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Department of the Interior, Bureau of Reclamation

IRRIGATION OPERATION AND MAINTENANCE

BULLETIN NO. 64

April, May, June 1968

In This Issue:

Evaluation of Cost and Effectiveness of Canal and Lateral Aquatic Weed Control

The Irrigation Operation and Maintenance Bulletin is published quarterly, for the benefit of irrigation project people. Its principal purpose is to serve as a medium of exchanging operation and maintenance information. It is hoped that the material herein concerning the evaluation of cost and effectiveness of canal and lateral aquatic weed control, prepared by the Salt River Valley Water Users' Association, in cooperation with the Bureau of Reclamation, will result in improved efficiency and reduced costs for those operators adapting these ideas to their needs.

* * * * *

Division of Irrigation Operations
Office of Chief Engineer
Denver, Colorado

COVER PHOTOGRAPH:
This is a turbine compressor and it is shown operating in a lined channel using a contoured nozzle, as described in this Bulletin.
Photo PX-D-60882

UNITED STATES
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DIVISION OF IRRIGATION OPERATIONS
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CONTENTS

INTRODUCTION

A significant maintenance expenditure for most open ditch irrigation projects is for aquatic weed control. To evaluate the cost and effectiveness of various aquatic weed control techniques, the Bureau of Reclamation entered into a contract on July 15, 1963, for a joint study with the Salt River Valley Water Users' Association, which operates and maintains the Salt River Project in south-central Arizona. Included in this study was use of a new turbine compressor; as well as the conventional methods of anchor chain and disc, gradall, backhoe, acrolein, and solvent. In addition to approximately 475 miles of general channel maintenance, 6 miles of test channels were set up to obtain specific data on controlling aquatic weeds and silt separately.

Field data obtained from over 2, 600 operating miles covering a 3-year period were accumulated and evaluated; and is contained herein. Each method serves a specific purpose and has specific advantages and disadvantages. Although some methods result in a dual benefit, none can be used indiscriminately or thought of as a panacea for all aquatic weed problems.

EVALUATION OF COST AND EFFECTIVENESS OF CANAL AND LATERAL AQUATIC WEED CONTROL

GENERAL ANALYSIS

The Salt River Project

The Salt River Project in Arizona is one of the first constructed by the Bureau of Reclamation. Started in 1903, the first water was made available by the Federal Government in 1907. The project consists of 240,000 acres, 57 percent urbanized by the cities of Phoenix, Mesa, Tempe, Glendale, Chandler, Peoria, Gilbert, Tolleson, and Scottsdale. The Project still serves much of this urban area with irrigation water as well as supplying water to three city filtering plants from its canals.

The Project's gravity water is produced from snowmelt and rainfall on the 13,000 square miles of Salt and Verde River watersheds located in central Arizona. The water is impounded by four dams on the Salt River and two on the Verde River.

Water is released on demand into the irrigation system which consists of 1,265 miles of canals, laterals and waste ditches. Water from 250 deep-well pumps is used to supplement the gravity supply. The rate at which pump water is introduced into the system is a function of the stored gravity water and, therefore, quite variable. The first 2 years of this report, 1964 and 1965, approximately 40 percent was ground water, and in the third year, 1966, 14 percent was ground water.

Improvement and rehabilitation of many original project facilities is a continuing necessity to meet changing conditions, and a portion of this work was financed by the Rehabilitation and Betterment Program of Reclamation. This has resulted in the improvement of the system with 202 miles of open concrete-lined waterways and 323 miles of underground pipe, leaving 770 miles as open unlined waterways.

The map shown as Figure 1 on the following page, locates the system with respect to the borders of Arizona. Figure 2, is a map of the Project irrigation system.

The Study

Approximately 10 percent of the $746,000 average annual maintenance cost of the irrigation system is directed to the control of aquatic weeds in the canals and laterals. In the fall, winter and spring, algae are predominant; whereas in the summer months the rooted aquatic weeds are most prevalent. The algae are almost entirely of filamentous green type, of which Clapophora is the most common. The rooted aquatics are predominantly Potamogeton pectinatus (sago pondweed) and Heteranthera dubia (waterstar grass). Potamogeton foliosus, Vallisneria Americana and Zannichellia pallustris are also present in the system, but to a lesser degree.

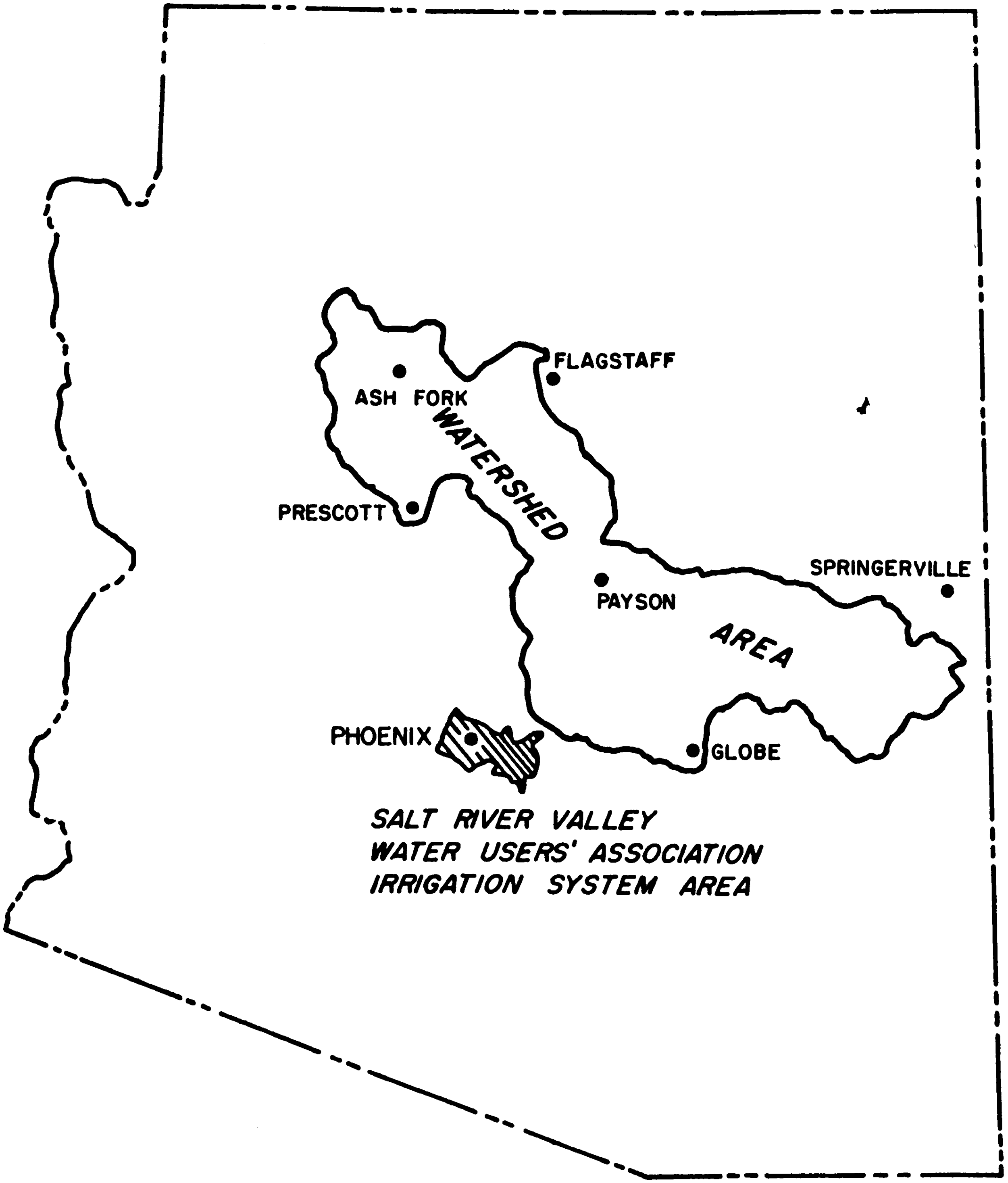

FLAGSTAFF
ASH FORK
WATERSHED
PRESCOTT
SPRINGERVILLE
PAYSON
AREA
PHOENIX
GLOBE
SALT RIVER VALLEY
WATER USERS' ASSOCIATION
IRRIGATION SYSTEM AREA

