

**TECHNICAL EVALUATION OF OPTIONS FOR LONG-TERM
AUGMENTATION OF THE COLORADO RIVER SYSTEM**

WATER IMPORTS USING OCEAN ROUTES

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ACRONYMS

AF	acre-feet
AFY	acre-feet per year
Basin	Colorado River Basin
CRWC	Colorado River Water Consultants
MG	million gallons
mm	millimeters
NRC	National Resource Council
OTA	Office of Technology Assessment (U.S. Congress)
Seven States	Seven Colorado River Basin States
TMDL	total maximum daily load
ULCC	ultra large crude carrier
U.S.	United States
USBR	U.S. Bureau of Reclamation
USEPA	U.S Environmental Protection Agency
VLCC	very large crude carrier
WDOE	Washington State Department of Ecology

1.0 WATER IMPORTS USING OCEAN ROUTES

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1.1 SUMMARY AND PURPOSE

This discussion of Water Imports Using Ocean Routes is one of a series of White Papers being prepared for the Seven Colorado River Basin States (Seven States). The purpose of the White Papers is to present evaluations of potential options to provide long-term augmentation of the water supply of the Colorado River system. This White Paper presents background information on the overall evaluation program, followed by a preliminary evaluation of the Water Imports Using Ocean Routes option.

1.2 BACKGROUND

The Seven States have authorized Colorado River Water Consultants (CRWC) to provide a technical evaluation of long-term options. The States will supplement the technical evaluations with legal, administrative, and/or institutional considerations.

The White Papers are the first step in an iterative process to develop, screen, and evaluate options. Evaluation parameters will be applied progressively and will be developed in increasing detail as selected options become more promising. In parallel with White Paper development, the CRWC research team will meet with representatives of the Seven States and will refine the White Papers/develop new White Papers based on their input. White Paper results will be reviewed with a Technical Steering Committee comprised of delegates from the Seven States.

Each White Paper will present a brief overview of the option being evaluated, followed by discussions of history and viability of obtaining additional water from the source, location of supply, quantity of water potentially available, water quality, technical issues, general reliability of supply, environmental issues, permitting issues, and project costs. A list of reference documents for each White Paper will be included, and general findings and conclusions will be provided.

1.3 OVERVIEW OF OPTION

Some of the options available for providing long-term augmentation of the water supply within the Colorado River Basin (Basin) include importing water from other sources. This White Paper discusses four options for importing water using ocean routes: undersea aqueduct, tankers, water bags, and towing icebergs. Options for importing water using land-based pipelines are discussed in a separate White Paper. The undersea aqueduct includes constructing an undersea pipeline from the Columbia River to California, where water could be discharged into the water supply system. System features for the undersea aqueduct include transition conduits, undersea pipelines, a terminal shore reservoir, and land based pumping facilities.

Tankers could be used to transport water from Alaska to southern California. System features for the tanker option would include land-based or offshore loading and unloading facilities, a terminal shore reservoir, and pipelines to transport water to and from these facilities.

The third option involves filling large nylon water bags with water from available sources in Alaska or from northern California, towing the water bags to southern California and discharging the water into the distribution system. Similar to the tanker option, system features would include land-based or offshore loading and unloading facilities, a terminal storage reservoir, and pipelines to transport water to and from these facilities.

The final option involves towing an iceberg, wrapped in some type of plastic, to California and capturing the meltwater. System features for this option would include a land-based or offshore facility to dock the iceberg and capture the meltwater.

1.4 HISTORY/VIABILITY OF OBTAINING WATER FROM THIS SOURCE.

1.4.1 Undersea Aqueduct

Pipelines are used in some areas to transport water between land masses typically over short distances and often between islands. The idea of using an undersea pipeline to augment water supplies in southern California has been considered since the early 1970s when the U.S. Bureau of Reclamation (USBR) began reconnaissance studies (USBR 1971) of the concept originally proposed by the National Engineering Science Company (Lee 1965). At that time, the idea was to capture water from rivers in northern California and transport that water through an undersea aqueduct to southern California (Bureau of Reclamation 1969, 1975). It was thought that this concept would eliminate many of the environmental impacts associated with an overland pipeline. The USBR conducted a significant amount of study and evaluation although the planned feasibility studies were not completed.

