6.0 Black Rock Reservoir Operation

6.1 Operations Concept

The following discussion focuses on the potential Black Rock reservoir operation given the availability of inflow from the Columbia River [3] and irrigation water for outflow from a Black Rock reservoir. Annual uncontrolled reservoir losses resulting from evaporation and seepage would need to be replaced.[5]

For this Assessment, the preliminary reservoir related operational parameters are summarized as follows:

- The only Columbia River water available for diversion would be that in excess of seasonal instream flow targets established in the December 2000 FCRPS Biological Opinion [4] and flow objectives for nonlisted salmon downstream from Priest Rapids Dam at Vernita Bar.

- Roza and Sunnyside Divisions would receive their water right supply entirely from a Black Rock reservoir. The monthly allocation and combined total supply (840,400 acre-feet) are as shown in table 3-6.[6] The combined maximum peak rate of withdrawal from the reservoir would be 2,500 cfs.

- Water delivery to Roza and Sunnyside Divisions would be reduced during proration years in the Yakima River basin consistent with Yakima Project operational procedures except that the proratable portion of their water rights would be not less than 70 percent of a full supply.

- No irrigation delivery of reservoir water would take place during the initial fill.

- The operational goal would be to maximize reservoir contents to assure carryover supplies for the water exchange. When water was available for pumping, and when the reservoir was less than full, pumps would operate to capacity to refill the reservoir.

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[5] Annual evaporation and seepage losses from the large reservoir are estimated at 45,100 acre-feet and 38,500 acre-feet from the small reservoir.

[6] As previously indicated, the water availability assessment [3] was based on a 840,400-acre-foot Roza and Sunnyside Division water exchange (810,400 acre-feet of April through October water rights and 30,000 acre-feet of March flood waters.)

6.2 Reservoir Capacity

As described in sections 3.2.4 and 5.6.10, two reservoir sizes were selected for analyses in this Assessment: a large reservoir with 1,300,000-acre-foot active capacity and a small reservoir with 800,000-acre-foot active capacity. Both reservoirs would contain inactive storage space of 157,610 acre-feet.

6.3 Operational Analysis

Reservoir operation related to inflow was analyzed through use of simulated Columbia River flows generated by BPA's Hyd-Sim computer model of the FCRPS. Hyd-Sim uses historic runoff over the 50-year period of 1929-1978, modified to reflect the current FCRPS operating requirements of each project, and the 1980 level of agricultural diversions. Reclamation used the simulated flows from this model to analyze pumping scenarios for a Black Rock reservoir as described in section 3.2. This analysis identified a need to pump throughout the year when flows were in excess of the flow targets, when reservoir space was available to meet identified irrigation demands, and to offset uncontrolled losses. A minimum 3,500-cfs pumping rate would be required in conjunction with the large reservoir and 6,000 cfs would be required with the small reservoir.

Adjustment of the irrigation delivery was necessary to account for proration conditions that would have been applied within the Yakima River basin in the 1929-1978 period. Based on data contained in the 1999 *Yakima River Basin Water Enhancement Project, Washington, Final Programmatic Environmental Impact Statement* [16], proratable water rights holders would have received less than their full water rights in 12 of the 50 years.

6.3.1 Time Required for Initial Reservoir Filling

Depending on Columbia River water availability conditions and assuming no delivery of stored water during the initial filling, the time to fill the 1,300,000-acre-foot reservoir would be 6 to 30 months with a 3,500-cfs pump capacity. The 800,000-acre-foot reservoir would take 2 to 13 months to fill with a 6,000-cfs pump capacity. The 157,610-acre-foot inactive pool for both reservoir sizes and pump capacities would fill in 1 month.

6.3.2 Annual Pumping

The volume of water pumped each month would vary in relation to the volume of Columbia River water available in excess of instream flow targets, the availability of reservoir space, and pump capability. The maximum monthly volume of water that could be pumped follows:

3,500-cfs pumping capability:
- 30-day period - 208,264 acre-feet
- 31-day period - 215,206 acre-feet

6,000-cfs pumping capability:

30-day period - 357,025 acre-feet

31-day period - 368,925 acre-feet

Using the two pumping plant/reservoir configurations and simulation of the 1929-1978 flow records, tables 6-1 and 6-2 show the monthly pumping that would have occurred.