Figure 1

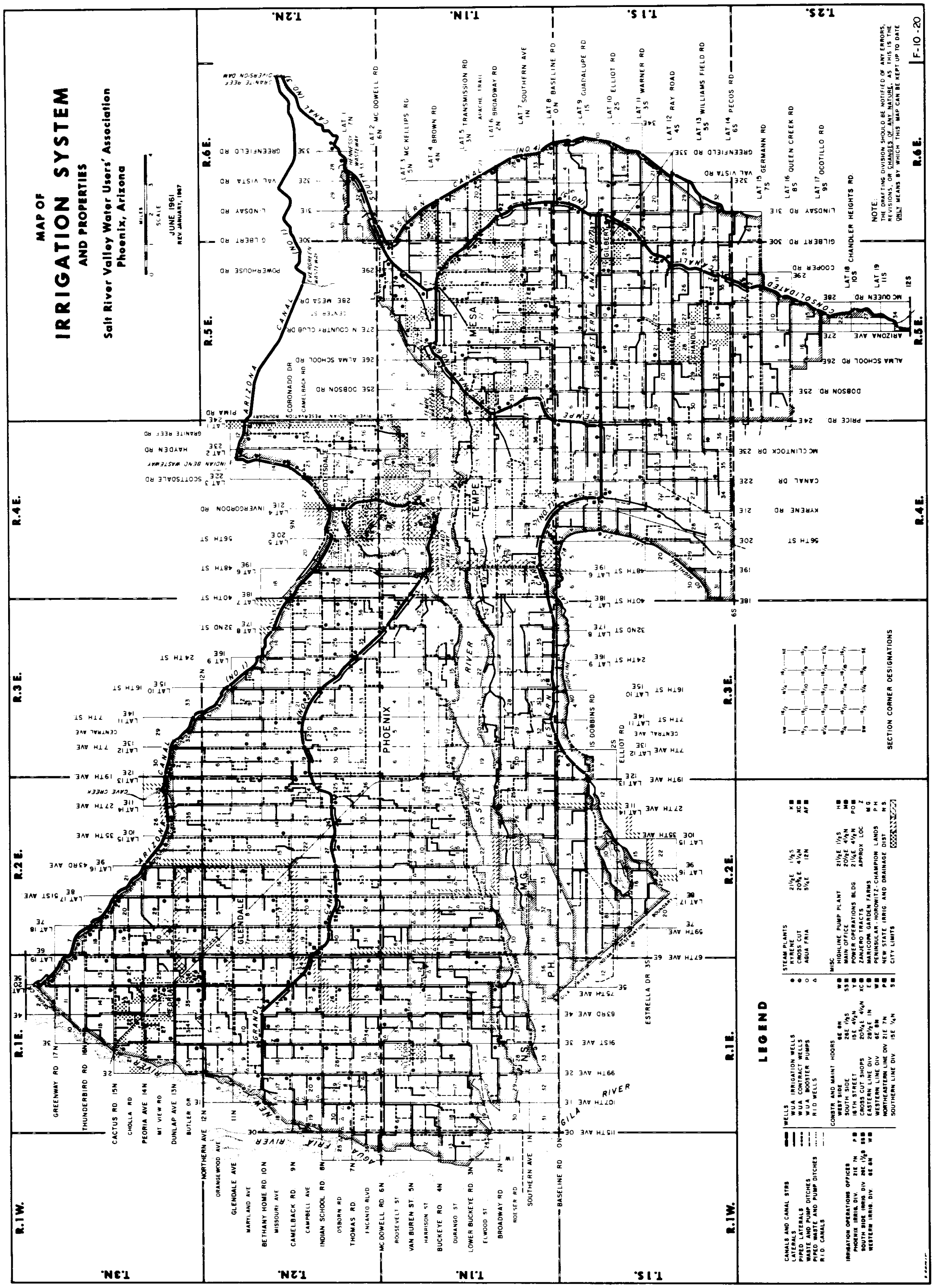

MAP OF
IRRIGATION SYSTEM
AND PROPERTIES
Salt River Valley Water Users' Association
Phoenix, Arizona
JUNE 1961
REV JANUARY, 1967
LEGEND
SECTION CORNER DESIGNATIONS
F-10-20
PHOENIX
TEMPE
MESA
GLENDALE
CHANDLER
GILBERT
SALT RIVER
GILA RIVER
ARIZONA CANAL
GRAND CANAL
WESTERN CANAL
CONSOLIDATED CANAL
EASTERN CANAL
HIGHLINE CANAL
TEMPE CANAL
NOTE: THE DRAFTING DIVISION SHOULD BE NOTIFIED OF ANY ERRORS, REVISIONS, OR CHANGES OF ANY NATURE, AS THIS IS THE ONLY MEANS BY WHICH THIS MAP CAN BE KEPT UP TO DATE

Figure 2

Problems on the Salt River Project are similar to those on other irrigation projects in the southwestern part of the United States and not too disimilar from those in many areas. In recent years new and different control methods have been introduced on Bureau-constructed projects, with little information obtained on costs for the work. To obtain comparable costs of various means of control for planning purposes the Bureau of Reclamation negotiated a contract with the Salt River Valley Water Users' Association on July 15, 1963. The contract required that the Association (a) evaluate the effectiveness of removing silt and aquatic weed growth by high-pressure jet water turbulence and other mechanical methods, and (b) collect, compile and evaluate cost data on aquatic weed control of all methods used.

This report presents the findings of the study with regard to the turbine compressor and other aquatic weed control methods and evaluates the costs collected for each method in response to the contract. The effects on wildlife were not evaluated in the various chemical and mechanical tests which were conducted in connection with this study.

Definition of Terms

For the purpose of this report terms used are defined as:

Aquatic weeds--All submersed or floating vegetative growth in the Project's canal and lateral system.

Canal--The main channels of the water transmission system feeding the laterals. A typical canal is 30 feet wide, has a 4-foot water depth, and an approximate flow range of 100 to 400 cfs.

Grates--Trashracks, consisting of portable or permanent grates made of 1-inch pipe fixed on 5-1/2-inch centers.

Lateral--The channels of the water distribution system receiving water from the canals and deep wells and delivering directly to users. In this report all channels used to convey well water (pump ditches) and waste water (waste ditches) are included as open laterals. Typical lateral sizes are 5 feet wide with 2-foot water depths, and have an approximate flow range of 15 to 25 cfs.

