Executive Summary

The Willow Springs Water Bank Conjunctive Use Project (WSWB or Water Bank) will leverage one-half million acre-feet of existing groundwater storage facilities and operate conjunctively with the State Water Project (SWP) to improve flexibility of SWP operations and provide tangible, near-term, and lasting benefits for the environment.

Operation of the State Water Project has fundamentally changed since it was designed, constructed, and placed into operation in the 1960s. Increased water demands, higher water quality standards, and new endangered species protections are among the factors restricting the timing and volume of water deliveries originally envisioned.

WSWB is a conjunctive use and reservoir reoperation project integrating the SWP reservoir and conveyance system with south-of-Delta groundwater storage. Through modest reoperation of Lake Oroville and San Luis Reservoir to shift water to the Water Bank, significant volumes of new yield can be captured during high flow periods when Delta outflows are above and beyond regulatory requirements. Under this Proposition 1 Water Storage Investment Program (WSIP) proposal, the Water Bank will pledge a portion of this new yield to enhance environmental resources.

Adding WSWB diversifies the state storage portfolio. The southern California location allows the State to have a more geographically distributed storage portfolio. Water will be stored downstream of the large pumping lift at Edmonston Pumping Plant, increasing the flexibility of when energy needs to be used to pump water over the Tehachapi Mountains. This can provide operational flexibility for the State and optimize when water is pumped to Southern California to minimize energy cost. Expanding storage south of the Delta is important because it mitigates the risk to water supplies in the event of Delta levee failure after earthquakes or floods. It also diversifies the risk from future dam safety issues and from operational issues such as toxic algae blooms.

WSWB modeling assumptions preserve base water supply and regulatory flows. The WSWB adds one-half million acre-feet of new storage to the state water supply system. Any project to be integrated with the existing system will require some degree of system reoperation that would be best done using a comprehensive systems approach. However, for this grant, the applicants have been provided two base CalSim II operations models that have already been optimized for certain water supply and environmental criteria. For the application, WSWB model studies preserve all water supply deliveries and regulatory flows, and float WSWB operations on top of these base simulations. A comprehensive analysis fully integrating the WSWB into operation of the state-wide system would further improve water supply and ecosystem flows. The project is resilient and is expected to produce greater benefits as climate change progresses.

Feather River pulse flow operations were identified as the preferred alternative for demonstrating environmental benefit, based on directly addressing two of the high priority flow and water quality objectives identified by the California Department of Fish and Wildlife. These benefits are expected to increase as climate change impacts increase. WSWB is very flexible and adaptable. Other analyzed benefits include Delta habitat creation funded from water supply revenues. These long-lasting benefits could be an integral part of WSWB implementation if desired.

The WSWB is an early implementation project with an on-line date of 2020. The land has been acquired, environmental documentation is complete, and facilities are partially designed and constructed. SGMA compliance is unambiguously simple; the groundwater basin is adjudicated, and ten percent of the recharged water will be left behind as a basin benefit. The project can begin demonstrating success 10 years or more before new surface water projects. The project will provide a substantial return on the State's investment, with a Public Benefits Ratio of 2.6, and public benefits equal to 82 percent of total benefits. Additional non-monetized benefits include reduced groundwater pumping lift, flood control, and recreation.

Although modest in scale when compared to overall scope of the WSIP program, the WSWB provides storage capacity and operational flexibility that can be leveraged by other elements of the investment program likely to come on line after the WSWB is fully operational.

Project facilities and operations

The Water Bank is an existing facility located in the Antelope Valley in southern California capable of storing one-half million acre-feet of water underground. Under this WSIP proposal, this storage would be operated conjunctively with existing State Water Project (SWP) facilities, allowing capture of additional Delta flows, and thereby increasing overall system yield. By capturing additional wet year flows and storing them in aquifers, these waters would be transformed to dry year reliable water supplies of high value to water users and the environment. Additionally, the Water Bank could also provide vital water supplies during water supply emergencies.

Situated on highly permeable soils near three major water conveyance facilities (the East Branch of the California Aqueduct, the Antelope Valley-East Kern (AVEK) West Feeder, and the Los Angeles Aqueduct), the Water Bank offers water storage opportunities to both upstream and downstream water agencies. The facilities are partially constructed and water was first recharged in 2010. Under this WSIP proposal, Proposition 1 funds would be used to construct 1) a new turnout and bi-directional conveyance pipeline for delivery of supply from the California Aqueduct to existing and additional recharge facilities and for the return of stored water back to the Aqueduct, and 2) a regulating reservoir and additional extraction wells.

WSWB does not rely on any new surface storage facilities to improve water reliability, since it can be operated conjunctively with existing facilities. Consequently, the Water Bank can be put into operation much faster and with fewer environmental impacts than proposals that rely on new dam construction. Environmental documentation is complete. The target online date for WSWB is 2020. Large new dams likely will take at least an additional 10 years to become operational. WSWB can be available during that 10-year window to store surface supplies during the next wet year. The facility has been designed with an Engineer's Cost Estimate that was updated in 2017 based on recently constructed facilities of similar scope and size.

WSWB is a publicly financed (CalPERS) and privately managed water storage facility in the recently adjudicated Antelope Valley Groundwater Basin. Its location within the Antelope Valley results in excellent water quality, which has been monitored annually since 2008 by a Monitoring Committee. The area for recharge and recovery facilities is located about 14 miles west of Rosamond and covers about 13,400 acres.

