



ALTERNATIVE GRAVEL PLACEMENT METHODS

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INTRODUCTION

PURPOSE

As part of the Central Valley Project Improvement Act (CVPIA) of 1992, the Anadromous Fish Restoration Program (AFRP) was developed (Section 3406(b)(1)). The goal of the AFRP is to make all reasonable efforts to double natural production of anadromous fish in Central Valley streams. As part of this program, moneys are spent each year to add spawning gravels to rivers and streams. The Bureau of Reclamation and Fish and Wildlife Service allocate CVPIA funds (Section 3406(b)(13)) that are used for gravel restoration projects on the Stanislaus, Sacramento, and American rivers. At specific locations along these rivers spawning sized gravels are introduced to provide increased spawning habitat for Chinook salmon and steelhead.

Due to dense vegetation, steep slopes, and lack of access, many ideal gravel addition sites cannot be accessed using conventional methods. The traditional method is to use a loader to place and shape the gravel in the riverbed. In order to do this direct access to the riverbed is required. In the past, in areas without direct access, spawning gravels were placed using a helicopter with a radio controlled hopper. The major disadvantage of the helicopter method is the expense, costing upwards of four-times the amount of the traditional loader method. This study was conducted to investigate if there are more cost effective alternatives to placing gravels in these hard to reach locations.

METHODS CONSIDERED

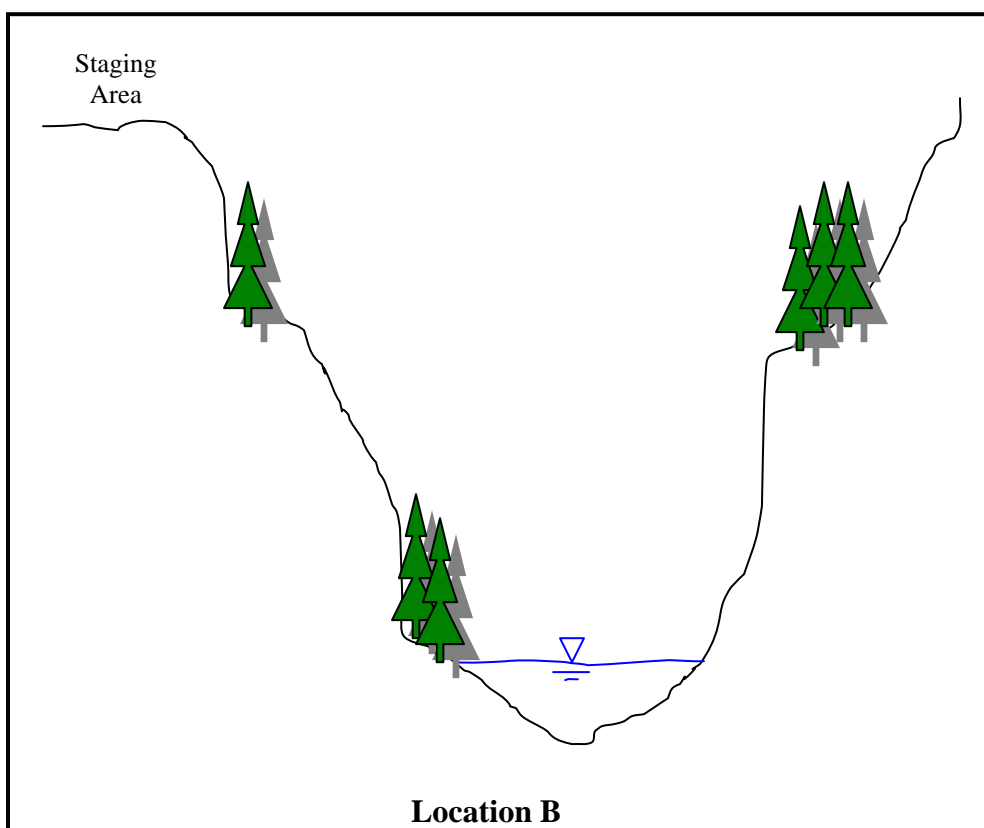
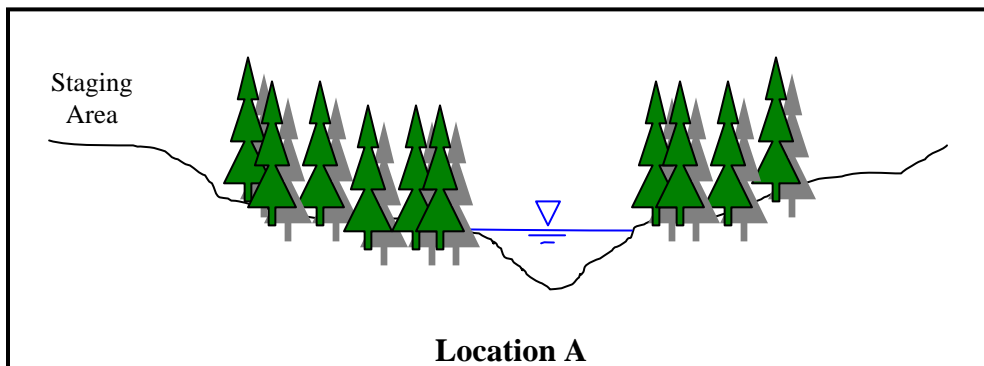
The following is a brief description of the alternative methods considered:

Habitat Builder	- Basically a gravel-pump system
Cable Skyline	- A timber logging technique utilized on steep slopes
Port-o-belt	- A portable conveyor system
Tele-belt	- A truck-mounted conveyor system
Creter Crane	- A crane-mounted conveyor system
Stone Slinger	- A dump truck with a small conveyor attached

ASSUMPTIONS

In an effort to compare the different methods the following assumptions were made:

1. Two different site layouts were assumed in analyzing the viability of these different methods. "Location A" has a relatively flat slope with heavy vegetation and no road access. "Location B" is a canyon setting, with steep slopes on either side of the stream (see depictions below).
2. In order to perform a cost analysis on the different methods, it was assumed that 1000 tons of gravel was to be placed.
3. Fishery agencies required the spawning gravel to meet certain cleanness and gradation requirements. Only washed and rounded natural gravels of the following gradations are considered: 100 percent passing a 5 inch sieve, 98-100 percent passing a 4 inch sieve, 60-80 percent passing a 2 inch sieve, and 0-5 percent passing a ½ inch sieve.



HELICOPTER

FOREWORD

This helicopter review is provided so that it can be compared to the alternative methods.

DESCRIPTION

In the past helicopters have been used to place spawning gravel in difficult locations since it can access virtually any job site. They are generally fitted with a radio-controlled hopper attached to a cable. The hopper is filled via a loader and then flown to the placement site. This method allows for reasonably good placement of materials.

PROS/CONS

The main drawback of the helicopter method is the high costs associated with it. Although a helicopter can access virtually any site, most helicopters cannot carry large loads and require frequent trips, increasing the amount of time required to place the material.



Picture 1. Helicopter Method

Average Cost Per Ton = \$89.00 (see Appendix A)

CONCLUSION

This is definitely a viable method, but the costs run close to four times as much as conventional gravel placement methods. If the idea is to place the greatest amount of gravel in the stream for the dollar, other methods should be considered.

“HABITAT BUILDER”

DESCRIPTION

The “Habitat Builder”, as it is termed, is basically a gravel pump system. There are two six-inch water pumps which Y into an eight-inch line. Gravel is fed into a hopper with a grizzly and vibrating plate attached. The gravel is then fed into the eight-inch line via the hopper and is directed to wherever it is to be placed. Barrels are used to support the discharge pipe on the water’s surface, and help with the placement of the material.



