## APPENDIX 5

# COLUMBIA BASIN IRRIGATION PROJECT PLANS AND ESTIMATES

CONTENTS

Plans and estimates—Continued.

# COLUMBIA BASIN IRRIGATION PROJECT

## PLANS AND ESTIMATES

### INTRODUCTION

1. In connection with the development of the Columbia Basin irrigation project, the following plans have been considered and will be treated in the order listed below:

| | |
|---|---|
| Greater Wenatchee project | Plan no. 6-A |
| Priest Rapids project | Plan no. 4 |
| Plan no. 2-A | Plan no. 4-A |
| Plan no. 2 | Plan no. 3 |
| Plan no. 1 | |

2. Following is a brief description of each of these proposed plans. These outlines will be followed with a detailed discussion and estimate of cost for each.

3. The greater Wenatchee project covers the Quincy tract by a gravity diversion from Wenatchee River. The reclamation of the Quincy tract in this manner in considered later also as one division of plan no. 6-A.

4. The Priest Rapids project includes 140,520 acres south of Saddle Mountains to be reclaimed by a pumping diversion from the Columbia River at Bend. This tract so reclaimed forms a division of plan no. 4-A discussed later.

5. Plan no. 2-A covers the maximum project with a gravity diversion (including supplemental pumping within 100 feet), the major portion of the water supply being secured from Clark Fork at Albany Falls. This supply would be supplemented in Spokane Valley by a diversion from Spokane River, the amount of which would be fixed by the limit to which regulation may be carried in Coeur d'Alene Lake. (See plate no. 127, page 909.) The main canal for this plan consists of a series of canal sections, tunnels, artificial lakes, and inverted siphons extending from Albany Falls to a point near Hillcrest at the upper end of the irrigable area, including a canal in the Spokane Valley connecting Spokane River to the main canal. For the location of the main canal and its constituent features see plate no. 128.[2] At the bifurcation works near Hillcrest the main canal is divided and the general distribution system begins. (See plate no. 129.[2])

6. Plan no. 2 is identical with plan no. 2-A in all respects except that the entire water supply is obtained from Clark Fork at Albany Falls and no physical connection is made between the main canal and Spokane River. The distributing systems are identical for both plans.

7. Plan no. 1 is identical with plan no. 2-A, except that no consideration is given to supplemental pumping.

8. Plan no. 6-A is a combination of a modification of plan no. 2-A and the greater Wenatchee project which has been discussed earlier in this report. The eastern and southern portion of the project is reclaimed as outlined in plan no. 2-A, and the Quincy area as outlined in the discussion of the greater Wenatchee project. See plate no. 130.[1] The total area reclaimed under this plan is somewhat less than that of plan no. 2-A, because of certain areas marginal to each unit where the cost of local distribution was prohibitive.

[2] Not printed.

9. Plan no. 4 contemplates a pumping diversion from the Columbia River at Grand Coulee. The water supply is pumped from the Columbia River to the Grand Coulee Reservoir from which it is delivered to the project through a gravity system similar in character to that of plan no. 2-A. Plan no. 4 includes also supplemental pumping to a maximum height of 100 feet, and represents the maximum area that can be included in a project with a pumping diversion, as shown on plate no. 131, page 940. The location of the canal system as required for this plan of development is shown on plate no. 132.[2]

10. Plan no. 4-A is identical with plan no. 4 as to area reclaimed. In plan no. 4-A it is proposed to reclaim the Priest Rapids area with a pumping diversion from Columbia River near Bend, the balance of the project being covered by the pumping diversion from Columbia River at Grand Coulee. The canal system is modified to meet these changed conditions.

11. Plan no. 3 is identical in all respects with plan no. 4, except that no consideration is given to supplemental pumping.

### GREATER WENATCHEE PROJECT

12. The greater Wenatchee project, as considered in this report, includes certain areas within the Wenatchee Valley above present irrigation systems, certain lands in the Wenatchee-Malaga, in the east Wenatchee and Moses Coulee districts, aggregating an area of 20,000 acres, and the Quincy tract with an irrigable area of 320,310 acres located in the western part of Grant County. (See plate no. 3, p. 591.)

13. The total irrigable area of the project consists of 340,310 acres. The classification of the lands on the Quincy tract was determined in the manner outlined in a general discussion of the Columbia Basin irrigation project following in this report.

14. The remaining 20,000 acres in the Wenatchee Valley and other districts, as noted above, was not classified for the present report. This irrigable area was fixed from the most reliable data available on the subject. Previous reports on the greater Wenatchee project give the results of certain land classifications of these areas. Reclassifications, made later, have resulted in revisions downward in the irrigable area. No detail information is available on this classification, but the 20,000 acres used in this report represents the opinion of those most familiar with the territory. These areas are given only general consideration in this report, the major objective of which is the reclamation of the Quincy, one of the principal areas on the Columbia Basin irrigation project. The main canal leading to the Quincy area secures its water supply from the Wenatchee River and passes in the approximate vicinity of the tracts that constitute the 20,000 acres mentioned. The present estimate makes provision only for a water supply of 3 acre-feet per acre net, for those areas, and capacity in the main canal for carrying that water to points where it may be diverted into canals leading to the areas under consideration.

15. The Quincy area represents about 95 percent of the area of the Greater Wenatchee project, and has been given the same consideration and treatment as has the Columbia Basin irrigation project. The irrigable area and water requirements for this area were determined

[2] Not printed.

in the manner described in the general discussion of the project which follows later in this report.

16. The water supply for this project is secured from the Wenatchee River. The present unregulated flow of the Wenatchee River is not fully utilized during the low-water season in providing for the irrigation requirements of the present development in the valley.

17. To provide an adequate water supply, the present plan includes regulation of the flow of the Wenatchee River by the construction of a dam across that stream about 1½ miles below Plains or 9 miles below the outlet of Wenatchee Lake. With regulation of Wenatchee Lake to elevation 1,980 by the construction of a dam at the site proposed, water supply would be available for the greater Wenatchee project after allowing 525 second-feet to flow down the river to meet the demand of existing rights.

18. Two power plants are in operation on the Wenatchee River at the present time. The upper or Chumstick plant has an installed capacity of 525 second-feet while the lower or Dryden plant has an installed capacity not exceeding that of the Chumstick plant. Water bypassed the dam at the Wenatchee Lake Reservoir to meet the demands of these power installations, is adequate to meet the irrigation demands on the river below the Dryden plant.

19. In designing the present system, the same canal losses have been used as determined for the Columbia Basin irrigation project.

20. No provision has been made for rediverted water on the project as it is believed the rediversions possible on the Quincy area were very limited in extent.

21. Engineering treatment given this project is the same as that given the Columbia Basin irrigation project. The Quincy area forming the major area of the plan now under discussion is one of the important areas of the Columbia Basin irrigation project. In the comparative estimates for the different plans for that project, plan no. 6-A includes the identical project now under discussion, and forms a very important part. In order to place these various plans of development for the Columbia Basin irrigation project on a comparable basis, the present plan has been given the same consideration and treatment as is outlined more fully in a general discussion of engineering treatment of the Columbia Basin irrigation project, which follows later in this report.

22. The system required for the development of the greater Wenatchee project consists of a dam for the regulation of Wenatchee Lake to elevation 1,980 and a main canal, consisting of a series of sections of open canal, tunnels, and siphons from the Wenatchee Lake Dam to a point on the Quincy area about 3½ miles northwest of Quincy, the end of the main canal.

23. From the end of the main canal the main east is carried easterly to a point south of Ephrata and the main west is carried south to the Low Gap Tunnel, and to the southern slope of the Frenchman Hills. From these main laterals, diversions are made into the distributing system which serves the irrigable land within the project.

24. The main canal estimate is based upon a projection made on line topographic sheets prepared by the Columbia Basin Survey Commission, while the lateral and distributing systems have been estimated upon projections made on the United States Geological Survey quadrangles.

MAIN CANAL

25. Gravity diversions from Wenatchee River.

| | | |
|---|---|---|
| Area reclaimed by gravity, Quincy area | acres | 284, 090 |
| Area reclaimed by supplemental pumping, Quincy area | do | 36, 230 |
| Total area reclaimed, Quincy area | do | 320, 310 |
| Area provided main canal delivery only | do | 20, 000 |
| Total area greater Wenatchee project | do | 340, 310 |
| Mean irrigation requirement at land, acre-feet, per acre | | 2. 94+ |
| Total seasonal requirement at land, acre-feet | | 1, 001, 137 |
| Capacity of main canal at head | second-feet | 3, 400 |
| Diversions to Wenatchee areas | do | 210 |
| Capacity of main canal at bifurcation works | do | 3, 190 |
| Loss in main canal | do | 64 |
| Requirements at bifurcation works | do | 3, 126 |

26. Table no. 1 gives the monthly requirement at the land and the monthly requirement at the point of diversion after correcting for canal and reservoir losses. No water is rediverted on this project.

TABLE NO. 1.—*Water requirements for the greater Wenatchee project (acre-feet)*

| Place | Apr. | May | June | July | Aug. | Sept. | Oct. | Total |
|---|---|---|---|---|---|---|---|---|
| At land | 102, 617 | 178, 202 | 170, 394 | 192, 218 | 182, 708 | 120, 837 | 54, 161 | 1, 001, 137 |
| At bifurcation works | 109, 167 | 189, 577 | 181, 270 | 204, 487 | 194, 370 | 128, 550 | 57, 619 | 1, 065, 040 |
| At diversion | 111, 402 | 193, 460 | 184, 982 | 208, 676 | 198, 350 | 131, 183 | 58, 799 | 1. 086, 852 |
| Diversion requirements | 111, 402 | 193, 460 | 184, 982 | 208, 676 | 198, 350 | 131, 183 | 58, 799 | 1, 086, 852 |

NOTE.—No reservoir loss; no rediverted water.

27. In designing the main canal no reduction in capacity was due to canal losses. The lower end of the canal will have a slight excess capacity.

28. Following are the features listed geographically, which constitute the entire main canal and storage system for the greater Wenatchee project:

29. *Feature no. 1—Wenatchee Lake Dam.*—This structure would be located on the Wenatchee River about 1½ miles below Plains and about 9 miles below the mouth of Wenatchee Lake and effects the regulation of that lake and serves as a diversion structure from the river. This structure is of the rock-fill type.

30. In connection with a combined plan of irrigation and power development involving the complete regulation of the Wenatchee River a plan was prepared of this structure with a top elevation of 2,015. For the purpose of the present plan which is limited to irrigation, the structure was modified in dimensions to meet the requirements for regulation to elevation 1,980. For the purpose of preparing plans for this structure, a topographic survey was made of the dam site during the present investigation. (See plate no. 22.[2]) No testing or drilling was done to determine foundation conditions, but a geological investigation was made to determine the suitability of the site.

[2] Not printed.

31. Regarding the geological features the report by Henry Landes is, in part, as follows:

At the dam site there is a sloping outcrop of bedrock on the east side, which reaches a height of about 50 feet above the water level. Beyond this point the rock is covered by a veneer of soil that has but a slight depth. The entire east end of the dam would rest upon rock in place. The formations are mainly conglomerate and sandstone with very little shale. The strata have a strike that is north and south, or in the same direction as the river at this place. The dip or pitch of the beds is about 40° to the west.

The bed of the river at the dam site contains rock similar to that on the east bank. The river has beveled off the strata and made a fairly smooth floor of conglomerate and sandstone over which it flows. There is no overburden at the dam site and at the date this examination was made (Oct. 21, 1930) the water was both low and clear, so that the bottom of the channel could readily be seen. The stream bed is smooth and without potholes or inequalities of any size.

On the west side of the Wenatchee no rock in place outcrops between the river bed and the foot of the mountain, nearly 3,000 feet away. Along the center line of the dam, across the terraces, the distance vertically to bedrock can be determined only by drilling. The rock is probably but a little way below the surface because the erosion of the Wenatchee Valley in this locality has been done by the river only and not by glaciers. The glaciers which came down the White and the Upper Wenatchee Rivers ended at the foot of Wenatchee Lake, where they left terminal moraines that created the lake. The glacier that descended the Chiwawa River came to an end before the mouth of that stream was reached. Since the valley cutting at the dam site was stream work only, the bedrock in the cross section is not likely to be any lower anywhere else than it is in the present channel. In other words, it is wholly unlikely that on the west side of the valley there is any former river course, once deeply carved in the rock and later filled and abandoned.

In order to determine the actual depth to bedrock it is suggested that a hole be drilled on the line of the dam, at a point about 1,000 feet west of the river bank. If bedrock should be reached at a depth of less than 40 feet, or the approximate level of the river bed, it would be wise to locate a second hole half way between no. 1 and the river, and a third one half way between no. 1 and the west end of the dam. The results from three holes would probably be enough to give the approximate depth to bedrock at the site now under consideration.

The formations which outcrop on the east bank and in the bed of the river would afford good materials for the support of a dam. The rocks have been derived from a disintegrated granite and the sediments have been laid down in a very compact manner. The percentage of voids is low and the soluble material of very limited extent.

32. The outlet tunnel from the Wenatchee Lake Reservoir discharges directly into the main canal.

33. *Feature no. 2.*—Headworks, included in feature no. 1.

34. *Feature no. 3.*—Open canal, Wenatchee Lake Dam to Chumstick Tunnel. Length, 2.92 miles. Type no. 55, plate no. 156.[2] This section of canal extending from the Wenatchee Lake Dam to the Chumstick Tunnel involves no unusual features except as to classification of material which will probably be solid rock through the greater portion of the distance.

35. *Feature no. 4.*—Chumstick Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 4,580 feet or 0.87 mile. No geological report is available on this site or that of the other tunnels which follow on the main canal leading to the Quincy area. A very large part of the area traversed shows sandstone at the surface and there can be but little question as to the nature of the material to be encountered in tunnels along this line. The Columbia Basin Survey Commission gives the classification of material to be found in these tunnels but the report is silent as to any further geological comment. Full timbering for 10 percent of the length was assumed for the present estimate.

[2] Not printed.

36. *Feature no. 5.*—Open canal, Chumstick Tunnel to Chumstick siphon. Length, 1.21 miles. Type no. 55, plate no. 156.[2] No unusual items in this section of canal were found. Solid-rock excavation throughout.

37. *Feature no. 6.*—Chumstick siphon. See plate no. 134 [2] for typical design. This structure consists of one steel pipe line with the required concrete end and foundation works. Length, 2,020 feet, horizontal distance. One steel pipe. Diameter, 18 feet. Maximum head, 309 feet. No unusual items were encountered in this feature. This structure must be constructed as a single unit.

38. *Feature no. 7.*—Open canal, Chumstick siphon to Eagle Tunnel. Length, 1.39 miles. Type no. 55, plate no. 156.[2] This section of canal is through a section where the entire excavation will probably be in solid rock.

39. *Feature no. 8.*—Eagle Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 13,300 feet or 2.52 miles. This structure will be through sandstone formation. For the present estimate, it has been assumed that 10 percent of full timbering will be required.

40. *Feature no. 9.*—Open canal, Eagle Tunnel to Eagle siphon. Length, 0.18 mile. Type no. 55, plate no. 156.[2] This section of canal will be in sandstone throughout.

41. *Feature no. 10.*—Eagle siphon. See plate no. 134 [2] for typical design. This structure consists of one steel pipe line with the required concrete end works and footings. Length, 900 feet, horizontal distance. One steel pipe. Diameter, 18 feet. Maximum head, 122 feet. This structure must be built as one unit. There are no unusual items in this structure.

42. *Feature no. 11.*—Derby Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 11,100 feet or 2.10 miles. This tunnel will be through sandstone throughout. It has been assumed that 10 percent of full timbering will be required.

43. *Feature no. 12.*—Open canal, Derby Tunnel to Nahahum Tunnel. Length, 0.95 mile. Type no. 55, plate no. 156.[2] There is no change in character of canal work in this section. There probably will be solid-rock excavation throughout.

44. *Feature no. 13.*—Nahahum Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 31,000 feet or 5.87 miles. This tunnel is the longest on the system and will be in sandstone throughout. For the present estimate, it has been assumed that 10 percent full timbering will be required. This tunnel, nearly 6 miles in length, will require the longest period for completion of any feature on the project. The cover over this tunnel is deep, a minimum of about 900 feet being reached in the Ollallie Canyon practically midway between the tunnel portals. Using a shaft at this point allowing 4 working faces, the tunnel would probably be driven in 3 years; without the use of the shaft, about 5 years would be required.

45. *Feature no. 14.*—Open canal, Nahahum Tunnel to Warm Springs Tunnel. Length, 1.10 miles. Type no. 55, plate no. 156.[2] This section of canal will probably be in solid-rock excavation throughout and has been estimated on that basis.

46. *Feature no. 15.*—Warm Springs Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 15,700 feet or 2.97 miles. This tunnel is still in the sandstone area and that formation will be encountered throughout in this tunnel.

[2] Not printed.

47. *Feature no. 16.*—Open canal, Warm Springs Tunnel to Sunnyslope Tunnel. Length, 1 mile. Type no. 55, plate no. 156.[2] This section of canal will encounter a large percentage of solid-rock excavation.

48. *Feature no. 17.*—Sunnyslope Tunnel. See plate no. 156.[2] Single bore. Diameter, 20.42 feet. Length, 11,350 feet, or 2.15 miles. This tunnel will be in granite throughout its entire length. For the present estimate, 10 percent of full timbering has been assumed.

49. *Feature no. 18.*—Open canal, Sunnyslope siphon to Columbia River siphon. Length, 0.44 mile. Type no. 55, plate no. 156.[2] This section of canal leading from the Sunnyslope Tunnel to the Columbia River siphon will encounter a large percentage of solid-rock excavation. Some diversion will be made from this section of canal.

50. *Feature no. 19.*—Columbia River siphon. See plate no. 157.[2] This structure carrying the main canal across the Columbia River presents the greatest engineering problem encountered in the preparation of the present report because of the amount of water to be carried through the structure and the extremely high head necessary.

51. In preparing an estimate for this feature several alternative plans were considered. Plans were prepared for various combinations of steel pipe lines carried across the Columbia River on a stee' structure of five 350-foot spans, each span consisting of four parallel steel trusses on a steel structure of such height as to insure a clearance of 45 feet during the high-water period. This study included the consideration of several combinations of pipe lines in an effort to provide a structure at minimum cost.

52. The large amount of material required in the pipe lines, and the supporting structure across the stream, led to the consideration of the use of a pressure tunnel passing under the river. Tentative estimates showed this type of structure to be much less expensive and it has been used in the present estimate. Total length of structure, 7,370 feet, consisting of the following: Station 1402 + 90 − 1411 + 20, 830 feet, one steel pipe line, diameter 17.33 feet, maximum head 620 feet; station 1411 + 20 − 1468 + 66, 5,746 feet, single-bore shaft and pressure tunnel, diameter 17.33 feet, maximum head 1,346 feet; station 1468 + 66 − 1476 + 60, 794 feet, one steel pipe line, diameter 17.33 feet, maximum head 570 feet.

53. The pipe lines are carried to a point where a plate thickness of 1⅝ inches would be required and then pass into the pressure shafts and tunnel. The shafts and tunnels carry this same thickness of steel as a lining backed up by concrete and pressure grouted. A great deal of study and investigation has been devoted to this problem and the best opinion available suggests the use of a special steel for this structure. Accordingly a chrome-nickel steel has been considered at a considerable advance in cost. With this class of steel a working stress of 20,000 pounds has been used instead of 15,000 pounds as used for the commercial steel plate.

54. This structure is so large that a vast amount of study will be required to develop a final plan before construction, but the present study seems to be sufficiently developed for this estimate.

55. *Feature no. 20.*—East Bank Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 600 feet, or 0.11 mile. In-

[2] Not printed.

cluded with this tunnel are 680 feet of canal leading from the Columbia River siphon. This tunnel will be in basalt, and 10 percent of full timbering was assumed for the present estimate.

56. *Feature no. 21.*—Open canal, East Bank Tunnel to Valley View siphon. Length, 2.89 miles. Types no. 56 and no. 57, plate no. 156.[2] This section of canal will encounter a large percentage of solid-rock excavation. No diversions are made from this section of main canal.

57. *Feature no. 22.*—Valley View siphon. See plate no. 134,[2] for typical design. This structure consists of one steel pipe line with concrete cradles and end structures. Length, 500 feet, horizontal distance. One steel pipe. Diameter, 17.92 feet. Maximum head, 84 feet. There are no unusual items in this feature. If so desired, a reinforced concrete structure throughout may be used at this site at about the same cost.

58. *Feature no. 23.*—Open canal, Valley View siphon to Liberty siphon. Length, 3.70 miles. Types no. 56 and no. 57, plate no. 156.[2] This section of canal is over an area of broken topography and a large percentage of solid-rock excavation will be encountered. A diversion of 28 second-feet is made from this section of the main canal.

59. *Feature no. 24.*—Liberty siphon. See plate no. 134 [2] for typical design. This structure consists of one steel pipe line with the necessary concrete end structures and footings. Length, 400 feet, horizontal distance. One steel pipe. Diameter, 17.92 feet. Maximum head, 51 feet.

60. Final plans for this structure will probably show the economy in using reinforced concrete throughout instead of the steel pipe.

61. *Feature no. 25.*—Open canal, Liberty siphon to Rock Island Tunnel. Length, 10.80 miles. Types no. 56 and no. 57, plate no. 156.[2] This section of canal is over an area of irregular topography, and a large percentage of solid-rock excavation will be encountered. A diversion of 88 second-feet is required from this section of the main canal.

62. *Feature no. 26.*—Rock Island Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.92 feet. Length, 9,900 feet, or 1.87 miles. No geological report on this site was made. Surface conditions leave but little doubt as to basalt being encountered throughout. Ten percent of full timbering was assumed for the present estimate.

63. *Feature no. 27.*—Rock Island siphon. See plate no. 134 [2] for typical design. This structure consists of five parallel pipe lines with the necessary concrete end structures and foundations. Length, 3,750 feet, horizontal distance. Five steel pipe lines. Diameter, 8.5 feet. Maximum head, 736 feet. This structure may be constructed as five units in the interest of a stage development. The first unit consisting of the concrete work and one pipe line, each of the four succeeding units consisting of one pipe line only.

64. *Feature no. 28.*—Moses Coulee Tunnel. See plate no. 156.[2] Single bore. Diameter, 17.75 feet. Length, 15,650 feet, or 2.96 miles. No geological report on this tunnel was made, but surface conditions leave very little doubt as to basalt being encountered throughout. Ten percent of full timbering was assumed for the present estimate.

65. *Feature no. 29.*—Open canal, Moses Coulee Tunnel to Moses Coulee siphon. Length, 0.87 mile. Type no. 56, plate no. 156.[2]

[2] Not printed.

Topography in this section of canal is still somewhat broken. A large percentage of solid-rock excavation will be encountered. A diversion of 39 second-feet is made from this section of the main canal.

66. *Feature no. 30.*—Moses Coulee siphon. See plate no. 134 [2] for typical design. This structure consists of four parallel steel pipe lines with the required concrete collateral works. Length, 6,200 feet, horizontal distance. Four steel pipe lines. Diameter, 9.5 feet. Maximum head, 675 feet. This structure may be built in four units in the interest of a stage development.

67. *Feature no. 31.*—Open canal, Moses Coulee siphon to Willow Springs Tunnel. Length, 0.72 mile. Type no. 56, plate no. 156.[2] The same conditions prevail on this section of canal as were found in feature no. 29. A large percentage of the excavation will be in solid rock.

68. *Feature no. 32.*—Willow Springs Tunnel. See plate no. 156.[2] Single bore. Diameter, 16.75 feet. Length, 7,150 feet or 1.35 miles. No geological report is available on this tunnel. Surface indications point to basalt throughout. Ten percent full timbering was assumed for the present estimate.

69. *Feature no. 33.*—Open canal, Willow Springs Tunnel to Willow Springs siphon. Length, 5.69 miles. Types no. 56 and no. 57, plate no. 156.[2] Topography is generally favorable for canal construction but a large percentage of excavation may be in solid rock.

70. *Feature no. 34.*—Willow Springs siphon. See plate no. 134 [2] for typical design. This structure consists of one steel pipe line with the required concrete end structures and cradles. Length, 900 feet, horizontal distance. One steel pipe line. Diameter, 16.58 feet. Maximum head, 98 feet. This structure consisting of only one pipe line is not adapted to a stage construction.

71. *Feature no. 35.*—Open canal, Willow Springs siphon to Quincy Tunnel. Length, 1.10 miles. Types no. 56 and no. 57, plate no. 156.[2] Topography is favorable for canal construction but the largest percentage of excavation will probably be in solid rock.

72. *Feature no. 36.*—Quincy Tunnel. See plate no 156.[2] Single bore. Diameter, 16.75 feet. Length, 6,050 feet or 1.15 miles. No report is available on the geology of this site. The tunnel will probably be in basalt throughout. Ten percent of full timbering was assumed for the present estimate.

73. *Feature no. 37.*—Open canal, Quincy Tunnel to bifurcation works. Length, 0.15 mile. Type no. 56, plate no. 156.[2] This section leading from the Quincy Tunnel to the bifurcation works is ideal from a construction standpoint. Excavation will probably be largely solid rock because of the depth of cut leaving tunnel.

74. *Feature no. 38.*—Bifurcation works. No drawing. This structure is located at the lower end of the main canal and at the beginning of the Quincy area, at this point the water being divided into two main laterals, the main east and the main west.

75. *Distributing system.*—The distributing system begins at the bifurcation works. At this point the main canal is divided into the main east and the main west. The main east extends eastward along the north boundary of the Quincy tract to a point north of Moses Lake, covering an area of 152,680 acres. The main west extends along the west boundary of the tract to the Frenchman siphon,

[2] Not printed.

and then easterly to the Low Gap Tunnel. After passing through that tunnel it extends both easterly and westerly to cover the area on the south of the Frenchman hills. The main west covers an area of 167,630 acres.

76. The entire distributing system has been projected on the United States Geological Survey quadrangles and details of estimates are found only in the office records.

77. *Main east.*—The main east consists of the following features listed geographically:

78. *Feature no. 1.*—Open canal, bifurcation works to turnout N-9, plan no. 2. Length, 16.00 miles. This section of canal is based upon a mile-to-mile estimate prepared from a projection made on the United States Geological Survey quadrangles. For details see office records. This section of canal is ideal from a construction standpoint. This canal connects with lateral N-9, as described under plan no. 2, at its point of diversion from the main north.

79. *Feature no. 2.*—Open canal. Same as feature N-9-B, plan no. 2.

80. *Feature no. 3.*—Siphon no. 1. Same as feature N-9-C, plan no. 2.

81. *Feature no. 4.*—Open canal. Same as feature N-9-D, plan no. 2.

82. *Feature no. 5.*—Siphon no. 2. Same as feature N-9-E, plan no. 2.

83. *Feature no. 6.*—Open canal. Same as feature N-9-F, plan no. 2.

84. The following lateral system diverts from the main east and for convenience is presented in table no. 2.

TABLE NO. 2.—*Lateral system, main east, Greater Wenatchee project*

| Lateral no. | Canal | | Siphon | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section | Barrel | Number of pipes | Length | Diameter | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Feet* |
| E-1 | 19.8 | (1) | | | | | |
| E-1-1 | 10.1 | (1) | | | | | |
| E-2 | 2.15 | (1) | Concrete | 1 | 5,400 | 5.92 | 44 |
| E-3 | 5.15 | (1) | Steel flume | | 2,800 | [2] (#84) | |
| E-4 | 3.15 | (1) | | | | | |

[1] Based on projection on United States Geological Survey quadrangles.
[2] Refers to stock size.

85. *Feature no. 7.*—Sublaterals. The canals listed above terminate when the capacity has been reduced to 100 second-feet. The present plan contemplates a system extending to the farm units but all laterals having a capacity of 100 second-feet or less are not shown individually but are covered by a blanket estimate based upon the acreage served.

86. *Main west.*—The main west consists of the following features listed geographically:

87. *Feature no. 1.*—Open canal, bifurcation works to Great Northern Tunnel. Length, 2.2 miles. This section of canal together with all features following has been estimated on a mile-to-mile basis from a projection made on the United States Geological Survey quadrangles. Details are shown on office records. Conditions on this section of canal are ideal from a construction standpoint.

88. *Feature no. 2.*—Great Northern siphon. See plate no. 158,[2] for typical design. This siphon consists of one steel pipe line with the

[2] Not printed.

required concrete end structures and cradles. Length, 1,860 feet, horizontal distance. One steel pipe line. Diameter, 13.40 feet. Maximum head, 160 feet. This structure passes under the main line of the Great Northern Railway.

89. *Feature no. 3.*—Open canal, Great Northern siphon to Potholes siphon. Length, 7.3 miles. This section is favorable for canal construction. No unusual features were encountered.

90. *Feature no. 4.*—Potholes siphon. See plate no. 134 [2] for typical design. This structure consists of one steel pipe line with the necessary concrete and structures and footings. Length, 11,500 feet, horizontal distance. One steel pipe. Diameter, 10.75 feet. Maximum head, 434 feet. This structure consisting of only one pipe line is not adapted to a stage development.

91. *Feature no. 5.*—Open canal, Potholes siphon to Frenchman siphon. Length, 10.5 miles. This section of canal is over an area, the topography of which is rough and broken in places and some solid-rock excavation will be encountered especially at the lower end. Lateral W-1 is diverted from this section.

92. *Feature no. 6.*—Frenchman siphon. This feature is identical with feature no. 35, Main North, plan no. 2-A.

93. *Feature no. 7.*—Open canal, Frenchman siphon to Low Gap Tunnel. This feature is identical with feature no. 36, Main North, plan no. 2.

94. *Feature no. 8.*—Low Gap Tunnel. This feature is identical with feature no. 37, Main North, plan no. 2.

95. *Feature no. 9.*—Open canal, Low Gap Tunnel to 100 second-foot capacity. This feature is identical with feature no. 38, Main North, plan no. 2.

96. The lateral system in table no. 3 diverts from the Main West.

TABLE NO. 3.—*Lateral system, Main West, Greater Wenatchee project*

| Lateral no. | Canal | | Siphon | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section | Barrel | Number of pipes | Length | Diameter | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Feet* |
| W-1 | 2.10 | (1) | | | | | |
| W-2 | 3.20 | (1) | | | | | |
| W-3 | 4.74 | (1) | Concrete | 1 | 14,072 | 6.67 | 94 |
| W-4 | 1.00 | (1) | | | | | |

[1] Based on projection on United States Geological Survey quadrangles.

97. *Feature no. 10.*—Sublaterals. The laterals listed above are those having a capacity of 100 second-feet or more. Those having a capacity of less than 100 second-feet are not treated individually, but are covered by a blanket estimate based upon acreage served.

## GENERAL PROJECT ITEMS

98. Above has been given a brief description of the canal system as proposed for the Greater Wenatchee project. The items following pertain to the general project rather than to any of the subdivisions mentioned above.

[2] Not printed.

99. *Drainage.*—A blanket estimate is included to cover the item of drainage. The question of drainage is one that will require considerable detail study and one that will not be determined until some years after the land has been put under irrigation. For the purpose of this estimate, a blanket estimate of $5 per acre has been included to cover this item.

100. *Wasteways.*—Wasteways along the Main Canal are included with the feature on which they are located. Wasteways on the project are the same as those used in the Gault report for the Quincy area.

101. *Supplemental pumping.*—In all the various plans considered later in this report, consideration is given to pumping to certain desirable lands lying above the gravity system. On those plans considered later, locations favorable to power development are available along the canal system, and it is proposed to develop this power to be utilized in pumping to these high areas. In order to put the project, now under consideration, on the same basis for comparative purposes, it is proposed to pump to the desirable lands that can be reclaimed with a lift of not to exceed 100 feet. The project now under consideration offers no opportunity for developing power on the project with water used for irrigation and the power requirements for this supplemental pumping must be secured from an outside source. The power installation required to meet the demand of this supplemental pumping is 3,300 kilowatts.

102. The total area on the Quincy tract under supplemental pumping is 36,230 acres, the seasonal water requirements of which are 113,200 acre-feet. These areas to be covered by supplemental pumping vary in extent from several thousand acres to areas as small as 20 acres and are scattered throughout the project as is indicated on plate no. 127, page 909. The average lift to cover these areas is 70 feet gross.

103. Estimates for pumping installations to cover these tracts are taken from graphs. The cost of the installation includes all electrical equipment from the step-down transformers, pumping equipment, valves, pipe lines, etc., and is expressed on an acre-foot-foot basis.

104. To meet the requirements of supplemental pumping all installations are capable of handling 113,230 acre-feet during the season against a gross head of 70 feet or 7,925,400 acre-feet-feet.

105. It is apparent that the cost of any pumping installation is dependent upon the size of the unit. The approximate size of the units required will be as follows:

| | |
|---|---|
| 50 percent, or 3,962,700 acre-feet-feet | 1,000-kilowatt installation. |
| 30 percent, or 2,377,620 acre-feet-feet | 300-kilowatt installation. |
| 10 percent, or 792,640 acre-feet-feet | 250-kilowatt installation. |
| 5 percent, or 396,270 acre-feet-feet | 100-kilowatt installation. |
| 5 percent, or 396,270 acre-feet-feet | 10–50-kilowatt installation. |

106. The cost of these developments was determined by applying the unit prices as determined from the graph to the unit quantities as given above.

107. *Telephones.*—An estimate is included to cover the expense of a telephone system adequate to meet the requirements of the system when in operation.

108. *Wells.*—As explained more fully in discussion of the Columbia Basin irrigation project, which follows later in this report, this item is included to meet requirements during the construction period.

109. *Permanent buildings.*—This item covers the buildings, offices, shops, warehouses, and quarters, etc., required in the operation of the completed system.

ESTIMATES OF COST

110. The following tabulation itemizes the cost of all features of the Greater Wenatchee project.

| Feature no. | MAIN CANAL SYSTEM | |
|---|---|---|
| 1. | Wenatchee Lake Dam (including $673,300 overflow damages) | $9, 278, 450 |
| 2. | Included in feature no. 1. | |
| 3. | Canal | 721, 520 |
| 4. | Chumstick Tunnel | 670, 320 |
| 5. | Canal | 556, 990 |
| 6. | Chumstick siphon | 562, 030 |
| 7. | Canal | 657, 600 |
| 8. | Eagle Tunnel | 1, 940, 090 |
| 9. | Open canal | 58, 820 |
| 10. | Eagle siphon | 167, 990 |
| 11. | Derby Tunnel | 1, 596, 810 |
| 12. | Canal | 416, 700 |
| 13. | Nahahum Tunnel | 4, 605, 090 |
| 14. | Canal | 532, 350 |
| 15. | Warm Springs Tunnel | 2, 271, 500 |
| 16. | Canal | 453, 540 |
| 17. | Sunnyslope Tunnel | 2, 009, 170 |
| 18. | Canal | 130, 570 |
| 19. | Columbia River siphon | 8, 350, 570 |
| 20. | East Bank Tunnel | 191, 150 |
| 21. | Canal | 780, 000 |
| 22. | Valley View siphon | 102, 510 |
| 23. | Canal | 928, 520 |
| 24. | Liberty siphon | 87, 610 |
| 25. | Canal | 2, 760, 630 |
| 26. | Rock Island Tunnel | 1, 471, 960 |
| 27. | Rock Island siphon | 2, 223, 620 |
| 28. | Moses Coulee Tunnel | 2, 227, 520 |
| 29. | Canal | 232, 300 |
| 30. | Moses Coulee siphon | 3, 434, 060 |
| 31. | Canal | 245, 130 |
| 32. | Willow Springs Tunnel | 939, 670 |
| 33. | Canal | 1, 188, 640 |
| 34. | Willow Springs siphon | 127, 960 |
| 35. | Canal | 257, 870 |
| 36. | Quincy Tunnel | 803, 090 |
| 37. | Canal | 56, 350 |
| 38. | Bifurcation works | 34, 190 |
| | Total main canal system | 53, 072, 890 |
| | MAIN EAST | |
| 1. | Main East | 2, 670, 920 |
| E-1. | Lateral E-1 | 754, 070 |
| E-1-1. | Lateral E-1-1 | 253, 090 |
| E-2. | Lateral E-2 | 190, 130 |
| E-3. | Lateral E-3 | 216, 590 |
| E-4. | Lateral E-4 | 83, 440 |
| 2. | Sublaterals | 3, 206, 280 |
| | Total Main East | 7, 374, 520 |

| Feature no. | MAIN WEST | |
|---|---|---|
| 1. | Canal | $249, 860 |
| 2. | Great Northern siphon | 135, 640 |
| 3. | Canal | 824, 000 |
| 4. | Potholes siphon | 1, 295, 990 |
| 5. | Canal | 975, 750 |
| 6. | Frenchman siphon | 880, 750 |
| 7. | Canal | 1, 211, 620 |
| 8. | Low Gap Tunnel | 865, 040 |
| 9. | Canal | 1, 418, 820 |
| W-1. | Lateral W-1 | 93, 000 |
| W-2. | Lateral W-2 | 90, 130 |
| W-3. | Lateral W-3 | 567, 400 |
| W-4. | Lateral W-4 | 31, 510 |
| 10. | Sublaterals | 3, 520, 230 |
| | Total Main West | 12, 149, 740 |
| | PROJECT ITEMS | |
| | Preliminary surveys | 200, 000 |
| | Supplemental pumping (less power development and transmission lines) | 693, 470 |
| | Drainage | 1, 601, 550 |
| | Wasteways | 65, 640 |
| | Permanent buildings | 350, 000 |
| | Wells | 55, 000 |
| | Telephone system | 100, 000 |
| | Total project items | 3, 065, 660 |
| | RECAPITULATION | |
| | Main canal (including Wenatchee Lake Dam) | 53, 072, 890 |
| | Main East | 7, 374, 520 |
| | Main West | 12, 149, 740 |
| | Project items | 3, 065, 660 |
| | Total Quincy area | 75, 662, 810 |

### STAGE DEVELOPMENT

111. The necessity and importance of a stage development on a project the magnitude of the one now under consideration is set forth in a discussion of plan no. 2-A for the Columbia Basin irrigation project which follows in this report (par. 358). On the basis as outlined in that discussion, table no. 4, gives the set-up for the stage development in the present plan.