Figure 1 - Schematic of Willow Springs Water Bank Conjunctive Use Project

WSWB is uniquely situated to contribute towards enhanced efficiency of SWP operations and Delta restoration measures. The Bank has been in partial operation since 2010. In 2011, it recharged roughly 20,000 acre-feet. The Bank's planned capacity would be reached through building the remaining facilities that include the bi-directional conveyance pipeline for delivery to recharge and return conveyance from the added extraction wells and collection system. The fully built-out facilities would include about 1,000 acres of percolation ponds, pump stations, 98 water wells, and an 84-inch bi-directional pipeline to convey water to and from the East Branch of the California Aqueduct. The recharge component is co-located with about 640 acres of existing solar panels.

For demonstrating environmental benefit, pulse flow operations on the Feather River were identified as the preferred alternative for this analysis based on directly addressing two of the high priority objectives identified in the guidance document of the California Department of Fish and Wildlife (CDFW Ecosystem Priorities 2 and 6).

Environmental documentation is complete. The Water Bank's environmental impact report (EIR) was approved by Kern County in 2006; the EIR approved the bank for recharge and recovery capacities of 350 cubic feet per second (250,000 acre-feet per year) and 310 cubic feet per second (225,000 acre-feet per year), respectively, and 500,000 acre-feet of water storage with potential to expand to 1,000,000

acre-feet.[1] Through future agreements with DWR and/or agencies that receive SWP supplies, extracted water would be used to serve water demands south of the Water Bank via the East Branch of the California Aqueduct (or by exchange to other SWP water contractors). Over 60 percent of SWP demands are located south of WSWB.

The Engineer's Cost Estimate identifies $306 million to complete the buildout of WSWB. WSWB is seeking funds under Proposition 1 to support this buildout. In return, WSWB will dedicate a portion of its capacity to public benefits for the life of the project. Under a future agreement with the California Department of Fish and Wildlife (CDFW), stored water would be extracted in dry and critically dry years to provide blocks of water for environmental purposes. For purposes of demonstration of the value of environmental benefits WSWB could provide, this proposal assumes the dedicated blocks of water would be used through a water exchange to enable pulse flow releases from Oroville Reservoir into the Feather River low flow channel in dry and critically dry years to facilitate outmigration of spring and fall run Chinook salmon and for attraction of adult spawning of spring run Chinook salmon.

The capital cost estimate is an Engineer's Cost Estimate updated in 2017 that is based on the project master plan that was completed in early 2016. The Engineer's Cost Estimate is based on standard cost estimating principles, and utilizes recent construction bids when available.

If WSIP funds are made available, WSWB could immediately put it to use. Criteria for siting wells specified in the Master Plan are established and preliminary locations are identified. This project could also leverage other private, state, and federal funding. In 2010, federal funding came from a $5.0 million ARRA grant.[2] Recently, state funding was secured for $1.2 million in grants to develop the potential of using the Bank to reduce energy costs. Additional state and federal funds would enable buildout to proceed more quickly to provide the benefits described in this application.

Integration with state water systems

Conjunctive Operation. Through a future agreement with DWR, the Water Bank could operate conjunctively with the SWP system to increase yield and reliability, while providing enhanced benefits to environmental resources. Current operation of San Luis Reservoir keeps the reservoir nearly full in wet periods. To take full advantage of opportunities to export Delta water during high flow events, a core operation would include pre-release of SWP supplies from San Luis Reservoir and conveyance to the Water Bank. This would provide reservoir space to store available Delta exports during high flow events more quickly than Water Bank recharge capacity would allow. Supplies in Lake Oroville that would eventually be delivered to southern California could also be pre-positioned in the Water Bank. This would improve availability of storage capacity in Oroville, creating opportunities to store additional flood flows and improve flood protection. Water supplies stored in the Water Bank that are above and beyond baseline SWP obligations would be dedicated to providing environmental benefits, improving water supply reliability for California water users, and serving as a vital source of water during emergencies.

Yield from WSWB that is dedicated to environmental benefits would be subject to the terms of an agreement to be developed and executed with CDFW. While this dedicated yield could be used flexibly and adaptively managed, a specific operation was evaluated for this WSIP proposal to demonstrate the

[1] An additional 60 cubic feet per second can be achieved through an in-aqueduct exchange with the SWP contractor Antelope Valley East Kern Water Agency (AVEK). An EIR addendum for the one-million acre-foot storage capacity will be published in early 2018, but this is not needed for the facilities described in this proposal.

[2] The American Recovery and Reinvestment Act of 2009

value of those ecosystem benefits. For the purposes of this proposal, it is assumed that water stored in the Water Bank would be exchanged for a similar quantity of water stored in Lake Oroville during dry and critically dry years. Water recovered directly from the Water Bank would be used to complete delivery of SWP contract water supplies to southern California SWP contractors, while water stored in Oroville Reservoir would be released as pulse flows to benefit salmonids migrating through the Delta and Sacramento and Feather rivers.

WSWB could complement similar facilities in the Central Valley that are part of the Central Valley Project. Water stored in WSWB could be used south of the Delta via exchanges to help fulfill a variety of environmental water roles, including water for the Delta and for wildlife refuges.

Part of the IRWMP. The Bank is an important component of Antelope Valley Integrated Regional Water Management Plan.[3] The objectives in the IRWMP are focused on reliable supply and water quality benefits to the Antelope Valley. SWP reliability and fishery benefits are not included in the IRWMP. Emergency supply and climate change mitigation are common to both the IRWMP and this grant proposal. Additionally, WSWB could be integrated with water recycling, water supply, water quality, and other projects to help diversify portfolios included in IRWM plans throughout the region and the State, to provide for water supply reliability and enhanced ecological benefits.

Increased operational flexibility

Operational Storage. The Bank could be used to provide storage both on a short-term operating basis and a long-term carryover basis. Seasonally, the Bank could be operated as an expansion of San Luis Reservoir for capture of Delta flows not needed to satisfy regulatory requirements. This additional storage could also be used to add operational flexibility and redundancy for backup when San Luis Reservoir pump storage facilities are offline.