The undersea aqueduct idea was resurrected during the early 1990s when the governor of Alaska proposed constructing a pipeline from southeastern Alaska to northern California. This concept was evaluated by the Office of Technology Assessment (OTA 1992). That pipeline would be 1,400 to 2,100 miles long, depending on the start and end locations, and would carry 4 million acre-feet (AF) of water annually. No detailed engineering studies were completed, but a preliminary evaluation was conducted. The potential of using an undersea aqueduct to transport water from the Columbia River to California, discussed in this paper, was evaluated based on the USBR and Alaska aqueducts previously proposed.

1.4.2 Tankers

For many years, tankers and barges have been making deliveries to regions willing to pay premium prices for small amounts of fresh water, such as the Bahamas, Cyprus, and other islands with inadequate sources. Tankers have also supplied water during short-term droughts and disasters such as the 1995 Kobe earthquake in Japan (Gleick 2001). Many

single hull tankers became available when changes in petroleum tanker regulations required double hulls. Although contamination issues were a serious concern, it was proposed that these tankers could be used to transport water. Using new single hulled tankers would avoid the contamination issues.

Several companies have made proposals in recent years to use tankers to transport water to areas that need to augment their supplies. Transglobal Trade LLC has entered into long-term lease agreements for bulk water rights from several Native American groups in Alaska with the understanding that water would be shipped to the western United States (U.S.). They have identified needed infrastructure improvements and have stated that they will have the capacity to deliver up to 1,000 AF per day to the California water system. Transglobal Trade LLC plans to purchase and use single hulled tankers to transport water after they have been cleaned and retrofitted (West 2006). Global H2O Resources, a company based in British Columbia, has rights to 4.8 billion gallons of glacier water per year for 30 years under a license granted by Alaska and the City of Sitka. Initially, they are selling bottled water, but have plans for bulk water shipments to Asia and the Middle East. They also plan to build a loading pier in Sitka capable of handling up to 50,000-ton ships (Doyle 2001). An Australian company, Aquatankers, has proposed using specially designed tankers to transport potable water from western Australia to Perth. They have stated that their plan is the most cost-effective and energy efficient method for supplying water to the region (Solar Sailor 2005).

1.4.3 Water Bags

Water bags have been used for about 10 years to augment the water supply of water scarce areas. In 1997, Aquarius Water Transportation began delivering water in 500,000 gallon bags from mainland Greece to nearby resort islands. In 2000, Nordic Water Supply began using 5 million gallon bags to transport water from Turkey to Cyprus. The bags are sausage-shaped and about 200 meters long. In 2002, Nordic Water supply transported about 1.6 billion gallons of water using their water bags. They plan to build larger bags up to 350 meters long that would carry 25 million gallons of water (Doyle 2001). Another inventor, Terry Spragg, has developed a system to link water bags together so several could be towed at the same time (Gleick 2001).

1.4.4 Towing Icebergs

The concept of towing icebergs has been around for a long time, and a considerable amount of study has been devoted to the feasibility of towing and using icebergs as a water source. In the 1950s, John Isaacs, an oceanographer, suggested towing icebergs into Los Angeles. There was an international conference addressing the issue in 1977, and in 1978 the idea of towing icebergs to the U.S. was endorsed by the California State Senate (Eslinger 2004). As recently as May 2006, there were reports that Thames Water was considering towing icebergs from the Arctic to help alleviate drought conditions (Smith 2006). The major problems identified with this concept include the need to wrap icebergs to avoid losing most of the water during transport and energy costs associated with transport. To date, this concept has not been demonstrated to be feasible.

1.5 LOCATION OF SUPPLY

The source of supply for the undersea aqueduct is the Columbia River. The intake facility would be located near the mouth of the river, but far enough upstream to avoid salt water intrusion. The source of supply for both the tanker and water bag options would most likely be rivers in southern Alaska although northern California is also a possibility. Specific rivers have not been identified. Icebergs would most likely be towed from the Arctic.

1.6 AMOUNT OF WATER

It was estimated that the aqueduct proposed by the USBR could supply up to 14 million acre-feet per year (AFY) from six rivers in northern California and Oregon (McCammon 1966). That amount was equivalent to about half of the annual flow, and storage reservoirs were required to capture winter flows. No estimate of water available for the Alaska aqueduct was developed.