Picture 2. Two 6-inch water pumps and hopper



Picture 3. Discharge pipe with barrels attached

PROS/CONS

This system is ideal in locations where leaving a minimal construction footprint is desired. The eight-inch “Yelomine” pipe is durable and fairly flexible and can be placed over the existing ground surface. Head-loss is a large concern with this system, so it needs to be placed in such a manner so that the pipe continuously maintains a downward slope. Clogging is an area of concern, although recent modifications have reduced this problem. The water pumps need to be within 30 vertical feet of a water source in order to have sufficient head to pump the water.

Average Cost Per Ton = \$44.50 (see Appendix A)

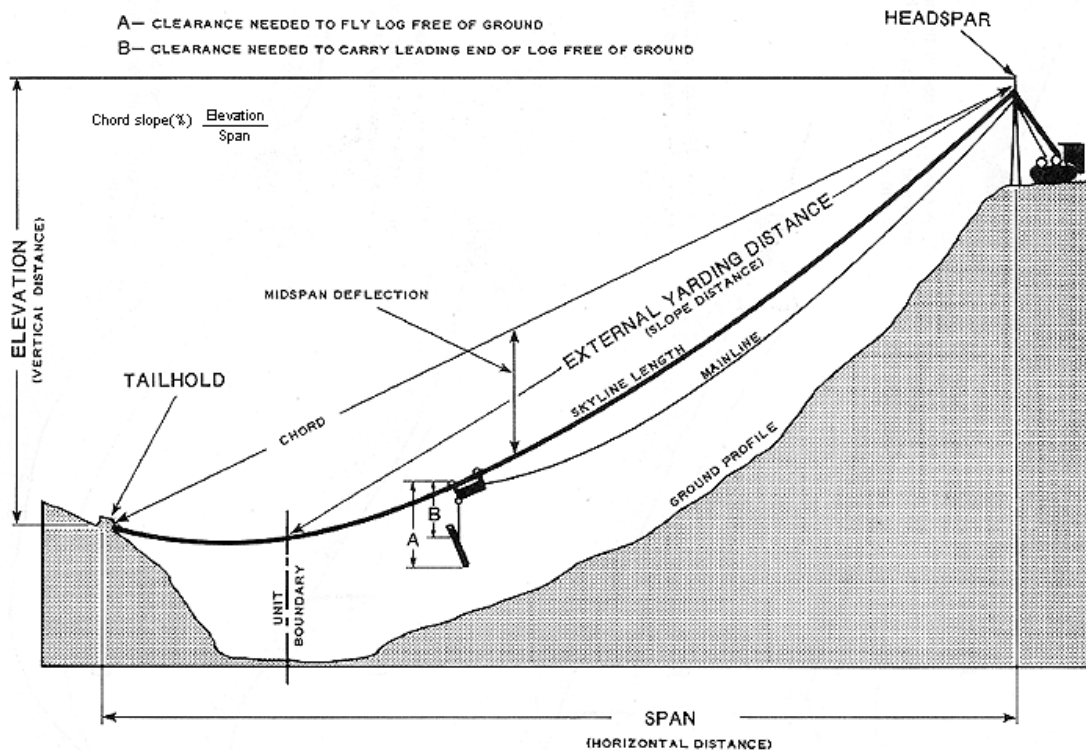
CONCLUSION

In most all cases this system could be used as long as there is a close water source. If the distance of the aggregate placement is great, additional pipe may need to be bought (at about \$5/foot) which could greatly increase the overall cost. By decreasing the maximum aggregate size, clogging can be less of an issue. This has been utilized by Carl Mesick Consultants on the Lower Stanislaus with positive results.

CABLE SKYLINE

DESCRIPTION

The cable skyline system has been utilized for a long time by the logging industry for obtaining timber on steep slopes. The “skyline” method would consist of a mobile yarder, the actual cable skyline, a tailhold, and a hopper mechanism to transport the aggregate (see Picture 4). This system is ideal for large canyon environments where there is a clear path for the cable and payload to pass through. The maximum load and span length depends on the amount of sag in the cable, the greater the sag the greater the load.