Table 6-1. Monthly water volumes that could be pumped from Priest Rapids Lake for a 1,300,000-acre-foot active capacity reservoir and a 3,500-cfs pumping capacity (acre-feet)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1929	215,206	0	0	158,859	0	0	0	0	0	0	0	208,264	582,330
1930	215,206	0	0	0	194,380	0	0	0	0	0	0	208,264	617,851
1931	215,206	0	0	0	0	0	0	0	0	0	0	208,264	423,471
1932	215,206	0	0	0	0	215,206	208,264	215,206	208,264	215,206	0	208,264	1,485,619
1933	215,206	0	215,206	30,182	2,062	0	0	0	208,264	215,206	0	208,264	1,094,392
1934	215,206	33,133	1,656	1,714	2,062	32,932	93,520	133,997	0	0	0	208,264	722,484
1935	215,206	0	197,811	1,714	2,062	0	0	0	0	3,158	0	208,264	628,216
1936	215,206	0	0	0	0	70,835	0	215,206	0	0	0	208,264	709,512
1937	215,206	0	0	0	0	0	0	0	0	0	0	208,264	423,471
1938	215,206	0	215,206	215,206	194,380	215,206	33,528	215,206	0	0	0	208,264	1,512,205
1939	215,206	0	0	215,206	0	186,829	0	0	0	0	0	208,264	825,507
1940	215,206	0	215,206	211,836	1,829	32,932	0	0	0	0	0	208,264	885,274
1941	215,206	0	215,206	157,429	0	0	0	0	0	0	0	208,264	796,106
1942	215,206	0	215,206	98,447	2,062	0	0	0	140,623	215,206	0	208,264	1,095,016
1943	189,491	0	3,660	1,714	2,062	32,932	93,001	133,235	150,476	153,282	0	208,264	968,117
1944	101,934	0	1,513	1,714	0	0	0	0	0	0	0	208,264	313,426
1945	215,206	0	0	0	0	0	0	0	0	0	0	208,264	423,471
1946	215,206	0	215,206	215,206	194,380	215,206	86,638	141,514	0	215,206	0	208,264	1,706,829
1947	194,152	0	3,660	1,714	2,062	32,932	0	215,206	0	215,206	0	208,264	873,196
1948	206,462	2,004	1,656	1,714	2,062	32,932	36,366	180,757	151,393	154,203	0	208,264	977,812
1949	103,762	0	3,660	1,714	2,062	32,932	93,520	133,997	0	0	0	201,536	573,182
1950	215,206	0	113,341	46,739	2,062	32,932	93,520	133,997	151,393	154,203	0	208,264	1,151,657
1951	103,762	2,004	1,656	1,714	2,062	32,932	93,520	133,997	0	215,206	0	208,264	795,117
1952	194,152	2,004	1,656	1,714	2,062	32,932	93,520	133,997	0	0	0	208,264	670,300
1953	215,206	0	0	199,525	2,062	28,114	0	215,206	163,703	154,203	0	208,264	1,186,285
1954	103,762	778	1,656	1,714	2,062	32,932	46,760	180,757	151,393	154,203	76,551	182,784	935,351
1955	52,692	0	3,654	1,714	0	0	0	0	208,264	215,206	0	208,264	689,795
1956	215,206	35,195	1,656	1,714	2,062	32,932	93,520	133,997	151,393	154,203	0	208,264	1,030,142
1957	103,762	0	3,660	1,714	0	34,994	46,760	180,757	151,393	0	0	208,264	731,303
1958	215,206	0	46,418	1,714	2,062	32,932	0	215,206	163,703	0	0	208,264	885,506
1959	215,206	44,762	1,656	1,714	2,062	32,932	46,760	180,757	151,393	154,203	0	208,264	1,039,709
1960	103,762	2,004	1,656	1,714	2,062	32,932	93,520	0	208,264	215,206	0	208,264	869,384
1961	119,884	2,004	1,656	1,714	2,062	32,932	46,760	180,757	151,393	0	0	208,264	747,426
1962	215,206	0	12,811	1,714	0	0	128,513	0	0	0	0	208,264	566,509
1963	215,206	208,264	123,544	1,714	2,062	32,932	0	0	0	7,816	0	208,264	799,803
1964	215,206	0	215,206	170,823	2,062	0	0	0	208,264	215,206	0	208,264	1,235,033
1965	215,206	25,295	1,656	1,714	2,062	32,932	93,520	133,997	151,393	154,203	0	208,264	1,020,242
1966	103,762	2,004	1,656	1,714	0	14,927	46,760	0	0	215,206	0	208,264	594,293
1967	215,206	0	163,362	1,714	2,062	32,932	46,760	0	208,264	215,206	0	208,264	1,093,771
1968	166,644	2,004	1,656	1,714	2,062	32,932	0	0	208,264	215,206	0	208,264	838,747
1969	213,404	2,004	1,656	1,714	2,062	32,932	93,520	133,997	151,393	132,394	0	208,264	973,340
1970	103,762	0	3,660	1,714	2,062	32,932	0	0	208,264	0	0	0	352,393
1971	215,206	0	215,206	211,836	2,062	32,932	93,520	133,997	151,393	154,203	0	208,264	1,418,619
1972	103,762	989	1,656	1,714	2,062	32,932	46,760	180,757	151,393	154,203	76,551	182,784	935,561
1973	52,692	0	3,660	1,714	0	0	0	0	0	0	0	0	58,065
1974	215,206	0	215,206	215,206	143,027	32,932	93,520	133,997	151,393	154,203	76,551	182,784	1,614,026
1975	52,692	0	3,660	1,714	2,062	32,932	0	215,206	163,703	154,203	0	208,264	834,436
1976	103,762	2,004	1,656	1,714	2,062	32,932	93,520	133,997	53,685	199,857	76,551	182,784	884,523
1977	52,692	0	3,660	1,714	0	0	0	0	0	0	0	208,264	266,330
1978	215,206	0	215,206	98,447	2,062	32,932	46,501	179,736	0	215,206	0	208,264	1,213,561

