1601. *e'''. Stage development.*—A stage development for this plan is shown in table no. 217. 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. 217.—*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	108,750		
6		18,548,150			
7	3	4,830,600	98,980	54,370	
8		5,770,360		54,380	
9	4	3,500,000	110,510	49,490	54,370
10		5,414,180		49,490	54,380
11	5	10,113,750	98,440	55,250	49,490
12		16,814,000		55,260	49,490
13	6	8,694,900	117,460	49,220	55,250
14		12,923,430		49,220	55,260
15	7	5,812,550	82,580	58,730	49,220
16		7,814,480		58,730	49,220
17	8	8,656,720	58,540	41,290	58,730
18	9	6,529,540	114,600	41,290	58,730
19		10,116,160		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

1602. 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	or	$185.96
Capital cost	159,448,230	or	154.19
Interest	32,856,090	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			11.54

1603. 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.

1604. *b''. 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. 218 and no. 219.

TABLE NO. 218.—*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. 219.—*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

1605. For convenience, tables nos. 220, 221, and 222, give general data relative to canal sections, tunnels, and siphons constituting the system as proposed for plan no. 4-A.

TABLE No. 220.—*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
						No.	Material	Concrete	Reinforcing steel	Structural steel	Concrete	Reinforcing steel			
			Feet	Feet	Feet			Cubic yards	Pounds	Pounds	Cubic yards	Pounds			
		Siphons:													
A	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	3,900	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	8,200	18,190	200,040
	do	Potholes	15,200	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	2,199,120	2,734,050	2,320	179,920	7,160	80,070	880,750
	W-1	W-1	11,000	6.0	234	1	Steel			3,821,080	3,020	205,700	1,600	32,320	355,480
	W-2-C	W-2-C	1,000	8.0	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	1,083,650		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			15,019,450	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	6,260	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	5,996	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	20,000		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	5,700	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	Steel			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	8,670	88,700
Total			175,093					58,798	9,874,720	244,853,980	182,430	13,209,530	363,800	2,522,000	25,537,630

TABLE No. 221.—*Tunnels, plan no. 4-A*

Division	Canal	Tunnel	Length	Diameter	Bore	Excavation	Timbering	Concrete lining	Drainage 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	38,427	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	49	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. 222.—*Canals, plan no. 4-A*

Division	Canal	Length	Excavation			Canal lining			Minor structures, turnouts, 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 divisions A and B, plan no. 4-A		172,840,410

[1] Includes bifurcation works.

[2] With Priest Rapids Dam.

[3] Includes pipe lines.

1606. *c''. 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.

1607. 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.

1608. 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.

1609. 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.

1610. It was found to be unfeasible to include Rattlesnake Flat and the surrounding area in plan no. 4-A.

1611. 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	acres	1, 266, 540
Capital cost plus interest	$227, 829, 950 or..per acre	$179. 88
Capital cost	$188, 586, 460 or.....do	148. 90
Interest	$39, 243, 490 or.....do	30. 98
Annual interest charge after completion	do	7. 20
Annual cost of operation and maintenance	do	1. 60
Annual cost of depreciation	do	1. 35
Annual power charge	do	1. 30
		4. 25
Total annual charge	do	11. 45

1612. *o'. Plan no. 3.*—Plan no. 3 is identical with plan no. 4 except that no provision is made for supplemental pumping. An area of 980,340 acres would be reclaimed under this plan, all served through a gravity system. The distributing system on the project affords an opportunity for developing a considerable amount of power during the irrigation season that can be utilized to reclaim desirable areas above the canal system. Plan no. 3 makes no provision for developing power on the project for the purpose of supplemental pumping and has been eliminated because of the fact that it does not utilize the possibilities to the fullest extent. Plan no. 4 does take advantage of the opportunity afforded for supplemental pumping.