Picture 4. The Skyline system includes a mobile tower (headspar), skyline, and a tailhold.

PROS/CONS

This method has been used for years in various situations. Experienced loggers can find a way to make it work in virtually any steep environment. One of the main problems is the need to follow the path of the cable. Not only can the aggregate not be placed outside of the path of the cable, but precise placement may be difficult. The gravel additions may not be spread in a uniform manner, and there is the danger of dumping too much gravel in one spot so that it protrudes above the water elevation.

Average Cost Per Ton = \$46.50 (see Appendix A)

CONCLUSION

In the case of “Location A”, this method would prove highly ineffective, yet it appears to be ideal at a site such as “Location B. The only concern with using this method would be the effectiveness of placing the materials accurately.

“PORT-O-BELT”

DESCRIPTION

The “Port-o-belt” conveyor system was developed by ROTEC Industries. It is a portable conveyor system which comes in 50-foot sections that can be used in conjunction to convey aggregate thousands of feet (as shown in Picture 5). In order to place aggregates throughout the cross section of a river, a telescopic conveyor is needed at the end of the line to help with the placement (see Picture 6). The conveyor is capable of conveying a maximum aggregate size of six inches, and is able to conform to the ground surface with the use of hinges.



Picture 5. Port-o-belt sections



Picture 6. Port-o-belt swinger

PROS/CONS

There currently are no contractors with this system on the West Coast that I am aware of, and the main cost will be in transporting these sections to the job site. The sections are relatively light and easy to set-up, but the swinger requires a landing at the bank of the river and will require some assembly. In addition, the swinger is limited to a maximum reach of 65 feet, so for wide channels it may not be effective. The maximum slope in which the conveyor can effectively work is $\pm 15^\circ$. It has a very high discharge rate, at up to 570 tons per hour, but is limited as to how quickly material can be placed on the belt.

Average Cost Per Ton = \$79.00 (see Appendix A)

CONCLUSION

This system would not work for this application due to the slope restrictions, need for riverbank access, and the high costs of transporting the conveyor sections to the job site.

“TELEBELT”

DESCRIPTION

The “Telebelt” system is simply a truck-mounted telescopic conveyor developed by Putzmeister. There are four main sizes of “Telebelts”, the TB 50, TB80, TB105, and the TB 130, the number representing the maximum horizontal conveyor distance. All trucks have an eighteen inch conveyor unit attached to a three section telescopic boom. They are capable of conveying up to four inch aggregates, and can place materials utilizing 360 degree continuous rotation.



Picture 7. The Putzmeister TB 105 Telebelt

PROS/CONS

Berkeley Concrete Pumping is a local contractor that owns a Putzmeister TB 105 (shown in Picture 7 above). This truck is limited to a maximum horizontal reach of 105 feet, meaning it would still require access to the riverbank in most cases. The “Telebelt” can actually handle five inch aggregate, but it will have to be placed directly on the belt and not utilize the hopper.

Average Cost Per Ton = \$48.85 (see Appendix A)

CONCLUSION

Although this system may not be practical for placing aggregates where there is no bank access, it could be used as an alternative to traditional methods. For jobs requiring a thousand plus tons of aggregate, the cost of utilizing this system could be comparable to using a loader, may be done at a faster rate, and would not require any in-stream work

“CRETER CRANE”

DESCRIPTION

This is a massive crane/conveyor system developed by ROTEC Industries. A 24” telescopic conveyor is attached to what is essentially a large crane. It is capable of extending out a maximum of two-hundred feet. The large hopper is capable of handling ten cubic yards at once, with the conveyor able to handle aggregate of up to six inches. Of all the methods this has the greatest discharge rate, at approximately nine hundred tons per hour.



