



# Stream Simulation

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## Appendix G—Additional Tools and Tips

Sections G.1 through G.3 of this appendix provide additional information that may be useful in stream-simulation final design and contract development. Section G.4 summarizes results from a workshop where construction engineers and biologists shared their experience doing major in-stream work. Participants identified common problems and solutions they had used or developed.

### G.1 CONTRACT PREPARATION CHECKLIST

#### ■ Plan views

- ✓ Plans drawn to scale with scale, north arrow, at least three reference points (more are preferred) outside of construction disturbance area.
- ✓ Clearing limits: all work areas covered by special project requirements, notes.
- ✓ Structure location: inlet and outlet **inverts** located with XYZ coordinates, or equivalent (taken from long profile).
- ✓ Extension of channel excavation and filling (taken from long profile).
- ✓ Road locations, edges, centerline, geometric description of curvature, widths, and curve widening, p-line, or XYZ coordinates.
- ✓ Channel work identified: bank erosion control features, **grade control**, channel linings.

#### ■ Dewatering system

- ✓ Location, height, and width of diversion dam.
- ✓ Bypass pipe size, length, location, coupling method.
- ✓ Sump locations, estimate of necessary flow and sump capacity.
- ✓ Backwater prevention method.
- ✓ Sediment treatment plan with methods, release point, extent.

#### ■ Footings

- ✓ Estimated bearing capacity parameters.
- ✓ Depth, width, and eccentricity from bearing capacity equations.
- ✓ Dimension of footing or footing options with enough width for arch attachment.
- ✓ Reinforced concrete details and calculate temperature steel.
- ✓ Quantities of concrete and reinforcing steel.
- ✓ Estimated construction time.

#### ■ Streambed Details

- ✓ Thalweg, slope, bank shape, material gradation(s).
- ✓ Step, bank, rock-placement details: elevations, spacing, diameters, and locations.
- ✓ Extent of streambed-simulation material, excavation, and infilling.
- ✓ Quantities of materials.
- ✓ Details for any retention structures (sills): construction, attachment, and backfilling.

#### ■ Structure Details

- ✓ Structural section, gauge or thickness requirement for live load, dead load.
- ✓ Minimum and maximum cover limits.
- ✓ Structures (drawn to scale) on elevation view showing bed material location relative to structure, special backfill zones.
- ✓ Special concrete structure details for collar headwalls, inlets, thrust beams, footings.
- ✓ Structure attachment to footing details.
- ✓ Structure length, all details necessary for costing.
- ✓ Structural excavation quantity, total excavation estimate.

#### ■ Details for creating a bypass road around project

- ✓ Traffic control plan with signs.
- ✓ Traffic bypass road design, including maximum grade, minimum width, surfacing, and curve radius.
- ✓ Over-structure embankment details, estimate of delay time during construction.

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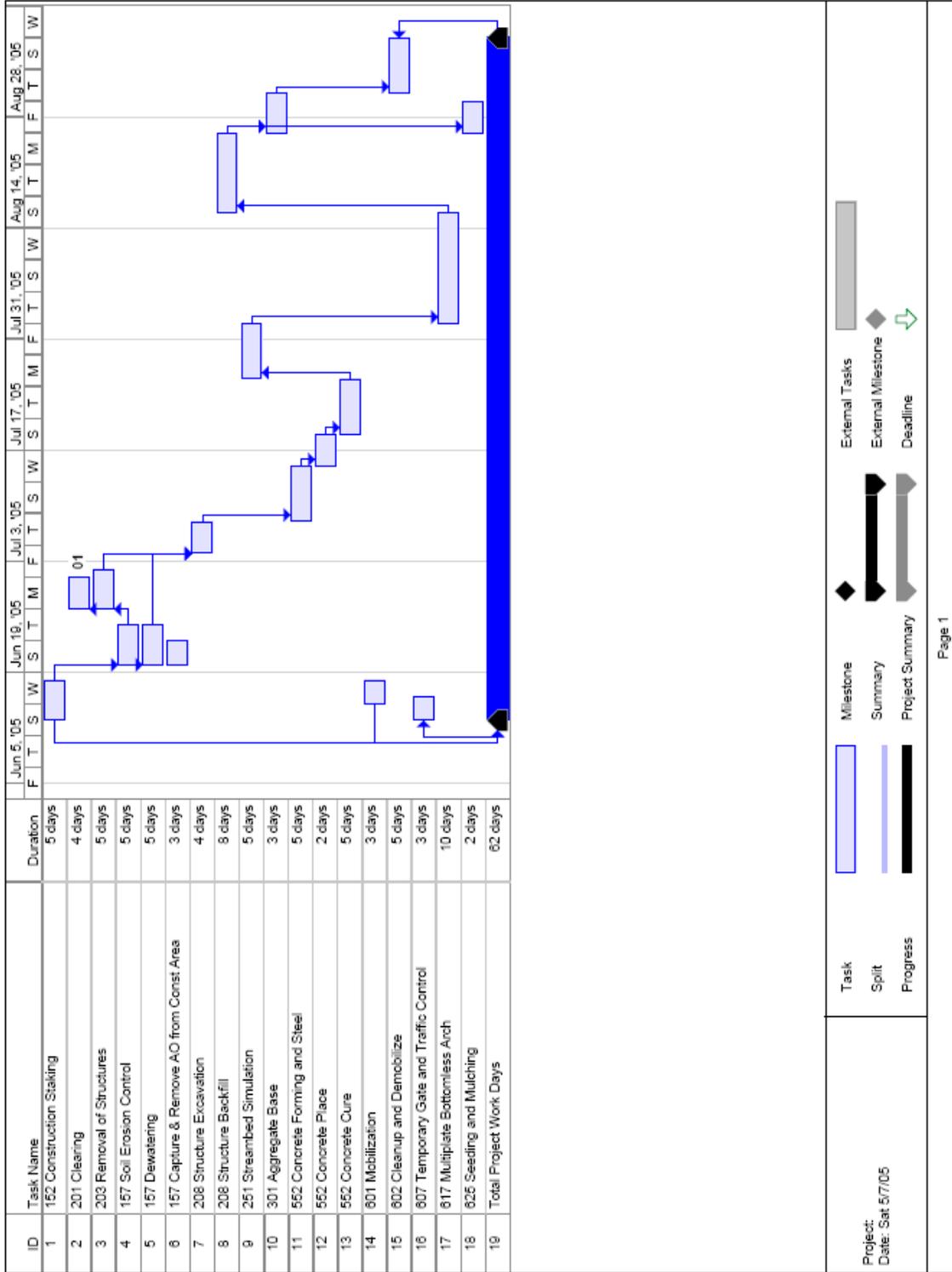
### G.2 SAMPLE PROJECT SCHEDULE

Figure G.1, a Gantt chart, shows which tasks in this project depend on others and how many actual workdays (weekends are included with workdays on this chart) are necessary for completing a hypothetical project. To get total contract time, the designer should add any anticipated shutdown time for fire and weather, as well as holidays and “contingency” days.

Most permits have a “construction window” of time when work is allowed to take place in the stream. This window protects spawning and migrating species and ensures ample time for “winterizing” a project if the project going to take more than one season. Using the project Gantt chart, you can fit the project into the construction window allowed in the permit and establish realistic start dates, completion dates, and a time estimate.

A thoughtful, well-constructed project schedule helps the contractor and inspector plan their work. It will help both to minimize unnecessary field trips and to plan for critical events such as aquatic organism capture and transport, compaction testing, and concrete pours (see figure G.2).

# Appendix G—Additional Tools and Tips



3 **Figure G.1—Sample project schedule: Gantt chart.**

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## Project Timeline Graphic

The following graphic illustrates which work will be in progress and specifications will most likely apply as the project progresses along the timeline beginning with the work immediately following contract award through completion and beyond into use of the project.

Contract Time and Milestones <----->	Contract Award	Pre Work Meeting	Construction Staking	Mobilization	Clearing	Diverting/De-watering	Vehicle Bypass	Excavation	Structure Excavation	Structure Installation	Backfill	Permanent Erosion Control	Demobilization, Cleanup, and Project Acceptance	Post Construction Monitoring
Specification/Pay Item														
Preconstruction														
151 Mobilization														
157 Soil Erosion Control/Water Quality Monitoring														
152 Construction Staking														
201 Clearing and Grubbing														
204 Excavation and Embankment														
205 Rock Blasting														
208 Structure Excavation and Backfill														
208 Structure Excavation (De-water/Diversion)														
251 Rip Rap														
301 Aggregate Base														
402 Hot Bituminous Pavement														
601 Minor Concrete Structures														
602 Culverts and Drains														
603 Structural Plate Structures														
606 Currugated Metal Spillways														
608 Paved Waterways														
624 Topsoil														
625 Turf Establishment														
626 Plant, Trees, Vines, and Groundcovers														
634 Permanent Traffic Control														
635 Temporary Traffic Control														
Post Construction														

Figure G.2—This project construction timeline is a reminder of the specifications that apply at various phases of construction. Work under some specifications continues throughout much of the project.