Table 6-2. Monthly water volumes that could be pumped from Priest Rapids Lake for an 800,000-acre-foot active capacity reservoir and a 6,000-cfs pumping capacity (acre-feet)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1929	206,323	0	0	5,017	0	0	0	0	0	0	0	357,025	568,365
1930	368,925	0	0	0	115,269	0	0	0	0	0	0	357,025	841,219
1931	366,595	0	0	0	0	0	0	0	0	0	0	357,025	723,620
1932	368,925	0	0	0	0	44,035	91,910	131,633	97,510	88,401	0	254,600	1,077,015
1933	51,723	0	3,405	1,612	1,884	0	0	0	357,025	205,000	0	257,655	878,304
1934	52,323	1,838	1,567	1,612	1,884	32,563	92,947	133,158	0	0	0	357,025	674,916
1935	256,310	0	3,405	1,612	1,884	0	0	0	0	1,842	0	357,025	622,078
1936	368,925	0	0	0	0	41,320	0	262,083	0	0	0	357,025	1,029,353
1937	256,310	0	0	0	0	0	0	0	0	0	0	357,025	613,335
1938	368,925	0	156,359	1,612	1,884	32,563	15,383	179,631	0	0	0	357,025	1,113,381
1939	256,310	0	0	5,017	0	32,385	0	0	0	0	0	357,025	650,738
1940	368,925	0	102,731	1,612	975	32,563	0	0	0	0	0	357,025	863,831
1941	368,925	0	62,488	1,612	0	0	0	0	0	0	0	357,025	790,050
1942	368,479	0	3,405	1,612	1,431	0	0	0	82,030	331,638	0	228,630	1,017,226
1943	46,625	0	3,405	1,612	1,884	32,563	92,429	132,395	149,484	152,035	0	256,128	868,559
1944	52,023	0	821	1,612	0	0	0	0	0	0	0	357,025	411,481
1945	368,925	0	0	0	0	0	0	0	0	0	0	278,578	647,504
1946	368,925	0	145,035	22,268	1,884	32,563	55,100	140,388	0	303,357	0	257,655	1,327,176
1947	52,323	0	3,405	1,612	1,884	32,563	0	226,105	0	150,640	0	325,269	793,800
1948	52,323	1,838	1,567	1,612	1,884	32,563	21,083	179,631	150,401	152,956	0	257,655	853,513
1949	52,323	0	3,405	1,612	1,884	32,563	92,947	133,158	0	0	0	117,563	435,454
1950	368,925	0	18,179	1,612	1,884	32,563	92,947	133,158	150,401	152,956	0	257,655	1,210,280
1951	52,323	1,838	1,567	1,612	1,884	32,563	92,947	133,158	0	303,357	0	257,655	878,903
1952	52,323	1,838	1,567	1,612	1,884	32,563	92,947	133,158	0	0	0	357,025	674,916
1953	256,310	0	0	5,017	1,884	16,216	0	226,105	150,401	152,956	0	257,655	1,066,544
1954	52,323	416	1,567	1,612	1,884	32,563	46,474	179,631	150,401	152,956	76,048	181,607	877,481
1955	52,323	0	3,399	1,612	0	0	0	0	357,025	206,883	0	257,655	878,897
1956	52,323	1,838	1,567	1,612	1,884	32,563	92,947	133,158	150,401	152,956	0	257,655	878,903
1957	52,323	0	3,405	1,612	0	34,446	46,474	179,631	150,401	0	0	357,025	825,317
1958	105,909	0	3,405	1,612	1,884	32,563	0	226,105	150,401	0	0	357,025	878,903
1959	105,909	1,838	1,567	1,612	1,884	32,563	46,474	179,631	150,401	152,956	0	257,655	932,490
1960	52,323	1,838	1,567	1,612	1,884	32,563	92,947	0	283,558	152,956	0	257,655	878,903
1961	52,323	1,838	1,567	1,612	1,884	32,563	46,474	179,631	150,401	0	0	357,025	825,317
1962	105,909	0	548	1,612	0	0	127,393	0	0	0	0	357,025	592,488
1963	368,925	22,381	1,567	1,612	1,884	32,563	0	0	0	4,559	0	357,025	790,516
1964	368,925	0	75,883	1,612	1,884	0	0	0	357,025	205,000	0	257,655	1,267,983
1965	52,323	819	1,567	1,612	1,884	32,563	92,947	133,158	150,401	100,824	0	257,655	825,751
1966	52,323	1,151	1,567	1,612	0	8,571	46,474	0	0	368,925	0	357,025	837,648
1967	67,016	0	3,405	1,612	1,884	32,563	46,474	0	330,032	152,956	0	257,655	893,597
1968	52,323	1,135	1,567	1,612	1,884	32,563	0	0	357,025	172,437	0	257,655	878,200
1969	52,323	1,838	1,567	1,612	1,884	32,563	92,947	133,158	150,401	76,606	0	257,655	802,553
1970	52,323	0	3,405	1,612	1,884	32,563	0	0	357,025	0	0	0	448,811
1971	368,925	0	116,895	1,612	1,884	32,563	92,947	133,158	150,401	152,956	0	257,655	1,308,996
1972	52,323	529	1,567	1,612	1,884	32,563	46,474	179,631	150,401	152,956	76,048	181,607	877,594
1973	52,323	0	3,405	1,612	0	0	0	0	0	0	0	0	57,340
1974	368,925	0	368,925	42,131	1,884	32,563	92,947	133,158	150,401	152,956	55,021	181,607	1,580,518
1975	52,323	0	3,405	1,612	1,884	32,563	0	226,105	150,401	152,956	0	257,655	878,903
1976	52,323	1,838	1,567	1,612	1,884	32,563	92,947	133,158	31,316	197,618	76,048	181,607	804,481
1977	52,323	0	2,891	1,612	0	0	0	0	0	0	0	357,025	413,850
1978	368,479	0	3,405	1,612	1,884	32,563	46,214	178,610	0	301,519	0	357,025	1,291,311