Lined laterals--Waterways of which sides and bottom have been lined with concrete.

Open laterals--As differentiated from underground pipe laterals (see laterals).

Mechanical aquatic weed control--The use of the anchor chain and disc, excavator, backhoe and turbine compressor.

Prior to compiling data, it was necessary to devise forms to log the aquatic weed control daily operations. Samples of the Field data sheets originally used for this purpose are included in the Appendix.

However, during this study, the field forms were revised for compatibility with an IBM 1401 computer. These revised field data sheets also are shown in the Appendix. The compilation of some of the detail data on the forms does not appear in the report because of its relative unimportance to the final summation of data. After the forms were filled in by field personnel, they were checked at the field office for errors. The forms were then forwarded to the Civil Engineering Department where labor and equipment charges were entered. The Planning and Statistical Division then prepared them for Data Processing where they were key punched for monthly, quarterly and annual reports.

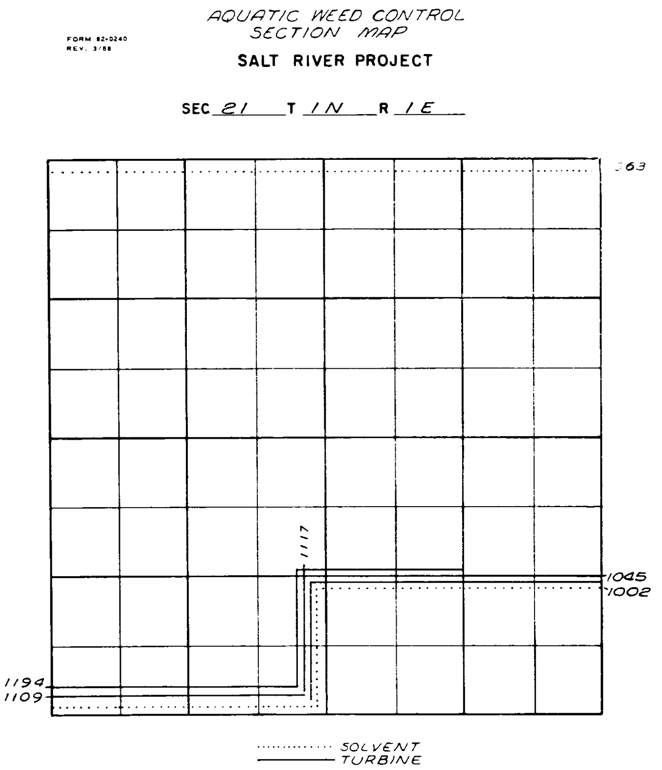


Figure 3

The Civil Engineering Department platted each report on a section map using a code for each type of treatment and identified it with a report number. From approximately 1,200 field reports, some 750 maps were plotted showing the number of times each channel was treated during the year. Figures 3 and 4 are examples. These provide a means of establishing an annual cost for aquatic weed control in any length of channel in the system and show at a glance those channels requiring extensive maintenance.

SYSTEM AQUATIC WEED CONTROL STUDIES

Turbine Compressor

A turbine compressor has been adapted to aquatic weed control by the Salt River Water Users' Association. The cover photograph shows the turbine compressor in operation in a lined wasteway. Its function is to dislodge the aquatic weed growth in lined ditches and to disperse silt with the use of high-volume, low-pressure air taken from the second stage of the turbine compressor.

The work done during the period of this report demonstrated that the turbine compressor method is most efficiently used on a preventive maintenance basis. This was done in 1965 by setting up this method on a scheduled program of inspection and treatment of channels before silt and aquatic weed conditions became acute.

The power-operated crane has a boom which can be extended 28 feet from the center of the truck bed and rotated 360°. The turbine truck is a diesel-powered 2-ton model.