### **G.3 ESTIMATED PROJECT COSTS: COMPARING DIFFERENT STRUCTURE TYPES AND SIZES**

#### **G.3.1 12-foot and 18-foot Open-bottom Arch Multiplate Structures—20-foot Fill**

Table G.1 compares estimated costs for two open-bottom arch multiplate structures on concrete footings, with step pools and stream-simulation bed, complete site dewatering and erosion control. Fill height is 20 feet; **bankfull** width is 12 feet.

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Table G.1—Sample cost estimates for 12-foot and 18-foot open bottom multiplate arches with 20-foot fill

Item No.	Description	Method of Measurement	Unit	Estimate Quantity 12'	Estimate Quantity 18'	Unit Price	Total for 12'	Total for 18'
152(02)	Construction staking and surveying (road)	AQ	Mile	0.2	0.2	\$5,000	\$1,000	Same
152(03)	Construction staking and surveying (structure)	AQ	Each	1	1	\$1,000	\$1,000	Same
201(03)	Clearing and grubbing, slash treatment methods for tops and limbs 12, logs 12, stumps 12, utilization of timber 2	LSQ	LS	All Req'd	All Req'd	\$1,500	\$1,500	Same
203(02)	Removal of existing 6-ft. dia. multiplate pipe, disposal method A	AQ	Ea	1	1	\$5,000	\$5,000	Same
157(19)	Soil erosion and pollution control	LSQ	LS	All Req'd	All Req'd	\$2,500	\$2,500	Same
157(20)	Dewatering and sediment control	LSQ	LS	All Req'd	All Req'd	\$15,000	\$15,000	Same
208(02)	Foundation fill (use mostly structural excavation, and bedding volume)	DQ	Cy	80	120	\$50	\$4,000	Add \$2,000
208(07)	Structural excavation	DQ	Cy	1,212	1,434	\$20	\$24,240	Add \$4,440
251(14)	Placed channel rock, rock-18, method D (2 steps constructed in pipe)	AQ	EA	16	24	\$80	\$1,280	Add \$480
251(15)a	Placed streambed simulation rock, bed class 12, method D	DQ	Cy	135	202	\$65	\$8,775	Add \$4,350
251(16)	Placed select borrow	DQ	Cy	8	12	\$50	\$400	Add \$200

## Appendix G—Additional Tools and Tips

Table G. 1—Sample cost estimates for 12-foot and 18-foot open bottom multiplate arches with 20-foot fill (continued)

Item No.	Description	Method of Measurement	Unit	Estimate Quantity 12'	Estimate Quantity 18'	Unit Price	Total for 12'	Total for 18'
301(10)	Untreated aggregate course, type base, grading C, compaction B	DQ	Cy	37	39	\$40	\$1,480	Add \$80
552(03)	Structural concrete, class A (AE), for footings	AQ	Cy	45 2' wide by 4' tall footings	55 2.5' wide by 4' tall footings	\$500	\$22,500	Add \$5,000
554(03)	Reinforcing steel	DQ	Lb	880	897	\$2.50	\$2,200	Add \$43
601(01)	Mobilization	LSQ	LS	All Req'd	All Req'd		\$12,940	\$16,118
607(03)	Gate temporary, type I barricade, size 4.9m wide by 800mm high (or other traffic-control features)	AQ	Each	2	2	\$2,250	\$4,450	same
617(06)	Galvanized steel corrugated open-bottom arch	AQ	Ft	12' by 6' by 76' @ \$435/ ft	18' by 9' by 74' @ \$650/ft		\$33,060	Add \$15,040
625(02)	Seeding, hydraulic method (with mulch)	DQ	acre	0.25	0.25	\$4,000	\$1,000	same
<i>Total estimate for 12' and 18' open bottom arches, fill height assumed at 20'</i>							<b>\$142,325</b>	<b>\$177,301</b>

**Cost difference = \$34,976 (24.5%)**

## Stream Simulation

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### **G.3.2 8-foot and 12-foot Embedded CMPs—20-foot Fill**

Table G.2 compares estimated costs for two embedded pipe single-piece structures with step pools and stream-simulation bed, complete site dewatering, and erosion control. Fill height is 20 feet; bankfull width is 8 feet.

## Appendix G—Additional Tools and Tips

Table G.2—Sample cost estimates for 8-foot and 12-foot embedded CMPs with 20-foot fill

Item No.	Description	Method of Measurement	Unit	Estimate Quantity 8'	Estimate Quantity 12'	Unit Price	Total for 8'	Total for 12'
171(02)	Construction staking, precision C, method 1	AQ	Mile	0.2	0.2	\$5,000	\$1,000	Same
171(03)	Staking structures, precision C, method 1	AQ	Each	1	1	\$1,000	\$1,000	Same
201(03)	Clearing and grubbing, slash treatment methods for tops and limbs 12, logs 12, stumps 12, utilization of timber 2	LSQ	LS	All Req'd	All Req'd	\$100	\$1,000	Same
202(02)	Removal of existing 4-ft. dia. steel pipe, disposal method A	AQ	Ea	1	1	\$2,500	\$2,500	Same
157(19)	Soil erosion and pollution control	LSQ	LS	All Req'd	All Req'd	\$1,000	\$1,000	Same
157(20)	Dewatering and sediment control	LSQ	LS	All Req'd	All Req'd	\$8,000	\$8,000	Same
206(02)	Foundation fill (use mostly structural excavation, and bedding volume)	DQ	Cy	53	80	\$50	\$2,650	Add \$1,350
206(07)	Structural excavation	DQ	Cy	388	456	\$20	\$7,760	Add \$1,360
251(14)	Placed channel rock, rock-12, method D (2 steps constructed in pipe)	AQ	EA	16	24	\$65	\$1,280	Add \$480
251(15)a	Placed streambed simulation rock, bed class 6, method D, both pipes embedded 4' add 10% for adjacent channel work	DQ	Cy	78	98	\$65	\$5,070	Add \$1,300

# Stream Simulation

Table G.2—Sample cost estimates for 8-foot and 12-foot embedded CMPs with 20-foot fill (continued)

Item No.	Description	Method of Measurement	Unit	Estimate Quantity 8'	Estimate Quantity 12'	Unit Price	Total for 8'	Total for 12'
251(16)	Placed filler material	DQ	Cy	8	10	\$50	\$400	Add \$100
304(10)	Crushed aggregate, type base, grading C, compaction B	DQ	Cy	15	17	\$40	\$600	Add \$80
601(01)	Mobilization	LSQ	LS	All Req'd	All Req'd		\$5,240	\$6,390
607(03)	Gate temporary, type I barricade, size 4.9m wide by 800mm high (or other traffic control features)	AQ	Each	2	2	\$2,250	\$4,450	same
617(06)	Galvanized steel 3" by 1" corrugated pipe (installed)	AQ	Ft	8' diam by 76' @ \$200 /ft	12' diam by 74' @ \$300/ft	Always check for latest prices	\$15,200	Add \$7,000
625(02)	Seeding, hydraulic method (with mulch)	DQ	acre	0.25	0.125	\$4,000	\$500	same
<b>Total estimate for 8' and 12' embedded pipes, fill height assumed at 20'</b>							<b>\$57,650</b>	<b>\$69,110</b>

Cost difference = \$11,460 (20%)

### **G.3.3 8-foot and 12-foot Embedded CMPs—12-foot Fill**

Table G.3 compares estimated costs for two embedded pipe single-piece structures with step pools and stream-simulation bed, complete site dewatering, and erosion control. Fill height is 12 feet; bank full width is 8 feet.

# Stream Simulation

Table G.3—Sample and cost estimate for 8-foot and 12-foot embedded CMPs with 12-foot fill

Item No.	Description	Method of Measurement	Unit	Estimate Quantity 8'	Estimate Quantity 12'	Unit Price	Total for 8'	Total for 12'
171(02)	Construction staking, precision C, method 1	AQ	Mile	0.2	0.2	\$5,000	\$1,000	Same
171(03)	Staking structures, precision C, method 1	AQ	Each	1	1	\$1,000	\$1,000	Same
201(03)	Clearing and grubbing, slash treatment methods for tops and limbs 12, logs 12, stumps 12, utilization of timber 2	LSQ	LS	All Req'd	All Req'd	\$1,500	\$1,500	Same
202(02)	Removal of existing 4-ft. dia. steel pipe, disposal method A	AQ	Ea	1	1	\$3,000	\$3,000	Same
157(19)	Soil erosion and pollution control	LSQ	LS	All Req'd	All Req'd	\$2,500	\$2,500	Same
157(20)	Dewatering and sediment control	LSQ	LS	All Req'd	All Req'd	\$10,000	\$10,000	Same
206(02)	Foundation fill (use mostly structural excavation, ad bedding volume)	DQ	Cy	53	80	\$50	\$2,650	Add \$1,350
206(07)	Structural excavation	DQ	Cy	1148	1296	\$20	\$22,960	Add \$2,960
251(14)	Placed channel rock, rock-12, method D (2 steps constructed in pipe)	AQ	EA	16	24	\$65	\$1,280	Add \$480
251(15)a	Placed streambed simulation rock, bed class 6, method D, both pipes embedded 4' add 10% for adjacent channel work	DQ	Cy	78	98	\$65	\$5,070	Add \$1,300
251(16)	Placed filler material	DQ	Cy	8	10	\$50	\$400	Add \$100

