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Waterjet Stinger:

A tool to plant dormant unrooted cuttings of willows, cottonwoods, dogwoods, and other species

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Introduction

Opportunities for riparian revegetation around the nation are numerous. Planting dormant unrooted cuttings often called pole plantings, post plantings, or live stakes is one technique that is often recommended for streambank stabilization and riparian buffer planting. This method is limited to species that can easily sprout from hardwood cuttings, such as: willows, cottonwoods, and dogwoods. There are other species that will sprout from hardwood cuttings, but do not root as readily.

Dormant unrooted cuttings are used because they are easy to harvest, easy to plant, inexpensive, and effective. In the arid and semi-arid West, it is extremely important that any plant that is installed in a riparian zone have its roots in the lowest watertable of the year. This is often difficult when using bareroot or containerized plants especially when the riparian zone has been dewatered to the point that the water table may be several feet below the soil surface. Unrooted cuttings have been planted as deep 12 ft (average depth is about 5-6 ft) by the Riparian/Wetland Plant Development Project at the Aberdeen PMC using a long bar attached to a backhoe (Hoag and Ogle 1994). Most riparian and stream protection projects require planting depths of 3-6 ft. The biggest problem we faced was finding a method and developing equipment that could dig a hole more than 3-4 ft deep quickly and efficiently. The Waterjet Stinger is the result of this equipment development effort.



To plant unrooted cuttings successfully, the bottom of the cutting should be placed about 8-12 in into the lowest watertable of the year. The top of the cutting should extend out of the ground at least 10-12 in or high enough to be out of the shade cast by surrounding vegetation such as grasses or forbs. This allows the bottom of the cutting to act like a straw and pull water up the cutting keeping the roots, stems and leaves hydrated. In some riparian zones, the lowest water table of the year can be several feet deep.

Waterjet Stinger



The Waterjet Stinger was specially designed to use high-pressure water to hydrodrill a hole in the ground to plant unrooted hardwood cuttings into riparian revegetation. This is not new technology, in fact, it has been around for a long time. Oldham (1989) described a water drill that he used to drill holes in the ground to plant stem and pole cuttings 4-5 ft deep. His hydrodriller was a steel pipe that was beveled at the bottom and was hooked up to a “water tank (spray rig) or portable pump.” Drake and Langel (1998) reported using a water jet tool to plant willow cuttings. They designed a nozzle that is made out of stainless steel welded to a steel pipe. They used a high-pressure pump and the

nozzles to plant cuttings over 2 meters deep. An engineering technician in Manitoba, Canada (Andrews, personal communication) described working with a water jet to drill holes for geotechnical test holes ten years ago. He indicated that they had taken a steel pipe and pounded the end flat to increase the water pressure. These earlier jets did not last very long because the pounding tended to weaken the steel.

The advantages of using the waterjet stinger to drill a hole for planting unrooted willow and cottonwood cuttings are:

- 1) simple to operate and transport
- 2) little training necessary to operate
- 3) hydrodrilling the planting hole is fast
- 4) plant large number of cuttings in a short period of time
- 5) allows cutting to be planted directly into a wet environment
- 6) allows for saturated soil conditions to surround the cutting for a longer period of time
- 7) liquefied soil will settle around the cutting eliminating air pockets in the rooting zone



Waterjet Nozzle

Based on a request from Scott Henderson, an Idaho NRCS Field Office employee, and others, Boyd

Simonson, PMC Biological Technician, used the paper written by Drake and Langel (1998) and attempted to modify their design to better fit the coarse soils in the Intermountain West. He started with the actual probe itself. A local machinist used the detailed drawing to build the nozzle out of stainless steel and welded it to a ½ in steel pipe. Boyd added a T-handle at the top to help with the planting operation and a ball valve at the handle to turn the water on and off (see Appendix A).



After testing in the field, we decided to add a set of vanes to be bottom on one of the probes. Three vanes were welded to the probe pipe directly above the stainless steel tip. The individual vanes were about four inches long, tapering down to the nozzle, and about 5/8 inch tall. The vanes provide several benefits. They open the hole up all the way down to accept wider diameter cuttings. This is especially true in compacted layers like clay. They also allow the user to nudge rocks slightly out the way in the hole. With the smooth pipe, it is almost impossible to get any leverage on rocks. For silt soils, the vanes are a real help. With cobbly soils, it does not provide a major advantage. We work in a combination of silts and gravels so we put vanes on one probe and left the other without vanes.



It took quite a bit of research to come up with the right size pump. . Drake and Langel (1998) describe a “cube” pump, but we had difficulty finding anything with that name. We determined that the basic specifications for the pump were:

- 1) gasoline powered
- 2) small enough to fit on the back of an ATV
- 3) output of at least 80 psi or higher
- 4) 120 gallons/minute output
- 5) vertical lift of at least 18 ft

There are many different pumps that meet these specifications available on the market.

