Appendix 206

THE COLORADO RIVER COMPACT:

COMMENTS BY A. P. DAVIS, COMMISSIONER OF RECLAMATION

(Extract from the Congressional Record, January 30, 1923, pp. 2713–2717; part of extension of remarks by Hon. Carl Hayden, Representative from Arizona)

DEPARTMENT OF THE INTERIOR,
UNITED STATES RECLAMATION SERVICE,
Washington, January 30, 1923.

HON. CARL HAYDEN,
House of Representatives.

MY DEAR MR. HAYDEN: Reference is made to your letter of January 8, inclosing a list of questions relating to the Colorado River compact as it affects the State of Arizona.

Inclosed please find original and two carbon copies of our replies to the above questions.

Yours very truly, A. P. DAVIS, DIRECTOR.

(Inclosures.)

Question 1. Referring to paragraphs (a), (f), and (g) of Article II of the Colorado River compact as to waters diverted from drainage area of the Colorado River and its tributaries in the States of Colorado, New Mexico, Utah, and Wyoming.

Question 1-A. How many acre-feet of water are now so diverted annually and where is such water being used?

Answer 1–A. The following table gives the present transmountain diversion from the Colorado River watershed, showing the average annual diversion in acre-feet:

Utah:	*Acre-feet*
Strawberry River to Provo River	4, 500
Strawberry River to Spanish Fork River	78, 000
Price River to Spanish Fork River	1, 500
Virgin River to Pinto Creek	23, 000
Total, Utah	107, 000

Colorado:	Acre-feet
Colorado (Grand) to Cache la Poudre	15, 000
Fraser to Clear Creek	500
Blue to Tarryall	800
Eagle to Arkansas	1, 200
Cochetopa to Rio Grande	2, 500
Total, Colorado	20, 000
Total acre-feet existing diversions, upper basin	127, 000

Question 1–B. Where are the proposed projects which contemplate additional diversions from the upper basin and the estimated cost of the same?

Answer 1–B. In Senate Document 142, the following proposed diversions are listed, all in Colorado. No cost data are available:

Proposed diversion (acre-feet annually):	Acre-feet
Colorado (Grand) to Cache la Poudre (irrigation)	10, 000
Fraser to Clear Creek or South Boulder (municipal and irrigation, Denver)	110, 000
Williams Fork to Clear Creek (municipal and irrigation, Denver)	50, 000
Blue and tributaries to South Platte (municipal and irrigation, Denver)	100, 000
Eagle and tributaries to Arkansas	40, 000
Extensions to existing diversions. irrigation	7, 000
Total, Colorado	317, 000

Question 1–C. What is the probable amount of water that will be diverted annually from the upper basin in the future?

Answer 1–C. It does not appear probable that any large increase will take place in diversions from the upper basin in the near future. The only one that can be reasonably included as at all "probable" at the present time would be the proposed Fraser River diversion of 110,000 acre-feet for the Denver City water supply. For purposes of computation, however, we have included the entire amount as listed above.

	Acre-feet
Present diversions	127, 000
Proposed diversions	317, 000
Total	444, 000

Question 2. As to waters diverted from the drainage area of the Colorado River and its tributaries in the States of Arizona, California, and Nevada.

Question 2–A. Is any other such diversion proposed except into the Imperial and Coachella Valleys?

Answer 2–A. No data are at hand in regard to any proposed diversion from the drainage area of the Colorado River in the States of

Arizona, California, or Nevada unless the Imperial Valley diversion be so considered.

Question 2–B. How many acre-feet of water are now being used annually in the Imperial Valley?

Answer 2–B. The present annual diversion of the Imperial Valley Canal is given as follows:

Imperial irrigation district system:	*Acre-feet*
United States land	1, 597, 000
Mexican lands	540, 000
Main canal waste	580, 000
Losses in Alamo Channel	173, 000
Total diversion	2, 890, 000

Question 2–C. How many acre-feet of water will be required to irrigate all of the lands that it is feasible to bring under cultivation in the Imperial and Coachella Valleys?

Answer 2–C. Net ultimate acreage in Imperial irrigation district in the United States and Coachella Valley is given in Senate Document 142, page 48, as 785,000 acres, and, using the duty of water stated in that report, the total requirement would be 3,400,000 acre-feet.