Four years in the 1929-1978 period would have little water available for diversion. In 1931, 1937, and 1945, water in excess of flow targets would only be available for diversion in September and October. In those 3 drought years, a Black Rock reservoir would have needed to provide carryover for use during April through August. Similarly, while 1973 has Columbia River water available for pumping for 3 months (November through January), no water would be available for pumping after January, and no water would be available in September. Black Rock reservoir carryover would have been needed to supply the full water delivery criteria in April through September of 1973.

6.4 Reservoir Contents

Typically, reservoir water storage would be highest during the winter months when water was being stored. As water was released during the irrigation season, the storage would decrease, and the water surface would lower. Columbia River water would be available for diversion to a Black Rock reservoir in September and October and often in December through March. As release from a Black Rock reservoir would occur from April through October during the irrigation season, the storage would typically be lowest at the end of August. After August, a Black Rock reservoir would start to refill. Table 6-3 shows monthly maximum, minimum, and average reservoir contents for the 50-year period of analysis.

Table 6-3. End-of-month reservoir contents based on meeting the water delivery criteria (1,000 acre-feet*)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Storage	1,300,000-acre-foot active capacity reservoir											
Maximum	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1223	1300
Minimum	286	284	448	446	444	626	614	480	329	175	21	123
Average	1103	1109	1166	1210	1224	1230	1182	1141	1081	1031	888	983
Average percent full	85	85	90	93	94	95	91	88	83	79	68	76
800,000-acre-foot active capacity reservoir												
Maximum	800	800	800	800	800	800	800	800	800	800	723	800
Minimum	393	391	677	675	673	681	591	461	316	167	20	71
Average	769	768	792	793	795	787	736	695	653	610	468	647
Average percent full	96	96	99	99	99	98	92	87	82	76	59	81
* Add 157,610 acre-feet inactive pool to the above storage numbers (for both reservoir sizes) for the potential reservoir pool available throughout the year.												

Based on the water supply analysis of the 1929-1978 period, it is clear that in some water years it would be necessary to rely primarily on carryover of stored water from prior years to meet the majority of the irrigation delivery criteria. With reference to the 4 water-short years (1931, 1937, 1945, and 1973), the carryover conditions would have been as shown in table 6-4 for the large reservoir and table 6-5 for the small reservoir.

Table 6-4. Dry-year carryover based on a 1,300,000-acre-foot active capacity reservoir and 3,500-cfs pumping capacity

Period	Pumped	Released	Seepage Evaporation Losses	End-of-Month Reservoir Content
	(acre-feet)			
Aug 1930	0	119,600	5,800	475,400
Sept 1930	208,300	83,700	4,300	595,700
Oct 1930	215,200	40,800	2,900	767,200
Nov 1930 - Aug 1931	0	567,500	37,800	161,900
Sept 1931	208,300	83,700	4,300	282,200
Aug 1936	0	147,300	5,800	483,500
Sept 1936	208,300	101,900	4,300	585,600
Oct 1936	215,200	49,800	2,900	748,100
Nov 1936 - Aug 1937	0	688,700	37,800	21,600
Sept 1937	208,300	101,900	4,300	123,700
Aug 1944	0	134,400	5,800	635,400
Sept 1944	208,300	93,400	4,300	746,000
Oct 1944	215,200	45,600	2,900	912,700
Nov 1944 - Aug 1945	0	668,500	37,800	206,400
Sept 1945	208,300	98,900	4,300	311,500
Aug 1972	0	147,300	5,800	1,223,500
Sept 1972	182,700	101,900	4,300	1,300,000
Oct 1972	52,700	49,800	2,900	1,300,000
Nov 1972 - Aug 1973	5,300	607,900	37,800	659,600
Sept 1973	0	89,900	4,300	564,400

Table 6-5. Dry-year carryover based on an 800,000-acre-foot active capacity reservoir and 6,000-cfs pumping capacity