Picture 8. The Creter Crane

PROS/CONS

The “Creter Crane” is such a massive unit that it must be disassembled and shipped in pieces to the job site. In addition, there currently are no units on the West Coast, so mobilization costs are high. It would require onsite assembly, and a large working area. Although the discharge rate is substantial, it is limited to a two hundred foot horizontal distance which is insufficient in most applications. In addition to the crane unit, a small Port-o-belt unit discussed previously would be required to feed the hopper.

Average Cost Per Ton = \$108.00 (see Appendix A)

CONCLUSION

This system would not work in either of the applications considered, and the costs simply do not merit its consideration.

“STONE SLINGER”

DESCRIPTION

A “Stone Slinger” is simply a conveyor unit attached to a large dump truck. The conveyor unit can move side to side, practically perpendicular to the vehicle. The operator can manually control the unit from the side of the truck, or remote units are also available. By extending the conveyor, and propelling the aggregate off the end, aggregate can be placed as far as seventy feet from the end of the dump truck. Crushed stone from a twenty-ton dump truck can be unloaded and spread in about twelve minutes. Use of a stone slinger replaces the need of double or triple handling material, by quickly placing the materials where they are needed.



Picture 9. The Stone Slinger

PROS/CONS

Although “Stone Slingers” are ideal for placing aggregates in hard to reach places, they are highly limited. The maximum aggregate size that can be conveyed is two inches, and this size would simply trickle off of the belt, greatly reducing the distance in which it could be placed. Even if the aggregates were capable of being slung the maximum of seventy feet, access would be required to the riverbank in which case a loader could be used anyhow. The nearest contractor is in San Luis Obispo, CA.

Average Cost Per Ton = \$47.50 (see Appendix A)

CONCLUSION

Due to limitations of aggregate size, placement distance, and that there are no local contractors, this methodology should not be considered. Still, this method was utilized for placing spawning gravels along Clarks Creek in the state of Washington.

APPENDIX A

METHODOLOGY	ITEM	UNIT PRICE	QUANTITY	SUB-TOTALS	TOTAL COST	COST PER TON
Helicopter	Everything Included	\$89.00/Ton ¹	1000 Tons	\$89,000	\$89,000	\$89.00
“Habitat Builder”	Everything Included	\$44.50/Ton ²	1000 Tons	\$44,500	\$44,500	\$44.50
Cable Skyline	Gravel Equipment & Crew Engineering	\$25.00/Ton ¹ \$2500/Day ³ \$800/Day ³	1000 Tons 7 Days 5 Days	\$25,000 \$17,500 \$4,000	\$46,500	\$46.50
“Port-O-Belt”	Gravel Conveyor Swinger Transport Labor Loader	\$25.00/Ton ¹ \$20.00/Foot ⁴ \$200,000/Each ⁴ \$10,000 \$450.00/Day \$2000/Week	1000 Tons 900 Feet ±5% (To Rent) Lump Sum 4 Days 1 Week	\$25,000 \$18,000 \$10,000 \$10,000 \$1,800 \$2,000	\$66,800	\$66.80
“Telebelt”	Gravel Equipment & Crew Usage Transport	\$25.00/Ton ¹ \$285/Hour ⁵ \$2.50/Ton ⁵ \$175/Hour ⁵	1000 Tons 70 Hours 1000 Tons 8 Hours	\$25,000 \$19,950 \$2,500 \$1,400	\$48,850	\$48.85
“Creter Crane”	Gravel Creter Crane Conveyor Transport/Assembly Labor Loader	\$25.00/Ton ¹ \$1,700,000/Each ⁴ \$20.00/Foot ⁴ \$15,000 \$750/Day \$2000/Week	1000 Tons ±3% (To Rent) 50 Feet Lump Sum 2 Days 1 Week	\$25,000 \$51,000 \$1,000 \$15,000 \$1,500 \$2,000	\$95,500	\$95.50
“Stone Slinger”	Gravel Equipment & Crew Transport	\$25.00/Ton ¹ \$250/Hour \$5,000	1000 Tons 70 Hours Lump Sum	\$25,000 \$17,500 \$5,000	\$47,500	\$47.50