We did try a 1600-psi pressure washer thinking that it was ready made for this type of application. The main problem is that pressure washers do not put out enough water volume for this application. The pressure washers typically put out about 2-3 gpm while the high-pressure pump puts out 120 gpm (about 12-15 gpm at the nozzle). Pressure washers have more than enough water pressure, but they tend to blow all the soil out of the hole for the first couple of inches making it pretty messy. After the hole is drilled, there is very little water left in the hole to hydrate the willow cuttings. We do not recommend using a pressure washer for this application.

Next, Boyd felt that for safety’s sake, a pressure relief valve should be installed so when both waterjets were shut off, the water from the pump would bypass back into the stream or other

water source. This would decrease the pressure on the pump and eliminate turning the pump on and off. A manifold was designed to fit on the pump to allow the water to flow from the stream to either the waterjet stingers or to the bypass hose. When a certain internal pressure is reached inside the manifold, the water will divert to the bypass hose and back into the stream automatically. An additional benefit to the pressure relief valve was that it allows one to release air out of the system. This made the priming go much faster.

The garden hose quick coupler manifold allows two waterjets to run simultaneously. It is attached to the main manifold just past the pressure relief valve. Quick couple attachments (available at most lawn and garden stores) are used to keep the connections simple, reduce the possibility of stripping the threads on the hose ends, and to allow the hoses to be hooked up in either direction. Water is delivered through heavy-duty 5/8 in garden hoses with a pressure rating of 100 psi that are 100 ft long. The hoses run from the garden hose quick couple manifold to the waterjets.



At the planting site, the hoses are laid out parallel to the stream channel. The two waterjets can be operated with two separate crews. One crewmember runs each waterjet and the other crewmembers transport the cuttings and push them into the holes after they are hydrodrilled. As the holes are hydrodrilled and planted in the 200 ft length, the ATV with the waterjet stinger pump is driven further down the streambank and the process starts all over again. If the streambank is too high and the lift is too great to get water from the stream to the pump, the pump can be dismounted from the ATV and placed on a flat shelf that is cut right into the streambank. This way the pump is placed closer to the water, lift is reduced, and pressure increased at the nozzles.

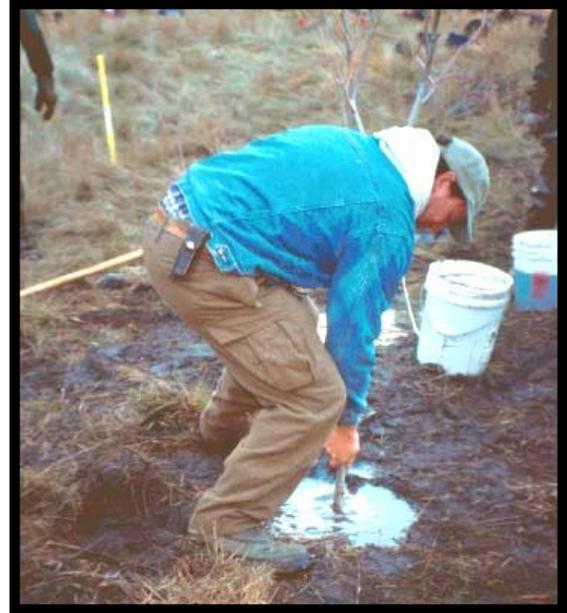
Planting Process

Once the pump is set up and pushing water to the waterjets, hydrodrilling holes can begin. Planting sites with vegetation are scalped down to mineral soil to get rid of competing above ground biomass. The waterjet is placed in the center of the scalp and the ball valve is turned on. At this point most beginning users get nervous about being splashed with water. We have found that water rarely splashes up, rather it tends to bubble as it liquefies the soil. Splashing might occur if the hydrodrilling is attempted on soils that are crusted or have a hard layer. However, as soon as the waterjet goes through the surface layer of soil, the splashing is eliminated (except in rocky soils).



After turning on the ball valve and the water starts jetting out of the nozzle, the waterjet will slowly start sinking into the ground. If a hard layer is encountered, the waterjet will stop. If the user leaves the waterjet in place and let the water work on the layer, eventually it will go through it. We have demonstrated this with several demonstration projects from a site with a 6 in hard calcic layer to a site with a 2 ft thick layer of decomposed granite. If medium sized rocks (with lots of fines around them) are encountered, the user must wiggle the jet back and forth until the water can find a way around it. This does make a larger hole below the surface, but the liquefied soil will normally settle back into place after the cutting has been installed.