TABLE NO. 4.—*Stage development, Greater Wenatchee project*

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| 1 | | $100, 000 | | | |
| 2 | 1 | 365, 000 | | | |
| 3 | | 1, 800, 000 | | | |
| 4 | | 3, 400, 000 | | | |
| 5 | 2 | 5, 700, 000 | | | |
| 6 | | 10, 500, 000 | | | |
| 7 | | 30, 852, 530 | 52, 740 | | |
| 8 | | 2, 430, 810 | | 52, 740 | |
| 9 | 3 | 3, 147, 510 | 87, 670 | 43, 830 | |
| 10 | 4 | 6, 962, 400 | 49, 860 | 43, 840 | 52, 740 |
| 11 | | 4, 085, 650 | | 49, 860 | 43, 830 |
| 12 | 5 | 3, 526, 970 | 93, 820 | 46, 910 | 43, 840 |
| 13 | 6 | 2, 791, 940 | 36, 220 | 46, 910 | 49, 860 |
| 14 | | | | 36, 220 | 46, 910 |
| 15 | | | | | 46, 910 |
| 16 | | | | | 36, 220 |

112. Under the plan of development as outlined above the first land would be brought under cultivation in the eighth year and repayments on that area would begin at the end of the tenth year, the last area in the project would be brought under cultivation in the fourteenth year and repayments on that area begin at the end of the sixteenth year. Carrying all capital expenditures to the end of the sixteenth year with interest at the rate of 4 percent and deducting an annual repayment of $11.85 per acre which also carries interest at the rate of 4 percent to the end of the sixteenth year gives the following:

| | *Per acre* |
|---|---|
| Capital cost plus interest, $94,896,200 | $296. 26 |
| Capital cost, $75,662,810 | 236. 22 |
| Interest, $19,233,390 | 60. 04 |
| Annual interest charge after completion | 11. 85 |
| Annual cost of operation and maintenance | 1. 10 |
| Annual depreciation charge | . 80 |
| Total annual charge less power | 1. 90 |

## PRIEST RAPIDS PROJECT

### GENERAL DATA

113. The Priest Rapids project consists of the irrigable area within the tract bounded on the west and south by Columbia River, on the east by the steep sidehill slope extending from the Pioneer Ranch opposite the lower end of Savage Island, northeast to a point about 1 mile west of Scooteney Lake, and on the north by the Saddle Mountains. (See plate no. 3.) This area, if developed as a separate project, would eliminate from plan no. 4 all areas below the Scooteney siphon in that plan. The area so eliminated from plan no. 4 amounts to 165,320 acres. The irrigable area of the Priest Rapids project is 140,520 acres, the difference 24,800 acres representing high areas that cannot be feasibly reclaimed under the plan now proposed for the Priest Rapids project.

114. The irrigable area of this project consists of 140,520 acres. The classification of this land and its water requirements were determined in the manner outlined under the discussion following, relating to the Columbia Basin irrigation project of which this Priest Rapids project forms a part. This area includes the Priest Rapids-Highland project, a development proposed and sponsored by the Washington Irrigation & Development Co. during 1920–22. This proposed development, said to reclaim 100,000 acres, has never progressed beyond the preliminary stages, and that area is included in the project now under discussion.

115. The water supply for this project will be secured by a pumping diversion from the Columbia River at a point about 3 miles above Bend or about 10 miles above Priest Rapids. The plan now under consideration is strictly an irrigation project and no power development is included. The comprehensive development of the water resources of the Columbia River includes a power development at Priest Rapids. This development would be the logical source of power for pumping purposes on the irrigation project now being considered, and the estimate has been based upon securing power from that source. An alternative estimate is also given based upon the securing of power from the development of the Columbia River

at Grand Coulee as proposed under plan no. 4 for reclaiming the Columbia Basin irrigation project.

116. In designing an irrigation system for this Priest Rapids project, the same engineering treatment has been rendered as outlined for the Columbia Basin irrigation project which is discussed later in this report.

117. The same seasonal distribution of water has been used, the canal losses determined in the same manner, the same general type and character of construction work is proposed for each case.

118. The irrigation system proposed for this project consists of the pumping plant with collateral works and the canal system necessary to deliver the water to the lands of the project.

119. The area to be reclaimed amounts to 140,520 acres with a seasonal water requirement of 443,132 acre-feet at the pumping plant.

120. In order to reduce the pumping head as much as possible the water will be delivered from the pumps to two canals; the high-line canal having a water-surface elevation at 1,005 at the head and the low-line canal having an elevation of 850. The unregulated low-water elevation of Columbia River at the site of the pumping plant is 470. With the high dam at Priest Rapids, as considered in the power section of this report, the elevation of the pool above that development will be at elevation 540.

121. The high-line canal includes a repumping station about 30 miles downstream from the bend pumping plant, to serve a desirable area in that section. The high-line canal, with repumping as noted, serves an area of 66,420 acres, requiring a maximum canal capacity of 660 second-feet. The low-line canal serves an area of 74,100 acres with a maximum canal capacity of 730 second-feet.

### BEND PUMPING PLANT

122. This proposed pumping plant located on the Columbia River about 3 miles above Bend in section 15, township 15 north, range 23 east Williamette meridian, consists of the following items:

One concrete-steel building, 40 by 60 by 180 feet, with the necessary substructure and intake channel leading to the pumps.

For the high-line canal, three pumping units, each unit consisting of two single-stage pumps connected in series, capacity of each unit 330 second-feet, total head 545 feet, each unit discharging into steel discharge pipe, 78 inches in diameter, 860 feet in length, leading to the canal. Each pump is actuated by a 15,000-horsepower motor with the necessary electrical equipment. This installation provides for one stand-by unit.

For the low-line canal, three pumping units, each unit consisting of two single-stage pumps connected in series, capacity 365 second-feet, total head 390 feet, each unit discharging into a discharge pipe 82 inches in diameter, 580 feet in length, leading to the canal. Each pump is actuated by a 12,000-horsepower motor with the necessary electrical accessories.

123. The above description includes pumping heads, motor capacities, etc., that are based upon pumping from the Columbia River in its unregulated condition. With the Priest Rapids power development these data would be modified to meet a river elevation of 540 instead of 470, as used above.

CANAL SYSTEM

124. As described heretofore, the canal system consists of two main canals—the high-line canal and the low-line canal.

125. *High-line canal.*—The high-line canal extends eastward from the pumping plant, along the south slope of Saddle Mountains for a distance of 34 miles at which point a repumping plant is located to raise the water through a head of 222 feet. The canal then continues in an easterly and southerly direction for a distance of about 16 miles where its capacity reaches 100 second-feet.

| | | |
|---|---|---|
| Pumping diversion from Columbia River: | | |
| Static head | feet | 535 |
| Pumping head | do | 545 |
| Area reclaimed primary pumping | acres | 26,480 |
| Area reclaimed by repumping | do | 39,940 |
| Total area under high-line canal | do | 66,420 |
| Maximum capacity high-line canal | second-feet | 660 |
| Loss in high-line canal | do | 40 |
| Net delivery to land | do | 620 |

No rediverted water.

126. The high-line canal consists of the following features listed geographically.

127. *Feature no. 1—Open canal.*—Bend pumping plant to repumping plant. Length, 34.17 miles. This section of canal extends along the south slope of the Saddle Mountains for its entire length. The topography is somewhat broken, especially at the upper end of the section. The first mile of canal will be over steep ground with a large percentage of solid rock excavation. Other than the upper portion of this section the conditions are average from a construction standpoint. No laterals divert from this section of the high-line canal.

128. *Feature no. 2—Repumping plant.*—The water is delivered to this pumping plant at elevation 945, and 395 second-feet is repumped to elevation 1,150. This pumping plant consists of the following items: Concrete-steel pump house, 30 by 40 by 60 feet; 3 pumping units, each unit consisting of a single-stage pump, capacity 200 second-feet, total head 222 feet, each pump discharging into a steel pipe line 60 inches in diameter and 2,410 feet in length leading to the canal above, each pump to be actuated by a 7,500-horsepower motor with the necessary electrical accessories. One stand-by unit is provided in the above plan.

129. *Feature no. 3—Open canal.*—Repumping plant to Kohler siphon. Length, 12.2 miles. This section of canal extends along the south slope of Saddle Mountains to reach the land west of the drainage leading south from Scooteney Lake. No unusual items are found in this section of canal. This section is very favorable from a construction standpoint. A small amount of classified material will be encountered in this section of the canal work.

130. *Feature no. 4—Kohler siphon.*—No special drawing. This structure consists of a single steel-pipe line, 75 inches in diameter, with the necessary concrete end structures and cradles. Length, 6,019 feet, horizontal distance. One steel-pipe line. Maximum head, 148 feet. This structure crosses a low depression located between the high-line canal and an area of irrigable land located in the vicinity of the Windspear ranch.

131. *Feature no. 5—Open canal, Kohler siphon to 100 second-feet capacity.*—Length, 4.90 miles. This section of canal extends from the

end of the Kohler siphon to a point where the capacity is reduced to 100 second-feet. Conditions are very favorable for canal construction.

132. *Feature no. 6—Wasteway Canal.*—Length, 4.36 miles. This canal is used as a wasteway only. It extends from the repumping plant southward to an area of waste land bordering Columbia River. This canal affords an outlet for the discharge of the high-line canal should the repumping station be put out of commission on short notice. This section of canal is favorable from a construction standpoint. While it will be used only intermittently, it will require a concrete lining because of excessive grades.

133. *Feature no. II-1—Lateral H-1.*—Length, 6.90 miles. This lateral extends from the repumping plant in a southeasterly direction for 6.90 miles and is really an extension of the high-line canal beyond the repumping plant. This section of canal is favorable from a construction standpoint.

134. *Feature no. 7—Sublaterals.*—The system as described above constitutes the entire high-line canal system having a capacity of 100 second-feet or more. The present plan includes a canal system capable of making water delivery to each farm unit but the laterals having a capacity of less than 100 second-feet are not estimated individually, but are covered by a blanket estimate based upon the area served.

135. *Low-line canal.*—The low-line canal is eastward of the Bend pumping plant, and is approximately parallel to the high-line canal which is located farther up the slope on the south side of Saddle Mountains. This canal, except for the first 2 miles which are located over an area broken in topography and rocky in character, is favorable for canal construction. Three laterals, L-1, L-2, and L-3 are diverted from the low-line canal.

| | | |
|---|---|---|
| Pumping diversion from Columbia River: | | |
| Static head | feet | 380 |
| Pumping head | do | 390 |
| Area reclaimed by primary pumping | acres | 74,100 |
| Maximum capacity low-line canal | second-feet | 730 |
| Losses in low-line canal | do | 44 |
| Net delivery to land | do | 686 |
| No rediverted water. | | |

136. The low-line canal consists of the following features listed geographically.

137. *Feature no. L-1—Lateral L-1.*—Length, 3.3 miles. This lateral involves no unusual items. It is located over an area ideal from a construction standpoint.

138. *Feature no. L-2—Lateral L-2.*—Length, 6.90 miles. This lateral involves no unusual items and is first class from a construction standpoint.

139. *Feature no. L-3—Lateral L-3.*—Length, 4 miles. This lateral includes the Haven siphon consisting of one steel pipe line 42 inches in diameter, 6,019 feet in length. Other than this siphon the lateral involves no unusual items and is ideal from a construction standpoint.

140. *Feature no. 2—Sublaterals.*—As explained in a similar feature under the high-line canal, the laterals having a capacity of less than 100 second-feet are not treated individually, but are covered by a blanket estimate based upon the area served.

GENERAL PROJECT ITEMS

141. Above has been enumerated the various features that constitute the proposed irrigation works consisting of pumping plants and canal system. The following items, necessary adjuncts to a completed system, pertain to the general project rather than to any of the subdivisions mentioned above.

142. *Drainage.*—This phase of the problem is discussed fully under plan no. 2, Columbia Basin irrigation project which follows in this report. The matter is given the same consideration in the plan now under discussion. A blanket estimate of $5 per acre is allowed to cover this item. In the plan of stage development proposed the cost of this development is all placed in the last years of construction.

143. *Wasteways.*—Wasteways required on this project are covered by an individual estimate under the canal system to which they are appurtenant.

144. *Supplemental pumping.*—No pumping is considered in the present study except that outlined at the Bend pumping plant on the Columbia river and at the repumping plant on the high-line canal. Supplemental pumping is given consideration only on those projects where opportunity is provided in the canal system for developing power to be used for pumping to higher lands. In the plan now under consideration, no opportunity for developing power exists along the proposed canal system.

145. *Telephone systems.*—An estimate is included to cover the cost of a telephone system thought to meet the requirements during operation of the proposed system.

146. *Wells.*—This phase is discussed fully under plan no. 2 of the Columbia Basin irrigation project, and is included in the present plan for the same reasons as outlined in discussions.

147. *Permanent buildings.*—This item covers the cost of buildings, offices, shops, warehouses, quarters, etc. required in the operation of the completed system.

148. *Preliminary work.*—This item is included to cover the preliminary work necessary and incidental to the development of the final plan of reclamation of the area.

149. *Other features.*—The estimate includes an item for fencing all canals and for providing bridges, where required, on existing highways. Where bridges are required, standard types of the Washington Highway Department with an H-15 loading have been used in all cases. The fences, bridges, etc. are included in the estimate for the feature of which they form a part.

ESTIMATES OF COST

150. Following are the estimates of the various features that constitute the irrigation system as designed for the Priest Rapids irrigation project. It should be noted that the estimate includes no power development. Power for pumping purposes is to be transmitted from Grand Coulee power plant.

| | |
|---|---|
| Bend pumping plant (including power transmission line from Grand Coulee power plant) | $5,077,510 |

| Feature no. | HIGH-LINE CANAL SYSTEM | |
|---|---|---|
| 1. | Canal | 2,293,020 |
| 2. | Repumping plant | 839,590 |
| 3. | Canal | 592,030 |
| 4. | Kohler siphon | 211,150 |
| 5. | Canal | 176,430 |
| 6. | Wasteway | 266,780 |
| H-1. | Lateral H-1 | 225,020 |
| 7. | Sublaterals | 1,394,820 |
| | Total high-line canal | 5,998,840 |

| | LOW-LINE CANAL SYSTEM | |
|---|---|---|
| 1. | Canal | 1,090,220 |
| L-1. | Lateral L-1 | 74,840 |
| L-2. | Lateral L-2 | 235,740 |
| L-3. | Lateral L-3 | 195,560 |
| 2. | Sublaterals | 1,556,100 |
| | Total low-line canal | 3,152,460 |

| | PROJECT ITEMS | |
|---|---|---|
| | Preliminary surveys, etc | 100,000 |
| | Wasteways | 0 |
| | Drainage | 702,600 |
| | Supplemental pumping | 0 |
| | Permanent buildings | 140,000 |
| | Wells | 45,000 |
| | Telephone system | 30,000 |
| | Total project items | 1,017,600 |

| | RECAPITULATION | |
|---|---|---|
| | Bend pumping plant | 5,077,510 |
| | High-line canal system | 5,998,840 |
| | Low-line canal system | 3,152,460 |
| | Project items | 1,017,600 |
| | Project total | 15,246,410 |

## STAGE DEVELOPMENT

151. In determining the final per-acre cost, where interest is considered on all money invested, it is necessary to build the system by stages in order to reduce the items of interest to the lowest possible point.

152. For the same reason it is important to coordinate the construction of the system to meet the rate of colonization. The stage development proposed for the plan under consideration divides the project into four stages or units. It has been assumed that the land can be colonized at the rate of approximately 35,000 acres per year, that interest on all balances due will be at the rate of 4 percent per annum, that the land will be placed under cultivation when irrigation water is made available and that repayments will begin after the third crop had been produced and that the rate of repayment would be at least 4 percent on the final per-acre cost.

153. *Power from Grand Coulee power development.*—Using power developed at Grand Coulee the following program of stage development is outlined:

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | 1 | $218,000 | | | |
| 2 | 2 | 2,200,000 | | | |
| 3 | | 4,298,470 | 26,480 | | |
| 4 | 3 | 3,263,990 | 39,940 | 26,480 | |
| 5 | 4 | 2,527,280 | 37,050 | 39,940 | |
| 6 | 5 | 2,738,670 | 37,050 | 37,050 | 26,480 |
| 7 | | | | 37,050 | 39,940 |
| 8 | | | | | 37,050 |
| 9 | | | | | 37,050 |

154. Under the above plan of development the first land would be placed under cultivation in the fourth year and repayments begin at end of the sixth, the last area would be brought under cultivation in the seventh year and repayments begin at the end of the ninth. Carrying all capital expenditures through to the end of the eighth year with interest at the rate of 4 percent and deducting an annual repayment of $4.91 per acre, which also carries interest at the rate of 4 percent from time repayment is made to the end of the eighth year, gives the following:

| | | *Per acre* |
|---|---|---|
| Capital cost plus interest | $17,257,470 | =$122.81 |
| Capital cost | 15,246,810 | = 108.50 |
| Interest | 2,010,660 | = 14.31 |
| Annual interest charge after completion at 4 percent | | 4.91 |
| Annual cost of operation and maintenance | | 1.05 |
| Annual depreciation charge | | 1.20 |
| Total annual charge less power | | 2.25 |
| Annual cost of power | | 1.83 |
| Total annual charge (operation, maintenance and depreciation) | | 4.08 |

155. The preceding estimate is based upon the assumption that power is to be purchased at and transmitted from the proposed Grand Coulee power development. If conditions are such that this power required for the operation of this system can be secured from the proposed Priest Rapids power development, then the Bend pumping plant can be reduced in cost. This reduction in cost is effected through the reduction of pumping head and the large reduction in the cost of the necessary transmission cost of the necessary transmission lines. If the Priest Rapids high dam is constructed and power secured from that source, the cost of the Priest Rapids irrigation project will be as follows:

*Recapitulation*

| | |
|---|---|
| Bend Pumping plant | $3,223,280 |
| High-line canal (no change) | 5,998,840 |
| Low-line canal (no change) | 3,152,460 |
| Project items (no change) | 1,017,600 |
| Project total | 13,392,180 |

156. This change in the capital cost changes the set-up of the stage development to conform to that shown in paragraph 157.

157. *Power from Priest Rapids power development.*—Using power developed at Priest Rapids the following program of stage development is outlined:

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | 1 | $218,000 | | | |
| 2 | 2 | 1,700,000 | | | |
| 3 | | 3,317,270 | 26,480 | | |
| 4 | 3 | 3,152,440 | 39,940 | 26,480 | |
| 5 | 4 | 2,357,080 | 37,050 | 39,940 | |
| 6 | 5 | 2,647,390 | 37,050 | 37,050 | 26,480 |
| 7 | | | | 37,050 | 39,940 |
| 8 | | | | | 37,050 |
| 9 | | | | | 37,050 |

158. The change in the stage development due to securing power from Priest Rapids affects only the capital expenditures. No change is made in the rate of colonization or other items except that the minimum rate of repayment is $4.30 per acre instead of $4.91 as shown in the first case. Carrying these revised calculations through to the end of the eighth year gives the following results:

| | | *Per acre* |
|---|---|---|
| Capital cost plus interest | $15,092,800 = | $107.40 |
| Capital cost | 13,392,180 = | 95.30 |
| Interest | 1,700,620 = | 12.10 |
| Annual interest charge after completion at 4 percent | | 4.30 |
| Annual cost of operation and maintenance | | 1.05 |
| Annual depreciation charge | | 1.20 |
| Total annual charge less power | | 2.25 |
| Annual cost of power | | 1.59 |
| Total annual charge (operation, maintenance, and depreciation) | | 3.84 |

PASCO PROJECT

159. Consideration was given the reclamation of an area located north and east of Pasco, by pumping diversions from Snake River. See plate no. 3. Tentative estimates indicate the possibility of reclaiming about 100,000 acres in that manner at a per-acre cost practically identical with that of plan no. 4-A of which this area forms a part.

160. Provision was made in plan no. 4-A for the use of 710 second-feet of rediverted water. While unable in this present study to fix the point of application for this rediverted water, the topographic conditions indicate that the greater portion would be available only on the lands of lower elevation of which the Pasco tract considered forms the larger portion. For that reason the Pasco tract is considered a desirable portion of the area to be covered by plan no. 4-A.

161. More detailed studies, however, may demonstrate the advisability of reclaiming a small area, possibly 10,000 or 15,000 acres by an independent system with a pumping diversion from Snake River.

PLAN NO. 2-A

162. *Main canal system.*—Gravity diversion (maximum project with supplemental pumping). Diversion from Clark Fork and Spokane River.

| | | |
|---|---|---|
| Area reclaimed by gravity | acres | 1, 256, 940 |
| Area reclaimed by supplemental pumping | do | 262, 950 |
| Total area reclaimed | do | 1, 519, 890 |
| Mean irrigation requirement at land | acre-feet per acre | 2. 88+ |
| Total seasonal requirements at land | acre-feet | 4, 378, 357 |
| Capacity of main canal, Clark Fork to Spokane Canal Junction | second-feet | 11, 750 |
| Capacity of Spokane Canal | do | 2, 490 |
| Capacity of main canal, Spokane Canal Junction to bifurcation works | second-feet | 14, 240 |
| Loss in main canal | do | 290 |
| Loss in reservoirs | do | 295 |
| Quantity delivered at bifurcation works | do | 13, 655 |
| Rediverted water on project | do | 890 |
| Total requirements for project | do | 14, 545 |

Table No. 5 gives the monthly requirements at the land and the monthly diversion requirements after correcting for losses in canals and reservoirs and taking credit for water rediverted on the project.

TABLE NO. 5.—*Water requirements for plan no. 2-A (acre-feet)*

| Place | April | May | June | July | August | September | October | Total |
|---|---|---|---|---|---|---|---|---|
| At land | 448, 782 | 779, 348 | 745, 196 | 840, 644 | 799, 050 | 528, 468 | 236, 869 | 4, 378, 357 |
| At bifurcation works | 477, 427 | 829, 093 | 792, 762 | 894, 303 | 850, 053 | 562, 200 | 251, 989 | 4, 657, 827 |
| At diversion—canal loss only | 487, 171 | 846, 013 | 808, 941 | 912, 554 | 867, 401 | 573, 673 | 257, 131 | 4, 752, 884 |
| Reservoir loss | 13, 500 | 14, 900 | 15, 680 | 17, 720 | 16, 760 | 14, 060 | 13, 030 | 105, 650 |
| Total requirements | 500, 671 | 860, 913 | 824, 621 | 930, 274 | 884, 161 | 587, 733 | 270, 161 | 4, 858, 534 |
| Less rediverted water | 6, 822 | 27, 379 | 39, 112 | 54, 758 | 46, 935 | 35, 201 | 23, 464 | 233, 671 |
| Diversion requirements | 493, 849 | 833, 534 | 785, 509 | 875, 516 | 837, 226 | 552, 532 | 246, 697 | 4, 624, 863 |

163. In designing the main canal, no modification in capacity was made at any point for losses accruing above that point, the main canal from the Spokane Canal junction to the bifurcation works having a designed capacity of 14,240 second-feet.

164. In considering the main canal, reference is made to 16 detail line topographic sheets, scale 400 feet to 1 inch, with a contour interval of 5 feet, and to detail profiles in three sections, giving the data upon which the estimates were based. These topographic maps and profiles are unpublished.

165. The following features, listed geographically, constitute the entire irrigation system for plan no. 2-A.

166. *Main canal.*—Main canal features are shown on plate no. 128,[2] condensed profile on plate no. 159.[2]

167. *Feature no. 1.*—Albany Falls Dam. See plate no. 160.[2] The Albany Falls Dam serves to divert water from Clark Fork into the main canal for the various plans considered, and to serve as regulatory works for Pend Oreille Lake, located 20 miles upstream, which forms one of the reservoirs considered in the utilization of the water of Clark Fork. The fall in the river between the lake and dam is about 7 feet when the discharge of the river is 40,000 second-feet. This fall is somewhat less at higher stages of the river. At Albany Falls the river is divided into three channels by rock islands located at the crest of the falls. The banks and bottom of the channel are located in solid rock and offer a very favorable site for the location

[2] Not printed.

of a structure of the type proposed. The estimate for this structure includes an item covering the cost of overflow damages incidental to regulating Pend Oreille Lake to an elevation of 2,170.00, United States Geological Survey datum, or elevation 2,166.80, United States Coast and Geodetic Survey datum.

168. This structure, while referred to as the Albany Falls Dam, is in reality nothing more than a gate structure of large proportions and is so designed. Without regulation the water surface in the lake has reached or exceeded elevation 2,066.8 on an average of 1 year in 5 during the years of record, and doubtless will do so in the future. It is important that the flow through the channel at Albany Falls be not reduced, and the structure is designed to pass the maximum discharge of record without adversely affecting the water surface at the lake. To provide the necessary floodway the structure is provided with four 30-foot by 130-foot rolling gates with the necessary abutments and piers. Provision is made for passing water required to satisfy existing rights downstream, and a chute is provided to handle log transportation on the river. Provision is also made for the construction of navigation locks if and when required. Present plans provide for development of the limited power possibilities at this site.

169. *Feature no. 2—Diversion head works.*—See plate no. 161.[2] The diversion headworks are located a short distance above the Albany Falls Dam and consist of two similar structures, each serving to regulate the flow through one of the two bores of the twin-bore Newport tunnel. The controlling feature in the design of the headworks is elevation. Pend Oreille Lake is regulated in the interest of navigation on the lake, power at and below Albany Falls, flood control on the lake, and irrigation of Columbia Basin irrigation project. It is essential, therefore, that the diversion headworks be at an elevation which will permit of the water required for irrigation being withdrawn, even when the lake is drawn down to provide water for power at Albany Falls and below. Plate no. 177 [2] shows diversion headworks for single-bore Newport tunnel which was designed for the purpose of a comparative estimate.

170. For plan no. 2, the critical period of regulation was in August 1926. The elevation of the diversion works was fixed so that the irrigation requirements for that month could be satisfied and permit 7,000 second-feet to pass Albany Falls for power uses. Plan no. 2 requires a maximum diversion of 14,240 second-feet for irrigation, while plan no. 2-A requires the diversion of only 11,750 second-feet the difference being made up by diversion from Spokane River. The headworks for plan no. 2-A could, therefore, be set at a higher elevation than the headworks for plan no. 2. This would permit of a reduction in size of tunnels and canals, as the drop, and hence the velocity, would be greater. However, the same elevation was used in each case, the advantages to irrigation in plan no. 2-A being sacrificed in the interests of power, the lower elevation permitting more draw down of storage with a consequent increase in low-water flow past Albany Falls from 7,000 second-feet to 8,660 second-feet during the months of July, August, September, and October.

171. *Feature no. 3—Newport Tunnel.*—Twin bore. See plate no. 133.[2] Diameter, 27.33 feet. Length, 28,549 feet or 5.41 miles. This

[2] Not printed.

tunnel begins at the point of diversion from Clark Fork and has the same location as considered in the report of the Columbia Basin Survey Commission and subsequent reports of other agencies. Mr. Kirk Bryan, geologist in the United States Geological Survey, in appendix B (unpublished) of the Gault report on the general engineering features and estimates of the Columbia Basin irrigation project, reports on the geology of this site as follows:

> The tunnel enters the hillside in such a deep cut that it can be assumed that the upper portal is in rock. This rock is a granite-gneiss. It is much shattered and slickensided as seen in the nearby railroad cut. The large diameter of the tunnel will cause much difficulty in rock of this type, for loose blocks will fall from the roof unless prevented by timbering. Outcrops of rock similar to that near the portal can be found along the tunnel line for about 2,000 feet. From this point for 5 miles the tunnel is covered by gravel which masks the underlying rock. Occasional outcrops off the line of the tunnel indicate, however, that the same granite-gneiss continues.
>
> The tunnel line then crosses an open gravel-filled valley nearly a quarter of a mile across. The depth of gravel in this section cannot be predicted. The gravel is water bearing and will feed water to the fissures of the underlying rock. Thus assuming a rock section for the tunnel, provision should be made for pumping large quantities of water in this part of the tunnel. The 800 to 900 feet intervening between this valley and the lower portal is occupied by granite-gneiss, grano-diorite, and a plated granite-gneiss which is almost a schist. These rocks occur as nearly vertical belts. The granite-gneiss is in contrast to that at the other end of the tunnel in being massive with widely-spaced joints. The grano-diorite is also a firm rock with massive joints. The plated granite-gneiss may, however, require timbering.

While the geologist's report is somewhat indefinite in regard to the amount of timbering required in this tunnel, it is indicated that full timbering might be required in some sections and partial or no timbering in other sections. For the purpose of the present estimate 50 percent full timbering was assumed throughout the tunnel.

172. As stated in paragraph 1395 of the main report, an analysis of single versus double-bore tunnels was made in connection with the present study. Typical double-bore construction with the necessary transitions is shown on plate no. 162.[2] Single-bore construction is shown on plate no. 163.[2]

173. *Feature no. 4—Canalization Little Spokane River.*—Unlined canal section. See plate no. 133.[2] Length 5.74 miles. From the lower portal of the Newport tunnel the water is carried to Chain Lake Reservoir by improvement or canalization of Little Spokane River. This work of canalization is very heavy at the upper end (maximum cut 75 feet), but gradually decreases until Chain Lake Reservoir is reached where the cut is reduced to about 5 feet.

174. *Feature no. 5—Great Northern Railway Line change.*—The canalization of Little Spokane River and the utilization of Chain Lake Reservoir to be created by the construction of the Camden Dam will necessitate the relocation and construction of a section of the main transcontinental line of the Great Northern Railway. This line is located at present through Little Spokane River Canyon at an elevation considerably below the water surface of the proposed reservoir. Above the reservoir, and through the section where the Spokane River is canalized, the railroad is located in the middle of the narrow valley and must be moved to one side to allow sufficient width for the canalization. The railroad located at the present time has a maximum permissible adverse grade for eastbound traffic from the station of Milan.

[2] Not printed.

In order to relocate this line at a point high enough to pass the Chain Lake Reservoir it will be necessary to rebuild the line from a point about a mile west of Milan to a point near Scotia, a distance of about 14 miles. Another small section between Scotia and Penrith must be moved from the center to one side of the valley to provide the required space for the river canalization. This total improvement will aggregate about 11 miles of relocation of the railroad, a portion of which will be heavy construction involving a few short tunnels.

175. It has been suggested that this conflict with the Great Northern Railway through the Little Spokane River Canyon might be avoided in another manner. Several miles of their main line extending eastward from Camden through the Canyon is located with a maximum adverse grade for eastbound traffic, has a large amount of curvature, and, because of foundation conditions over a portion of the line, is an expensive section to maintain. It has been suggested that an arrangement might be made whereby the Great Northern Railway would acquire joint ownership in the line of the Spokane International Railway from a point near Dover to Spokane and abandon their present line for main-line purposes. Portions of the present line might be left from Dover to Albany Falls, and from Elk to Spokane, to serve as branch lines. This would eliminate conflict with the Chain Lake Reservoir. It is possible that this change will have been effected before any need exists for the Chain Lake Reservoir. If not, a payment to assist in the acquisition of the joint ownership of the section of the Spokane International Railway might be made in lieu of the expense of the reconstruction of their present line.

176. *Feature no. 6—Camden Dam.*—See plate no. 164.[2] This dam across the Little Spokane River Canyon forms the Chain Lake Reservoir, an almost indispensable link in the main canal system. Chain Lake Reservoir is about 5 miles in length and replaces at least 6 miles of canal, the greater portion of which would be located along a steep, rocky canyon wall where construction would be difficult and extremely expensive. Two sites have been considered in the previous reports as the location for this dam; one location about three eighths of a mile upstream from the Camden depot, and the second about a thousand feet farther upstream.

177. The geological report accompanying the Gault estimate, based upon data secured from the sinking of 4 test holes at the lower site and 1 at the upper, seems to indicate the upper site to be the better of the 2. A. J. Wiley, while engaged as consulting engineer on this work, expressed the opinion that the upper site was the more desirable one. The geological report made by Henry Landes, while engaged as consulting geologist in connection with the preparation of the present plan, renders the following conclusion: "It is clear that no better selection of a site could be made anywhere in that close vicinity." The upper site was adopted. No additional testing was done at this site, but a topographical survey was made in order to better locate and define the extent of the dam required. The structure proposed is a rock-fill type with a heavy earth or gravel face.

178. The canalization of Little Spokane River, the feature leading to the reservoir formed by this dam, involves a large amount of gravel excavation. At points the canyon is so narrow that there is some question as to the availability of dumping ground for the material

[2] Not printed.

excavated. This waste material would be particularly well adapted for use on the upstream face of the dam and could readily be moved into position by the railroad extending through the canyon at the present time. This plan of procedure is contemplated in the present estimate. This reservoir involves no storage consideration. Elevation of normal water surface in the Chain Lake reservoir is 2,030. Typical control and outlet works are shown on plate no. 165.[2]

179. *Feature no. 7—Open canal, Camden Dam to Dry Creek Reservoir.*—See plate no. 133.[2] Length, 5.23 miles. Types 2 and 3, modified. This section of canal leads from the canal outlet structure, included as a part of the Camden Dam to the Dry Creek Reservoir. About one half mile below the head, this section of canal reaches the end of the Little Spokane River canyon and from that point the canal skirts along the rolling hillside and gradually leaves the vicinity of that stream.

180. *Feature no. 8—Dry Creek Dam.*—See plate no. 166.[2] This dam forms the Dry Creek Reservoir, the only object of which is to eliminate the several miles of canal that would be required to pass around the border of this site, with its attendant cost and loss of head in the canal. This reservoir could be eliminated if necessary, but is included because of its economy. The upper of the two sites, as outlined in the Gault report, is used in the present plan, as the geological study made in connection with the Gault report, based upon borings at each site, leads to the conclusion that the upper site is the superior. No additional exploratory work was made in connection with the present report. A small additional amount of topography was taken at the dam site. Recommendations of Mr. Wiley as to design are as follows:

> The Dry Creek Dam has a maximum height above stream bed of 104 feet. It is underlaid by sand and gravel resting on the Latah formation, and the dam is sealed to the formation by a cut-off trench at the upstream toe with sheet piling extending into this formation. It is recommended that a second cut-off trench of less depth and without the sheet piling should be added.

181. *Feature no. 9—Open canal, Dry Creek Reservoir to Milan Tunnel.*—See plate no. 133.[2] Length, 1.21 miles. Type no. 4, modified. This section of canal leads from the Dry Creek Reservoir to Milan Tunnel. There are no special features.

182. *Feature no. 10—Milan Tunnel.*—See plate no. 133.[2] Twin bore. Diameter, 26.25 feet. Length, 13,800 feet or 2.61 miles. Location is the same as that used in Columbia Basin Survey Commission and Gault reports. Kirk Bryan reports on this site, in part, as follows:

> The upper and lower portals are in granite-gneiss. * * * The granite-gneiss of this area is not closely jointed and should form a good roof. There are many pegmatite dikes which will on the whole probably have wider spaced joints than the main mass of the rock. Incomplete or partial timbering may be necessary in places, but generally rock will stand. The tunnel line crosses a divide that is on the whole well drained.

183. For the purpose of the present estimate, 10 percent of full timbering was assumed throughout the tunnel. Typical transition canal to tunnel is shown on plates nos. 167[2] and 168.[2]

184. *Feature no. 11—Open canal, Milan Tunnel to Deep Creek Tunnel.*—See plate no. 133.[2] Length, 1.95 miles. Type no. 4, modified. This section of canal leads from the Milan Tunnel to the Deep Creek Reservoir, and involves no special features.

[2] Not printed.

185. *Feature no. 12—Deep Creek Tunnel.*—See plate no. 133.[2] Twin bore. Diameter, 26.25 feet. Length, 5,820 feet or 1.1 miles. The location is the same as that considered in the report of the Columbia Basin Survey Commission and subsequent reports. The geology at this site is reported by Kirk Bryan as follows:

> Both portals are in plowed fields and the intervening ridge is largely cultivated. The top of the divide is occupied by coarse, angular gravel, doubtless of glacial origin. From nearby outcrops it is evident that a thin plate of Latah formation 50 to 200 feet thick overlies granite-gneiss. The tunnel will be located on or close to the contact of these two formations. Since the Latah is thin and weathered, it will be a relatively soft clay or clayey gravel. The granite-gneiss near the contact with the Latah is always soft and decomposed. This tunnel, will, therefore, be in soft and weak material that will require complete timbering during construction. The gravel and soil overlying the tunnel absorbs a large part of the local rainfall which may penetrate the underlying rocks and will add to their softness. However, the total quantity of water will probably be small for there is only a small drainage area from which this water may be derived.

186. For the purpose of present estimate, 100 percent full timbering is used.

187. *Feature no. 13—Open Canal, Deep Creek Tunnel to Deep Creek Reservoir.*—See plate no. 133.[2] Length, 0.70 mile (0.50 mile type no. 4, modified, 0.20 mile channel in reservoir). This section of canal leads from the Deep Creek Tunnel to Deep Creek Reservoir, and involves no unusual features.

188. *Feature no. 14—Deep Creek Dam.*—See plate no. 169.[2] This dam is an earth-fill structure with loose rock on the downstream face, rock paving on the upstream face and a blanket of clay extending upstream.

189. This dam forms the Deep Creek Reservoir which is incorporated in the main canal system in the interest of economy and the conservation of elevation. This reservoir could be eliminated if necessary, but at some additional expense. No additional field or exploratory work was done at this site in the preparation of the present report. The geological report by Mr. Bryan as to the suitability of the reservoir site renders the following conclusion: "If leakage is cut off at the dam, then porous formations will be full of water, but there will be no exit for it except through the underlying granite-gneiss and Latah."