- Notes :
1. This value is based upon costs in past years and updated to 2003 dollars.
 2. This is based upon an average \$44.50/Ton estimate given by Sean Smith (includes cost of gravel).
 3. These values were obtained from Ed Aulerich of Forest Engineering.
 4. These values were obtained from Nathan Larson of ROTEC Industries.
 5. These values were given by Curt with Berkeley Concrete Pumping.

APPENDIX B

Method	Description	Limitations	Horizontal Distance (ft)	Discharge Rate (tons/hr)	Cost per ton (\$)
Helicopter	This has been the common method used in the past. The helicopter simply hauls the gravel using a radio-controlled hopper.	<ul style="list-style-type: none"> • High cost • Noise • Limited Payload 	unlimited	20*	\$89.00
“Habitat Builder” Gravel Pump	Water is fed through two 6" pumps which then combine into an 8" line. Gravel is fed into a hopper which includes a double screen and vibrator. The gravel enters the 8" line and is pumped to the location. The pipe comes in 20' lengths and is supported on the water using barrels at each joint.	<ul style="list-style-type: none"> • Must be w/in 30 ft vertical distance of water source • Clogging has occurred in past • Low flows are needed to accurately place aggregate 	500+	20*	\$44.50
Cable Skyline Logging Technique	This system consists of a mobile yarder and at least one tailhold. A radio controlled hopper would be attached to the cable. This system is ideal for areas with steep slopes. The more sag allowed in the cable, the greater the capacity. This can be utilized on slopes as great as $\pm 60^\circ$.	<ul style="list-style-type: none"> • Material can only be placed along cable's path (narrow strip) • The sag in the cable is what ultimately determines the capacity (site specific) 	5000	varies	\$46.50
“Port-O-Belt” Conveyor System	This is a portable conveyor system which can conform to the slope of the terrain with the use of hinges and can convey up to 6" aggregate. It comes in 50 foot sections which can be used in conjunction for up to 1000 feet. In most cases it requires a swinger which has a small telescopic conveyor.	<ul style="list-style-type: none"> • No local manufacturers • Maximum slopes of $\pm 15^\circ$ • A landing is required for the swinger 	50 - 1000	570	\$79.00
“Telebelt” Truck-Mounted Conveyor	This is simply a telescopic conveyor mounted to a truck. Berkeley's truck can reach up to 105 ft horizontally. While the maximum aggregate size is 4", the hopper can be modified to allow larger rock onto the belt.	<ul style="list-style-type: none"> • Maximum reach of 105 ft • 4" Maximum aggregate size (this can be adjusted by the manner in which material is loaded onto the belt) 	105	576	\$48.85
“Creter Crane” Crane w/ Conveyor	This is a crane with a 24" telescopic conveyor attached to it. It is capable of conveying 6" aggregate, and the hopper can hold 10 yd ³ at a time. The crane is actually a Grove 9100, and is so large it must be shipped in pieces and assembled at the site.	<ul style="list-style-type: none"> • It's massive size • Maximum reach of 200 ft • No local contractor • High cost 	72 - 200	980	\$108.00
“Stone Slinger” End Dump w/ conveyor	This is basically an end-dump with a conveyor system attached to the back. The system can propel aggregates to a maximum of 70 feet from the truck. For larger aggregates (maximum of 2"), the distance shortens substantially.	<ul style="list-style-type: none"> • 2" maximum aggregate • Maximum reach of 70 ft • San Luis Obispo is nearest contractor 	60 - 70	80	\$47.50

* - Actual output from past jobs.