As the waterjet liquefies the soil, it will continue down until it hits something it cannot cut through, the T-handle hits the ground, or the user stops. We have held the waterjet at a stationary point to have the water cut further into the soil. We have been able to duplicate Drake and Langel's (1998) depth of 6.6 ft (2 m). The depth the waterjet will penetrate depends mainly on the soil texture and the length of the probe.



As the user pulls the waterjet back up out of the hole, the nozzle should be rotated back and forth to increase the size of the hole. The rotation should continue the entire length of the hole from the bottom to the ground surface. The waterjet probe is $\frac{1}{2}$ in diameter and the user should be planting at least $\frac{3}{4}$ in diameter or larger cuttings (Bentrup and Hoag 1998, Hoag 1993). In order to get larger diameter cuttings in the hole, the soil needs to be liquefied all the way to the soil surface.

Once the hole has been hydrodrilled, the single cutting or a bundle of three to four cuttings can be pushed into the hole. The longer one waits to shove the cutting into the hole, the higher the chance there is to for the suspended sediment to settle to the bottom of the hole. This will limit the depth that the cutting can be pushed to.

An alternative option is to start the hole with the waterjet and then place the cutting or bundle right next to the waterjet pipe and push both the waterjet and the cuttings into the hole at the same time. If done properly, the cutting or bundle will go down as the waterjet liquefies the soil. If the cutting hits a tight spot, the operator will immediately know it and he can spiral the nozzle around a little to loosen the obstruction. A word of caution - make sure that the cutting does not extend past the nozzles



or the pressurized water will cut the bark off.

One problem that we have observed is that if there is a coarse soil layer under a layer of fine textured soil, when the waterjet drills into this coarse layer, the water in the hole will drain out into the coarse layer. This will defeat the purpose of planting the cuttings into a slurry to eliminate air pockets. Pulling the waterjet nozzle up to just above the layer will allow sediment to settle back into the bottom of the hole and seal it again.

We have found that a three-person team per waterjet works very well for the planting process. One member of the team runs the waterjet, the other two members haul the cuttings and shove them in the holes. The team members can rotate jobs through the planting day to keep everyone fresh and interested in the planting job. An extra person to transport the cuttings from the soaking location to the planting location with another ATV will speed the process up. The speed of the entire planting process will depend upon the soil, the labor force, and the cutting or bundle sizes.

Once the cutting is shoved into the hole to the depth of the low water table, the sediment will start to settle around the stem. It is important that the operator not allow significant amounts of sediment to bubble up out of the hole while drilling. The more sediment that is allowed to bubble out, the more sediment that will have to be replaced after the water moves out into the surrounding soil. After planting, the planting team needs to return to each of the stems and replace soil that bubbled out and created a depression around the stem. The depression is caused by the sediment settling in and compacting around the stem. By replacing soil around the stem, it is possible to provide more opportunity for root development in the upper part of the soil profile. When replacing the soil, use a mud slurry or tamp shoveled soil around the stem to prevent air pockets.

In cobbly soils, the waterjet stinger has the same problems as most of the other techniques that one would use to plant hardwood cuttings. In our experience, the waterjet stinger will cut down through the silt layer on top of the cobble layer and stop as it hits the cobbles. In some cases, when there are a lot of fine soils around the cobbles, the waterjet will liquefy the soil around the cobbles and allow the cobbles to shift slightly so the user can get the probe around the side of the cobble. In most cases however, it is very difficult even with the waterjet to go very deeply into a cobbly soil profile. Several other methods can be successful on cobbly soils. See “The Practical Streambank Bioengineering Guide” (Bentrup and Hoag 1998) for detailed instructions on how to install these treatments.

Safety

We would be remiss if we did not mention safety. Before the start of each planting session, safety concerns should be discussed with the planting team members. This ensures that proper safe working conditions are fresh in everyone’s mind before starting to work. Potential safety problems that might occur can be discussed. The proper response to these problems can then be considered. This helps everyone know what to do if problems actually occur.

The water coming out of the waterjet nozzles is concentrated and under extremely high pressure. If the waterjet nozzle were ever pointed at a foot or hand, it could cut through a boot or glove

and into the skin. Severe damage could occur if the nozzle were pointed at the face, eyes, or any unprotected part of the body. The waterjet stinger is not a toy and should always be operated by, or at least supervised by, an experienced, mature adult. Caution should always be exercised around the pump. Inspect the hoses regularly to ensure that they are not kinked, cut, or abraded. The quick couple hose attachments should be tested several times during the operation of the waterjet stinger to ensure they are firmly attached. If for some reason the hoses are disconnected from the waterjets, shut the pump down immediately to ensure the metal tipped ends do not whip around and hurt one of the team members. It is much better to anticipate and discuss safety concerns than to heal the wounds caused by a mistake or faulty equipment.