190. The site of the proposed dam is the same as that considered in the report of the Columbia Basin Survey Commission, and reports by other agencies subsequent thereto. The exploratory work consists of one hole sunk by the Columbia Basin Survey Commission and three sunk in preparation of the Gault estimate. Predicated upon this exploratory work the geological opinion by Mr. Bryan is as follows:

> It is believed that this material is adequate to support the weight of a dam with a relatively small base. The upper fine material is not sufficiently impervious or continuous so that a cut-off trench landed in it will be adequate protection against percolation of water under the dam. There are, therefore, two alternatives in the construction of the dam: (1) To make a mechanical connection between the impervious part of the dam and the bedrock; (2) prevent percolation under the dam by an upstream blanket.

191. The latter alternative was adopted for the present plan.

192. *Feature no. 15—Deadman Tunnel.*—See plate no. 133.[2] Twin bore. Diameter, 26.25 feet. Length, 8,770 feet or 1.56 miles. Loca-

[2] Not printed.

tion of this tunnel is the same as that considered in the report of the Columbia Basin Survey Commission and the reports subsequent thereto. Mr. Bryan reports on the geology at this location, in part, as follows:

> The plateau which divides these drainages is composed of granite-gneiss, and the tunnel will be wholly in this rock. The outcrops indicate normal jointing and only incomplete or partial timbering at places where the joints are unusually numerous will be necessary. The divide has good natural drainage and large quantities of water are not to be expected in the tunnel.

193. Ten percent full timbering is used in the present estimate.

194. *Feature no. 16—Open Canal, Deadman Tunnel to Deadman Reservoir.*—See plate no. 133.[2] Length, 0.51 mile. Type no. 4, modified. This section of canal extends from Deadman Tunnel to the Deadman Reservoir and contains no unusual elements.

195. *Feature no. 17—Deadman Creek Dam.*—See plate no. 170.[2] The Deadman Creek Dam forms the Deadman Creek Reservoir, a link in the main canal system. This reservoir is about 3 miles in length and replaces about 4 miles of canal and an inverted siphon about 3,500 feet in length. This reservoir is incorporated in the canal system in the interest of economy and the conservation of grade. It might be omitted from the canal system but at an additional expense.

196. Regarding this reservoir site, Kirk Bryan reports, in part, as follows:

> As explained more at length regarding Deep Creek Lake, if percolation through the valley fill is stopped at the dam, no loss from the lake can take place through the Latah formation or the granite-gneiss.

197. Two sites have been considered as the location of this dam. The lower site selected by the Columbia Basin Survey Commission was not favorably considered from a geological standpoint.

198. The upper site is located about a mile upstream from the lower one and is considered the more desirable. The geological report based upon the sinking of 10 test holes, which was made in conjunction with the Gault report, is somewhat lengthy and cannot be quoted in full. The following extract from that report indicates the suitability of the site for a dam of certain type.

> It is believed that the gravels and sands of the flood plain will afford an adequate foundation for a dam with a base of moderate width. The fine sands, silts, and clays at the top of the older fill consist of lenticular masses. The logs of the drill holes show that there is no continuous clay bed across the section. There is, therefore, no assurance that percolation under the dam can be stopped by making a mechanical connection between the impervious part of the dam and these fine gray sands and clays. An upstream blanket seems the most suitable device for preventing percolation under the dam.

199. A. J. Wiley reports regarding this structure as follows:

> It is recommended that the plans for the dam at this site as shown by the Reclamation Bureau report should be modified by flattening the slopes to 4 to 1 on the upstream and 6 to 1 on the downstream face. The upstream blanket shown by the plans should be retained and should be extended to cover the entire length of the dam instead of the main creek crossing as shown. It is also recommended that cut-off trenches * * * be added to the design for the Deadman Dam.

200. This structure is of the rolled-fill embankment type designed along the lines recommended by Mr. Wiley except as to modification as to downstream slope.

[2] Not printed.

201. *Feature no. 18—Open canal, Deadman Creek Reservoir to Pleasant Prairie Tunnel.*—See plate no. 133.[2] Length, 4.82 miles. Type no. 3, modified. This section of canal leads from the Deadman Creek Reservoir to Pleasant Prairie Tunnel. There are no unusual features.

202. *Feature no. 19—Pleasant Prairie Tunnel.*—See plate no. 133.[2] Twin bore. Diameter, 25.16 feet. Length, 16,640 feet, or 3.15 miles. The location is the same as that considered in the report of the Columbia Basin Survey Commission and other reports subsequent thereto. Kirk Bryan reports on the geology of this site, in part, as follows:

> The upper portal of the tunnel lies in a wooded hillside, covered by soil of glacier till. The deep entrance cut will doubtless carry the grade below this material into the Latah formation. The lower portal is in a bench of gravel. The entrance cut will doubtless pass through the gravel and place the portal in granite-gneiss which is exposed in the hillside above. This rock is locally massive with few and widely spaced joints. It is the best rock to be encountered on any of the tunnels. The outcrops of granite-gneiss can be followed for three quarters of a mile to a point where it is overlaid by the Latah. The granite-gneiss was a hill during the deposition of the Latah shales. The contact between the two may, therefore, have any slope characteristic of a hillside * * *. If the contact has a slope of 1 in 1, there will be a mile of granite-gneiss in the tunnel. If the slope is 1 in 2, the granite-gneiss will extend one quarter mile further.
>
> The Latah formation is a compact clay shale or sandy clay shale with well-marked joints. The vertical joints are spaced at intervals of 6 inches to several feet and divide the mass into blocks. Generally, the shale will stand vertically for heights of 20 to 30 feet. * * * Tunnels of small diameter would require little timbering, but a tunnel that will be 27 feet in diameter before lining will doubtless require a timber arch during construction. * * * As the tunnel grade is well above the water table in Spokane valley, little water will doubtless be encountered.

203. Fifty percent full timbering is used in the present estimate.

204. *Feature no. 20—Open canal, Pleasant Prairie Tunnel to Spokane River Crossing.*—See plate no. 133.[2] Length, 1.26 miles. Type no. 4. This section of canal involves no unusual features.

205. *Feature no. 21—Spokane River Crossing.*—See plate no. 135.[2] The location is the same as that considered in the Gault report. Alternative plans were considered for this structure. One, a concrete pressure tunnel consisting of three barrels passing below the bed of the stream, and the other, a flume consisting of three through steel barrels supported on concrete arches. The latter type was adopted for economic reasons. The intake to this structure incorporated a spillway, the first on the main canal, when the entire capacity of the canal might be discharged for an unlimited period of time. The ability to drop water diverted from Clark Fork into the Spokane River at this point might be a decided asset to this proposed canal system. During the irrigation season, except July, the month of maximum irrigation demand, the excess water might be discharged into the Spokane River and during the nonirrigation season the entire capacity of the canal so discharged. This additional water supplementing the supply of Spokane River at this point would be of decided value to power development downstream from this crossing. If the diversion of large quantities of water from one watershed to another is permissible, tentative studies have indicated that the benefits to be derived from the sale of this water would amount to about $26 per acre, depending

[2] Not printed.

upon the area of the project considered. A further discussion of this matter will be found in the section on Tributary effects, of the main report.

206. The Board of Engineers of the Bureau of Reclamation, composed of six members—Louis E. Hill, Joseph Jacobs, Charles H. Locher, Richard R. Lyman, Arthur J. Turner, and O. L. Waller—February 1925 proposed a dam in the Spokane River at this crossing; this dam to serve two purposes: (1) As a crossing for the main canal from Clark Fork, and (2) to divert water from the Spokane River into the canal system. This plan was not favorably considered in the present report. A dam in Spokane River at this point, of sufficient height to divert water into the canal, would develop overflow damages in this, a suburban section of Spokane, which would be expensive and objectionable.

207. Spokane Valley at this point, and for several miles upstream, consists of a coarse gravel deposit of unknown depth, and the losses from a reservoir would in all probability be excessive. For these reasons it was deemed advisable to cross the Spokane River as planned in the Gault report, the water from Spokane River being diverted through a canal leaving that stream at a point a short distance east of the Washington-Idaho State line and joining the main canal a short distance above the portal of the Manito Tunnel.

208. *Feature no. 22-A—Open canal, Spokane River Crossing to Spokane Valley Canal junction.*—See plate no. 133.[2] Length, 2.50 miles. Type no. 4, modified. This section of canal extends from the Spokane River crossing to the junction with the Spokane Valley Canal. This section of canal has no unusual features. It passes through the suburbs of the city of Spokane, and the cost of the right of way will be considerable. A new topographic survey was made of the Spokane Valley in order to insure a better location of this section of canal. The location used for the report is made independent of those made for previous reports. This section of canal extends to its junction with the Spokane Valley Canal, and the canal below that junction carries the full supply to meet the irrigation requirements for plan no. 2-A.

209. *Feature no. S-V-1—(Spokane Valley Canal)—Coeur d'Alene Lake Regulation.*—The diversion of a portion of the water supply from the Spokane River, as contemplated in plan no. 2-A, involves the regulation of Coeur d'Alene Lake, located about 10 miles upstream from the proposed point of diversion of the Spokane Valley Canal. Coeur d'Alene Lake has been regulated to a limited extent for the past 16 years by the Washington Water Power Co. in the interests of their power developments along the Spokane River. In order to provide further water for irrigation development, it will be necessary to regulate the lake to a point somewhat higher than regulated at present.

210. The Washington Water Power Co. has acquired overflow rights at Coeur d'Alene Lake to elevation 2,125.1, but has regulated only to elevation 2,123.6. Regulation to elevation 2,129.1 is intended as a part of the present plan of development, and is discussed more fully in the power section, of the main report. This further regulation of Coeur d'Alene Lake will be effected by some slight additions to the present regulatory works now maintained at Post Falls

[2] Not printed.

by the Washington Water Power Co. The overflow damages given consideration in the present plan are those that result from regulation of the lake between elevations 2,123.6 and 2,129.1.

211. *Feature no. S-V-2—(Spokane Valley Canal)—Diversion dam and headworks.*—This structure is located on Spokane River about 2.5 miles below the present regulatory works at Post Falls, and is designed for the purpose of diverting water from the Spokane River into the Spokane Valley Canal, which, in turn, delivers it to the main canal of plan no. 2-A, 16.5 miles down the valley.

212. The diversion dam consists of an overflow section 250 feet in length, with a maximum height of 35 feet for a short distance. The elevation of this dam is fixed so that 60,000 second-feet may be passed without affecting the power developments at Post Falls. No exploratory work was done at this site, but it is believed that solid rock foundation will be found throughout, except under the upper portion of the structure on the north bank. The headworks to the canal consists of the necessary concrete work with one Stoney gate, 30 by 20 feet.

213. *Feature no. S-V-3—(Spokane Valley Canal)—Open canal, diversion dam to Spokane Valley Junction.*—Length, 16.49 miles. Types nos. 58, 48, 59, and 60. Plate no. 156.[2] This section of canal extends from the diversion works in the Spokane River to a junction with the main canal at a point designated Spokane Valley Junction. This canal has a capacity of 2,490 second-feet throughout its entire length. It is located on the south side of Spokane River, and passes through an area a portion of which is highly improved. No unusual features are encountered in this section of canal other than the cost of right-of-way, which will be relatively high, and the large number of bridges required to accommodate existing highways, streets, and railroads.

214. *Feature no. 22-B—Open canal, Spokane Valley Junction to Manito Tunnel.*—Capacity, 14,240 second-feet. (11,750 second-feet from Clark Fork, 2,490 second-feet from Spokane River.) Length, 2.50 miles. Plate no. 133.[2] Type no. 4. This canal extends from the Spokane River junction to Manito Tunnel. It has no unusual features. A portion of this section of canal is still within the suburban district of Spokane, and right-of-way will be a considerable item.

215. *Feature no. 23—Manito Tunnel.*—See plate no. 133.[2] Twin bore. Diameter, 37 feet. Length, 15,850 feet, or 3 miles. The location of this tunnel is substantially the same as that considered in the previous report. The geology of this site is reported on by Kirk Bryan as follows:

> The upper portal enters the hillside at the Underwood playground in the city of Spokane. The approach cut will be largely in gravel, but it is assumed that the gravel is shallow enough so that the portal will be in rock. The tunnel will enter in the younger basalt and will pass through into Latah formation, or possibly into granite-gneiss. The position of the contact of the younger basalt on the older rocks cannot be predicted closely. * * * This material is difficult to shoot and will require complete timbering.

216. This report is silent as to the possible timber requirements in the lower section of the tunnel. Fifty percent full timbering was used in the present estimate. Additional surveys were made to definitely locate the portals of this tunnel.

[2] Not printed.

217. *Feature no. 24—Latah Creek Dam.*—See plate no. 171.[2] The location is the same as considered in the Gault report. This structure forms the Latah Creek Reservoir, which is about 10 miles in length and replaces at least 13 miles of canal over rough broken country where cost of construction would be high. This reservoir is an almost indispensable link in the main canal. Its elimination would require the utilization of several feet in elevation, a condition that would add to the cost of the canal features below.

218. Regarding the reservoir basin, Mr. Bryan reports, in part, as follows:

> The gravels are easily permeable, but if discharge through them is prevented at the dam site no leakage out of the basin can take place except through the underlying Latah formation. * * * The conclusion is unavoidable that so far as the Latah formation is concerned, little leakage is possible.

219. The same authority gives in detail a report on the conditions at the proposed dam site and outlines the structural features that will be required by a structure adapted to this location.

220. A. J. Wiley also advised as follows regarding the proposed structure at this site:

> The Latah Creek Dam is about 130 feet high above the general level of the stream bed. It is a structure of the earth embankment, loose rock, downstream face type, similar to the dams previously described. The general formation under the dam is the Latah, with a basalt intrusion beneath the stream bed at the west or left abutment. Near the east edge of the valley floor there is a sand-gravel- and boulder-filled gorge about 100 feet deep, cut in the Latah formation. Sheet piling seems to be impracticable because of the numerous boulders in the filling of this gorge, and an upstream blanket is depended upon as a substitute. The filling of this gorge has ample supporting power, and seepage through it would not menace the safety of the dam, but it is suggested that there be a downstream blanket of coarse gravel, sand, and boulders from the east abutment to prevent piping at the downstream toe. This blanket should be about 100 feet long and 10 to 5 feet in depth.
>
> Cut-off trenches * * * should be extended entirely across the valley and up the abutments. Also the slopes and top widths should be modified * * *.
>
> The riprap of this dam should be changed to a minimum of 3 feet of loose rock, underlaid and filled with gravel * * *. In case hand-laid paving is used, it should be not less than 18 inches thick, of one course rock laid normal to the slope with all rock extending through the full depth of the paving.

221. These recommendations were incorporated in the design included in this report.

222. The drainage area above this reservoir basin covers an area of approximately 650 square miles. A wasteway with a capacity of about 15,000 second-feet, with a normal water surface in the reservoir, is provided at the west end of this structure.

223. *Feature no. 25—Bonnie Lake Tunnel.*—See plate no. 133.[2] Double bore. Diameter, 33.5 feet. Length, 84,500 feet, or 16 miles, not including 200 feet of entrance cut leaving Latah Creek Reservoir The location of the tunnel is substantially the same as that used in the report of the Columbia Basin Survey Commission and reports by other agencies subsequent thereto.

224. This tunnel constitutes the major feature on any of the plans of reclamation depending upon Clark Fork and Spokane River as a source of water supply. This tunnel is of such magnitude that it is absolutely without precedent in any irrigation work heretofore considered. The present plan contemplates the use of 3 shafts to expedite the work—1 due northwest of Spangle, 1 at Rock Creek, and 1 at

[2] Not printed.

Saunders Creek. These shafts would each be about 600 feet in depth. Eight working faces would thus be provided, and it is estimated that 5 years will be required to complete one bore.

225. Regarding the material through which this tunnel will pass, Kirk Bryan reports, in part, as follows:

> The portal is in a soil-covered and timbered slope, apparently underlain by basalt. The approach cut is in basalt, which is well exposed in the creek bed. However, the form of the granite ridge under ground is not predictable, and it is entirely possible that the tunnel may run through a spur of this ridge. The trend of the ridge is westerly to Browns Butte and Cheney, so that the southwesterly course of the tunnel carries it away from the ridge. The plateau from Latah Creek to Bonnie Lake is capped with basalt which dips gently in the direction of the tunnel course. The lower portal is definitely in basalt. It is a natural presumption that a greater part of the tunnel will be in this rock. The tunnel may, however, pass from one flow into another of different quality, or may pass from the massive center of a flow to its frothy end. Whenever contacts are crossed or scoriaceous basalt and breccia are encountered, the rock will be unsound enough to require some timbering * * *. The tunnel grade is below the bed of Latah Creek, which marks the ground-water level in the vicinity. It is also below the level of the creek which feeds Bonnie Lake and which lies at the level of ground water in its vicinity. In all pervious rock the tunnel will receive water and tend to drain the overlying rock. If the tunnel encounters granite, but little water will doubtless be obtained from that massive rock. In the basalts, however, large quantities will doubtless be obtained, for throughout the Columbia Basin, wells which reach the permanent ground-water table yield water freely. Bonnie Lake Tunnel, as previously pointed out, will be at or below that level throughout its course. That the rock overlying the tunnel is more or less saturated is evident from swamps and living streams on the top of the plateau and from the fact that wells obtain water at various depths above the main water table.

226. No additional field or exploratory work was done on this feature of the work in connection with this report. For the purpose of the present estimate, 10 percent of full timbering was used.

227. *Feature no. 26—Open canal, Bonnie Lake Tunnel to Rock Lake Reservoir.*—See plate no. 133.[2] Length, 1 mile. Type no. 5. This section of canal connects Bonnie Lake Tunnel with Rock Lake Reservoir. It is merely an enlargement or improvement of a small stream bed leading into the reservoir. This section of canal has no lining.

228. *Feature no. 27—Rock Lake Dam.*—See plate no. 172.[2] Rock Lake Dam, located on Rock Creek about 1 mile east of Ewan, a station on the Chicago, Milwaukee, St. Paul & Pacific Railroad, forms the Rock Lake Reservoir. This reservoir will submerge and connect Rock Lake and Bonnie Lake, and will be about 16 miles in length, with a maximum width of about 1 mile. It forms an indispensable link in the main supply line, and replaces at least 20 miles of canal, a large portion of which would be along almost precipitous canyon walls where tunneling would perhaps be most economical. This reservoir is also used to a limited extent as a regulatory feature on the main canal. The reservoir covers an area of about 3,400 acres with the water surface at elevation 1,798.9, the elevation required to provide a full head in the main canal below. The dam is designed for a maximum water-surface elevation of 1,802.4 in the reservoir, affording a storage capacity of about 12,200 acre-feet.

229. Regarding the suitability of the reservoir basin, Bryan's report gives the following:

> The existing lakes, Rock and Bonnie, occupy the lowest parts of the surrounding region. They are fed by, and form a part of, the channel of Rock Creek, a

[2] Not printed.

stream that has a considerable low-water flow throughout the dry or summer season. The stream and lakes must receive their water during the dry season from ground-water sources and must, therefore, mark the lowest level of the water table for the locality. The water table necessarily slopes toward the stream and lakes from both sides. * * * On the foregoing assumption that Rock Creek and its two lakes lie in a depression of the water table, the proposed lake can leak only at or around the ends of the dam.

230. In connection with the present investigation, a further geological study was made of this reservoir basin and dam site by Henry Landes, geologist. The report is as follows:

It is proposed to construct a dam at the lower end of Rock Lake which will raise the water surface nearly 80 feet above that of the present low-water stage. When this is done, the low ground at the head of Rock Lake, between it and Bonnie Lake, will be covered, and the artificial reservoir will have a length of about 15 miles.

Rock and Bonnie Lakes, in a tandem arrangement, occupy the bed of a canyon which has been excavated in basalt. Above the present water surfaces of the lakes the cliffs of rock, often in perpendicular form, rise to heights that vary from 100 to 300 feet. At the outlet of the lake the floor rock is but a few feet below the bed of the stream. The inference is that the unusual depth of Rock Lake is due to the recession of a large waterfall, as suggested by Bryan in his report.

In observing the cliffs along Rock Lake, one is impressed by the fact that the flows of lava are rather massive and of unusual thickness. They appear to have a slight pitch or inclination toward the southwest, and their slope seems to conform rather closely to that of the broad surface area. In other words, the general slope of the surface of the country conforms to that portion of the large structural basin that underlies east central Washington.

Assuming that the passage of water through the basalt is almost wholly within the pervious material between the sheets of lava, any escape of water from the present deep lake would follow the inclination of the basalt beds far out under the plains to the southwest. With the raising of the level of Rock Lake the water will come in contact with basalt which is now clearly above the water table. The situation is helped by the fact that the beds are unusually thick and the seepage opportunities between flows are correspondingly restricted. That some water will enter the basalt, in an 80-foot rise of the lake, is not to be questioned. The writer believes the seepage will be very small, partly due to the massive condition of the rock, but more to the infrequency of the pervious beds. The escaping water would practically all be carried out under the plains to the southwest, following the dip of the lava beds in that direction.

231. Upon the recommendations of the geologist, the south end of the dam was relocated. The dam, as located for the Gault report, crossed a low area with questionable foundation at the southern end, immediately before reaching the hillside with which it connects. The relocation recommended does not cross this low area but continues in an easterly direction along a rocky ridge, and finally connects with the hillside at a point east of La Vista station on the Chicago, Milwaukee, St. Paul & Pacific Railroad. This new location passes around the upper end of the low area, and has a favorable foundation throughout. The dam will be much longer, but it will be relatively low and will perhaps be no more expensive than would have been one at the former location, had the foundation conditions over the low area been favorable. The new location as proposed eliminates any conflict with the location of the main freight line of the Chicago, Milwaukee, St. Paul & Pacific Railroad which passes the south end of the dam.

232. Regarding the suitability of this new location, Landes reports as follows:

The site for the dam is located at the extreme lower end of Rock Lake. Except for an overburden of soil, which varies from 0 to 5 feet, plus or minus, the dam will rest directly upon the bedrock, which is basalt. The basalt lays in

sheets which are fairly thick and massive. The rock is quite fresh in appearance and scarcely decomposed at any point. It is very stable in character and possesses the minimum of shrinkage cracks or steam holes.

The southern end of the dam rests upon a flat ridge of basalt which is narrow at one or two places, and through which there may be a slight percolation of water. It will be very necessary to pressure grout the basalt below the dam, especially along the ridge, in order that the cut-off of the water will be essentially complete. The water seepage, if any, can in no way affect the stability or permanency of the dam, because of the superior quality of the basalt, which provides the foundation. All things considered, both the proposed reservoir and dam at Rock Lake appear to be perfectly feasible and to be attended by no difficulties that would make their construction unwise or inexpedient.

233. No additional testing was done at this dam site, but a topographic survey was made over the territory on the south side of the lake to cover the new location recommended for that portion of the structure.

234. *Feature no. 28—Open canal, Rock Lake Reservoir to Wassun Creek siphon.*— See plate no. 133.[2] Length, 10.21 miles. Types nos. 3 and 6. This section of canal extends from the Rock Lake Reservoir to the Wassun Creek siphon and carries no unusual features. The rock to be encountered in this section of canal will be basalt.

235. *Feature no. 29—Wassun Creek siphon.*—See plate no. 134 [2] for typical design. This structure consists of four parallel steel pipe lines with the necessary concrete end structures and foundations. Length of siphon, 1,250 feet. Four parallel steel pipe lines. Diameter, 19 feet. Maximum head, 150 feet. Steel pipe lines were used in this as well as in the other main canal siphons, to be considered later. A final analysis may show a saving by replacing the ends of these pipe lines, where the head is small, with concrete barrels. The steel type of construction, however, lends itself more readily to a stage construction, a feature of importance in projects, the magnitude of those being considered. In connection with a stage development this structure is planned to be built in four units. The end walls, transitions, foundations, and one pipe line forming the first unit, each of the three remaining pipe lines constituting a unit to be constructed as required.

236. *Feature no. 30—Open canal, Wassun Creek siphon to Dragoon siphon.*—See plate no. 133.[2] Length, 5.67 miles. Type no. 3. This section of canal, extending from the Wassun Creek siphon to the Dragoon siphon, includes no unusual features.

237. *Feature no. 31—Dragoon siphon.*—See plate no. 134[2] for typical design. This structure consists of four parallel steel pipe lines with necessary concrete structure or transitions at either end. Length of siphon, 600 feet. (Four parallel steel pipes.) Diameter, 19 feet. Maximum head, 80 feet. This structure is designed for a final development in four stages. The original plans of the Columbia Basin Survey Commission contemplated the use of Dragoon and McCall Lakes (sometimes referred to as Twin Lakes) as a part of the canal system. The geological report by Mr. Bryan, prepared in connection with the Gault estimate, pronounced these sites unsuitable for reservoir purposes. In order to eliminate these two objectionable sites a resurvey was made and the line relocated over about 5 miles immediately east of the Patterson Tunnel. This relocated line includes this Dragoon siphon, a structure necessary in crossing a draw leading to Dragoon Lake.

[2] Not printed.

238. *Feature no. 32—Open canal, Dragoon siphon to Patterson Tunnel.*—See plate no. 133.[2] Length, 3.18 miles. Types nos. 3 and 6. This section of canal crosses some very rough, broken, and rocky terrain and represents the most adverse conditions found along the main canal system.

239. *Feature no. 33—Patterson Tunnel.*—See plate no. 133.[2] Double bore. Diameter, 37 feet. Length, 3,350 feet, or 0.63 mile. The location of the upper end of this tunnel may vary somewhat from that used in previous reports because of the relocation of the section of canal leading to it.

240. Following is Mr. Bryan's geological report, in part, of this location:

> There is, therefore, a minimum thickness of rock over the tunnel, of 50 feet. The water table of the region is below the canal grade on both sides of the ridge. In view of the pervious character of the rock, it is probably thoroughly drained under the ridge, and, therefore, the tunnel will be practically dry.

241. Regarding the probable amount of timbering, the above report is silent, but 10 percent full timbering was assumed for the present estimate.

242. *Feature no. 34—Open canal, Patterson Tunnel to Cow Creek siphon.*—See plate no. 133.[2] Length, 11.94 miles. Types nos. 3 and 7. This section of canal involves some heavy rock work. The section immediately east of the Cow Creek siphon, about 4,000 feet in length, is located over rocky territory, too low in many places to offer support for a regular canal section. To cross this area a section was used consisting of rubble masonry walls with a gunite lining, the bottom being back filled to grade, with a concrete lining.

243. *Feature no. 35—Cow Creek siphon.*—See plate no. 134.[2] This structure crosses Cow Creek and consists of four parallel steel pipes with the necessary concrete structures and transitions. Length of pipe line, 4,828 feet, horizontal distance. (Four parallel steel pipes.) Diameter, 19 feet; maximum head, 150 feet. This structure, as in the two siphons previously mentioned, is to be constructed in four stages.

244. *Feature no. 36—Open canal, Cow Creek siphon to bifurcation works.*—See plate no. 133.[2] Length, 2.54 miles. Type no. 3. This section of canal extends from the Cow Creek siphon to the bifurcation works. Other than the rocky character of the area traversed, this section involves no unusual features.

245. *Feature no. 37—Bifurcation works.*—See plate no. 173.[7] This structure is located at the lower end of the main canal and at the upper end of the irrigable tract. At this point the water is divided, and diverted through the main north and the main south, which serve as the main laterals leading over the project.

246. *Distributing system.*—The distributing system begins at the bifurcation works. At that point the main canal is divided into the main north and the main south. The main north extends along the north boundary of the project to the Quincy area, and thence south to Frenchman Hills. The area covered by the main north and its lateral system is that portion of the project located north of Lind Coulee to its confluence with Crab Creek, and then north of that creek to its junction with Columbia River, and consists of an area

[2] Not printed.

of 689,700 acres, including area to be covered by supplemental pumping.

247. The main south extends in a southwesterly direction from the bifurcation works. About 15.5 miles below its head the main central is divided, the main south continuing in a southerly and westerly direction to a point near Pasco, and the main central extending westerly to the Priest Rapids area.

248. The main south, with its distributing system, serves 251,760 acres, including area under supplemental pumping, while the main central, and its lateral system covers an area of 578,450 acres, including area covered by supplemental pumping.

249. The design of the distributing system for plan no. 2 is based on unpublished office records which show the location of all canals having a capacity of 100 second-feet or more, the area served by each lateral, water requirements for that area, canal sections and capacities.

250. The larger laterals, when so stated, have been located upon line topographic sheets and transferred from those sheets to the work map while the balance of the system has been projected directly upon the United States Geological Survey quadrangles which form the background for the work map when they were available. For those lines that have been projected upon line topographic sheets, profiles were prepared and form the basis of the estimate for those sections. These topographic sheets and profiles are unpublished. The general location of the distributing system is shown on plate no. 129.[2] Condensed profiles of the main north, main south, and main central are shown on plate no. 174.[1]

251. *Main north.*—The main north consists of the following features, listed geographically.

252. *Feature no. 1—Open canal, bifurcation works to McElroy Tunnel.*—Length, 8.49 miles. Type no. 6. Plate no. 156.[2] Topography and classification over this section are favorable for canal construction.

253. This section of canal together with others following on the main north to and including feature no. 29 were projected upon line topographic maps, nos. 9 to 14, inclusive (unpublished), prepared by the Columbia Basin Survey Commission. Estimates are based upon projection and profile prepared for the present study.

254. *Feature no. 2—McElroy Tunnel.*—See plate no. 156.[2] Single bore. Diameter, 27.5 feet. Length, 8,200 feet, or 1.56 miles. The location of this tunnel is substantially the same as that considered by the Columbia Basin Survey Commission and by Gault. The geologist makes the following comments regarding the three tunnels on the upper section of the main north:

> The main north has three tunnels, the McElroy, 8,200 feet long, the Paha, 2,000 feet, and the Klemmer, 20,300 feet. They are all large tunnels. * * * The first two are at a low enough elevation be to quite certainly in basalt. The Klemmer tunnel has from 135 to 180 feet of overburden. If the Palouse-Ritzville soil has its normal thickness of 100 to 150 feet, this tunnel will be close to the contact and may be partly in earth.

255. No comment is made regarding the probable amount of timbering required. For the purpose of the present estimate, 75 percent of full timbering was used.

[2] Not printed.

256. *Feature no. 3—Open canal, McElroy Tunnel to Paha Tunnel.*—Length, 2.50 miles. Type no. 8. Plate no. 156.[2] This section of canal is located over an area favorable for canal construction and involves no unusual features.

257. *Feature no. 4—Paha Tunnel.*—See plate no. 156.[2] Single bore. Diameter, 27.5 feet. Length, 2,000 feet or 0.38 mile. The location is the same as that considered by previous agencies. Geologist's comment on this site is quoted under feature no. 2. No opinion was expressed as to probable amount of timbering that would be required. For the purpose of the present estimate, 75 percent of full timbering was assumed.

258. *Feature no. 5—Open canal, Paha Tunnel to Paha siphon.*—Length, 0.20 mile. Type no. 8. Plate no. 156.[2] This is a short section of canal connecting the Paha tunnel and the Paha siphon and involves no unusual features.

259. *Feature no. 6—Paha siphon.*—See plate no. 134[2] for typical design. This structure consists of two parallel steel pipe lines with the necessary concrete end structures. Length, 1,980 feet, horizontal distance. Two parallel steel pipe lines. Diameter, 20.25 feet. Maximum head, 105 feet. This structure crosses the Paha Coulee at Paha, a station on the main line of the Great Northern Railway. This structure crosses under that railroad as well as the State highway paralleling it on the east side. Under a stage development, this structure would be constructed as two units; the first unit consisting of all concrete work, railroad and highway crossings, and one steel pipe line, the second unit consisting of one steel pipe line only. A final analysis might show a reinforced concrete structure to be more economical for this site.

260. *Feature no. 7—Open canal, Paha siphon to Klemmer Tunnel.*—Length, 4.80 miles. Type no. 8. Plate no. 156.[2] This section of canal passes over an area favorable to canal construction. No unusual features are involved. Lateral N-1 is diverted from this section.

261. *Feature no. 8—Klemmer Tunnel.*—See plate no. 156.[2] Single bore. Diameter, 27.0 feet. Length, 20,300 feet or 3.84 miles. This tunnel has the same location as that considered by the Columbia Basin Survey Commission and by Gault. The comments regarding the geology of this site are noted under feature no. 2. For the purpose of this estimate, 75 percent of full timbering was assumed.

262. *Feature no. 9—Open canal, Klemmer Tunnel to third coulee siphon.*—Length, 2.80 miles. Type nos. 8 and 9. Plate no. 156.[2] This section of canal is located over an area favorable for ditch construction. No unusual features are involved. Lateral N-2 is diverted from this section.

263. *Feature no. 10—Third coulee siphon.*—See plate no. 134[2] for typical design. This structure consists of two parallel steel pipe lines with the required concrete end structures and foundations. Length, 2,680 feet, horizontal distance. Two steel pipe lines. Diameter, 19.58 feet. Maximum head, 90 feet. This structure, as in previous siphons discussed, is susceptible of being built in two units in the interest of a stage development.

264. *Feature no. 11—Open canal, third coulee siphon to second coulee siphon.*—Length, 17.59 miles. Type no. 9. Plate no. 156.[2] This

[2] Not printed.

section is located over an area favorable to canal construction. No unusual features are involved.

265. *Feature no. 12—Second coulee siphon.*—See plate no. 134[2] for typical design. This structure consists of two parallel steel pipe lines with the necessary concrete end structures and foundations. Length, 43.15 feet, horizontal distance. Two steel pipe lines. Diameter, 19.17 feet. Maximum head, 197 feet. This structure may be built in two units to meet the demands of a stage development.

266. *Feature no. 13—Open canal, second coulee siphon to Flaig siphon.*—Length, 5.13 miles. Types nos. 9 and 10. Plate no. 156.[2] This section of canal continues over terrain favorable to economical canal construction. Lateral N-3 is diverted from this section.

267. *Feature no. 14—Flaig siphon.*—See plate no. 134 [2] for typical design. This structure consists of two parallel steel pipe lines with the necessary concrete end walls and foundations. Length, 2,550 feet, horizontal distance. Two steel pipe lines. Diameter, 18.91 feet. Maximum head, 100 feet. The use of steel pipes adapts this structure to a development in two stages. A final analysis might show the economy of a reinforced concrete structure throughout.

268. *Feature no. 15—Open canal, Flaig siphon to first coulee siphon.*—Length, 4.14 miles. Type nos. 9 and 11. Plate no. 156.[2] No unusual items are encountered in this feature. It traverses an area favorable for ditch construction. Lateral N-4 is diverted from this section.

269. *Feature no. 16—First coulee siphon.*—See plate no. 134[2] for typical design. This structure consists of two parallel steel pipe lines with the necessary concrete end structure and foundation. Length, 4,100 feet, horizontal distance. Two steel pipe lines. Diameter, 16.75 feet. Maximum head, 248 feet. This structure may be constructed in two units to meet the requirements of a stage development.

270. *Feature no. 17—Open canal, first coulee siphon to Sand Coulee siphon.*—Length, 7.84 miles. Type nos. 11 and 12. Plate no. 156.[2] This canal traverses an area favorable to canal construction and involves no unusual items. Lateral N-5 is diverted from this section.

271. *Feature no. 18—Sand Coulee siphon.*—See plate no. 134[2] for typical design. This structure consists of two parallel steel pipe lines with the necessary concrete end walls and foundations. Length, 5,500 feet, horizontal distance. Two steel pipe lines. Diameter, 16.67 feet. Maximum head, 104 feet. The steel pipe line structure may be constructed in two stages in the interest of a stage development. A final analysis may demonstrate the economy of utilizing reinforced concrete construction for a portion of this structure.

272. *Feature no. 19—Open canal, Sand Coulee siphon to Black Rock siphon.*—Length, 2.89 miles. Type no. 12. Plate no 156.[2] This section of canal enters an area more or less broken and rocky as the Black Rock Coulee is approached. No unusual features are involved in this section of canal. Lateral N-6 is diverted at the upper end of this section, immediately below the Sand Coulee siphon.

273. *Feature no. 20—Black Rock siphon.*—See plate no. 134[2] for typical design. This structure consists of two parallel steel pipe lines with the customary end walls and foundations. Length, 4,050 feet, horizontal distance. Two steel pipe lines. Diameter, 16.75 feet.

[2] Not printed.

Maximum head, 154 feet. This siphon crosses the end of a small lake located in the coulee. Soundings were made at this crossing. No testing of foundation was made, but the probable depth to suitable footing for the piers was predicated upon surface indications on either side. The distance across this lake is 550 feet, with a maximum depth of 12 feet at the crossing site. This lake can be drained for the purpose of constructing the supporting piers for the siphon. For a stage development this structure can be constructed in two units.

274. *Feature no. 21—Open canal, Black Rock siphon to Broken Rock siphon.*—Length, 8.08 miles. Type nos. 12, 14, and 13. Plate no. 156.[2] A portion of this section of canal passes over an area where conditions are fairly favorable for canal construction while a portion is over a rough broken area where a large amount of solid rock excavation will be encountered.

275. *Feature no. 22—Broken Rock Coulee siphon.*—See plate no. 134 [2] for typical design. This structure consists of two parallel steel pipe lines with the required concrete transitions at either end and concrete saddles. Length, 8,890 feet, horizontal distance. Two steel pipe lines. Diameter, 16.5 feet. Maximum head, 168 feet. The topography at this site is very rough and broken, and considerable solid rock excavation will be required along the pipe line to secure a suitable profile. This structure can be constructed in two stages to meet the requirements of a stage development.

276. *Feature no. 23—Open canal, Broken Rock siphon to Round Lake siphon.*—Length, 11.44 miles. Type nos. 12, 14, and 15. Plate no. 156.[2] This section of canal passes through an area a portion of which is favorable to canal construction, and a portion where a large percentage of solid-rock excavation will be encountered. Lateral N-7 is diverted from this section of the main north.