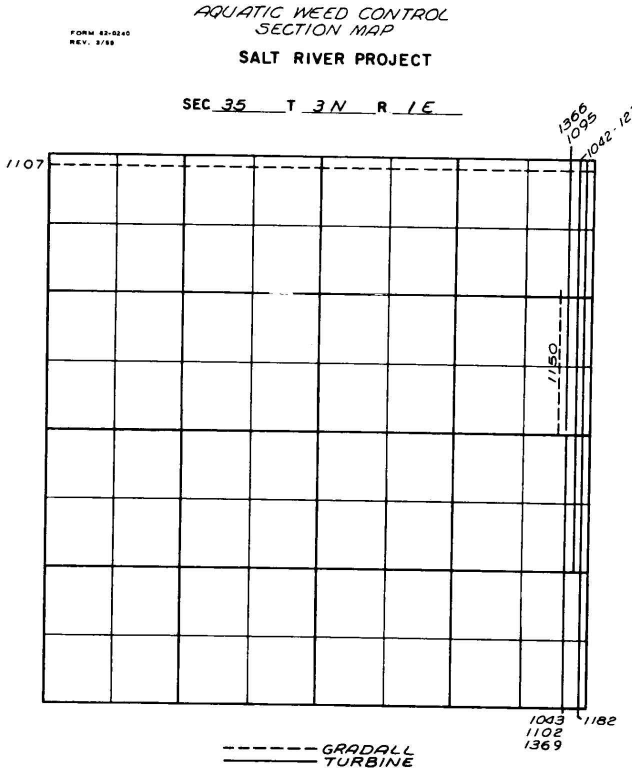


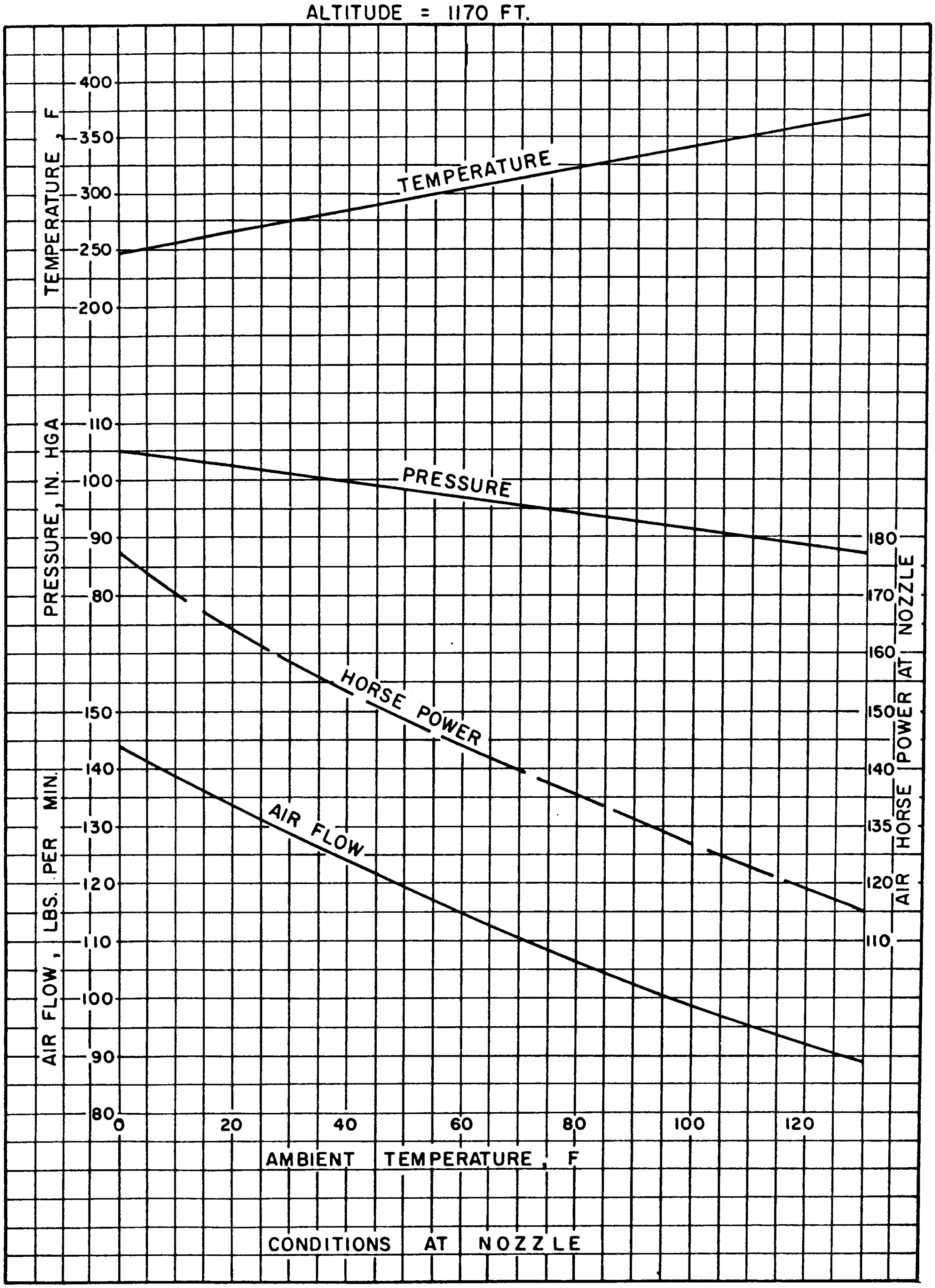
Figure 4

The power unit is of the pneumatic power turbine compressor type. The efficiency of the engine is dependent upon orifice openings in the nozzle totaling 2-1/2 to 3 square inches. Larger openings could cause overheating of the turbine, and smaller openings would reduce the extreme turbulence necessary to provide efficient aquatic weed and silt control. For conditions at the nozzle at 100° F ambient temperature (typical Phoenix summer temperature) see the chart on the following page.

The first nozzle was tried in 1962 and showed promise as a tool for aquatic weed control in lined channels. Several more nozzles were then developed and tested.

A pipe nozzle, 10 feet long with 5/16 holes on 3-inch centers was made to drag in the canals perpendicular to the flow. It proved to be inefficient due to (a) insufficient air volume over the 10-foot span, and (b) nonconfinement of water. The confinement or restriction of the flow of water in waterways being treated is necessary to concentrate the extreme turbulence required to dislodge aquatic weed growth and silt.

Several nozzles were tested in unlined laterals and were also found to be ineffective due to nonconfinement of flowing water in waterways where lengths of irregular widths and bottoms were encountered.


ALTITUDE = 1170 FT.
TEMPERATURE , F
400
350
300
250
200
TEMPERATURE
PRESSURE, IN. HGA
110
100
90
80
PRESSURE
HORSE POWER
AIR FLOW
AIR FLOW , LBS. PER MIN.
150
140
130
120
110
100
90
80
AIR HORSE POWER AT NOZZLE
180
170
160
150
140
135
120
110
0
20
40
60
80
100
120
AMBIENT TEMPERATURE , F
CONDITIONS AT NOZZLE

In lined channels some benefit accrued in dislodging algae from the sides by the use of a contoured nozzle, Figure 5. However, there was an insufficient force of air to tear the attachment cells from the lining, so that only partial algae removal resulted. Since the solvent and acrolein aquatic weed control methods are more economical than the turbine compressor for algae control, and because rapid algae regrowth occurs when the algae attachment cells are not removed or destroyed, the use of this nozzle was discontinued.

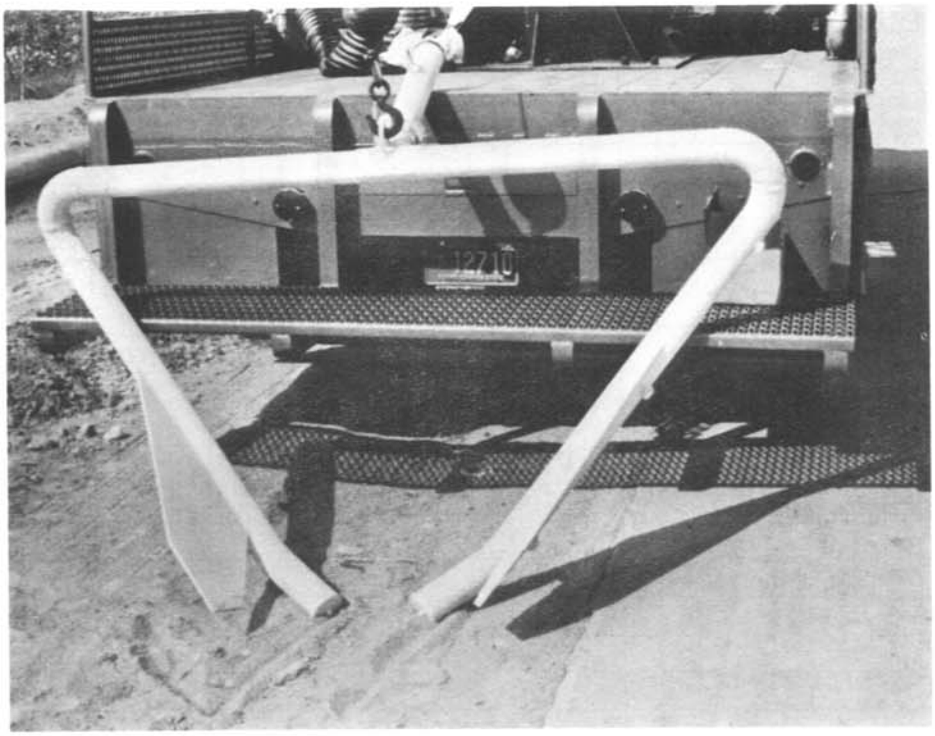


Figure 5. Closeup view of a contoured nozzle used for dislodging aquatic weed growth from sides and bottom of channel. Photo PX-D-60883

In the spring of 1965 a plow-type nozzle was developed, Figure 6. This nozzle combines the effectiveness of high-volume air and mechanical plowing. The combination of the plow and airstream dislodges and breaks up all of the silt accumulation into fine particles, including the denser portions. The dislodged aquatic weeds float downstream.

The preventive maintenance schedule as described earlier is based on a complete list of 1- and 2-foot bottom lined laterals totaling 80 miles compiled and arranged in geographical sequence. Nozzles of the plow-type design were made to fit the bottoms of these channels.