## Appendix G—Additional Tools and Tips

Table G.3—Sample and cost estimate for 8-foot and 12-foot embedded CMPs with 12-foot fill (continued)

Item No.	Description	Method of Measurement	Unit	Estimate Quantity 8'	Estimate Quantity 12'	Unit Price	Total for 8'	Total for 12'
304(10)	Crushed aggregate, type base, g grading C, compaction B	DQ	Cy	37	39	\$40	\$1,480	Add \$80
601(01)	Mobilization	LSQ	LS	All Req'd	All Req'd		\$7,350	\$9,410
607(03)	Gate temporary, type I barricade, size 4.9m wide by 800mm high (or other traffic control features)	AQ	Each	2	2	\$2,250	\$4,450	same
617(06)	Galvanized steel 3" x 1" corrugated pipe (installed)	AQ	Ft	8' dia. by 76' @ \$200 /ft	12' dia. by 74' @ \$300/ft	Always check for latest prices	\$15,200	Add \$7,000
625((02)	Seeding, hydraulic method (with mulch)	DQ	acre	0.25	0.25	\$4,000	\$1,000	same
<b>Total estimate for 8' and 12' embedded pipes, fill height assumed at 20'</b>							<b>\$80,840</b>	<b>\$103,520</b>

**Cost difference = \$22,680 (28%)**

## Stream Simulation

### G.4 TIPS FROM ENGINEERS AND BIOLOGISTS EXPERIENCED IN STREAM-SIMULATION CONSTRUCTION

This section includes details about tools, procedures, and problems common in stream-simulation projects. Several subsections summarize results of a workshop in February 2004 where experienced construction engineers and biologists discussed the common problems that can arise in placing embedded pipes, and their solutions.

#### G.4.1 Diversion, Dewatering, and Water Treatment System Components

A dewatering plan contains the information in supplemental specification 157 (appendix H, figures H.7, H.8, and H.13).

Figures G.3 through G.6 from the State of Oregon Department of Transportation show various types of dewatering systems.

##### G.4.1.1 Bypass and backwater dams

Different bypass and **backwater** dam structures are suitable for different conditions. Commercial cofferdams provide an ideal solution under some circumstances, especially in larger projects.

Following are the advantages and disadvantages of different bypass and backwater dams:

Water-filled cofferdams: flexible bladders that conform to the ground to form a seal (figures 2.7 and G.4). (For additional information, see [www.waterstructures.com/](http://www.waterstructures.com/) , [www.aquabarrier.com](http://www.aquabarrier.com) , [www.portadam.com](http://www.portadam.com).)

- Advantages.

- ▲ Are flexible, conform to streambed surface.
- ▲ Can be quickly installed.
- ▲ Are reusable.

- Disadvantages.

- ▲ Are expensive.
- ▲ May not provide for inserting a pipe through the dam, although some do.



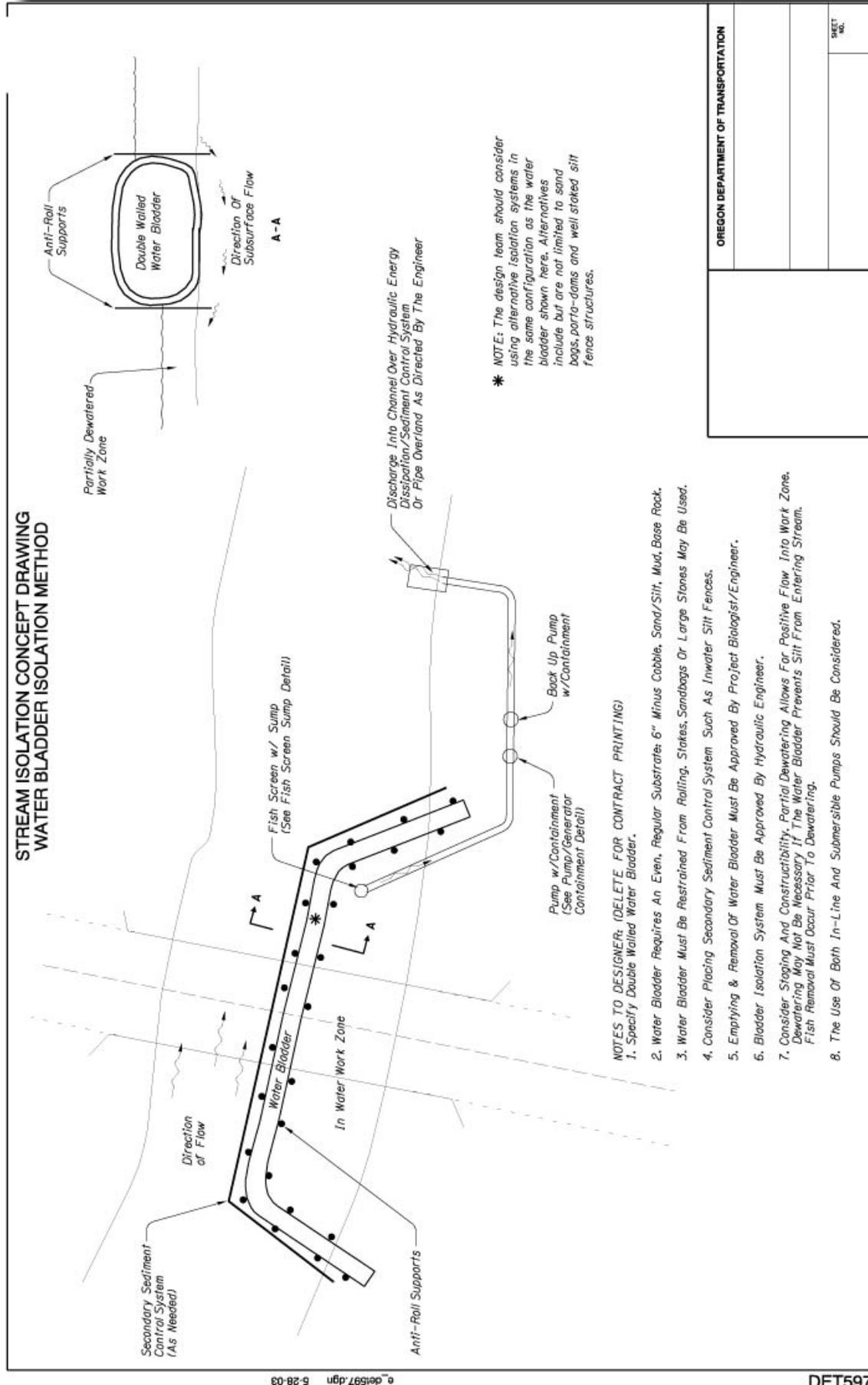
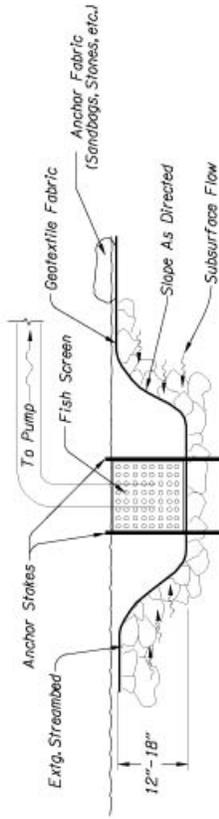


Figure G.4—Typical dewatering plan—water bladder isolation method—Oregon Department of Transportation.

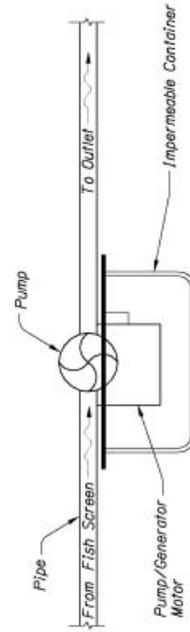
**DEWATERING CONCEPT DRAWING  
FISH SCREENING AND  
PUMP/GENERATOR CONTAINMENT**



**Fish Screen Sump Detail**

- General Notes:**
1. Screen Mesh Openings Shall Not Exceed  $\frac{1}{12}$ " For Woven Wire Or Perforated Plate Screens, Or  $\frac{1}{16}$ " For Profile Wire Screens, With A Minimum 27% Open Area, If Fry-Sized Fish Are Never Present At The Site (By Determination Of ODFW) Screen Mesh Openings Shall Not Exceed  $\frac{1}{4}$ " For Woven Wire, Perforated Plate Screens, Or Profile Wire Screens, With A Minimum Of 40% Open Area.
  2. For Information Not Provided Here, See "Juvenile Fish Screen Criteria For Pump Intakes", Developed By National Marine Fisheries Service.
  3. Active Screening Systems Should Be Considered When Heavy Debris Is Expected.
- Formula For Minimum Effective Screen Area For Passive Screens:  $\frac{\text{Max. Flow (cfs)}}{0.2 \text{ (fps)}} = \text{Minimum Effective Screen Area (Ft}^2\text{)}$   
Calculated Screen Areas Shown At Right.