1613. *b. Soils.*—The soils of the Columbia Basin irrigation project vary considerably in their productive capacity. There are areas where soil of good texture extends to a depth of 6 feet, where the drainage below that depth is adequate, and where the surface is sufficiently level to permit of satisfactory irrigation. Such areas would be highly productive under irrigation and would have a wide range of crop adaptability. Over a large portion of the total irrigable area under the canal line, however, the soil conditions do not meet this high standard. Various factors enter which limit production or increase costs to such an extent, in some cases, that they reduce the land to a submarginal class where irrigation development will not be justified.

1614. Under ideal conditions roots may occupy the top 6 feet of soil; this is particularly true of perennial crops. If the conditions in the top 6 feet are satisfactory, high yields may be expected. If this zone for root development is restricted by impervious subsoils or hardpan, occurring within the top 6 feet, the conditions for maximum growth are reduced. Since the large proportion of the feeding roots of most crops is in the top 3 feet of soil, the soil depth may be restricted to a 3-foot zone without seriously impairing production, if other conditions are favorable. A further restriction, however, will affect yields of all but shallow-rooted crops, such as grain, and if the root zone is materially reduced, the range of crop adaptability will also be reduced.

1615. Anything which creates unfavorable conditions within a root zone, such as the presence of excessive quantities of alkali, rapid leaching of plant food, or inadequate aeration, will, of course, react directly upon production. Proper drainage to allow adequate aeration is essential. High ground water, or a local water table formed above an impervious stratum will restrict root development as effectively as the impervious stratum itself. On the other hand, where a constant high-water table exists (without the complicating effect of alkali concentration) the moisture condition in the root zone may be at a maximum, which would be favorable for meadow grasses or other shallow-rooted crops. Such land can be profitably planted to bluegrass and clover, where alfalfa would be short-lived.

1616. The cost of irrigation, as well as the cost of development, may be affected by topography, even where the soil itself may be highly productive. The surface soil may be so rough that the cost of preparing the land for irrigation will be greater than the value of the land after it has been developed. In other cases the cost of spreading the water over a steep slope may be so great as to increase the unit cost of production to a point where the land cannot compete with other areas. Such lands may be productive, but the high cost of water distribution may make operation unprofitable. In addition, the danger of erosion on steep slopes is considerable, particularly where contour furrows are used, where the overflow from one furrow may start a stream directly down the hill, with resulting damage to the land.

1617. Applying these criteria to the soils of the Columbia Basin irrigation project, it is apparent that the areas of irrigable land will be restricted by conditions both of soil and topography. Lands too shallow for successful cultivation, rolling land where the cost of irrigation would be excessive or where the slope is too steep for satisfactory irrigation, lands containing excessive quantities of alkali, and areas where the surface is so rough as to require excessive cost in leveling, will have to be eliminated in order to restrict the project to lands which can bear some share of the cost of development.

1618. *a′. Irrigable area.*—The irrigable area as shown in this report is based on a modification of the land classification made by Strahorn.[86] Certain areas included as class 1 land in Strahorn's report were found to be above the canal level, and were eliminated. In other cases second-class land was eliminated in the present estimate of irrigable land on account of boulders in the surface profile. This was particularly true in the Ephrata section where large areas contain boulders which could not be removed economically.

1619. Some rolling land which is suitable for fruit production but which is too steep to be considered satisfactory for general agriculture under conditions which will obtain during the next 40 years is included as ultimately irrigable, but it should be eliminated from present considerations on economic grounds.

1620. The area of first-class land may be reduced to some extent by possible further elimination of small, isolated areas which cannot be reached economically and by other areas where subsoil conditions, not recognized in the reconnaissance report, are unfavorable. On the other hand, the area of first-class land will be increased by the inclusion of areas which were placed in the second-class in the preliminary report, but which will prove to be of good quality after more thorough examination. The sum total of this readjustment will probably result in a reduction in the area of first-class lands.

1621. The area of second-class lands will probably be materially reduced by the elimination of excessively shallow lands underlain with impervious material or excessively porous sands and gravels. Some of the land placed in class 2, but included in the estimation of the possible ultimate irrigable area, will be eliminated from consideration in plans for early development on economic grounds, due either to high cost of leveling or high cost of water distribution.