Emergency Storage. Water stored long-term would be available to meet up to 215,000 acre-feet per year of SWP demand during emergencies, such as a major failure of Delta levees or a loss of SWP conveyance north of the WSWB facilities due to seismic events or other unplanned aqueduct outages or an extended drought emergency.

Ecological Benefits. Under this proposal, an agreement would be developed and executed with CDFW to manage a block of water dedicated to produce ecosystem benefits. That block of water could be managed adaptively and used productively in a variety of ways. For the purpose of demonstrating environmental value for this proposal, it assumed the block of water would be exchanged for similar supplies in Lake Oroville during dry and critically dry years and released to provide pulse flows into the Feather and Sacramento rivers.

Pulse flows would be released into the low flow channel between April and June to facilitate the outmigration of spring and fall run Chinook salmon and the attraction of adult spring run Chinook salmon. Water from WSWB will be released to serve SWP contractors on the East Branch of the California Aqueduct to compensate for these fisheries releases.

Importance of new water

The state water system is highly constrained and, as demonstrated by the recent drought, conflicts between human use of water and water for ecosystem needs are commonplace. The modeling

[3] Antelope Valley Integrated Regional Water Management Plan 2013 Update, Appendix K, pp. 3-4 (listed under previous name "Antelope Valley Water Bank")

provided by the CWC suggests SWP deliveries will drop by a half-million acre-feet per year by 2070. These conditions will only be exacerbated by population growth and climate change. The Water Bank would add one-half million acre-feet of groundwater storage conjunctively operated with the State Water Project to help restore flexibility to SWP operations and provide tangible and lasting benefits for the environment. Through modest reoperation of Oroville and San Luis reservoirs to shift water to the Water Bank, this storage would allow greater flexibility in the timing of diversions and deliveries, free up reservoir capacity to capture new water from high Delta outflows that are above and beyond regulatory requirements and use this water to improve SWP reliability while achieving substantial benefits for endangered and other aquatic resources.

Contributions to sustainable groundwater management

WSWB is located in the Antelope Valley and is subject to the terms of the Antelope Valley Groundwater Basin adjudication. Under those terms the Basin and WSWB will be sustainably operated. The basin adjudication also requires that ten percent of all water that is recharged to be left in basin. This benefit helps all the users of the basin, reduces the region's dependency on imported water, and will reduce pumping lifts; this benefit has been accounted for but not monetized in this application.

Ability to expand

The EIR for WSWB was approved in 2006, the property was acquired in 2007 and 2008, and Water Bank facilities are partially built out, with proven ability to store and extract water. WSWB is approved under CEQA for one-half million acre-feet of storage.

Physical and economic magnitude of public and non-public benefits

WSWB will produce both public benefits and non-public water user benefits. WSWB is a conjunctive use and reservoir reoperation project (as defined in Water Code section 79756(a)) that is not subject to a 50 percent funding limitation.[4] There will also be unquantified benefits (e.g., recreation, pump lift reduction, flood damage reduction) that will be discussed qualitatively in the application. Of the five possible public benefit categories, WSWB focuses on the following two:

1. **Ecosystem benefits** — Benefits resulting from operations of the WSWB to Endangered Species Act (ESA) protected fish species in the Central Valley, as well as a variety of other resident and anadromous fish species, can be achieved through water exchanges of WSWB water for use in making pulse flow releases from Lake Oroville into the lower Feather River during the spring of dry and critically dry water years to improve survival and migration of juvenile fall-run and spring-run Chinook salmon and steelhead and increase attraction of adult spring-run Chinook salmon.
2. **Emergency response** – WSWB would enter into agreements to provide water for emergency response to events such as a seismic failure of Delta levees or outages of the California

[4] The WSIP Regulations state that a "conjunctive use project" means the coordinated and planned management of existing surface water and groundwater resources to maximize the efficient use of both resources. Conjunctive use projects may include development of new operational agreements and construction of appurtenant infrastructure. To be considered for a maximum project cost share exception, pursuant to Water Code section 79756(a), these projects shall use existing facilities and resources to the maximum extent practicable. Conjunctive use projects do not include those that meet the definition of groundwater storage projects. (emphasis added) "Groundwater storage project" means a designed project that captures, infiltrates, injects, or recharges (direct or in-lieu) water supplies into a groundwater basin for later use or to avoid or address undesirable groundwater results.

Aqueduct north of the WSWB facilities. The water in WSWB is south of the Delta so it will be available if the levees fail. Up to 215,000 acre-feet of storage will be loaned from the stored reoperation yield, with the loan to be repaid within five years.[5]

Benefits Preface

Compared to proposals for new large surface storage facilities, WSWB is a project of modest scale and scope. Nevertheless, the project offers important benefits both as a stand-alone effort and as a project able to leverage the functionality of other storage and conveyance facilities.

Key attributes of the WSWB are:

- **Timeliness**: Because the proposed project is an expansion of an existing groundwater storage facility, the project can be implemented quickly and, once operational, can generate benefits immediately. The WSWB would thus begin generating benefits as early as 2020, ten years or more before a new surface water reservoir might be able to provide new benefits.
- **Location**: Situated in the Antelope Valley, the WSWB is in a location where groundwater storage can be developed and operated at costs lower than those of similar facilities in the L.A. Basin while providing comparable responsiveness of service. The WSWB will be able to deliver water to Southern California under normal conditions as well as under emergency conditions (e.g., Delta levee failures) or during periods when hydrology or other factors restrict conveyance from the Delta.
- **Ecosystem:** Feather River pulse flow operations were identified as the preferred alternative for demonstrating ecosystem benefit, based on directly addressing two of the high priority flow and water quality objectives identified by the California Department of Fish and Wildlife (CDFW). These benefits are expected to increase as climate change impacts increase.
- **Emergency supply:** Expanding storage south of the Delta would mitigate the risk to water supplies in the event of Delta levee failure or damage to SWP conveyance facilities resulting from earthquakes or floods. It also avoids the risk posed by future dam safety issues and from reservoir operational issues such as toxic algae blooms.
- **New yield:** WSWB is very flexible and adaptable. In addition to ecosystem and emergency supply benefits, through modest reoperation of Lake Oroville and San Luis Reservoir to shift stored water to the Water Bank, the existing SWP system could more effectively divert and store water during intermittent high flow periods when Delta outflows are above and beyond regulatory requirements. A portion of this water will be transferred to others and will offset the costs of supplying ecosystem benefits.
- **Value**: The project will provide a substantial return on the State's investment, with a Public Benefits Ratio of 2.6, and public benefits equal to 82 percent of total benefits. Additional non-monetized benefits include reduced groundwater pumping lift, flood control, and recreation.