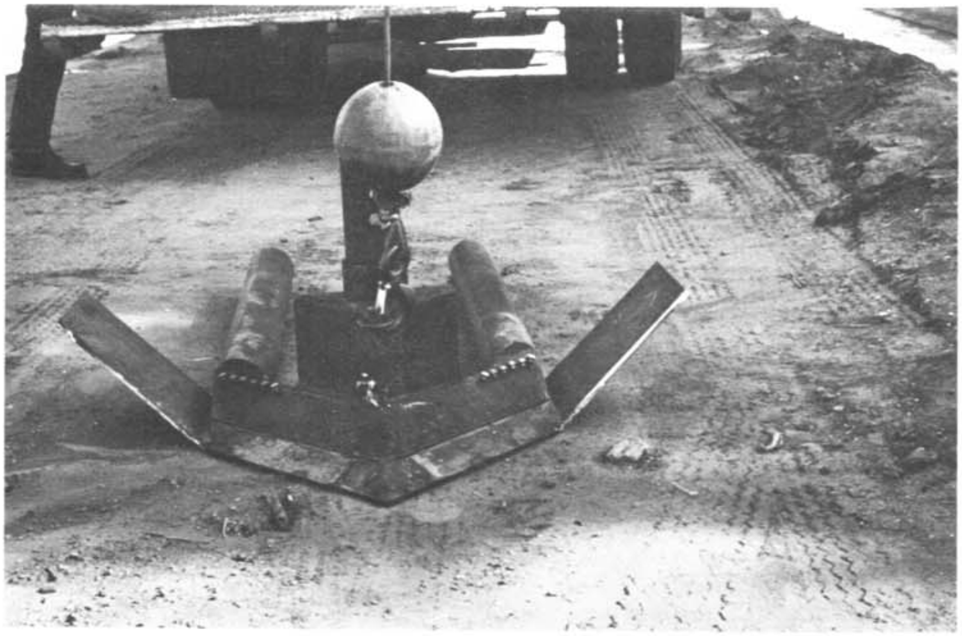


Figure 6. Plow-type nozzle head used for cleaning the bottom of a 2-foot bottom lined channel. Photo PX D-60884.

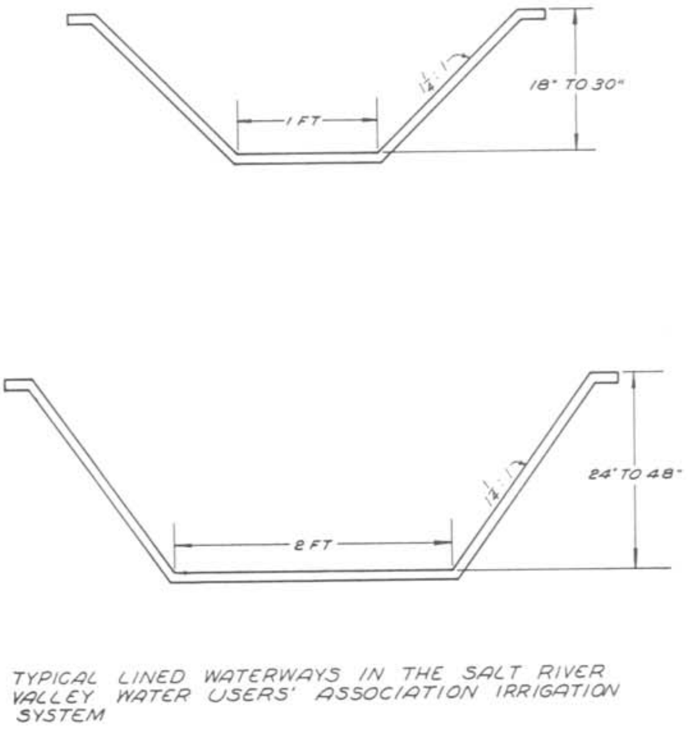


Figure 7. Typical lined waterways in the Salt River Valley Water Users' Association irrigation system.

Typical cross section of these channels are shown on Figure 7.

In the most recent nozzle design, the airstream is directed downward toward the leading edge of the plow through slits in the forward section of the nozzle. The total orifice opening is approximately 3 square inches in order to maintain a sufficient turbulence to dislodge the aquatic weed growth and silt effectively, shown as Figure 8 on the following page.

An additional use for the turbine compressor has been the removal of obstructions from culverts and from pipelines up to one-eighth mile in length. An attachment for this purpose consists of a short length of perforated pipe attached to the end of the duct. The duct and pipe section are pulled through the culvert, preferably when the culvert is two-thirds or more filled with water. In the treatment of pipelines, as

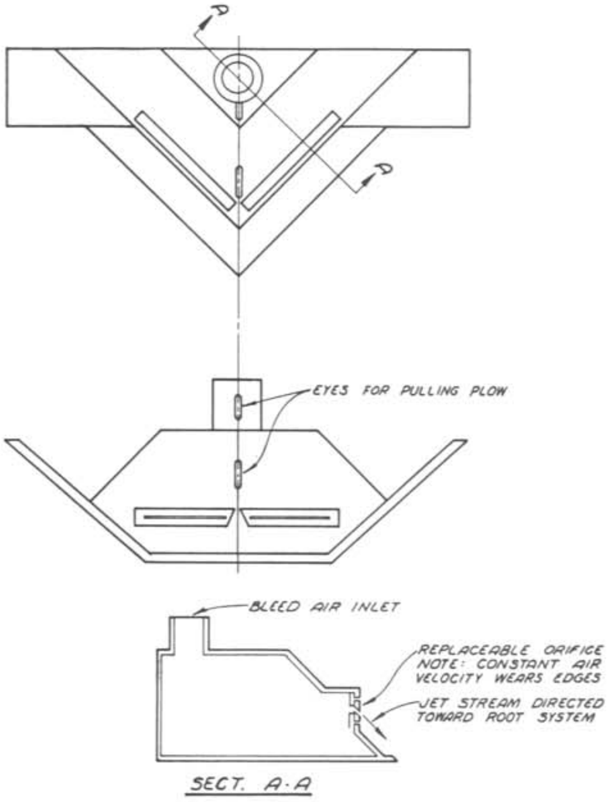


Figure 8. Plow-type aquatic weed control nozzle.

shown in Figure 9, the nozzle is introduced into the downstream cell near the bottom of the structure and the turbine is operated until water flows freely through the treated section.

The turbine compressor aquatic weed control crew and equipment consists of the turbine and truck unit, a truck driver, a unit operator and occasionally a laborer to remove dislodged aquatic weeds from grates. The operator has been trained in the operation and preventive maintenance of the turbine compressor by the manufacturer. This operator, in turn, has trained others.

Under normal circumstances, the turbine operator makes the preventive maintenance inspection of the channel system to determine whether treatment is

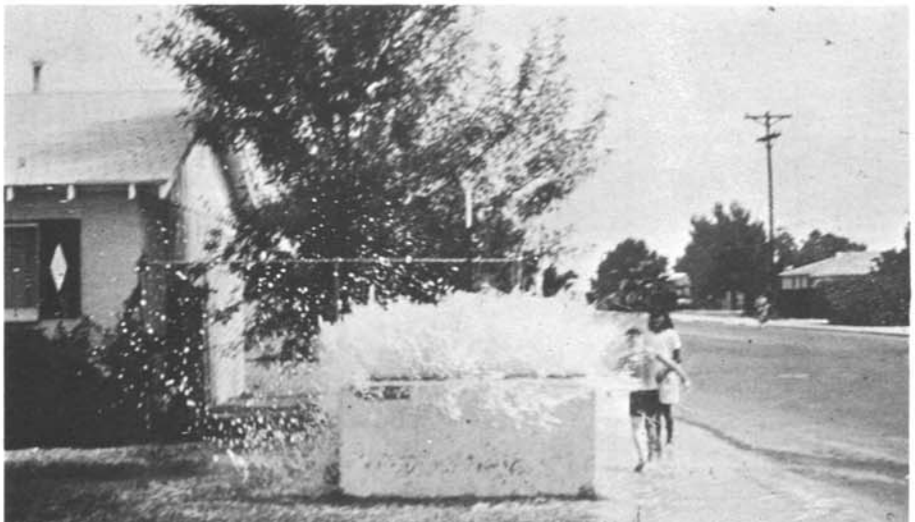


Figure 9. Turbine compressor shown blowing a pipeline clean. Photo PX-D-60885.

necessary. The program was set up on a continuous inspection and "treatment if necessary" basis following the sequence of the 80 miles of laterals which had been established. The average time involved in one complete circuit averaged 30 working days.