Question 2–D. What is the estimated cost of the All-American Canal and other works for the irrigation of these lands?

Answer 2–D. Senate Document 142, page 86, gives estimated total cost of the All-American Canal and other works as $49,191,000.

Question 3. What are the present, the probable, and the maximum possible number of acre-feet of water that may be used for irrigation from the Colorado River system in each of the four States of the upper division?

Answer 3. The following table answers the question, the quantities being in acre-feet:

Use of Colorado River, upper basin

Upper basin	Acreage irrigated, 1920	Consumption of water	New acreage	Consumption of water	Total acreage	Total consumption of water
Colorado	740, 000	1, 184, 000	1, 018, 000	1, 527, 000	1, 758, 000	2, 711, 000
New Mexico	34. 000	54, 400	483, 000	724, 500	517, 000	778, 900
Utah	359. 000	574, 400	456. 000	684. 000	815. 000	1, 258, 400
Wyoming	367. 000	587. 200	543. 000	814, 500	910, 000	1, 401, 700
Total	1, 500. 000	2, 400, 000	2, 500, 000	3, 750, 000	4, 000, 000	6, 150, 000

Of the above "new acreage" total of 2,500,000 acres, it is estimated in Senate Document 142, page 33, that a total of 1,008,000 acres will be irrigated in the upper basin in the near future.

Question 4. If the maximum quantity of water is diverted for irrigation in the upper basin, how much of it will return to the river by seepage and drainage and be available for use at Lee Ferry?

Answer 4. Above figures are based upon an average figure for "consumptive use"; that is, diversion minus return flow, and are believed to be large enough to include evaporation from local reservoirs which will be used for irrigation. They therefore represent the net reduction in the flow of the river to be anticipated under the assumed conditions.

Question 5. After deducting the maximum quantity of water that may be diverted out of the upper basin and the maximum amount that may be consumed by irrigation and domestic uses, what is your estimate of the average annual run-off from the upper basin in acre-feet at Lee Ferry?

Answer 5.—

		Acre-feet
Mean discharge at Lee Ferry, 1903–1920 (assumed same as Laguna)		16, 400, 000
Past depletion, upper basin, 1,094,000 acres (average) at 1.54 acre-feet per acre		1, 700, 000
Reconstructed river at Lee Ferry		18, 100, 000
Upper basin:		
Maximum consumption	6, 150, 000	
Diversion out of basin	444, 000	
		6, 590, 000
Remaining flow at Lee Ferry		11, 510, 000

Question 6. If the same maximum deductions are made from the quantity of water in the Colorado River when that stream had the least recorded annual flow, how many acre-feet would remain for use in the lower basin?

Answer 6. The above maximum deductions could not be made when the Colorado had its least recorded annual flow because sufficient water would not be available in the tributaries for maximum diversion. Assuming that the consumptive use would be reduced 25 percent during this shortest year, and taking the flow at Lee Ferry, the same as that at Laguna, as given on page 5 of Senate Document 142, we have—

	Acre-feet
Discharge at Lee Ferry, 1902	9, 110, 000
Depletion, 1902 (665,000 acres at 1.54), by 75 per cent	770, 000
Reconstructed river at Lee Ferry, 1902	9, 880, 000
Maximum consumption, upper basin, 1902 (75 per cent of 6,590,000)	4, 940, 000
Available at Lee Ferry, 1902	4, 940, 000

This indicates that under the compact the flow of the lowest year would be available in approximately equal portions for the use of each basin.

Question 7. If a reservoir of 30,000,000 acre-feet capacity had been in existence at that time, how much water would have been carried over from previous years to aid in meeting any deficiency?

Answer 7. Plate XII–A, Senate Document 142, page 30, shows that starting in 1899 with a 26,400,000 acre-foot reservoir half full, the reservoir would have filled in 1900 and again in 1901, and the full demands for irrigating 1,500,000 acres below could have been met not only through 1902 but through the succeeding low years of 1903 and 1904. In addition, sufficient water would have been available for discharge through the months of low irrigation demand to maintain a year around output of 700,000 horsepower.

Question 8. How many acres are now being irrigated; what additional areas can be irrigated from the main Colorado River, and what is the estimated cost of the reclamation of the lands in Arizona within the projects that have been investigated by the Reclamation Service up to the present time?