Summary

The waterjet stinger is easy to operate and transport. Very little training is necessary to operate the waterjet stinger. The pump intake should be placed in a fairly sediment free location in the streambed to operate properly. Hydrodrilling a planting hole with the waterjet stinger is fast and relatively splash-free. A large number of cuttings can be planted in a short period of time with very little effort compared to conventional planting methods. Planting into a hole filled with water allows each cutting to be planted directly into a wet microenvironment. The liquefied soil will settle around the cutting eliminating air pockets in the rooting zone that prevent root growth. In addition, the waterjet stinger creates saturated soil conditions around the cutting for a longer period of time. This means the cutting is in the best microenvironment to produce the largest and most desirable root mass possible, which in turn means that the establishment success rate will increase.

Overall, the waterjet stinger is relatively inexpensive when compared to other planting methods. The PMC prototype waterjet stinger cost about \$1000 for parts (see Appendix B) and labor to build it was about \$500 for a total of about \$1500. The design layout was planned to make the entire piece of equipment as simple as possible to build and operate. The most complicated part is putting the manifold together and this only takes about a half-hour. All of the parts can be ordered or purchased locally, except the pump. An experienced machinist can build the waterjet nozzle in a couple of hours with the plans provided in this paper. Once the parts are purchased and delivered, the entire waterjet stinger can be assembled in less than a day.

The waterjet stinger is not new technology, but we have taken it to another level. We have included all the information necessary for a person to build one. After it has been built, it will take some experimentation and experience in your particular soils and conditions to figure out the best way to hydrodrill your planting holes.

More information can be obtained by calling Chris Hoag at 208-397-4133 or Boyd Simonson at 208-397-4501. For those people who have access to the Internet, email messages can be sent to choag@id.usda.gov.



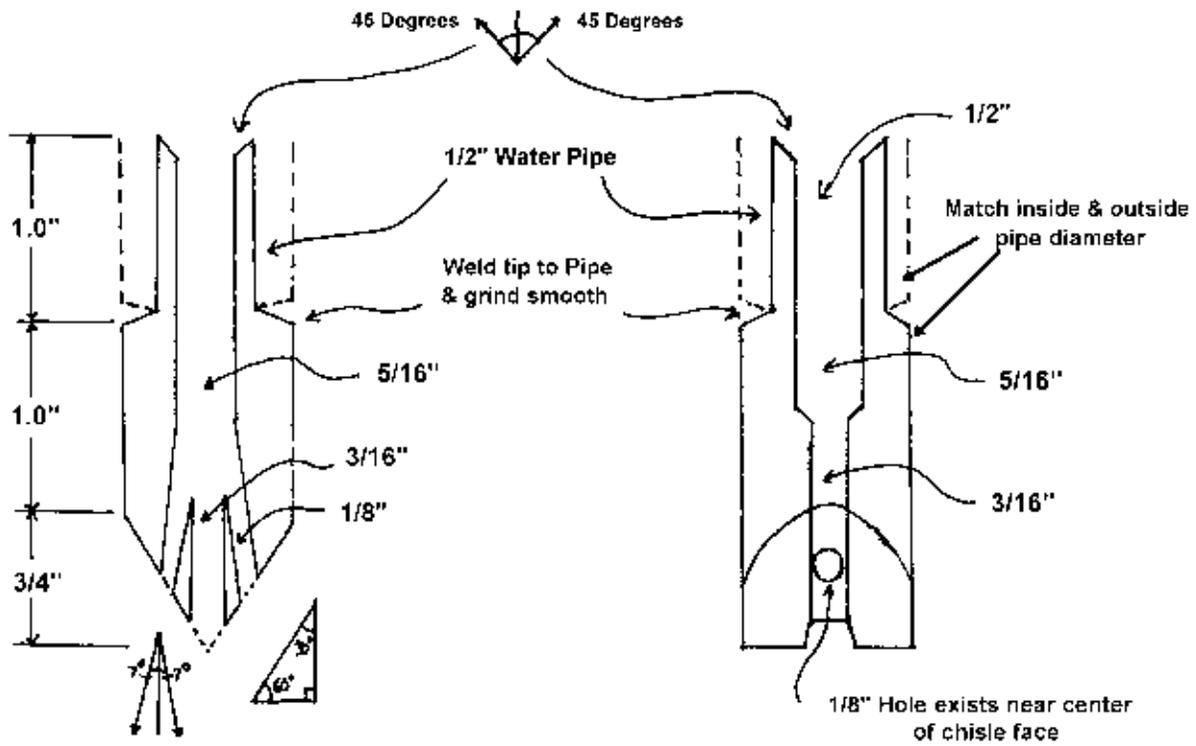
Acknowledgements

The development of the Waterjet Stinger would not be possible without the support and the generous financial assistance provided by the South Bingham Soil and Water Conservation District, Gem Soil and Water Conservation District, Squaw Creek Soil and Water Conservation District, the Camas Soil and Water Conservation District and Dick Scully (Regional Fisheries Biologist), Southeast Region, Idaho Department of Fish And Game.