The amount of water available for withdrawal from the Columbia River is not known. The amount would depend on the surplus available after other uses were satisfied including currently permitted withdrawals and that needed for fisheries, navigation and other designated uses. The National Research Council (NRC) (2004) was asked by the Washington State Department of Ecology (WDOE) to evaluate the effects of additional water withdrawals because WDOE had many pending water withdrawal permits which at that time exceeded 250,000 AFY. The NRC study did not identify an exact amount of water available for withdrawal, but identified several potential problems with increased withdrawals. Only 1 percent of the total water withdrawals occur during January so more water would be available for withdrawal in the winter.

According to Davidge (1994), southeast Alaska is the most probable source of bulk exportable water using tankers or water bags. This region has a mean annual runoff of about 300 million AF. Peak stream discharges occur in July, August, and September coinciding with traditional peak demand periods. It is estimated that up to 1 million AF of water may be available for water export. The specific amount available would depend on the rivers used and the water rights agreements that would be obtained. According to Transglobal Trade LLC (West 2006), they will have the capacity to deliver about 1,000 AF per day. Alaska Water Exports has applied for water rights to two northern California rivers for a total of 30,000 AFY. According to Solar Sailor (2006), large tankers could have capacities of 90 to 145 million gallons (MG) (276 to 445 AF). Water bags are expected to have capacities of about 13 MG (40 AF) (McCabe 2002).

The total amount of water available in the form of icebergs has not been quantified. A small iceberg contains from 250 to 850 AF of water.

The total annual quantity available under this option was estimated to range from 10,000 to 300,000 AFY.

1.7 WATER QUALITY

The water quality of the Columbia is generally good. The Columbia River is listed on the Clean Water Act Section 303d list for dioxin, and a total maximum daily load (TMDL) was developed by the U.S. Environmental Protection Agency (USEPA). Quality deteriorates somewhat during the summer when urban activities and agricultural return flows have a greater effect on the river. However, the water quality should not pose any special problems for treatment at existing facilities. Specific source rivers in Alaska have not been identified for transport via tanker or water bags. Most rivers in southern Alaska have generally good water quality although some have been degraded due to mining activities, and some have heavy sediment loads. Iceberg water is considered to be extremely pure and free of pollutants. A Canadian company manufactures vodka using iceberg water.

1.8 TECHNICAL ISSUES

1.8.1 Undersea Aqueduct

Construction of an undersea aqueduct would require extensive engineering, geotechnical, and oceanographic feasibility studies prior to implementation. It has been estimated that the oceanographic studies alone could take 10 years to complete. However, the OTA study concluded that the aqueduct could be built if enough time and money were invested (OTA 1992). Some of the major technical issues to be resolved include methods to lay the pipeline, crossing major fault zones and submarine canyons, selection of pipe materials, and design of pumping facilities and storage facilities.

Previous proposals for an undersea aqueduct have included pipelines located several miles from shore at depths of 250 to 300 feet. The bathymetry of some of the areas to be crossed includes slopes of 2 to 8 degrees and irregular sand and mud deposits. There are several large submarine canyons that cut the shelf along the potential pipeline route and would have crossing lengths of 1 to 2 miles (McCammon and Lee 1966).

The selection of pipe materials is also an issue. The USBR aqueduct proposed using high strength fiberglass material that together with the fresh water would produce a buoyant pipeline that would be suspended above but anchored to the bottom. The evaluation conducted for the Alaska aqueduct concluded that not enough is known about those materials for use in the aqueduct. For the Alaska aqueduct, it was estimated that pumping stations would be required about every 150 miles along the route. Many other design issues for the offshore and land-based facilities would need to be resolved.

1.8.2 Tanker Transport

Tankers are currently used in some areas to supplement local water supplies, thus demonstrating the feasibility of making bulk water deliveries using tankers. Very large crude carrier (VLCC) or ultra large crude carrier (ULCC) class tankers, respectively, can carry 225 to 307 AF of water per trip. Turn around time would be about 10 days from southeastern Alaska to California. Tankers could be filled or pumped out in about 20

hours (Davidge 1994). Storage reservoirs large enough to accommodate a full tanker load of water would be required near shore to minimize the amount of time that the tanker stayed in port.