Answer 8. Senate Document No. 142, gives the following figures for lands irrigated in Arizona, 1920, from the main stream of the Colorado:

Irrigated 1920, Arizona

Main stream:	*Acres*
Parker project	4,000
Yuma project	46,000
Total, 1920	50,000

Additional irrigable, Arizona

Main stream:	*Acres*
Cottonwood Island	2,000
Parker project	106,000
Mojave Valley	26,000
Yuma project	75,000
Cibola Valley	16,000
Isolated tracts	4,000
Total additional	229,000

Cost data for most of the above projects are not available in sufficient detail to be of value. An engineer of the Indian Service estimated in 1920 a cost of $78 per acre for the Parker project, exclusive of storage, flood control, and power (S. Doc. No. 142, p. 55). Gravity lands on the Yuma project are subject to a construction charge of $75 per acre.

77831—48——16

Question 9. I would like to have the same information as to the projects in California on the Colorado River above the Laguna Dam.

Answer 9. Senate Document No. 142 gives the following figures:

	Irrigated, 1920	New acreage	Total
	Acres	*Acres*	*Acres*
Mojave Valley		1,000	1,000
Chemehuevis Valley		2,300	2,300
Palo Verde Valley	35,000	43,000	78,000
Palo Verde Mesa and Chuckawalla Valley		62,000	62,000
Total	35,000	108,300	143,300

Question 10. Is it true that, if the Colorado River compact is adopted, all of the water that Arizona will ever get out of the main river will be enough to irrigate only 280,000 acres of land, of which 130,000 acres are now embraced in the Yuma project and 110,000 acres in the Parker project?

Answer 10. The Colorado River compact does not attempt to divide the water of the river between individual States. Except for rights already initiated by California and Nevada, there is nothing in the compact that will prevent the State of Arizona from taking from the river all the water that it can put to beneficial use. Rights already initiated will have to be respected in any event, and future development under the compact will be undertaken only in competition with the two States named, and with the cooperation instead of against possible opposition of the States of the upper basin. The present and prospective use of water in the lower basin is estimated, as follows:

Use of Colorado River, lower basin

Lower basin	Acreage irrigated, 1920	Consumption of water, acre-feet	New acreage	Consumption of water, acre-feet	Total acreage	Total consumption of water, acre-feet
Arizona	58,000	290,000	229,000	860,000	287,000	1,150,000
California	450,000	2,250,000	490,000	1,540,000	940,000	3,790,000
Nevada	5,000	20,000	35,000	140,000	40,000	160,000
Total, Main River	513,000	2,560,000	754,000	2,540,000	1,267,000	5,100,000

From this the surplus available for any further development that may be found feasible may be deduced as follows:

	Acre-feet
Mean annual flow at Lee Ferry after deducting all future uses in the upper basin (see question 5)	11,510,000
Total visible demands	5,100,000
Surplus	6,410,000

This would irrigate nearly 2,000,000 acres of land in addition to the acreage figured above, and since water must flow downhill, and since a reservoir at Boulder Canyon of the size proposed will completely control the stream at that point, it only remains to find the land to which this water can be profitably applied.

Question 11. What information have you with respect to the Arizona High Line Canal plan?

Answer 11. We have asked our field engineers for report on Arizona High Line Canal, which has just been received as follows:

The Arizona High Line Canal as outlined more recently contemplates—

A storage reservoir at or near Glen Canyon. Its capacity has not been stated in definite terms.

A second dam at Boulder Canyon to be built to elevation 1,350 feet, or 1,375 feet, or a dam at the lower end of the Grand Canyon of a less height that will raise the water to the same elevation.

A tunnel from the Detrital Sacramento Wash through the Black Mountains some 15 or 20 miles in length which would come out on the western side of the Black Mountains in the general region of Eldorado Ferry, water to be delivered at the end of the tunnel at an elevation not less than 1,325 feet.

A large canal, extending southward and generally parallel with the Colorado River, following along the west side of the Black Range, the greater portion of which would be in tunnel from a point back of Eldorado Ferry to Mount Davis. These tunnels may aggregate another 15 miles or more; thence an open canal crossing a detrital wash country with many deep washes southward along the Blue Ridge and Black Mountains, crossing Sacramento Wash and the main line of the Santa Fe Railroad a few miles from Franconia; thence south and southwesterly toward the Colorado River, where it would pass around the west face of the Chemehuevi Mountains and the Williams Mountains; thence easterly along the north side of the Williams River to a crossing on the Williams River. Through this region there would be more or less tunnel work.