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- Hoag, JC. 1993. *How to plant willows and cottonwoods for riparian rehabilitation*. USDA Natural Resources Conservation Service, Idaho Plant Materials Technical Note No. 23, Boise, ID. 12 pp.
- Oldham, JA. 1989. The hydrodriller: an efficient technique for installing woody stem cuttings. Society of Ecological Restoration and Management annual meeting, Oakland, CA. Jan. 16-20, 1989. 6 pp.

APPENDIX A: DETAILED DRAWING OF THE WATERJET NOZZLE TIP FROM DRAKE AND LANGEL (1998).

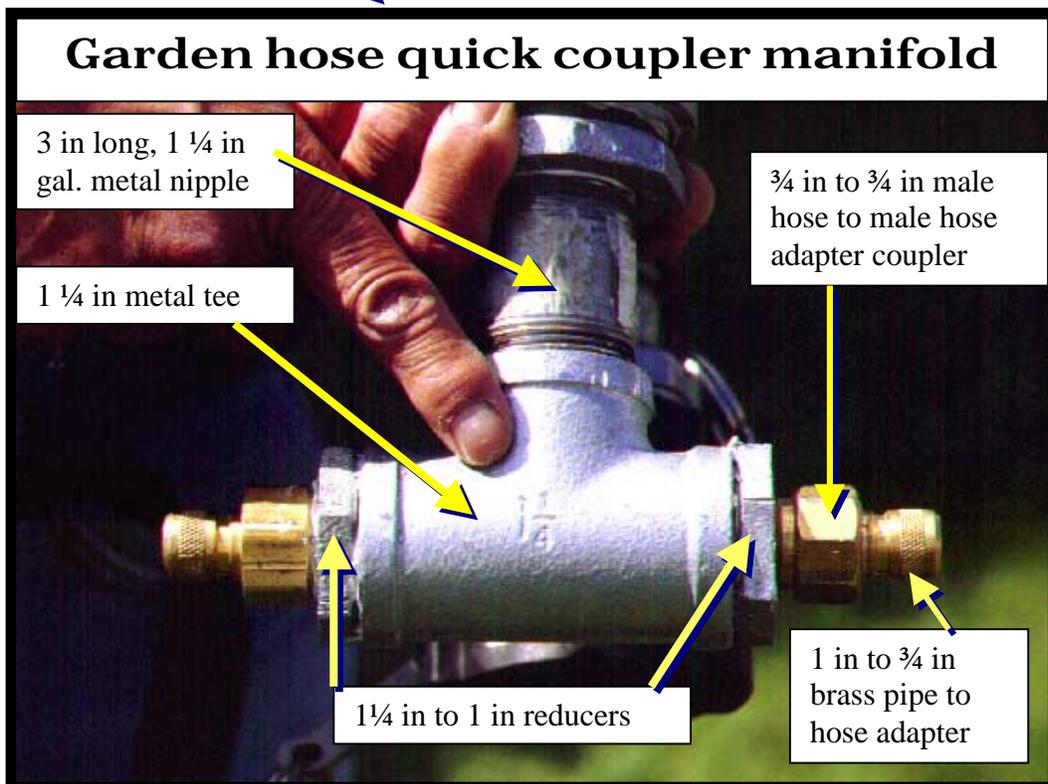
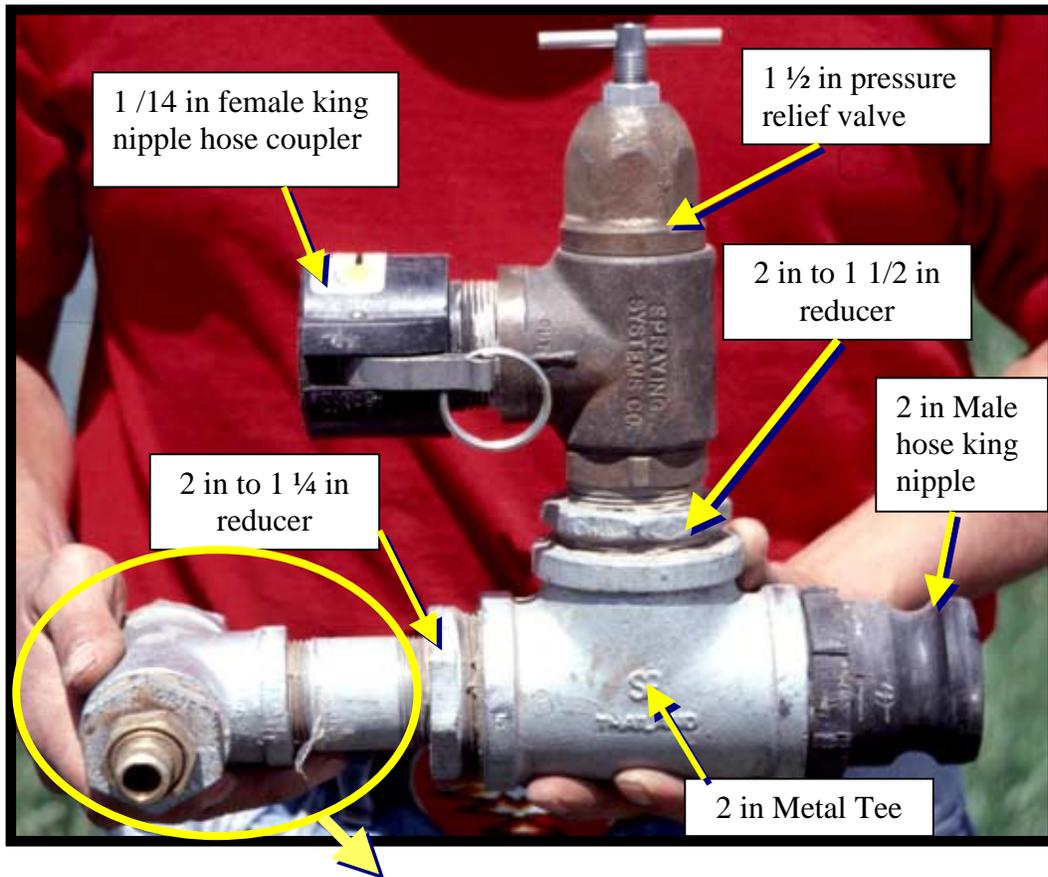