1622. The final determination of the irrigable area cannot be made until a detailed soil classification has been completed. Such a soil study will require a detailed topographic survey, which is beyond the scope of this report. A soil survey of Franklin County made in 1914 and a soil survey of the Quincy area made in 1911 by the Bureau of Soils, United States Department of Agriculture, present certain facts about the soils of the project area, but no attempt was made in these reports to classify the area from the standpoint of irrigation. These maps would be of value in the preparation of a detailed land classification. Such a classification should be based on a topographic survey and should be preceded by a thorough study of the root development of trees, alfalfa, and other crops on the various types of land

[86] "Report on Land Classification", by A. T. Strahorn and Party, Bureau of Soils, U.S. Department of Agriculture, pp. 154–200.

which are now under irrigation within the project. This study of root development would establish a basis for the intelligent classification of the land. The effect of gravelly subsoil, hardpan, or other impervious material, on drainage could also be determined through field studies to establish facts on which to base judgment in determining the irrigability of lands so affected.

1623. In general the soil studies made in connection with this report have clearly demonstrated that there is a sufficiently large area of irrigable land to justify the assumptions as to yields and returns as shown in the discussion of irrigation in paragraphs 1771–1842 of this report.

1624. *b′. General discussion of soil conditions in different areas.*—In general, the soils east of a line drawn from Connell to Wheeler are 4 feet or more in depth, are of good texture, and are well drained. These soils have been designated as the "Ritzville series" in Strahorn's classifications. Hardpan occurs occasionally, but where it is exposed it appears to be cracked and broken, and would probably not offer a serious obstacle to water penetration. Portions of this area are sufficiently level to permit of satisfactory irrigation and are suited to the production of a wide range of crops.

1625. The largest bodies of this type of soil, and with favorable topography, are located on Rattlesnake Flat and Michigan Prairie. The major portion of the area covered by the Ritzville soil series is deeply eroded, so that the topography is rolling, with slopes exceeding 6 percent in much of the territory. The first-class lands are confined quite largely to the flatter portions of the ridges, which form very irregular areas and which would require a rather expensive distributing system for water delivery.

1626. The silty character of the land makes the irrigation of the slopes more difficult than would be the case if the soils contained more clay or gravel. If the fields are corrugated, with the corrugations running directly down the slope, the feeder ditches would have to be very close, in some cases as close as 200 feet, in order to permit the use of sufficiently small streams to prevent erosion. This would increase the cost of irrigation appreciably, as it would require very much more labor than would be required for the irrigation of a similar area of better topography. If contour furrows are used, great care would have to be taken in their preparation, to prevent an overflow from one furrow into the one below, which would, in turn, overflow and create a stream of sufficient volume to cause considerable damage. Orchards would do well on these slopes, as they could be irrigated by a contour system, or, where the slope is not too great, and where a sod cover crop is growing, the land could be irrigated directly down the slope. The irrigation of these slopes would present a difficult problem.

1627. In the central and western portions of the project shallow soils underlain with gravel predominate. The surface soil usually varies from 1 to 3 feet in depth, while the gravel extends down to an undetermined depth, in some cases exceeding 100 feet. A lime hardpan is sometimes found between the surface soil and the underlying gravel. This cemented material varies in thickness from 2 or 3 inches to a foot or more. Where exposed, the hardpan appears to be sufficiently porous to permit of water penetration. Where areas of this kind were irrigated in the Moses Lake section, and also in the Kittitas

Valley, where similar conditions exist, there is no indication that water stood on top of the hardpan. Some of this area can be included in class 1, if the standard is not too restricted.

