These variations may have some effect on the storage reserve from time to time and relative losses by evaporation.

In these several respects, as before stated, a more accurate accounting of reservoir service cannot be obtained short of detailed computations by months by Tables and Chart as shown in the earlier Memorandum.

Maximum Plant Capacity

Having regard to the average H.P. capable of production, as shown by Table A, it is observed that potential power in excess of 75,000 H.P. occurs in eleven years out of the twenty-five years 1923-24 to 1947-48. Assuming an average annual load factor of 50 per cent this would provide for a plant capacity of 150,000 H.P.

Table B

Table B shows the total amount of energy per year to be obtained from regulated water supply, as per Table A, for a plant capacity of this size. A deduction for pumping water for irrigation in the months May to October inclusive, 45,552,600 K.W. Hrs. (see Table 4 above) is made to arrive at the balance of energy available for commercial use. For this purpose Table B indicates that an average of 371·4 M.K.W. Hrs. could be obtained over a period of 25 years, and is reduced to an average of 314·4 M.K.W. Hrs. for the 14 consecutive dry years 1928-29 to 1941-42.

A report by the P.F.R.A. entitled "Water Supply Study" dated January 1952, Page 5, under the heading "Firm Commercial Energy", states:

> "The end result of the reservoir study was to discover just how much commercial energy could be produced *after* all other demands had been satisfied".

This presumably refers to supply of water for irrigation, pumping and water to Regina and Moose Jaw with attending seepage and evaporation losses. Then follows the statement:—

> "It is found, using the above procedure, that this project could produce, each and every year, energy in the following amounts . . . . total every year 326,500,000 K.W. Hrs."

TABLE B

Showing commercial energy available from a 150,000 H.P. plant at 60% load factor less energy required for pumping plants for irrigable lands estimated at 45,562,600 K.W. hrs.

The Table also shows the deficit in energy required to maintain a 150,000 H.P. Plant at a normal load factor of 50%.

Year	Max. H.P. per month at 80%	plant 150,000 H.P.	Energy per year M.K.W. Hrs.	Loss for pumping M.K.W. Hrs.	Bal. for commercial use M.K.W. Hrs.	Deficit for 150,000 H.P. Plant— M.K.W. Hrs.
1923-24	90,200	75,000	489·4	45·5	443·9	
1924-25	87,940	75,000	489·4	45·5	443·9	
1925-26	87,780	75,000	489·4	45·5	443·9	
1926-27	146,520	75,000	489·4	45·5	443·9	
1927-28	178,100	75,000	489·4	45·5	443·9	
1928-29	69,220	69,220	450·6	45·5	405·1	38·8
1929-30	69,360	69,360	452·5	45·5	407·0	36·9
1930-31	63,980	63,980	417·5	45·5	372·0	71·9
1931-32	62,400	62,400	407·2	45·5	361·7	82·2
1932-33	64,700	64,700	422·2	45·5	376·7	67·2
1933-34	52,700	52,700	343·9	45·5	298·4	145·5
1934-35	53,610	53,610	349·8	45·5	304·3	139·6
1935-36	53,770	53,770	350·8	45·5	305·3	138·6
1936-37	46,360	46,360	302·5	45·5	257·0	186·9
1937-38	51,770	51,770	337·8	45·5	292·3	151·6
1938-39	51,450	51,450	335·7	45·5	290·2	153·7
1939-40	51,600	51,600	336·7	45·5	291·2	152·7
1940-41	24,590	24,590	160·4	45·5	114·9	329·0
1941-42	58,540	58,540	372·0	45·5	326·5	117·4
1942-43	90,330	75,000	489·4	45·5	443·9	
1943-44	80,980	75,000	489·4	45·5	443·9	
1944-45	74,400	75,000	489·4	45·5	443·9	
1945-46	75,300	75,000	489·4	45·5	443·9	
1946-47	80,340	75,000	489·4	45·5	443·9	
1947-48	107,510	75,000	489·4	45·5	443·9	
Totals: M.K.W. Hrs. for 25 years			10,423·0	1,137·5	9,285·5	1,812·0
Average for 25 years			416·9	45·5	371·4	72·5
Total M.K.W. Hrs. for 14 years—(1928-29 to 1941-42)			5,039·6	637	4,402·6	1,812·0
Average for 14 dry years			355·9	45·5	314·4	129·4

It is difficult to reconcile the above statements with the figures shown by Table B for the individual years during 1933-34 to 1940-41. In these years the available commercial power varies from 305·3 M.K.W. Hrs. to as low as 114·9 M.K.W. Hrs. with an average, for the whole period 1928-29 to 1941-42, at 314·4 M.K.W. Hrs. The differences cannot be readily accounted for since the P.F.R.A. generally agreed in total with the amounts of water required for irrigation, seepage and evaporation.

Table B also shows the amount of auxiliary energy which would be required to maintain a Plant Unit of 150,000 H.P. at 50 per cent load factor amounting to an average of 129·4 M.K.W. Hrs. for the 14 dry years and varying from 36·9 M.KW. Hrs. to 329·0 M.K.W. Hrs. Excluding the very dry year 1940-41, the average requirement would approximate 150·0 M.K.W. Hrs. To produce this amount of energy would require an auxiliary steam plant, or power from other sources, of 46,000 H.P. at 50 per cent load

factor to balance out the energy that should be supplied by a Plant Unit of 150,000 H.P. capacity.

Effect of Enlarged Reservoir

By changing the location of the proposed dam in Qu'Appelle Valley from the site at Elbow to the site at 3rd Meridian, the capacity of the reservoir is increased by 387,279 acre feet or its approximate equivalent 6,120 c.f.s. mos. The mean area of the reservoir is increased by 16,975 acres.

To make a comparison between the two reservoirs, tables similar to Tables A and B should be worked out to ascertain the commercial energy which could be obtained from the smaller reservoir. Some general observations respecting the merits of the larger reservoir, however, may indicate the need for a careful reconsideration of the enlarged reservoir.

Referring to Table A, in respect of available water for all purposes, the decrease in average surface area for the smaller reservoir of 16,975 acres at losses of 2·5 feet per acre for seepage and evaporation, amounts to 42,337 acre feet or its equivalent average of approximately 705 c.f.s. mos. This gain from evaporation would improve water supply for all years and be of particular benefit in the period of 14 dry years.

In respect of reservoir storage as shown by Table A, (with small adjustment) the decrease of storage capacity by 6,120 c.f.s. mos. would have no effect on the available supply for power in excess of 75,000 H.P., as shown by Table B, for the succeeding five years as there is surplus water supply in this period. The reserve storage ending 1928-29, however, would be reduced by 6,120 c.f.s. mos. leaving 38,040 c.f.s. mos. for the subsequent dry years ending 1931 when an empty reservoir is shown by Table A.

In the subsequent ten years, 1932 to 1941 inclusive, there would be no loss in storage reserve as the smaller reservoir would be sufficient to store and regulate the inflow for this period and incidentally recover 7,050 c.f.s. mos. gained by reduced evaporation. Again in 1942-43 the reservoir reserve would be depleted by 6,120 c.f.s. to 38,040 c.f.s. mos. which would affect the available supply ending 1945 but would gain by reduced evaporation.

The enlarged reservoir has the effect of losing power head for a given volume of inflow in dry years as the build-up in the reservoir would be slower in a large reservoir than it would be in a smaller one.

From an economic standpoint, the enlarged reservoir requires more right-of-way and the possibility, not clearly shown, of decreasing irrigable land in the Qu'Appelle Valley which may be covered by the larger reservoir.

For the purpose of supplying water to Regina and Moose Jaw—29,000 acre feet—a dam may be required at the 3rd Meridian to form a reservoir, but one of limited size would serve to make a reservoir sufficient to meet this requirement.