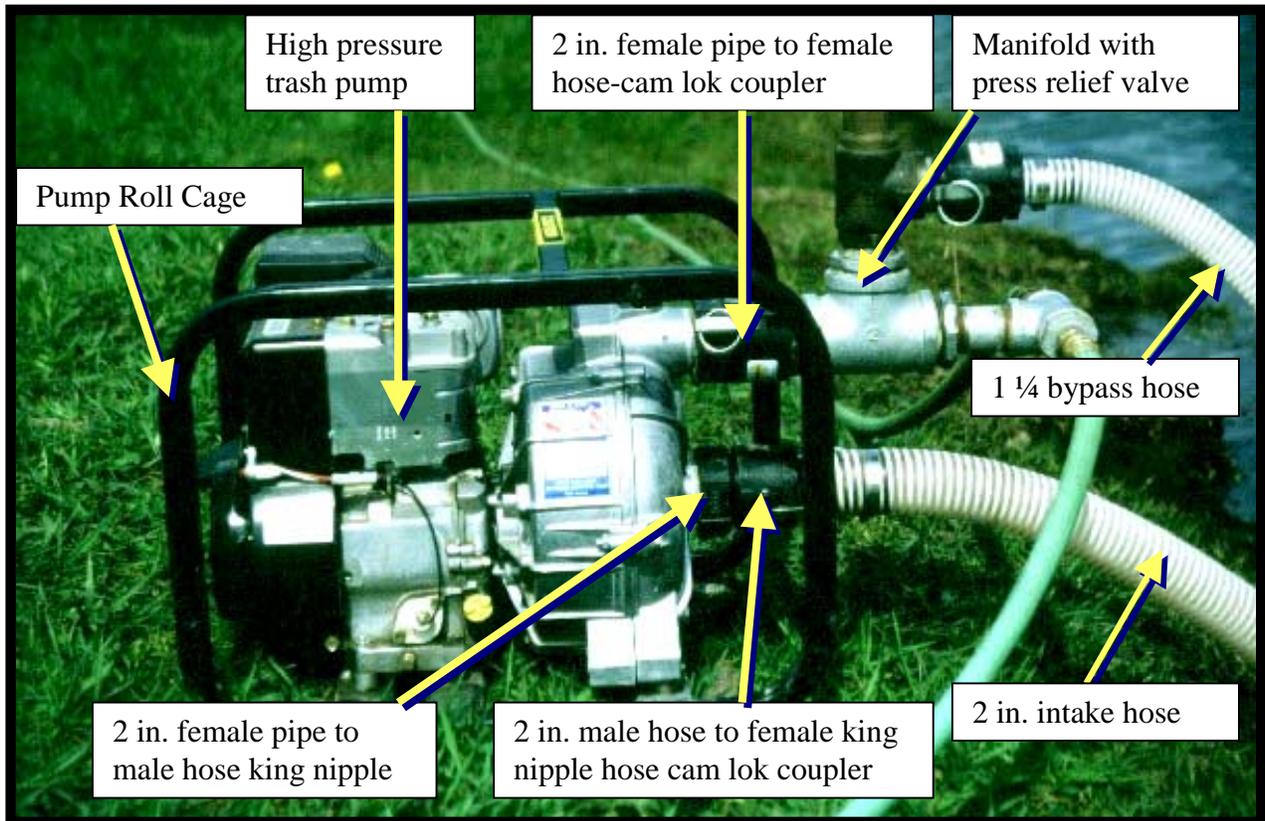
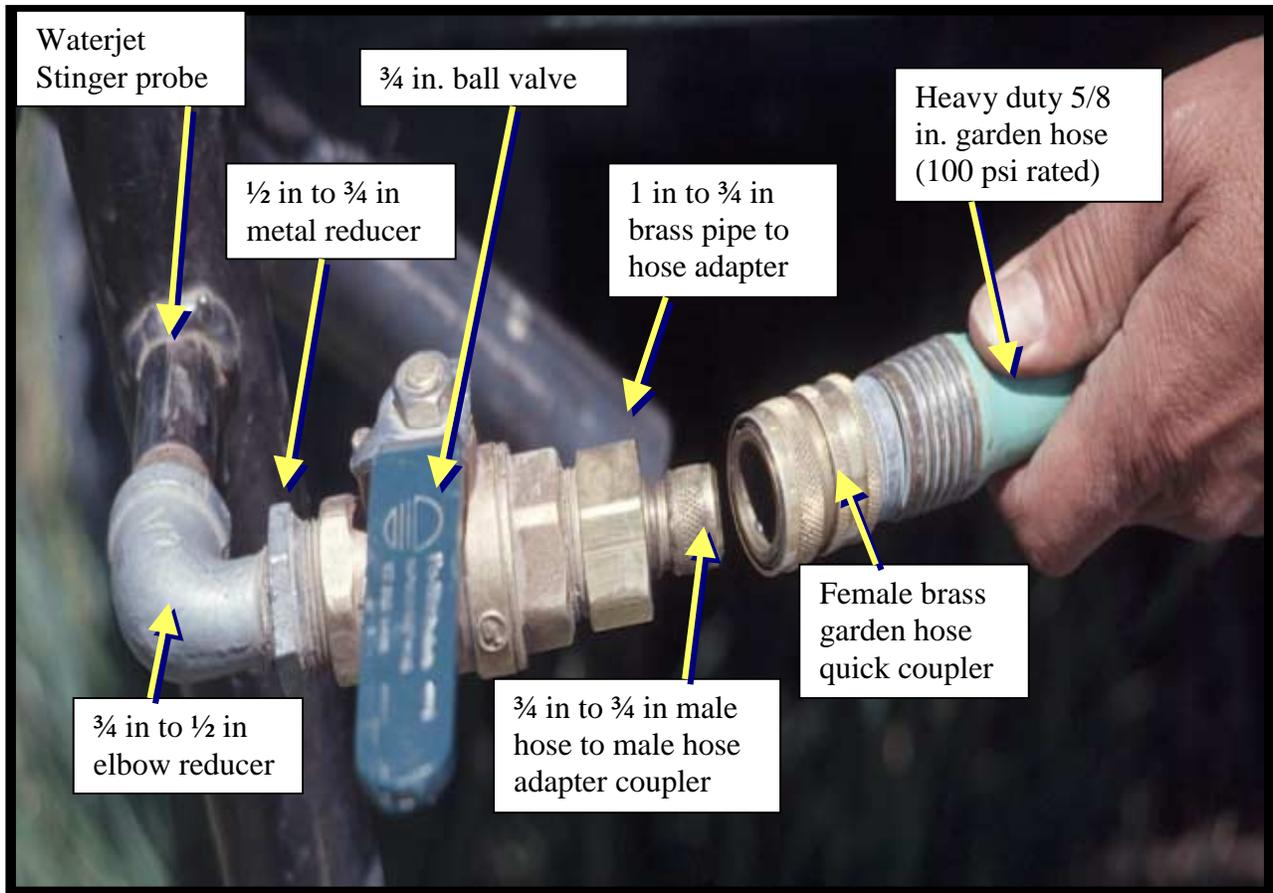
Pictures of the stainless steel nozzles that were welded to 1/2 in steel pipe. The stainless steel is expected to increase the life of the waterjet. A machinist built the pipe, handle, and nozzles as a single unit. The ball valve is added by the end user.