The table below lists the cost of aquatic weed control by the turbine compressor method for the period of this report.

Turbine Compressor
Control Costs

	1964	1965	1966	Total
Physical operation in laterals	$10,656.65	$ 9,801.72	$6,515.90	$26,974.27
Removal and disposal of weeds from portable grates after dislodgement from laterals	2,949.90	929.61	30.94	3,910.45
Field supervision	535.50	84.60	27.00	647.10
Office cost	210.15	112.95	37.80	360.90
Total cost	$14,352.20	$10,928.88	$6,611.64	$31,892.72
Total miles of operation	105.6	123.4	63.7	292.7
Average cost per mile of operation	$ 135.91	$ 88.56	$ 103.79	$ 108.96

The average cost per mile of operation of $135.91 for 1964 included experimentation which involved considerable supervisory and office time as well as mechanical changes in design of the nozzles. Early experimentation in heavily infested areas was responsible for the high cost of removal and disposal of aquatic weeds from the laterals.

In 1965, using the plow-type nozzle and operating primarily on a preventive maintenance schedule, costs per mile of operation were reduced to $88.56. Removal and disposal was reduced to $929.61 from $2,949.90 and supervision was reduced to $84.60 from $535.50.

The $103.79 average cost per mile for 1966, an increase cost of $15.23 per mile over 1965, is due to a part preventive maintenance schedule coupled with a part "on call" operation, and the reduced efficiency resulting from less mileage being treated during the year.

Efforts are being continued to determine the best operating procedures for the turbine compressor.

Anchor Chain and Disc

The anchor chain and disc method employs two crawler tractors, one on each canal bank, with anchor chain and disc assemblies dragged between them on the canal bottom, as shown in Figure 10. The chains and discs dislodge the aquatic weed growth, which floats downstream to temporary grates. Figures 11 and 12 are views of the chain and discs used. Figure 13 is a view of grates used to collect dislodged weeds. Figure 14 shows the weeds being removed.

Figure 10. Dislodging aquatic weeds and silt by the anchor chain and disc method in the Grand Canal. The chains and discs in the canal are not visible. Photo PX-D-60886.

Figure 11. Disc and anchor chain shown in dragging arrangement at Northside Construction and Maintenance Headquarters. Photo PX-D-60887.

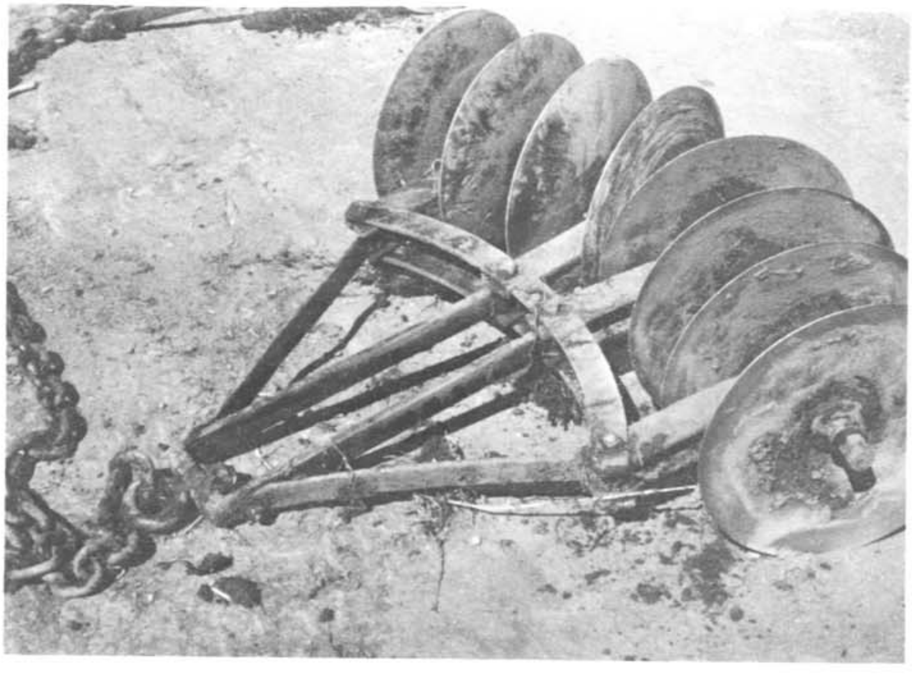


Figure 12. Closeup view of disc assembly. Photo PX-D-60888.

Figure 13. Dragline shown placing grates in canal. Photo PX-D-60889.

Figure 14. Removal of aquatic weeds from grates. Photo PX-D-60890.

Only moderate interruptions occur to irrigation operations. There are some dislodged weeds that slip through the grates and collect on canal and lateral gates, and in farmers' irrigation ditches, which must be removed immediately to avoid flow reduction.

Silt accumulations are leveled as the equipment passes through the system. A supplemental advantage to this operation is weed and brush control resulting from the chains dragging on the canal banks, but urbanization with the resultant increase in traffic and road crossings is making this method more difficult.

The aquatic weeds removed from the grates are usually loaded on trucks and hauled to a dump area. The silt, which is agitated during the operation, moves downstream and settles at a rate dependent on the velocity and the amount of water in the canal. It may travel a short distance or several miles. A portion of the silt flows onto water users' property.

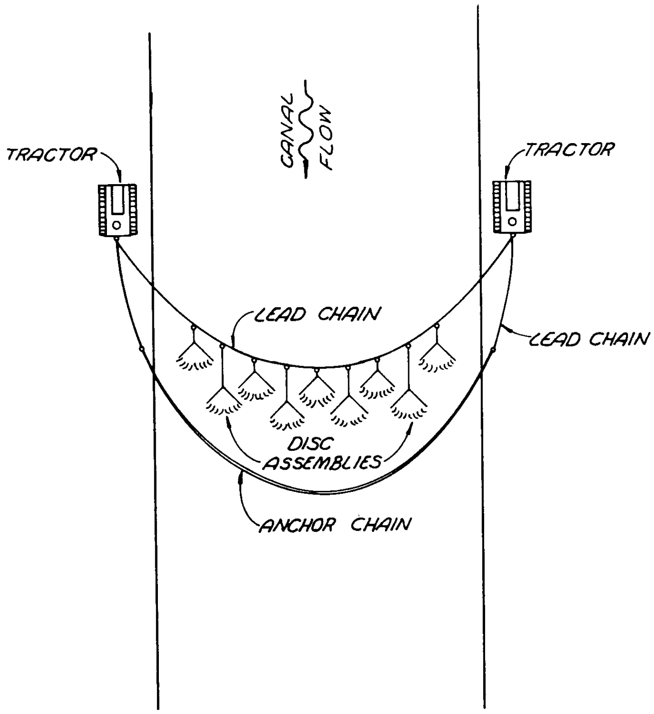


Figure 15. Anchor chain and disc arrangement for aquatic weed control in canals.