Proposed Operation of Willow Springs Water Bank

Conjunctive operations of WSWB and the SWP were modeled using the Calsim II water operations model, jointly developed by DWR and USBR to simulate joint operation of the SWP and Central Valley

[5] Assumed similar to surface water loan practices.

Project (CVP). Operation of WSWB was applied to the 2030 and 2070 climate change scenarios supplied by the CWC. The model was operated to meet all environmental flow requirements, while not diminishing water deliveries to SWP or CVP contractors. Other factors, such as keeping San Luis Reservoir from dipping below Low Point[6] levels more frequently, were also constrained to avoid impacts. Delta salinity impacts were evaluated using the DSM2 model; impacts were generally beneficial (lowered salinity) and below the limits of model accuracy (+/- 5 percent).

Under these proposed operations, water is pre-released from San Luis or pre-positioned from Oroville and delivered to the water bank during periods when water can be conveyed through the Delta. Lowered levels in San Luis allows for the capture of Delta flows in wetter years in excess of those needed to meet established operational and regulatory requirements, creating new yield. Releases are made from the Water Bank to the East Branch to allow a like amount of water to remain upstream to 1) provide "backstop" flows to mitigate potential supply reductions; 2) to allow pulse flow releases from Oroville Reservoir for fishery enhancement, and 3) for improved water supply reliability. Ten percent of the water recharged will remain in the groundwater basin as "leave-behind" as required by the Antelope Valley Groundwater Basin adjudication.[7]

Operation of the Water Bank inflows and outflows is summarized in Table 1, which demonstrates how climate change progression would allow capture of slightly more water under 2070 hydrologic conditions. At times, all the extraction capacity of WSWB will be dedicated to creating new yield for fish protection and backstop operations. This justifies its description as a conjunctive use project with the primary purpose of fishery enhancement.

Table 1 - Summary Average Annual Water Budget of Project Operation under 2030 and 2070 Hydrologic Conditions (thousand acre-feet per year)

	2030	2070
WSWB INFLOW (SOURCES)		
Pre-release from San Luis	16.3	20.1
Pre-position from Oroville	17.6	19.1
WSWB SOURCES	34.0	39.2
WSWB OUTFLOW (SINKS)		
Water supply reliability improvements	13.7	12.1
SWP backstop	2.4	5.9
San Luis backstop	6.1	7.6
Environmental benefits	8.4	9.7
Leave-behind in groundwater basin	3.4	3.9
WSWB SINKS	34.0	39.2

[6] Low water levels in San Luis Reservoir, generally regarded as around 300,000 acre-feet, may facilitate blooms of toxic algae which may compromise the water supply to Santa Clara Valley Water District.

[7] The adjudication states, "Any Stored Water that originated as other Imported Water may be exported from the Basin, subject to a requirement that the Watermaster make a technical determination of the percentage of the Stored Water that is unrecoverable and that such unrecoverable Stored Water is dedicated to the Basin.

Monetized Public Benefits

As outlined in the following section, monetized net public benefits of the WSWB have been determined for ecosystem improvement and emergency response while non-quantified benefits are described for flood control, and recreation purposes.

Ecosystem Benefits

Physical Benefit. Yield from WSWB that is dedicated to ecosystem benefits would be subject to the terms of an agreement to be developed and executed with CDFW. While this dedicated yield could be used flexibly and adaptively managed, pulse flow operations on the Feather River were determined to be the "preferred alternative" that provides the greatest monetized benefit for water dedicated to ecosystem improvement. These benefits directly address Ecosystem Priorities 2 and 6, two of the high priority objectives identified in the WSIP Technical Reference.[8] These priorities are:

- P2 – Provide flows to improve habitat conditions for in-river rearing and downstream migration of juvenile salmonids.
- P6 – Increase attraction flows during upstream migration to reduce straying of anadromous species into non-natal tributaries.

In addition, the Water Bank would address four other Relative Environmental Values (REVs) as described by CDFW. The preferred alternative would most directly improve habitat conditions during spring months in the Feather River low flow channel, followed by the high flow channel and all subsequent downstream reaches including the San Francisco Bay Delta.

As described, the preferred alternative would also address the following two primary and two secondary Recovery Actions for the Feather River outlined by NMFS in the 2014 Recovery Plan[9]:

1. Identify and implement actions intended to minimize straying of Feather River Hatchery salmon and steelhead (Primary Recovery Action).
2. Manage releases from Oroville Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat availability (Primary Recovery Action).
3. Negotiate agreements with landowners and Federal and State agencies to provide additional instream flows or purchase water rights in the Feather River (Secondary Recovery Action).
4. Evaluate pulse flow benefits in the Feather River for adult immigration and juvenile outmigration during peak migration periods for years with low water availability. If pulse flows are determined to be effective for attracting adult spring-run Chinook salmon and steelhead or for improving survival during juvenile outmigration, implement the most beneficial pulse flow regime (Secondary Recovery Action).