It is in these several respects that the enlarged reservoir might be considered.

Red Deer River Project

Under the terms of reference P.C. 4435 dated 24th August 1951 relative to the proposed South Saskatchewan River Project,

the Commission was requested to ascertain "whether the said project represents the most profitable and desirable use which can be made of the physical resources involved".

This request has directed the attention of the Commission to a former proposed project referred to as the "William Pearce Scheme" initiated about 1922, by which a part of the lands in the proposed South Saskatchewan River Project might be irrigated. In view of this possibility a review has been made of the available data pertaining to this early scheme and the subsequent plans and surveys which have been made for the Red Deer Project. It was thought to be possible that the proposed South Saskatchewan River Project and the proposed Red Deer Project might be joined to form the most profitable and desirable use of the physical resources involved.

Plans and Surveys

Altogether, six plans and surveys have been made. A seventh survey is now under way as an alternative in some respects to the original William Pearce Scheme. Three of the surveys involved plans for using Sullivan Lake as a reservoir and three to create reservoirs by dykes at the sites of Craig and Hamilton Lakes. These several plans and surveys have been reviewed and may be briefly described as follows:—

Diversion of Water to Sullivan Lake

Plan 1. (William Pearce Scheme). Under this scheme water was proposed to be diverted from the North Saskatchewan River into the Clearwater River and the combined flow into the Red Deer River, whence by dam 175 feet high located on the Red Deer River in Section 4-38-25-4th, water would be diverted by canal 98 miles in length, including a large syphon across the Red Deer River, into Sullivan Lake. From Sullivan Lake water would be distributed to lands in Alberta (present Red Deer Project) and by way of Sounding Creek, canal and natural channels, to a proposed reservoir at Tramping Lake from which water would be delivered to lands in that part of the South Saskatchewan River Project west of the river.

The delivery of water could be extended by syphon to the east side of the river which, however, was not contemplated in the original plans. The project was estimated to supply water to a potential irrigable area of 1,410,980 acres, or such part thereof as might be found best suited to irrigation within limits of available and economical water supply.

Plan 2. As an alternative to the dam and diversion in Section 4-38-25-4 as above, it was planned to build a dam 90 feet high on the Red Deer River below the mouth of Ravin River and by canal, surveyed 94 miles in length, to join the canal 11 miles below the point of diversion as per Plan 1, and thence into Sullivan Lake, total length 171½ miles.

Plan 3. This plan provided for a dam 185 feet high located in Section 10-38-22-4 to create a reservoir in Red Deer Valley, Tail Creek and Buffalo Lake with total capacity of 1,000,000 to 1,500,000 acre feet by which a mean power head of 140 feet could be obtained to pump water, viz:

(a) Into the canal at a point east of the syphon as per Plan 1, during May to

October against a mean head of 135 feet and thence into Sullivan Lake.

(b) To trade winter power produced by a flow of 300 c.f.s. for riparian rights at the proposed dam for summer power from Bow River plants to pump water in the period May to October, as per item (a) into Sullivan Lake.

The following plans provided for use of reservoirs at Craig and Hamilton Lakes.

Plan 4. To transmit power as per item 3a or 3b of Plan 3 about 30 miles to a pump site at the east end of Buffalo Lake north of Stettler and raise water 50 feet into a canal 70 miles in length for delivery of water into Craig and Hamilton Lake reservoirs. This plan eliminates Sullivan Lake and by reason of elevation of the reservoirs, would not irrigate lands west of Berry Creek, unless further pumping were to be done to raise water against a head of 90 feet into Lanes Lake as an auxiliary reservoir or against a less head for use of water direct from the canal at a point below Federal.

Plan 5. A gravity canal diverted from the Red Deer River west of Ardley thence on the west side of the river through Haynes Creek Valley, thence around the north shore of Buffalo Lake and on to Craig and Hamilton Lake Reservoirs.

Plan 6. A dam about 175 feet high located 500 feet upstream from the railway bridge 3 miles north of Ardley. This dam would create a reservoir in the Valley of the Red Deer River extending into Haynes Creek Valley with capacity of about 300,000 acre feet. The canal would be diverted from the east side of the reservoir in Haynes Creek Valley thence along level to rolling ground to Tail Creek crossed by syphon, thence eastward through very broken country following sloughs and depressions and heavy cuts to a summit north of Stettler and thence south and east to reservoirs at Craig and Hamilton Lakes.

Choice of Plans

Any plan by which lands east of the proposed Red Deer Project could be irrigated requires the use of Sullivan Lake as a reservoir, hence requires Plan 1, 2 or 3.

A considerable amount of investigation has been made of the available data relative to the different plans. With respect to the surveys for the original William Pearce Scheme Plan 1, a great deal of the survey data cannot be found and it is at present impossible to obtain a comprehensive knowledge of all the works involved and present estimates of cost.

Plan 2 was largely of a reconnaissance survey. It was abandoned in view of rough country, many large structural requirements and length of canal.

Referring to Plan 3, this involves raising Buffalo Lake to a point to cause a great deal of railway and highway damage and all water, including canal and reservoir losses, must be lifted 135 feet to flow into Sullivan Lake. Under this plan, with a mean power head of 140 feet to pump water 135 feet, it would require as much water for power as the quantity pumped, thereby resulting in a loss of 50 per cent of the available water for irrigation. The only advantage of using Buffalo Lake as a storage reservoir would be in eliminating storage on the North Saskatchewan, Clearwater and Red Deer Rivers as may be required for Plan 1.

The main canal would be shortened by 30 miles and an expensive syphon across the Red Deer River would not be required.

The following information relates to Plans 4, 5 and 6 for use in irrigating lands in the Red Deer Project.

Referring to plan (4), this plan eliminates Sullivan Lake. It would require about 40 per cent of the power needed for Plan 3a or 3b and is limited to use in the Red Deer Project.

In reference to Plan 5, no details are available but from comments obtained the plan was not acceptable because of length of canal line and property damage.

Plan 6, pending further investigation at present under way, has been the last recent plan for the proposed Red Deer Project. It too has objectionable and expensive features which are probably more than offset by the objectional features of other plans, but appears on the basis of surveys made to best meet the requirements for the Red Deer Project.

It would not serve to irrigate lands extending east into Saskatchewan.

Proposed New Plan

At the present time a new survey is under way.

This plan is understood to revert back to the use of Sullivan Lake as a reservoir, by whatever method may be best suited to getting water into that reservoir and extend eastward by canal other than by the Sounding Creek location, as planned for the William Pearce Scheme, to irrigate an entirely new area of land reported to be of better general quality than the lands in the Red Deer Project. These investigations are incomplete. It is probable that this plan would be an alternative to the original William Pearce Scheme for irrigating lands in Saskatchewan, and may require new surveys to obtain missing data in the original plans for the William Pearce Scheme, or some alternative in plans for obtaining water from the North Saskatchewan, Clearwater and Red Deer Rivers for diversion into Sullivan Lake.

Irrigable Lands

A general review has been made of the records pertaining to the irrigable lands in the Red Deer Project. Early estimates of the irrigable areas in this Project were very large. Later information indicates an area of approximately 500,000 acres, but upon completing topographical surveys and soil tests, this area may be further reduced. Much of the land in the drainage area of Berry Creek has been eroded and rough and includes inferior soils. The better lands are represented to be in and around the marginal areas of the drainage area but require water to be pumped to heights of 35, 60 and 90 feet. Including all areas in the Red Deer Project, it is possible that the maximum area of irrigable land of fair quality would not exceed 300,000 acres.