Specifically this method employs two tractors which are used to pull 80 feet of 16" x 7" anchor chain. Connected to each end of the anchor chain is a short length of 4" x 3" lead chain which is fastened to the drawbars of each tractor. Eighteen-inch-diameter concave discs, in gangs of 8, are connected as needed to a 4" x 3" lead chain which is attached at each end to the tractor drawbar and pulled in front of the anchor chain, as depicted in Figure 15. Normally two trucks are required to haul the equipment to and from the site.

The equipment involved in removing the material collected on the grates consists of a dragline and truck used to haul dragline equipment. Trash trucks are used when necessary to haul material which has been removed by hand labor or dragline. The dragline is also used to place and remove the portable grates.

The normal crew consists of eight men. This is augmented by additional labor when necessary.

The table below lists the costs of the anchor chain and disc aquatic weed control method for the period of this report. Of the 138 miles of canals, 37 miles did not require any treatment during this period.

Anchor Chain and Disc Control Costs

	1964	1965	1966	Total
Physical operation in canals	$25,957.75	$18,945.61	$22,525.54	$ 67,428.90
Removal and disposal of aquatic weeds after dislodgement from grates	21,004.52	11,140.19	11,958.68	44,103.39
Field supervision	463.50	136.80	70.20	670.50
Office cost	169.65	91.80	37.35	298.80
*Machine shop and transportation	8,564.38	4,872.60	6,753.32	20,190.30
Total cost	$56,159.80	$35,187.00	$41,345.09	$132,691.89
Total miles of operation	257.9	218.0	203.2	679.1
Average cost per mile of operation	$ 218.37	$ 161.40	$ 203.47	$ 195.39

When machine shop costs for maintenance of chain and disc assemblies are considered, the average costs per mile for the 3 years are comparable. There was a lesser infestation of rooted aquatic weeds in 1966 as compared to 1965 and 1964 because of increased turbidity in the canals due to heavy runoff upstream in 1966. This contributed to the reduction in the total miles of operation over the test period.

All-hydraulic Excavator

The all-hydraulic-type excavator shown in Figure 16 is a readily available tool for removing aquatic weeds and silt in congested waterways,

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*The Project machine shop repairs and maintains chain and disc assemblies.

and is a good road vehicle. It is accessible to any area within the Project boundaries on short notice and practically no setup time is necessary at the site.

Figure 16. Aquatic weeds and silt being removed from an unlined lateral by an all-hydraulic type. Photo PX-D-60891.

Characteristically, about 95 percent of the aquatic weed growth in an unlined ditch is on the bottom. The sides are relatively free of growth up to the waterline, and weeds and bermuda grass grow on the bank above the water level. A skilled operator can remove the bank vegetation with little or no damage to the low-growing bermuda grass, thereby saving the bermuda root system which is desirable for stabilization of the unlined channel banks.

The excavating machine scoops silt and aquatic weeds from a wet or dry channel and piles them on the bank. When necessary, the piles of spoil are removed by dump trucks. Most of the aquatic weed growth is removed from the lateral; however, some of it floats downstream before the bucket is raised above the water surface. This creates moderate interruptions to irrigation deliveries.

The machine is used mainly in short stretches of heavy infestations, especially when irrigation deliveries cannot be stopped in order to employ solvent. The cost of a solvent application in a short stretch could equal the cost of using the machine method, without the benefit of any silt removal.

Multipurpose-type excavators are used. Each has a custom-built perforated bucket 6 feet wide (approximately 1/3-yard capacity) and each has the outer-boom pipe-roller guides reworked to withstand wear.

The crew consists of an operator and a driver who moves the machine forward as the task progresses.

The following table lists the cost of the aquatic weed control by this method for the period of the report.

All-hydraulic Excavator
Control Costs

	1964	1965	1966	Total
Physical operation in laterals	$3, 168.02	$1, 771.59	$4, 066.74	$9, 006.35
Removal and disposal of spoil from lateral banks	141.11	70.84	249.40	461.35
Field supervision	40.50	13.05	25.20	78.75
Office cost	40.95	16.65	13.95	71.55
Total cost	$3, 390.58	$1, 872.13	$4, 355.29	$9, 618.00
Total miles of operation	24.5	14.6	23.3	62.4
Average cost per mile of operation	$ 138.39	$ 128.23	$ 186.92	$ 154.13

The average cost per mile of operation was $186.92 in 1966 against the $138.39 in 1964, which is probably due to removing more silt during the aquatic weed control operation in 1966.

Backhoe

Although the backhoe is similar in operation and provides similar results to the all-hydraulic-type excavator discussed previously, it is a smaller machine with a shorter reach and is a one-man operation. Figure 17 on the following page, shows a backhoe in operation. The limited use of this machine during the period of this report provided limited cost data and is included only as a matter of interest.

Diesel-powered backhoes, modified for front and rear operation, are used with special 5-foot perforated buckets. The units are hauled on trailers pulled by a pickup truck.

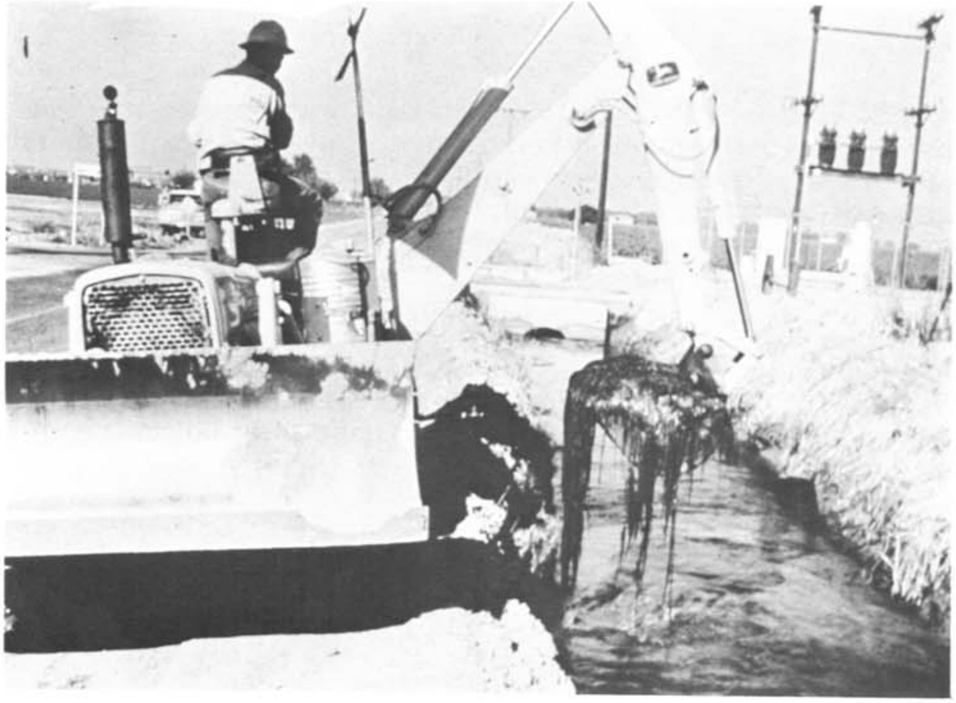

Figure 17. Backhoe removing aquatic weeds and silt from an unlined waterway. Photo PX-D-60892.