Period	Pumped	Released	Seepage Evaporation Losses	End-of-Month Reservoir Content
	(acre-feet)			
Aug 1930	0	119,600	4,800	207,100
Sept 1930	357,000	83,700	3,600	476,800
Oct 1930	366,600	40,800	2,600	800,000
Nov 1930 - Aug 1931	0	567,500	32,300	200,200
Sept 1931	357,000	83,700	3,600	469,900
Aug 1936	0	147,300	4,800	344,600
Sept 1936	357,000	101,900	3,600	596,100
Oct 1936	256,300	49,800	2,600	800,000
Nov 1936 - Aug 1937	0	688,700	32,300	79,000
Sept 1937	357,000	101,900	3,600	330,500
Aug 1944	0	134,400	4,800	140,600
Sept 1944	357,000	93,400	3,600	400,600
Oct 1944	368,900	45,600	2,600	721,300
Nov 1944 - Aug 1945	0	668,500	32,300	20,500
Sept 1945	315,400	98,900	3,600	232,700
Aug 1972	79,900	147,300	4,800	724,000
Sept 1972	181,500	101,900	3,600	800,000
Oct 1972	52,400	49,800	2,600	800,000
Nov 1972 - Aug 1973	5,000	607,900	32,300	164,800
Sept 1973	0	89,900	3,600	71,300

Despite significant active storage capacity, the reservoir would have drafted to the lowest level of 21,600 acre-feet in August 1937 (large reservoir) and to 20,500 acre-feet in August 1945 (small reservoir).

6.5 Potential Reservoir Surface Area

Based on an inactive pool of 157,610 acre-feet and end-of-month reservoir contents of the active pool, the surface area (acres) of the summertime reservoir pool would be as shown in table 6-6 during a repeat of the 1929-1978 record period.

Table 6-6. Summertime reservoir pool based on end-of-month reservoir contents and a 157,610-acre-foot inactive pool (acres)

	May	Jun	Jul	Aug	Sep	Oct
large reservoir	(acres)					
Maximum storage	8,732	8,732	8,732	8,732	8,732	8,732
Minimum storage	4,715	3,922	3,127	2,196	2,838	3,701
Average storage	7,984	7,695	7,457	6,924	7,197	7,801
small reservoir						
Maximum storage	6,334	6,334	6,334	6,334	6,334	6,334
Minimum storage	4,619	3,856	3,090	2,189	2,524	4,260
Average storage	5,832	5,618	5,397	4,828	5,571	6,187

7.0 Field Construction Cost Estimates

This chapter presents appraisal-level estimates only of field construction costs. Field construction costs are limited to the costs of construction contracts and do not include noncontract costs such as preparation of final engineering designs and specifications, regulatory compliance and permitting activities, environmental mitigation and monitoring, and construction contract administration and management. Thus, total estimated project costs, which have yet to be prepared, would be substantially in excess of estimated field construction costs.

Field construction cost estimates were prepared for this Assessment solely for screening potential facility options and developing preliminary configurations of the Black Rock alternative. These cost estimates are appraisal level based on available field data, which at this time are considerably limited. Thus, the field construction cost estimates presented here are only a preliminary indication of what actual field construction costs might be. Furthermore, these estimates of field construction costs will inevitably change if more data are collected, designs are refined, and feasibility-level analyses are prepared.

The configuration of the Black Rock alternative facilities and the appraisal-level field construction cost estimates provided in this Assessment reflect a maximum water exchange. A reduction in the amount of exchange water would result in a reduction in facility capacities, and possibly in the construction cost estimates.

7.1 Black Rock Assessment Field Data

Reclamation conducted site topographic work for this Assessment in 2003, and developed 2-foot contour maps for the potential Columbia River intake area, the intake pump/generation plant, the inflow conveyance system, Black Rock dam and reservoir area, the anticipated alignment of the outflow conveyance system, the outlet facility, and Black Rock powerplant. USGS maps with 20-foot-contour intervals provided topographic information not covered by the 2003 topographic work, including the Roza and Sunnyside delivery system alignments and Sunnyside powerplant. For the most part, the above-ground characteristics of the Black Rock site between the Columbia River and Roza Canal are adequately covered.

Field data of the below-ground characteristics are, however, very limited. WIS performed exploratory drilling in late 2002 [11] at five holes along their proposed damsite alignment. Bedrock was encountered at a depth of about 215 feet at the upstream toe of the alignment near the right abutment. In the center of the valley at the maximum section of the dam, depth to bedrock is about 160 feet. Depth to bedrock at the other holes is 10 feet (right abutment), less than 1 foot (left abutment), and about 12 feet (left abutment, upstream toe of dam). Because the actual overburden depth along this alignment significantly exceeded the depth they assumed during their study, WIS identified an alternate alignment located about 1 mile west of the original alignment that appeared to have the potential for shallower overburden depths.