Effective Flow Rate Of Pump		Minimum Effective Screen Area (ft <sup>2</sup> )
Gallons Per Minute	Cubic Feet Per Second	
50	0.111	.560
100	0.223	1.11
150	0.334	1.67
200	0.446	2.23
250	0.557	2.79
300	0.668	3.34
400	0.891	4.46
500	1.114	5.57
600	1.337	6.68
700	1.560	7.79
800	1.782	8.91
900	2.005	10.02
1000	2.228	11.14
1200	2.674	13.37
1400	3.119	15.60
1600	3.565	17.83
1800	4.010	20.06
2000	4.456	22.28
3000	6.684	33.42



**PUMP/GENERATOR CONTAINMENT DETAIL**

- General Notes:**
1. Size Container To Hold All Fuel And Lubricants Stored In The Pump/Generator Motor
  2. Mechanically Fasten Pump/Generator Housing To Container
  3. Support Container To Prevent Overturning

OREGON DEPARTMENT OF TRANSPORTATION	
SHEET NO.	

Figure G.5—Typical dewatering details—fish screening and pump/generator containment—Oregon Department of Transportation.

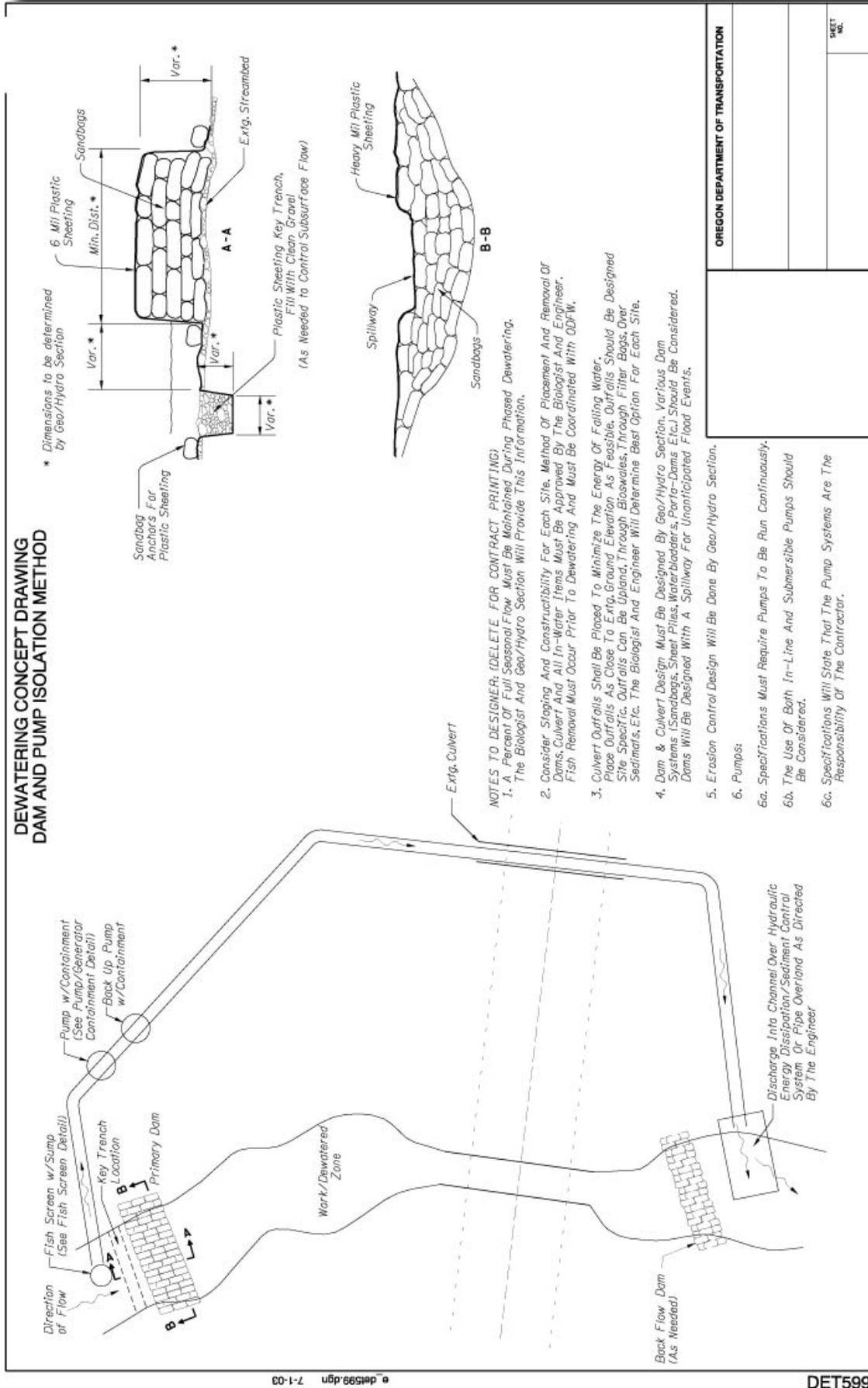


Figure G.6—Typical dewatering plan—dam and pump isolation method—Oregon Department of Transportation.

## Appendix G—Additional Tools and Tips

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- ▲ May need to be placed on a smoothed surface for a good seal.
- ▲ May require the addition of a impermeable membrane for intercepting additional subsurface flow.

### Pile cofferdams

- Advantages.
  - ▲ Can form a tight seal without a membrane.
  - ▲ Are sturdy.
  - ▲ Can be used to dewater deep water.
  - ▲ Can be used as retaining walls to hold back both water and deep excavations.
  - ▲ Can be fitted to conform to the site.
- Disadvantages.
  - ▲ Are expensive (to mobilize pile driver).
  - ▲ Create noise and vibration impacts.
  - ▲ Sometimes difficult to remove.

### Sandbag dams

- Advantages.
  - ▲ Simple and easy to construct.
  - ▲ Create a good seal when used with an impermeable membrane liner.
  - ▲ Relatively inexpensive.
  - ▲ Conform to the site easily.
- Disadvantages.
  - ▲ Labor intensive.

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### G.4.1.2 Pump types and characteristics

Table G.4—Characteristics of various pumps. Information was drawn from company Web sites.

Brand/Model	Pump Type	Max Solids	GPM	CFS	Max Head
Little Giant 6E-CIA-RFSN	Sump/effluent	1/2"	50	0.11	20'
Multiquip MQD306H	Diaphragm	1.5"	85	0.19	25'
Tsurumi TE2-50HA	Centrifugal	3/8"	137	0.31	115'
Tsurumi TE2-80HA	Centrifugal	3/8"	264	0.59	105'
Tsurumi EPT2-50HA	Trash	1"	190	0.42	90'
Multiquip QP2TH self prime	Trash	1"	215	0.48	90'
Multiquip QP302TY diesel	Trash	1.5"	416	0.93	90'
Multiquip QP301TI self prime	Trash	1.5"	416	0.93	90'
Multiquip QP40TH self prime	Trash	2"	611	1.36	90'
Multiquip41TDY diesel	Trash	2"	611	1.36	90'
Multiquip MQ61TDH diesel	Trash	2"	1,083	2.41	100'
Multiquip MQ600TD80 diesel	Trash	3"	1,600	3.56	150'
6" Godwin CD150M Dri-Prime	Trash	3"	1,750	3.90	160'
8" Godwin CD225M Dri-prime	Trash	3 1/8"	3,250	7.24	180'
10" Godwin CD250M	Trash	3 1/8"	3,600	8.02	180'
10" Godwin CD300M	Trash	3 3/4"	3,601	8.02	180'
12" x 10" Godwin HL10M	Trash	3"	4,500	10.03	390'

Pumping conditions—combinations of volume, pressure head, suction head, site access, available power, and water condition—determine what size and type of pump to use.

#### Sump Pumps

Powered by electricity, these can handle small solids and low flows with moderate heads. Their best use is for removing minor amounts of clear seepage at the inlet and outlet dewatering sump ponds and for very small stream flows. You can use multiple pumps.

#### Diaphragm Pumps

Engine-powered, these can handle shallow depths and slurry water, can handle air without losing their prime, and can handle water with a solid content greater than 25 percent by volume. These work where centrifugal pumps will lose their prime or plug. Nicknames include mud hogs, mud hen, and mud sucker. These pumps use a diaphragm rather than an impeller, and are more durable than other pumps. Their best use is for dewatering muddy sump ponds.

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### Trash Centrifugal Pumps

These are capable of handling large amounts of debris, with inlet diameters of 2 to 6 inches. They can handle solids, such as sticks, stones, and other debris. They can be quickly disassembled for service or inspection, and are available in diesel power. These are most suited for dewatering applications, such as diversion of flow during construction of dewatering dams, sump duty in large streams, and backup storm-water sump pumps.

### High-Pressure Centrifugal Pumps

These have high discharge and pressure. They are generally not capable of handling solids or even sandy water. Instead, they are used for wash-down equipment, or for irrigation and emergency standby pumps in areas with a high risk of fire. They are not suited for dewatering applications (except in very clean water as a help or backup pump). They may have use as a project high-pressure pump for washing fines into bed material from a clean-water source and for cleaning rock and soil off asphalt haul road surfaces.