Pending a very material improvement in farm values, an important economic question arises as to pumping water in excess of 60 feet, and then only if auxiliary reservoirs are available to supply the very irregular direct demands for irrigation. This condition applies to a large area in the proposed Red Deer Project and also in the South

Saskatchewan River Project. This may warrant, for the time being, a considerable reduction in the area proposed to be irrigated in both of the projects pending the outcome of farming developments as well as the availability of water supply.

Water Supply

Water supply from the Red Deer and Clearwater Rivers has been reviewed and an extensive compilation of records made to ascertain the probable available supply which would be of use to the Red Deer Project. Records for the Red Deer River are relatively complete for the period 1912 to 1950, and for the Clearwater River from 1914 to 1930 and again for the period 1945 to 1950. For a period of 14 dry years, 1928-29 to 1941-42 inclusive, interpolations had to be made for the Clearwater River. As a result of these compilations it is estimated that an approximate average of 1,200,000 acre feet per year, subject to reservoir control and regulation of flow, would be available to a canal for diversion during the months May to October for use in the Red Deer Project. The losses of water by seepage and evaporation would vary with length of canal and reservoir facilities used according to plans adopted.

For purposes of a rough analysis an estimate of three acre-feet per acre to supply irrigation and losses would provide for the irrigation of 400,000 acres of land. If the water in excess of the needs for the Red Deer Project were to be used to irrigate lands east of the Red Deer Project, further losses would occur so that taken together a total of say 350,000 acres may be the limit of area irrigable by waters of the Red Deer and Clearwater Rivers. Any additional area extending to the South Saskatchewan River Project, for which present surveys now under way may apply, would require diversion of water from the North Saskatchewan River as planned in the original William Pearce scheme about which, as stated, much data is missing.

In these various circumstances of incompleted plans and data, it at present appears that no definite report can be made relative to the possibility of using waters from the North Saskatchewan, Clearwater and Red Deer Rivers as an alternative to the plans for irrigating lands in the South Saskatchewan River Project from the Coteau Creek Dam.

It is assumed that the primary objective desired for the physical resources involved, is the use of the limited quantities of water, which can be economically made available, to irrigate land with power as an incidental feature. Power can be obtained at points which would not affect irrigation or by steam plants using the large resources of coal, oil or gas which occur in abundance in Alberta and Saskatchewan.

In several respects, as related to the physical aspects pertaining to the two projects, the following features warrant specific consideration:

(a) The advisability of attempting to irrigate land requiring a pump lift in excess of 60 feet and then preferably if water can be pumped into an auxiliary reservoir to supply the irregular demands for irrigation. This would apply to an area of 78,600 acres in the South Saskatchewan

River Project for which water is required to be pumped 120 feet, and to areas requiring a 60 foot lift if auxiliary reservoirs are not available. It also applies to areas in the Red Deer Project where a large area of the better land requires water to be pumped 90 feet. These are subject to future developments in farm values.

(b) The power potential for commercial use in the South Saskatchewan River Project for the period of 14 consecutive dry years in relation to the output from a plant capacity of 150,000 H.P., and the amount of auxiliary power needed to sustain a plant of this size.

(c) The advisability of enlarging the reservoir by dam in the Qu'Appelle Valley at the 3rd Meridian as compared with the potential power available with a dam at Elbow.

(d) The possible use of waters from the North Saskatchewan, Clearwater and Red Deer Rivers for Joint use in Alberta and Saskatchewan which may be conditional upon surveys now under way and at present indefinite as to areas of land and works involved.

(f) The potential possibility of using waters tributary to the reservoir at Outlook on lands in Alberta by extensions of existing schemes excepting for the advisability, if economically possible, of aiding in the development of lands in Saskatchewan for national reasons.

(g) The total estimated costs in relation to the benefits to be obtained.

SCHEDULE 1a

Relative to irrigation factors and crops grown in Eastern Irrigation District Project

Year	Gross Irrig. area acres	Area Irrig. during year (a)	Summer-fallow and idle land	Irrig. factor %	Duty of water		Plow Ratio		Aver. size farm unit	Kind of Crops					
					Amount used ac. ft. (b)	Ac. ft. per acre, depth	Max. flow c.f.s. (c)	Ratio to max. area		Grain acres	Hay and pasture acres	Sugar beets acres	Canning crops acres	Misc. acres	Total acres
1941	156,501	156,501	24,697	100 (84·2)	543,222 218,882	3·47 1·38	3,829	1—40·8	138	100,173	23,748	nil	nil	7,883	156,501
1942	158,793	158,793	17,788	100 (88·8)	456,346 120,518	2·87 0·76	3,207	1—49·5	138	101,020	27,694	nil	nil	12,291	158,793
1943	166,253	157,149	29,423	94·6 (70·0)	609,006 247,506	3·88 1·57	3,814	1—41·2	138	84,720	32,815	nil	nil	19,295	166,253
1944	165,386	162,086	23,419	98·0 (83·8)	650,602 239,453	4·01 1·47	3,799	1—42·7	139	93,565	34,975	nil	nil	13,427	165,386
1945	163,829	158,036	23,607	96·5 (82·0)	604,744 204,445	3·83 1·29	3,912	1—40·4	139	83,332	35,261	nil	nil	21,629	163,829
1946	164,790	161,807	17,328	98·2 (87·7)	591,330 210,746	3·65 1·30	4,118	1—39·8	140	85,117	37,583	nil	400	24,362	164,790
1947	167,758	165,336	21,586	98·6 (85·7)	467,398 186,840	2·83 1·13	3,920	1—42·2	140	98,411	29,689	nil	550	17,522	167,758
1948	172,914	171,331	26,744	99·1 (83·6)	391,794 157,557	2·29 0·92	4,117	1—41·6	140	99,831	32,908	nil	700	12,731	172,914
1949	177,084	176,486	20,382	99·7 (88·1)	647,358 279,860	3·67 1·59	4,129	1—42·7	141	112,172	32,463	nil	850	11,217	177,084
1950	177,759	177,359	26,286	99·9 (84·7)	398,479 221,507	2·25 1·25	3,807	1—46·4	141	102,238	32,686	nil	1,000	15,549	177,759

All summerfallow in the Eastern Irrigation Distri[illegible]s irrigated and there is very little idle land.

	Grain	Hay	Sugar beets	Canning	Miscellaneous
(1) Average number of irrigations per season	2	2	—	3½	2
(2) Average number of days used for one irrigation	22	5	—	2½	2
(3) Approximate depth of water for one irrigation	6"	6"	—	6"	6"

Notes: (a) Reported irrigated area includes summerfallow. Figures in ( ) show Irrigation Factor with summerfallow deducted.
(b) Under "Total Water Supplied", first figure represents total water diverted at Bassano Dam, and second figure—water delivered at farm headgates.
(c) Represents diversion at Bassano Dam plus amounts of water drawn off Lake Newell, and the Cowoki, Douglas and One Tree Reservoirs.

