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IRRIGATION SYSTEMS FOR RESTORATION & MITIGATION SITES

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I. Introduction

This paper summarizes Sound Native Plants' experiences with designing, installing and operating three different types of irrigation systems on mitigation and/or restoration sites in western Washington over the past 1½ years. Each system is described and the installation and operation costs, pros and cons, and preliminary plant survival data for each system are presented.

II. Overview of three systems

The first system uses hand watering for individual plants. The second system uses drip irrigation to deliver water to individual plants. The third system uses drip irrigation to wet the entire site.

A. SYSTEM 1: HAND WATERING

1. Description of site/system:

During 2002, Sound Native Plants irrigated 14 separate wetland and stream mitigation sites in Clark County using hand watering. Six of the sites had been originally planted 1-2 years earlier. Mid-March through April 2002, more plants were added to the six sites and eight new sites were planted in entirety. The sites varied in size from a few thousand square feet to 3.26 acres, and the number of plants at each site ranged from 65 to 1,412. In total, 8,280 plants were irrigated, of which 4,261 were installed in 2002 and the remaining 4,019 plants had been installed 1-2 years earlier. The older plantings had received maintenance of less consistent quality prior to 2002. Some of the 2002 plantings were replacements for earlier plantings that had died.

A 3,000-gallon water truck was filled at one of two near-by hydrants and driven to the sites. The water truck had a gasoline-powered pump that provided water pressure to the hoses. Upon arrival at a site each day, the 2-person crew laid out lightweight fire hoses. These were branched with Y connectors so that individual hoses could reach all areas of the site. Crew members used watering wands attached to the hoses to water individual plants. When one site was completed, the crew moved to the next.

Two full-time crew people operated the system. In addition to irrigating the sites, the crew people also performed other site maintenance activities, including weeding and maintaining tree protectors, weed barrier mats, and mulch. Watering began in late May and continued through the end of September. Each site was watered once every two to three weeks on average. In reality, the schedule was modified so the driest sites were watered more often and the wettest sites were watered less often.

2. Cost
Construction cost: $0
Operation cost was $56,996 for one season.

Operation cost breakdown	
Water & hydrant fees	$1,471
Truck lease incl. insurance	14,388
Labor	39,729
Miscellaneous	1,408
Total	**$56,996**

Average cost of irrigation per plant, total for the season: $6.88
Average cost of irrigation per plant per watering: $1.01

An additional $4,769 (approximately1.5 person-days per week) was spent on other maintenance activities such as weeding, mulch renewal, etc., for a labor total of $61,765. Average cost of *all* maintenance (irrigation and other) per plant for the season was $7.46.

3. Effectiveness

a. Overall survival rate: 98.7%. This does not include the poor survival of the bareroot alders, which were not replanted due to extensive natural recolonization.

b. Other influences on survival

Most of the plants that died were planted in previous years and had received less consistent maintenance before 2002. The greatest losses of the 2002 plantings were bareroot alder planted in rocky soil on a steep slope. We have found that bare root alder performs poorly in general, both on restoration sites and in the nursery.

Other factors contributing to plant mortality included animal damage and inappropriate plant selection for constructed site hydrology. Clark County reports an overall survival rate for all 24 sites in its jurisdiction of 94% in 2002. Prior to 2002, the primary contributors to plant mortality were weed eater damage, improper planting, inadequate weeding and use of unhealthy bareroot stock.

4. Pros

- The crew gave attention to each individual planting throughout the season.
- The watering was tailored to each individual plant and microsite.
- It was easy to adjust the schedule to compensate for changing weather.
- Extensive information gathered about each site led to better adaptive management.
- Individual watering did not encourage weed growth between plantings.
- Provides best overall stewardship of site.

5. Cons

- Very labor-intensive.
- Difficult to make water soak into ground, especially on slopes – more runoff.
- Repetitive work over an entire season affected crew interest and motivation .
- Distance from some sites to refill stations may have reduced efficiency.