### G.4.1.3 Sediment removal methods

Following are some common methods for removing sediment from construction-area water, along with some of the strengths and weaknesses of each method.

#### Gravity-based settling systems— large capacity *Sediment basins*

A pump inlet is attached to a floating suction hose placed in a stable location in the sump basin. The sump pump operation may be controlled by floats to save fuel and to control pool elevation. The dirty water is pumped to a basin with sufficient volume to hold both water and sediment long enough to allow it to settle and for water to seep into the surrounding soil or evaporate.

**Strengths:** Sediment basins hold large volumes of sediment. Such heavy settling sediments as sands settle out very effectively.

**Weaknesses:** As sediments settle into the basin, the retention time decreases, along with efficiency. These basins require a relatively large surface area. Silt and clay particles may take days or weeks to settle out, requiring the construction of a very large settling pond.

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### Tanks

There are two basic tank types: a standard storage tank with a single storage chamber, and a weir tank with multiple chambers to help increase settling efficiency. Tanks with capacities of up to approximately 18,000 to 21,000 gallons can be mobile.

**Strengths:** Mobile tanks eliminate the need for permanent dedication of space or construction of earthen dikes. The tanks can hold a large volume of solids before requiring clean out. Tanks require very little operational maintenance. The tanks can be operated in either batch or continuous operating modes. Properly designed tanks are easier to drain down than sediment basins, allowing a more rapid return to full storage capacity.

**Weaknesses:** Like sediment basins, tanks are rather ineffective in removing fine to medium-sized sediments. Mobile tanks have a limited storage capacity. A weir tank has a practical limit of 65 gallons per minute per tank for adequate sediment settling. (The flow capacity can be higher for larger sediments, such as large sands.) The tanks must be cleaned out when the project is completed.

### Passive Filtration Systems

#### Pressurized Sand Filters

Sand filters have a high filtering rate, meaning that the area they occupy is very small compared to sediment basins and tanks. A 100 gallon per minute sand filter will typically be 3 feet wide by 8 feet long. Sand filters produce reliable results. A portable sand filter using very fine sand can remove sediment down to the 50 micron range.

**Strengths:** They need only a small area. The ability to backwash makes a sand filter a very cost-effective choice in situations with medium to heavy sediments. For multiple-year projects, their setting-up, self-cleaning, backwashing capability makes them effective in removing large amounts of sediments. An automatic backwash controller eliminates the need for constant operational supervision.

**Weaknesses:** Sand filters do not effectively remove fine silts or clays. A medium-head pump is required for pressurizing the system. The backwash generates a concentrated waste stream that must be disposed of or treated by other methods.

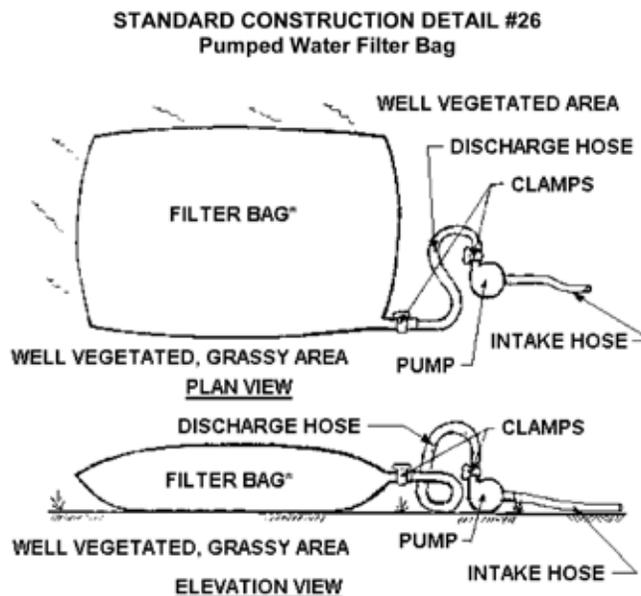
## Appendix G—Additional Tools and Tips

### Bag Filters

These filters are lightweight fabric bags capable of filtering particles as small as fine sand (figure G.7). They are available in various sizes to suit project requirements. When full, they must be removed, generally by cutting and disposing of sediments.

**Strengths:** They are effective in removing heavy sediments. They are best used in vegetated areas where the vegetation is used as additional filtration.

**Weaknesses:** They will not remove such fine sediments as silts and clays until a filter cake builds up. The length of time it takes for a filter cake to develop is unpredictable. When the filter cake is built up, the flow rate diminishes. Bag filters become heavy with sediment and are difficult to remove. They are not reusable.



Filter bags shall be made from non-woven geotextile material sewn with high strength, double stitched "J" type seams. They shall be capable of trapping particles larger than 150 microns.

A suitable means of accessing the bag with machinery required for disposal purposes must be provided. Filter bags shall be replaced when they become  $\frac{1}{2}$  full. Spare bags shall be kept available for replacement of those that have failed or are filled.

Bags shall be located in well-vegetated (grassy) area, and discharge onto stable, erosion resistant areas. Where this is not possible, a geotextile flow path shall be provided. Bags shall not be placed on slopes greater than 5%.

The pump discharge hose shall be inserted into the bags in the manner specified by the manufacturer and securely clamped.

The pumping rate shall be no greater than 750 gpm or  $\frac{1}{2}$  the maximum specified by the manufacturer, whichever is less. Pump intakes should be floating and screened.

Filter bags shall be inspected daily. If any problem is detected, pumping shall cease immediately and not resume until the problem is corrected.

Figure G.7—Typical bag filter system (Pennsylvania DEP 2000).

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**Pressurized Bag Filters** These are fabric bags contained inside portable cylinders that allow the bags to be pressurized.

**Strengths:** They can be easily moved from one location to another. They are most effective in removing medium to heavy sediments.

**Weaknesses:** They do not efficiently remove fine sediments such as silts and clays. The smaller bag surface area and volume means that the sediment-holding capacity is much less than for gravity bag filters.

**Wound Cartridge Filters** These are tightly wound filaments that form a cartridge, which is used as the filter media inside pressurized cylinders.

**Strengths:** They are capable of removing silts and some clay not removed by sediment basins, sand filters, or bag filters. Wound cartridge systems provide the best sediment removal efficiency without the need for chemical treatment. They are highly portable and use a small area. Operational effectiveness is consistent.

**Weaknesses:** Wound cartridges will not remove colloidal clays. They have a low sediment-holding capacity.

## Polymer Treatment Systems

These systems work by adding a polymer to the untreated water, which creates a floc (a flocculent mass formed in a fluid through precipitation or aggregation of suspended particles). The flocs are either allowed to settle or are filtered out.

**Strengths:** Water-based polymer treatment systems provide consistent removal of fine sediments. They are highly effective in removing colloidal clays. The settling tanks or ponds can be designed to hold large quantities of sediments. Ground application of the polymer enhances erosion and sediment control simultaneously, at a low relative cost. Small in-hose cartridges are available for projects with small flow rates and small **sediment loads**.

**Weaknesses:** Water-based polymer treatment systems are water treatment systems (as opposed to the simple passive filtration systems used to remove sediment.) As such, they are more complex and costly than other sediment removal measures. Depending on local regulations, these systems may require a permit for use, as well as licensed personnel to design and monitor the system during operation.

### G.4.2. Foundation and Footing Design

#### Considerations

This section highlights several considerations that many designers miss during foundation design for open-bottom structures. Skilled designers should always review all preliminary and final designs.

#### G.4.2.1 Overturning forces

Actual foundation stresses are complex.

- On the fill side of the footing is pressure from the overlying embankment soil.
- On the streamside is a variable depth of saturated stream-simulation material that may change in depth from scour and aggradation during the project's lifespan.
- The footing receives the structure load at the angle of the structure to the footing.
- The foundation rests on material that may be saturated or partially saturated.
- The stress from the embankment weight and traffic can increase along the footing, ranging from none at the inlet and outlet to a variable amount at the embankment edges. This load can be averaged over the length of the footings.

The resulting load on a footing is a combination of overturning forces that create an eccentric load beneath the structure's leg. The footing is typically sufficiently offset to center the load and spread it evenly, thereby reducing peak soil stress. Short, wide footings (2 feet by 2 feet) experience a minimal eccentric load, which you may ignore under most circumstances. Taller footings develop increasing eccentricity with depth. To remove this eccentricity, move the center of footing to the center of the footing reaction. For most moderate or high strength soils, either a spread footing and stem wall or a rectangular or wedge-shaped footing will usually work. Concrete footings for arches tend to be massive, partly for constructability reasons.

Design each footing's reinforcement for the forces present, and then check to see if temperature steel is needed in addition. (Reinforcement for temperature is not normally added to structural steel.) Have a design engineer with expertise in reinforced concrete review the designs.

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### G.4.2.2 Scour

Open-bottom arch footings should extend to 2.5 to 5 feet below the lower vertical adjustment potential line identified in sections 5.2.2.2 and 6.1.2. Although footings are normally 2 to 5 feet wide, larger sizes may be necessary when scour potential is large or soils are soft.