Alternatives to Helicopter Placement of Spawning Gravel at Goodwin Canyon, Stanislaus River, California

Background:

The cost of processing and delivering the spawning gravel to stockpiles near the placement sites has ranged from about \$13/ton in 1997 to \$22/ton in Aug 2002. In August 2000 a helicopter company was hired to **place only** 1000 tons at a cost of \$85,000 - or \$85/ton. The same scope of work conducted in September 1997 cost \$50/ton (but bids ranged as high as \$84/ton).

The present worth value of a \$42,000 per year expenditure (i.e. half of \$85,000 which is assumed to be spent every other year) over 25 years at 8 % interest rate is about \$420,000 (the present worth factor is 10.675). Using the life cycle costs of alternate ways of placing the gravel it may be economical to construct some features or buy some equipment that have a significant initial costs but have a low annual operating cost.

For example, if 1000 tons of gravel were placed every other year using the bucket brigade method of Alternative 8, and the initial and bi-annual costs were as follows:

- initial cost of floating dock system: \$100,000 (assume lasts 25 years so no replacements)
- costs \$30,000 per bi-annual deployment to deploy the system, place the gravel (staff and other equipment costs), demobilize the system, and perform any necessary maintenance

Then the present worth cost of this alternative would be the present worth of the bi-annual cost (use ½ of 30,000 to convert to annual equivalent cost, times the factor 10) would be 150,000; then add this to the initial cost. The present worth value would be $100,000 + 150,000 = \$250,000$. Comparing this to the estimated \$420,000 present worth for the helicopter placement method there appears to be the potential for a significant savings over the lifetime of the project by using the alternative placement method.

This is a brief, simplified analysis but it demonstrates that additional investigation of alternatives is warranted.

Below are some possible alternative methods of placing this spawning gravel along with advantages and disadvantages associated with each. This is not an exhaustive list of possible alternate methods and their pros and cons but should serve to hopefully spark other creative ideas to solve this problem. An interdisciplinary team of biologists, engineers, designers, construction specialists, cost estimators and other stakeholders could be convened to build on this initial group of alternatives.

Alternatives: (note that left and right refer to when looking downstream)

1. Helicopter

Advantages: Previously used at this site, sufficient industry experience, adequate competition so best possible price, fast placement (1000 tons in 5 days), accurate and flexible placement, method is understood by involved parties (CDFG, COE, OID), no equipment for agencies to operate and maintain; does least disturbance to environment (no footprint)

Disadvantages: High cost (\$85/ton), noisy, requires attention to safety for flight operations, no-fly zone below and around path of helicopter; helicopters sometimes not available or get re-directed if called for fire suppression - could affect ability to place in required timeframes but has not happened yet; relies on use of OID staging area

2. Gravel slurry in pipe (proprietary)

Advantages: Low cost (not estimated), apparent ability to accurately direct gravel discharge point, requires cutting a trail through heavily vegetated land but the footprint is relatively small (much less than a road would be). Only a moderate amount of initial setup/mobilization compared to other alternatives.

Disadvantages: Unproven method, potential for clogging pipe with few oversize gravel particles, this can be cause for concern if the method fails the timeframe for placement then may lose opportunity for placement for that season; sole source method so possibly costly; if agencies purchased a system then must learn to operate and maintain, also must store before next use; must obtain large quantity of water for sluicing the gravel (previously purchased from CVO? from OID canal) - would have to arrange for each placement;

3. Highline cableway (to span the canyon)

Advantages: High initial cost to build it once but then operate it yearly with CDFG staff.