A crossing of the Williams River either by a high dam in that stream where the river is confined in a box canyon, through the Rawhide Mountains, or by a high aqueduct or a large siphon. Some surveys are being conducted at the present time by the Arizona Engineering Commission to ascertain data on this crossing. The canal would then run westerly along the south side of the Williams River through the Buckskin Mountains, tunneling through the Osborne Pass; thence in a general southerly direction through the Cactus Plain to the general region of Bouse.

The first tracts of tillable land of any consequence encountered would be that lying within what is commonly called the Bouse Valley. The proposed canal line would probably cross the Phoenix branch of the Santa Fe Railroad between Bouse and Vicksburg. What the irrigable area of these valleys amounts to is as yet an undetermined quantity.

The main canal would continue in a southeasterly direction, passing to the south of the Little Harqua Hala Mountains through a pass that has been estimated to be from 16 to 25 miles in length. This part of the construction would be a deep cut, the depth of the cut depending upon the elevation at which a canal would reach that point. Before reaching this cut the canal would bifurcate. some of the water being taken south and southwesterly to irrigate other possible

areas. It is planned that the water would finally reach Centennial Wash. The south and southwesterly branch would pass between the S. H. Mountains and the Little Horn Mountains to the Palomas Plain, from which point it would be on the Gila watershed and would be conveyed to other lands on the Gila.

These several branches would bifurcate, carrying water to different valleys, some of which contemplate considerable pumping lifts. The acreage under this possible system is impossible to state, as up to the present time it is nothing more than the roughest kind of a guess, and one upon which no figures can be given. There are not sufficient data at hand to make an estimate as to the cost of constructing such a large canal. The Arizona engineering commission is at the present time trying to ascertain the elevation of certain controlling points, and it is hoped that in the near future the commission will be able to give some idea as to the practicability or impracticability of conducting any further investigations as to the merits or demerits of such a scheme.

Question 12. It has been said that the Arizona High Line Canal project is just as feasible as the Columbia River Basin gravity project recently approved by Gen. George W. Goethals. Please compare the main features of these two projects.

Answer 12. As far as this office is advised no surveys or detailed estimates are available from which any statement of the construction quantities or costs involved in the main features of the Arizona High Line Canal can be even approximated. No comparison is therefore now possible.

Question 13. In his report on the Columbia River Basin project, General Goethals discusses a pumping plan which contemplates building a dam 285 feet high across the Columbia River near the head of the Grand Coulee and using the energy thus stored to operate 17 pumps, each with a capacity of 1,000 second-feet, which will raise the water 450 feet to an artificial lake, whence the water flows by gravity to the basin area, where 1,403,000 acres may be irrigated. The total estimated cost of this pumping project is $241,487,285, or $172 per acre, and the annual operating cost is estimated at $1.56 per acre.

It has occurred to me that, as an alternative to the upper and more expensive part of the Arizona High Line Canal plan, consideration might be given to a pumping project, the essential features of which would be as follows:

A. Utilize the power site about 5 miles above Parker, for which application has been made by Beckman and Linden, by constructing a dam about 75 feet high for the generation of hydroelectric energy. If this dam will not provide enough power, after the flow of the Colorado River is regulated, then supplement the same by power developed in the Grand Canyon.

B. Raise the water about 900 feet by pumping from the Colorado River through a conduit or conduits about 15 miles long up the Osborne Wash to the level of the proposed Arizona High Line Canal, from whence it would flow by gravity as proposed in the original scheme.

I shall be pleased to receive your comments on this idea.

Answer 13. As to this, our field engineers report as follows:

This plan appears infeasible, but as a possibility the Arizona Engineering Commission has considered and is considering the possibility of a diversion at this point to divert water for the lands lying along the Colorado River south of the dam site spoken of above, with the possibility of pumping water therefrom to moderate lifts. From this dam site south to a point about opposite Lighthouse Rock, the topography is such that a canal might be constructed. At or near Lighthouse Rock it might be possible to raise water in the distant future some 100 or 150 feet, passing through the Trigo and Chocolate Mountains, reaching the plain lying east of Castle Dome at an elevation that certain lands lying on the lower Gila might be served. The acreage and the difficulties encountered in this are not definitely known and the whole proposition only stands out as a remote possibility of the development of lands on the extreme lower Gila.