SCHEDULE 1b

Relative to irrigation factors, crops grown and related data, water taken from Keho Reservoir, Lethbridge Northern Irrigation District

Year	Gorss irrig. area acres	Area irrig. during year	Summer-fallow and idle land	Irrig. factor %	Duty of Water		Rainfall-Lethbridge		Flow Ratio		Aver. size farm unit	Kind of Crops			
					Amount used ac. ft.	Ac. ft. per acre depth	Total for year inches	Apr. 1 to Oct. 31, inches	Mx. flow c.f.s.	Ratio to max. area		Grain acres	Hay and Pasture acres	Sugar Beets Acres	Misc. vegs. Acres
1941	52,289	39,708	.....	·76	63,001	1·58	16·34	12·72	632	1– 82	160			7,030	From
1942	52,278	20,334	.....	·39	36,349	1·78	20·63	16·46	455	1–115	160	no records were ob-		8,220	2,500
1943	52,278	42,735	.....	·82	78,974	1·85	11·32	6·44	462	1–113	160	tained of areas in		8,830	to
1944	52,074	48,567	.....	·93	77,753	1·60	15·15	9·71	404	1–128	160	grain, hay and pas-		9,010	3,000
1945	51,959	36,701	.....	·71	54,399	1·48	20·47	13·58	545	1– 95	160	ture crops.		9,350	acres.
1946	52,096	44,383	.....	·85	65,520	1·47	21·48	10·67	530	1– 98	160	Waste water used		9,330	acres
1947	52,067	37,643	.....	·72	50,460	1·34	23·84	16·05	539	1– 96	160	for irrig. land ad-		9,450	per
1948	52,044	37,992	.....	·73	41,830	1·10	17·44	12·05	495	1–105	160	joining district,		9,580	year.
1949	51,862	46,889	.....	·90	74,070	1·58	18·06	9·04	508	1–102	160	balance to river.		9,690	
1950	51,862	50,071	.....	·96	68,260	1·36	12·39	6·13	466	1–111	160			9,800	

	Grain	Hay	Beets	Vegetables
(1) Average number of irrigations per season	2	2	3	3
(2) Average number of days per irrigation	Varies probably 15 to 20 days			
(3) Average size of ditch head—no difference for size of farm unit	average 2 c.f.s.			
(4) Average depth of water per application	6 inches			

NOTE: Irrigation practice in this District is to turn on more water than used for crops with excess going back to river or used by farmers on land adjoining District who pick up waste water. The total flow includes lateral and main canal seepage and waste water thereby increasing duty of water.

SCHEDULE 1c

Relative to irrigation factors, crops grown and related data, St. Mary's and Milk River Project (formerly A.R. & I. Lethbridge-Coaldale)

Year	Gross Irrig. area acres	Area Irrig. during year	Summer-fallow and idle land	Irrig. factor %	Duty of Water		Rainfall		Flow Ratio		Aver. Size farm unit	Kind of Crops				
					Amount used ac. ft.	Ac. ft. per acre, depth	Total for year inches	Apr. 1 to Oct. 31, inches	Max. flow c.f.s.	Ratio to max. area		Grain acres	Hay and pasture acres	Sugar beets acres	Canning crops acres	Misc. acres
1941	76,597	59,447	17,150	·75	70,600	1·19	16·34	12·72	649	118	120	No records		9,051	No records	
1942	76,767	34,545	42,222	·45	42,000	1·22	20·63	16·46	560	137	120	"	"	17,109	"	"
1943	75,706	66,621	9,085	·88	88,663	1·33	11·32	6·44	730	104	120	"	"	18,511	"	"
1944	75,725	60,580	15,145	·80	80,276	1·33	15·15	9·71	624	121	120	"	"	18,055	"	"
1945	75,765	56,824	18,942	·75	65,696	1·16	20·47	13·58	677	112	120	"	"	18,978	"	"
1946	76,013	68,417	17,596	·90	93,017	1·36	21·48	10·67	709	107	110	"	"	18,650	"	"
1947	76,207	64,775	11,432	·85	73,443	1·13	23·84	16·05	737	104	110	"	"	17,905	"	"
1948	76,351	26,723	49,628	·35	32,559	1·22	17·44	12·05	571	134	110	"	"	10,985	"	"
1949	77,225	61,780	15,445	·80	73,179	1·18	18·06	9·04	658	117	110	"	"	12,902	"	"
1950	77,674	55,245	22,429	·80	69,057	1·25	12·39	6·13	790	98	110	"	"	15,808	"	"

	Grain	Hay	Beets	Canning	Misc.
(1) Average number of irrigations per season	2	3	3	2	2
(2) Average number of days used for one irrigation	15	10	6	6	6
(3) Approximate depth of water for one irrigation	6"	4"	3"	3"	3"

Average flow in c.f.s. or "ditch head" requested by farmers
160 acre unit—3 c.f.s.
80 acre unit—2 c.f.s.

SCHEDULE 1d

Relative to irrigation factors, crops grown and related data, Canada Land & Irrigation Company Project, Vauxhall, Alberta

Year	Gross irrig. area Acres	Area irrig. during year	Summer-fallow and Idle land	irrig. factor %	Duty of Water		Rainfall		Flow Ratio		Aver. size farm unit	Kind of Crops		
					Amount used ac. ft.	Ac. Ft. per acre depth	Total for year inches	Apr. 1 to Oct. 31, inches	Max. flow c.f.s.	Ratio to max. area		Grain Acres	Hay and pasture Acres	Misc. vegs. Acres
1941	43,093	29,893	13,200	69·5	31,469	1·05	11·40	9·58	630	1– 68	120	26,916	2,595	382
1942	43,427	30,245	13,182	69·7	24,724	·82	14·10	11·80	460	1– 94	120	29,279	2,733	326
1943	43,701	31,476	12,225	72·2	37,220	1·18	7·50	5·16	536	1– 81	120	25,372	3,851	470
1944	44,632	32,069	12,563	71·8	35,807	1·11	9·96	7·46	423	1–105	120	26,871	3,096	979
1945	45,373	31,300	14,073	68·9	34,009	1·09	9·74	7·54	557	1– 81	120	25,530	3,215	2,554
1946	44,624	33,722	10,902	75·5	36,136	1007	12·18	10·68	437	1–102	120	27,709	3,252	2,941
1947	44,959	35,115	9,844	78·1	31,783	·90	16·96	12·51	548	1– 82	120	29,738	2,834	1,864
1948	45,954	34,348	11,606	74·7	30,264	·88	12·04	8·81	570	1– 80	120	29,678	3,217	1,713
1949	48,759	37,440	11,319	76·7	50,653	1·35	12·86	8·39	668	1– 73	120	32,260	3,013	2,108
1950	48,954	36,508	12,446	74·6	39,460	1·08	13·24	9·21	641	1– 76	120	29,052	3,000	3,428
	453,476	332,116			351,525	1·05								

	Grain	Hay	Beets	Vegetables
(1) Average number of irrigations per season	2	2	—	3
(2) Average number of days per irrigation		12 to 16 days		
(3) Average size of ditch head—no difference for size of farm unit		2 to 3·5 c.f.s.		
(4) Average depth of water per application		6 inches		

Note: All water deliveries refer to net quantities delivered to farm units for irrigation and exclude seepage losses. Deliveries do not include stock water streams or flow for farm reservoirs.

CHAPTER 7

An Estimate of Cost

Mannix Ltd. Report on South Saskatchewan River Project

August 11, 1952

The Royal Commission on
The South Saskatchewan River
Development,
Ottawa, Canada

Gentlemen:

Re: South Saskatchewan River Development

Following the request of the Commissioners on April 4, 1952, Mannix are pleased to submit herewith our estimate of cost on the reservoir works of the South Saskatchewan River Project which is represented in the attached schedules.

The estimate is based on the report and drawings supplied by the P.F.R.A. and covers the following items:

1. The Main Dam across the South Saskatchewan River, including the cost of unwatering, cofferdam structures and care of the river.

2. The construction of necessary spillway and outlet facilities at the Main Dam.

3. The Saddle Dam located in the Qu'Appelle Valley near the third meridian, and referred to as the "Third Meridian" Dam.

4. The dam across Coteau Creek.

5. The Powerhouse and auxiliary structures.

6. Highway and railway relocation, and a high fill across Aiktow Creek and referred to as Elbow Railway Crossing.

7. Services and General Plant operation.

8. Land damage and acquisition.

9. Contractor's General Expense.

10. Allowance for Contractor's contingencies.

11. Escalation of wages and materials.

12. Engineering.

13. Interest during construction.

14. Contractor's profit.

The estimate does not include:

1. Irrigation structures, outlets or distribution system.

2. Contingencies for changes in design or over-run in quantities.

In the preparation of this estimate, Mannix Ltd. have availed themselves of the experience and professional knowledge of the following companies:

(1) Morrison-Knudsen Co., Inc.; (2) International Engineering Co., Inc.; (3) Caterpillar Tractor; (4) Bucyrus-Erie; (5)

Euclid; (6) John W. Stang Corp; (7) Noble Manufacturing Co.; (8) Bowdinson Manufacturing Co.