Disadvantages: To be efficient the cableway would have to remain in place year round. Being open to weather will increase maintenance effort and cost. Construction is difficult in the rugged terrain. Remote power required to operate hoisting equipment. Unknown if permanent power can be established. Requires OID permission (and maybe COE) to construct permanent towers on canyon sides. Need to assess if have adequate access for gravel trucks to load bucket. May have to cut a path through foliage for bucket travel. Cableway system only places gravel along the path of the cable. Cannot achieve distributing gravel in upstream to downstream direction on the right riverbank as is usually preferred. Consider 2 towers/buckets on right bank to achieve better distribution which increases costs, possible overhead hazard. Cable must remain in position year

round and would be a visual nuisance. Increased potential for vandalism. Requires trained staff to operate safely and maintain. Probably takes longer time to accomplish placement than by helicopter.

4. Barge from left bank to right bank

Advantages: Easier to construct and operate than a highline system. Requires permanent road to edge of water. Barge can be motored to right bank or pulled with temporary cable system.

Disadvantages: Requires working on moving water surface - with inherent safety issues (personnel, equipment tipping and environmental damage if fuel spill occurs). Requires constructing permanent road through prized vegetation area to allow deployment of barge, gravel truck and excavating equipment - i.e. has largest permanent footprint impact. CDFG would have to learn to operate waterborne equipment. Uncertain how barge would be affected by river currents. Probably takes longer time to accomplish placement than by helicopter.

5. Conventional conveyor system from left bank to right bank. Conveyor could be buckets on rails or belt on rollers.

Advantages: Greater confidence that system would perform compared to the gravel slurry pipeline system (less possibility of clogging). But would have somewhat less capability to direct location of gravel placement (system is less flexible).

Disadvantages: Requires firm, stable foundations regularly along length (i.e. underwater oiers or spuds). No experience with this method. Much initial setup/mobilization. Requires constructing permanent road through prized vegetation area to allow deployment of system. Probably takes longer time to accomplish placement than by helicopter.

6. Deploy temporary floating bridge from left bank to right bank and use smaller capacity hauling equipment to transport gravel

Advantages: System does not require underwater foundation elements.

Disadvantages: Requires constructing permanent road through prized vegetation area to allow deployment of system. Much initial setup/mobilization. Uncertain how system would be affected by river currents. Probably takes longer time to accomplish placement than by helicopter.

7. Deploy temporary floating bridge from left bank to right bank and use conveyor system to transport gravel. Conveyor could be buckets on rails or belt on rollers.

Advantages: Similar to Alt 6 except motorized equipment would not be operated over water - reduces potential hazard. Probably smaller, lighter bridge. Should be able to move dump point at end of bridge to place gravel in preferred locations.

Disadvantages: Similar to Alt 6.

8. Bucket brigade on temporary floating dock from left bank to right bank.

Advantages: Similar to Alt 6 except motorized equipment would not be operated over water - reduces potential hazard. Should be able to move dump point at end of dock to place gravel in preferred locations. Consider using public to participate as a community service project.

Disadvantages: Similar to Alt 6 and 7 except footprint of new access road may be a smaller path. Labor intensive as opposed to “yellow equipment” intensive. Probably takes longer time to accomplish placement than by helicopter.

9. Gravel chute from right bank

Advantages: Avoids disturbance to prized vegetated area on left bank.

Disadvantages: Difficult to accomplish upstream to downstream distribution of gravel. Best to leave installation permanent which will be a visual nuisance, increase maintenance and potential for vandalism. Uncertain if adequate access exists or can be established along OID/SJID canal road for gravel haul trucks, construction equipment

Alternatives were conceived assuming about 1000 tons to be placed every other year. All alternatives will require a separate bi-annual contract for supplying the processed gravel.

Alternatives can vary with regard to amount of work to be performed by agencies vs by construction contractor. For example:

Helicopter must be by contractor

Gravel slurry pipeline could be implemented by contractor or a system could be purchased by/for CDFG and operated annually by CDFG staff.

Highline cableway would be initially constructed by contractor but then operated (and maintained) annually by CDFG.

Barge

Conveyor

Floating bridge with hauling equipment

Floating bridge with conveyor system

Bucket brigade on floating bridge

Gravel chute - right bank