Reclamation's exploratory drilling program during late 2003 and early 2004 focused on seven holes at the alternate damsite that WIS identified. Bedrock was encountered in only four of the seven holes due to limitations of the drilling equipment on site at that time. Bedrock in three holes (in the middle of the damsite alignment) was at a depth of approximately 145 feet, and at about 90 feet in the fourth hole (near the left abutment). One of these holes was drilled to a maximum depth of about 560 feet into the deep bedrock foundation. The top of bedrock is represented by the Pomona Basalt that was intersected in that hole at a depth of about 145.3 feet.

To date, only one groundwater exploratory hole has been drilled to assess the hydraulic conductivity of the reservoir basin. Reclamation used a specific geologic exploration hole drilled to perform a groundwater test to determine localized horizontal water conductivity as well as vertical conductivity between aquifers. While it appears the Pomona Basalt is a hydraulic barrier that may inhibit vertical leakage, this, and the potential for horizontal leakage near the dam abutments and the reservoir rim, needs further investigation. Groundwater flow direction and speed need further investigation to minimize impacts around the dam and reservoir.

Further geologic investigation of the dam and reservoir are necessary to better define top of bedrock and address potential issues relating to stability and strength of the foundation materials, slope stability, deformability of materials, groundwater occurrence and behavior, seepage paths, dewatering requirements, foundation grouting treatment, reservoir water-holding capability, seismicity and faulting, reservoir-induced seismicity, landslides, and sedimentation.

No exploratory drilling has been done at the identified site of the intake pump/generation plant, along the inflow conveyance alignment, at Black Rock reservoir intake and outlet structures, along the outflow conveyance alignment, at the outlet facility and Black Rock powerplant, along the delivery system alignments, or at Sunnyside powerplant. Geologic investigations of these sites are necessary to identify depth of overburden, bedrock characteristics, slope stability, groundwater occurrence, and dewatering requirements.

Field construction cost estimates were prepared within this framework of, and are limited by, available field data. The following sections explain how Reclamation developed the appraisal-level field construction cost estimates for this Assessment.

7.2 Comparison of Major Facilities

Appraisal-level cost estimates for construction pay items of potential major Black Rock alternative facilities [6] located between the Columbia River and Roza Canal MP 22.6 were developed to screen facility options when several options were being considered. For example, two options were being considered for the inflow conveyance system: an all tunnel option and a tunnel/pipeline option. A field cost estimate of each option was developed and the least costly identified.

Cost estimates of construction pay items were prepared using available existing design data from past WIS work and field data collected by Reclamation in 2003 and 2004. These cost estimates were generated using industry-wide, accepted cost estimating methodology, standards, and practices and reflect June 2004 prices.

Anticipated in-field activities are the primary basis for preparing cost estimates of construction pay items of the major Black Rock facility options. These in-field activities include those costs that would be incurred by contractors for labor and materials such as the following:

- Excavation of materials for structure foundations such as pumping plants and dams; and the alignment of tunnels, pipelines, channels, canals, access roads; and relocation of existing facilities
- Drilling and cement grouting in the foundation and abutments of the embankment storage dam
- Furnishing, forming, and placing concrete for structures
- Furnishing, placing, and compacting earth and rock materials for the embankment storage dam and backfilling and covering of structures and pipelines
- Furnishing and installing mechanical and electrical equipment in structures.

Based on preliminary general designs and drawings, approximate quantities (such as cubic yards of excavation, cubic yards of earth and rock material required for embankments, cubic yards of concrete, pounds of steel, and specific items of equipment such as pumps and motors) were developed for the primary activities, or pay items. Unit prices (in June 2004 prices) were then determined and applied against these quantities. Table 7-1 compares construction pay item cost estimates for potential major facility options located between the Columbia River and Roza Canal MP 22.6. It also includes the construction pay item cost for the potential Sunnyside powerplant and bypass structure that would be located at the point of exchange water discharge into Sunnyside Canal at MP 3.83.

Table 7-1. Comparison of appraisal-level construction pay item cost estimates for potential major facility options

Feature	Large Reservoir Pump Only Inflow= 3,500 cfs	Large Reservoir Pump/Generation Inflow= 3,500 cfs	Small Reservoir Pump Only Inflow= 6,000 cfs
Priest Rapids fish screen and intake	$58,035,920	$64,551,120	$78,815,990
Priest Rapids pumping plant	$182,919,070		$275,309,975
Priest Rapids pump/generation plant		$226,254,880	
Black Rock inlet/outlet tower		$85,565,400	
(Priest Rapids to Black Rock reservoir)			
Inflow conveyance:			
(Priest Rapids to Black Rock reservoir)			
all tunnel option	$186,471,700	$186,471,700	$248,397,600
tunnel/pipeline option	$357,838,420		
Black Rock dam:			
concrete face rockfill embankment	$774,496,000	$774,496,000	$621,530,800
central core rockfill embankment	$733,280,000	$733,280,000	$573,117,150
roller compacted concrete	$1,239,036,300	$1,239,036,300	$980,587,000
Low-level outlet works:			
for both embankment dams	$83,494,115	$83,494,115	$79,000,000
for roller compacted concrete dam	$23,384,515	$23,384,515	$22,000,000
Highway and utility relocations	$57,320,000	$57,320,000	$57,320,000
Black Rock reservoir outlet structure	$3,269,850	$3,269,850	$3,269,850
(Black Rock reservoir to Roza Canal)			
Outflow conveyance (2,500 cfs)	$306,402,600	$306,402,600	$306,402,600
(Black Rock reservoir to Roza Canal)			
Black Rock outlet facility:			
1,500-cfs powerplant	$104,010,535	$104,010,535	$104,010,535
900-cfs powerplant	$102,165,985	$102,165,985	$102,165,985
Sunnyside powerplant/bypass	$32,300,000	$32,300,000	$32,300,000