1628. Where these shallow soils, underlain with gravel, have sufficient soil material filling the spaces between the gravel and the cobblestones, good yields can be secured. More frequent irrigation might be necessary on these gravelly soils than on soils which have less excessive drainage, and, as the years go by, the loss of soil fertility by leaching would have to be replaced through fertilization and rotation of crops. This statement is borne out by the fact that yields in the Kittitas Valley, under similar conditions, have decreased during the past 30 years, so that fertilization is now being undertaken on some soils with marked results. The application of superphosphate in demonstration plots in the Kittitas Valley has more than doubled the yield of alfalfa in places.[87]

1629. There is a large area west of Moses Lake, a portion of which is included in Strahorn's class 1 area, where coarse, black basaltic sand underlies the surface at from 2 to 3 feet, and extends to a depth of from 1 to 40 feet, as shown by logs of wells in that section. Hardpan underlies this black sand. In section 2-19-25 a well went through 3 feet of soil, 12 inches of black sand, 3 feet of lime hardpan, and 60 feet of compacted soil material. Three miles east another well showed 3 feet of soil and 40 feet of black sand, then hardpan. The black sand appears to be crushed basalt, and it contains relatively little soil material and is considered of little value by local farmers. A formation where from 2 to 3 feet of soil is underlain by a porous and comparatively infertile sand, which in turn rests on impervious hardpan, would not present particularly favorable conditions for profitable irrigation development, because of the restricted soil area and the danger of the accumulation of water on top of the impervious subsoil. The cultivation of such land would probably prove profitable if drainage is provided.

1630. The drainage of the areas with gravelly subsoil would not be difficult, as there would be a rather free movement of water through the gravelly subsoils. Without adequate drainage the subsoils would rapidly fill with water, creating lakes in the low areas and causing damage to portions of the land which might otherwise be productive. In all probability the gravelly subsoil will be partially filled with water, even with drainage. This will enable landowners to pump water for irrigation of high lands, or to secure a supplementary supply, as is done in so many projects where the gravity supply is limited. The lift is now too great—100 to 150 feet—but when the water table rises, pumping can be resorted to, both as a supplemental water supply and for domestic use. Pumping water from the subsoil for supplemental irrigation would serve to prevent a damaging rise of ground water and might permit the irrigation of a larger area than originally planned.

1631. A portion of the area underlain with gravel contains large boulders close to the surface, so that cultivation is impossible without the expenditure of a good deal of money to remove these boulders. In many cases the cost of removing boulders would be far beyond the value of the land. Much of the area north of Moses Lake and in the territory around Ephrata and Adrian is unfit for irrigation develop-

[87] Unpublished report of W. O. Passmore, Kittitas County agricultural agent.

ment, because of the presence of these large boulders in the surface profile. These areas have been largely eliminated from the irrigable area.

1632. In the vicinity of Burke the surface soil is comparatively shallow and in places is underlain with a lime formation, which occasionally rests upon basaltic rock. The basaltic rock sometimes comes to the surface as it does in other parts of the project, and where this occurs the land is known as scabland. Here drainage conditions would be unsatisfactory, and successful crop production would be limited to restricted areas where the surface soil is 3 feet or more in depth, and where drainage is provided either artificially or by natural channels.

1633. *c'. Conclusion.*—So much depends upon the permanent productive quality of the soil of the Columbia Basin as well as upon the initial cost of leveling the land in areas where the surface is uneven, and also upon the annual cost of distributing the water over the ground in the more rolling sections of the project, that it is recommended that a detailed soil classification be made prior to construction in order to determine the exact location and area to be irrigated. The studies made in connection with this report verify the conclusions of previous reports that there is a sufficiently large area of irrigable land to justify a project. The investigations, however, clearly indicate the necessity for a detailed classification which was beyond the scope of this report. This classification should be based on (1) the adaptability of the land for crops, (2) a study of the permanent productive quality of the soil after water has been applied, (3) upon the cost of preparing land for irrigation, and (4) upon the effect of topography on the cost of distributing water over the surface of the ground.

1634. These four considerations should be the controlling factors in the classification of the land for it is upon these factors that economic feasibility depends.