Question 14. While I fully realize that the Colorado River compact makes no reference to the location of storage reservoirs on that stream, yet, the subject is of great interest to the people of Arizona. I shall, therefore, appreciate it if you will make a brief comparison of the Bulls Head, Black Canyon, Boulder Canyon, Diamond Creek, and Glen Canyon dam sites.

Question 15. For the same reason, I would like to have a summary of the available information relative to the Sentinel, San Carlos, and Solomonville dam sites on the Gila, and the Horseshoe and Camp Verde dam sites on the Verde River.

Answers 14 and 15. The following table gives the data available in this office relative to these dam sites.

Name	Storage capacity (acre-feet)	Estimated cost [1]	Height of dam (feet) [2]	Width at base (feet)	Depth to bedrock (feet)	Character of rock in walls	Horsepower developed
San Carlos	1,600,000	$9,792,763	249	222	20	Quarzite or quartzitic sandstone.	6,500
Horseshoe	233,000	1,909,000	166	200	30		[3] 20,000
Camp Verde	421,000	1,701,800	210	-------	25	Sandstone	----------
Solomonville-Guthrie	225,800	----------	140	-------	-------	----------	----------
Sentinel	2,200,000	4,250,000	130	-------	(4)	Basalt	----------
Bulls Head	2,000,000	----------	155	-------	-------	Granite	[5] 341,000
Boulder Canyon	31,400,000	55,000,000	594	665	140	do	700,000
	26,500,000	50,000,000	558	-------			600,000
Black Canyon	31,400,000	----------	590	-------	[6] 123	Volcanic breccia; latite, and andesite.	700,000
	26,500,000	----------	555	-------			600,000
Diamond Creek:							
Ultimate	1,250,000	----------	420	-------	45	Granite	935,000
Present	340,000	12,000,000	255	380	45		200,000
Glen Canyon	18,000,000	----------	500	-------	-------	Sandstone	500,000

[1] Costs based on preliminary estimates and incomplete information; subject to revision in all cases.
[2] Above low-water level or stream bed.
[3] Developed at drop 20 miles below dam.
[4] Foundation is lava or cemented gravel underlaid by sand and silt to a depth of at least 200 feet.
[5] Assuming equated flow.
[6] Drilling not completed.

NOTE.—Average annual net evaporation loss measured at Roosevelt is 60 inches, and this figure has been the basis of evaporation estimates for most of the reservoir studies in this region.

Question 16. It has been said that the Colorado floods have never initiated any serious damage to the Yuma project or the Imperial Valley but that the Gila River constitutes the principal menace; that the only method of curbing the Gila is an adequate levee system, which can be constructed in 18 months at one-fifth the cost of the Boulder Canyon Dam. Will expensive levees have to be maintained on both sides of the Colorado River below Yuma after a large flood-control dam has been constructed on the main Colorado River?

Answer 16. A dam at Boulder Canyon will control all the floods on the main river capable of doing any damage at Yuma except those from the Gila, and it is the only reservoir site on the river of sufficient capacity which is below the sources of all these floods. Until the Gila floods are otherwise controlled it will be necessary to maintain levees to prevent damage from the floods on this stream. As is well known, however, floods from the Gila are of flashy character, and while they may be of sufficient magnitude to inflict some damage, they will subside as quickly as they arise and the days and weeks of night-and-day struggle with the river during each recurring Colorado flood will be a thing of the past. Even if a Gila flood should be experienced of sufficient magnitude to break into the Imperial Valley, its quick subsidence would leave the breach practically dry for repair if the water from the main river could be cut off or regulated at Boulder Canyon.

The annually recurring menace to Yuma and the Imperial Valley against which they are without defense at present is that a Gila flood may come down on top of an early Colorado rise or that breaches made by Gila floods may open the way for the summer floods of the Colorado to break into Imperial Valley. The breaks of 1905–6 and the flood of January 1916 illustrate the possibilities of such a combination.