Mannix Ltd. believes this to be an accurate and comprehensive estimate of the project based on the information at hand.

All of which is respectfully submitted.

Yours very truly,
MANNIX LTD.
William T. Pyott
Chief Engineer

General Summary

Item	Description	Cost
100	Diversion, Care of River, and Unwatering working places	$ 2,821,000
200	Main Dam	19,971,230
300	Conduit and Intake	25,179,005
400	Powerhouse Area	2,054,695
450	Powerhouse and Switchyard	16,354,350
500	Spillway	10,087,400
600	Coteau Creek Dam	1,630,335
700	Third Meridian Dam	4,721,650
800	Elbow Railway Crossing	5,242,255
900	Railway Relocation	2,857,690
1000	Cement	8,368,665
1100	Operators Village	300,000
—	Road Relocation and Bridges	3,000,000
—	Miscellaneous Service and General Plant Operation	5,157,900
—	Land Damage and Acquisition	600,000
—	Contractor's General Expense	12,301,400
—	Allowance for Contractor's Contingencies	4,000,000
—	Escalation of wages and materials	10,000,000
—	Engineering	8,000,000
—	Interest during Construction	6,125,000
—	Contractors' Overhead and Profit	15,000,000
	Total	$163,772,575

Item No.	Item	Quantity
100	DIVERSION AND CARE OF RIVER	
1.0	COFFERDAMS	
.1	Sheet Pile Cofferdam	L.S.
.2	Pumping	L.S.
.3	Misc. Cofferdam and Dikes	L.S.
.4	Bridge	L.S.
.5	Rock fill	30,000 cy
2.0	Wellpoints and De-watering	L.S.
200	MAIN DAM	
1.0	Clear and Grub	
.1	Right Abutment	150 A.
.2	Left Abutment	200 A.
.3	Borrow Pits	— A.
.4	Structure sites	— A.
2.0	Strip and Waste	
.1	Right Abutment	158,000 cy
.2	Left Abutment	292,000 cy
.3	Plateau Section	33,000 cy
.4	Borrow Areas	535,000 cy
3.0	Exc. Impervious and Haul to Emb.	
.1	Right Abutment	2,256,000 cy
.2	Left Abutment	672,000 cy
.3	Left Abutment Trim	843,000 cy
.4	Plateau Section	608,000 cy
.5	Borrow Areas	15,614,000 cy
4.0	Exc. Pervious and Haul to Emb.	
.1	Right Abutment	607,000 cy
.2	Left Abutment	646,000 cy
.3	Left Abutment Trim	5,473,000 cy
.4	Plateau Section	879,000 cy
.5	Borrow Areas	4,219,000 cy
5.0	Exc. Shale for Cutoff and Waste	
.1	Right Abutment	63,000 cy
.2	Left Abutment	22,000 cy
.3	Plateau Section	28,000 cy
.4	Left Abutment Trim	32,000 cy
6.0	Exc.-Common-Toe Drains	
.1	Right Abutment	142,000 cy
.2	Left Abutment	90,000 cy
7.0	Exc.-Common-Surface Ditch	18,000 cy

Item No.	Item	Quantity
200		
8.0	Foundation Preparation—Exposed Shale	
.1	Right Abutment	231,000 SY
.2	Left Abutment	149,000 SY
.3	Plateau Section	14,000 SY
9.0	Place and Compact Impervious Fill in Dam	
.1	Right Abutment	5,086,000 cy
.2	Left Abutment	6,617,000 cy
.3	Closure Section	4,895,000 cy
.4	Plateau Section	889,000 cy
.5	Upstream Blanket	1,771,000 cy
10.0	Place and Compact Pervious Fill in Dam	
.1	Right Abutment	4,008,000 cy
.2	Left Abutment	7,126,000 cy
.3	Closure Section	5,590,000 cy
.4	Plateau Section	470,000 cy
11.0	Place only Gravel in Toe Drain Trench	29,000 cy
12.0	Place only Selected Pervious Fill in D.S. Filters and Toe Drain	
.1	Right Abutment	428,000 cy
.2	Left Abutment	325,000 cy
13.0	Place only Gravel Filter under Riprap	299,000 cy
14.0	Furnish and Place Riprap on Face of Dam	
.1	Upstream Face	241,000 cy
.2	Downstream Face	58,000 cy
15.0	Furnish and Install Perforated Vit. Clay Pipe in Toe Drains	
.1	12″ Diameter	3,000 l.f.
.2	15″ Diameter	3,000 l.f.
.3	18″ Diameter	2,700 l.f.
16.0	Furnish and Install 18″ Diameter R.C. Pipe Outfall Drains with Cemented Joints	1,000 l.f.
17.0	Furnish and Install Piezometer Tips and Tubing	L.S.
18.0	Furnish and Install Piezometer Wells and Gages	L.S.
19.0	Furnish and Install Settlement Gauges	L.S.
20.0	Additional Water for Compaction	3,870 Mil. G.
21.0	Construction Bridge	Deleted
22.0	Dredge Fill to El. 1646	2,145,000 cy
23.0	Access and Haul Roads	
24.0	Snow Removal	

Item No.	Item	Quantity
300	CONDUITS AND INTAKE	
1.0	Strip and Waste	54,000 cy
2.0	Excavation—Impervious and Haul to Embankment	396,000 cy
3.0	Excavation—Pervious and Haul to Embankment	586,000 cy
4.0	Excavation Shale and Haul to Waste	665,000 cy
5.0	Foundation cleanup—Included in conc.	
6.0	Concrete	
.1	Class A in Intake Structure above El. 1670	39,885 cy
.2	Class B in Intake Structure below El. 1670	25,770 cy
.3	Class B in Intake Portal Structure	6,785 cy
.4	Class B in Intake Approach Channel Paving	18,640 cy
.5	Class B in Plate-lined Two Cell Blocks	407,060 cy
.6	Class B in Plate-lined One Cell Block	6,070 cy
.7	Class B in Plate-lined One Cell Block	14,135 cy
.8	Class C Concrete Fill	106,200 cy
7.0	Reinforcing Steel	
.1	Class A Concrete	4,400,000 lb
.2	Class B Concrete	39,448,000 lb
8.0	Longitudinal Water Stops in Conduit	38,400 lb
9.0	Transverse Water Stops in Conduit	15,100 lb
10.0	6″ Plastic Joint between Conduit Blocks	255,000 S.F.
11.0	Conduit Liner—1¼″ Steel Plate	33,000,000 lb
12.0	Intake Tower Access (Replaced by Access Tunnel) (See Item 22)	
13.0	Intake Gates	
.1	Gates (16)	1,280,000 lb
.2	Guides (16)	288,000 lb
.3	Hoists (16)	960,000 lb
14.0	Concrete Conduit Plugs	3,500 cy
15.0	Trash Racks	
.1	Racks	300,000 lb
.2	Embedded Metal	75,000 lb
.3	Gantry	18,000 lb
16.0	Miscellaneous Metal	100,000 lb

Item No.	Item	Quantity
300		
17.0	Electrical System	L.S.
18.0	Misc. Mechanical	L.S.
19.0	Water Level Recorder	L.S.
20.0	Formed Vents—Forms Only	36,000 s.f.
21.0	Access to Intake Tower	
.1	Class A Concrete	5,670 cy
.2	Reinforcing Steel	366,000 lb
22.0	Elevator shaft to Intake Control Tower	
.1	Class A Concrete	1,185 cy
.2	Reinforcing Steel	124,215 lb
23.0	Elevator to Intake Control Tower	L.S.
24.0	Ladder—Including Landings	200 l.f.