Foundations are not inherently prone to scour, but material placed next to the foundations can scour if not sized properly for the hydraulic forces in the culvert during large flood events. Shaping the streambed and providing edge diversity can keep water from eroding a trench against the side of the culvert. Trench erosion tends to occur along footings because the smooth concrete surface provides less resistance to flow than a standard or deep corrugated culvert. The thickness of the stream-simulation bed against the structure edge is important for providing sufficient interlocking of large particles for stability.

To increase footing **roughness** and help hold sediment against the smooth concrete, use deeply textured concrete forms. You can construct a roughened surface from deeply textured forms by simply attaching lumber (2 by 4 or larger) to the inside of the formwork.

The top of the footing normally reaches above the bankfull height measurement of the channel. If the footing is constructed above the bankfull line, the structure itself will receive less abrasion from mobile stream sediments and therefore last longer.

### G.4.2.3 Bedrock

When bedrock is located at shallow depths or only slightly deeper than necessary for the foundation support, you can pour the footings directly onto the bedrock. Although placing a footing on rigid bedrock is not standard engineering practice, the procedure is safe as long as the design (a) contains an adequate safety factor and (b) requires good quality, well-compacted backfill. Use structural backfill (A-1-a) for all bedrock foundations. Doweling to attach footings to bedrock is seldom necessary, because of the high friction developed between rock and concrete. That high friction prevents movement under all but the most extreme debris-slide impacts.

### G.4.2.4 Soil strength

For sites with very soft soil, an embedded pipe or bridge with a driven pile footing may be a better option than a bottomless arch and footing. For

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bridges, you can use a driven or drilled pile foundation to support the load on a deep, firm surface below the softer surface soils. Alternatively, you can drive piles deeply into soft substrates to produce enough support.

Settlement is a concern, especially with fine-grained streambeds. If the culvert is replacing an existing pipe and the embankment height is not changed, then the foundation may be consolidated and settle little under the new structure. If any special foundation treatment is required, it should be detailed on the drawings and covered with a supplemental specification based on the embankment compaction specification. For example, if settlement is projected to be excessive for the road standard, the foundation area can sometimes be excavated to a depth of stiffer material and backfilled with high-strength material. If doing so is not feasible, a bridge with pile foundations may be the only practical option to use.

Settlement of embankment and backfill material can cause drag forces in the culvert if the culvert cannot settle at the same rate or slightly more than the embankment. Be sure to analyze both the foundation material and backfill material for settlement potential.

### General principles for arch foundations

Chapter 12, article 12.1.6.3, in AASHTO Standard Specifications for Highway Bridges, Soil-Corrugated Metal Structure Interaction Systems (AASHTO 2002) is an excellent reference for footing design. The chapter lists the following design principles for arch foundations:

- Making the metal arch relatively unyielding or fixed, compared with the adjacent sidefill, is not a good idea.
- The footing design should provide uniform longitudinal settlement of acceptable magnitude, to reduce drag forces caused by **consolidation** of the adjacent roadfill.
- Footing reactions from the arch thrust should be calculated to act tangentially to the metal plate at its point of connection to the footing. For example:
  - ▲ Half-round arches have a 90-degree attachment angle.
  - ▲ Other arch shapes attach at an angle up to 20 degrees.
- Knowing the effect of the depth of the base of the footing and the direction of the footing reaction from the arch is important. The deeper the footing, the more eccentricity the arch-attachment angle will produce.

### G.4.3 Revegetation and Erosion Control

For a project to be successful, erosion control and revegetation must complement each other. Erosion control is a collection of tools working together; no single tool can be completely effective by itself. Success will come with a staged approach: first, minimize the amount of soil disturbed; second, stabilize whatever soil is disturbed; and, third, achieve long-term stabilization of all disturbed materials. Except in very arid environments, long-term site stabilization usually occurs only when the disturbed area is fully revegetated.

Temporary erosion and sediment control measures should be designed with the long-term stabilization plan in mind, so that they do not conflict. Where possible, design long-term measures into the short-term erosion control plan (figure G.8). For example, a steep ditch on an approach road needs both short- and long-term erosion and sediment control measures. Short-term sediment control might consist of sandbag check dams to be removed after construction, along with a sediment basin that will detain ditch runoff water both during the project and during stabilization.

Supplemental specifications for revegetation and erosion control should be written as performance-based specifications (for example, “% or # of plants must be alive in x years; downstream turbidity shall not exceed \_\_\_”). Do not specify methods: planting methods, watering intervals, filtration methods, silt fence locations, etc. Method-based specifications are difficult to administer, and failures are blamed on the method. With performance based specifications, contractors are free to choose the method that best suits their work style, and the responsibility for achieving the end product is theirs.

Environmental documents may require planting indigenous (native) species, providing for rapid site stabilization by seeding a pioneer species such as sterile wheat, or using bioengineering techniques. Note that the topic of revegetation includes several sub-categories, including:

- “Turf establishment” or “reseeding”—typically growing grasses, forbs, and sometimes shrubs from seed.
- “Plantings/cuttings” (involving the planting of container plants or the use of shrub cuttings).
- Bioengineered structures (willow wattles, live fascines, etc.).



<b>Colorado Department of Transportation</b> 4201 East Arkansas Avenue Denver, CO 80222 Phone: (303) 757-9883 FAX: (303) 757-9820	<b>Computer File Information</b> Path: <a href="http://www.dot.state.co.us/traffic/projects/design/Support/NE/roadentm/">www.dot.state.co.us/traffic/projects/design/Support/NE/roadentm/</a> Drawing File Name: 208010107.dwg Acad Version: R14 Scale: MA Units: English		<b>Standard Plan Revised</b> Date: _____ Comments: _____	<b>TEMPORARY EROSION STANDARD PLAN NO.</b> M-208-1
	<b>Project Development Branch</b> SD			<b>CONTROL (Typical Layout)</b> Issued By: Project Development Branch October 1, 2000 Sheet No. 1 of 7

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Figure G.8—Sample temporary erosion control drawing sheet 1 (Colorado Department of Transportation).

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Revegetation, particularly with native species, is an extensive topic that this guide presents only as an overview. (For bioengineered structures, see section G.4.3.9.)

Timing is critical in revegetation, particularly with native species. In some instances, plant materials must be grown from seed collected from the site. Doing so requires a project lead time of 1 to 2 years (and sometimes more). If you do not consider revegetation planning at the project's start, your oversight can delay the entire project.

### G.4.3.1 Salvaging and storing topsoil

In the contract, define topsoil by depth and rock/wood content. Topsoil refers to the uppermost soil horizon, usually 2 to 8 inches deep. Topsoil may include live vegetation less than 3 feet in height, limbs less than 3 inches in diameter, and organic duff.

Remove topsoil before doing anything else. To avoid compaction, do not drive on topsoil before, during removal, or after replacement.

If less topsoil is available for salvaging than you will need for revegetation:

- Use commercial mulches in place of topsoil. The mixture must be free of weed seeds, harmful bacteria or disease spores, and substances toxic to plant growth.
- Spread topsoil thin to maximize cover of the seed bank contained in topsoil.

To maintain and store “living soil:”

- Stipulate topsoil storage details in special contract requirements or supplemental specifications (depth of piles, length of storage time, number of moves, etc.).
  - ▲ After topsoil has been stored for extensive periods (i.e., 3 months for nonforest sites and 6 months for forest sites), spread it thin and allow it to revegetate.
  - ▲ Do not store conserved wetland sod for more than 1 month.
- Avoid contaminating topsoil with unsuitable material. Do not mix topsoil with subsoils.

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- Designate topsoil stockpile location.
- Store topsoil close to where you found and removed it, to protect it from loss and contamination.
- Put up a sign indicating topsoil, to avoid mixing it with other excavated materials. Also designate the source location and return topsoil/seed bank to its original location.
- Avoid over-winter storage.
- Install sediment control measures around storage site.

Dealing with topsoil infested with noxious or invasive weeds:

- Specify that topsoil sources shall be free of weeds and invasive species.
  - ▲ Map known areas of infestation and control them mechanically or chemically. (Note: Before using herbicides, consult national herbicide **BMPs**.)
- Do not use infested topsoil. Enlist help from the project team for proper disposal or treatment.
- Make sure to pressure-wash or steam clean all incoming equipment.

Replacing topsoil on steeper slopes:

- You may need special equipment and manual methods for proper workmanship in difficult terrain. Design slopes with planting pockets and ledges that hold the soil in place to promote revegetation.

### **G.4.3.2 Collecting seeds and cuttings for native species revegetation**

Environmental documents sometimes require seedlings, which take 1 or 2 seasons to grow from seed. Plan at least 2 to 3 years in advance to have native plant materials available (i.e., to find and collect seed and cuttings).

- Understand safe storage requirements for the species you intend to use.

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### G.4.3.3 Water quality monitoring

- Thoroughly understand water quality permit and NEPA document requirements.
  - ▲ Include requirements in special contract requirements or supplemental specifications to make sure they are part of the contract.
- Before construction, establish the baseline for the following factors (or others as required by the permit or NEPA document):
  - ▲ Turbidity.
  - ▲ Temperature.
  - ▲ Dissolved oxygen.
- During construction, ensure that proper water quality monitoring methods are employed, and that monitoring frequency is adequate to meet permit or environmental document requirements.