(5) MARKETS

1635. The economic feasibility of irrigation development in the upper Columbia Basin depends in large part upon the demand for products which can be raised to advantage. If the demand is not equal to the supply the increased production would depress prices of agricultural products in the Northwest generally. Such a result would react unfavorably on any new development as well as on existing enterprises. On the other hand, if the local supply of farm products does not equal the demand, consumers would have to pay prices which would be set by the cost of the marginal supply which was imported. At the present time, for example, Seattle is the highest priced hog market in the United States because 85 percent of the hogs killed in the State are imported and the price is governed by the cost of the marginal supply which comes from the Dakotas. It is desirable, therefore, that production be increased at a rate which will take care of increased demand in the markets where products from the Northwest are consumed.

1636. Since the Columbia Basin irrigation pumping project embraces over 97 percent of all land which can be economically irrigated from the Columbia in the upper Columbia Basin, outside of the very small areas of river-bottom land, the discussion of markets in this section of the report is based on an analysis of the markets for products of the pumping project.

1637. Assuming that the Columbia Basin irrigation project will include 1,000,000 acres of irrigable land and that 5 percent of the land will be in buildings, roads, etc., and 5 percent of the remainder will be idle for one cause or another, there will be 902,500 acres actually irrigated. Following the analysis of land utilization given in the discussion of irrigation in paragraphs 1781–84, the 902,500 acres would be divided as follows: 539,125 acres in hay, forage crops, and pasture; 213,750 acres in grain; 59,375 acres in potatoes and other vegetables; 71,250 acres in beans and peas; and 19,000 acres in fruit.

1638. The hay, forage crops, pasture, grain, cull potatoes, bean straw, corn roughage, etc., will go largely toward feeding livestock. Dairy products, meat products, wool, and eggs will be the commodities sold. With the exception of lambs and eggs, which will be marketed in part in the East, practically all of the animal products should find a coast market.

1639. The relationship, which supply of livestock products from the Columbia Basin irrigation project might have to the demand for these products in the Northwest in 1960, is shown in table no. 223.

TABLE No. 223.—*Estimated production of livestock products on Columbia Basin irrigation project compared to the estimated demand of the increased population in 1960*

Farms	Class of animals	Number of animals per farm	Total number of animals	Acres required to produce the feed for 1 animal unit	Total acres required	Total production	Per capita consumption	Estimated increase in population in Washington, Oregon, and Idaho in 1960	Total consumption in 1960
12,500	Dairy cows	9	112, 500	2. 4	270, 000	Butter, 25,300,000 pounds. Cheese, 9,187,500 pounds.	Butter, 17.6 Cheese, 3.5	1, 438, 000	Butter, 25,300,000. Cheese, 5,330,000.
12,500	do					787,500,000 pounds skimmed milk.	Fed to calves, hogs, and chickens.		
12,500	Hogs	55	687, 500	[1] 1. 07	48, 125	109,312,500 dressing 75 percent.	82 pounds	1, 438, 000	117,916, 000.
12,500	Cattle	[2] 9	112, 500	. 9	101, 250	78,390,000 dressing 67 percent.	60 pounds	1, 438, 000	86,280,000.
12,500	Sheep	[3] 10	125, 000	. 2	25, 000	10,000,000	12.4 pounds	1, 438, 000	17,831,200.
12,500	Chickens	100	1, 250, 000	. 0025	31, 250	15,625,000 dozen	20 dozen 5.9 chickens.	1, 438, 000	28,710,000 dozen.
12,500	Horses	4	50, 000	1. 5	75, 000				

[1] Plus cull potatoes and skimmed milk. [2] Feeders. [3] Ewes.

1640. According to this analysis the project lands when fully developed can supply practically all of the butter, cheese, pork, beef, mutton, and eggs consumed by the estimated increase in population in 1960, with 166,815 acres in hay and grain left over. This surplus can be used to produce feed to be sold to the dairymen on the coast who are in the whole-milk market and require outside feedstuffs. If the per capita consumption of whole milk remains as at present, an increase of 1,150,000 people in western Washington and western Oregon by 1960 would consume 1,265,000,000 pounds of whole milk which would require approximately 400,000 acres of irrigated land to produce. According to this estimate the Columbia Basin irrigation project would supply about 40 percent of the needed area.