We do not know what type of articulated joints will be used between major structures founded on shale or earth foundation, and have only made an allowance for conventional water stops of copper, steel, and rubber.

Item No.	Item	Quantity
400	POWERHOUSE AREA	
1.0	Excavation	
.1	Stripping	7,000 cy
.2	Exc. clay or sand	61,000 cy
.3	Exc. shale	248,000 cy
2.0	Foundation Seepage Protection	L.S.
3.0	Drain Tile	
.1	Furnish and Install Half Round 6" Diam	2,300 l.f.
.2	Furnish and Install Half Round 8" Diam	990 l.f.
.3	Furnish and Install Half Round 12" Diam	900 l.f.
4.0	Class A Concrete Stilling Basin Walls	40,200 cy
5.0	Class B Concrete	
.1	Surge Tank Base	4,800 cy
.2	Pavement 1 foot thick	6,400 cy
.3	Pavement 3 feet thick	9,500 cy
6.0	Reinforcing steel	2,900,000 lb
7.0	Steel Surge Tank	1,755,000 lb
8.0	Wye Branches—Steel	1,200,000 lb
9.0	Backfill—Upstream P.H.	37,400 cy

We do not know what type of articulated joints will be used between major structures founded on shale or earth foundations, and have only made an allowance for conventional water stops of copper, steel, and rubber.

Item No.	Item	Quantity
450	POWERHOUSE	
1.0	Class A Concrete	
.1	Super Structure	4,700 cy
.2	Transformer Deck and Slab	550 cy
2.0	Class B Concrete	
.1	Substructure	41,000 cy
.2	Switchyard Foundations	200 cy
.3	Curbs, Gutters and Misc.	500 cy
3.0	Reinforcing Steel	1,800,000 lb
4.0	Copper Water Stops	12,800 lb
5.0	Structural Steel in Super Structure	1,430,000 lb
6.0	Structural Steel in Switchyard	685,000 lb
7.0	Misc. Embedded Metal	10,000 lb
8.0	Roofing and Flashing	31,000 lb
9.0	Partition Walls—8" Hollow Tile	8,000 s.f.
10.0	Concrete Floor Finish—1½"	4,600 cy
11.0	Checkered Steel Floor Plates	16,000 lb
12.0	Steel Floor Gratings	12,000 lb
13.0	Misc. Architectural	
.1	Aluminum Angles for Contraction Joints	500 lb
.2	Abrasive Metal Stair Treads	9,000 lb
.3	Metal Handrails	10,000 lb
.4	Metal Doors, Frames, Sash, Louvres, Hardware	1,500 s.f.
.5	Glass and Glazing	5,000 s.f.
.6	Painting Concrete Surfaces	800 sy
.7	Painting Interior Metalwork and Equipment	L.S.
.8	Painting Exterior Metalwork and Equipment	L.S.
.9	Painting Submerged Metal Surfaces	800,000 s.f.
.10	Painting Contraction Joints	500 sy
14.0		
.1	Exc. Switchyard—Uncl.	50,000 cy
.2	Cable Tunnel	L.S.
15.0	Gravel Surf. Switchyard	10,000 cy
16.0	Landscaping	L S.

Item No.	Item	Quantity
450		
17.0	Electrical Equipment	
.1	Main Generators, 30,000 KVA 80% PF	6 ea
.2	House Turbo-Generators, 4,000 KW	2 ea
.3	Elec. Stand-by Unit Diesel—200 KW	1 ea
.4	Rotor Erection Pedestal	3,600 lb
.5	Main Transformers—Sing. Ph.	19 ea
.6	Aux. Transformer	7 ea
.7	Oil Circuit Breakers	14 ea
.8	Main Switchgear	L.S.
.9	Conduit	L.S.
.10	Power and Control Wiring	L.S.
.11	Power Centres	L.S.
.12	Cable Trays	L.S.
.13	Unit Control Boards	6 ea
.14	Station Serv. Control Boards	L.S.
.15	Lighting System	L.S.
.16	Grounding System	L.S.
.17	Telephone System	L.S.
.18	Carrier Current System	L.S.
.19	Shop Equipment	L.S.
.20	Metering Equipment	L.S.
19.0	Mechanic Equipment	
.1	Hydraulic Turbines and Governors—34,500 hp	6 ea
.2	Powerhouse Bridge Crane-Cap. 275 T	1 ea
.3	Butterfly Valves	1,200,000 lb
.4	Draft Tube Gate Guides	130,000 lb
.5	Draft Tube Gates	74,000 lb
.6	Draft Tube Gantry—20 T	15,000 lb
.7	Machine Shop Equipment	
.8	Drainage and Unwatering System	L.S.
.9	Oil System	L.S.
.10	Comp. Air System	L.S.
.11	CO_2 System	L.S.
.12	Raw Water System	L.S.
.13	Treated Water System	L.S.
.14	Heating System	L.S.
.15	Ventilating System and Air Conditioning	L.S.
.16	Tail-water Gauge and Appurtenances	L.S.
.17	Piezometer Piping	L.S.
.18	Plumbing and Sanitation Facilities	L.S.

We do not know what type of articulated joints will be used between major structures founded on shale or earth foundations, and have only made an allowance for conventional water stops of copper, steel, and rubber.

Item No.	Item	Quantity
500	SPILLWAY	
1.0	Clear and Grub	22 AC
2.0	Strip and Waste	246,000 cy
3.0	Excavation	
.1	Pervious—Common	6,225,000 cy
.11	Pervious—Aggregates	2,000,000 cy
.2	Impervious	1,457,000 cy
.3	Shale to waste	1,898,000 cy
.4	Structural—Clay	12,000 cy
.5	Structural—Shale	2,000 cy
.6	Foundation Preparation	15,500 cy
4.0	Fill	
.1	Place only Pervious Fill	817,000 cy
.2	Place only Impervious Fill behind Chute Walls	50,200 cy
.3	Place only Impervious Fill in Cut-off Trench	383,000 cy
.4	Place only Pervious Fill for Roadway Bridge Abutments	45,100 cy
.5	Place only Graded Gravel for Filter Drains	21,700 cy
5.0	Pump and Unwater Working Areas	L.S.
6.0	Riprap in Stilling Basin	8,000 cy
7.0	Supply and Place Top Soil	18,300 cy
8.0	Supply and Place Perforated Vit. Clay Pipe	
.1	6" Diameter	24,400 l.f.
.2	12" Diameter	26,400 l.f.
9.0	Supply and Place 12" Concrete Pipe	100 l.f.
10.0	Class A Concrete	
.1	Front Cut-off Walls	445 cy
.2	Wing Walls	23,500 cy
.3	Walls at Piers	4,700 cy
.4	Chute Walls	20,680 cy
.5	Stilling Basin Walls and Wings	36,250 cy
.6	Bridges	7,250 cy
.7	Concrete Block Out	90 cy
.8	Manholes and Catchbasins	165 cy
.9	Concrete Backfill	2,510 cy