### G.4.3.4 Training and quality control

- Effectively communicate which resources the erosion control plan protects.
  - ▲ Use well-written performance-based supplemental specifications.
  - ▲ Conduct an in-depth review of the erosion control plan, permit, and contract requirements with the contractor, the project team, and inspectors.
  - ▲ Use well-trained COR and inspectors for communicating and enforcing contract requirements.
- Ensure sufficient quality control.
  - ▲ Train designers and contract administrators in effective erosion control measures and temporary stabilization methods.
- If the contractor requests—or unexpected site conditions demand—a change to a previously permitted erosion control plan, review the design/protection criteria from NEPA document (what you are protecting and why). Consult with the project team before making a change to ensure the change will meet the intent of the original erosion control plan.

### G.4.3.5 Temporary soil stabilization until vegetation is fully established

Temporary methods for stabilizing disturbed soil (near streams) before permanent revegetation is fully established include:

- Temporary seeding (annual grass).
- Temporary cover such as plastic sheeting, mulch, netting.
- Rock blankets/riprap.
- Entrenched coir logs.
- Matting.
- Silt fence at ditch relief outlets.
- Chemical soil stabilizers.

‘In stream’ construction windows do not necessarily coincide with best streamside planting times. (These time differences often require two separate contracts—one for the crossing construction and one for revegetation.)

- Install and maintain temporary erosion control measures until revegetation criteria are met. Make sure that these measures are contract requirements. (If they are not in the contract before construction, add them through a contract modification.)

The agency must provide manpower and funding for several years, either to enforce revegetation and erosion control contract provisions or to maintain the erosion/revegetation plan after work on the contract has been accepted. The contractor is not responsible for erosion/revegetation work needed after the contract is closed.

### G.4.3.6 Miscellaneous ‘things that can go wrong’ during construction

“Maximum area disturbed” clause of contract is ignored.

- This clause is the first line of defense for sediment control, and is especially critical in rainy environments. Enforce contract requirements for maximum disturbance area.

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Occasionally, a contractor may deliberately violate water quality permit conditions. Actions that have been observed include shoveling sediment from a silt fence into the stream, and pumping muddy water from structure excavation into the stream.

- Check erosion control installations daily, especially after rain events.

Although silt fences must be maintained to remain effective, they are frequently placed in inaccessible locations.

- Use brush windrow wrapped with biodegradable fabric (may be left permanently).
- Ensure that a difficult location is important to long-term erosion control objectives. If the location is negotiable, work with permitting agency in design phase.

Temporary instream sediment traps (for example, filter cloth/lay-back trap) may trap too much sediment for hand removal.

- Do not construct such structures unless they are accessible by equipment for maintenance.
- Rely on erosion controls first. Always think of sediment controls as a last resort.

Large storm events may exceed capacity of erosion control system.

- Check history of large events during construction window and any information available on what measures worked at that time of year.
- Design for controlled failure and minimize consequences of failure.
- Place the burden of performance on the contractor—use performance-based specifications.

### **G.4.3.7 Seasonal work shutdown and resumption of work**

Design for temporary stabilization over winter. Plan longer-term sediment controls for multiseason projects or for shut-down in extreme weather conditions.

- Include provisions in supplemental specifications or special contract requirements for periodic maintenance.
- In the erosion control plan, define locations for sediment cleaned-out of silt fences, settling basins and other sediment control facilities.

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Temporary stabilization for winter is often underbid and frequently overrun. In late fall, the contractor may be behind schedule and view this work as a second priority.

- Enforce contract requirements for temporary stabilization. The COR must remind the contractor of the requirements well in advance of seasonal closure and ensure the site is protected according to the contract.

Final maintenance of erosion control measures before seasonal shut down:

- Clean out silt fences.
- Water bar closed roads.
- Divert runoff to “safe” area with erosion control measures.
- Check periodically during winter for maintenance needs. (For example, rain on existing snow packs may cause greatly increased runoff and erosion.)
- Stabilize area left disturbed over winter.

Runoff-season drainage patterns may differ greatly from construction season.

- On south-facing cuts/slopes, frost will thaw more quickly.
- Muddy runoff may enter stream running over snow while silt fences are still buried under snow.
- On disturbed soils, fluffy surfaces will thaw faster and can slide on top of frozen surfaces.

Before construction resumes in the spring, inspect, maintain, and enforce all erosion control measures (all erosion control contract provisions).

### G.4.3.8 Common problems with revegetation

Revegetation is a critical element in the long-term stabilization of any construction project—and particularly vital to projects close to waterways requiring aquatic organism passage. The lack, or subsequent loss, of long-term stability can not only cause an otherwise successful project to fail but also damage the aquatic environment that the project originally intended to enhance.

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Common problems along with suggestions for *avoiding* or *solving* them follow. These problems have no quick or easy answers, so adequate research and planning are vital. Using performance-based specifications for revegetation, either as a part of the construction contract or as a separate contract, can avoid many of these problems by giving the revegetation contractor responsibility for successful vegetation establishment.

Plant materials specified in contract are not available.

- Call local plant nurseries or local Natural Resource Conservation Service (NRCS) office to identify plants that are or are not commercially available. NRCS offices can also help you distinguish native plants from nonnative plants for a given ecological setting. (While this work should have been done during the design phase, you may need to do it during construction if plant substitutions are required.)
- Develop a list of acceptable grass, forb, and shrub plants in the local area. Then refine this list to identify species that are:
  - ▲ Native or nonnative to that ecological area.
  - ▲ Commercially available as seed or container plantings.
  - ▲ Available to be collected (cuttings).
- Ensure you know the best time to plant each species, and which can substitute for others.
- To be successful, plant substitutions should ideally mimic the ecologic role of the originally specified plant (assuming that the role was identified). If the original plant was intended to thrive in a riparian zone, is the substituted plant an upland species? Will the plant stabilize the soil with deep or widespread roots, or is it intended to serve as ground cover to protect riparian soils from rainfall impact? As these details will vary with each project, you need to factor them in for the intent of the revegetation to be successful.
- If the plants will be commercially ordered, know the delivery schedule and ensure it meets the desired planting window.

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Plant materials are at risk of dying or do not grow as quickly as desired. For example, work might be complete in the fall, as planned, but a drought makes it unlikely that the plants will survive.

- For projects encountering weather problems, either delay the revegetation work or modify the contract to do revegetation as a separate contract.
- If these options are not available, pay the contractor for watering the plants long enough for germination and establishment (typically several weeks, but possibly a month or two).
- Use “dry water,” a type of water-saturated gel that can be placed in the ground with container plants. (Guidelines based on successful experience are not widely available yet.)
- Native plants in many ecosystems may begin to establish themselves in the first year but may take 2 to 3 years to become fully established. Do not expect native plants to establish as quickly as some commercial turf grasses.

Plant materials do not grow at all. Improper selection, handling, or storage is a frequent cause.

- Base the revegetation specifications on site-specific conditions. To be successful, the revegetation specifications must include site-appropriate species. Sampling and analysis may be needed to characterize the soil materials that will be revegetated; if so, they should be specified.
- Develop guidelines for the proper storage, transportation, and handling of the specified plant materials. Contact local nurseries and offices of the NRCS to learn what methods are necessary.
- Provide necessary training for CORs and Inspectors regarding transporting, handling, storing, and planting seed or plants.

Plant materials are damaged or killed after successful establishment.

- In areas where herbicides are part of the weed eradication program, use grass species rather than forb (broad-leaf) species in the specifications, since grass is often more resistant to herbicides.

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- In areas where wild grazing animals are common, select species that are less attractive to grazing animals to reduce chances of heavy grazing.
- In areas where the herding of domestic animals is common, seek cooperation with local animal owners: Ask that they delay herding or provide alternate herding routes during the times critical to germination and establishment of permanent vegetation.

Invasive or noxious plants are observed on site before or after construction.

- Determine which plants are invasive. For a list of invasive or noxious plant species, by state, see the USDA Animal and Plant Health Inspection Service Web site, listed under Resources.
- Before construction, physically remove weeds observed on-site or treat them with herbicide methods where legal. (See NEPA documentation before using herbicides.)
- During construction, take a proactive approach to avoid inadvertently transporting invasive species to the site. Include in the special contract requirements or supplemental specifications the provision that all construction vehicles be washed before entering the construction area. This provision will minimize the transport of noxious weed seeds from other areas.
- Require plant seed used in revegetation be tested for the presence of invasive or noxious weed seeds at appropriate state seed labs.
- Do all you can to foster a healthy revegetated area—it will be more resistant to invasive or noxious weed species than areas that are not successfully revegetated.

### G.4.3.9 Resources for revegetation and erosion control

Lewis, Lisa. 2000. Soil bioengineering – an alternative to roadside management – a practical guide. 0077-1801—SDTDC. San Dimas, CA: U.S. Department of Agriculture, Forest Service, San Dimas Technology and Development Center. 44 p.