Findings: **The appraisal-level construction pay item cost estimate for the all tunnel inflow conveyance system is $171 million less than the cost estimate for the tunnel/pipeline inflow conveyance system; therefore, the tunnel/pipeline option should be removed from further evaluation.**

The appraisal-level construction pay item cost estimates for the rockfill embankment dams are significantly lower (about $500 million for the large dam and about $400 million for the small dam) than the cost estimates for the roller compacted concrete dams; therefore, the roller compacted concrete dams should be removed from further evaluation.

The appraisal-level construction pay item cost difference between the large dam concrete face rockfill option and the large dam central core rockfill option is $41 million; for the small dam, the

cost difference is $48 million. Both of these rockfill embankment dam options should receive further evaluation.

The difference between the appraisal-level construction pay item cost estimates for the 1,500-cfs and 900-cfs Black Rock powerplants at Roza Canal is less than 2 percent ($2 million). The selection of which option to pursue should consider costs associated with the Roza and Sunnyside delivery systems.

7.3 Comparison of Alternative Configurations

Following screening of facility options, appraisal-level field construction cost estimates were prepared for the major facilities of the three preliminary configurations of the Black Rock alternative. Field costs include the itemized pay items, plus costs for contractor mobilization, plus an allowance for unlisted items (collectively referred to as construction contract costs) and contingencies.

Mobilization costs include mobilizing contractor personnel and equipment to the work site during initial start up. The assumed ±5 percent of the pay items subtotal cost used in this Assessment is based on past experience with similar projects. The mobilization line item is a rounded value per Reclamation rounding criteria that may cause the dollar value to deviate from the actual percentage shown.

Unlisted items are a means to recognize the confidence level in the estimate, the level of detail, and the knowledge of site characteristics that was used to develop the estimated cost. This line item covers minor design changes and also provides an allowance for minor pay items that have not been itemized, but that would have some influence on the total construction cost. Reclamation’s Cost Estimating Handbook guidelines state the allowance for unlisted items in appraisal-level estimates should be at least ±10 percent of the listed items. Typically, a value of ±15 percent is used. Based on the level of detail provided for this Assessment's cost estimates, the unlisted items are set at ±10 percent of the sum of the pay item cost plus mobilization costs for all facilities. The unlisted line item is a rounded value per Reclamation rounding criteria that may cause the dollar value to deviate from the actual percentage shown.

Contingencies are then added to the construction contract cost (the sum of the pay items, mobilization costs, and unlisted items) to determine the field cost. Contingencies are funds to be used after construction starts to pay contractors for items such as overruns on quantities, changed site conditions, and changed orders. Reclamation’s Cost Estimating Handbook guidelines, state appraisal-level estimates should have ±25 percent added for contingencies. Based on the current level of design data, geologic information, and general knowledge of conditions at the various sites, the contingency line item was set at ±25 percent of the construction contract cost for all facilities. The contingency line item is a rounded value per Reclamation rounding criteria that may cause the dollar value to deviate from the actual percentage shown. Table 7-2 shows the estimated field cost for the three preliminary Black Rock alternative configurations located between the Columbia River and Roza Canal MP 22.6. It also includes the field cost for the potential Sunnyside powerplant and bypass structure that would be located at the point of exchange water discharge into the Sunnyside Canal at MP 3.83.

Table 7-2. Comparison of appraisal-level field construction costs for three preliminary configurations of the Black Rock alternative

Feature	Large Reservoir Pump Only Inflow = 3,500 cfs	Large Reservoir Pump/Generation Inflow = 3,500 cfs	Small Reservoir Pump Only Inflow = 6,000 cfs
Priest Rapids fish screen and intake	$58,035,920	$64,551,120	$78,815,990
Priest Rapids pumping plant	$182,919,070		$275,309,975
Priest Rapids pump/generation plant		$226,254,880	
Inflow conveyance (all tunnel)	$186,471,700	$186,471,700	$248,397,650
Black Rock inlet/outlet tower		$85,565,400	
Black Rock dam (central core rockfill embankment)	$733,280,000	$733,280,000	$573,117,150
Low-level outlet works	$83,494,115	$83,494,115	$79,000,000
Highway and utility relocations	$57,320,000	$57,320,000	$57,320,000
Black Rock reservoir outlet structure	$3,269,850	$3,269,850	$3,269,850
Outflow conveyance (2,500 cfs)	$303,132,750	$303,132,750	$303,132,750
Black Rock outlet facility (1,500 cfs)	$104,010,535	$104,010,535	$104,010,535
Sunnyside powerplant and bypass	$32,302,450	$32,302,450	$32,302,450
Subtotal of pay items	**$1,744,236,390**	**$1,879,652,800**	**$1,754,676,350**
Total mobilization costs (±5%)	**$87,600,000**	**$94,600,000**	**$87,600,000**
Total unlisted items (±10%)	**$165,163,610**	**$182,747,200**	**$184,723,650**
Construction contract cost	**$1,997,000,000**	**$2,157,000,000**	**$2,027,000,000**
Total contingencies (±25%)	**$510,000,000**	**$540,000,000**	**$480,000,000**
Total field cost	**$2,507,000,000**	**$2,697,000,000**	**$2,507,000,000**