277. *Feature no. 24—Round Lake siphon.*—See plate no. 134 [2] for typical design. This structure consists of a single steel pipe with the necessary concrete end structures and foundations. Length, 4,450 feet, horizontal distance. One steel pipe line. Diameter, 20.83 feet. Maximum head, 210 feet. Topography makes it necessary to carry this siphon across the north end of Round Lake on 15 specially designed piers spaced 24 feet, center to center. Estimates were also prepared for a steel span structure crossing this lake. The former plan was adopted in the interest of economy. This structure consisting of only one pipe line does not lend itself to a stage development.

278. *Feature no. 25—Open Canal, Round Lake siphon to Adrian siphon.*—Length, 1.57 miles. Type no. 15. Plate no. 156.[2] This section of canal is similar to that described in feature no. 23. No unusual features are encountered.

279. *Feature no. 26—Adrian siphon.*—See plate no. 134 [1] for typical design. This structure consists of one steel pipe line with the necessary concrete end and foundation structures. Length, 14,850 feet, horizontal distance. One steel pipe line. Diameter, 20.08 feet. Maximum head, 235 feet. This siphon crosses under the main line of the Great Northern Railway, a branch line of the Northern Pacific Railway, and a cross-over between these two lines, as well as under the North Central State Highway. This structure consisting as it does of a single pipe line does not permit of stage development.

280. *Feature no. 27—Open canal, Adrian siphon to Soap Lake siphon.*—Length, 3.72 miles. Type no. 15. Plate no. 156.[2] This

[2] Not printed.

section of canal is located over an area where topography is favorable but considerable solid rock excavation will be encountered. Lateral N-8 is diverted from this section of canal.

281. *Feature no. 28—Soap Lake siphon.*—See plate no. 134 [2] for typical design. This structure consists of a single steel pipe line with the necessary concrete transitions and saddles. Length, 15,200 feet, horizontal distance. One steel pipe line. Diameter, 19.0 feet. Maximum head, 290 feet. This structure is lengthened to pass around the south end of Soap Lake. A direct line between the inlet and outlet structures of this siphon crosses the lake for a distance of about 4,000 feet. The depth of water precludes the short route across the lake. This siphon crosses over the North Central Highway at two points.

282. *Feature no. 29—Open canal, Soap Lake siphon to point near Quincy.*—Length, 21.62 miles. Type nos. 15, 16, and 17. Plate no. 156.[2] This section of canal is located over a rough, rocky area at the upper section, but gradually enters a section which is ideal for canal construction. This feature ends at the end of the line topographic survey made by the Columbia Basin Survey Commission, and the location of the main north below this feature is based upon a projection on the United States Geological Survey quadrangle sheets. Laterals N-9 and N-10 are diverted from this section of the main north.

283. *Feature no. 30—Open canal, point near Quincy to Great Northern siphon.*—Length, 3.60 miles. Estimates of canals projected on United States Geological Survey quadrangle sheets are based on office records which show details as to distances, canal sections, and quantities. This section of canal is ideal from a construction standpoint.

284. *Feature no. 31—Great Northern siphon.*—See plate no. 158,[2] for typical design. This is a reinforced concrete structure of one barrel, crossing under the main line of the Great Northern Railway at a point about 3 miles west of Quincy. Length, 1,700 feet, horizontal distance. One barrel, reinforced concrete. Diameter, 12.25 feet. Maximum head, 100 feet. The head acting upon a portion of this siphon exceeds that considered economical for a concrete structure; but as it is necessary to bury the portion having the maximum head, especially where it crosses under the railroad grade, it was believed advisable to use concrete throughout rather than change to a steel pipe for the short distance.

285. *Feature no. 32—Open canal, Great Northern siphon to Potholes siphon.*—Length, 6.90 miles. This section is located over an area very favorable to canal construction. No unusual features are involved.

286. *Feature no. 33—Potholes siphon.*—See plate no. 134 [2] for typical design. This structure consists of a single steel-pipe line with the necessary end and foundation structures. Length, 15,200 feet, horizontal distance. One steel pipe. Diameter, 16.17 feet. Maximum head, 182 feet. A final analysis may show the advisability of substituting reinforced concrete for the steel pipe on the ends where the head is permissible. This structure must be constructed as one unit.

287. *Feature no. 34—Open canal, Potholes siphon to Frenchman siphon.*—Length, 7.00 miles. This section of canal is somewhat rough and broken in spots, and some solid-rock excavation will be encountered, particularly at the lower end. Lateral N-11 is diverted from this section of the main north.

[2] Not printed.

288. *Feature no. 35—Frenchman siphon.*—No special drawing. This structure consists of one pipe line with the necessary end structures and foundations. A reinforced-concrete pipe is used when the head is favorable and a steel pipe substituted when the head is beyond that limiting an economical concrete design. Length, 10,700 feet, horizontal distance, 8,010 feet steel-pipe line. Diameter, 13.08 feet, 2,090 feet reinforced-concrete pipe line. Diameter, 11.92 feet. Maximum head, 165 feet. This structure must be built as a single unit.

289. *Feature no. 36—Open canal, Frenchman siphon to Low Gap Tunnel.*—Length, 10.50 miles. This section of canal is favorable as to topographic features, but considerable solid rock excavation will be encountered.

290. *Feature no. 37—Low Gap Tunnel.*—See plate no. 156.[2] Single bore. Diameter, 12.83 feet. Length, 8,200 feet or 1.55 miles. This tunnel carries the water through to the area south of Frenchman Hills. The geological report of Kirk Bryan makes no comment regarding conditions at this tunnel site other than to state it would pass through basalt. For the present estimate, 75 percent full timbering was assumed.

291. *Feature no. 38—Open canal, Low Gap Tunnel to end.*—Length, 28.10 miles. This section of canal is generally favorable for canal construction. Some solid rock excavation will be encountered. Laterals N-12, N-13, and N-14 are diverted from this section of the main north.

292. *Lateral system.*—The following lateral systems divert from the main north and for convenience are presented in table no. 6.

TABLE NO. 6.—*Lateral systems, main north*

| Lateral no. | Canal | | Siphons | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section | Barrel | Number of pipes | Length | Diameter | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Feet* |
| N-1 | 14.77 | (a) | | | | | |
| N-2 | 11.70 | (a) | Steel | 1 | 3,000 | 10.42 | 120 |
| | | | do | 1 | 8,800 | 6.00 | 120 |
| N-2-1 | 2.10 | (b) | | | | | |
| N-2-2 | 5.30 | (b) | | | | | |
| N-3 | 3.50 | (b) | | | | | |
| N-4 | 15.22 | (a) | Concrete | 1 | 4,300 | 8.17 | 37 |
| | | | do | 1 | 400 | 7.92 | 13 |
| | | | do | 1 | 200 | 4.58 | 13 |
| N-4-1 | 1.60 | (b) | | | | | |
| N-4-2 | 2.20 | (b) | | | | | |
| N-5 | 12.20 | (b) | | | | | |
| N-6 | 2.60 | (b) | | | | | |
| N-7 | 2.70 | (b) | | | | | |
| N-8 | 11.52 | (b) | Steel | 1 | 11,000 | 6.00 | 234 |
| N-8-1 | 4.50 | (b) | | | | | |
| N-9 | 14.42 | (a) | Concrete | 1 | 1,000 | 8.00 | 40 |
| | | | do | 1 | 5,450 | 10.08 | 60 |
| N-9-1 | 2.15 | (b) | do | 1 | 5,400 | 5.92 | 44 |
| N-9-2 | 5.15 | (b) | Steel flume | 1 | 2,800 | c (#84) | |
| N-9-3 | 3.15 | (b) | | | | | |
| N-10 | 19.30 | (b) | | | | | |
| N-10-1 | 7.40 | (b) | | | | | |
| N-11 | 2.10 | (b) | | | | | |
| N-12 | 3.20 | (b) | | | | | |
| N-13 | 4.74 | (b) | Concrete | 1 | 14,072 | 6.67 | 94 |
| N-14 | 1.00 | (b) | | | | | |

[a] Based on projection on line topographic sheet. For canal sections, see profile of lateral under consideration (unpublished).
[b] Based on projection on U.S. Geological Survey quadrangle sheets. For canal sections see detail estimate for lateral under consideration (unpublished).
[c] Refers to stock size.

[2] Not printed.

293. *Feature no. 39—Sublaterals.*—The laterals listed above all terminate where the required capacity has been reduced to 100 second-feet. The present plan contemplates a system extending to the individual farm units, but laterals having a capacity of 100 second-feet or less are covered by a blanket estimate based upon the acreage served.

294. *Main south.*—The main south consists of the following features listed geographically:

295. *Feature no. 1—Milwaukee siphon.*—See plate no. 158.[2] This is a reinforced concrete structure, twin barrel, crossing a depression at the head of Lind Coulee. Length, 1,225 feet, horizontal distance. Twin barrels. Diameter, 18.00 feet. Maximum head, 20 feet. This structure crosses under the main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad and across the low part in a saddle between the Lind Coulee and Cow Creek drainage areas. A short piece of canal (about 200 feet in length) is required between the upper end of this structure and the bifurcation works at the end of the main canal. This short section of canal is included in the estimate for this siphon.

296. *Feature no. 2—Open canal, Milwaukee siphon to main south tunnel.*—Length, 9.85 miles. Type no. 27. Plate no. 156.[2] This section of canal is favorable from a construction standpoint. A small amount of loose rock excavation may be encountered. This section of canal, as well as feature no. 4 on the main south, was projected upon line topographic sheets and profiles constructed from which a station-to-station estimate was prepared. Lateral no. S-0 is diverted from this section of the main south.

297. *Feature no. 3—Main South Tunnel.*—See plate no. 156.[2] Single bore. Diameter, 26.58 feet. Length, 3,900 feet. The location of this tunnel is substantially the same as that used by the Columbia Basin Survey Commission and by Gault. Regarding this site, Kirk Bryan, geologist, reports as follows: "The central south tunnel has about 100 feet of cover, and is doubtless at, or close to, the contact of the soil and rock." He rendered no opinion as to the probable amount of timbering that would be required; 75 percent of full timbering was assumed.

298. *Feature no. 4—Open canal, Main South Tunnel to main central bifurcation works.*—Length, 5.82 miles. Type no. 27. Plate no. 156.[2] No unusual features are involved in this section of canal. It is ideal for canal work. There are no indications of other than earth excavation. Lateral no. S-1 is diverted from this section of the main south.

299. *Feature no. 5—Main central bifurcation works.*—No special drawing published. This structure serves as a diversion works for the main central which begins at this point. This structure is of same general type as the bifurcation works at the end of the main canal, modified, of course, to suit local topographic conditions and different capacities of the canals. Below this bifurcation works the main south extends in a southerly and the main central in a westerly direction.

300. *Feature no. 6—Main south penstock no. 1.*—No drawing. Three parallel steel pipe lines. Diameter, 10 feet. Length, 2,440

[2] Not printed.

feet, including intake structure. Head, 95 feet, Q = 1,815 second-feet. Immediately below feature no. 5 the main south encounters an excessive grade for some distance. It is proposed to utilize this drop for the development of power for the purpose of supplemental pumping to desirable areas that are located above the gravity canal. In this, as well as similar cases where it is proposed to develop power, the penstock pipe lines required for power development are included as a part of the canal system. Other costs of power development are included in a special item. The pipe lines, however, are considered as a part of the irrigation system, adapted, of course, to meet the requirements for power development. In a later discussion of power development, this installation will be referred to as power plant no. 1.

301. *Feature no. 7—Open canal, main south penstock no. 1 to turnout lateral S-2.*—Length, 12 miles. This, with all following features of the main south, is based upon a projection made upon the United States Geological Survey quadrangle sheets, and details as to location, length, capacity, canal sections, gradients, and other elements entering into the estimates may be found in the office records. The terrain covered by this section of canal is favorable from a construction standpoint. Some solid rock excavations will be encountered. No unusual features are involved in this section.

302. *Feature no. 8—Open canal, turnout S-2 to Kahlotus siphon.*—Length, 5.0 miles. This section is similar to that in feature no. 7 as to character of work to be encountered.

303. *Feature no. 9—Kahlotus siphon.*—See plate no. 134 [2] for typical design. This structure consists of one steel pipe line with the necessary concrete end structures and foundations. Length, 9,600 feet, horizontal distance. One steel pipe line. Diameter, 13.33 feet. Maximum head, 509 feet. This structure crosses Washtucna Coulee and also a branch line of the Oregon-Washington Railroad & Navigation Co. extending to Connell. The most economical design for this structure was found to be the single pipe line, and it, therefore, is not adapted to a stage development.

304. *Feature no. 10—Open canal, Kahlotus siphon to turnout lateral S-4.*—Length, 4.30 miles. This section of canal passes over an area where considerable solid rock excavation will be encountered. Lateral S-3 diverts from the upper end of this section and lateral S-4 turnout constitutes the lower end of this feature.

305. *Feature no. 11—Open canal, turnout lateral S-4 to turnout lateral S-5.*—Length, 2.90 miles. This section is the same as that described under the preceding feature. There are no unusual characteristics in this section of the work.

306. *Feature no. 12—Open canal, turnout lateral S-5 to turnout lateral S-6.*—Length, 5.20 miles. General characteristics of this section are the same as those of the two preceding features. No unusual items are included in this feature.

307. *Feature no. 13—Open canal, turnout lateral S-6 to penstock no. 2.*—Length, 17.70 miles. This section of canal is located over an area that requires a very steep grade in many places to find supporting ground for the canal. The grade and sections have been changed numerous times in this portion of the system. The grade is such that in places the canal has developed into long chutes, while at other

[2] Not printed.

points it is carried on a normal grade. This section offers no unusual construction features. Some solid rock excavation will been countered.

308. *Feature no. 14—Main south penstock no. 2.*—No drawing. One steel pipe line. Diameter, 9 feet. Length, 535 feet, including intake structure. Head, 100 feet. Q=417 second-feet. This is another instance where the drop or other structure has been adapted to meet the requirement for power development at the site. The penstock is included as a part of the canal system. In the power development discussion to follow, this development will be referred to as power plant no. 2.

309. *Feature no. 15—Open canal, penstock no. 2 to end of canal.*—Length, 13.70 miles. This section of canal extends from the main south penstock no. 2 to a point where it has decreased to a capacity of 100 second-feet. The territory covered offers conditions favorable to ditch construction. Some solid rock excavation will be encountered, but this will represent a small percentage of the total yardage to be moved.

310. *Lateral system.*—The following laterals are diverted from the main south, and, for convenience are listed in table no. 7.

TABLE NO. 7.—*Lateral systems, main south*

| Lateral no. | Canal | | Siphon or penstock | | | | |
|---|---|---|---|---|---|---|---|
| | Length, miles | Section and capacity | Barrel | Number of pipes | Length, feet | Diameter, feet | Maximum head, feet |
| S-0 | 12.00 | (1) | | | | | |
| S-1 | 3.00 | (1) | | | | | |
| S-2 | 2.00 | (1) | | | | | |
| S-3 | 9.00 | (1) | | | | | |
| S-4 | 16.20 | (1) | | | | | |
| S-5 | 26.00 | (1) | Steel | 1 | 2,000 | 6 | [2] 85 |
| S-6 | 2.00 | (1) | | | | | |

[1] Based on projection on U.S. Geological Survey quadrangle sheets.
[2] Penstock pipe for power plant no. 3.

311. *Feature no. 16—Sublaterals.*—The sublateral system under the main south, consisting of all ditches having a capacity of 100 second-feet or less, is covered by a blanket estimate based upon the acreage served.

312. *Main central.*—As stated under feature no. 5 of the main south, the main central is diverted from that canal and continues westward to the Priest Rapids area. The following features, listed geographically, constitute the main central and its distributing system:

313. *Feature no. 1—Open canal, bifurcation works to main central tunnel no. 1.*—Length, 4.93 miles. Type no. 11. Plate no. 156.[2] Beginning with this section of the main central and continuing to and including feature no. 18, the location is based upon a projection on the line topographic sheets and a station-to-station estimate prepared, except for a section in features nos. 13 and 16 where no line topography was available.

[2] Not printed.

314. The main difference between the distributing system as here planned and that prepared by Gault is in this section of canal. The Gault plan carried the water supply for the Priest Rapids area down the main north for a distance of about 5 miles below the bifurcation works at the end of the main canal, and it was then dropped into the Lind Coulee. It was carried down that coulee for a distance of about 40 miles to a point north and west of Warden, where it was again diverted into a supported canal, southward past Othello to a point on the north side of the depression leading to Scooteney Lake. This depression was crossed by a long siphon which extended to the high ground on the west of Scooteney Lake, whence a supported canal was continued westward to the Priest Rapids area. The present plan contemplates carrying the water for the Priest Rapids area through the main south to the main central diversion, and then through the main central westward. The depression in the vicinity of Scooteney Lake would be crossed by a siphon arriving at a point west of the lake, identical with that reached by the siphon mentioned in the Gault plan. Comparative estimates were made of these two plans, and the present one adopted for economic and other reasons. But little data were available as to the work necessary to improve Lind Coulee to the extent that it would form a part of the canal system as planned by Mr. Gault. A careful reconnaissance was made of this section of the work and an estimate prepared of the improvement that would be required in Lind Coulee to adapt it to the purpose proposed. The estimated cost of this improvement, together with that of the canal leading to the Scooteney Lake section was considerably in excess of the additional cost for carrying the water through the main south and main central systems the entire distance from the bifurcation works at the end of the main canal. In addition to the economic features involved, the question of canal loss is involved. The Lind Coulee improvement, of course, would be an unlined section throughout its entire length, and the probable seepage loss, particularly in the lower end, is an unknown quantity. Another item in favor of the plan adopted, but of secondary importance, is the benefit to potential power development. Water carried through Lind Coulee offers no possibilities for power development, while the supply flowing through the main central affords one site with a net head of 132 feet available for power development. Lateral C-1 is diverted from this section of the main central.

315. *Feature no. 2—Main central tunnel no. 1.*—See plate no. 156.[2] Single bore. Diameter, 22.75 feet. Length, 3,000 feet or 0.57 mile. Location of this tunnel is practically the same as that used in the Gault report of which Kirk Bryan reported as follows:

> Central tunnels, nos. 1, 2, and 3, have respectively lengths of 3,000, 3,300, and 1,400 feet, and have a maximum of 105, 118, and 70 feet of cover respectively. Their grade lines are close to the contact, and no. 3 is probably wholly in earth.

316. The above report is silent as to the probable amount of timbering required. For the purpose of this estimate, 75 percent of full timbering was used.

317. *Feature no. 3—Open canal, tunnel no. 1 to Hatton Coulee siphon.*—Length, 2.27 miles. Type no. 11. Plate no. 156.[2] This section of canal connecting these two tunnels is ideal from a construction standpoint.

[2] Not printed.

318. *Feature no. 4—Hatton Coulee siphon.*—See plate no. 158,[2] for typical design. This construction consists of a concrete barrel and the necessary end structures and foundations. Length, 1,000 feet, horizontal distance. One concrete barrel. Diameter, 19.75 feet. Maximum head, 80 feet. Consisting of but one unit, this structure is not adapted to a stage development.

319. *Feature no. 5—Open canal, Hatton Coulee siphon to tunnel no. 2.*—Length, 1.26 miles. Type no. 11. Plate no. 156.[2] There are no unusual features in this section. It is very favorable from a construction standpoint.

320. *Feature no. 6—Main central tunnel no. 2.*—See plate no. 156.[2] Single bore. Diameter, 22.67 feet. Length, 3,300 feet or 0.62 mile. Location of this tunnel is the same as used by Gault. Geologist's opinion is noted under feature no. 2. Assumed 75 percent full timbering for the purpose of this estimate.

321. *Feature no. 7—Open canal, main central tunnel no. 2 to main central tunnel no. 3.*—Length, 3.29 miles. Type no. 28. Plate no. 156.[2] The canal work through this section continues to be ideal. No unusual features are involved in this section. Lateral no. C-2 is diverted from this section of the main central.

322. *Feature no. 8—Main central tunnel no. 3.*—See plate no. 156.[2] Single bore. Diameter, 22.33 feet. Length, 1,400 feet or 0.27 mile. The location is substantially the same as the Gault location. For geological comment see feature no. 2. For the purpose of this estimate, full timbering was used throughout.

323. *Feature no. 9—Open canal, main central tunnel no. 3 to Providence Coulee siphon.*—Length, 3.22 miles. Type no. 28. Plate no. 156.[2] The canal work remains ideal through this entire section. No unusual features are involved.

324. *Feature no. 10—Providence Coulee siphon.*—See plate no. 156 [2] for typical design. This structure is of reinforced concrete throughout and consists of one barrel with the necessary end structures. Length, 2,200 feet, horizontal distance. One barrel. Diameter, 19 feet. Maximum head, 100 feet. This structure crosses Providence Coulee. In the floor of this coulee the siphon crosses under the main line of the Northern Pacific Railway and the State highway extending from Pasco to Lind. This structure does not lend itself to a stage development.

325. *Feature no. 11—Open canal, Providence Coulee siphon to main central penstock.*—Length, 7.75 miles. Types nos. 28 and 29. Plate no. 156.[2] This section is all in earth and is first class from a construction standpoint. No unusual features are involved. Laterals C3-, C-4, and C-5 are diverted from this section of the main central.

326. *Feature no. 12—Main central penstock.*—No drawing. This structure consists of three parallel steel-pipe lines. Length, 2,675 feet, horizontal distance. Three steel-pipe lines. Diameter, 10.00 feet. Net head, 138 feet. These pipe lines are provided to take advantage of the power possibilities of this site where an excessive fall is encountered in the location of the main south. They are included as a part of the canal system even though some modification is made to adapt this site to power development. This site is the

[2] Not printed.

location of power plant no. 4, the largest and most desirable power site on the irrigation project.

327. *Feature no. 13—Open canal.*—Main central to point near Shano. Length, 11.60 miles. This section of canal has been projected upon the United States Geological Survey quadrangles. Ideal conditions are found for canal construction.

328. *Feature no. 14—Open canal, point near Shano to Shano siphon.*—Length, 3.18 miles. Types nos. 29, 32 and 33. See plate no. 156.[2] The location of this section of canal is based upon a location made on the line topographic sheets. The territory covered is ideal for canal construction.

329. *Feature no. 15—Shano siphon.*—No drawing submitted. This structure consists of one barrel. A reinforced concrete construction is used on each end of this structure, and one steel pipe in the center portion where the head is beyond that permissible for an economic design for a concrete structure. Length, concrete 3,300 feet, horizontal distance; steel 9,700 feet, horizontal distance; diameter, concrete 11.08 feet; steel 12.00 feet; maximum head, 200 feet. This structure is not adapted to a stage development.

330. *Feature no. 16—Open canal, Shano siphon to Scooteney siphon.*—Length, 1.60 miles. This section of canal represents a new location proposed in the present plan. Its location is based upon a projection made upon the United States Geological Survey quadrangle sheets, as no line topography was available. Some solid-rock excavation may be encountered in this section. Lateral C-7 is diverted from this section of the main central.

331. *Feature no. 17—Scooteney siphon.*—No drawing submitted. This structure consists of one steel-pipe line with the necessary concrete end structures and foundations. Length, 18,380 feet, horizontal distance. One steel-pipe line. Diameter, 13.00 feet. Maximum head, 195 feet. This structure is not adapted to a stage development.

332. *Feature no. 18—Open canal, Scooteney siphon to end of line topography.*—Length, 19.74 miles. Types nos. 17, 18, 29 and 19. Plate no. 156.[2] This section of canal represents the last feature, the location of which is based upon a projection on line topographic sheets. The conditions of this section of the canal are generally favorable from a construction standpoint. Some solid-rock excavation will be encountered particularly on the upper end of the section. Laterals C-8 and C-9 are diverted from this section of the main central.

333. *Feature no. 19—Open canal, end of line topography to end of canal.*—Length, 25.70 miles. The location of this section of canal is based upon a projection on the United States Geological Survey quadrangle sheets. Included in this feature is a pipe line near the lower end, where advantage is taken of excess grade for the purpose of power development. This power site is designated as power plant no. 5 in the discussion following. No unusual features are encountered on this section of canal. Conditions are generally favorable but some solid-rock excavation will be encountered. Laterals C-10, C-11 and C-12 are diverted from this section of the main central.

334. *Lateral system.*—Table no. 8 gives the laterals and sublaterals which form part of the main central system, locations of which are

[2] Not printed.

based upon projections on United States Geological Survey quadrangle sheets unless otherwise noted.

TABLE NO. 8.—*Laterals and sublaterals, main central system*

| Lateral no. | Canal | | Penstock or siphon | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section and capacity | Barrel | Number of pipes | Length, | Diameter, | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Fee* |
| C-1 | 16.00 | (1) | | | | | |
| C-1-1 | 8.40 | (1) | | | | | |
| C-2 | 7.20 | (1) | | | | | |
| C-3 | 13.30 | (1) | | | | | |
| C-4 | 22.07 | (2) | Steel [3] | 1 | 1,855 | 10 | 150 |
| | | | do [4] | 1 | 4,365 | 8 | 93 |
| C-4-1 | 10.60 | (1) | | | | | |
| C-4-2 | 5.70 | (1) | | | | | |
| C-5 | 9.20 | (1) | | | | | |
| C-6 | 45.20 | (1) | Steel [5] | 2 | 1,200 | 10 | 102 |
| C-6-1 | 1.80 | (1) | | | | | |
| C-6-2 | 6.60 | (1) | | | | | |
| C-6-3 | 4.30 | (1) | | | | | |
| C-7 | 3.30 | (1) | | | | | |
| C-8 | 11.00 | (1) | Steel [6] | 1 | 3,268 | 8 | 150 |
| | | | do [6] | 1 | 2,000 | 6 | 90 |
| C-8-1 | 2.20 | (1) | | | | | |
| C-9 | .50 | (1) | | | | | |
| C-10 | 1.50 | (1) | | | | | |
| C-11 | 3.90 | (1) | | | | | |
| C-12 | 8.50 | (1) | | | | | |

[1] Projected on U.S. Geological Survey quadrangles.
[2] Projected on line topographic sheets.
[3] Penstock, power plant no. 6.
[4] Penstock, power plant no. 7.
[5] Penstock, power plant no. 8.
[6] Siphon.

335. *Feature no. 20—Sublaterals.*—The sublateral system under the main central consists of all ditches having a capacity of 100 second-feet or less, and are covered by a blanket estimate based upon the acreage covered.

336. *General project items.*—Above has been given a general description of the main canal and its distributing system consisting of the main north, main south, and main central with their respective lateral systems. The following items pertain to the general project rather than to any one of the subdivisions mentioned above.

337. *Drainage.*—A blanket estimate is included to cover this item. The question of drainage is one that will require a great deal of detail study, and is one that will probably not be determined until some time after water has been applied to the land. The requirements for drainage will vary with different sections of the tract. Some sections will require extensive work, while others will require little or none. For the present purposes, an estimate of $5 per acre was included to cover this item throughout the entire project. In the plan of stage development, it was assumed that this expenditure would be required 5 years after the land in question was first placed under irrigation.

338. *Wasteways.*—At the Spokane River crossing a wasteway, the only one on the main canal, is provided, that will waste the entire flow of the main canal for an unlimited time. About 35 miles below this wasteway Rock Lake Reservoir is located, where the storage facilities will provide for the entire flow of the main canal for only a very limited period. Below the Rock Lake Reservoir no wasteway is provided for the main canal. The possibility of providing one at Cow Creek siphon merits consideration in any further study of this

plan. A favorable site for such a wasteway exists at that crossing, but the improvements required in Cow Creek from that point to its junction with the Palouse River, a distance of 20 miles or more, may be excessive.

339. Wasteways on the project for the present study are the same as those used by Gault with the addition of an item covering the improvement of Lind Coulee. As shown earlier, the Gault report used the Lind Coulee as the upper end of the system, carrying water to the Priest Rapids area. Under the present plan Lind Coulee will be used only as a wasteway.

340. *Supplemental pumping.*—The main south and the main central are located over territory, the topography of which is such that drops or chutes are required in certain portions of the system to absorb the excess grade. At these points in the system, where conditions are favorable, it is proposed to develop the power for pumping water to desirable lands located above the gravity system. This power would, of course, be strictly seasonal in character, and would be available only during the irrigation season. While the commercial value of this product, because of its seasonal character, would be low, it is particularly adapted to meet the requirements for pumping to lands located above the gravity system.

341. There is, according to the present land classification, an area of 262,950 acres lying above the gravity system that can be covered by pumping against a static head of not to exceed 100 feet. The greater portion of this land is very desirable and it is proposed to utilize the power possibilities along the gravity system to provide the power necessary to pump water to these supplemental areas.

342. Table no. 9 shows the power possibilities that have been given consideration in this report.

TABLE NO. 9.—*Power possibilities, plan no. 2-A*

| Power plant no. | Location [1] | Quantity | Net head | Penstock [2] | Capacity | |
|---|---|---|---|---|---|---|
| | | *Second-feet* | | | *Horse-power* | *Kilo-watts* |
| 1 | Main south | 1,815 | 95 | | 15,000 | 11,200 |
| 2 | do | 417 | 100 | | 3,790 | 2,820 |
| 3 | Lateral S-5 | 320 | 85 | | 3,000 | 2,240 |
| 4 | Main central | 2,988 | 132 | | 38,000 | 28,350 |
| 5 | do | 139 | 138 | | 1,850 | 1,380 |
| 6 | Lateral C-4 | 677 | 49 | | 3,200 | 2,390 |
| 7 | do | 392 | 80 | | 3,040 | 2,270 |
| 8 | Lateral C-6 | 926 | 100 | | 8,400 | 6,270 |
| 9 | Lateral C-12 | 85 | 255 | | 2,100 | 1,570 |
| Total | | | | | 78,380 | 58,490 |

[1] For locations see pl. no. 127, page 909.
[2] Penstocks included as a part of canal.

343. In designing penstocks for the above-listed power plants some sacrifice in output of power was made in order that the cost of penstock pipes might be reduced. These penstocks are of considerable length, and are included as a part of the canal system. As the power possibilities on the project are in excess of the demands for supplemental pumping to a maximum elevation of 100 feet, this loss at the pipe line is not objectionable.

344. The total area to be provided with water by supplemental pumping, in the plan under consideration, amounts to 262,950 acres in tracts of various areas. The seasonal water requirements of these areas are 739,040 acre-feet. The average gross head is 70 feet. Acre-feet-feet per season, 51,733,430.

345. These areas vary in extent, from 15,000 acres to those as small as 20 acres, and are scattered throughout the project as will be seen from plate no. 127, page 909.

346. Estimates for pumping installations to cover these tracts are taken from graphs, and include all electrical equipment from the low side of the step-down transformers, also pumping equipment, valves, pipe lines, etc., and is dependent upon the acre-feet-feet of water to be pumped. It is evident that the per-unit price of these installations depends upon the size of the development.

347. To meet the requirements of supplemental pumping, it has been shown that the total installation required amounts to 51,733,430 acre-feet feet per season. The following installations would be required:

50 percent, or 25,866,715 acre-feet feet, 1,000 kilowatt installation.
30 percent, or 15,520,000 acre-feet feet, 500 kilowatt installation.
10 percent, or 5,173,340 acre-feet feet, 250 kilowatt installation.
5 percent, or 2,586,670 acre-feet feet, 100 kilowatt installation.
5 percent, or 2,586,670 acre-feet feet, 10–50 kilowatt installation.

348. The cost of these developments was determined by applying the unit prices as determined from the graph, to the unit quantities as given above.

349. The power installation required to furnish electrical energy to operate the above pumping units is 22,000 kilowatts. The above is based upon the seasonal requirement of water as outlined elsewhere for the various plans considered and on a 65 percent over-all efficiency of the power and pumping system.

350. Plans were not developed for the individual power plants on the project. The estimates for each plant were prepared upon the following unit-cost basis:

| | *Per kilowatt* |
|---|---|
| Hydraulic equipment | $13 |
| Electrical equipment | 27 |
| Power house and miscellaneous [7] | 20 |
| Total | 60 |

351. The following estimate is for the development of the power required to meet the demands of supplemental pumping up to the 100-foot limit only. This requires 22,000 kilowatts, leaving 39,490 kilowatts to be developed for further use. The disposition of this excess power will be discussed later in the present report.

352. Included in the estimate for supplemental pumping is the cost of transmission lines necessary for delivering the power from the power plants to the points of use at various locations on the project. This item includes 348 miles of primary transmission line and 100 miles of secondary line. This amount of transmission line would deliver power to 95 percent of the area to be covered by supplemental pumping. The remaining 5 percent represents small isolated areas that would be reclaimed at a later date when commercial lines will be available for transmitting the small amount of power required for

[7] Penstocks included as a part of the cost of canal system.

that purpose. The estimate of the cost of transmission lines includes the step-down transformers necessary to deliver the current to the pumping units at the proper voltage.

353. *Telephone system.*—Included in the estimate is an item covering the telephone plant necessary in the operation of the system. No detail plans have been made of this feature, but an estimate was made of the cost of a system believed to be adequate to cover the completed project. This includes about 400 miles of pole line, 1,500 miles of metallic circuit, instruments, equipment, etc.

354. *Wells.*—In fixing unit prices for concrete throughout the project, no attention was given to the availability of water for construction purposes. Rather than use a variable unit price for concrete construction because of water conditions, an item was included for making water available within a reasonable distance of any feature of the work. In view of the availability of water at certain points on the project at the present time, and because the stage development proposed will improve water conditions for the later stages, it is believed that the present estimate will be adequate. The estimate includes the cost of a system of wells with their equipment, minus salvage value after completion of the construction work.

355. *Permanent buildings.*—This item covers the buildings, offices, shops, warehouses, quarters, etc., required in the operation of the completed system. No details were prepared covering this feature and the estimate used in the Gault report has been accepted.

356. *Other features.*—The estimate includes an item for fencing all canals in the system, also bridges over all ditches that cross existing highways. Where bridges are required, standard types of the Washington State Highway Department with an H-15 loading are used in all cases. The fences, bridges, etc., are included in the estimate of the feature of which they form a part.