In addition to benefiting the Recovery Actions, the preferred alternative would address three of the five listing factors identified by NMFS for the decline in Central Valley spring-run Chinook and steelhead abundance.

[8] Technical Reference pages 4-90 and 4-91

[9] NMFS. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead.

Emergency Response Benefits

Emergency response benefits are the second important monetized public benefit to be generated by the WSWB project. This benefit arises because the location of the WSWB insulates the facility from conditions that may interrupt conveyance into or through the Delta. In addition, as a groundwater storage facility, Willow Springs is resistant to damage from seismic activity that may jeopardize surface water storage and conveyance facilities. Conversion of dry year storage into emergency storage will increase the amount of water available to southern California in the event of earthquakes or other catastrophic events.

Preferred Alternative: Feather River Pulse Flows in Spring of Dry and Critical Years

Benefits resulting from Water Bank operations to Endangered Species Act (ESA) protected fish species in the Central Valley, as well as a variety of other resident and anadromous fish species, can be achieved through exchanges of pre-positioned WSWB water for use in making pulse flow releases from Oroville Reservoir into the lower Feather River during the spring of critically dry and dry water years. These releases are intended to improve survival and migration of juvenile fall-run and spring-run Chinook salmon and steelhead and increase attraction of adult spring-run Chinook salmon.

Under this alternative, the project would provide spring pulse flows to benefit juvenile spring-run and adult fall-run Chinook Salmon, addressing Ecosystem Priority 1 to provide cold water at times and locations to increase the survival of salmonid eggs and fry.[10]

The pulse flow benefit would be achieved by exchanging up to 40,000 acre-feet of water pre-positioned in the Water Bank for water stored in Oroville Reservoir for release into the Feather River low flow channel and subsequently the high flow channel during spring of critically dry and dry water years to benefit salmonid migration and survival. Pulse flow releases would occur in April and May, although pulse flow releases could be made earlier in the spring based on results of real-time monitoring of salmonid migration. Flow released into the low flow channel would be increased to 2,500 cubic feet per second during four two-day pulse flow releases (approximately 10,000 acre-feet per pulse).

A life-cycle approach was used to monetize potential fishery benefits. Table 2 displays data from CDFW 2017 GrandTab[11] used to calculate the average number of adult spring-run and fall-run Chinook salmon (the two species are combined in GrandTab) to the Feather River between 2009 and 2016 (average 54,056 fish).

[10] Technical Reference Table 4-10

[11] California Central Valley Chinook population database report "GrandTab"

Table 2 - Chinook Salmon Lifecycle Calculation

Adult Spawners	54,000
Females	50%
	27,000
Fecundity	3,900
Number eggs	105,300,000
Egg-fry survival[\1]	23%
Number fry	24,219,000

[\1] from 2017 Juvenile Production Estimate

Assuming a value of $2,500 per adult fall-run and $100,000 per adult spring-run Chinook salmon, based on grant submittal guidance,[12] the net monetized benefit between the base case and proposed pulse flow operation was estimated. Results of the analysis, presented in Table 3, show an estimated annual net monetized benefit of $66,500,000 for spring-run and $34,500,000 for fall-run Chinook salmon, for each dry or critically dry year that pulse flow releases are made.

Table 3 - Fishery Benefit from Spring Pulse Flows

		With WSWB Pulse Flows	
	Base Case	During Low Flow	During Pulse Flow
Proportion of Juvenile Migration	100%	30%	70%
Number Migrating Fry	24,219,000	7,265,700	16,953,300
Survival to Golden Gate in Dry/Critical Year	2.80%	2.80%	5.90%
Number at Golden Gate Critical	678,132	203,440	1,000,245
Ocean Survival	2.75%	2.75%	2.75%
Number in Ocean/year	18,649	5,595	27,507
Total	18,649	33,101	
Increase from Base Case		14,453	

	With WSWB Pulse Flows	
	Spring-run	Fall-run
Percentage Run	4.6%	95.4%
Net Change in abundance	665	13,788
Value per Fish[\2]	$100,000	$2,500
Value per Dry/Critical Year	$66,500,000	$34,470,000
	$100,970,000	
Frequency of Dry and Critical Years	36.6%	
Average Annual Benefit	36,940,000	
Present Value Benefit (P/A,50,3.5%)	$755,100,000	

[\2] From CWC Technical Reference, p. 3-23

Adult Chinook salmon have been shown to be attracted by pulse flows and to increase upstream migration prior to spawning.[13] Pulse flows on the lower Feather River during the adult spring-run

[12] CWC Technical Reference p. 5-32

[13] Peterson et al. 2017; Del Real and Saldate 2013, 2015; NMFS 2009; Marston et al. 2012

Chinook salmon migration period, especially during dry and critical water years when attraction flows are reduced, would be expected to increase adult attraction and reduce the potential for adult straying.

Adult straying rates for Chinook salmon produced in the Sacramento River basin have been reported to typically be low (approximately 1%[14]) for salmon imprinted on natal waters. Pulse flow operations would increase adult spring-run Chinook salmon attraction to the Feather River and reduce straying to 0.5 percent. The number of Spring-run Chinook salmon returning to the Feather River between 2010 and 2016 has averaged 2,934 fish per year.[15] Assuming average adult escapement in dry and critically dry years of 2,934 salmon, the net benefit of pulse flows is estimated to be 15 adult spring-run Chinook salmon per pulse flow year. Therefore, these pulse flows will address Ecosystem Priority 6 to **i**ncrease attraction flows during upstream migration to reduce straying of anadromous species into non-natal tributaries.[16]

Assuming a value of $100,000 per adult spring-run based on grant submittal guidance, the estimated monetized value is $1,500,000 in each dry or critically dry year that pulse flow releases are made as shown in Table 4.