6. Some appropriate applications

Large site or multiple sites in one area.

7. Special considerations

In order to do the best job, you need a crew that is familiar with the site and knowledgeable of native plants and landscaping. It is hard to find a landscape contractor with a water truck and the necessary knowledge. A leased or contracted water truck operator will not likely have the needed expertise to do the watering, so you would need to have the truck operator work with an experienced crew. Unless you have enough work for a close-to-full-time crew, it might be hard to find a contractor willing to take on the job, since they would need to lease a truck full-time.

B. SYSTEM 2: DRIP IRRIGATING INDIVIDUAL PLANTS

1. Description of site / system

In December 2001-January 2002, Sound Native Plants installed a drip irrigation system on a 3.3 acre riparian restoration site located on a tidal slough of the Chehalis River in Grays Harbor County. The site was planted in January 2002, following irrigation system installation. In total, 5,460 plants were installed, 951 of which were trees.

The irrigation system was divided into three zones, each with an independent sub-system. Each sub-system consisted of drip-tubing with pressure-compensating emitters pre-installed every 48" along the tubing. Each emitter delivered 0.9 gallons per hour. Runs of tubing were placed 10' apart, and covered about 75% of the project site. Headers at both ends connected the drip-tubing runs. The supply header distributed water to the individual runs, and the drain header helped equalize the pressure throughout the system. A ball valve on the header allowed each zone to be turned on or off. A master header was constructed to distribute water to each zone. The master header was fitted with a pressure regulator and a "Y" filter. After the system was installed, trees and shrubs were planted adjacent to each emitter.

An independent water truck operator provided water periodically to the system. The operator attached the 1,500-gallon truck to the master header and ran his pump until the truck was empty. The site was watered a total of three times during the summer. Three thousand gallons were used on the first watering day in July, and 1,500 gallons on both of the watering days in August.

SYSTEM 2: DRIP IRRIGATING INDIVIDUAL PLANTS continued

2. Cost

Construction cost (parts + labor)*	$4,930
Operation cost (water + truck w/ operator)	$800
Total	**$5,730**

The average cost of irrigation per plant, total for the season, was $1.05*
Average cost of irrigation per plant per watering was: $0.35*

*Does not include cost of agency staff who assisted with irrigation set-up and troubleshooting, which was three person days.

3. Effectiveness

a. Overall survival rate

The overall survival rate: 76.4%*
The survival rate not counting the bareroot alders: 93.0%*

*Only trees were monitored for survival, not shrubs. Trees constituted 17.5 % of the plantings.

b. Other influences on survival

Only two of the eight tree species planted showed any mortality: red alder (*Alnus rubra*) which had 75% mortality and black cottonwood (*Populus balsamifera v. trichocarpa*) which had 23% mortality; the remaining six species had 100% survival. The bare root alder were received in poor health and many probably would have died even with perfect maintenance. The shrubs, which are not included in the survival data, were placed with 5 plants clumped around each emitter, due to over-ordering of plant materials.

The site was very dry. Irrigation would have been more effective if only one plant was placed at each emitter, as originally designed. The plants were not mulched, which reduced the effectiveness of irrigation because more moisture was lost to evaporation. Also, irrigating the site was a low priority for the water truck operator, causing delays.

4. Pros

- Pre-installed emitter tubing is the most economical type of drip-irrigation system to install, in terms of both materials cost and labor.
- Drip irrigation is very water-efficient.
- The system does not encourage weed growth between the plantings.
- Rows of evenly spaced plants significantly eases maintenance and monitoring.
- Winter draining is unnecessary because the emitters drain the system automatically.
- Pressure-compensating emitters can be used on sloping sites.
- The system operates at very low pressure.

5. Cons

- The system must be installed prior to planting, and the plants must be installed at the exact locations of the emitters, no location adjustments can be made in the field due to rocks, roots, microtopography, etc.
- Planting in rows reduces the "naturalness" of the site appearance.
- The drip tubing may be vulnerable to chewing by rodents and should be inspected regularly. This was not a problem on this site.
- Pre-installed emitter tubing is not intended for this kind of use, so there is not much technical expertise available in the landscaping industry for your assistance.