## ESTIMATES OF COST

357. Following are the estimates of the various features that constitute the irrigation system as designed for plan no. 2-A. They include overflow damages in Pend Oreille and Coeur d'Alene Lakes.

| Feature no. | MAIN CANAL | |
|---|---|---|
| 1. | Albany Falls Dam | $6, 468, 670 |
| | (The above includes an item of $2,471,370 covering overflow damages at Pend Oreille Lake.) | |
| 2. | Diversion headworks | 470, 920 |
| 3. | Newport tunnel | 18, 598, 620 |
| 4. | Canalization Little Spokane River | 2, 743, 500 |
| 5. | Great Northern Railway line change | 3, 000, 000 |
| 6. | Camden Dam | 1, 552, 620 |
| 7. | Canal | 2, 012, 830 |
| 8. | Dry Creek Dam | 1, 177, 490 |
| 9. | Canal | 445, 260 |
| 10. | Milan Tunnel | 7, 285, 560 |
| 11. | Canal | 733, 200 |
| 12. | Deep Creek Tunnel | 4, 044, 230 |
| 13. | Canal | 201, 540 |
| 14. | Deep Creek Dam | 687, 430 |
| 15. | Deadman Creek Tunnel | 4, 756, 040 |
| 16. | Canal | 157, 640 |
| 17. | Deadman Creek Dam | 4, 402, 460 |
| 18. | Canal | 2, 284, 210 |
| 19. | Pleasant Prairie Tunnel | 9, 032, 010 |

| Feature no. | | |
|---|---|---|
| | MAIN CANAL—continued | |
| 20. | Canal | $499,690 |
| 21. | Spokane River crossing | 713,170 |
| 22-A. | Canal | 1,373,350 |
| S-V-1. | Overflow damages Couer d'Alene Lake | 2,561,350 |
| S-V-2. | Diversion canals and headworks | 138,450 |
| S-V-3. | Canal | 3,170,090 |
| 22-B. | Canal | 1,133,490 |
| 23. | Manito Tunnel | 10,431,810 |
| 24. | Latah Creek Dam | 2,667,600 |
| 25. | Bonnie Lake Tunnel | 47,151,630 |
| 26. | Canal | 407,850 |
| 27. | Rock Lake Dam | 3,609,390 |
| 28. | Canal | 6,191,370 |
| 29. | Wassun Creek siphon | 977,200 |
| 30. | Canal | 3,068,900 |
| 31. | Dragoon siphon | 511,040 |
| 32. | Canal | 3,330,810 |
| 33. | Patterson Tunnel | 2,279,200 |
| 34. | Canal | 8,404,880 |
| 35. | Cow Creek siphon | 3,333,630 |
| 36. | Canal | 1,361,980 |
| 37. | Bifurcation works | 104,010 |
| | Total, main canal | 173,475,120 |
| | MAIN NORTH | |
| 1. | Canal | $1,633,330 |
| 2. | McElroy Tunnel | 2,618,570 |
| 3. | Canal | 991,000 |
| 4. | Paha Tunnel | 699,740 |
| 5. | Canal | 118,270 |
| 6. | Paha siphon | 851,400 |
| 7. | Canal | 1,909,500 |
| 8. | Klemmer Tunnel | 6,357,760 |
| 9. | Canal | 980,860 |
| 10. | Third Coulee siphon | 601,030 |
| 11. | Canal | 4,386,280 |
| 12. | Second Coulee siphon | 1,722,810 |
| 13. | Canal | 1,582,180 |
| 14. | Flaig siphon | 931,330 |
| 15. | Canal | 1,387,030 |
| 16. | First Coulee siphon | 1,492,580 |
| 17. | Canal | 2,256,580 |
| 18. | Sand Coulee siphon | 1,629,390 |
| 19. | Canal | 1,031,680 |
| 20. | Black Rock siphon | 1,263,100 |
| 21. | Canal | 1,809,570 |
| 22. | Broken Rock siphon | 2,827,180 |
| 23. | Canal | 2,872,960 |
| 24. | Round Lake siphon | 1,191,410 |
| 25. | Canal | 366,880 |
| 26. | Adrian siphon | 3,223,540 |
| 27. | Canal | 843,790 |
| 28. | Soap Lake siphon | 3,927,150 |
| 29. | Canal | 2,833,380 |
| 30. | Canal | 380,460 |
| 31. | Great Northern siphon | 200,040 |
| 32. | Canal | 780,720 |
| 33. | Potholes siphon | 2,156,850 |
| 34. | Canal | 771,230 |
| 35. | Frenchman siphon | 880,750 |
| 36. | Canal | 1,211,620 |
| 37. | Low Gap Tunnel | 855,040 |
| 38. | Canal | 1,418,820 |
| N-1. | Lateral N-1 | 602,060 |
| N-2. | Lateral N-2 | 1,585,850 |

| Feature no. | | |
|---|---|---|
| | MAIN NORTH—continued | |
| N-2-1. | Lateral N-2-1 | $51, 700 |
| N-2-2. | Lateral N-2-2 | 141, 150 |
| N-3. | Lateral N-3 | 122, 320 |
| N-4. | Lateral N-4 | 815, 580 |
| N-4-1. | Lateral N-4-1 | 38, 390 |
| N-4-2. | Lateral N-4-2 | 54, 700 |
| N-5. | Lateral N-5 | 310, 340 |
| N-6. | Lateral N-6 | 81, 810 |
| N-7. | Lateral N-7 | 152, 770 |
| N-8. | Lateral N-8 | 907, 990 |
| N-8-1. | Lateral N-8-1 | 141, 250 |
| N-9. | Lateral N-9 | 1, 138, 600 |
| N-9-1. | Lateral N-9-1 | 190, 130 |
| N-9-2. | Lateral N-9-2 | 216, 590 |
| N-9-3. | Lateral N-9-3 | 83, 440 |
| N-10. | Lateral N-10 | 737, 150 |
| N-10-1. | Lateral N-10-1 | 253, 090 |
| N-11. | Lateral N-11 | 93, 000 |
| N-12. | Lateral N-12 | 90, 130 |
| N-13. | Lateral N-13 | 567, 400 |
| N-14. | Lateral N-14 | 31, 510 |
| 39. | Sublaterals | 14, 483, 700 |
| | Total, main north | 85, 886, 460 |
| | MAIN SOUTH | |
| 1. | Milwaukee siphon | 530, 290 |
| 2. | Canal | 2, 039, 180 |
| 3. | Main South Tunnel | 1, 187, 260 |
| 4. | Canal | 1, 303, 570 |
| 5. | Main central bifurcation works | 73, 630 |
| 6. | Main south penstock no. 1 | 491, 070 |
| 7. | Canal | 1, 490, 720 |
| 8. | Canal | 598, 100 |
| 9. | Kahlotus siphon | 1, 599, 500 |
| 10. | Canal | 481, 650 |
| 11. | Canal | 286, 930 |
| 12. | Canal | 312, 660 |
| 13. | Canal | 786, 100 |
| 14. | Main south penstock no. 2 | 41, 380 |
| 15. | Canal | 474, 540 |
| S-0. | Lateral no. S-0 | 410, 590 |
| S-1. | Lateral no. S-1 | 78, 790 |
| S-2. | Lateral no. S-2 | 52, 820 |
| S-3. | Lateral no. S-3 | 270, 360 |
| S-4. | Lateral no. S-4 | 491, 780 |
| S-5. | Lateral no. S-5 | 1, 040, 390 |
| S-6. | Lateral no. S-6 | 36, 440 |
| 16. | Sublaterals | 5, 286, 540 |
| | Total, main south | 19, 364, 290 |
| | MAIN CENTRAL | |
| 1. | Canal | 1, 047, 300 |
| 2. | Main Central Tunnel no. 1 | 736, 660 |
| 3. | Canal | 382, 840 |
| 4. | Hatton Coulee siphon | 262, 050 |
| 5. | Canal | 231, 440 |
| 6. | Main Central Tunnel no. 2 | 805, 500 |
| 7. | Canal | 565, 400 |
| 8. | Main Central Tunnel no. 3 | 375, 050 |
| 9. | Canal | 508, 170 |
| 10. | Providence Coulee siphon | 574, 390 |
| 11. | Canal | 1, 108, 190 |
| 12. | Main central penstock no. 1 | 564, 970 |
| 13. | Canal | 1, 387, 570 |
| 14. | Canal | 257, 030 |
| 15. | Shano siphon | 1, 050, 880 |

| Feature no. | | |
|---|---|---|
| | MAIN CENTRAL—continued | |
| 16. | Canal | $211,710 |
| 17. | Scooteney siphon | 1,825,740 |
| 18. | Canal | 2,301,260 |
| 19. | Canal | 1,858,100 |
| C-1. | Lateral no. C-1 | 549,700 |
| C-1-1. | Lateral no. C-1-1 | 223,750 |
| C-2. | Lateral no. C-2 | 218,600 |
| C-3. | Lateral no. C-3 | 546,590 |
| C-4. | Lateral no. C-4 | 1,338,090 |
| C-4-1. | Lateral no. C-4-1 | 340,110 |
| C-4-2. | Lateral no. C-4-2 | 157,600 |
| C-5. | Lateral no. C-5 | 261,600 |
| C-6. | Lateral no. C-6 | 3,938,480 |
| C-6-1. | Lateral no. C-6-1 | 29,080 |
| C-6-2. | Lateral no. C-6-2 | 219,980 |
| C-6-3. | Lateral no. C-6-3 | 116,700 |
| C-7. | Lateral no. C-7 | 97,610 |
| C-8. | Lateral no. C-8 | 566,380 |
| C-8-1. | Lateral no. C-8-1 | 70,870 |
| C-9. | Lateral no. C-9 | 15,220 |
| C-10. | Lateral no. C-10 | 33,280 |
| C-11. | Lateral no. C-11 | 90,690 |
| C-12. | Lateral no. C-12 | 317,960 |
| 20. | Sublaterals | 12,147,450 |
| | Total, main central | 37,333,990 |
| | PROJECT ITEMS | |
| | Preliminary surveys | 1,000,000 |
| | Supplemental pumping | 7,570,170 |
| | Drainage | 7,599,450 |
| | Wasteways | 8,690,990 |
| | Permanent buildings | 1,502,000 |
| | Wells | 200,000 |
| | Telephone system | 300,000 |
| | Total, project items | 26,862,610 |
| | RECAPITULATION | |
| | Main canal | 173,475,120 |
| | Main north | 85,886,460 |
| | Main south | 19,364,290 |
| | Main central | 37,333,990 |
| | Project items | 26,862,610 |
| | Project total | 342,922,470 |

358. *Stage development.*—In determining the final per-acre cost, where interest is considered on all money invested, it is important that the system be constructed by stages in order to keep the item of interest as low as possible. It is also important, for the same reason, to coordinate the construction of the various stages with the rate of settlement in order that no capital expenditure be made until the colonization of the land demands that addition to the system.

359. The stage development proposed gives proper consideration to this feature, and the construction of each stage is delayed as long as possible, consistent with the colonization of the area to be served.

360. Some features of the construction work do not readily lend themselves to a stage development. For example, the main canal is long and expansive, being approximately 50 percent of the cost of the entire project. Certain features in the main canal system can be developed by stages; the tunnels are planned for a double-bore type of construction which adapts itself in a measure to a stage development; siphons may be constructed in four stages, but many features such as the canal sections, dams, rights of way and other

items are not possible of a stage development and in those cases the initial investment represents the final one.

361. In order to outline a stage development, assumptions must be made as to the rate of colonization, as the construction of the system must keep step with the demand for water on the land.

362. It has been assumed that interest on unpaid balances would be at the rate of 4 percent per annum, that the land would be colonized at an approximate rate of 50,000 acres per year, that land would be placed under cultivation when irrigation water was made available, that repayments would begin after the third crop had been produced.

363. In constructing the canal system to meet the requirements of the above-assumed rate of colonization, the system has been divided into 16 stages. This stage development of the canal system on the project must be modified to meet local topographic and other conditions, and most of the individual stages include an area requiring 2 or even 3 years to colonize. Table no. 10 gives the proposed stage development. The first stage brings no land under cultivation, but is for preliminary work; the second stage, covering a period of 5 years, includes the construction of all of the main canal that does not lend itself to a stage development and to the first units of those features that may be constructed in stages, together with that portion of the system required to cover the area within the unit considered.

TABLE NO. 10.—*Stage development—Plan no. 2-A*

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | 1 | $500,000 | | | |
| 2 | | 600,000 | | | |
| 3 | | 7,400,000 | | | |
| 4 | | 9,450,000 | | | |
| 5 | 2 | 25,386,190 | | | |
| 6 | | 39,392,600 | | | |
| 7 | | 49,912,500 | 104,600 | | |
| 8 | 3 | 4,155,000 | | 52,300 | |
| 9 | | 6,498,140 | 85,580 | 52,300 | |
| 10 | 4 | 1,830,000 | | 42,790 | 52,300 |
| 11 | | 2,159,380 | 98,980 | 42,790 | 52,300 |
| 12 | 5 | 4,903,000 | | 49,490 | 42,790 |
| 13 | | 5,745,380 | 123,180 | 49,490 | 42,790 |
| 14 | | 427,900 | | 41,060 | 49,490 |
| 15 | 6 | | | 41,060 | 49,490 |
| 16 | | 11,515,870 | 49,240 | 41,060 | 41,060 |
| 17 | 7 | 16,695,750 | 65,940 | 49,240 | 41,060 |
| 18 | 8 | 15,059,370 | 90,640 | 65,940 | 41,060 |
| 19 | 9 | 25,345,000 | | 45,320 | 49,240 |
| 20 | | 31,355,120 | 100,450 | 45,320 | 65,940 |
| 21 | 10 | 3,566,200 | | 50,220 | 45,320 |
| 22 | | 6,395,220 | 133,690 | 50,230 | 45,320 |
| 23 | 11 | 1,853,200 | | 37,860 | 50,220 |
| 24 | | 7,553,480 | | 37,870 | 50,230 |
| 25 | | 19,335,710 | 127,050 | 37,860 | 37,860 |
| 26 | 12 | 715,000 | | 42,350 | 37,870 |
| 27 | | 4,777,950 | | 42,350 | 37,860 |
| 28 | | 9,859,680 | 115,670 | 42,350 | 42,350 |
| 29 | 13 | 200,000 | | 38,560 | 42,350 |
| 30 | | 2,785,250 | | 38,560 | 42,350 |
| 31 | | 2,753,120 | 93,820 | 38,550 | 38,560 |
| 32 | 14 | 3,633,080 | | 46,910 | 38,560 |
| 33 | | 9,300,360 | 137,440 | 46,910 | 38,550 |
| 34 | | 1,410,500 | | 45,810 | 46,910 |
| 35 | 15 and 16 | 1,410,500 | | 45,810 | 46,910 |
| 36 | | 1,879,000 | 150,000 | 45,820 | 45,810 |
| 37 | | 1,410,500 | | 50,000 | 45,810 |
| 38 | | 2,097,700 | | 50,000 | 45,820 |
| 39 | | 1,410,500 | 50,000 | 50,000 | 50,000 |
| 40 | | 2,243,720 | 13,710 | 50,000 | 50,000 |
| 41 | | | | 13,710 | 50,000 |
| 42 | | | | | 63,710 |
| Total | | 342,922,470 | 1,519,890 | | |

364. Under this plan of development the first land would be brought under cultivation in the eighth year and repayments begin in the tenth; the last area would be brought under cultivation in the forty-first year and repayments begin in the forty-third. Carrying all capital expenditures to the end of the forty-second year with interest at the rate of 4 percent, and deducting an annual repayment of $15.74 per acre per year, which also carries interest at 4 percent from the time repayment is made to the end of the forty-second year, gives the following:

| | | *Per acre* |
|---|---|---|
| Capital cost plus net interest | $598, 285, 020 or | $393. 63 |
| Capital cost | 342, 922, 470 or | 225. 62 |
| Interest | 255, 362, 550 or | 168. 01 |
| Annual interest charge after completion | | 15. 74 |
| Annual cost of operation and maintenance | | 1. 22 |
| Annual depreciation charge | | . 83 |
| Total annual charge- operation, maintenance, and depreciation | | 2. 05 |

PLAN NO. 2

365. Plan no. 2 covers the maximum project with a gravity diversion (including area to be covered by supplemental pumping with a head not exceeding 100 feet). This plan (no. 2) is identical with plan no. 2-A, except as to the source of water supply. Plan no. 2 secures its entire water supply from Clark Fork, while plan no.2-A secures its water supply from both Clark Fork and Spokane River.

366. In plan no. 2-A the main canal leading from Clark Fork has a capacity of 11,750 second-feet to Spokane Valley Junction, where it is joined by the Spokane Valley canal carrying 2,490 second-feet diverted from the Spokane River. Below Spokane Valley Junction the main canal has a capacity of 14,240 second-feet to the bifurcation works at the head of the irrigable area on the project.

367. The plan now under consideration (plan no. 2) requires a modification of the main canal from Spokane Valley Junction to the point of diversion from Clark Fork at Albany Falls. The capacity of this section of the canal must be increased to 14,240 second-feet. The Spokane Valley canal with its diversion works and the regulation of Coeur d'Alene Lake, as proposed for plan no. 2-A, are omitted from plan no. 2.

368. The above is the only difierence between plan no. 2 and plan no. 2-A. Below the Spokane Valley junction they are identical in every respect. The point of diversion of the main canal from Clark Fork for plan no. 2 is at the same elevation as that proposed for plan no. 2-A. As plan no. 2 demands a greater quantity of water from Clark Fork than is required under plan no. 2-A, the amount of water passing Albany Falls will be somewhat reduced. Under plan no. 2-A, with regulation of Pend Oreille Lake as proposed, a minimum discharge of 8,680 second-feet could pass Albany Falls without interfering with the irrigation requirements, while in the case of plan no. 2 the amount would be reduced to 7,000 second-feet. Should the irrigation project be constructed as outlined in plan no. 2, power development on the Clark Fork below Albany Falls would be adversely affected to that extent.

ESTIMATES OF COST

369. The features listed in the following estimate constitute the entire irrigation system for plan no. 2. These features are identical

with those described in plan no. 2-A, except those marked (*), which have been modified to meet the demands of a larger capacity between the point of diversion at Albany Falls and the Spokane Valley junction.

| Feature no. | MAIN CANAL | |
|---|---|---|
| 1. | Albany Falls Dam | $6, 468, 670 |
| | (The above includes an item of $2,471,370 covering overflow damages at Pend Oreille Lake.) | |
| 2. | Diversion Headworks | *554, 030 |
| 3. | Newport Tunnel | *20, 865, 880 |
| 4. | Little Spokane River improvement | *3, 288, 750 |
| 5. | Great Northern Line change | 3, 000, 000 |
| 6. | Camden Dam | 1, 552, 620 |
| 7. | Canal | *2, 341, 270 |
| 8. | Dry Creek Dam | 1, 177, 490 |
| 9. | Canal | *474, 000 |
| 10. | Milan Tunnel | *8, 207, 240 |
| 11. | Canal | *780, 400 |
| 12. | Deep Creek Tunnel | *4, 365, 330 |
| 13. | Canal | *216, 280 |
| 14. | Deep Creek Dam | 687, 430 |
| 15. | Deadman Creek Tunnel | *5, 322, 120 |
| 16. | Canal | *165, 300 |
| 17. | Deadman Creek Dam | 4, 402, 460 |
| 18. | Canal | *2, 493, 670 |
| 19. | Pleasant Prairie Tunnel | *10, 033, 470 |
| 20. | Canal | *526, 560 |
| 21. | Spokane River Crossing | *805, 040 |
| 22. | Canal | *2, 562, 400 |
| 23. | Manito Tunnel | 10, 431, 810 |
| 24. | Latah Creek Dam | 2, 667, 600 |
| 25. | Bonnie Lake Tunnel | 47, 151, 630 |
| 26. | Canal | 407, 850 |
| 27. | Rock Lake Dam | 3, 609, 390 |
| 28. | Canal | 6, 191, 370 |
| 29. | Wassun Creek siphon | 977, 200 |
| 30. | Canal | 3, 068, 900 |
| 31. | Dragoon Creek siphon | 511, 040 |
| 32. | Canal | 3, 330, 810 |
| 33. | Patterson Tunnel | 2, 279, 200 |
| 34. | Canal | 8, 404, 880 |
| 35. | Cow Creek siphon | 3, 333, 630 |
| 36. | Canal | 1, 361, 980 |
| 37. | Bifurcation works | 104, 010 |
| | Total, main canal | 174, 121, 710 |
| | Main north: It is identical with main north, plan no. 2-A | 85, 886, 460 |
| | Main south: It is identical with main south, plan no. 2-A | 19, 364, 290 |
| | Main central: It is identical with main central, plan no. 2-A | 37, 333, 990 |
| | Project items: They are identical with project items, plan no. 2-A | 26, 862, 610 |

RECAPITULATION

| | |
|---|---|
| Main canal | 174, 121, 710 |
| Main north | 85, 886, 460 |
| Main south | 19, 364, 290 |
| Main central | 37, 333, 990 |
| Project items | 26, 862, 610 |
| Project total | 343, 569, 060 |

370. *Stage development.*—The stage development for plan no. 2 is identical with plan no. 2-A in all respects except for the capital expenditures which would be modified somewhat during the earlier stage of the construction period, because of the increase in capacity of the main canal above Spokane Valley Junction, and because of the

elimination of the Spokane Valley Canal. The stage development on the project, the date of starting, and rate of colonization are identical with those of plan no. 2-A. Details are given in table no. 11.

TABLE NO. 11.—*Stage development—plan no. 2*

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | 1 | $500,000 | | | |
| 2 | | 600,000 | | | |
| 3 | 2 | 7,630,000 | | | |
| 4 | | 9,880,000 | | | |
| 5 | | 26,521,440 | | | |
| 6 | | 37,627,900 | | | |
| 7 | | 47,964,400 | 104,600 | | |
| 8 | 3 | 4,155,000 | | 52,300 | |
| 9 | | 6,498,140 | 85,580 | 52,300 | |
| 10 | 4 | 1,830,000 | | 42,790 | 52,300 |
| 11 | | 2,159,380 | 98,980 | 42,790 | 52,300 |
| 12 | 5 | 4,903,000 | | 49,490 | 42,790 |
| 13 | | 5,745,380 | 123,180 | 49,490 | 42,790 |
| 14 | | 427,900 | | 41,060 | 49,490 |
| 15 | 6 | | | 41,060 | 49,490 |
| 16 | | 11,735,960 | 49,240 | 41,060 | 41,060 |
| 17 | 7 | 17,115,750 | 65,940 | 49,240 | 41,060 |
| 18 | 8 | 15,529,370 | 90,640 | 65,940 | 41,060 |
| 19 | 9 | 26,015,000 | | 45,320 | 49,240 |
| 20 | | 32,139,260 | 100,450 | 45,320 | 65,940 |
| 21 | 10 | 3,566,200 | | 50,220 | 45,320 |
| 22 | | 6,395,220 | 113,590 | 50,230 | 45,320 |
| 23 | 11 | 1,853,200 | | 37,860 | 50,220 |
| 24 | | 7,553,480 | | 37,870 | 50,230 |
| 25 | | 19,335,710 | 127,050 | 37,860 | 37,860 |
| 26 | 12 | 715,000 | | 42,350 | 37,870 |
| 27 | | 4,777,950 | | 42,350 | 37,860 |
| 28 | | 9,859,680 | 115,670 | 42,350 | 42,350 |
| 29 | 13 | 200,000 | | 38,560 | 42,350 |
| 30 | | 2,785,250 | | 38,560 | 42,350 |
| 31 | | 2,753,120 | 93,820 | 38,550 | 38,560 |
| 32 | 14 | 3,633,080 | | 46,910 | 38,560 |
| 33 | | 9,300,360 | 137,440 | 46,910 | 38,550 |
| 34 | 15 and 16 | 1,410,500 | | 45,810 | 46,910 |
| 35 | | 1,410,500 | | 45,810 | 46,910 |
| 36 | | 1,879,600 | 150,000 | 45,820 | 45,810 |
| 37 | | 1,410,500 | | 50,000 | 45,810 |
| 38 | | 2,097,700 | | 50,000 | 45,820 |
| 39 | | 1,410,500 | 50,000 | 50,000 | 50,000 |
| 40 | | 2,243,630 | 13,710 | 50,000 | 50,000 |
| 41 | | | | 13,710 | 50,000 |
| 42 | | | | | 63,710 |
| Total | | 343,569,060 | 1,519,890 | | |

371. Under this plan of development the first land would be brought under cultivation in the eighth year and repayments begin at the end of the tenth; the last area would be brought under cultivation in the forty-first year and repayments begin in the forty-third. Carrying all capital expenditures to the end of the forty-second year with interest at the rate of 4 percent, and deducting an annual repayment of $15.74 per acre per year, which also carries interest at 4 percent from the time repayment is made to the end of the forty-second year, gives the following:

| | | *Per acre* |
|---|---|---|
| Capital cost plus interest | $597,879,490 or | $393.37 |
| Capital cost | 343,569,060 or | 226.05 |
| Interest | 254,310,430 or | 167.32 |
| Annual interest charge after completion | | 15.73 |
| Annual cost of operation and maintenance | | 1.22 |
| Annual depreciation charge | | .83 |
| Total annual charge operation, maintenance and depreciation | | 2.05 |

PLAN NO. 6-A

372. This plan for developing the Columbia Basin irrigation project contemplates the reclamation in two divisions. Division A covers the eastern and southern portion of the project consisting of the Lind, Palouse, Pasco, and Priest Rapids area, which secures its water supply from the Clark Fork and Spokane River in the manner described for plan no. 2-A. Division B consists of the Quincy area which is reclaimed in the manner heretofore described under the greater Wenatchee project. (See plate no. 130.[2])

373. The combination of divisions A and B constitutes the entire Columbia Basin irrigation project, as outlined for a gravity diversion under plan no. 2-A, except for the elimination of some marginal areas that cannot be economically included in either division considered separately.

374. As stated, division B is discussed fully under the greater Wenatchee project and the following will deal with the details of division A.

375. Division A. Division A is covered by a canal system which is a modification of plan no. 2-A. In that plan the main north extends to and provides a water supply for the Quincy area. In the plan now under consideration the Quincy area is eliminated and the main north is modified accordingly. The modification of the main north requires a like modification in the main canal system extending from the bifurcation works to the Clark Fork.

376. The curtailment of the area under the main north permits of the following modification of the system as outlined for plan no. 2-A to meet the requirements of the plan now under consideration. The main canal from Clark Fork to the bifurcation works at the head of the irrigable area can be reduced in capacity to the extent of 3,840 second-feet. The demand on the regulated flow from Pend Oreille Lake will be decreased, and during the critical period of the year the elevation at that point will be at elevation 2,060 instead of elevation 2,053 as in plan no. 2-A. This allows 7 feet additional grade to be used in the main canal all of which is absorbed in the Newport tunnel. The main north is reduced in capacity from the bifurcation works to the Black Rock siphon where it is discontinued. Except as to these changes, division A is identical with plan no. 2-A in all respects.

*Main canal*

| | | |
|---|---|---|
| Area reclaimed by gravity | acres | 922, 490 |
| Area reclaimed by supplemental pumping | do | 206, 890 |
| Total area reclaimed | do | 1, 129, 380 |
| Mean irrigation requirement | acre-feet per acre | 2. 86— |
| Total seasonal requirement at land | acre-feet | 3, 227, 122 |
| Capacity of main canal, Clark Fork to Spokane Canal Junction | second-feet | 8, 140 |
| Capacity of Spokane Valley Canal | do | 2, 260 |
| Capacity of main canal, Spokane Canal Junction to bifurcation works | second-feet | 10, 400 |
| Loss in main canal | do | 295 |
| Loss in reservoir | do | 290 |
| Quantity delivered at bifurcation works | do | 9, 815 |
| Rediverted water | do | 830 |
| Total requirements of division A | do | 10, 645 |

[2]Not printed.

377. Table no. 12 gives the monthly requirements at the land and the monthly diversion requirements after correcting for loss in canals and reservoirs and taking credit for rediverted water.

TABLE NO. 12.—*Water requirements for plan no. 6-A (acre-feet)*

| Place | April | May | June | July | August | September | October | Total |
|---|---|---|---|---|---|---|---|---|
| At land | 330,780 | 574,428 | 549,256 | 619,607 | 588,950 | 389,514 | 174,558 | 3,227,122 |
| At bifurcation works | 351,894 | 611,094 | 584,315 | 659,157 | 626,543 | 414,376 | 185,731 | 3,433,110 |
| At diversions: | | | | | | | | |
| Canal loss only | 359,075 | 623,565 | 596,240 | 672,609 | 639,329 | 422,833 | 189,522 | 3,503,173 |
| Reservoir loss | 13,500 | 14,900 | 15,680 | 17,720 | 16,760 | 14,060 | 13,030 | 105,650 |
| Total requirements | 372,575 | 638,465 | 611,920 | 690,329 | 656,089 | 436,893 | 202,552 | 3,608,823 |
| Less rediverted water | 6,178 | 24,794 | 35,420 | 49,884 | 42,504 | 31,878 | 21,249 | 211,907 |
| Diversion requirements | 366,397 | 613,671 | 576,500 | 640,445 | 613,585 | 405,015 | 181,303 | 3,396,916 |

378. The main canal system is made up of the same features as described under plan no. 2-A modified to meet the new capacities.

379. *Distributing system.*—The distributing system is as outlined for plan no. 2-A except as noted above regarding the main north.

380. *Main north.*—The main north consists of features no. 1-19 inclusive, as outlined and described in plan no. 2-A, modified as to capacity and the laterals diverting therefrom without change.

381. *Main south.*—The main south is identical in all respects with the main south of plan no. 2-A.

382. *Main central.*—The main central is identical in all respects with the main central of plan no. 2-A.

383. *Project items—drainage.*—As described in plan no. 2-A the estimate covering this item is based upon a blanket estimate of $5 per acre for the area served.

384. *Wasteways.*—The wasteways in this plan are the same as for plan no. 2-A, less the Gault estimate for wasteways on the main north below Black Rock siphon.

385. *Supplemental pumping.*—Possible power development on the project is the same as that under plan no. 2-A. No change whatever is made in the main south and main central upon which the various proposed power developments are located.

386. The area to be reclaimed by supplemental pumping under the present plan is 206,890 acres with a seasonal requirement of 634,080 acre-feet. The average gross pumping head is 70 feet giving a seasonal requirement of 44,385,600 acre-feet-feet.

387. As in plan no. 2-A, the cost of these installations was determined from graphs with the same proportion of unit installations to meet the requirements of supplemental pumping. The cost of these developments was determined by applying the unit prices as determined from the above-mentioned graphs to the unit quantities noted.

50 percent, or 22,192,800 acre-feet-feet, 1,000 kilowatts installations.
30 percent, or 13,315,680 acre-feet-feet, 500 kilowatts installations.
10 percent, or 4,348,560 acre-feet-feet, 250 kilowatts installations.
5 percent, or 2,219,280 acre-feet-feet, 100 kilowatts installations.
5 percent, or 2,219,280 acre-feet-feet, 10 50 kilowatts installations.

388. The present plan contemplated the installation of power development to the extent of 21,000 kilowatts to meet the requirements for supplemental pumping on the project. This will provide sufficient power to provide for supplemental pumping on the plan now under

consideration and also to provide power for that purpose on the Quincy area of the greater Wenatchee project. As stated in the discussion of that project, no possibilities for power development are available in the canal system on the Quincy area while a surplus exists on the part of the project now being considered. As it is proposed ultimately to combine division A with the greater Wenatchee for the purpose of comparing with other plans for the Columbia Basin irrigation project, provision is made for providing power to the Quincy area from division A. Considered separately, the estimates for the greater Wenatchee and division A are unbalanced to the extent that division A carries the cost of power for supplemental pumping on the Quincy area. In like manner the cost of transmission lines and step-down transformers sufficient to meet the requirements of the Quincy area are included with the estimate for those items for division A.

389. *Telephone system.*—Included in this estimate is an item covering the cost of telephone system necessary in the operation of the system.

390. *Wells.*—This item is included for the reason outlined in the discussion in plan no. 2-A.

391. *Permanent buildings.*—This estimate is a modification of the estimate as given in plan no. 2-A.

392. *Preliminary work.*—This item is also a modification of the one used in plan no. 2-A.

393. *Other features.*—Included in the estimate are items for fencing all canals in the system, for providing highway crossings over all canals and ditches that will cross existing highways. Where bridges are required standard types of the Washington State Highway Department with a H-15 loading have been used in all cases. The fences, bridges, etc., are included in the estimate of the particular feature of which they form a part.

ESTIMATES OF COST

394. Following are the estimates of the various features that constitute the irrigation system as designed for plan no. 6-A, division A:

| Feature no. | DIVISION A—MAIN CANAL | |
|---|---|---|
| 1. | Albany Falls Dam<br>This feature includes an item of $2,471,370, covering overflow damages at Pend Oreille Lake. | $6, 468, 670 |
| 2. | Diversion headworks | 294, 350 |
| 3. | Newport Tunnel | 10, 209, 520 |
| 4. | Canalization Little Spokane River | 2, 178, 390 |
| 5. | Great Northern line change | 3, 000, 000 |
| 6. | Camden Dam | 1, 530, 070 |
| 7. | Canal | 1, 795, 740 |
| 8. | Dry Creek Dam | 1, 150, 360 |
| 9. | Canal | 369, 060 |
| 10. | Milan Tunnel | 4, 383, 850 |
| 11. | Canal | 611, 940 |
| 12. | Deep Creek Tunnel | 2, 266, 750 |
| 13. | Canal | 168, 600 |
| 14. | Deep Creek Dam | 783, 530 |
| 15. | Deadman Creek Tunnel | 2, 669, 400 |
| 16. | Canal | 131, 310 |
| 17. | Deadman Creek Dam | 4, 372, 610 |
| 18. | Canal | 1, 879, 220 |
| 19. | Pleasant Prairie Tunnel | 5, 334, 190 |
| 20. | Canal | 408, 200 |
| 21. | Spokane River crossing | 533, 420 |

| Feature no. | DIVISION A—MAIN CANAL—continued | |
|---|---|---|
| 22-A. | Canal | $1, 126, 740 |
| S-V-1. | Coeur d'Alene storage | 2, 561, 350 |
| S-V-2. | Diversion dam and headworks | 138, 450 |
| S-V-3. | Canal | 3, 170, 090 |
| 22-B. | Canal | 1, 063, 920 |
| 23. | Manito Tunnel: | |
| | First bore | 4, 576, 070 |
| | Second bore | 4, 491, 590 |
| 24. | Latah Creek Dam | 2, 667, 600 |
| 25. | Bonnie Lake Tunnel: | |
| | First bore | 19, 378, 900 |
| | Second bore | 19, 310, 280 |
| 26. | Canal | 358, 180 |
| 27. | Rock Lake Dam | 3, 600, 310 |
| 28. | Canal | 5, 599, 040 |
| 29. | Wassun Creek siphon | 732, 900 |
| 30. | Canal | 2, 793, 320 |
| 31. | Dragoon Creek siphon | 383, 310 |
| 32. | Canal | 2, 912, 560 |
| 33. | Patterson Tunnel: | |
| | First bore | 1, 086, 960 |
| | Second bore | 890, 290 |
| 34. | Canal | 7, 488, 670 |
| 35. | Cow Creek siphon | 2, 521, 010 |
| 36. | Canal | 1, 236, 130 |
| 37. | Bifurcation works | 96, 240 |
| | Total, main canal | 138, 723, 090 |
| | MAIN NORTH | |
| 1. | Canal | 1, 091, 770 |
| 2. | McElroy Tunnel | 1, 650, 270 |
| 3. | Canal | 607, 880 |
| 4. | Paha Tunnel | 447, 380 |
| 5. | Canal | 69, 580 |
| 6. | Paha siphon | 391, 730 |
| 7. | Canal | 1, 169, 520 |
| 8. | Klemmer Tunnel | 3, 923, 180 |
| 9. | Canal | 581, 640 |
| 10. | Third coulee siphon | 2, 222, 590 |
| 11. | Canal | 2, 567, 860 |
| 12. | Second coulee siphon | 583, 450 |
| 13. | Canal | 793, 520 |
| 14. | Flaig siphon | 294, 700 |
| 15. | Canal | 570, 620 |
| 16. | First coulee siphon | 333, 600 |
| 17. | Canal | 620, 890 |
| 18. | Sand coulee siphon | 187, 240 |
| 19. | Canal | 1, 870 |
| N-1. | Lateral N-1 | 602, 060 |
| N-2. | Lateral N-2 | 1, 585, 850 |
| N-2-1. | Lateral N-2-1 | 51, 700 |
| N-2-2. | Lateral N-2-2 | 141, 150 |
| N-3. | Lateral N-3 | 122, 320 |
| N-4. | Lateral N-4 | 615, 580 |
| N-4-1. | Lateral N-4-1 | 38, 390 |
| N-4-2. | Lateral N-4-2 | 54, 700 |
| N-5. | Lateral N-5 | 310, 340 |
| N-6. | Lateral N-6 | 81, 810 |
| 20. | Sublaterals | 6, 282, 990 |
| | Total, main north | 26, 196, 180 |
| | Main south: The main south is the same as for plan no. 2-A | 19, 364, 290 |
| | Main central: The main central is the same as for plan no. 2-A | 37, 333, 990 |

PROJECT ITEMS

| | |
|---|---|
| Supplemental pumping | $6, 867, 240 |
| Drainage | 5, 646, 900 |
| Wasteways | 8, 396, 870 |
| Permanent buildings | 1, 302, 200 |
| Wells | 165, 000 |
| Telephone system | 275, 000 |
| Preliminary work | 900, 000 |
| Total | 23, 553, 210 |

RECAPITULATION

| | |
|---|---|
| Main canal | 138, 723, 090 |
| Main north | 26, 196, 180 |
| Main south | 19, 364, 290 |
| Main central | 37, 333, 990 |
| Project items | 23, 553, 210 |
| Total project, division A | 245, 170, 760 |

395. *Stage development.*—The following stage developments are predicated upon the same assumptions as in plan no. 2-A. An annual rate of colonization of 50,000 acres is assumed, interest on unpaid balances is computed at the rate of 4 percent, payments to begin at the end of the third year of crop and the payments to equal, at least, 4 percent on the final per acre cost. Table no. 13 gives the stage development proposed for the plan under consideration.

TABLE NO. 13.—*Stage development, plan no. 6-A, division A*

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | 1 | $400, 000 | | | |
| 2 | | 612, 000 | | | |
| 3 | | 6, 350, 000 | | | |
| 4 | 2 | 8, 200, 000 | | | |
| 5 | | 21, 799, 180 | | | |
| 6 | | 37, 782, 600 | | | |
| 7 | | 50, 566, 620 | $104, 600 | | |
| 8 | 3 | 4, 155, 000 | | 52, 300 | |
| 9 | | 6, 508, 140 | 85, 580 | 52, 300 | |
| 10 | 4 | 1, 830, 000 | | 42, 790 | 52, 300 |
| 11 | | 2, 169, 380 | 98, 980 | 42, 790 | 52, 300 |
| 12 | 5 | 5, 807, 680 | | 49, 490 | 42, 790 |
| 13 | | 9, 245, 380 | 123, 180 | 49, 490 | 42, 790 |
| 14 | 6 | 4, 027, 900 | | 41, 060 | 49, 490 |
| 15 | | 4, 600, 000 | | 41, 060 | 49, 490 |
| 16 | 7 | 9, 153, 850 | 49, 240 | 41, 060 | 41, 060 |
| 17 | 8 | 14, 842, 910 | 65, 940 | 49, 240 | 41, 060 |
| 18 | | 4, 949, 370 | 90, 640 | 65, 940 | 41, 060 |
| 19 | 9 | 8, 385, 000 | | 45, 320 | 49, 240 |
| 20 | | 13, 840, 180 | 100, 450 | 45, 320 | 65, 940 |
| 21 | 10 | 2, 316, 200 | | 50, 220 | 45, 320 |
| 22 | | 4, 510, 840 | 115, 880 | 50, 230 | 45, 320 |
| 23 | 11 | 2, 703, 200 | | 57, 840 | 50, 220 |
| 24 | | 3, 883, 080 | | 57, 840 | 50, 230 |
| 25 | | 5, 832, 420 | 137, 440 | 45, 810 | 57, 840 |
| 26 | | 2, 300, 000 | | 45, 810 | 57, 840 |
| 27 | | 2, 878, 400 | | 45, 820 | 45, 810 |
| 28 | | 4, 633, 430 | 157, 650 | 50, 000 | 45, 810 |
| 29 | | | | 50, 000 | 45, 820 |
| 30 | | | | 57, 650 | 50, 000 |
| 31 | | | | | 50, 000 |
| 32 | | | | | 57, 650 |

396. Under this plan of development the first area would be brought under cultivation in the eighth year and repayments would begin on that unit at the end of the tenth year. The last area would be placed under cultivation in the thirtieth year and repayments on that unit begin at the end of the thirty-second year. Carrying all capital expenditures to the end of the thirty-first year with interest at the rate

of 4 percent on unpaid balance and deducting annual payments at the rate of $12.24 per acre, also carrying interest at the rate of 4 percent to the end of the thirty-first year gives the following:

| | Per acre |
|---|---|
| Capital cost plus interest, $345,425,130 | $305. 85 |
| Capital cost, $245,170,760 | 217. 08 |
| Interest, $100,254,370 | 88. 77 |
| Annual interest charge after completion | 12. 24 |
| Annual cost of operation and maintenance | 1. 32 |
| Annual depreciation charge | . 79 |
| Total annual charge (operation, maintenance, and depreciation) | 2. 11 |

397. As stated earlier, division B is identical in all respects with the greater Wenatchee project discussed earlier in this report. Table no. 14 gives the results of combining these two areas to secure the cost of reclaiming the Columbia Basin irrigation project by these two methods.