Item No.	Item	Quantity
500		
11.0	Class B Concrete.....	
.1	Approach Slab.....	4,000 cy
.2	Crest.....	10,300 cy
.3	Piers.....	12,555 cy
.4	Chute Floors.....	71,310 cy
.5	Stilling Basin Floor.....	47,530 cy
12.0	Reinforcing Steel.....	11,428,400 lb
13.0	Water Stops.....	
.1	Cooper—12".....	45,040 lb
.2	Stainless Steel—12".....	3,630 lb
.3	Rubber.....	660 l.f.
14.0	Expansion Joint—1/8" Mastic	131,930 sf
15.0	Staff Gauge.....	
16.0	Misc. Metal Work.....	692,930 lb
17.0	Cast Iron.....	11,000 lb
18.0	Tainter Gates.....	
.1	11 Gates.....	806,400 lb
.2	Guides.....	67,900 lb
.3	Hoists.....	11 ea
.4	Anchors.....	250,000 lb
19.0	Emergency Gate..	
.1	Stop Logs.....	98,000 lb
.2	Stop Log Guides.....	31,700 lb
20.0	Structural Steel—Hiway Bridge.....	1,189,000 lb
21.0	Rocker Assembly—Cast Steel.	105,600 lb
22,0	Hand Rail.....	800 l.f.
23.0	Bubbler System.....	L.S.
24.0	Foundation Piezometers.....	L.S.
25.0	Electrical.....	L.S.
26.0	Control Building.....	L.S.

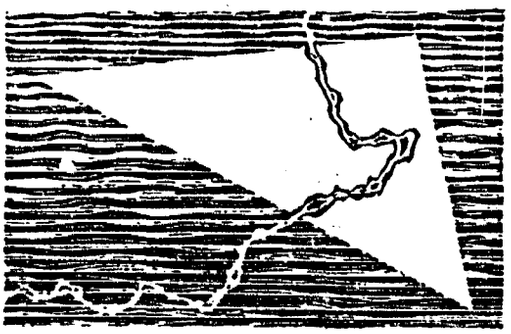
We do not know what type of articulated joints will be used between major structures founded on shale or earth foundations, and have only made an allowance for conventional water stops of copper, steel, and rubber.

Item No.	Item	Quantity
600	COTEAU CREEK DAM	
1.0	Strip and Waste	
.1	Dam Foundation.....	62,000 cy
.2	Borrow Areas.....	24,000 cy
2.0	Excavation—Impervious and Haul to Embankment.....	
.1	Dam Foundation.....	91,000 cy
.2	Borrow Area.....	613,000 cy

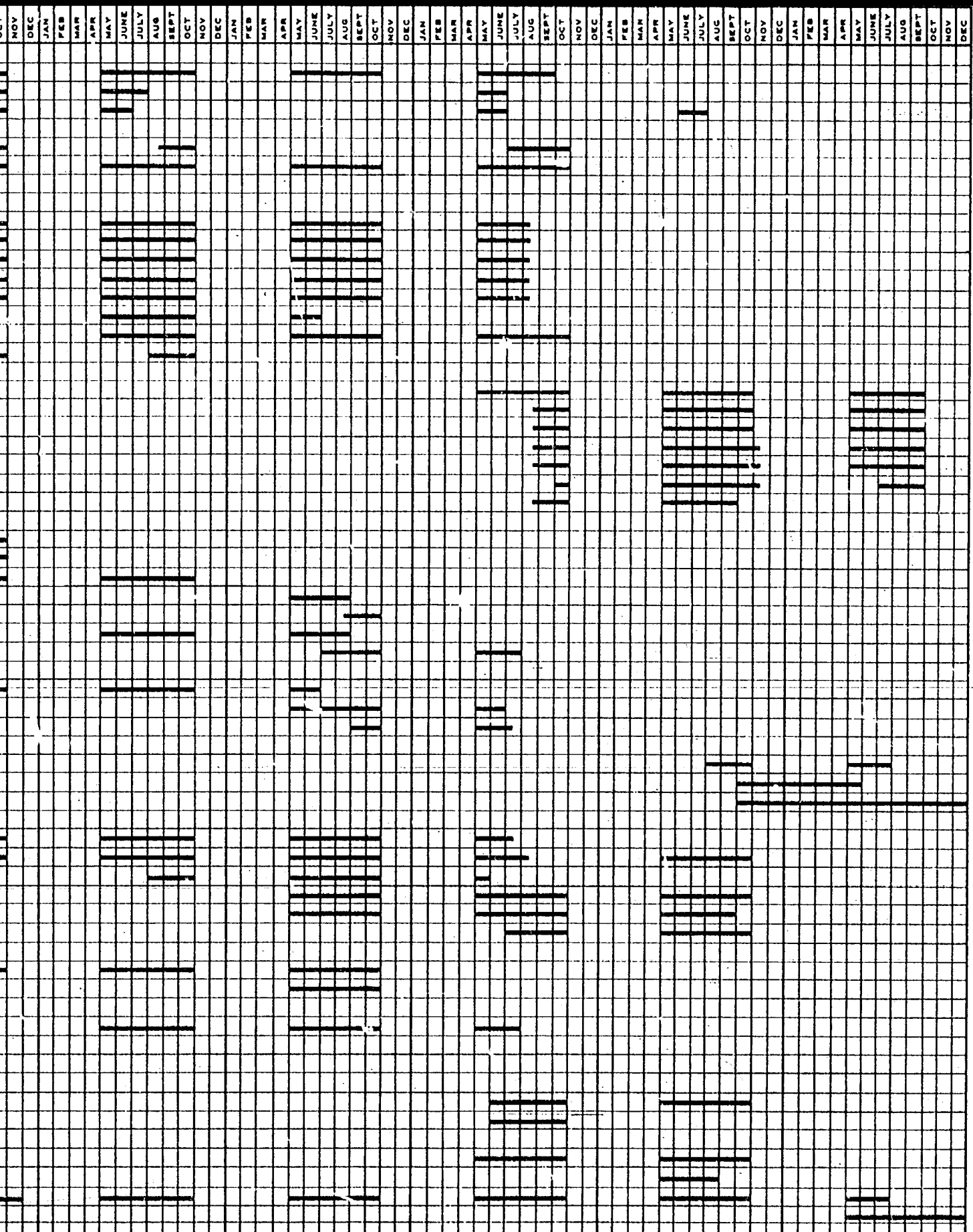
Item No.	Item	Quantity
600		
3.0	Excavation Pervious in Dam Foundation and Haul to Embankment.....	822,000 cy
4.0	Excavation—Shale in Dam Foundation and Haul to waste.....	21,000 cy
5.0	Foundation Preparation of exposed shale.....	5,300 cy
6.0	Common Escavation for Toe Drain and Haul to Embankment or waste.....	1,000 cy
7.0	Place and Compact Impervious Fill in Dam.....	1,708,000 cy
8.0	Place and Compact Previous Fill in Dam.....	1,498,000 cy
9.0	Furnish additional water for Compacting Fill.....	338 Mil. G.
10.0	Furnish and Place Gravel in Toe Drain Trench.....	1,100 cy
11.0	Place Select Pervious Fill in Downstream Filter Blanket and Toe Drain.....	60,500 cy
12.0	Furnish and Place Riprap on Upstream face to Dam.....	66,000 cy
13.0	Furnish and Place Gravel Filter Under Riprap.....	33,000 cy
14.0	Furnish and Install Perforated Vit. Clay Pipe in Toe Drain	
.1	9" Diameter.....	2,200 l.f.
.2	12" Diameter.....	2,000 l.f.
15.0	Diversion and Care of Creek...	L.S.
700	THIRD MERIDIAM DAM	
1.0	Clear and Grub.....	None
2.0	Strip and Waste.....	
.1	Dam Foundation.....	177,000 cy
.2	Borrow Areas.....	165,000 cy
3.0	Common Exc. Dam Cut-off and Haul to Embankment or Waste.....	160,000 cy
4.0	Common Exc. for Upstream Blanket and Haul to Embankment or Waste.....	150,000 cy
5.0	Common Exc. for Toe Drain and Haul to Embankment or Waste.....	2,000 cy
6.0	Excavate Impervious and Haul to Embankment.....	6,364,000 cy
7.0	Excavate Pervious and Haul to Embankment.....	1,567,000 cy