Table 4 - Pulse Flow Benefits to Adult Spring-Run Chinook Salmon

	Base Case	With WSWB Pulse Flows
Adult Spawners	2,934	2,934
Stray Rate	1.0%	0.5%
Number Adults Straying per year	29	14
Improvement from Base Case		15
Value per Fish\2		$100,000
Value per Dry/Critical Year		$1,500,000
Frequency of Dry and Critical Years		36.6%
Average Annual Benefit		$549,000
Present Value Benefit (P/A,50,3.5%)		$10,800,000

\2 From CWC Technical Reference, p. 3-23

Delta Habitat Restoration Alternative

Water stored in the Willow Springs Water Bank south of the Delta has a high value for municipal water supplies, especially in critical water years. As an alternative to the pulse flow operations, water stored in the Water Bank could be transferred to a third party in dry and critical water years and the proceeds used to fund shallow water aquatic habitat in the Delta (Priority 11). This analysis is described in the Ecosystems Benefits attachment.[17]

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[14] Marston *et al.* 2012

[15] GrandTab 2017

[16] Ecosystem Priority (6) Increase attraction flows during upstream migration to reduce straying of anadromous species into non-natal tributaries.
Increase water flow (in cfs) at appropriate locations (river system and stationing) and timing (within-and among-year).
Abundance (#, % change) or proportion of stray vs. indigenous adults (Technical Reference Table 4-10)

[17] See Public Benefits Tab, Attachment A2 - Ecosystem Benefits, File WSWB_EcoBenefit_1of1, Section 4-2

Summary of Monetized Fishery Benefits

The estimated monetized ecosystem benefits to salmonids of the WSWB are presented in Table 5 below.

Table 5 – Summary of Monetized Fishery Benefits

	Spring-Run Chinook	Fall-Run Chinook	Winter-Run Chinook	Total Annual Salmonid Benefit	Present Value Benefit
Preferred Pulse Flow Alternative					
Spring Pulse for juvenile survival	$24,330,000	$12,610,000	--	$36,940,000	$755,100,000
Spring pulse for spring-run adult attraction	$549,000	--	--	$549,000	$10,800,000
Total	$24,879,000	$12,610,000	$0	$37,489,000	$765,800,000
Delta Habitat Restoration Alternative					
1,000 acres of Delta shallow water habitat\1	$17,000,000	$8,920,000	$4,160,000	$30,080,000	$520,500,000

\1 Present value adjusted for on-line dates of 2026 and 2031 for first and second 500-acre habitat additions

Emergency Response Benefits

WSWB would enter into agreements to provide water for emergency response to events such as a seismic failure of Delta levees or outages of the California Aqueduct north of the WSWB facilities. Up to 215,000 acre-feet of storage will be loaned from the stored reoperation yield, with the loan to be repaid within five years. It is assumed that such an event will happen once in the 50-year life of the project, and the chance of the event occurring is equal in all years. It is assumed that the water would be valued at the value for critical year Delta export water given in Table 5-5 of the Technical Reference. Assuming an average rate of filling, the storage benefit will be available after seven years of operation and will have a present value of $38.3 million. This analysis is presented in the Emergency Response Benefits attachment.[18]

Non-monetized Public Benefits

Flood Control Benefits

A challenge in quantifying flood control benefits is that the volume of storage needed to reduce flood peaks sufficiently to generate quantifiable flood control benefits (e.g., reduce flooding damage) exceeds the volume of releases needed to develop ecosystem benefits. Therefore, while the volume of "pre-positioned" WSWB storage that will be released from Oroville is sufficient to apply standard methodologies to estimate physical ecosystem benefits, the volume of storage created by releases of "pre-positioned" water will not reduce flood peaks adequately to support a reliable calculation of avoided flood damages. Therefore, no quantitative estimate of flood management benefits attributable to this project is attempted.

When viewed as a stand-alone project, the flood control benefits of the WSWB are marginal. However, flood management is an instance where, when taken within the context of other activities that may be

[18] See Public Benefits Tab, Attachment A1 - Emergency Response Benefits Supporting Documents, File WSWB_EmergencyBenSupport_1of1, Section 4-3

supported by the WSIP, the reduction in flood peaks resulting from the full array of projects may generate a worthwhile flood control benefit.

Recreational Benefits

The project will generate local recreation benefits by construction of hiking and walking trails through 320 acres in the immediate vicinity of the recharge facilities. Conjunctive operations with the SWP could allow reservoirs like Perris and Castaic to be operated for recreational enhancement.

Greenhouse Gas Emissions Reductions

The greenhouse gas (GHG) reduction benefits result from onsite renewables, shifting of water deliveries to period of renewable energy surplus, and lack of methane creation in a surface reservoir. These benefits will not use any of the proposed WSIP grant funding. Onsite solar is partially implemented, with an expansion being studied as part of a California Energy Commission (CEC) funded water/energy grant. GHG reductions due to shifts in water delivery to periods of renewable energy surplus will be confirmed in the ongoing CEC water/energy bank study. GHG reductions due to avoidance of using surface water storage reservoirs is a new and emerging area of environmental science. It is due to the creation of an anaerobic layer is surface reservoirs that contributes methane gas to the atmosphere. Methane is a powerful GHG.

The use of groundwater storage at WSWB results in the following GHG reductions:

1. Reduced GHG due to the onsite solar energy = 140,000 metric tons per year (MT/yr)
2. Reduced GHG due to the shift of water deliveries due to the water/energy bank = 94,000 MT/yr
3. Reduced GHGs because WSWB is not a surface reservoir w/methane gas = 59,000 MT/yr (benefit from an avoided action, the construction of an equivalent surface reservoir)
4. Total GHG reduction = 293,000 MT/year, equivalent to taking 62,000 cars off the road.