TABLE NO. 14.—*Plan no. 6-A*

| Division | Area | Capital cost plus interest | | Capital cost | | Interest | | Annual interest charge after completion |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per acre | Total | Per acre | Total | Per acre | |
| A | 1, 129, 380 | $345, 425, 130 | $305. 85 | $245, 170, 760 | $217. 08 | $100, 254, 370 | $88. 77 | $12. 24 |
| B [1] | 320, 310 | 94, 896, 200 | 296. 26 | 75, 662, 810 | 236. 22 | 19, 233, 390 | 60. 04 | 11. 85 |
| Total | 1, 449, 690 | 440, 321, 330 | 303. 73 | 320, 833, 570 | 221. 31 | 119, 487, 760 | 82. 42 | 12. 15 |

[1] B=greater Wenatchee.

PLAN NO. 4

398. *Main canal system.*—Pumping diversion (maximum pumping project with supplemental pumping). Diversion from the Columbia River at Grand Coulee.

| | | |
|---|---|---|
| Area reclaimed by direct pumping | acres | 980, 340 |
| Area reclaimed by supplemental pumping | do | 219, 090 |
| Total area reclaimed | do | 1, 199, 430 |
| Mean irrigation requirement at land | acre-feet per acre | 2. 92 |
| Total seasonal requirement at land | acre-feet | 3, 502, 047 |
| Capacity of main canal, pumping plant to Grand Coulee Reservoir | second-feet | 16, 000 |
| Capacity Grand Coulee Reservoir to bifurcation works | do | 11, 160 |
| Rediverted water on project | do | 710 |
| Requirement at head of irrigable area | do | 11, 870 |

399. Table no. 15 gives the monthly requirement at the land and the monthly requirement at the point of diversion after correcting for canal and reservoir losses and taking credit for rediverted water on the project.

TABLE NO. 15.—*Water requirements for plan no. 4 (acre-feet)*

| Place | April | May | June | July | August | September | October | Total |
|---|---|---|---|---|---|---|---|---|
| At land | 358, 960 | 623, 365 | 596, 048 | 672, 306 | 639, 124 | 422, 697 | 189, 460 | 3, 502, 047 |
| At bifurcation works | 381, 841 | 663, 100 | 634, 043 | 715, 254 | 679, 864 | 449, 642 | 201, 538 | 3, 725, 282 |
| At diversion | 389, 665 | 676, 687 | 647, 035 | 729, 910 | 693, 795 | 458, 855 | 205, 667 | 3, 801, 614 |
| Loss in reservoir | 59, 504 | 61, 488 | 59, 504 | 61, 488 | 61, 488 | 59, 504 | 61, 488 | 424, 464 |
| Total at diversion | 449, 169 | 738, 175 | 706, 539 | 791, 398 | 755, 283 | 518, 359 | 267, 155 | 4, 226, 078 |
| Less rediverted water | 6, 259 | 21, 907 | 31, 295 | 43, 813 | 37, 554 | 28, 166 | 18, 777 | 187, 771 |
| Net diversion requirements | 442, 910 | 716, 268 | 675, 244 | 747, 585 | 717, 729 | 490, 193 | 248, 378 | 4, 038, 307 |

408. The proposed pumping plant is located on the upstream side of the dam, with a floor elevation slightly above the normal back water surface. The plant consists of 10 pumping units, each consisting of 2 pumps of 1,600 second-feet capacity, operating in series, each pump being driven by a 50,000-horsepower synchronous motor. (See plates nos. 57 and 58.)

409. Each pump unit discharges into an individual pipe line 11.5 feet in diameter, extending for a distance of approximately 530 feet to the structure at the head of the irrigation canal.

410. The ten 1,600-second-foot units proposed give a capacity well above the maximum irrigation requirement. This excess capacity provides spare units; it also permits of refilling the reservoir at any time when secondary power is available; it also permits of shutting down some of the pumps to care for a peak commercial power demand and making up the deficiency during the off-peak hours.

411. *Feature no. 3—Open canal, pumping plant to Grand Coulee Reservoir.*—Length, 1.67 miles. (See plate no. 136,[2] type no. 43.) This section of canal extends from the structure at the end of the discharge pipes to the north end of the Grand Coulee Reservoir. Normal water surface in the Grand Coulee Reservoir is elevation 1,560, while the elevation of extreme high water is 1,570. This section of canal is designed to discharge its full capacity, 16,000 second-feet, into the reservoir when the water surface is at elevation 1,570.

412. The canal is designed to operate under normal condition of flow when the elevation of the water surface in the reservoir is 1,560, and the canal banks are raised to give the required capacity when the water surface in the reservoir is at elevation 1,570.

413. *Feature no. 4—North Reservoir Dam.*—Grand Coulee Reservoir. (See plate no. 137.)[2] The Grand Coulee Reservoir forms an important link in the Main Canal system of the plan under consideration. The reservoir is formed by the construction of two dams—the north reservoir dam located about 1½ miles from the Columbia River at Grand Coulee and the south reservoir dam located about 4½ miles north of Coulee City. The reservoir thus formed will be about 23 miles in length and will vary from ½ to 3 miles in width. With a flow line to elevation 1,570, the area submerged is 23,100 acres.

414. This reservoir is important because of the 24.4 miles of canal which would be required if it were eliminated and because of the conservation of elevation which it effects. The canal required to eliminate this reservoir utilizes 50 feet in grade between the two dams, while the loss of head for that distance utilizing the reservoir amounts to only 2.3 feet. If the loss in the reservoir amounts to 1,000 second-feet, as assumed, no material change in power requirements will be apparent if the reservoir be omitted, as the increase in head for the one case is equalized by the reduction of the quantity of water required in the second.

415. The use of this reservoir is desirable as a matter of capital cost. The capital cost of the two dams and the overflow damages in the reservoir basin are $17,656,220 less than the cost of the section of canal that would be required to detour the basin.

416. As the utilization of this reservoir is desirable from the standpoint of both first cost and possibly the cost of operation, a considerable amount of additional work has been done during the prep-

[2] Not printed.

aration of the present plans to determine the suitability of the basin for reservoir purposes, and to the selection of the most desirable sites for the dam required at each end. A topographic survey was made of the reservoir basin. This survey was made by plane-table method by the United States Geological Survey for the War Department. The map was made on a scale of 1:31,680, with a contour interval of 5 feet to elevation 1,560, above which the interval is 20 feet. Topographic surveys were made of the one favorable location for the north reservoir dam, and for three possible sites for the south reservoir dam. Tests for foundation conditions were made at the north reservoir dam site and at two of the sites proposed for the south reservoir dam. At the site for the north reservoir dam, six test holes were drilled with depths varying from 120 to 320 feet.

417. At the Coulee City site for the south reservoir dam, 11 holes were drilled to depths that varied from 31 to 199 feet. (See plate no. 138.)[2] At the Orchard site for this structure (the one adopted for the present report) no drilling was done, but shallow tests were made by hand auger to determine the suitability of the site for the type of structure proposed.

418. Several geological studies have been made to determine the watertightness of the reservoir basin and the characteristics of the various dam sites. Of the various geological reports [8] to which reference will be made, one was prepared in connection with the Gault report, and the remainder were prepared in connection with the present study. These geological reports form the basis of the assumption that the basin is suitable for reservoir purposes, and that the dam sites are adapted to the structures proposed for the respective sites.

419. The geological report made in connection with the Gault plan of development includes a detailed discussion of the geological characteristics of the area. The conclusion by Kirk Bryan as to the watertightness is covered by the following:

> The conclusion has been reached that leakage from the proposed reservoir or lake in Grand Coulee is unlikely. The area of greatest danger lies a short distance above the Coulee City Dam where the Coulee monocline crosses the reservoir. This is a restricted zone and in the event of leakage, contrary to expectations, a remedy can be obtained by the expenditure of a large but measureable sum.

420. This reservoir site, because of its perched position and because of its importance as an element of any plan based upon a pumping diversion from the Columbia River at Grand Coulee, has been the subject of considerable detailed study in the preparation of this report. It was thought advisable to obtain further opinion as to the suitability of the basin for reservoir purposes, and to secure something tangible regarding the probable seepage loss, for which provision must be made in determining the cost of installation and operation of the pumping equipment required.

421. A geological examination and report made in 1930 by Henry Landes [9] in connection with the present study includes the following conclusion regarding this reservoir basin:

> The leakage from the Grand Coulee Reservoir would be of the slow but persistent type, in an amount difficult to calculate in advance. Once the water

[2] Not printed.

[8] Kirk Bryan, Gault Report, App. B (unpublished); Henry Landes, Report of Oct. 26, 1929, App. no. 3; Henry Landes, Report of Oct. 13, 1930, App. no. 3; Ira A. Williams, Report of Oct. 22, 1930, App. no. 3; F. L. Ransome, Report of Dec. 10, 1930, App. no. 3.

[9] Appendix no. 3.

entered the basalt its opportunity to be contained in the lower and lower layers would be almost unlimited. The great basaltic basin that lies to the south, and which covers many hundreds of square miles, is capable of storing an enormous volume of water. The leakage would be at such a depth that probably no indication of it would appear anywhere at the surface, certainly not for a long space of time.

422. A further geological examination and report was made by Ira A. Williams,[9] in conjunction with the present study, the conclusion of which is given in the following quotation:

> Based upon consideration of present data, therefore, I recognize now in and about Grand Coulee, no conditions that in my judgment should be prohibitive of its development as a successful storage basin to the proposed elevation 1,552.50. Such outcome is contingent, of course, upon the effecting of suitable closures across the Coulee bottom by the two proposed dams, the southerly one of which shall be located conservatively to the northward of the position of the monoclinical fold that crosses the lower end of the Coulee.
>
> I am expressing the above opinion, and have made the preceding comments, as the result of my brief field study and of careful deliberation over all available matter on the situation. It cannot be gainsaid, I think, that the creation of a reservoir in Grand Coulee amounts to the partial reproduction of some of the water conditions that formerly existed there, of which those of the present are but a bare remnant.
>
> Admittedly, any suspended body of ground water is in a geologically precarious position; as is that in the Coulee today. Increasing the bulk and extent of this body of water by artificial means would, therefore, be unavoidably rather more experimental than is sometimes the case, and an instance as it were of adding to the load, or the contents, of a now partially emptied elevated vessel (the Coulee) whose ultimate integrity must depend upon the physical continuity and tightness of every part of the bottom and sides and ends. A comparatively few important openings could be disastrous in much greater degree than if the disposition of surrounding ground water conditions were different from what they appear to be.
>
> As expressed in my introductory paragraphs, it nevertheless goes without saying that favorable as the locality may appear superficially, further careful study of the region and more detailed investigations of both dam sites, and of intervening portions of the Coulee trough, should be made before its adoption is decided upon, and in advance of the definite laying out of plans of development.

423. A third geological examination and report was made by F. L. Ransome,[9] in the interest of the present study. The conclusion reached in this latest geological report is as follows regarding the watertightness of the reservoir basin:

> The reservoir, although probably subject to a rather high evaporation loss, owing to its large area and shallow depth, will not develop any appreciable leakage.

424. In addition to the above-mentioned geological reports regarding the suitability of the basin as a reservoir site, advice was secured from A. J. Wiley, a consulting engineer of wide experience in irrigation and power development, as to the suitability of the various dam sites, and the Grand Coulee Reservoir in general.

425. As the various geological reports indicate that the point of greatest loss in the reservoir would be at the Coulee monocline, about 4 miles north of Coulee City, it was decided to locate the south reservoir dam north of that point, leaving the questionable area outside the reservoir. With the elimination of this area from the reservoir, the various geological reports seem to justify the conclusion that any loss in the reservoir would not be exorbitant.

426. Regarding the possible amount of leakage to be expected, Mr. Ransome [9] remarks that, "Leakage, if any, will probably not lower the water surface as much as 1 inch per day."

[9] Appendix no. 3.

427. In the present plan it has been assumed that the daily loss from seepage and evaporation, would amount to 1,000 second-feet. This estimated reservoir loss has been used throughout in the water-supply studies, and is used in determining pumping plant requirements both as to installations and power consumption.

428. While the reservoir has been included in the present plan on the basis outlined above, further examinations and investigations should be made of this phase of the matter before any definite plan is fixed.

429. Mr. Wiley has recommended that before any action be taken that definitely commits the project to the use of this reservoir, tests be made to determine its watertightness.

430. In considering the present plan of irrigation development with the construction of the high dam in the Columbia River at Grand Coulee, and utilizing storage in the Grand Coulee Reservoir between elevations 1,560 and 1,570, secondary power will be used almost entirely for pumping purposes. Should the reservoir be eliminated the amount of water required from the pumping plant would be reduced 1,000 second-feet, the estimated loss in the reservoir, the head as stated would be increased 21 percent. The resultant increase in the demand on the pumping plant due to the elimination of the reservoir would be small, about 2 percent, the advantages of storage in the Grand Coulee Reservoir would be lost.

431. Practical test, however, might prove the losses in the reservoir to be prohibitive, in which case the only alternative would be the substitution, with its additional cost, and increase in pumping head and power consumption, of the section of canal required to replace the reservoir. The adoption of one or the other of these plans would, of course, be necessary before the design and construction of the pumping plant could be undertaken.

432. It is assumed that 6 years will be required in the construction of the high dam in the Columbia River. During the earlier portion of this period, a practical test might be made to determine the watertightness of the reservoir basin. This testing would involve the construction of a dike at each end of the basin to the height required to cover the floor of the basin, and the pumping of a large volume of water from the Columbia River for a period of several months. The expense involved in this test would be large, but small as compared to errors that might follow a false assumption as to the seepage losses. This testing could be accomplished and the system completed according to one method or the other by the time of completion of the dam in the Columbia River.

433. The estimate given for plan no. 4 is based upon the use of the reservoir with the seepage and other losses assigned above. Following that estimate is a statement as to the per acre cost for plan no. 4, if the reservoir proves to be unserviceable. As stated previously, the Grand Coulee Reservoir is formed by the construction of two dams, the North Reservoir Dam and the South Reservoir Dam.

434. For the North Reservoir Dam, the topographic conditions are such that the site for a structure of reasonable cost is limited to a restricted area. The site considered in the present report is the one used by all prior agencies reporting on a proposed pumping plan for developing the project. Additional testing was made at this site

to determine foundation conditions, and geological opinion, to supplement that accompanying the Gault report, secured as to the suitability of the dam site.

435. Regarding this dam site, the following conclusions have been rendered by the geologists:

Mr. BRYAN: "The contact rises east and north of the dam where it quickly attains elevations above the proposed flow line. If, then, the movement of the water through the basalt is resisted at the dam, no leakage can take place. The massive basalt of the abutment will not transmit much water, but the base, where it rests on the granite, may prove to be much more open. Grout holes should therefore be carried to the contact. It is a matter of regret that test drilling was not carried on to determine the position and character of this contact."

436. The above opinion was rendered in 1924. The remaining opinions are based upon the results of five of the six test holes drilled during the present investigation.

Mr. WILLIAMS:[9] "I would anticipate that such openness as may exist in and between the layers of basalt at the westerly side of this Grand Coulee site, can be corrected and the abutment rock rendered sufficiently resistant against movement of water around the end of the dam, by application of customary deep grouting methods during construction.

"On the whole, therefore, and as stated, I recognize no condition at this time which appears prohibitive to the placing of a safe and effective dam at this location in Grand Coulee, at some position within the limits outlined by the present drill holes."

Mr. RANSOME:[9] "It is suggested that, before final plans for a dam are made, at least one drill hole should be put down through the basalt of the north abutment to make sure that this is resting on compact silt and not on any loose or bowldery material through which water might readily escape eastward to the Columbia. * * * In my opinion, unless unexpected unfavorable conditions are brought to light by the additional drill hole suggested, it will be practicable to build a safe and effective dam, approximately 60 feet high, at the Grand Coulee site. To the geologist, the site appears better suited for an earth or rock-earth embankment than for a concrete dam."

437. The test hole suggested in the last opinion as noted was sunk to a depth of 190 feet. Broken and shattered lava of various dimensions was encountered practically the entire depth. The estimate for the structure includes an item for grouting this section of the foundation.

438. Regarding the type of structure to be used at this site, Mr. Wiley recommended:

This forms the north or upper end of the Grand Coulee Reservoir and is about 70 feet in maximum height. It is planned to make this an earth embankment with downstream slope of loose rock. I suggest that the top width of the earth embankment be made not less than 20 feet and that its slope be 3 to 1 starting from the top, omitting the 1½ to 1 slope shown in the plan. Connections should be made with the earth foundation by a number of deep trenches with side slopes of 1½ to 1 carried down to the relatively firm material. I think the material noted as black mud and wind blown sand should both be stripped from the foundation.

The material noted as no. 2, consisting of very firm volcanic ash and found about 1½ miles south of the dam, as well as similar material found anywhere in the vicinity, though entirely free from clay and devoid of plasticity as pointed out by the geological report, will make a satisfactory dam when moistened and rolled in 4-inch layers.

The upstream face should be protected by rock paving as shown, but that part of the face which will be exposed to wave action by the possible drawdown of the reservoir should have hand-laid paving with a minimum thickness normal to the face of not less than 18 inches, and a maximum of 24 inches underlaid by 12 inches of gravel.

[9] Appendix no. 3.

439. This structure has been designed along the lines recommended above with the addition of one large Stoney gate and wasteway leading to the Columbia River.

440. *Feature no. 5—South Reservoir Dam—Grand Coulee Reservoir.*—See plate no. 139.[2] The proper location of this structure has been the subject of considerable study during the present investigation. Surveys were made of three possible sites; one at Coulee City, one at a point about 4½ miles north of Coulee City, and a third about 1 mile still further north. Drilling was done at the Coulee City site and the geological opinions, while generally agreeing that the site was a suitable one, favored the site located 4½ miles above, because of conditions in the reservoir basin. About 4 miles above Coulee City, the Coulee Monocline crosses the basin and the geologists generally agree that that geological feature would introduce an element of doubt if included within the reservoir basin. For that reason the site located 4½ miles above Coulee City and well above the monocline in question has been adopted for the present plan. No drilling was done at this dam site. For structures of the type proposed, the character of the upper 20 or 25 feet of soil is of most importance. In this case the upper strata were tested by hand augers and found to be satisfactory. Regarding the suitability of the site selected, Mr. Ransome [9] rendered the following opinion:

> With attention to the modification of position suggested and with fuller information concerning the material under the flat bottom of the Coulee, I am of the opinion that it will prove entirely feasible to construct a safe and effective dam, to the approximate height of 60 feet at the no. 2 Coulee City site.
>
> The question of the character of dam suitable for this site is one for the engineers to decide. To the geologist it appears that the site is more appropriate for an earth-fill, or for a combination earth-fill and rock-fill embankment than for a concrete structure.

441. Regarding the type and design of structure for this location, Mr. Wiley advised as follows:

> The dam at Coulee City is to be located about 4½ miles above Coulee City where there is a very uniform profile with a flat bottom formed by a dry lake bed. This dam is about 100 feet high with its base in the dry lake bed. There are no borings, so the undersurface conditions are unknown. The east end of the dam will be on a gentle slope composed of fine volcanic ash soil suitable for use in the embankment. The west end of the dam will close against solid rock spurs projecting beyond the regular side walls of the coulee.
>
> The flow line will be above the projecting spurs and it will be necessary to excavate the talus slopes to connect the top of the dam with the solid lava slope.
>
> The section of the dam will be of the same dimensions and made in the same way in all respects as the dam at the upper end of the reservoir except that the base to which connection will be made at this site will have to be investigated by boring before plans for cut-off trenches can be decided upon. From the information now available, it appears that the dam as shown will be satisfactory if the upstream slope and top width are changed to correspond with those recommended for the dam at the upper end of the coulee.

442. *Feature no. 6—Open canal, South Reservoir Dam to Bacon siphon.*—Length, 5.88 miles. See plate no. 136,[2] type no. 43. This section of canal, leading from the Grand Coulee Reservoir, has a capacity of 11,160 second-feet. It extends to the Bacon siphon over territory where a very large percentage of solid rock will be encountered. Other than the nature of the classification, there are no unusual features in this section of the work.

[2] Not printed.
[9] Appendix no. 3.

443. The location of the entire main canal is based upon a projection made upon line topographic maps prepared for the present report on a scale of 400 feet to 1 inch with a contour interval of 5 feet.

444. *Feature no. 7—Bacon siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the necessary concrete and structures and saddles. Length of siphon, 825 feet, horizontal distance. Diameter, 21.84 feet. Maximum head, 90 feet. This structure discharges directly into the Bacon tunnel. Consisting as it does of two lines of pipe, it will be constructed in two stages to meet the requirements of the colonization on the project.

445. *Feature no. 8—Bacon tunnel.*—See plate no. 136.[2] Twin bore. Diameter, 25.5 feet. Length, 10,700 feet or 2 miles. This tunnel is substantially the same as that used in the Gault report, concerning which Bryan reported as follows:

> The principal tunnel of the pumping project is 9,500 feet long and is located in the seabland south of Coulee City, on the canal between the Coulee City Dam and Trail Lake. This tunnel will be in basalt and as it lies above the local water table, will probably be dry.

446. No expression was given as to the probable amount of timbering that would be required. Ten percent of full timbering was assumed for the purpose of this estimate. This tunnel will be constructed in two stages.

447. *Feature no. 9—Open canal, Bacon Tunnel to Trail Lake Tunnel.*—Length, 1.65 miles. See plate no. 136.[2] Type no. 48. This section of canal, extending between Bacon Tunnel and Trail Lake Tunnel, is required to eliminate Trail Lake Reservoir from the canal system. Trail Lake Reservoir site was examined in connection with the preparation of the Gault report and found to be unfit, at least in part, for reservoir purposes. Bryan reported as follows: "It seems, therefore, unadvisable to create a lake, when leakage will take place at such high rate."

448. No unusual features are involved in this section of the work, except the classification of material, all of which will be solid rock excavation.

449. *Feature no. 10—Trail Lake Tunnel.*—See plate no. 136.[2] Twin bore. Diameter, 25.5 feet. Length, 2,300 feet, or 0.43 mile. The location of this tunnel is in the locality near those used in the Gault estimate of which Bryan reported as follows:

> The tunnel has a southwest trend and, therefore, the dip will be lower in the direction of its course. It will, however, cross the contact between flows, each of which will be a relatively weak place in the roof at which timbering may be anticipated.

450. Twenty-five percent full timbering was assumed for the purpose of the present estimate.

451. *Feature no. 11—Bifurcation works.*—See plate no. 176.[2] This structure is located at the end of the main canal and 400 feet from the lower portal of the Trail Lake Tunnel. The section of open canal between the lower end of the tunnel and the bifurcation works is practically all used in transitions between the two structures and is included in the estimate for the bifurcation works.

452. *Distributing system.*—See plate no. 132.[2] The distributing system begins at the bifurcation works where the main canal is

[2] Not printed.

divided into the main west and the main east. The main west extends in a southwesterly direction, crossing Dry Coulee, and Grand Coulee at the upper end of Soap Lake. From the upper end of Soap Lake it extends in a southerly direction for a distance of 2½ miles to a point about 1 mile west of Soap Lake where it joins the main north of plan no. 2-A, which has previously been considered. Below this junction the main west of plan no. 4 is identical in every respect with the main north of plan no. 2-A.

453. The main west canal serves that portion of the project lying west of a line extended north from Moses Lake and north and west of that portion of Crab Creek extending from Moses Lake to the Columbia River, consisting of an area of 370,710 acres including that to be covered by supplemental pumping.

454. The main east canal extends in a southerly and southeasterly direction from the bifurcation works along the eastern boundary of the project, and serves all lands within the project that are located east of a line extending northward from Moses Lake and south of that portion of Crab Creek located between that lake and the Columbia River, consisting of an area of 828,720 acres including area to be covered by supplemental pumping.

455. In designing the distributing system, certain essential data are shown only on office records (unpublished). These records indicate the location of all canals having a capacity of 100 second-feet or more, area of land served under each lateral with the water requirements for that area and the capacities of all canals and laterals.

456. The locations of the larger laterals when so stated have been projected upon line topographic sheets and transferred from those sheets to the work maps, while the balance of the system has been projected on the United States Geological Survey quadrangles which, when they were available, have formed the background for the work maps.

457. For those lines that have been projected upon line topographic sheets, profiles were prepared which form the basis for the estimates for those sections.

458. *Main west canal.*—The main west consists of the following features, listed geographically.

459. *Feature no. 1—Open canal, bifurcation works to Dry Coulee Tunnel No. 1.*—Length, 4.77 miles. See plate no. 136.[2] Type no. 47. The location of the main west canal, from the bifurcation works to the point where it joins the main north canal of plan no. 2-A, was projected upon line topographic sheets prepared by the Columbia Basin Survey Commission, except for the section crossed by the Soap Lake siphon where a new survey was made for the present study. This section of canal, extending from the bifurcation works to Dry Coulee Tunnel No. 1, crosses an area where topographic features are fair, but a large percentage of the excavation will be in solid rock. No water diversions are made from this section.

460. *Feature no. 2 Dry Coulee Tunnel No. 1.*— See plate no. 136.[2] Single bore. Diameter, 18.6 feet. Length, 2,540 feet, or 0.48 mile. This tunnel has the same general location as the tunnel on the Gault line. No geological report is available regarding this tunnel. It will doubtless extend through basalt the entire distance, and 25 percent of full timbering was assumed for the purpose of the present estimate.

[2] Not printed.

Between this tunnel and Dry Coulee Tunnel No. 2 there is a section of canal 375 feet in length. This section of canal is included in the estimate for Tunnel No. 1.

461. *Feature no. 3—Dry Coulee Tunnel No. 2.*—See plate no. 136.[2] Single bore. Diameter, 18.6 feet. Length, 1,875 feet, or 0.35 mile. No geological report was available. Like Tunnel No. 1, this tunnel will be in basalt, and 25 percent of full timbering is allowed in the present estimate.

462. *Feature no. 4—Open canal, Dry Coulee Tunnel No. 2 to Dry Coulee siphon.*—Length, 0.50 mile. See plate no. 136.[2] Type no. 47. This section of canal involves no unusual features, except for the large amount of solid rock excavation that will be encountered.

463. *Feature no. 5.—Dry Coulee siphon.*—No special drawing. This structure consists of one steel pipe line with the necessary concrete footings and end structures. Length of siphon, 2,680 feet, horizontal distance. One steel pipe. Diameter, 18.66 feet. Maximum head, 240 feet. This structure consisting of one pipe line is not adaptable to a stage development.

464. *Feature no. 6—Open canal, Dry Coulee siphon to Soap Lake siphon.*—Length, 7.57 miles. See plate no. 136.[2] Type no. 47. This section of canal, extending from the Dry Coulee siphon to the Soap Lake siphon, involves no unusual features. A large percentage of the excavation in this section of canal will doubtless be solid rock. Lateral W-1 is diverted from this section of the main west.

465. *Feature no. 7—Soap Lake siphon.*—No special drawing. This structure consists of one steel pipe line with the necessary concrete appurtenant works. Length of siphon, 9,650 feet, horizontal distance. Diameter, 14.75 feet. Maximum head, 323 feet. This siphon carries the main west across Grand Coulee on the upper or north side of Soap Lake. A topographic survey was made of this site in connection with the present investigation. This structure offers no possibilities for a stage development.

466. *Feature no. 8—Open canal, Soap Lake siphon to point near Quincy.*—Length, 23.46 miles. See plate no. 136.[2] Type nos. 47, 48, 15, 16, and 17. This canal extends from the lower end of the Soap Lake siphon for a distance of about 2 miles along a steep, rocky hillside. At a point 2.61 miles below the outlet of the Soap Lake siphon, the line intersects the location of the main north of plan no. 2-A. Below that point the main west of plan no. 4, and the main north of plan no. 2-A, are identical in every respect. The lower end of this section of canal work is ideal from a construction standpoint. This section of canal is the last on the main west, the location of which is based upon a projection on line topographic sheets. Below this feature the projections were made on the United States Geological Survey quadrangle sheets. Lateral nos. W-2 and W-3 are diverted from this section of the main west.

467. *Feature no. 9—Open canal, point near Quincy to Great Northern siphon.*—Length, 3.60 miles. In consideration of all canals, the estimate for which is based upon a projection made upon the United States Geological Survey quadrangle sheets, reference must be made to certain office records (unpublished) for details as to distances, canal sections, and quantities. This section of canal is ideal from a construction standpoint.

[2] Not printed.

468. *Feature no. 10—Great Northern siphon.*—See plate no. 158 [1] for typical design. This is a reinforced concrete structure consisting of 1 barrel crossing under the main line of the Great Northern Railway at a point about 3 miles west of Quincy. Length, 1,700 feet, horizontal distance. Diameter, 12.25 feet. Maximum head, 100 feet. The head acting upon a portion of this siphon exceeds that considered economical for a concrete structure; but, as it is necessary to bury the portion having the maximum head, especially where it crosses under the railroad grade, it is believed advisable to use concrete throughout, rather than change to a steel pipe for the short distance where the head is excessive for a concrete pipe.

469. *Feature no. 11—Open canal, Great Northern siphon to Potholes siphon.*—Length, 6.90 miles. This section is located over an area very favorable to canal construction. No unusual features are involved.

470. *Feature no. 12—Potholes siphon.*—See plate no. 134 [2] for typical design. This structure consists of a single steel pipe line with the necessary end and foundation structures. Length, 15,200 feet, horizontal distance. Diameter, 16.17 feet. Maximum head, 182 feet. A final analysis may show the advisability of substituting reinforced concrete for the steel pipe on the ends where the head is permissible. This structure must be constructed as one unit, and does not lend itself to a stage development.

471. *Feature no. 13—Open canal, Potholes siphon to Frenchman siphon.*—Length, 7 miles. This section of canal is over an area somewhat rough and broken in spots, and will encounter some solid rock excavation, particularly at the lower end. Lateral W-4 is diverted from this section of the main west.

472. *Feature no. 14—Frenchman siphon.*—No special drawing. This structure consists of one pipe line with the necessary end structures and foundations. A reinforced concrete pipe is used where the head is favorable, and a steel pipe substituted where the head is beyond that limiting an economical concrete design. Length, 10,700 feet, horizontal distance, consisting of 8,010 feet of steel pipe line, diameter, 13.08 feet, and 2,090 feet of reinforced concrete pipe line, diameter, 11.92 feet. Maximum head, 165 feet. This structure must be built as a single unit.

473. *Feature no. 15—Open canal, Frenchman siphon to Low Gap Tunnel.*—Length, 10.50 miles. This section of canal is favorable as to topographic features, but considerable solid rock excavation will be encountered.

474. *Feature no. 16—Low Gap Tunnel.* See plate no. 136.[2] Single bore. Diameter, 12.83 feet. Length, 8,200 feet, or 2.64 miles. This tunnel carries the water through to the area south of the Frenchman hills. The geological report makes no comment regarding conditions at this tunnel site other than to state it would pass through basalt. For the purpose of the present estimate, 75 percent full timbering was assumed.

475. *Feature no. 17—Open canal, Low Gap Tunnel to end.*—Length, 28.10 miles. This section of canal is generally favorable for canal construction. Some solid rock excavation will be encountered. Laterals W-5, W-6, and W-7 are diverted from this section of the main west.

[2] Not printed.

476. *Lateral system.*—The following laterals divert from the main west canal and for convenience are presented in table no. 16.

TABLE NO. 16.—*Lateral system, main west*

| Lateral No. | Canal | | Siphons | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section | Barrel | Number of pipes | Length | Diameter | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Feet* |
| W-1 | 19.10 | (1) | Concrete | 1 | 11,000 | 6.00 | 234 |
| W-1-1 | 4.50 | | | | | | |
| W-2 | 14.42 | (1) | Concrete | 1 | 1,000 | 8.00 | 40 |
| | | | do | 1 | 5,450 | 10.08 | 60 |
| W-2-1 | 2.15 | (2) | do | 1 | 5,400 | 5.92 | 44 |
| W-2-2 | 5.15 | (2) | Steel flume | 1 | 2,800 | [3](#84) | |
| W-3 | 19.30 | (2) | | | | | |
| W-3-1 | 7.40 | (2) | | | | | |
| W-4 | 2.10 | (2) | | | | | |
| W-5 | 3.20 | (2) | | | | | |
| W-6 | 4.74 | (2) | Concrete | 1 | 14,072 | 6.67 | 94 |
| W-7 | 1.00 | (2) | | | | | |

[1] Location based on projection on line topographic sheets.
[2] Location based on projection on United States Geological Survey quadrangles.
[3] Refers to stock size.

477. *Feature no. 18.*—The laterals listed above all terminate where the required capacity has been reduced to 100 second-feet. The present plan contemplates a system extending to the individual farm units, but all laterals having a capacity of less than 100 second-feet are not shown individually but are covered by a general estimate based upon the acreage served.

478. *Main east.*—The main east consists of the following features, listed geographically.

479. *Feature no. 1—Open canal, bifurcation works to Long Lake Tunnel.*—Length, 2.27 miles. See plate no. 136.[2] Type no. 45. The location of this feature of the main east is based upon line topographic sheets prepared in the present investigation. This section of canal crosses an area characterized by rough, broken topography and the excavation will be entirely in solid rock. This section involves one crossing with a branch line of the Northern Pacific Railway. No diversions are made in this section of canal.

480. *Feature no. 2—Long Lake Tunnel No. 1.*—See plate no. 136.[2] Twin bore. Diameter, 21.92 feet. Length, 1,700 feet, or 0.32 mile. This tunnel has the same general location as that considered in the Gault report regarding which Kirk Bryan made the report that they "will be in horizontal basalt, and as they lie in the cliffed slopes of the coulee, they will be dry." No comment was made regarding the probable amount of timbering that would be required. For the purpose of the present estimate, 20 percent of full timbering was assumed. This tunnel may be constructed in two stages.

481. *Feature no. 3—Open canal, Long Lake Tunnel No. 1 to Long Lake Tunnel No. 2.*—Length, 1 mile. See plate no. 136.[2] Type no. 45. This section of canal is over an area of somewhat broken topographic features, and the excavation will probably all be in solid rock. The location of the main east, from Long Lake Tunnel No. 1 to and including feature no. 15, is based upon a projection on line

[2] Not printed.

topographic sheets that had been prepared by the Columbia Basin Survey Commission. No diversions are made from this section of the main east.

482. *Feature no. 4—Long Lake Tunnel No. 2.*—See plate no. 136.[2] Twin bore. Diameter, 21.92 feet. Length, 900 feet, or 0.17 mile. The geological report accompanying the Gault estimate made the same comment regarding this tunnel as was made for Long Lake Tunnel No. 1. For the present estimate, 20 percent of full timbering was assumed. This tunnel may be developed in two stages.

483. *Feature no. 5—Open canal, Long Lake Tunnel No. 2 to Stratford Tunnel.*—Length, 3.42 miles. See plate no. 136.[2] Type no. 45. This section of canal passes over rough broken terrain where the classification will doubtless be solid rock. No diversion is made from this section of the main east.

484. *Feature no. 6—Stratford Tunnel.*—See plate no. 136.[2] Twin bore. Diameter, 21.92 feet. Length, 3,900 feet, or 0.74 mile. This tunnel is located in the same formation as the Long Lake Tunnels. We have the same report from the geologist, and the same allowance is made for timbering in the present estimate as was made for the two preceding tunnels. This tunnel may be built in two stages.

485. *Feature no. 7—Open canal, Stratford Tunnel to Crab Creek siphon.*—Length, 1.34 miles. See plate no. 136.[2] Type no. 45. Topography is rough and irregular. Classification of material in this section will probably all be solid rock. No diversions are made from this section of the canal.

486. *Feature no. 8—Crab Creek siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the required concrete footings and end structures. Length of siphon, 5,480 feet, horizontal distance. Diameter, 19.25 feet. Maximum head, 269 feet. This siphon crosses Crab Creek, the north central highway, and the main line of the Great Northern Railway. The steel pipes are laid in an 18-inch concrete casing through these crossings. This structure is adapted to construction in two stages.

487. *Feature no. 9—Open canal, Crab Creek siphon to Broken Rock siphon.*—Length, 4.92 miles. See plate no. 136.[2] Types no. 45, no. 51, and no. 44. Topography of this section of canal is generally rough and broken, and solid rock excavation will be encountered throughout the entire distance. Lateral E-1 is diverted from this section of the main east.

488. *Feature no. 10—Broken Rock siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the required concrete end structures and footings. Length of siphon, 8,700 feet, horizontal distance. Diameter, 21.33 feet. Maximum head, 150 feet. This structure crosses the Broken Rock Coulee and may be constructed in two stages to suit a stage development. The main east, now being considered, intersects the main north of plan no. 2-A at this structure; the intake of the siphon on the main east being identical with the outlet of the siphon for plan no. 2-A.

489. *Feature no. 11—Open canal, Broken Rock siphon to Black Rock siphon.*—Length, 10.47 miles. See plate no. 136.[2] Types no. 44, no. 46, and no. 44. The topography of the upper end of this section of canal is rough and broken. At the lower end it is more favorable for canal construction. The greater portion of this section of canal will

[2] Not printed.

be in solid rock excavation. No diversions are made from this section of the main east.

490. *Feature no. 12—Black Rock siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with concrete end structures and saddles. Length of siphon, 4,500 feet, horizontal distance. Diameter, 20.67 feet. Maximum head, 123 feet. No unusual items in connection with this structure are present. Consisting of two pipe lines, it may be constructed in two units to meet the requirements of a stage development.

491. *Feature no. 13—Open canal, Black Rock siphon to Long Ridge Tunnel.*—Length, 1 mile. See plate no. 136.[2] Type no. 44. This section of canal is located over an area where topography is favorable for canal construction, but solid rock excavation will be encountered over the entire distance. No diversions are made from this section of the main east.