1641. The 19,000 acres in fruit would be planted to apples, pears, peaches, apricots, prunes, and small fruits. At present Washington produces approximately 25 percent of the apples on the United States market. If the population of the United States increases as predicted there will be an increase of 23 percent by 1960. If the 19,000 acres in fruit were all planted to apples the area would represent an increase of about 25 percent in the acreage of trees in the State, which is a trifle more than a proportional increase as compared to the possible increase in the United States market. Since the area will not be planted wholly to apples and since Washington fruit finds a ready foreign market it would appear that the increase in fruit acreage would not produce any serious problem of surplus.

1642. The production of potatoes and other vegetables and the production of beans and peas during the next 30 years will present no serious marketing problem if the population of California and the Northwest and the total of the United States increases as predicted. The acreage in these crops is but nine one-hundredths of an acre per capita for the estimated increase in population in the Northwest, which is slightly less than the acreage required per capital to supply the truck crops consumed.

1643. This brief analysis of the possible market for agricultural products of the Columbia Basin irrigation project indicates that the pumping project or some similar area elsewhere will be needed to produce the food required by the estimated increase in population in 1960. Whether or not this method of meeting the requirement is the best method is an inquiry which is not within the scope of this report. It should be borne in mind, however, that the development of a new producing area creates a local and regional buying power and demand which in itself is an important factor in the development of a market.

1644. The estimate of acreage needed to supply the demand in 1960 is based on an assumption that the population will increase as predicted. It is also assumed that construction work will begin almost immediately and that the full area (1,000,000 acres) will be settled and developed by that time. If development is retarded by delayed construction or settlement, the estimated production would not be secured. Any delay would improve the marketing condition.

F. Combined Uses

1645. The navigation section of this chapter contains plans and estimates of cost of improving the river in the interest of navigation alone by three methods: Open-river, partial canalization, and complete canalization. The power section contains plans and estimates of cost of developing the potential water power of the river, and the power dams would be at the same sites and of the same dimensions as required for complete canalization, discussed under the navigation section.

1646. A saving in the cost of navigation facilities could be effected by combining navigation improvements with power development. Estimates of cost of this combination of interests are given below. These estimates are based on the assumption that the power plants will be constructed as outlined in the power section, the entire cost of the dams and lateral canals being charged to power development, navigation to be charged with the cost of locks and other navigation features.

1647. Between Snake River and Priest Rapids the improvement would be as given in the navigation section of this chapter, paragraph 456, and is for navigation only, as no power development is contemplated for this section of the river. The estimate of cost of dredging and of constructing the locks and lateral canals at the two places there cited is $1,750,000.

1648. *Priest Rapids.*—The power development involves a dam at the lower end of the rapids, with a power house located on the right bank. That portion of the dam across the river channel would be constructed of concrete, with sufficient controlled spillway capacity to pass the maximum flood. The shore ends of the dam would be constructed of earth with a concrete core. This dam would back the water to Rock Island Rapids, submerging Cabinet Rapids.

1649. The improvement for navigation would consist of a flight of three locks located on the right bank near the power house, passing through the earth-filled section of the dam. The difference in head would be 140 feet.

The estimated cost of the navigation features is as follows:

Cofferdam	$40, 000
Excavation:	
Earth, 140,000 cubic yards, at $1	140, 000
Rock, 100,000 cubic yards, at $3	300, 000
Concrete, 350,000 cubic yards, at $11	3, 850, 000
Gates	260, 000
Machinery and valves	80, 000
Engineering and contingencies	730, 000
	5, 400, 000
Estimated cost of private power development (table no. 139)	60, 523, 811
Total	65, 923, 811

1650. *Rock Island Rapids.*—At this point a power company is now (1931) completing a power development which is described in paragraphs nos. 670–688. A lock would be located at the right bank and would consist of a single lift to overcome a difference in head of 51.0 feet.