Luna, Tara; Dumroese, R. Kasten; Landis, Thomas D. 2006. Collecting dormant hardwood cuttings for western riparian restoration projects. 0624-2334—MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. <http://www.fs.fed.us/t-d/pubs/htmlpubs/htm06242334/> (Username: t-d, Password: t-d)

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Salix Applied Earthcare. 2002. Erosion Draw 4.0 , (<http://www.erosiondraw.com/>), or SAE homepage: <http://www.salixaec.com>)

Salix Applied Earthcare. 2002. Bio Draw 2.0 , (<http://www.biodraw.com/>), or SAE homepage: <http://www.salixaec.com>)

U.S. Department of Agriculture. 2002. The PLANTS Database, Version 3.5 (<http://plants.usda.gov>). U.S. Department of Agriculture, Natural Resources Conservation Service, National Plant Data Center, Baton Rouge, LA 70874-4490.

U.S. Department of Agriculture. Various links to Noxious Weed lists and Federal Seed Act information (<http://www.aphis.usda.gov/ppq/weeds/nwauthor.html>)

### G.4.4 Aquatic Organism Capture and Transport

Following are recommended procedures for successfully capturing and transporting aquatic organisms during dewatering.

Block off site upstream and downstream. Set block nets to prevent organisms from entering the construction zone from upstream and downstream while the site is being dewatered.

Dewater all or part of the channel in stages. Dewatering slowly minimizes shock and harm to the organisms.

Trap and transport aquatic organisms. As the site is dewatered, trap organisms with dip nets and by hand. (Electroshocking may be necessary for some fish.)

Stage and control rewatering after the project is completed. Rewatering the site slowly prevents turbidity and temperature levels from rising suddenly, and minimizes harm and shock to aquatic organisms.

No standard method exists for capture and handling of aquatic organisms. The biological opinion from the regulatory agency should cover the methods for Endangered Species Act-listed species. State fish and game agencies are a good source for guidelines for handling captured aquatic organisms. As a general rule, place captured fish in a bucket of water kept at near stream temperature.

Knowing which fish, mollusks, crustaceans, and amphibian species inhabit each site is important, because different species are more easily captured at different stages of dewatering. Capture begins immediately after you have isolated the construction area with block nets. Capture stages for aquatic species encountered in Oregon are as follows:

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- Before actual dewatering begins, use nets and/or seines to efficiently capture juvenile salmon, adult and juvenile cutthroat trout, dace and red side shiners, other small minnow-like fish, and slow-moving amphibians.
- After dewatering begins and as the water level is dropping, capture red-legged frogs, mollusks, and crustaceans.
- When the water level at the site is drawn down, capture stream-bottom oriented fish, sculpin, and three-spine stickleback.
- After dewatering, capture stream-bottom species such as lamprey, because they come out of the substrate when the ground is disturbed.

Place traps and/or screens on the bypass system pumps and hoses. When using a passable pipe or channel bypass system, review the outlet, water depth, and velocity to ensure that aquatic organisms can pass through the system unharmed.

The following case examples demonstrate procedures for capturing and transporting aquatic organisms from construction sites. The principles are the same for stream restoration projects, as illustrated in the third example.

### G.4.4.1 South Fork Desolation Creek

Block nets were placed above and below the work site the day before construction started. Fish were removed from the construction site by electro-fishing (figure G.10). Captured fish were placed in 5-gallon buckets filled with water kept at stream temperature, and the buckets were carried downstream for release. Dewatering consisted of confining streamflow to the middle of the creek and dewatering the foundation trenches with pumps during placement of the precast concrete footings. As dewatering progressed in the foundation trenches, more aquatic organisms were captured and removed. Block nets were kept in place until construction was completed and the entire streambed within the open-bottom arch was rewatered. Figure G.11 shows block nets in place both upstream and downstream, with the stream diverted to the middle between the footings of the newly placed arch.

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*Figure G.10—South Fork Desolation Creek looking upstream. The crew captured fish trapped within the construction area as the foundation trenches were dewatered.*



*Figure G.11—South Fork Desolation Creek construction site showing block nets.*

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### G.4.4.2 Karnowski Creek habitat restoration

Karnowski Creek was rerouted to the valley margin in the late 1800s when cross-valley drainage ditches were constructed to drain the valley bottom for pasture and hay land. During the habitat restoration project, the drainage ditches were plugged and Karnowski Creek was relocated in its historic midvalley location. Aquatic organisms were captured and relocated before, during, and after each ditch was dewatered, plugged, and backfilled. (See figures G.12 to G.13/9.) Figure G.14 shows the percentage of individuals of each species captured before plugging and after the ditches were fully plugged and dewatered. The majority of the salamanders, frogs, and lampreys were captured after plugging.



*Figure G.12—Trout and sculpin are seined from ditch prior to plugging, and captured with dip nets.*

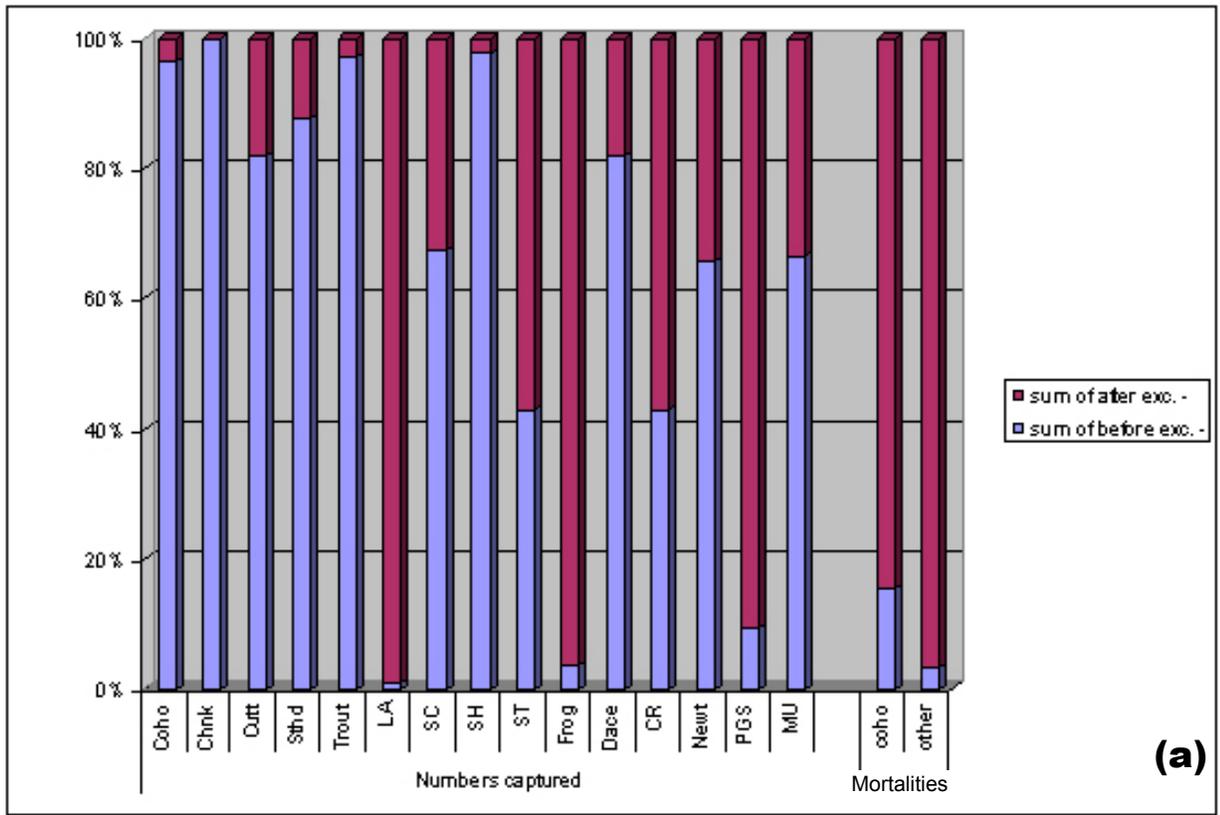
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*Figure G.13—Capturing aquatic organisms by hand as the site is dewatered.*

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Common Name	Abbrev.
<i>coho salmon</i> .....	<i>coho</i>
<i>chinook salmon</i> .....	<i>chnk</i>
<i>cutthroat trout (1+)</i> .....	<i>cutt</i>
<i>steelhead trout (1+)</i> .....	<i>stlhd</i>
<i>trout (0+)</i> .....	<i>trout</i>
<i>pacific lamprey</i> .....	<i>LA</i>
<i>sculpin</i> .....	<i>SC</i>
<i>red-sided shiner</i> .....	<i>SH</i>
<i>three-spine stickleback</i> .....	<i>ST</i>
<i>red-legged frog</i> .....	<i>frog</i>
<i>dace</i> .....	<i>dace</i>
<i>crayfish</i> .....	<i>CR</i>
<i>newt</i> .....	<i>newt</i>
<i>pacific giant salamander</i> .....	<i>PGS</i>
<i>mussel</i> .....	<i>MU</i>
<i>coho mortalities</i> .....	<i>coho mort</i>
<i>other mortalities</i> .....	<i>other mort</i>

Figure G.14—(a) Percentages of total individuals of each species captured before and after dewatering. (b) Species identification table.