492. *Feature no. 14—Long Ridge Tunnel.*—See plate no. 136.[2] Twin bore. Diameter, 24.58 feet. Length, 1,900 feet, or 0.36 mile. Regarding the tunnel in this general location, Bryan collaborating with Gault reported as follows: "This line also has a tunnel in the scabland at Black Rock Coulee which will be in basalt." No comment was made as to timbering. For the present estimate, 20 percent of full timbering was assumed.

493. *Feature no. 15—Open canal, Long Ridge Tunnel to Sand Coulee siphon.*—Length, 2.40 miles. See plate no. 136.[2] Types no. 46 and no. 49. Topography of this area is fair. A considerable portion of the excavation in this section will be in solid rock. Lateral E-2 is diverted from this section of the main east. Feature no. 15 is the last on the main east, the location of which is based upon a projection made on line topographic sheets prepared by the Columbia Basin Survey Commission. From this point forward, to and including feature no. 43, the location is based upon a projection made on line topographic sheets made during the present investigation. This new line topography is done on a scale of 400 feet to 1 inch, with a contour interval of 5 feet.

494. *Feature no. 16—Sand Coulee siphon.*—No special drawing. This structure consists of a twin-bore concrete siphon. Length, 700 feet, horizontal distance. Diameter, 18.50 feet. Maximum head, 40 feet. This structure is of reinforced concrete throughout and may be built in two stages at some additional cost.

495. *Feature no. 17—Open canal, Sand Coulee siphon to Rocky Branch siphon.*—Length, 7.77 miles. (See plate no. 136,[2] type no. 49.) This section of canal covers an area favorable for canal construction. Topography is good, and but very little solid rock excavation will be encountered. Lateral E-3 is diverted from this section of the main east.

496. *Feature no. 18—Rocky Branch siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the necessary concrete end structures and foundations. Length, 1,450 feet, horizontal distance. Diameter, 20.25 feet. Maximum head, 122 feet. This structure, consisting of two steel pipe lines, may be constructed in two units to meet the requirements of a stage development.

[2] Not printed.

497. *Feature no. 19—Open canal, Rocky Branch siphon to Rocky Coulee siphon.*—Length, 0.84 mile. (See plate no. 136,[2] type no. 49.) This section of canal is first class from a construction standpoint. A small amount of solid rock excavation may be encountered.

498. *Feature no. 20—Rocky Coulee siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the required concrete end structures and saddles. Length, 5,000 feet, horizontal distance. Diameter, 20.16 feet. Maximum head, 150 feet. This structure is to be built in two units in the interest of a stage development.

499. *Feature no. 21—Open canal, Rocky Coulee siphon to Weber Branch siphon.*—Length, 9.46 miles. (See plate no. 136,[2] type no. 50.) This section of canal is ideal from a construction standpoint. A small amount of solid rock excavation may be encountered. Laterals E-4 and E-5 are diverted from this section of the main east. Lateral E-5 is of major proportions and leads to the Priest Rapids area.

500. *Feature no. 22—Weber Branch siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the required concrete end structures and saddles. Length, 8,300 feet, horizontal distance. Diameter, 17.33 feet. Maximum head, 168 feet. This structure, consisting of two pipe lines, is adapted to construction in two units to meet the requirements of a stage development.

501. *Feature no. 23—Open canal, Weber Branch siphon to Weber Coulee siphon.*—Length, 2.23 miles. (See plate no. 136,[2] type no. 9.) This section of canal is ideal from a construction standpoint. Very little solid rock excavation will be encountered.

502. *Feature no. 24—Weber Coulee siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the necessary concrete end structures and other appurtenant works. Length, 5,450 feet, horizontal distance. Diameter, 17.16 feet. Maximum head, 178 feet. This structure, consisting of two pipe lines, may be constructed in two units to meet the requirements of a stage development.

503. *Feature no. 25—Open canal, Weber Coulee siphon to Lind Coulee siphon.*—Length, 17.31 miles. (See plate no. 136,[2] type no. 9.) This section of canal is ideal from a construction standpoint. A very small percentage of the excavation will be in solid rock. Lateral E-6 is diverted from this section of the main east.

504. *Feature no. 26—Lind Coulee siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the necessary concrete end structures, saddles, etc. Length, 4,900 feet, horizontal distance. Diameter, 16.58 feet. Maximum head, 124 feet. This structure crosses Lind Coulee and the main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad. This structure may be built in two stages.

505. *Feature no. 27—Open canal, Lind Coulee siphon to Providence Tunnel.*—Length, 6.70 miles. (See plate no. 136.[2]) Type no. 28. This section of canal is located along the south side of Lind Coulee and is a favorable piece for construction work. Some solid-rock excavation will be encountered. Lateral E-7 is diverted from this section of the main east.

506. *Feature no. 28—Providence Tunnel.*—(See plate no. 136.[2]) Single bore. Diameter, 18.58 feet. Length, 16,100 feet or 3.05

[2] Not printed.

miles. The location of this tunnel is substantially the same as that used by Gault, regarding which Kirk Bryan reported as follows: "This tunnel has about 250 feet of cover and will be in basalt." No opinion was given regarding timbering, and 20 percent of full timbering was assumed for the present estimate. Tunnels heretofore considered on the main east have been of the double-bore design. The double-bore design involves a total capital cost in excess of the design of single bore. When considered with an interest charge on the capital invested, it has been found desirable to assume the additional cost of the double-bore type because of the interest on the investment. At this tunnel, however, the time elapsing between the construction of the first bore and the demand for the second is so short that the single-bore construction is ultimately the cheaper.

507. *Feature no. 29—Open canal, Providence Tunnel to lateral E-8, bifurcation works.*—Length, 1.67 miles. Type no. 28. (See plate no. 136.[2]) Conditions are first class from a construction standpoint on this section of the work. A small amount of solid-rock excavation will be encountered. Lateral E-8 is diverted at the lower end of this section.

508. *Feature no. 30—Lateral E-8, bifurcation works.*—No special drawing. This structure consists of a combined check in the main east and headworks for lateral E-8. This is a special structure designed to divert into E-8 with a minimum loss of head, as it is desired to hold the water surface in the lateral at the highest consistant elevation.

509. *Feature no. 31—Open canal, E-8 bifurcation works to Providence Branch siphon.*—Length, 4.45 miles. (See plate no. 136.[2]) Type no. 17. The canal work continues to be very favorable from a construction standpoint. A very small percentage of solid-rock excavation may be encountered. This section of canal includes a bridge for the main line of the Northern Pacific Railway. No diversions are made from this section of the main east.

510. *Feature no. 32—Providence Branch siphon.*—No special drawing. This is a reinforced concrete structure throughout. Length, 1,040 feet, horizontal distance. One concrete barrel. Diameter, 14.33 feet. Maximum head, 61 feet. This structure, consisting of a single barrel, is not adapted to a stage development.

511. *Feature no. 33—Open canal, Providence Branch siphon to Hatton Coulee siphon.*—Length, 2.98 miles. (See plate no. 136.[2]) Type no. 17. The area crossed by this section of canal is ideal from a construction standpoint. A very small percentage of solid-rock excavation may be encountered.

512. *Feature no. 34—Hatton Coulee siphon.*—No special drawing. This is a reinforced concrete structure throughout. Length, 2,340 feet, horizontal distance. One concrete barrel. Diameter, 14.08 feet. Maximum head, 95 feet. This structure must be built as a single unit.

513. *Feature no. 35—Open canal, Hatton Coulee siphon to Rattlesnake Tunnel.*—Length, 7.04 miles. (See plate no. 136.[2]) Type no. 17. The area crossed by this section of canal continues to be ideal from a construction standpoint. A very small amount of solid-rock excavation may be encountered. Laterals E-9 and E-10 are diverted from this section of the main east.

[2] Not printed.

514. *Feature no. 36—Rattlesnake Tunnel.*—(See plate no. 136.[2]) Single bore. Diameter, 15.25 feet. Length, 3,200 feet or 0.61 mile. No geological report is available for this tunnel. It will probably be in basalt for the major portion of the distance. For the present estimate 20 percent of full timbering was assumed.

515. *Feature no. 37—Open canal, Rattlesnake Tunnel to Rattlesnake siphon.*—Length, 0.43 mile. (See plate no. 136.[2]) Type no. 17. The conditions are splendid over this section for canal construction. A very small amount of solid-rock excavation may be encountered. No diversions are made from this section of the main east.

516. *Feature no. 38—Rattlesnake siphon.*—No special drawing. This structure is of reinforced concrete throughout. Length, 1,050 feet, horizontal distance. One concrete barrel. Diameter, 13.16 feet. Maximum head, 56 feet. This structure must be built as a single unit.

517. *Feature no. 39—Open canal, Rattlesnake siphon to Reeder Tunnel.*—Length, 2.07 miles. (See plate no. 136.[2]) Type no. 17. Conditions over the area covered by this section of canal remain very favorable for canal construction. No diversions are made from this section of the main east.

518. *Feature no. 40—Reeder Tunnel.*—(See plate no. 136.[2]) Single bore. Diameter, 15.00 feet. Length, 5,100 feet or 0.97 mile. The geological comment by Kirk Bryan accompanying the Gault report regarding a tunnel having the same general location as the present one is as follows: "The Reeder Tunnel is 5,000 feet long and has a maximum cover of 220 feet. This tunnel will also be in basalt." For the purpose of the present estimate, full timbering for 20 percent of the distance was assumed.

519. *Feature no. 41—Open canal, Reeder Tunnel to Washtucna siphon.*—Length, 5.09 miles. (See plate no. 136.[2]) Type no. 18. Topography over this section of canal is becoming more broken, but conditions are still favorable for canal construction. No diversions are made from this section of the main east.

520. *Feature no. 42—Washtucna siphon.*—No special drawing. This structure consists of two parallel steel pipe lines with the necessary concrete end structures, saddles and anchor blocks. Length, 5,980 feet, horizontal distance. Diameter, 10.92 feet. Maximum head, 461 feet. This structure crosses Washtucna coulee. A crossing is also made of a branch line of the Oregon-Washington Railroad & Navigation Co., extending from Colfax, Wash., to Connell, located in the south-central portion of the project. This structure may be built in two stages to meet the demands of a stage development at practically no additional cost.

521. *Feature no. 43—Open canal, Washtucna siphon to end of line topography.*—Length, 1.03 miles. (See plate no. 136.[2]) Type no. 18. This section of canal is favorable for canal construction. A very small percentage of rock excavation will be found in this section. This feature is the last one on the main east, the location of which is based upon a projection made on line topographic sheets. The location of all features, from and including feature no. 17 to the one now under consideration, covering a distance of 80.45 miles, is based upon line topography taken during the present investigation. The location of

[2] Not printed.

the main east below this feature is based upon a projection made on the United States Geological Survey quadrangles. No diversions are made in this section of the main east.

522. *Feature no. 44—Open canal, end of line topography to Dunnigan Tunnel.*—Length, 8.40 miles. This section of canal crosses an area where conditions from a construction standpoint are very favorable. A small percentage of solid-rock excavation may be encountered. Laterals E-11 and E-12 are diverted from this section of the main east.

523. *Feature no. 45—Dunnigan Tunnel.*—(See plate no. 136.[2]) Single bore, Diameter, 11.33 feet. Length, 1,000 feet or 0.19 mile. No geological report is available at this particular site. The tunnel will doubtless be in basalt for the greater portion of the distance, and 20 percent of full timbering has been assumed for the present estimate.

524. *Feature no. 46—Open canal, Dunnigan Tunnel to Rye Grass Tunnel.*—Length, 4.90 miles. The general conditions are favorable for canal construction over this section. It is estimated that as much as 10 percent of solid-rock excavation may be encountered. Lateral E-13 is diverted from this section of the main east.

525. *Feature no. 47—Rye Grass Tunnel.*—(See plate no. 136.[2]) Single bore. Diameter, 8.83 feet. Length, 1,300 feet or 0.25 mile. The same conditions prevail at this tunnel as at the Dunnigan Tunnel preceding. The same assumptions were made as to the classification and probable amount of timbering that would be required.

526. *Feature no. 48—Open canal, Rye Grass Tunnel to Rye Grass siphon.*—Length, 4.20 miles. This section of canal is generally the same as that of the preceding canal section and the same amount of solid-rock excavation may be encountered.

527. *Feature no. 49—Rye Grass siphon.*—No special drawing. This structure consists of one steel pipe line with the required concrete end structures and supports. Length, 6,000 feet, horizontal distance. One steel pipe line. Diameter, 7.75 feet. Maximum head, 164 feet. This siphon crosses a coulee and involves no unusual features. This siphon eliminates 10 miles or more of canal that would be required to pass around the head of the coulee. This structure must be built as one unit.

528. *Feature no. 50—Open canal, Rye Grass siphon to Smith siphon.*—Length, 6.30 miles. Topography is somewhat rough and broken, but conditions are generally favorable for the construction of a canal of the required capacity. Ten percent of the excavation may be in solid rock.

529. *Feature no. 51—Smith siphon.*—No special drawing. This is a reinforced concrete structure throughout. Length, 3,700 feet, horizontal distance. One concrete barrel. Diameter, 7 feet. Maximum head, 88 feet. This structure involves no unusual items. Consisting as it does of only one barrel, the structure must be built as a single unit.

530. *Feature no. 52—Open canal, Smith siphon to end.*—Length, 17.10 miles. The lower 15.2 miles of this feature is identical with the lower end of feature S-5, plan no. 2, which includes penstock pipe for power plant no. 3. Topography and classification are the same as that for the last section of canal work described. This feature ends when the capacity of the canal is dropped to 100 second-feet. Beyond that point the system is covered by the blanket estimate.

[2] Not printed.

531. *Lateral system.*—The following lateral system diverts from the main east canal. For convenience, these laterals are presented in table no. 17.

TABLE NO. 17.—*Lateral system diverting from main east*

| Lateral no. | Canal | | Siphons or penstocks | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section | Barrel | Number of pipes | Length | Diameter | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Feet* |
| E-1 | 4.77 | (1) | | | | | |
| | 3.56 | (1) | | | | | |
| | 4.70 | (2) | | | | | |
| E-2 | 2.60 | (2) | | | | | |
| E-3 | 12.20 | (2) | | | | | |
| E-4 | 10.20 | (2) | Concrete | 1 | 200 | 4.58 | [3] 13 |
| E-4-1 | 4.20 | (2) | | | | | |
| E-5 | 84.00 | (1) (2) | Steel penstock | 3 | 2,640 | 10.00 | [4] 163 |
| | | | Concrete | 1 | 2,800 | 10.58 | [5] 26 |
| | | | Steel | 1 | 16,000 | 16.17 | [6] 234 |
| | | | Steel penstock | 1 | 1,200 | 6.00 | [7] 140 |
| E-5-1 | 11.00 | (2) | Steel | 1 | 3,268 | 8.00 | 150 |
| | | | Steel | 1 | 2,000 | 6.00 | [3] 90 |
| E-5-1-1 | 2.20 | (2) | | | | | |
| E-5-2 | .50 | (2) | | | | | |
| E-5-3 | 1.50 | (2) | | | | | |
| E-5-4 | 3.90 | (2) | | | | | |
| E-5-5 | 8.50 | (2) | | | | | |
| E-6 | 2.20 | (2) | | | | | |
| E-7 | 25.80 | (2) | Concrete | 1 | 1,200 | 7.08 | [3] 25 |
| E-7-1 | .70 | (2) | | | | | |
| E-8 | 31.00 | (2) | Steel penstock | 2 | 1,200 | 10.00 | [8] 102 |
| E-8-1 | 2.10 | | | | | | |
| E-8-2 | 7.60 | (2) | | | | | |
| E-8-3 | 6.50 | (2) | Steel | 1 | 9,240 | 4.00 | [3] 207 |
| E-8-4 | 1.80 | (2) | | | | | |
| E-8-5 | 6.60 | (2) | | | | | |
| E-8-6 | 4.30 | (2) | | | | | |
| E-9 | 1.80 | (2) | | | | | |
| E-10 | 5.60 | (2) | | | | | |
| E-11 | 7.10 | (2) | | | | | |
| E-12 | 10.50 | (2) | | | | | |
| E-13 | 29.10 | (2) | Steel penstock | 1 | 535 | 9.00 | [9] |

[1] Location based on projection on line topographic sheets.
[2] Location based on projection on United States Geological Survey quadrangles.
[3] Unnamed siphons.
[4] Northern Pacific siphon.
[5] Penstock, power plant no. 10.
[6] Scooteney siphon.
[7] Penstock, power plant no. 5.
[8] Penstock, power plant no. 8.
[9] Penstock, power plant no. 2.

532. *Feature no. 53—Sublaterals.*—The sublateral system under the Main east consists of those ditches having a capacity of 100 second-feet or less and is covered by a blanket estimate based upon the acreage served.

533. *General project items.*—Above has been given a brief description of the system as proposed for plan no. 4. The following items pertain to the general project rather than to any one of the subdivisions mentioned above.

534. *Drainage.*—A blanket estimate is included to cover this item. The question of drainage is one that will not be determined until some time after water has been applied to the land. The requirements for drainage will vary with different sections of the tract. Some sections will require extensive drainage systems while others will require little or none. For the purpose of the present

estimate $5 per acre throughout the entire project is included to cover this item. In the plan of stage development, it is assumed that this expenditure will be required 5 years after the first application of water to the land.

535. *Wasteways.*—For the plan under consideration no detailed estimate was prepared for the system of wasteways that would be required on the project. The system as proposed in the Gault report for the pumping plan of development seemed to be adequate and that estimate was adopted without modification.

536. *Supplemental pumping.*—As outlined in the discussion of this phase of the study in plan no. 2-A, a considerable amount of power could be developed on the project and used to pump water to desirable lands located above the gravity canal system. In the plan now under consideration there are also possibilities of developing power on the project, but to a somewhat less extent. The decrease in power possibilities is due to a material change in the location of the distributing system, particularly on the upper side of the project. Some of the power sites considered under plan no. 2-A will be eliminated entirely in the present plan, one new power site is available, and those on the lower portion of the project are common to both plan no. 2-A and plan no. 4. The power possibilities on the project under the present plan are all located on the main east canal and its distributing system, none are available on the main west.

537. In table no. 16 is given a list of available power. These power plants retain the same numbers as those used in the discussion of this subject in plan no. 2-A. Of the plants proposed under plan no. 2-A, nos. 1, 4, 6, and 7 will be eliminated in the present plan; plant no. 2 will be modified; plants nos. 3, 5, 8, and 9 will remain the same and plant no. 10 is available only under the present plan.

TABLE NO. 16.—*Available power—Plan no. 4*

| Power plant no. | Location [1] | Quantity | Net head | Penstock [2] | Capacity | |
|---|---|---|---|---|---|---|
| | | | | | Horsepower | Kilowatts |
| | | *Second-feet* | *Feet* | | | |
| 2 | Lateral E-13 | 392 | 80 | | 3,040 | 2,270 |
| 3 | Main east | 320 | 85 | | 3,000 | 2,240 |
| 5 | Lateral E-5 | 139 | 138 | | 1,850 | 1,380 |
| 8 | Lateral E-8 | 926 | 100 | | 8,400 | 6,270 |
| 9 | Lateral E-5-5 | 85 | 255 | | 2,100 | 1,570 |
| 10 | E-3 | 1,801 | 156 | | 25,800 | 19,240 |
| Total | | | | | 44,190 | 32,970 |

[1] For location see plate no. 131.

[2] Penstocks included as a part of canal.

538. In the proposed power developments under this plan the penstock pipes have been included as a part of the canal system. Some are of considerable length, and some sacrifice of power has been made in their design in the interest of economy. As the power possibilities exceed the requirements for pumping to lands within the limit of a 100-foot lift, it appears that this sacrifice in the design of the penstock pipes is advisable.

539. The total area for which water is to be provided through supplemental pumping amounts to 219,090 acres, in tracts of various areas. The seasonal water requirement is 627,227 acre-feet; the average gross

head through which the water is to be pumped is 70 feet; the acre-feet feet to be pumped per season are 43,905,890. These areas vary from 20 to 15,000 acres, and are scattered throughout the project as indicated on plate no. 131, 940.

540. Estimates of cost for pumping installations to cover these tracts are taken from graphs. The cost of the installation includes all electrical equipment from the low side of the step-down transformers, pumping equipment, valves, pipe lines, etc. It is evident that the unit cost of these installations will depend upon the size of the development.

541. To meet the requirements of supplemental pumping, it has been shown that the total installation required amounts to 43,905,890 acre-feet feet per season, requiring the following installations:

50 percent, or 21,952,940 acre-feet feet, 1,000 kilowatt installation.
30 percent, or 13,171,770 acre-feet feet, 500 kilowatt installation.
10 percent, or 4,390,590 acre-feet feet, 250 kilowatt installation.
5 percent, or 2,195,295 acre-feet feet, 100 kilowatt installation.
5 percent, or 2,195,295 acre-feet feet, 10-50 kilowatt installation.

542. The cost of these installations was determined by applying the unit prices as shown on the graph to the unit quantities as given above.

543. The power installation required to operate the units necessary for the above supplemental pumping units amounts to 19,000 kilowatts. These amounts are based upon the seasonal requirements for water as outlined elsewhere in this report, and upon an over-all efficiency of 65 percent in the power and pumping system.

544. Plans were not developed for the various power plants. Estimates for each were prepared upon the following unit cost basis:

| | *Per kilowat* |
|---|---|
| Hydraulic equipment | $13 |
| Electrical equipment | 27 |
| Power house and miscellaneous [10] | 20 |
| Total | 60 |

545. The following estimate for plan no. 4 includes only the last of the development of 19,000 kilowatts, the requirement to meet the demand for supplemental pumping on the project. The disposition of the balance of the power to be developed on the project amounting to about 14,000 kilowatts will be discussed later in the report.

546. Included in the estimate for supplemental pumping is the cost of the system of transmission lines required to deliver the power from the generating station to the points of use at various locations on the project. This item includes the construction of 180 miles of primary line (66,000 volts) and 150 miles of secondary line (11,000 volts). The transmission lines as proposed would make power available to 95 percent of the land to be reclaimed through supplemental pumping, the remaining 5 percent, representing small isolated areas, would be unreclaimed until such time as commercial transmission lines on the project made available the small amount of power required for that purpose. The estimate of the cost of the transmission lines includes the cost of the step-down transformers necessary to deliver the current to the pumping units at the proper voltage.

547. *Telephone system.*—Included in the estimate is an item covering the cost of the telephone system that will be required in the operation of the canal system. No details have been developed regarding this

[10] Penstocks included as a part of the cost of canal.

section of the work, but an approximate estimate was made of a system that was thought to be adequate to cover the project upon its completion.

548. *Wells.*—This item, discussed more fully in plan no. 2-A, is to provide water for construction purposes. The estimate represents the cost of the development, less salvage value, that may exist after the completion of the construction work.

549. *Permanent buildings.*—This item covers the buildings, offices, shops, warehouses, quarters, etc., required in the operation of the canal system. No detailed estimate has been prepared, but a lump estimate was based upon a percentage of the requirements as given in the estimate for plan no. 2.

550. *Preliminary work.*—Included in the project items is an allowance of $1,000,000 for preliminary work, and for testing of Grand Coulee Reservoir Basin.

551. *Other features.*—Included in the estimate are items for fencing all canals in the system, and for providing highway crossings over all canals and ditches that will cross existing highways. Where bridges are required, standard types of the Washington State Highway Department with a H-15 loading have been used. The fences, bridges, etc., are included in the estimate of the particular feature of which they form a part.

ESTIMATES

552. Following are the estimates of the various features that constitute the irrigation system as designed for plan no. 4. The estimate for the plan includes no item for power development on the Columbia River at Grand Coulee. The operating cost includes the purchase price of power required for pumping purposes.

| *Feature no.* | MAIN CANAL | |
|---|---|---|
| 1. | Grand Coulee Dam, not included as a part of the irrigation system. | |
| 2. | Pumping plant and pipe line | $15, 631, 300 |
| 3. | Canal | 2, 101, 080 |
| 4. | North Reservoir Dam | 1, 085, 560 |
| 5. | South Reservoir Dam | 3, 977, 270 |
| 6. | Canal | 4, 474, 330 |
| 7. | Bacon siphon | 403, 320 |
| 8. | Bacon Tunnel, first bore | 2, 688, 030 |
| | Bacon Tunnel, second bore | 2, 585, 050 |
| 9. | Canal | 1, 089, 060 |
| 10. | Trail Lake Tunnel, first bore | 793, 670 |
| | Trail Lake Tunnel, second bore | 617, 680 |
| 11. | Bifurcation works | 99, 200 |
| | Total main canal | 35, 545, 550 |
| | MAIN WEST | |
| 1. | Canal | 1, 057, 520 |
| 2. | Dry Coulee Tunnel No. 1 | 423, 440 |
| 3. | Dry Coulee Tunnel No. 2 | 294, 610 |
| 4. | Canal | 309, 120 |
| 5. | Dry Coulee siphon | 634, 490 |
| 6. | Canal | 1, 742, 800 |
| 7. | Soap Lake siphon | 1, 622, 090 |
| 8. | Canal | 3, 123, 690 |
| 9. | Canal | 380, 460 |
| 10. | Great Northern siphon | 200, 040 |
| 11. | Canal | 780, 720 |
| 12. | Potholes siphon | 2, 156, 850 |
| 13. | Canal | 771, 230 |

| Feature no. | | |
|---|---|---|
| | MAIN WEST—continued | |
| 14. | Frenchman siphon | $880, 750 |
| 15. | Canal | 1, 211, 620 |
| 16. | Low Gap Tunnel | 855, 040 |
| 17. | Canal | 1, 418, 820 |
| W-1. | Lateral W-1 | 1, 238, 050 |
| W-1-1. | Lateral W-1-1 | 141, 250 |
| W-2. | Lateral W-2 | 1, 138, 600 |
| W-2-1. | Lateral W-2-1 | 190, 130 |
| W-2-2. | Lateral W-2-2 | 216, 590 |
| W-2-3. | Lateral W-2-3 | 83, 440 |
| W-3. | Lateral W-3 | 737, 150 |
| W-3-1. | Lateral W-3-1 | 253, 090 |
| W-4. | Lateral W-4 | 93, 000 |
| W-5. | Lateral W-5 | 90, 130 |
| W-6. | Lateral W-6 | 567, 400 |
| W-7. | Lateral W-7 | 31, 510 |
| 18. | Sublaterals | 7, 784, 910 |
| | Total main west | 30, 428, 540 |
| | MAIN EAST | |
| 1. | Canal | 876, 800 |
| 2. | Long Lake Tunnel No. 1, first bore | 543, 260 |
| | Long Lake Tunnel No. 1, second bore | 410, 050 |
| 3. | Canal | 444, 000 |
| 4. | Long Lake Tunnel No. 2, first bore | 396, 530 |
| | Long Lake Tunnel No. 2, second bore | 259, 370 |
| 5. | Canal | 1, 698, 520 |
| 6. | Stratford Tunnel, first bore | 1, 014, 360 |
| | Stratford Tunnel, second bore | 846, 270 |
| 7. | Canal | 586, 610 |
| 8. | Crab Creek siphon | 2, 760, 270 |
| 9. | Canal | 2, 083, 830 |
| 10. | Broken Rock siphon | 3, 556, 350 |
| 11. | Canal | 2, 299, 310 |
| 12. | Black Rock siphon | 1, 588, 990 |
| 13. | Canal | 567, 380 |
| 14. | Long Ridge Tunnel, first bore | 682, 400 |
| | Long Ridge Tunnel, second bore | 527, 770 |
| 15. | Canal | 741, 200 |
| 16. | Sand Coulee siphon | 258, 160 |
| 17. | Canal | 1, 901, 750 |
| 18. | Rocky Branch siphon | 525, 140 |
| 19. | Canal | 246, 160 |
| 20. | Rocky Coulee siphon | 1, 833, 790 |
| 21. | Canal | 2, 034, 440 |
| 22. | Weber Branch siphon | 2, 410, 620 |
| 23. | Canal | 417, 950 |
| 24. | Weber Coulee siphon | 1, 718, 500 |
| 25. | Canal | 3, 314, 510 |
| 26. | Lind Coulee siphon | 1, 328, 760 |
| 27. | Canal | 1, 213, 840 |
| 28. | Providence Tunnel, single bore | 3, 253, 050 |
| 29. | Canal | 449, 300 |
| 30. | E-8 bifurcation works | 37, 940 |
| 31. | Canal | 667, 470 |
| 32. | Providence Branch siphon | 127, 020 |
| 33. | Canal | 597, 150 |
| 34. | Hatton Coulee siphon | 317, 450 |
| 35. | Canal | 1, 074, 650 |
| 36. | Rattlesnake Tunnel, single bore | 389, 000 |
| 37. | Canal | 87, 040 |
| 38. | Rattlesnake siphon | 107, 790 |
| 39. | Canal | 281, 920 |
| 40. | Reeder Tunnel, single bore | 566, 060 |
| 41. | Canal | 815, 760 |
| 42. | Washtucna siphon | 1, 345, 030 |

| Feature no. | | |
|---|---|---|
| | MAIN EAST—continued | |
| 43. | Canal | $150, 610 |
| 44. | Canal | 1, 224, 560 |
| 45. | Dunnigan Tunnel, single bore | 83, 660 |
| 46. | Canal | 652, 720 |
| 47. | Rye Grass Tunnell, single bore | 63, 530 |
| 48. | Canal | 489, 930 |
| 49. | Rye Grass siphon | 257, 310 |
| 50. | Canal | 473, 990 |
| 51. | Smith siphon | 121, 920 |
| 52. | Canal | 608, 000 |
| E-1 | Lateral E-1 | 605, 320 |
| E-2 | Lateral E-2 | 52, 580 |
| E-3 | Lateral E-3 | 253, 700 |
| E-4 | Lateral E-4 | 433, 780 |
| E-4-1 | Lateral E-4-1 | 113, 480 |
| E-5 | Lateral E-5 | 12, 803, 860 |
| E-5-1 | Lateral E-5-1 | 637, 250 |
| E-5-2 | Lateral E-5-2 | 16, 220 |
| E-5-3 | Lateral E-5-3 | 33, 280 |
| E-5-4 | Lateral E-5-4 | 90, 690 |
| E-5-5 | Lateral E-5-5 | 317, 960 |
| E-6 | Lateral E-6 | 51, 380 |
| E-7 | Lateral E-7 | 2, 041, 570 |
| E-7-1 | Lateral E-7-1 | 26, 700 |
| E-8 | Lateral E-8 | 6, 946, 060 |
| E-8-1 | Lateral E-8-1 | 55, 920 |
| E-8-2 | Lateral E-8-2 | 257, 350 |
| E-8-3 | Lateral E-8-3 | 285, 190 |
| E-8-4 | Lateral E-8-4 | 29, 080 |
| E-8-5 | Lateral E-8-5 | 219, 980 |
| E-8-6 | Lateral E-8-6 | 116, 700 |
| E-9 | Lateral E-9 | 42, 210 |
| E-10 | Lateral E-10 | 149, 280 |
| E-11 | Lateral E-11 | 139, 340 |
| E-12 | Lateral E-12 | 352, 120 |
| E-13 | Lateral E-13 | 1, 211, 460 |
| 53. | Sublaterals | 17, 403, 120 |
| | Total main east | 98, 015, 510 |
| | PROJECT ITEMS | |
| | Supplemental pumping | 6, 049, 270 |
| | Drainage | 5, 997, 150 |
| | Wasteways | 2, 162, 710 |
| | Permanent buildings | 1, 201, 600 |
| | Wells | 200, 000 |
| | Telephone system | 225, 000 |
| | Preliminary work | 1, 000, 000 |
| | Total | 16, 835, 730 |
| | RECAPITULATION | |
| | Main canal | 35, 543, 550 |
| | Main west | 30, 428, 540 |
| | Main east | 98, 015, 510 |
| | Project items | 16, 835, 730 |
| | Project total | 180, 825, 330 |

553. *Stage development.*—The necessity of a stage development is outlined in plan no. 2-A. The same necessity exists for a stage development in the plan now under consideration. The stage development outlined below is predicated upon (a) the colonization of 50,000 acres per year, (b) the construction stages to be developed as required by the colonization of the land and the demand for water, (c) the land to be placed under irrigation where the irrigation supply

is made available, (d) that interest on all unpaid balances be at the rate of 4 percent per annum, and (e) that repayments be made beginning at the end of the third year of crop from the land.

554. To meet the above requirements the system has been divided into 14 construction stages. Because of limitations fixed by local topographic and other conditions, most of the individual stages include an area requiring two or even three years to colonize. Table no. 17 gives the proposed stage development for the present plan. The first stage brings no land under cultivation, but is devoted to preliminary work and a portion of the main canal.

555. This development is based upon the construction of the high dam in the Columbia River at Grand Coulee, with the power development possible at that point. This phase of the development is considered in the power section of this report, and is of interest in connection with the stage development of the present plan of irrigation development, because of the fact that power for pumping purposes is to be obtained from that source.

556. It is estimated that 6 years will be required for the construction of the dam in the Columbia River; and in order to be able to deliver water to the first unit on the irrigation project at the beginning of the seventh year, the first stage should be begun during the third year of construction on the dam.

557. The second stage includes the construction of a portion of the pumping plant and the installation of two pumping units, each of 1,600 second-feet capacity, the completion of that portion of the main canal that is not susceptible of a stage development, and the first unit of those features that may be developed by stages, and also that portion of the distributing system that is required to reclaim the area in the first unit.

TABLE NO. 17.—*Stage development—Plan no. 4*

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | 1 | | | | |
| 2 | | | | | |
| 3 | | $500,000 | | | |
| 4 | | 2,122,000 | | | |
| 5 | 2 | 13,500,000 | | | |
| 6 | | 18,949,910 | 108,750 | | |
| 7 | 3 | 4,831,600 | | 54,370 | |
| 8 | | 5,770,360 | 98,980 | 54,380 | |
| 9 | 4 | 3,500,000 | | 49,490 | 54,370 |
| 10 | | 5,419,180 | 110,510 | 49,490 | 54,380 |
| 11 | 5 | 10,883,750 | | 55,250 | 49,490 |
| 12 | | 16,204,510 | 98,440 | 55,260 | 49,490 |
| 13 | 6 | 10,494,900 | | 49,220 | 55,250 |
| 14 | | 12,973,250 | 98,420 | 49,220 | 55,260 |
| 15 | 7 | 8,790,680 | 64,790 | 49,210 | 49,220 |
| 16 | 8 | 2,550,000 | | 49,210 | 49,220 |
| 17 | | 5,644,040 | 99,730 | 64,790 | 49,210 |
| 18 | 9 | 6,860,000 | | 49,860 | 49,210 |
| 19 | | 12,290,820 | 82,580 | 49,870 | 64,790 |
| 20 | 10 | 5,523,450 | 58,540 | 41,290 | 49,860 |
| 21 | 11 | 2,300,000 | | 41,290 | 49,870 |
| 22 | | 5,240,890 | | 58,540 | 41,290 |
| 23 | | 6,858,740 | 114,600 | 38,200 | 41,290 |
| 24 | 12 | 6,640,590 | 45,000 | 38,200 | 58,540 |
| 25 | 13, 14 | 3,124,000 | | 38,200 | 38,200 |
| 26 | | 2,505,000 | 100,000 | 45,000 | 38,200 |
| 27 | | 2,806,550 | | 50,000 | 38,200 |
| 28 | | 4,541,110 | 119,090 | 50,000 | 45,000 |
| 29 | | | | 50,000 | 50,000 |
| 30 | | | | 69,090 | 50,000 |
| 31 | | | | | 50,000 |
| 32 | | | | | 69,090 |

558. Under the plan of development as outlined in the table, stage development, plan no. 4, the first land will be brought under cultivation in the seventh year and repayments will begin at the end of the ninth; the last area would be placed under cultivation in the thirtieth year and repayments begin on that area at the end of the thirty-second year.

559. Carrying all capital expenditures to the end of the thirty-second year, with interest at the rate of 4 percent, and deducting an annual repayment of $7.39 per acre per year, which will also bear interest at the rate of 4 percent from the time repayment is made to the end of the thirty-second year, gives the following result:

| | | Per acre |
|---|---|---|
| Capital cost plus interest | $221, 722, 180. 00 or | $184. 86 |
| Capital cost | 180, 825, 330. 00 or | 150. 76 |
| Interest | 40, 896, 850. 00 or | 34. 10 |
| Annual interest charge after completion | | 7. 39 |
| Annual cost of operation and maintenance | 1. 52 | |
| Annual depreciation charge | 1. 28 | |
| Total annual charge less power | | 2. 80 |
| Annual cost of power | | 1. 20 |
| Total annual charge | | 11. 39 |

560. *Elimination of Grand Coulee Reservoir.*—The above plan is based upon the use of the Grand Coulee Reservoir as a part of the main canal system. Should tests demonstrate that the site at Grand Coulee be unfit for reservoir purposes, a modification of the main canal system would be required to eliminate that feature. If the reservoir is eliminated, the north and south reservoir dams together with the right-of-way in the basin would be replaced by a section of canal 24.5 miles in length including three tunnels and one siphon. A portion of this canal is located over an area favorable to canal construction while a portion will encounter a large percentage of solid rock excavation. The elimination of the reservoir from the main canal system will require some modification in the plan for the pumping plant. As stated earlier in this discussion, the substitution of a canal for the reservoir increases the pumping head 50 feet. On the other hand the use of the canal eliminates the requirement for pumping 1,000 second-feet to care for reservoir loss. Plan no. 4 provided an excess installation at the pumping plant to provide water for storage in the reservoir during periods favorable for the use of secondary power for that purpose. The additional expense due to the increase in pumping head necessary if the reservoir be eliminated is practically balanced by the decrease in the number of pumping units required.