6. Some appropriate applications

- Sloping sites, hummocky sites, or any sites with a lot of topography, because the pressure compensating emitters even out the water pressure across the system and because the lines are flexible.
- Large areas.

7. Special considerations

This system can be used anywhere that water is available, either on-site from a municipal supply, well, stream or pond, or by driving a water truck to the site. The system can be gravity-operated from a portable "fold-a-tank" if the tank site is high enough above the emitters. The system is not appropriate for rocky soils where the planting substrate may prevent planting adjacent to the emitters. The type of drip tubing used is designed to wet all the soil of an entire site, but can be used to water individual plants as we did.

C. SYSTEM 3: DRIP IRRIGATING ENTIRE SITE

1. Description of system

In July 2002, Sound Native Plants planted a 1,200 square foot shoreline restoration site located on McAllister Creek in Thurston County. In total, 326 plants were installed. A drip-irrigation system was installed shortly after planting was completed. The system was designed to wet the entire site, not individual plantings.

The irrigation system consisted of drip-tubing with pressure-compensating emitters pre-installed every 18" along the tubing. Each emitter delivered 1 gallon per hour. Runs of tubing were placed 18" apart, to cover the entire planting area. Headers at both ends connected the drip-tubing runs. The supply header distributed water to the individual runs, and the drain header helped equalize the pressure throughout the system. The supply header was fitted with a pressure regulator and a "Y" filter. The header was connected with commercial-grade garden hose to a nearby outdoor faucet, with water from a municipal system. On-site staff turned the faucet on and off.

The system was turned on as soon as installation was completed. The watering schedule was adjusted after a few weeks of observation. Ultimately, the system was turned on roughly once per week for 12-24 hours, which delivered 10,000 gallons of water to the site. The site was watered weekly from July through October, except after rains.

SYSTEM 3: DRIP IRRIGATING ENTIRE SITE continued

2. Cost

Construction cost (parts + labor):	$1,275
Operation cost (water cost was not calculated)	0
Total	**$1,275**

The average cost of irrigation per plant, total for the season, was $3.91
Average cost of irrigation per plant per watering was: $0.26

3. Effectiveness

a. Overall survival rate: 95.7%

b. Other influences on survival

The site was planted at the beginning of July, a high stress time for transplanting, which probably reduced the survival rate at the site. Also, salal was used as a ground cover because the site was believed to be shadier. In reality, much of the site received full sun. A more sun-tolerant ground cover species would probably have survived better. The entire site was thickly mulched with wood chips, which improved soil moisture retention.

4. Pros

- Pre-installed emitter tubing is the most economical type of drip-irrigation system to install, in terms of both materials cost and labor.
- Drip irrigation is very water-efficient.
- Plants can be placed anywhere; not just beside emitters, so planting locations can be adjusted in the field due to rocks, roots, microtopography, etc.
- The system can be installed after planting is completed.
- The system does not need draining because the emitters drain automatically.
- Pressure-compensating emitters can be used on sloping sites.
- The system operates at very low pressure.
- Pre-installed emitter tubing is intended to be used this way, so there is more existing technical expertise in the landscaping industry for designing such a system.

5. Cons

- The system encourages weed growth between the plantings.
- The system uses more water that a plant-specific drip irrigation system would.
- Materials and installation costs are higher than a system that waters individual plants.
- System installation after planting may damage some plantings.

6. Some appropriate applications

- Small sites that do not have high water demands.

- Sites where water supply is not limited.
- Sites where soil conditions may require adjusting the planting locations in the field.
- Sites where a non-linear, randomized planting design is specified.

7. Special considerations

In our experience, most sites have limited water availability so the water must be delivered to the plantings as efficiently as possible, which precludes this type of system. Where water is available and weed competition can be minimized, this kind of system is worth considering.