APPENDIX B: LIST OF MATERIALS FOR THE ENTIRE WATERJET STINGER.

Name of item	Location	Number	Cost
Manifold parts			
1 ½ in. pressure relief valve	Manifold	1	\$120.00
2 in. galvanized metal tee	Manifold	1	7.00
1 ¼ in. galvanized metal tee	Manifold	1	4.00
2 in. to 1 ½ in. galvanized metal reducer	Manifold	1	1.64
3-in.-long 1 ½ in. galvanized metal nipple	Manifold	1	1.59
3-in.-long 1 ¼ in. galvanized metal nipple	Manifold	1	1.19
2 in. to 1 ¼ in. galvanized metal reducer	Manifold	1	3.00
1 ¼ in. to 1 in. galvanized metal reducer	Manifold	2	5.00
2 in. male pipe to 2 in male coupler nipple	Manifold	1	4.75
1 ½ in male pipe to female cam lok coupler	Manifold	1	8.00
1 in. to ¾ in. brass pipe to hose adapter	Manifold	2	6.58
¾ in. to ¾ in. male hose to male hose adapter	Manifold	2	1.89
		Total:	164.64
Suction and Bypass parts			
1 ¼ in. plastic hose for discharge	Bypass	20 ft	30.00
1 ½ female cam lok to 1 ¼ male hose shank	Bypass	1	12.00
2 in. male pipe to male hose coupler	Screen	1	5.80
2 in. plastic hose for suction for intake	Intake	20 ft	40.00
2 in. male hose to female king nipple hose cam lok coupler	Intake	2	29.70
2 in. hose clamps for plastic hose	Intake	3	2.70
		Total:	120.20
Waterjet parts			
¾ in. ball valve	Probes	2	10.00
¾ in to ½ in elbow reducer	Probes	2	3.00
½ in to ¾ in metal reducer	Probes	2	2.00
1 in. to ¾ in. brass pipe to hose adapter	Probes	2	6.58
¾ in. male hose to ¾ in. male hose adapter	Probes	2	2.00
Female brass garden hose quick couplers	G. hoses	4	11.00
Heavy duty 5/8 in. garden hose (100 psi rated)		200 ft	120.00
Waterjets, manufactured by machinist		2	180.00
		Total:	334.58
Waterjet pump			
2 in. female pipe to male hose king nipple	Pump	1	5.30
2 in. female pipe to female hose-cam lok coupler	Pump	1	15.00
Pump and Motor (excludes freight)		1	495.00
Roll cage for pump		1	65.00
		Total:	595.30
Total cost of parts (as of March 2001)			\$1199.72

APPENDIX B: LIST OF MATERIALS FOR THE ENTIRE WATERJET STINGER.
 (continued)





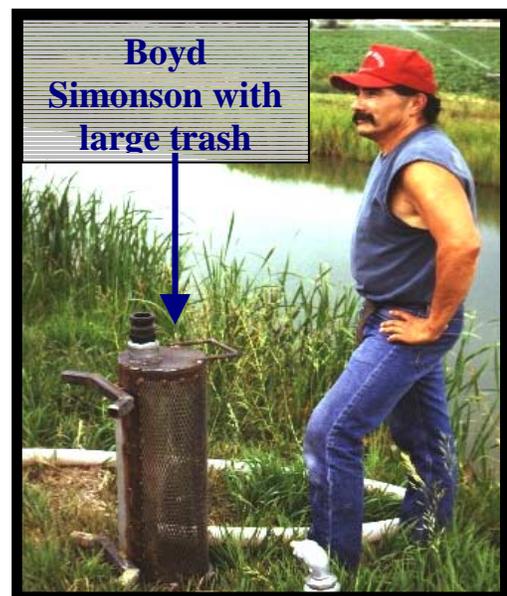
APPENDIX C: HIGH PRESSURE GASOLINE POWERED PUMP SPECIFICATIONS



Note: Metal cage around the pump and motor was purchased separately.

Specifications

- 5 HP Gas powered High pressure pump
- 7200 GPH, 200 foot head, 88 psi max
- Vertical lift 18 ft
- Self priming pump with 2 inch NPT suction and discharge ports
- Aluminum closed impeller
- Cast aluminum housing
- Cast Iron volute
- Built-in check valve
- Water and trash pump strainer 2 in included
- 64 pounds



Note: Trash Strainer shown was built for large stream systems so it could be perched above the stream bottom and was heavy enough not to move with the stream current. The pump was shipped with a small strainer that attaches to the end of the suction hose for use on smaller stream systems (Not shown).

APPENDIX D: AN ILLUSTRATED DIAGRAM OF AN OPERATING WATERJET STINGER

The waterjet stinger is sitting on a large 6-wheel ATV during a workshop in Lapwai, ID on Little Lapwai Creek. The 6-wheel ATV is larger than what is necessary to transport the waterjet stinger. The track option for the ATV is not necessary.