Item No.	Item	Quantity
700		
8.0	Place and Compact Impervious Embankment.....	
.1	Core of Dam.....	5,404,000 cy
.2	Upstream Blanket.....	662,000 cy
9.0	Place and Compact Pervious Embankment.....	1,567,000 cy
10.0	Furnish Additional Water for Compacting Fill.....	417 Mil. G.
11.0	Furnish and Place Riprap on Upstream Face of Dam.....	119,000 cy
12.0	Furnish and Place Gravel Filter under Riprap.....	60,000 cy
13.0	Furnish and Place Select Pervious Blanket under Downstream Pervious Zone of Dam.....	56,000 cy
14.0	Furnish and Place Gravel in Toe Drain Trench.....	1,500 cy
15.0	Furnish and Place Perforated Vit. Clay Pipe in Toe Drain.	
.1	12" Diameter.....	1,800 lf
.2	15" Diameter.....	2,100 lf
16.0	Furnish and Place 18" Diam. Conc. Drainage Pipe.....	1,500 lf
17.0	Conduit.....	
.1	Class A Concrete in Barrel Section.....	1,020 cy
.2	Reinforcing Steel.....	130,600 lb
.3	Rubber waterstops in conduit barrel.....	600 lf
.4	Structural Excavation.....	800 cy
.5	Pumping and Unwatering.....	L.S.
18.0	Intake Tower.....	L.S.
19.0	Access and Haul Roads.....	L.S.

Item No.	Item	Quantity
800	ELBOW CROSSING	
1.0	Clear and Grub.....	None
2.0	Strip and Waste.....	
.1	Foundation.....	117,000 cy
.2	Impervious Borrow Area.....	260,000 cy
.3	Pervious Borrow Area.....	337,000 cy
3.0	Excavate Impervious Material and Haul to Embankment..	3,347,000 cy
4.0	Excavate Pervious Material and Haul to Embankment..	2,315,000 cy
5.0	Place and Compact Impervious Embankment.....	3,043,000 cy
6.0	Place and Compact Pervious Embankment.....	2,315,000 cy
7.0	Furnish Additional Water for Compacting Fill.....	530 Mil. G.
8.0	Furnish and Place Riprap on Upstream and Downstream Slopes.....	210,000 cy
9.0	Furnish and Place Gravel Filter under Riprap	105,000 cy
10.0	Conduit.....	
.1	Struct. Excavation.....	4,000 cy
.2	Class A Concrete.....	4,455 cy
.3	Reinforcing Steel.....	489,000 lb
.4	Pumping and Unwatering.....	L.S.
11.0	Access and Haul Roads.....	L.S.
900	RAILROAD RELOCATION	
1.0	Build 32.8 M.—Abandon 27 M.....	
2.0	Struct. Steel—Bridge and Dam	
.1	Structural Steel.....	471,680 lb
.2	Cast Steel—Shoes and Rockers	61,600 lb
1000	CEMENT	1,497,000 bbls
1100	OPERATORS' VILLAGE ...	L.S.



ITEM No.	ITEM	QUANTITY		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT
		AMOUNT	UNIT									
	Access Railroad	-	L.S.									
	Access and haul roads	-	L.S.									
	Construction villages and shop facilities	-	L.S.									
	Construction plant including aggregate and concrete plants and placement trestle	-	L.S.									
100	DIVERSION AND CARE OF RIVER											
1.	Cofferdams	-	L.S.									
2.	Wellpoints and dewatering	-	L.S.									
200	MAIN DAM											
	Stage I East and West Abutments											
2.	Strip and Waste	702,000	Cy									
3.	Excavate impervious in foundations and borrow and haul to embankment	12,577,000	Cy									
4.	Excavate pervious in foundations and borrow and haul to embankment	8,588,000	Cy									
9.	Place and compact impervious fill in embankment and upstream blanket	12,792,000	Cy									
10.	Place and compact pervious fill in embankment	11,604,000	Cy									
12.	Place select pervious fill in downstream filters and toe drain	753,000	Cy									
13.	Place riprap	215,000	Cy									
22.	Place dredged fill below El. 1646	635,000	Cy									
	Stage II - Closure Section											
2.	Strip and waste	316,000	Cy									
3.	Excavate impervious in borrow areas and haul to embankment	7,133,000	Cy									
4.	Excavate pervious in borrow areas and haul to embankment	3,236,000	Cy									
9.	Place and compact impervious fill in embankment and upstream blanket	6,466,000	Cy									
10.	Place and compact pervious fill in embankment	5,590,000	Cy									
14.	Place riprap	85,000	Cy									
22.	Place dredged fill below El. 1646	1,510,000	Cy									
300	CONDUITS AND INTAKE											
1-5	Strip and excavate common and shale in foundation of conduit	1,641,000	Cy									
6	Concrete in preliminary paving of conduit excavation	20,000	Cy									
6.	Concrete in conduits and intake structure below El. 1670	539,235	Cy									
6.	Concrete in intake structure above El. 1670	39,885	Cy									
6.	Concrete in conduit portal structure and approach channel paving	25,425	Cy									
11.	Install plate steel liner inconduits	33,000,000	Lb									
13,15-24	Install gates, guides, hoists, trashracks, crane and miscellaneous metalwork	3,021,000	Lb									
400	POWERHOUSE AREA											
1.	Excavation	366,000	Cy									
4,5	Place concrete in stilling basin walls and paving and in surge tank bases	60,900	Cy									
7,8	Install surge tanks and wye branches	2,975,000	Lb									
450	POWERHOUSE											
1,2	Place concrete in substructure and superstructure and in switchyard	46,750	Cy									
5,6	Erect structural steel in superstructure and in switchyard	2,115,000	Lb									
17-19	Mechanical and electrical major and auxiliary installations	-										
500	SPILLWAY											
2.	Strip and waste	346,000	Cy									
3.	Excavate pervious and impervious and haul to embankment or aggregate plant	9,727,000	Cy									
3.	Excavate shale and haul to waste	1,998,000	Cy									
4.	Place pervious and impervious fill	1,295,000	Cy									
10,11	Place concrete in crest, chute and stilling basin structures	240,985	Cy									
18-21	Install gates, guides and hoists and erect structural steel in bridge	2,548,000	Lb									
600	COTEAU CREEK DAM											
7,8	Place and compact pervious and impervious fill in dam	3,206,000	Cy									
12.	Place riprap	66,000	Cy									
700	THIRD MERIDIAN DAM											
8,9	Place and compact pervious and impervious fill in dam and blanket	7,633,000	Cy									
11.	Place riprap	119,000	Cy									
12.	Construct concrete conduit and intake structure	-										
800	ELBOW RAILROAD CROSSING											
5,6	Place and compact pervious and impervious fill in embankment	5,358,000	Cy									
10.	Construct concrete conduit	4,455	Cy									
900	RAILROAD RELOCATION											
1.	Build 32.8 mi., abandon 27 mi. of track	-	L.S.									
2.	Erect structural steel spillway bridge	533,280	Lb									
1000	FURNISH CEMENT	1,497,000	Bbls									
1100	CONSTRUCT OPERATORS' VILLAGE	-	L.S.									



SOUTH SASK. RIVER PROJECT, MAJOR CONSTRUCTION ITEMS - CONSTRUCTION SCHEDULE - MANNIX LIMITED, CALGARY, ALTA., AUG. 1-52