Question 17. It has been said that if the depth to bedrock for the foundation of the proposed dam at Black Canyon is found to be over 100 feet, as it is reported to be at Boulder Canyon, that it might be more economical to build the Glen Canyon Dam first so as to have the benefit of the regulated flow from the upper reservoir during the construction of the deep and difficult foundations either at Black or Boulder Canyons. What are the results thus far obtained in prospecting for bedrock at these dam sites?

Answer 17. The maximum depth to bedrock at Boulder Canyon Dam site is about 140 feet below low water. Foundation and walls are of granite of excellent quality for a dam foundation. At site of the upstream cofferdam a line of drill holes shows a maximum depth of only 36 feet to bedrock. It is not considered advisable, however, to move the dam itself upstream to this point, as both the condition

and the topography of the side walls at this point are much less favorable than at the site under consideration.

The greatest depth to bedrock found so far at Black Canyon is 123 feet. Sufficient borings have not yet been made to develop this site completely, and work is still in progress.

The foundation and walls at Black Canyon are described as a hard volcanic breccia, overlaid by flows of latite and andesite. This formation as exposed in the canyon walls is entirely suitable for the construction of a high masonry dam, and unless future borings disclose unexpectedly inferior material in the foundation or excessive depth to bedrock, the site should be entirely satisfactory for the construction of a high masonry dam.

The rock in the abutments at the Glen Canyon site is a soft reddish sandstone, unsuitable for building stone or for either coarse or fine concrete aggregate, but probably of sufficient strength to support a concrete dam. Foundation conditions have not been fully tested, the single drill hole then being sunk having on December 15, 1922, reached a depth of 60 feet in the fine sand and silt of the river bed, without having reached bedrock. This drill work is being done by the Southern California Edison Co., and we have no later information as to the progress of this drilling.

As to the economy of building Glen Canyon Dam before one at the Boulder or Black Canyon site, attention is called to the fact that Glen Canyon is too far from power markets now available to be of value for power production for many years. For any given capacity up to complete regulation of the stream the height of a dam above low water at Glen Canyon must be greater than one at Boulder Canyon. Taking into consideration the greater distance from sources of supplies and labor, and other unfavorable conditions, a dam at Glen Canyon cannot cost less than a dam of equal capacity at Boulder Canyon, and will produce absolutely no direct financial return for many years.

The amount estimated for river control and diversion during construction at Boulder Canyon is $3,500,000. If the Glen Canyon dam cost $50,000,000, as estimated for Boulder Canyon in the table, one year's interest at 6 per cent would practically absorb the savings on the Boulder Canyon dam, and even assuming for the sake of argument that it would cost only $25,000,000, the saving would be swallowed up in two years. Under most favorable conditions power returns could not be realized in any considerable amount at Boulder Canyon in less time than that.

Question 18. The Interior Department appropriation act for the next fiscal year contains an item making $100,000 immediately available for further engineering investigations on the Colorado River by the United States Reclamation Service. Is it your intention to expend any part of this sum in ascertaining the depth to bedrock and in obtaining other injormation relative to the Glen Canyon dam site?

Answer 18. It had been our intention to undertake the drilling of the Glen Canyon site and push it to a conclusion next winter, beginning as soon as the subsidence of the summer floods would permit. If, however, the work of the Southern California Edison Co., now under way at this site, results in satisfactory development of foundation conditions, it will not be necessary for the Reclamation Service to put in a drill outfit there.

Question 19. Any further comment that you may care to make relative to the approval of the Colorado River compact by the Arizona State Legislature will be appreciated.

Answer 19. The Colorado River compact provides that the lower basin shall be guaranteed an average of 7,500,000 acre-feet of water annually from the upper basin and all of the yield of the lower basin, and that any water not beneficially used for agricultural and domestic uses shall likewise be allowed to run down for use below. This provides for all known uses of water in the lower basin and a very large surplus for such uses as may develop in the future. The greatest merit of the compact from the standpoint of Arizona is that it changes the attitude of the upper States from one of antagonism to one of friendship and advocacy of storage in the lower basin. If this fair offer is now rejected, the opposition of the upper basin to storage for the benefit of the lower basin will have stronger moral ground than ever, and the attitude of antagonism will be accentuated. This would accord with the wishes of those who are opposed to the development of the river and are opposing the compact. Arizona would thereby be placed in a position of preferring contention to development and her interests would suffer accordingly.