561. If the Grand Coulee Reservoir is replaced by a canal through the basin, an additional capital expenditure of $17,656,220 would be required. Carrying this capital expenditure through the stage development as outlined for plan no. 4, gives the following as the final cost of the project:

| | | Per acre |
|---|---|---|
| Capital cost plus interest | $248, 378, 010. 00 or | $207. 08 |
| Capital cost | 198, 481, 550. 00 or | 165. 08 |
| Interest | 49, 896, 460. 00 or | 41. 60 |
| Annual interest charge after completion | | 8. 28 |
| Annual cost of operation, depreciation, and maintenance | 2. 80 | |
| Annual cost of power | 1. 31 | |
| | | 4. 11 |
| Total annual charge | | 12. 39 |

PLAN NO. 4–A

562. This plan for the development of the Columbia Basin irrigation project contemplates the reclamation of the tract in two divisions. The first, or division A, is identical with plan no. 4 less the Priest Rapids area. The sum of the areas reclaimed under these two divisions is equal to and identical with the area reclaimed in plan no. 4, except as noted in the discussion of the Priest Rapids project.

563. *Division A.*—Division A is covered by a modification of the system proposed for plan no. 4. In that plan lateral E-5, a diversion from the main east, extended in a southwesterly direction to a point near Scooteney Lake, where a long siphon was required to carry the lateral to the high ground on the west side of the lake. From that high point, lateral E-5 continued westward along the south slope of the Saddle Mountains and covered the Priest Rapids area. In the plan now under consideration, the Priest Rapids area is eliminated from division A, and lateral E-5 ends at the site of the Scooteney siphon. The portion of lateral E-5,extending from the main east to the Scooteney siphon site, which is retained in the present plan, is reduced in dimensions and capacity to meet the requirements of the area served. This reduction in the capacity of lateral E-5 also requires a like reduction in capacity of the main east and the Main Canal from the bifurcation works to the Grand Coulee Reservoir. The Main Canal above the Grand Coulee Reservoir and the Columbia River pumping plant remain as outlined for plan no. 4. In plan no. 4 this portion of the system was given excess capacity for the purpose of utilizing secondary power for pumping purposes as explained in discussing that plan. The same excess capacity between the river and the Grand Coulee Reservoir is retained in the plan now under consideration.

564. Other than this modification in the dimensions and capacity of that section of the main canal system, and the reduction in the dimensions and capacity of lateral E-5 to the Scooteney siphon site beyond which point it is abandoned, the system for division A is identical in all respects with the system as outlined for plan no. 4.

565. *Main Canal.*—The salient figures relating to the main canal are given in the following tabulation:

| | | |
|---|---|---|
| Area reclaimed by gravity | acres | 834, 860 |
| Area reclaimed by supplemental pumping | do | 199, 250 |
| Total area reclaimed | do | 1, 034, 110 |
| Capacity of Main Canal, pumping plant to Grand Coulee Reservoir | second-feet | 16, 000 |
| Grand Coulee Reservoir to bifurcation works | do | 9, 760 |
| Rediverted water on project | do | 610 |
| Requirement at head of irrigable area | do | 10, 370 |

566. As in plan no. 4, the Main Canal has a capacity of 16,000 second-feet for reasons that concern the use of secondary power. The main canal below the Grand Coulee Reservoir has a capacity of 9,760 second-feet which is based upon the requirements of the area served with the same water duty and seasonal distribution as outlined for these areas under the plans previously discussed.

567. The main canal system of the plan now under consideration is made up of the same features as described under plan no. 4, modified where necessary to meet the reduction in capacity.

568. *Distributing system.*—The distributing system is the same as described and outlined for plan no. 4, except as noted above.

569. *Main west.*—The main west is identical in all respects with the main west and its lateral system as described in plan no. 4.

570. *Main east.*—The main east for the plan now under consideration is reduced in capacity to meet the requirements of the reduced area served. This reduction extends from the bifurcation works at the head of the main east to and including the turnout for lateral E-5, Below the turnout for lateral E-5, the main east is identical in all respects with the main east as described for plan no. 4. The laterals diverting from the main east, as described for plan. no 4, will remain the same for the plan now under consideration, except lateral E-5 which is modified in length and capacity to meet the water requirements of the reduced area which it serves.

571. The following lateral system diverts from the main east. For convenience, these laterals are presented in table no. 18.

TABLE NO. 18.—*Laterals diverting from main east—plan no. 4-A*

| Lateral number | Canal | | Siphons or penstocks | | | | |
|---|---|---|---|---|---|---|---|
| | Length | Section | Barrel | Number of pipes | Length | Diameter | Maximum head |
| | *Miles* | | | | *Feet* | *Feet* | *Feet* |
| E-1 | 4.77 | (1) | | | | | |
| | 3.56 | (1) | | | | | |
| | 4.70 | (2) | | | | | |
| E-2 | 2.60 | (2) | | | | | |
| E-3 | 12.20 | (2) | | | | | |
| E-4 | 10.20 | (2) | Concrete | 1 | 200 | 4.58 | [3] 13 |
| E-4-1 | 4.20 | (2) | | | | | |
| E-5 | 34.3 | (1) (2) | Steel penstock | 1 | 2,640 | 7.83 | [4] 163 |
| | | | Concrete | 1 | 2,800 | 5.83 | [5] 26 |
| E-6 | 2.20 | (2) | | | | | |
| E-7 | 25.80 | (2) | Concrete | 1 | 1,200 | 7.08 | [3] 25 |
| E-7-1 | .70 | (2) | | | | | |
| E-8 | 31.00 | (2) | Steel penstock | 2 | 1,200 | 10.00 | [6] 102 |
| E-8-1 | 2.10 | (2) | | | | | |
| E-8-2 | 7.60 | (2) | | | | | |
| E-8-3 | 6.50 | (2) | Steel | 1 | 9,240 | 4.00 | [3] 207 |
| E-8-4 | 1.80 | (2) | | | | | |
| E-8-5 | 6.60 | (2) | | | | | |
| E-8-6 | 4.30 | (2) | | | | | |
| E-9 | 1.80 | (2) | | | | | |
| E-10 | 5.60 | (2) | | | | | |
| E-11 | 7.10 | (2) | | | | | |
| E-12 | 10.50 | (2) | | | | | |
| E-13 | 29.10 | (2) | Steel penstock | 1 | 535 | 9.00 | [7] 80 |

[1] Projected on line topographic sheets. (See plate no. 136 (not printed) for sections.)
[2] Projected on U.S. Geological Survey quadrangle sheets.
[3] Unnamed siphons.
[4] Penstock, power plant no. 10.
[5] Northern Pacific siphon.
[6] Penstock, power plant no. 8.
[7] Penstock, power plant no. 2.

572. *Project items.*—The project items appurtenant to plan no. 4-A will differ to some extent from those of plan no. 4.

573. *Drainage.*—This item is covered by a blanket estimate of $5 per acre and the estimate for the present plan differs from plan no. 4 only as to the acreage involved.

574. *Wasteways.*—The item of wasteways for the present plan was treated in the same manner as in plan no. 4. The present estimate is

the same as that for plan no. 4, less the Gault estimate for the Hanford and Othello, and Lind Coulee wasteways.

575. *Supplemental pumping.*—Sites on the canal system favorable for the development of power for use in supplemental pumping differ to some extent from those enumerated for development in plan no. 4. Under the present plan, power plant no. 10 as listed for plan no. 4 will be reduced in capacity due to the reduction in the water requirements for land under lateral E-5 upon which the proposed power plant is located. Power plants nos. 5 and 9 will be eliminated entirely.

576. Table no. 19 gives the available developments of the present plan under this division.

TABLE NO. 19.—*Available developments, plan no. 4-A, division A. For location see plate no. 131, page 940*

| Power plant no. | Location | Quantity | Net head | Penstock[1] | Capacity | |
|---|---|---|---|---|---|---|
| | | | | | Horsepower | Kilowatts |
| | | *Sec.-feet* | *Feet* | | | |
| 2 | Lateral E-13 | 392 | 80 | | 3,040 | 2,270 |
| 3 | Main east | 320 | 85 | | 3,000 | 2,240 |
| 8 | Lateral E-8 | 926 | 100 | | 8,400 | 6,270 |
| 10 | Lateral E-5 | 391 | 156 | | 5,600 | 4,180 |

[1] Penstocks included as part of canal.

577. The total area to which water is to be supplied by supplemental pumping under the present plan is 199,250 acres, with a seasonal water requirement of 564,935 acre-feet. As in plan no. 4, the average head (gross) through which this water is to be pumped is 70 feet. The total power requirements for the season expressed in acre-feet feet is 39,545,450.

578. The extent of the areas to be reclaimed by supplemental pumping are as noted for plan no. 4, and the costs of pumping and electrical equipment for the various pumping units were determined in the manner described in that plan.

579. To meet the requirements of supplemental pumping for the plan under consideration, the size of installations required would be as follows:

50 percent or 19,772,725 acre-feet feet, 1,000 kilowatt installation.
30 percent or 11,863,635 acre-feet feet, 500 kilowatt installation.
10 percent or 3,954,545 acre-feet feet, 250 kilowatt installation.
5 percent or 1,977,270 acre-feet feet, 100 kilowatt installation.
5 percent or 1,977,270 acre-feet feet, 10–50 kilowatt installation.

580. The cost of these installations was determined by applying the unit prices as shown on graph to the unit quantities as given above.

581. The power installation required to operate the units necessary for the above supplemental pumping units amounts to 17,000 kilowatts. These requirements are based upon a seasonal water requirement as outlined earlier in this report, and upon an over-all efficiency of 65 percent.

582. Plans were not developed for these individual power plants, but the estimated cost was determined in the manner outlined in the discussion of this feature in plan no. 2 and plan no. 4. Included in the cost for supplemental pumping is an item covering cost of transmission line necessary to deliver power from the generating plant to the various pumping plants on the project. This item is the same as

for plan no. 4. Transmission lines for this division will be the same as for plan no. 4. The location will be changed somewhat, but the length and capacity will remain the same.

583. *Telephone system.*—The estimate includes an item covering the cost of a telephone system considered adequate to meet the operation requirements. This estimate was prepared as outlined in plan no. 4.

584. *Wells.*—This item is discussed fully in plan no. 2-A, and with some modification due to the decreased acreage in the project now under consideration, is included in the present estimate.

585. *Permanent buildings.*—This item covers the buildings, offices, shops, warehouses, quarters, etc., required in the operation of the canal system. Estimates for this item in the present report are a modification of that noted in plan no. 2-A for the same item.

586. *Preliminary work.*—Included in this estimate is an item of $900,000 which has been arbitrarily allowed for preliminary work.

587. *Other features.*—All fences, bridges for highways and railroads, etc., are included with the feature of the system of which they form a part.

ESTIMATE

588. Following are the estimates of the various features that constitute the irrigation system of division A of plan no. 4-A. The estimate for this plan includes no item for power development in Columbia River at Grand Coulee. The operating cost includes the purchase price of power for pumping purposes.

| *Feature no.* | MAIN CANAL | |
|---|---|---|
| 1. | Grand Coulee Dam (not included as part of the irrigation system). | |
| 2. | Pumping plant | $15,631,300 |
| 3. | Canal | 2,101,080 |
| 4. | North Reservoir Dam | 1,085,560 |
| 5. | South Reservoir Dam | 3,977,270 |
| 6. | Canal | 4,150,570 |
| 7. | Bacon siphon | 374,830 |
| 8. | Bacon Tunnel | 4,783,060 |
| 9. | Canal | 976,380 |
| 10. | Trail Lake Tunnel | 1,300,610 |
| 11. | Bifurcation works | 99,200 |
| | Total main canal | 34,479,860 |
| | MAIN WEST | |
| | The main west is identical in all respects with plan no. 4 | 30,428,540 |
| | MAIN EAST | |
| 1. | Canal | 766,080 |
| 2. | Long Lake Tunnel no. 1 | 865,820 |
| 3. | Canal | 363,800 |
| 4. | Long Lake Tunnel no. 2 | 655,280 |
| 5. | Canal | 1,460,390 |
| 6. | Stratford Tunnel | 1,743,010 |
| 7. | Canal | 493,140 |
| 8. | Crab Creek siphon | 2,632,690 |
| 9. | Canal | 1,818,480 |
| 10. | Broken Rock siphon | 3,203,260 |
| 11. | Canal | 2,027,080 |

| Feature no. | MAIN EAST—continued | |
|---|---|---|
| 12. | Black Rock siphon | $1, 469, 760 |
| 13. | Canal | 493, 580 |
| 14. | Long Ridge Tunnel | 1, 096, 490 |
| 15. | Canal | 670, 180 |
| 16. | Sand Coulee siphon | 206, 980 |
| 17. | Canal | 1, 805, 800 |
| 18. | Rocky Branch siphon | 477, 590 |
| 19. | Canal | 230, 950 |
| 20. | Rocky Coulee siphon | 1, 609, 300 |
| 21. | Canal | 1, 955, 110 |
| 22. | Weber Branch siphon | 2, 410, 620 |
| 23. | Canal | 417, 950 |
| 24. | Weber Coulee siphon | 1, 718, 500 |
| 25. | Canal | 3, 314, 510 |
| 26. | Lind Coulee siphon | 1, 328, 760 |
| 27. | Canal | 1, 213, 840 |
| 28. | Providence Tunnel | 3, 253, 030 |
| 29. | Canal | 449, 300 |
| 30. | Bifurcation works, lateral E-8 | 37, 940 |
| 31. | Canal | 667, 470 |
| 32. | Providence branch siphon | 127, 020 |
| 33. | Canal | 597, 150 |
| 34. | Hatton Coulee siphon | 317, 450 |
| 35. | Canal | 1, 074, 650 |
| 36. | Rattlesnake Tunnel | 389, 000 |
| 37. | Canal | 87, 040 |
| 38. | Rattlesnake siphon | 107, 790 |
| 39. | Canal | 281, 920 |
| 40. | Reeder Tunnel | 566, 060 |
| 41. | Canal | 815, 760 |
| 42. | Washtucna siphon | 1, 345, 030 |
| 43. | Canal | 150, 610 |
| 44. | Canal | 1, 224, 560 |
| 45. | Dunnigan Tunnel | 83, 660 |
| 46. | Canal | 652, 720 |
| 47. | Rye Grass Tunnel | 63, 530 |
| 48. | Canal | 489, 930 |
| 49. | Rye Grass siphon | 257, 310 |
| 50. | Canal | 473, 990 |
| 51. | Smith siphon | 121, 920 |
| 52. | Canal | 608, 000 |
| E-1. | Lateral E-1 | 605, 320 |
| E-2. | Lateral E-2 | 52, 580 |
| E-3. | Lateral E-3 | 253, 700 |
| E-4. | Lateral E-4 | 433, 780 |
| E-4-1. | Lateral E-4-1 | 113, 480 |
| E-5. | Lateral E-5 | 1, 875, 650 |
| E-6. | Lateral E-6 | 51, 380 |
| E-7. | Lateral E-7 | 2, 041, 570 |
| E-7-1. | Lateral E-7-1 | 26, 700 |
| E-8. | Lateral E-8 | 6, 946, 060 |
| E-8-1. | Lateral E-8-1 | 55, 920 |
| E-8-2. | Lateral E-8-2 | 257, 350 |
| E-8-3. | Lateral E-8-3 | 285, 190 |
| E-8-4. | Lateral E-8-4 | 29, 080 |
| E-8-5. | Lateral E-8-5 | 219, 980 |
| E-8-6. | Lateral E-8-6 | 116, 700 |
| E-9. | Lateral E-9 | 42, 210 |
| E-10. | Lateral E-10 | 149, 280 |
| E-11. | Lateral E-11 | 139, 340 |
| E-12. | Lateral E-12 | 352, 120 |
| E-13. | Lateral E-13 | 1, 211, 460 |
| 53. | Sub-laterals | 13, 931, 400 |
| | Total main cast | 79, 882, 040 |

| PROJECT ITEMS | |
|---|---|
| Supplemental pumping | $5, 234, 270 |
| Drainage | 5, 170, 550 |
| Wasteways | 1, 941, 370 |
| Permanent buildings | 1, 061, 600 |
| Wells | 155, 000 |
| Telephone system | 195, 000 |
| Preliminary work | 900, 000 |
| Total project items | 14, 657, 790 |

| RECAPITULATION | |
|---|---|
| Main canal | 34, 479, 860 |
| Main west | 30, 428, 540 |
| Main east | 79, 882, 040 |
| Project items | 14, 657, 790 |
| Project total | 159, 448, 230 |

589. *Stage development.*—A stage development for this plan is shown in table no. 20. It is based upon the same assumptions as in plan no. 4, i.e., interest at the rate of 4 percent on unpaid balances, rate of colonization, 50,000 acres per year, land to be placed under cultivation upon the delivery of water, annual repayments to begin at the end of the third year of crop, and to amount to at least 4 percent on the final per-acre cost.

TABLE NO. 20.—*Stage development—plan no. 4-A*

| Year | Stage | Capital expenditure | Area reclaimed | Area colonized | Area beginning repayment |
|---|---|---|---|---|---|
| | | | *Acres* | *Acres* | *Acres* |
| 1 | | | | | |
| 2 | | | | | |
| 3 | 1 | $400, 000 | | | |
| 4 | | 2, 022, 000 | | | |
| 5 | 2 | 13, 200, 000 | | | |
| 6 | | 18, 548, 150 | 108, 750 | | |
| 7 | 3 | 4, 830, 600 | | 54, 370 | |
| 8 | | 5, 770, 360 | 98, 980 | 54, 380 | |
| 9 | 4 | 3, 500, 000 | | 49, 490 | 54, 370 |
| 10 | | 5, 414, 180 | 110, 510 | 49, 490 | 54, 380 |
| 11 | 5 | 10, 113, 750 | | 55, 250 | 49, 490 |
| 12 | | 16, 814, 000 | 98, 440 | 55, 260 | 49, 490 |
| 13 | 6 | 8, 694, 900 | | 49, 220 | 55, 250 |
| 14 | | 12, 923, 430 | 117, 460 | 49, 220 | 55, 260 |
| 15 | 7 | 5, 812, 550 | | 58, 730 | 49, 220 |
| 16 | | 7, 814, 480 | 82, 580 | 58, 730 | 49, 220 |
| 17 | 8 | 8, 656, 720 | 58, 540 | 41, 290 | 58, 730 |
| 18 | 9 | 6, 529, 540 | | 41, 290 | 58, 730 |
| 19 | | 10, 116, 160 | 114, 600 | 58, 540 | 41, 290 |
| 20 | 10 | 6, 515, 590 | 45, 000 | 57, 300 | 41, 290 |
| 21 | 11 | 2, 974, 000 | 50, 000 | 57, 300 | 58, 540 |
| 22 | | 2, 196, 870 | 50, 000 | 45, 000 | 57, 300 |
| 23 | | 2, 656, 550 | 50, 000 | 50, 000 | 57, 300 |
| 24 | | 3, 943, 400 | 49, 250 | 50, 000 | 45, 000 |
| 25 | | | | 50, 000 | 50, 000 |
| 26 | | | | 49, 250 | 50, 000 |
| 27 | | | | | 50, 000 |
| 28 | | | | | 49, 250 |

590. Under this proposed stage development the first area would be placed under cultivation in the seventh year and repayments on that section begin at the end of the ninth; the last area would be brought under cultivation in the twenty-fifth year and repayments begin at the end of the twenty-seventh. Carrying all capital expenditures to the end of the twenty-sixth year with interest at 4 percent and deducting an annual repayment of $7.44 per acre, also bearing interest

at the same rate from the time repayment is made to the end of the twenty-sixth year, gives the following result:

| | | Per acre |
|---|---|---|
| Capital cost plus interest | $192,304,320.00 or | $185.96 |
| Capital cost | 159,448,230.00 or | 154.19 |
| Interest | 32,856,090.00 or | 31.77 |
| Annual interest charge after completion | | 7.44 |
| Annual cost of operation and maintenance | 1.60 | |
| Annual depreciation charge | 1.30 | |
| Annual cost of power | 1.28 | |
| | | 4.18 |
| Total annual charge | | 11.62 |

591. The above results for division A, plan no. 4-A, include no cost of power development and the annual operating expense must include the cost of power for pumping purposes.

592. *Division B.*—As stated, division B of plan no. 4-A, is identical with the Priest Rapids project which has been discussed earlier in this report. In order to make a comparison with plan no. 4 for developing the area within the Columbia Basin irrigation project, divisions A and B are combined in tables no. 21 and no. 22.

TABLE NO. 21.—*Plan no. 4-A, division A, power from Grand Coulee, division B, power from Grand Coulee*

| Division | Area in acres | Capital cost and interest | | Capital cost | | Interest | | Annual interest charge after completion |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per acre | Total | Per acre | Total | Per acre | |
| A | 1,034,110 | $192,304,320 | $185.96 | $159,448,230 | $154.19 | $32,856,090 | $31.77 | $7.44 |
| B | 140,520 | 17,257,470 | 122.81 | 15,246,810 | 108.50 | 2,010,660 | 14.31 | 4.91 |
| Total | 1,174,630 | 209,561,790 | 178.40 | 174,695,040 | 148.72 | 34,866,750 | 29.68 | 7.14 |

TABLE NO. 22.—*Plan no. 4-A, division A, power from Grand Coulee, division B, power from Priest Rapids*

| Division | Area in acres | Capital cost and interest | | Capital cost | | Interest | | Annual interest charge after completion |
|---|---|---|---|---|---|---|---|---|
| | | Total | Per acre | Total | Per acre | Total | Per acre | |
| A | 1,034,110 | $192,304,320 | $185.96 | $159,448,230 | $154.19 | $32,856,090 | $31.77 | $7.44 |
| B | 140,520 | 15,092,800 | 107.40 | 13,392,180 | 95.30 | 1,700,620 | 12.10 | 4.30 |
| Total | 1,174,630 | 207,397,120 | 176.56 | 172,840,410 | 147.14 | 34,556,710 | 29.42 | 7.06 |

593. For convenience, tables nos. 23, 24, and 25 give general data relative to canal sections, tunnels, and siphons constituting the system as proposed for plan no. 4-A.

TABLE NO. 23.—*Siphons and transitions—plan no. 4-A*

| Division | Canal | Name | Length | Diameter | Head | Barrels | | | | | Saddles, anchors, transitions | | Miscellaneous items and right-of-way | Administration, engineering and legal | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Number | Material | Concrete | Reinforcing steel | Structural steel | Concrete | Reinforcing steel | | | |
| | | | | | | | | *Cubic yards* | *Pounds* | *Pounds* | *Cubic yards* | *Pounds* | | | |
| A | | Siphons: | *Feet* | *Feet* | *Feet* | | | | | | | | | | |
| | Main canal | Bacon | 825 | 20.42 | 90 | 2 | Steel | | | 2,994,700 | 4,020 | 345,280 | $14,230 | $34,070 | $374,830 |
| | Main west | Dry Coulee | 2,680 | 18.67 | 240 | 1 | do | | | 6,643,750 | 3,990 | 315,920 | 10,200 | 57,680 | 634,490 |
| | Do | Soap Lake | 9,650 | 14.75 | 323 | 1 | do | | | 17,486,310 | 10,240 | 815,530 | 6,380 | 147,460 | 1,622,090 |
| | Do | Great Northern | 1,700 | 12.25 | 100 | 1 | Concrete | 3,212 | 735,030 | | 740 | 70,600 | 8,260 | 18,190 | 200,040 |
| | Do | Potholes | 15,260 | 16.17 | 182 | 1 | Steel | | | 20,625,550 | 21,830 | 1,925,110 | 10,200 | 196,080 | 2,156,850 |
| | Do | Frenchman | 10,690 | 13.08 / 11.92 | 165 | 1 | Steel and concrete. | 14,842 | 2,193,120 | 2,734,050 | 2,320 | 179,920 | 7,160 | 80,070 | 880,750 |
| | W-1 | W-1 | 11,000 | 6.00 | 234 | 1 | Steel | | | 3,821,080 | 3,020 | 205,700 | 1,600 | 32,320 | 355,480 |
| | W-2-C | W-2-C | 1,000 | 8.00 | 40 | 1 | Concrete | 826 | 87,720 | | 130 | 13,540 | 2,550 | 4,140 | 45,510 |
| | W-2-E | W-2-E | 5,450 | 10.08 | 60 | 1 | do | 7,090 | 1,053,650 | | 210 | 19,570 | 4,070 | 27,730 | 304,980 |
| | W-2-1 | W-2-1 | 5,400 | 5.92 | 44 | 1 | do | 2,524 | 406,540 | | 80 | 7,320 | 5,490 | 9,920 | 109,100 |
| | W-6 | W-6 | 14,072 | 6.67 | 94 | 1 | do | 9,395 | 1,831,580 | | 100 | 9,020 | 9,400 | 37,510 | 412,620 |
| | Main east | Crab Creek | 5,480 | 17.92 | 269 | 2 | Steel | | | 28,260,200 | 17,210 | 89,480 | 15,850 | 240,350 | 2,632,690 |
| | Do | Broken Rock | 8,700 | 19.75 | 150 | 2 | do | | | 32,947,990 | 23,230 | 1,630,560 | 75,300 | 291,210 | 3,203,260 |
| | Do | Black Rock | 4,500 | 19.08 | 123 | 2 | do | | | 15,619,450 | 11,340 | 966,410 | 21,230 | 133,610 | 1,469,760 |
| | Do | Sand Coulee | 700 | 16.25 | 40 | 2 | Concrete | 4,580 | 379,290 | | 1,430 | 135,950 | 6,910 | 18,180 | 206,980 |
| | Do | Rocky Branch | 1,450 | 18.58 | 122 | 2 | Steel | | | 4,396,050 | 5,670 | 376,270 | 7,280 | 43,420 | 477,590 |
| | Do | Rocky Coulee | 5,000 | 18.58 | 150 | 2 | do | | | 16,671,570 | 13,420 | 896,990 | 18,250 | 146,300 | 1,609,300 |
| | Do | Weber Branch | 8,300 | 17.33 | 168 | 2 | do | | | 25,657,000 | 17,060 | 1,469,800 | 7,880 | 219,150 | 2,410,620 |
| | Do | Weber Coulee | 5,450 | 17.17 | 178 | 2 | do | | | 18,136,350 | 11,870 | 1,020,170 | 21,970 | 156,230 | 1,718,500 |
| | Do | Lind Coulee | 4,900 | 16.58 | 124 | 2 | do | | | 13,330,690 | 10,270 | 881,520 | 39,470 | 120,800 | 1,328,760 |
| | Do | Providence Branch. | 1,040 | 14.33 | 61 | 1 | Concrete | 2,560 | 431,100 | | 520 | 49,590 | 6,290 | 11,550 | 127,020 |
| | Do | Hatton Coulee | 2,340 | 14.08 | 95 | 1 | do | 6,300 | 1,579,190 | | 490 | 46,740 | 5,810 | 28,860 | 317,450 |
| | Do | Rattlesnake | 1,050 | 13.17 | 56 | 2 | do | 2,220 | 331,070 | | 440 | 41,610 | 6,200 | 9,800 | 107,790 |
| | Do | Washtucna | 5,980 | 10.92 | 461 | 1 | Steel | | | 13,403,080 | 12,330 | 920,820 | 30,560 | 122,280 | 1,345,030 |
| | Do | Rye Grass | 5,990 | 7.75 | 164 | 1 | do | | | 2,775,650 | 1,630 | 154,770 | 1,660 | 23,390 | 257,310 |
| | Do | Smith | 3,700 | 7.00 | 88 | 1 | Concrete | 2,550 | 584,790 | | 140 | 13,400 | 1,340 | 11,080 | 121,920 |
| | E-4 | E-4 | 200 | 4.58 | 13 | 1 | do | 210 | 20,600 | | 60 | 5,500 | 220 | 420 | 4,580 |
| | E-5 | E-5 | 2,640 | 6.25 | 31 | 1 | do | 1,702 | 98,840 | | 80 | 7,600 | 4,550 | 5,760 | 62,750 |
| | E-7 | E-7 | 1,200 | 7.08 | 25 | 1 | do | 787 | 106,800 | | 110 | 10,350 | 1,500 | 3,180 | 34,940 |
| | E-8-3 | E-8-3 | 9,240 | 4.00 | 207 | 1 | Steel | | | 1,954,180 | 570 | 40,840 | 1,500 | 15,020 | 165,190 |
| | | Penstocks: | | | | | | | | | | | | | |
| | E-13 | P.P. no. 2 | 500 | 8.00 | 80 | 1 | do | | | 210,000 | 980 | 58,700 | 1,500 | 3,760 | 41,380 |
| | Main east | P.P. no. 3 | 2,000 | 6.00 | 85 | 1 | do | | | 630,000 | 1,420 | 113,850 | 1,500 | 7,670 | 84,420 |
| | E-5 | P.P. no. 5 | 1,200 | 6.00 | 138 | 1 | do | | | 375,300 | 840 | 50,770 | 1,500 | 4,560 | 50,210 |
| | E-8 | P.P. no. 8 | 1,200 | 10.00 | 102 | 2 | do | | | 12,096,000 | 2,330 | 126,450 | 1,500 | 19,200 | 211,300 |
| | E-5-5 | P.P. no. 9 | | | | | | | | | | | | | |
| | E-5 | P.P. no. 10 | 2,640 | 7.83 | 163 | 1 | do | | | 1,319,000 | 1,090 | 75,750 | 1,500 | 13,840 | 152,290 |
| B | High line | Kohler siphon | 6,000 | 6.25 | 148 | 1 | do | | | 2,294,170 | 1,110 | 107,140 | 2,550 | 19,200 | 211,150 |
| | Low line | Haven siphon | 6,020 | 3.42 | 100 | 1 | do | | | 1,089,860 | 200 | 10,990 | 500 | 8,070 | 88,700 |
| | Total | | 175,093 | | | | | 58,798 | 9,874,720 | 244,853,980 | 182,430 | 13,209,530 | 363,800 | 2,322,000 | 25,537,630 |

TABLE NO. 24.—*Tunnels—Plan no. 4-A*

| Division | Canal | Tunnel | Length | Diameter | Bore | Excavation | Timbering | Concrete lining | Right-of-way and miscellaneous items | Administration, engineering, and legal | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Feet* | *Feet* | | *Cubic yards* | *M b. m.* | *Cubic yards* | | | |
| A | Main canal | Bacon | 10,700 | 24.25 | Twin | 506,200 | 1,081 | 91,197 | $69,941 | $623,877 | $4,783,060 |
| | Do | Trail Lake | 2,300 | 24.25 | do | 151,560 | 597 | 25,039 | 67,328 | 169,646 | 1,300,610 |
| | Main west | Dry Coulee no. 1 | 2,250 | 18.50 | Single | 60,485 | 219 | 8,302 | 7,949 | 55,231 | 423,440 |
| | Do | Dry Coulee no. 2 | 1,855 | 18.50 | do | 34,916 | 161 | 5,848 | 4,220 | 30,427 | 294,610 |
| | Do | Low Gap | 8,200 | 12.87 | do | 83,350 | 1,548 | 17,975 | 11,212 | 111,528 | 855,040 |
| | Main east | Long Lake no. 1 | 1,700 | 20.33 | Twin | 120,060 | 323 | 17,233 | 52,908 | 112,932 | 865,820 |
| | Do | Long Lake no. 2 | 900 | 20.33 | do | 97,830 | 195 | 11,187 | 49,778 | 77,991 | 655,280 |
| | Do | Stratford | 3,900 | 20.33 | do | 228,170 | 675 | 33,867 | 58,598 | 219,860 | 1,685,590 |
| | Do | Long Ridge | 1,900 | 24.58 | do | 187,660 | 1,036 | 20,569 | 61,860 | 143,020 | 1,096,490 |
| | Do | Providence | 16,100 | 22.00 | Single | 365,610 | 1,412 | 65,260 | 51,278 | 424,308 | 3,253,030 |
| | Do | Rattlesnake | 3,200 | 15.25 | do | 62,955 | 205 | 9,404 | 6,547 | 50,739 | 389,000 |
| | Do | Reeder | 5,100 | 15.00 | do | 79,524 | 290 | 13,517 | 7,069 | 73,834 | 566,060 |
| | Do | Dunnigan | 1,000 | 11.33 | do | 43,430 | 40 | 1,784 | 2,899 | 10,913 | 83,660 |
| | Do | Rye Grass | 1,300 | 8.83 | do | 35,000 | 36 | 1,358 | 2,257 | 8,287 | 63,530 |
| B | None | | | | | | | | | | |
| | Total | | 60,405 | | | 2,056,750 | 7,827 | 322,540 | 453,844 | 2,120,593 | 16,315,220 |

TABLE NO. 25.—*Canals—Plan no. 4-A*

| Division | Canal | Length | Excavation | | | Canal lining | | | Minor structures, turn-outs, bridges, fence, etc. | Right of way | Administration, engineering, and legal | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Earth | Loose rock | Solid rock | Concrete | Reinforcing steel | Drainage | | | | |
| | | *Miles* | *Cubic yards* | *Cubic yards* | *Cubic yards* | *Cubic yards* | *Pounds* | *Linear feet* | | | | |
| A | Main canal | 9.13 | 61,620 | | 3,354,400 | 120,930 | 1,864,200 | 48,190 | [1] $189,660 | $15,560 | $942,800 | $7,327,230 |
| | Main west | 91.90 | 4,054,300 | | 1,700,960 | 338,500 | 16,514,880 | 472,550 | 223,050 | 90,240 | 1,408,170 | 10,795,980 |
| | Main west laterals | 86.15 | 1,295,790 | | 320,170 | 117,500 | 6,381,210 | 51,080 | 152,610 | 24,890 | 457,660 | 2,484,880 |
| | Main east | 133.10 | 16,102,050 | 4,740 | 4,454,720 | 689,510 | 33,530,540 | 725,760 | 458,840 | 50,940 | 3,209,220 | 24,398,150 |
| | Main east laterals | 216.30 | 6,189,980 | | 1,320,960 | 491,600 | 26,280,940 | 92,570 | 587,250 | 74,190 | 1,904,380 | 15,820,760 |
| | Sublaterals | | | | | | | | | | | 21,716,310 |
| B | High line | 62.57 | 1,747,420 | | 325,090 | 117,980 | 6,371,510 | 233,440 | 94,050 | 22,890 | 463,470 | 3,553,280 |
| | Low line | 31.06 | 578,310 | | 84,600 | 45,830 | 2,302,230 | 31,680 | 41,460 | 10,200 | 177,480 | 1,507,660 |
| | Sublaterals | | | | | | | | | | | 2,950,920 |
| | Total | 630.21 | 30,029,470 | 4,740 | 11,560,900 | 1,921,850 | 93,245,510 | 1,652,270 | 1,746,920 | 288,910 | 8,563,180 | 90,555,170 |

*Summary*

| | | |
|---|---|---|
| Canals | | $90,555,170 |
| Siphons | | 25,537,630 |
| Tunnels | | 16,315,220 |
| Pumping plants: | | |
| Grand Coulee [2] | $15,631,300 | |
| Bend [2 3] | 3,223,280 | |
| Bend Repump [3] | 839,590 | |
| | | 19,694,170 |
| Project items: | | |
| Division A | 14,657,790 | |
| Division B | 1,017,600 | |
| | | 15,675,390 |
| Dams: | | |
| North reservoir dam | 1,085,560 | |
| South reservoir dam | 3,977,270 | |
| | | 5,062,830 |
| Total division A and B, plan no. 4-A | | 172,840,410 |

[1] Includes bifurcation works.

[2] With Priest Rapids Dam.

[3] Includes pipe lines.

594. *Additional areas.*—Plan no. 4-A as described eliminates 320,460 acres of irrigable land that is included in the plans with a gravity diversion from the Clark Fork and Spokane River. This land is located east of the main east of plan no. 4-A and is above the 100-foot limit for supplemental pumping. This area excluded from plan no. 4-A includes Michigan Prairie and Rattlesnake Flat, two tracts that are particularly attractive as to soil and topographic conditions. In an effort to cover a portion of these attractive areas, a tentative plan was developed for repumping from the main east with power transmitted from Grand Coulee.

595. A gravity diversion from the main east at the intake to the Lind Coulee siphon was projected east through Lind Coulee, a distance of 16.6 miles to a point about 2 miles east of Servia, a station on the Chicago, Milwaukee, St. Paul & Pacific Railroad. At that point a repumping plant with a discharge pipe approximately 4,800 feet in length would deliver water to the high area south of Lind Coulee from where the water could be delivered by gravity to an irrigable area of 91,910 acres, including Michigan Prairie. The total head at the repumping plant is 470 feet.

596. To include this additional area in plan no. 4-A, some modification of that plan would be required. No increase in the capacity of the main pumping plant at Grand Coulee would be required, but the capacity of the main canal and the main east from the bifurcation works to the intake to the Lind Coulee siphon would be increased by 860 second-feet to meet the requirements of the additional area.

597. Below the diversion from the main east the additional canal system required would consist of the canal extending 16.6 miles upstream in Lind Coulee, the repumping plant and the necessary canal system to deliver water to the additional area, together with the transmission line from Grand Coulee to the repumping station.

598. It was found to be infeasible to include Rattlesnake Flat and the surrounding area in plan no. 4-A.

599. The capital cost of the modifications and additions to plan no. 4-A, as outlined above, necessary to reclaim this area which is referred to as the Michigan Prairie tract is $13,891,420. Carried through the stage development, as outlined in plan no. 4-A, the final cost, including interest, is $18,268,160, or $198.76 per acre. Combining this area with the area covered by plan no. 4-A with all power transmitted from Grand Coulee, gives the following:

| Total area reclaimed, 1,266,540 acres. | | *Per acre* |
|---|---|---|
| Capital cost plus interest | $227, 829, 950. 00 or | $179. 88 |
| Capital cost | 188, 586, 460. 00 or | 148. 90 |
| Interest | 39, 243, 490. 00 or | 30. 98 |
| Annual interest charge after completion | | 7. 20 |
| Annual cost of operation and maintenance | 1. 60 | |
| Annual cost of depreciation | 1. 35 | |
| Annual power charge | 1. 30 | |
| | | 4. 25 |
| Total annual charge | | 11. 45 |