III. Summary and Discussion

A. Note on water sources

Water sources are essential for irrigating restoration sites. Most sites do not have a well or municipal system nearby. If there is a natural water body nearby, it may be used as a water source if the project owner has a water right. Temporary water rights for irrigating sites used to be easily available from the Department of Ecology, but they have become increasingly difficult to obtain. Where water rights are available, any of these systems could be run off a gasoline-powered portable pump.

B. Weather data

It was a drier summer than normal in all three sites.

1. Site 1: Vancouver, WA weather station

Total precipitation, 2002 irrigation season:	2.31”	Normal: 4.96”
Average temperature, 2002 irrigation season:	64.94°	Normal: 63.89°

2. Site 2: Aberdeen, WA weather station

Total precipitation, 2002 irrigation season:	0.34”	Normal: 3.17”
Average temperature, 2002 irrigation season:	61.19°	Normal: 60.73°

3. Site 3: Olympia, WA weather station

Total precipitation, 2002 irrigation season:	1.44”	Normal: 8.54”
Average temperature, 2002 irrigation season:	58.2°	Normal: 58.7°

C. Comparative costs

Design is not included in the costs. These costs do include all the costs for constructing and operating the systems. All the labor costs were for actual billing rates, not the hourly wages paid to workers. System 1 costs include administrative and overhead costs that were built into the contract fee schedule. System 3 costs include a standard mark-up on part and supplies, which helps cover some of the same costs built into the contract for system 1. System 2 costs do not include a markup on the parts because the project owner procured the parts directly.

In order to be accurate, cost estimates must include all the costs for the system to be installed.

In general, most contractors markup parts at least 15-25% to help defray the procurement costs, which can be considerable. True labor costs must be estimated at the billing rate, not just the actual hourly wages paid to the workers. Billing rates usually are 50-100% above wages, in order to cover payroll taxes, fringe benefits, overhead and profit margin. These are necessary costs of doing business that are often omitted from restoration plan cost estimates, causing unrealistic expectations by the project owner.

D. Comparative results

1. **Survival and total cost per plant for the entire season***

Cost per plant*	% Survival
System 1 $ 6.88	98.7%
System 2 $ 1.05	93% (76.4%)
System 3 $ 3.91	95.7%

*Cost per plant for the entire season, the duration of which varied from site to site

2. **Survival and cost per plant per watering**

Cost per plant	% Survival
System 1 $ 1.01	98.7%
System 2 $ 0.35	93% (76.4%)
System 3 $ 0.26	95.7%

3. **System removal and disposal**

The cost of removing and disposing of the irrigation components for systems 2 and 3 have not been included. Eventually these systems will need to be removed from the site, which will add to the overall cost. There is no removal or disposal cost for system 1.

E. Problems with existing irrigation design parameters

Irrigation requirements for agriculture and landscaping are typically calculated in terms of inches of water per hour delivered to a given site. The designer determines a particular site's irrigation requirements using empirical equations based on weather data and soil characteristics. This method was developed for traditional irrigation systems that sprinkle water across an entire site, simulating rainfall. However, it cannot be applied effectively to restoration sites where only individual plantings require irrigation.

Ideally, the individual native plants' water needs should dictate the irrigation system design, because the limited water supply on most restoration sites often restricts irrigation to watering individual plants. The most useful parameter for designing irrigation systems on restoration sites would be gallons per plant per watering.

Unfortunately, we are not aware of any research into the water demands of individual plants on restoration sites. Of course, water needs are influenced by several factors, including plant species, size and form of planted materials, soil type, water table, and weather. Nevertheless, research aimed at determining minimum water requirements to successfully establish native species on restoration sites would be immensely valuable.

So far, we have mostly designed our systems to deliver as much water as possible from the available water sources, because the water source is usually the limiting factor. For example, if we have a 3,000-gallon water truck and 1,000 plants to water, each plant would receive 3 gallons per water-truck load. A system with 1 gpm (gallon per minute) emitters would take 3 hours to empty the truck, and refilling the truck would likely take 1-2 hours, so the most a plant would receive in a day is 2 water truck loads, or 6 gallons.