Although it has been suggested that single hull tankers previously used to ship oil could be used to transport water, it would be extremely difficult to adequately clean the vessels so they could be used to transport potable water (Gleick 2001). Fuel costs are a major expense for the tanker option. Aquatankers is proposing using solar sails on their tankers to significantly reduce fuel costs (Solar Sailor 2005).

1.8.3 Water Bags

Water bags are currently used in the Mediterranean and Aegean Seas to transport water. Companies using this technology are working to build bigger bags, potentially up to 25 MG (75 AF) and to design ways to tow more bags at one time. The bags, made of a polyester fabric coated with plastic are 2.0 millimeters (mm) (0.08 inch) thick, and have been compared to the fabric used in car seatbelts.

Use of water bags has had some technical problems. Bags have broken away from the tug boat during transport. Most are now equipped with a radar beacon to help other ships avoid collisions. The routes currently used are relatively short. To be transported along the west coast of the U.S., bags would have to withstand the strain of an ocean voyage. Bags have ripped open during transport on several occasions, especially at unloading terminals (Gleick 2001).

1.8.4 Towing Icebergs

It has been demonstrated that ships can successfully tow icebergs. For example, icebergs are routinely towed away from oil platforms in the North Sea. However, technical issues would need to be addressed before icebergs could be towed to areas where they would be used to augment water supplies. As an iceberg is towed into warmer water, it will melt, and water would be lost. It has been suggested that icebergs would need to be wrapped before transport. Small-scale experiments have been conducted to show that an iceberg can be wrapped in plastic. However, while the concept is simple, the process is complex and has not been accomplished on the size of iceberg that would be used. The iceberg used in the demonstration was about 3,000 metric tons, while the size of the icebergs that would be used as a water supply is in the range of 300,000 to 1 million metric tons (Quilty 2001).

1.9 GENERAL RELIABILITY OF SUPPLY

The reliability of obtaining Columbia River water via an undersea pipeline is dependent both on the ability to withdraw the water and to transport it. The ability to consistently withdraw water from the river would depend to a large degree on the withdrawal permit or agreements made. The NRC (2004) recommended that “if additional permits are issued, they should include specific conditions that allow withdrawals to be discontinued

during critical periods.” If such a condition were applied to this project, water may not be available at the time it is needed most. Large pipelines have been constructed and operated successfully in ocean environments for many years including oil pipelines in the North Sea. Although oceanographic and geotechnical characteristics of the route would be addressed in the aqueduct design, it is possible that the pipeline could be damaged by a number of natural phenomenon including earthquakes, landslides, and tsunamis. In addition, disruption in service is possible for cleaning or other minor repair. Water from Alaska, transported by tanker or water bags, would be a reliable source of supply if long-term water rights agreements were made with the State and cities. In 1992, Alaska passed legislation that allowed for the development of its bulk and bottled water exports. Alaska owns 40 percent of the nation’s free flowing fresh water and discharges about 1 billion AFY into the ocean. As stated by Ric Davidge, Director of Water (1994): “We believe we can responsibly offer our high quality renewable water resources to a thirsty world. These water resources are viewed by Alaska as potential new revenue sources.”

1.10 ENVIRONMENTAL ISSUES

Although an undersea aqueduct would have fewer environmental impacts than a comparable overland pipeline, significant environmental concerns exist for the concept. One primary concern is the effect that increased water withdrawal would have on salmon. Even if the water were withdrawn near the mouth of the river, some scientists believe that changes in salinity and temperature could alter migration patterns. Another concern is that increased withdrawals could affect the size of the Columbia Plume, which in turn affects coastal circulation (OTA 1992).

Construction activities also have the potential to produce adverse environmental impacts. Impacts associated with land-based facilities are fairly well know and would be similar to other existing similar facilities. Impacts could be minimized by proper siting of facilities. Potential adverse impacts of pipeline construction would be greatest in the near shore areas. It is anticipated that pipelines would be buried near shore and that construction methods would be particularly important in these regions.

Environmental issues for the tanker and water bag options are similar. One of the primary concerns is the effect that water withdrawal would have on the biological resources of the area, particularly on anadromous fish populations. Another concern is the energy consumption required to transport the water. There would also be the potential to have short-term adverse impacts associated with construction activities. In addition, for these options and for the undersea aqueduct, the potential for transport of exotic or invasive species should be evaluated.