The configuration of the large reservoir pump/generation option and the prior WIS work documented in their May 2002 report [2] for Benton County are similar in many respects. Following completion of the engineering work for this Assessment, Reclamation requested Benton County's assistance in obtaining WIS's review of this work. The WIS review focused primarily on differences in field construction cost estimates prepared by WIS and Reclamation. The November 30, 2004, letter from WIS to Reclamation provides the results of this review and is included in appendix B of this Summary Report.

Findings: **The appraisal-level field construction cost estimates for the large reservoir 3,500-cfs pump only option and the small reservoir 6,000-cfs pump only option are the same. Both reservoir sizes should receive further evaluation. Further analysis of the extent of the water exchange, timing of Columbia River water availability and diversions, economics, and other aspects would help refine the most desirable storage/pump configuration.**

The appraisal-level field construction cost estimate for the large reservoir 3,500-cfs pump/generation option is $190 million greater than the field cost estimate for the large reservoir 3,500-cfs pump only option. However, operational studies have not been

completed for the pump/generation option, and these studies may indicate a need to increase plant capacity to ensure annual delivery of exchange water when the facilities were operated in a pump/generation mode.

As discussed in section 5.8.4, upstream delivery plans 4, 4A, and 5 should receive further evaluation, as well as downstream delivery plans 1 and 2 for the Sunnyside Division. The maximum irrigation requirements of the Roza Division downstream from MP 22.6 could be met entirely by Columbia River exchange water without incurring additional costs for construction of water delivery facilities. Table 7-3 provides field construction cost estimates for these five delivery plans.

Table 7-3. Appraisal-level field construction cost estimates of select delivery system plans

	Sunnyside Division		Roza Division and Terrace Heights, Selah-Moxee, and Union Gap Irrigation Districts		
	(million $)				
	Plan 1	Plan 2	Plan 4	Plan 4A	Plan 5
Subtotal of Pay Items	$138.20	$44.83	$39.00	$43.00	$4.10
Mobilization (±5%)	$6.90	$2.20	$2.00	$2.00	$0.20
Unlisted Items (±15%)*	$19.90	$6.97	$6.00	$6.00	$0.70
Construction Contract Cost	$165.00	$54.00	$47.00	$51.00	$5.00
Contingencies (±25%)	$45.00	$14.00	$12.00	$13.00	$1.30
Total Field Cost	$210.00	$68.00	$59.00	$64.00	$6.30

* A 15-percent figure is used for unlisted items because of the level of the cost estimate.

As indicated, these appraisal-level field construction cost estimates are based on available, but limited, data and preliminary designs and drawings and professional assumptions [7 and 8]. Field costs are not the total construction cost necessary to take an authorized project to completion.

7.4 Summary of Field Construction Cost Estimates

Appraisal-level field construction costs of major facilities to divert, store, and deliver Columbia River water to Roza Canal MP 22.6 are estimated at about $2.5 to $2.7 billion (June 2004 price levels) depending on the configuration. Appraisal-level field construction costs to build new facilities or modify existing facilities to deliver exchange water from this point to participants' current facilities are estimated at up to $270 million depending on the type of delivery system and amount of a water exchange. Therefore, field construction costs are estimated at $2.8 to $3 billion.

7.5 Total Project Costs

Additional noncontract costs would need to be incurred once a proposed Federal water resource project was authorized and Congress provides construction appropriations. These additional cost estimates, which have yet to be prepared, would include such items as final design data collection, preparation of final designs, preparation of technical specifications, issuing and awarding construction contracts, coordination and project construction management by Reclamation and the contractor(s), and estimated costs associated with environmental activities. These additional costs are estimated to be from 20 to 35 percent of the field construction costs.

Based on current information, on these appraisal-level field construction cost estimates, and on industry-wide, accepted cost estimating methodology, standards, and practices, it is reasonable to anticipate the total project cost of the Black Rock alternative could range from $3.5 to $4 billion.

Additional data should be collected prior to refining potential concepts and project configurations. Value engineering methods of analysis should be applied to identify needs, major cost components, and to reduce overall costs. Value engineering is a problem-solving methodology that examines potential component features of a potential project to determine pertinent functions, governing criteria, and associated costs. Other proposals are then developed that either meet the necessary requirements at lower costs or that increase the long-term value.