Non-Monetized Ecosystem Benefits

The project would result in pulse flow releases of 2,500 cubic feet per second for each pulse flow (40,000 acre-feet total) during the spring of critically dry and dry water years.

In addition to the monetized benefits discussed above, pulse flows and/or Delta habitat restoration would provide incremental benefits that have not been monetized which include, but are not limited to the following:

- Pulse flow releases would provide an incremental contribution to increased Delta outflow and the downstream location of X2[19] during the spring of critically dry and dry years that is expected to improve downstream transport of fish eggs and larvae, increase the area of the low salinity estuarine habitat, and provide increased transport of nutrients, phytoplankton, and zooplankton downstream;
- Shallow water habitat restoration in the Delta is expected to increase primary and secondary production and food resources for resident and migratory fish and invertebrates;
- Shallow water habitat restoration is expected to provide additional juvenile and adult foraging habitat for species such as green and white sturgeon, delta smelt, splittail, and other native

[19] The discussion of Delta salinity often invokes "X2," the point identified by its distance from the Golden Gate Bridge where salinity at the channel bottom is 2 parts per thousand (ppt) and is the basis for standards to protect aquatic life (seawater salinity is about 35 ppt).

species as well as for non-native species such as striped bass and largemouth bass that support recreational fisheries in the Delta;

- Shallow water habitat is expected to provide recreational angling and boating opportunities;
- Shallow water habitat is expected to provide added habitat for migratory waterbirds and other wildlife.

Non-Public Benefit Categories

"Non-public benefit" is a benefit provided by a proposed project other than the public benefits identified in Water Code section 79753(a). Among the benefits generated by operation of the WSWB that are not recognized as public benefits in the pertinent section of the Water Code are:

- Sustaining groundwater elevations in aquifers underlying Willow Springs. Beneficiaries include nearby households and disadvantaged communities dependent on groundwater whose water supply security will increase while their pumping costs will decline.
- The conjunctive operation of the WSWB and SWP facilities will generate new net water supplies of about 14,000 acre-feet per year to improve water supply reliability for agencies entering voluntary agreements. The new yield increases the overall yield of the State Water Project.
- The WSWB will reduce energy costs by shifting pumping of imported water from peak hours to non-peak hours. This will be accomplished through onsite storage to avoid pumping wells and booster pumping to the California Aqueduct during peak hours. WSWB may also enable a seasonal shift of when imported water is delivered to Southern California. This is the purpose of an ongoing study of a water/energy bank recently funded by the CEC (EPC-16-026).

WSWB Operating Costs

Project costs are categorized as follows:

- Project operating costs: The annual costs for delivering water to the water bank for recharge and for recovering water from the bank are accounted for as negative benefits in the computation of annual net benefits and are expressed in the benefit component of the project's cost/benefit ratio.
- Project construction and maintenance costs: The costs to construct and maintain project facilities are detailed in the feasibility study included in this application and are expressed as the cost component of the project's cost/benefit ratio.

Delivery**.** Although the WSWB will be served from a new turnout from the California Aqueduct to be constructed by the project, it was assumed that the operations costs of water delivery to the turnout would be comparable to those of water delivered to AVEK turnouts, or about $250 per acre-foot.[20]

[20] Table 31 of the DWR documents *Southern Field Division, Monthly Delivery (East Branch)* report locations (by reach) and volumes of water delivered to each turnout supplying water to AVEK. These tables show the AVEK turnout in Reach 20A to be the most important point of delivery. Table B-25 - *Equivalent Unit Transportation Costs of Water Delivered from or through Each Aqueduct Reach* from Bulletin 132-15 was then used to determine the cost of transportation to Reach 20A ($186.35). The total cost of delivery to Reach 20a was then computed by adding the Delta Water Rate ($58.03) to the cost of transportation to arrive at a total delivery cost of $244. This cost has been rounded to $250 to estimate the cost of returning water via the bi-directional pipeline to the proposed WSWB turnout.

Recovery. The cost for recovery of water is estimated to be $110 per acre-foot.[21] This cost is applied to all returned water including water that is extracted from the WSWB for exchange with AVEK.

Summary of Benefits and Costs

The time series of benefits and operating costs is presented in the Monetized Benefits attachment.[22] This table also shows the present value of the benefits and costs discounted at 3.5% per year to 2015 levels. The project will provide $984 million in total present value benefits and $804 million in total net public benefits over its 50-year project life, with a Public Benefit Ratio of 2.6.

A summary present value benefits and costs is shown in **Table 6Error! Reference source not found.** and is further described in the sections below.

In this application, the net physical and economic public and non-public benefits of the WSWB are quantified, and these net benefits are allocated to support the project's request for Program funding.

Table 6 - Present Value Benefit and Cost Summary

	Present Value Benefit (2015$M)
Preferred Pulse Flow Alternative	
Spring Pulse for juvenile survival benefit	$754.6
Spring pulse for spring-run adult attraction benefit	$11.2
Public Benefits in Delta/Tribs	$765.8
Emergency Response Benefit (215 kaf, once in 50 yrs)	$38.3
Total Public Benefits	$804.1
Net Public Benefits	$804.1
Water Sale Benefits	$179.5
Total Benefits	$983.6
Operation and Maintenance Costs	($177.9)
Net PV Benefits	$805.7
Total Capital Cost	$343.1
Existing Facilities Contribution	($37.4)
Grant Request	$305.8
Percent of Public Benefits provided to Delta and tributaries	95%
Public Benefit Ratio (net public benefits / WSIP funding request)	2.6
Benefit:Cost Ratio (total net benefits / total capital cost)	2.3

[21] Based on a total energy requirement of 1,100 kWh (550 kWh/AF for pumping from wells plus 550 kWh/AF to lift the water to the California Aqueduct) at a $0.10 kWh melded electricity cost yields a total recovery cost of $110/AF.