The estimated cost of the navigation features is as follows:

Cofferdam	$20, 000
Excavation:	
Earth, 150,000 cubic yards, at $1	150, 000
Rock, 130,000 cubic yards, at $3	390, 000
Concrete, 75,000 cubic yards, at $11	825, 000
Gates	140, 000
Machinery and valves	45, 000
Engineering and contingencies	230, 000
	1, 800, 000
Estimated cost of private power development (par. no. 687)	28, 000, 000
Total	29, 800, 000

1651. *Rocky Reach.*—The power development considered consists of a dam with power canal on the left bank, the power house being located at the lower end of the canal about 1⅓ miles below the dam. This dam would back the water to the Chelan Dam site.

1652. The improvement for navigation would consist of a single lock located at the lower end of the canal and adjacent to the power house. The difference of head is 60 feet.

The estimated cost of the navigation features is as follows:

Cofferdam	$80,000
Excavation, 300,000 cubic yards, at $2	600,000
Concrete, 100,000 cubic yards, at $11	1,100,000
Gates	150,000
Machinery and valves	45,000
Engineering and contingencies	325,000
	2,300,000
Estimated cost of private power development (table no. 129)	37,969,968
Total	40,269,968

1653. *Chelan.*—The power development would consist of a dam about 4,500 feet upstream from the mouth of Chelan River. Due to the limited space available at this site for power house and spillways, the dam would be curved for 90°, with 400 feet radius where it crosses the river channel, with a straight section extending downstream 650 feet, on and parallel to the left bank. The power house would also be on the left bank at the end of the straight section of the dam. This development would back the water to Foster Creek Rapids.

1654. The improvement for navigation would consist of a flight of two locks, located on the left bank at the end of the power house. The total lift would be 97 feet.

The estimated cost of the navigation features is as follows:

Cofferdam	$30,000
Excavation:	
Rock, 100,000 cubic yards, at $3	300,000
Earth, 500,000 cubic yards, at $1	500,000
Concrete, 135,000 cubic yards, at $11	1,485,000
Gates	200,000
Machinery and valves	60,000
Engineering and contingencies	425,000
	3,000,000
Estimated cost of private power development (table no. 126)	39,039,600
Total	42,039,600

1655. *Foster Creek.*—The power development would consist of a dam a little more than a mile above the mouth of Foster Creek, with a power canal on the left bank about 4,000 feet long, extending to the power house. This dam would back the water up to Grand Coulee Dam site.

1656. The improvement for navigation would consist of a flight of four locks on the left bank, extending downstream from the lower end of the power canal to the river. The total lift would be 164 feet.

The estimated cost of navigation features is as follows:

Cofferdam	$200,000
Excavation, rock, 380,000 cubic yards, at $3	1,140,000
Concrete, 240,000 cubic yards, at $11	2,640,000
Gates	270,000
Machinery and valves	100,000
Increase power canal to reduce velocity to 5 miles per hour	400,000
Engineering and contingencies	650,000
	5,400,000
Estimated cost of private power development (table no. 123)	48,322,013
Total	53,722,013

1657. *Grand Coulee.* Two plans of development are considered: One for a dam to back the water to Kettle Falls and one to back the water to the international boundary, drowning out Grand Rapids and Kettle Falls. In both of these plans power development and irrigation are contemplated. Storage above either dam would be used to increase the low-water flow of the river. The forebay above the low dam would be drawn down 30 feet during low-water periods. With the high dam this drawdown would be 80 feet.

1658. The improvement for navigation would consist of a single lock through the dam to overcome the difference between high and low water in the upper pool. This lock would be connected with a flight of locks by a short canal with passing basin. For the low dam the flight would have four locks, with the high dam five locks. All of these structures would be on the right bank.

1659. The plan for the low dam would require a lock at Grand Rapids, to be used during the periods when the pool above Grand Coulee Dam was low. The high dam would not require a lock at Grand Rapids or at Kettle Falls, but rock removal would be required at Little Dalles to reduce current velocities when the pool is below normal level. The difference in head with the low dam would be 225 feet, and with the high dam 355 feet.