1.11 PERMITTING

The specific permits required for this undersea aqueduct have not been identified. However, a water withdrawal permit would be required. In addition, the routing of the pipeline and location of shore facilities will be a concern to States and coastal counties as

well as the California Coastal Commission, U.S. Department of the Interior, Navy, Army Corps of Engineers, and USBR. All of these agencies will want to review and regulate the project. Considerable opposition from the States of Washington and Oregon and from environmental groups should be expected if this option were proposed.

The most significant permit required for the tanker and water bag options would be the water rights permit. The State of Alaska passed legislation in 1992 to facilitate water exports. If water were to be transported from northern California to southern California, it would require approval from the State Water Resources Control Board and other agencies. Recent applications to withdraw water from the Gualala and Albion Rivers in northern California, met with considerable opposition. The California Coastal Commission required that additional environmental study be conducted, and the applications were withdrawn (Rossi 2003). The permits required for towing icebergs would depend on the place of origin.

1.12 COST

It was estimated that the Alaska aqueduct could have capital costs of about \$150 billion and that the cost of water from this option would be about \$3,000 to \$4,000 per AF of water (OTA 1992). These costs are in agreement with a Value Study conducted by the Bureau of Reclamation (Martin 1996) that concluded that costs for water from the undersea aqueduct could be reduced from original estimates to \$3,400 per acre-foot. The OTA (1992) report noted that the feasibility studies for the Trans Alaska Oil Pipeline cost more than \$450 million and that the feasibility studies for the aqueduct project would be more complex.

Cost information provided by Solar Sailor indicates that capital costs for a system capable of delivering 40,500 AFY would be about \$650 million and that shipping costs would range from \$900 to \$1,300 per acre-foot for distances of 1,400 to 2,000 miles. Complete cost estimates for the water bag option have not been obtained. Water bags cost between \$125,000 and \$275,000. Ocean-going tugboats cost about \$10,000 per day to operate. If one round trip from Alaska to California took 10 days, the cost of transporting the water in one large bag would be about \$1,300 per AF. Nordic Water Supply reported that in the first half of 2001 they transported about 844 AF of water at a cost of about \$2,700 per AF (Doyle 2001). They had a net loss of \$1.7 million. That time period was near the start of their operations and costs have likely decreased as their business has expanded and as they are using larger bags. Cost information for towing icebergs has not been developed.

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1.14 CONCLUSION

White Paper findings are summarized in Table 1.

Table 1	
Summary of Findings Related to Water Imports Using Ocean Routes Option	
Parameter	Findings
Location of Supply	The undersea aqueduct would draw water from the Columbia River. The tanker and water bag options would draw water from rivers in Alaska or potentially northern California. Icebergs would likely be from the Artic.
Quantity of Water Potentially Available	Quantity of water available from the Columbia River is not well defined; more water would be available in the winter. Up to 1 million AF of water may be available from Alaska. Each small iceberg could produce 250 to 850 acre-feet of water.
Water Quality	Water quality from all sources considered is generally good and in some cases excellent.
Technical Issues	Transporting water by tankers and water bags is technically feasible and occurs in limited areas now. The primary technical issues are fuel consumption and integrity of the water bags. The undersea aqueduct has major technical issues including crossing submarine canyons and fault zones, selection of pipe materials, and underwater construction in depths of 250 to 300 feet. The primary technical issue of towing icebergs is wrapping the iceberg to reduce water loss and fuel consumption.

Table 1	
Summary of Findings Related to Water Imports Using Ocean Routes Option	
Parameter	Findings
General Reliability of Supply	Reliability of the supply depends primarily on the water rights agreements made. Water bags have ripped open during transport.
Environmental Issues	Environmental issues include the effect of reduced river discharge on biological communities especially on anadromous fish species and impacts due to construction of facilities.
Permitting Issues	Permitting would be most complex for the undersea aqueduct. Water transport from northern California rivers would have significant opposition.
Cost	Cost estimates are not well defined but have been estimated as: Undersea aqueduct - \$3,000 to \$4,000 per AF. Tanker - \$2,000 to \$2,400 per AF. Water Bag – \$1,400 to \$2,700 per AF.