[22] See Benefit Calculation Tab, Attachment A3 - Monetized Benefits Analysis, File WSWB_MonetizedBenefit_1of1, Section 6-3, Table 6

These analyses present benefits and impacts at similar locations and times and in the same physical units to provide an accurate, reproducible calculation of major monetized net public and non-public benefits. This section also includes qualitative descriptions of ancillary benefits, such as flood control, that are difficult to quantify at the level of benefit expected from the WSWB as a stand-alone effort.

As the detailed analysis of benefits illustrates, 97 percent of the total monetized public benefits are attributable to ecosystem benefits in the Delta and its tributaries.

The capital cost of the project is $343 million, and is expected to produce total benefits of $984 million. $804 million of these benefits (82 percent) will be public benefits, for both the ecosystem and for emergency supply. The project is a conjunctive use and reservoir reoperation project, both classes that are exempted from the 50 percent cost match.

The value of the water supply and emergency response water will be used to defray the cost of providing ecosystem benefits. The public benefits to be provided assume that 100 percent of the grant funding requested will be approved by the Water Commission. A 100 percent grant is being requested. If a lesser grant is awarded, the public benefits would need to be proportionately reduced.

Public Benefit Ratio

The "Public Benefit Ratio" (PBR) is the ratio of the monetized net public benefits to the Program funding request. The net public and non-public physical benefits demonstrate improvements in physical and biological conditions that can be attributed to the WSWB while recognizing the negative impacts of the project.

The analysis of project feasibility presented in this application compares the present value of economic net public and non-public benefits with total project costs. As required by the regulations, this analysis provides the following information:

- The present value of the expected value of economic net public benefits over the planning horizon, expressed in 2015 dollars, discounted to the first year of project operations.
- The estimated Program cost share for each public benefit category, in present value dollars at the first year of project operation and an explanation of how the cost share was calculated, consistent with Technical Reference section 8.

As shown in **Table 6**, the project has a Public Benefit Ratio of 2.6 based on present value public benefits of $804 million and a grant request of $306 million. The project has a Benefit:Cost ratio of 2.3 based on a total cost of $343 million and total present value benefits of $806 million.[23]

Other relevant information

Other benefits of the Willow Springs Water Bank include:

Water Management Benefits

a. Diversifies the Storage Portfolio. The bank's location allows the State to have a more geographically distributed storage portfolio and moves the center of mass of the storage

[23] Using a critical year water sale value of $1,050 in 2030, the B:C ratio would be 2.7 – this is more representative of recent prices in critically dry years.

portfolio closer to the center of demand. Water is stored downstream of the large pumping lift at Edmonston Pumping Plant, increasing the flexibility of when energy is needed to pump water over the Tehachapi Mountains. This can provide operational flexibility for the State and optimize the timing of pumping to Southern California. Expanding storage south of the Delta is important because it mitigates the risk to water supplies in the event of Delta levee failure after earthquakes, floods, etc. It also reduces the risks posed by future dam safety issues and from operational issues such as toxic algae blooms.

b. Mitigates East Branch bottleneck. The Bank enhances the capacity of the East Branch of the California Aqueduct by providing a place to store water upstream of the hydraulic bottleneck at Pearblossom Pumping Plant.

c. Stabilizes Groundwater Elevations. The project will be operated within a managed operating range. The 10 percent leave-behind will contribute to protecting groundwater elevations in the project area.

d. Environmental Benefits. As a groundwater bank, it does not flood habitat, archeological sites, or Native American sites. Instead, it maintains the agricultural character of the area by growing crops when not used for percolation.

e. Helps DACs. The project also has the potential to help Disadvantaged Communities (DACs) in the region. It will provide hiking trails for recreation. It can also provide storage for imported surface water that can be used to replace well water in DAC systems with water quality problems. By stabilizing groundwater elevation, the project will also reduce the well pumping costs for local DACs by raising the water table overall.

f. WSWB becomes more effective with climate change. As climate change increases over time, WSWB's conjunctive use benefits become greater. Total capture rises from 34,000 acre-feet per year in 2030 to 39,200 acre-feet per year in 2070. This reflects more extremes of the wet and dry cycle and the ability of a groundwater bank used conjunctively with surface reservoirs to capture an increasing volume of Delta outflow at times when it provides low environmental value.

Green Energy Benefits

a. Pumped Storage. The Water Bank is evaluating the potential for a 5.2 MW pumped storage component, funded via a grant from the California Energy Commission. The project had the highest ranking of all 21 projects submitted to the CEC for funding requests (GFO-15-309 Group 11). Energy could be generated during peak hours. Also, the onsite reservoir storage that is part of the pumped storage can be used to shift hourly electric load for Demand Response benefits.

b. Reduced greenhouse gasses due to groundwater storage. The greenhouse gas (GHG) reduction benefits result from onsite renewables, shifting of water deliveries to period of renewable energy surplus, and lack of methane creation in a surface reservoir. These benefits will not use any of the proposed WSIP grant funding. Water Bank facilities are co-located with 640 acres of solar panels, enhancing the ability to meet the State's renewable energy goals by producing about 110 MW of renewable energy. Total GHG reduction is estimated to be 293,000 metric tons per year, the equivalent to taking 62,000 cars off the road.

c. Water/Energy Bank. The Water Bank was awarded a California Energy Commission grant of $1.0 M to conduct a "proof of concept" study of a water/energy bank (EPC-16-029). WSWB will use the water bank to shift electric load out of the peak summer period by shifting when imported

water is delivered. This could result in an average Demand Response benefit of 320 MW. The Demand Response benefits can help reduce California's need for peak power generation and can help improve renewables penetration by shifting electric load from a period of shortage to a period of renewable energy surplus.

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