V. Summary Table

	Site 1 – Clark County	Site 2 – Chehalis River	Site 3 – McAllister Creek
Type of irrigation system	Hand watering individual plants	Drip irrigating individual plants	Drip irrigating entire site
Size of site	14 separate sites, largest 3.26 acres	3.3 acres	1,200 square feet
# plants irrigated	8, 280	5, 460 (951 trees)	326
Time of year planted	mid-March through April	January	Early July
Overall survival rate	98.7%[1]	93% (of trees)[2] 76.4% if includes alders	95.7%
How often watered	Once every two to three weeks as needed	3 times in one summer	Weekly as needed
Total irrigation costs[3]	$56, 996	$5, 730[4]	$1,275
Irrigation cost per plant	$6.88	$1.05[4]	$3.91
Irrigation cost per plant per watering	$1.01	$0.35[4]	$0.26
Pros of this type of system	1. Each plant gets individual attention. 2. Easily adjusted to species & microsite needs, etc. 3. Watering schedule easily adjusted for weather changes. 4. Extensive on-site time gives better adaptive management and stewardship. 5. Individual watering discourages weed growth between installed plants.	1. Pre-installed emitter tubing is most economical, both for materials & labor. 2. Drip irrigation very water efficient, operates at low pressure & does not encourage weed growth between installed plants. 3. Planting in rows makes mowing, weeding & monitoring easier. 4. Pressure-compensating emitters can be used on slopes and sites with varied topography.	1. Pre-installed emitter tubing is most economical, both for materials & labor. 2. Drip irrigation very water efficient, operates at low pressure & does not encourage weed growth between installed plants. 3. Plants can be placed anywhere, not limited to emitter locations. 4. Pressure compensating emitters good on slopes, etc. 5. System can be installed after planting completed. 6.Lots of technical expertise available for these systems.

SUMMARY TABLE continued

Cons of this type of system	1. Labor intensive and therefore expensive. 2. Watering rate usually more than can soak into ground, more runoff, especially on slopes. 3. Repetitive work – hard to keep crew motivated & interested.	1. Plants must be installed at exact locations of emitters. 2. Planting in rows reduces "naturalness" of appearance. 3. Hard to use in rocky sites because plants must be installed directly by emitters, can't adjust location in the field.	1. Irrigating whole site encourages weed growth between plantings. 2. Uses more water & costs more to buy & install than a plant specific drip system. 3. Installing system after planting may damage plantings.
Some appropriate applications for this type of system.	Large site or multiple sites in one area. Sites subject to vandalism or other conditions where pipe on ground not safe or acceptable.	Large areas or sloping or topographically varied sites, as pressure-compensating emitters even out the pressure for even watering rates.	Sites with low water demands or plentiful water supply. Sites where planting in rows not ok. Sites where soil conditions may require location adjustments in field. Sites with topography or slopes (pressure-compensating emitters even out pressure).

[1] Does not include bareroot red alders (*Alnus rubra*), which we have found performs poorly in many cases, and were not replanted due to extensive natural recolonization.
[2] If poor survival (25%) of bareroot red alders is eliminated, the survival rate was 93%. The alders were received in poor condition. Only trees were monitored, shrubs were not included. Trees constituted 17.5% of the plantings.
[3] Design of the systems is not included in the costs.
[4] Does not include cost of agency staff that assisted with installation & troubleshooting, which was three person-days.