Estimated cost of navigation features, low dam, is as follows:

Cofferdam	$100, 000
Excavation, 600,000 cubic yards, at $2	1, 200, 000
Concrete, 350,000 cubic yards, at $11	3, 850, 000
Gates	600, 000
Machinery and valves	140, 000
Engineering and contingencies	1, 110, 000
	7, 000, 000
Estimated cost of public power development (table no. 111)	107, 633, 000
Total	114, 633, 000

1660. The probable cost of navigation features at the high dam, including necessary rock removal at Little Dalles to reduce current velocities when the pool is below normal, is $11,000,000. The estimated cost of public development for the high dam is $171,186,777, or a total of $182,186,777.

1661. *Grand Rapids.*—The estimated cost of a lock on the left bank at Grand Rapids, to provide for navigation over the rapids when the pool above Grand Coulee Low Dam is below normal, is $800,000.

1662. *Kettle Falls.*—The power development would consist of a dam with power house located at the lower end of Hayes Island, the end of the dam extending across the minor channel. This dam would back the water to the international boundary.

1663. The improvement for navigation would consist of three locks in flight, extending through the neck of land projecting out from the left bank below Hayes Island. The difference in head would be 124 feet. (This project would not be constructed if the higher dam at Grand Coulee were built, as the site would be submerged.)

The estimated cost of navigation features is as follows:

Cofferdam	$70,000
Excavation:	
Earth, 90,000 cubic yards at $1	90,000
Rock, 550,000 cubic yards at $3	1,650,000
Concrete, 165,000 cubic yards at $11	1,815,000
Gates	270,000
Machinery and valves	80,000
Engineering and contingencies	625,000
	4,600,000
Estimated cost of private power development (table no. 106)	31,189,044
Total	35,789,044

1664. A summary of cost of these combined navigation and power works is given in table no. 224.

TABLE No. 224.—*Summary of cost of constructing locks and other necessary improvements for navigation in connection with power development*

[Round numbers]

	Navigation features	Power development	Total
Snake River to Priest Rapids	$1,750,000		$1,750,000
Priest Rapids	5,400,000	[1] $60,500,000	65,900,000
Rock Island Rapids	1,800,000	[1] 28,000,000	29,800,000
Rocky Reach	2,300,000	[1] 38,000,000	40,300,000
Chelan	3,000,000	[1] 39,000,000	42,000,000
Foster Creek	5,400,000	[1] 48,300,000	53,700,000
Grand Coulee:			
Low Dam	7,000,000	[2] 107,600,000	114,600,000
High Dam	11,000,000	[2] 171,200,000	182,200,000
Grand Rapids	800,000		800,000
Kettle Falls	4,600,000	[1] 31,200,000	35,800,000
Little Dalles, rock removal	550,000		550,000
Total, with low Grand Coulee Dam	32,600,000	352,600,000	385,200,000
Total, with high Grand Coulee Dam	31,200,000	385,000,000	416,200,000

[1] Includes interest during construction period at 6 percent.
[2] Includes interest during construction period at 4 percent.

The estimated cost, in round numbers, of maintenance and operation of these navigation features is $500,000 a year.

1665. Power development may also be combined with irrigation. The power dams will elevate the water surface and permit of areas being irrigated by gravity from the pools so formed. The total area thus made possible of irrigation will be small, as the valley of the river is narrow and without much bottom land.

1666. The most extensive area that can be irrigated by gravity in this way is situated below the Foster Creek dam site. It lies along the Columbia River and extends up the Okanogan Valley.

1667. The second method by which power can aid irrigation is by providing cheap secondary power for pumping water to the areas which lie above those that can be irrigated by gravity. The area possible of such irrigation is large, the size depending principally upon the cost of pumping water.

1668. The Columbia Basin irrigation project is the outstanding single area that could be irrigated by pumping water from the pool above a dam to be built at the head of Grand Coulee. The details of a plan for such irrigation are given in paragraphs 1574–1611 as plan no. 4-A.

1669. A further discussion of the combination of this irrigation project with power development will be found in following chapters.