IV. Acknowledgements

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Julie Christian, Clark County Public Works Department, Vancouver, WA
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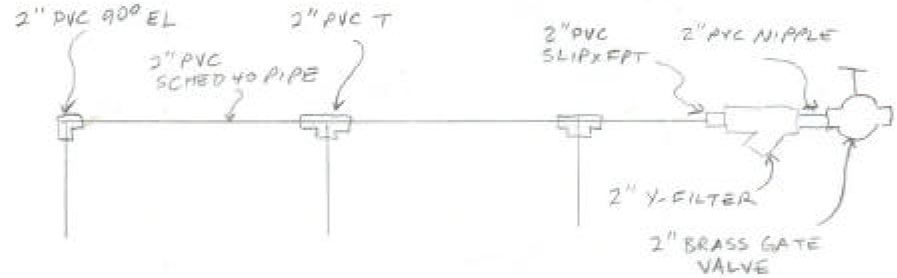
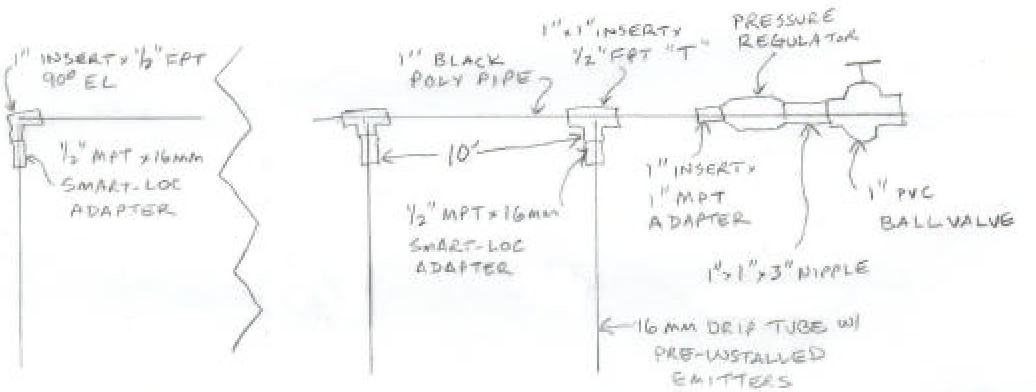
Chad Stemm, Sound Native Plants, Vancouver, WA

Irrigation schematic attached

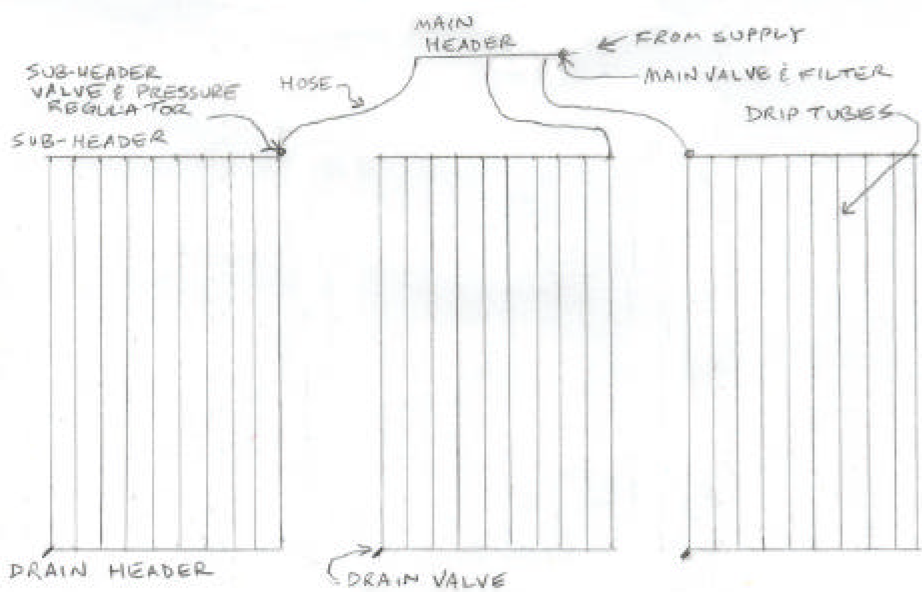


MAIN HEADER ASSEMBLY



NOTE: DRAINAGE HEADER ASSEMBLY IS IDENTICAL EXCEPT FOR NO PRESSURE REGULATOR

SUB-HEADER ASSEMBLY



SYSTEM SCHEMATIC