The table below lists the cost of the backhoe aquatic weed control for the period of this report, and because of the few number of miles completed, these costs are not considered significant.

Backhoe Control Costs

	1965	1966	Total
Aquatic weed control operation in laterals	$323.13	$64.46	$387.59
Removal and disposal of spoil from lateral banks	12.93	2.58	15.51
Field supervision	2.70	1.35	4.05
Office cost	6.75	.90	7.65
Total cost	$345.51	$69.29	$414.80

Total miles of operation	2.6	.3	2.9
Average cost per mile of operation	$132.89	$230.97	$143.03

Acrolein

Aquatic weed control with acrolein in canals was started in 1966. It is applied in the Project waterways at a rate averaging .35 parts per million for 48 to 90 hours, depending on water temperature and the seriousness of the weed infestation. Acrolein at this rate provides good control of algae and small plants and retards the growth of mature aquatic weeds.

At the rate mentioned above, good control of algae is obtained for 10 to 15 miles of canal per treatment, as well as an indeterminate number of miles of laterals. Since the Federal label does not approve the use of acrolein in domestic water supplies, it is used only downstream from the three filter plants on the system.

The acrolein treated water is considered harmless to crops and warm blooded animals at this low concentration. The treatment disintegrates the algae and causes a varying percentage of the rooted aquatic plants to break off in small pieces. These small pieces rarely interfere with irrigation operations, but occasionally collect along with other trash on canal structures and must be removed. This low application rate does not require a reduction in water delivery schedules. The acrolein treatment has no effect on the control of silt accumulation.

The acrolein used in the irrigation system was a commercially available product. Limited experimentation with a derivative of endothall is also being conducted. No significant costs have been accumulated and therefore are not included in this report.

The application of acrolein into the irrigation waterways is made from heavy-walled cylindrical containers which are supplied by the distributor. They are delivered to the application points from the warehouses by pickup truck. Dry nitrogen is used to maintain the desired pressure in the acrolein cylinders. Pressure regulators, a metering orifice, and plastic tubing complete the equipment requirements for the operation.

A 12-inch perforated pipe at the end of the plastic tubing serves to disperse the acrolein under water, and has a weight to keep the end of the tube on the bottom of the canal. It is desirable to make the acrolein applications from inside the wellsite enclosures for security reasons as shown in Figure 18. With the acrolein set in a wellsite, it needs to be attended only during the normal 8-hour working day.

The control of aquatic weeds by acrolein is a one-man operation, except that two men are needed to set up and remove the equipment. Training in the principles of the operation and safety requirements is necessary. The only specialized equipment which is required is a gas mask for an emergency such as a faulty valve or cylinder. A pickup truck is needed for the operator's transportation.

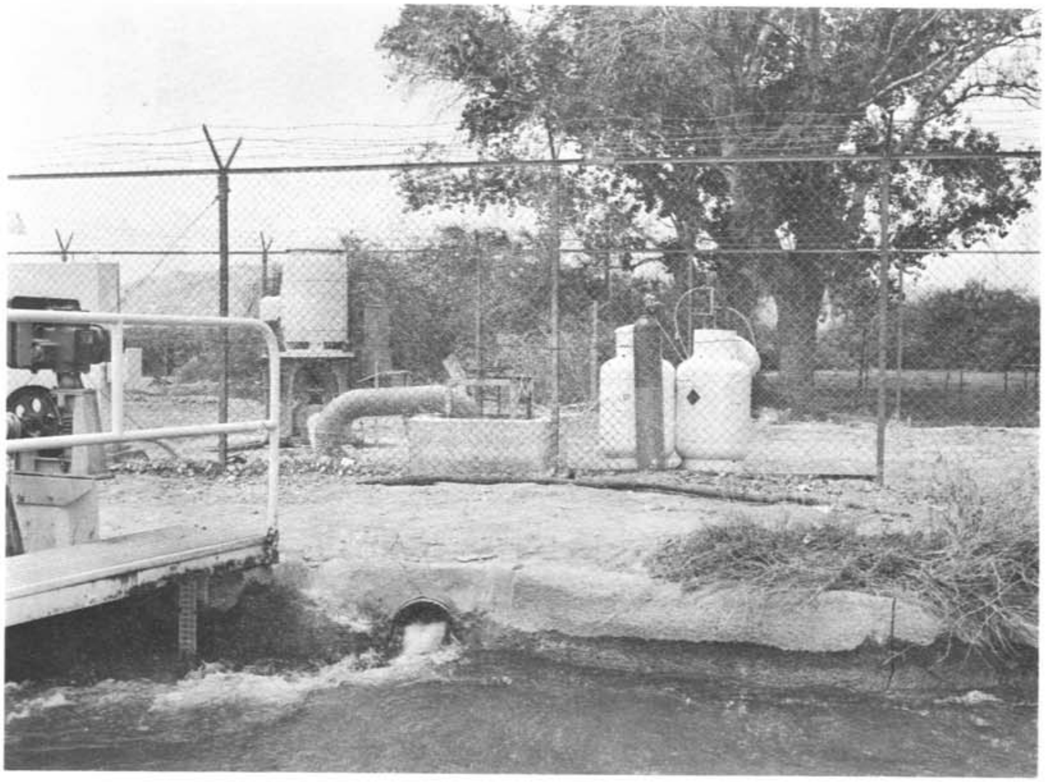

Figure 18. Introduction of acrolein into a Salt River Valley Water Users' canal from pressureized containers through a deep-well pump discharge structure. Photo PX-D-60893.

The table on the next page presents the cost of aquatic weed control by the acrolein method for the period of this report. The cost reflects that for the canal system and the adjacent laterals in which comparable control was attained.

Acrolein Control Costs

	1966
Physical operation in waterways	$11,246.82
Removal and disposal of aquatic weeds	.00
Field supervision	204.75
Office cost	25.65
Total	$11,477.22
Total miles of operation	213.1
Average cost per mile of operation	$ 53.86

Solvent

An aromatic solvent of an intermediate distillation range with an emulsifier introduced into the irrigation channels destroys the algae and disintegrates the leaves and part of the leaves and stems of the rooted aquatic plants. Disintegrated aquatics float downstream but rarely interfere with farmers' irrigation. However, silt accumulation continues though aquatic weed growth is controlled.

The solvent method was adopted by the Salt River Valley Water Users' Association in 1949 and is used in laterals and occasionally in the lower reaches of canals. The solvent-treated water is not used for irrigation until it is diluted in a larger channel or until at least 5 hours after its introduction into the waterway. For economy, waterflow is reduced during treatment, but reduced to a point of water channeling among the weeds.

One solvent charge lasts 2 to 3 hours, depending upon water temperature and the weed infestation, and is effective for approximately 1 mile. Additional charges are made downstream so that the entire reach is exposed to an effective treatment. During 1964 aromatic solvent of intermediate distillation range was applied at a rate of 12 gallons per cfs of water. In 1965 and 1966, with the use of xylene, the rate was reduced to 10 gallons per cfs.

The material is a xylene-type aromatic solvent, with an emulsifier, added at a 1-percent-by-volume rate. Two-ton trucks with 1,000- or 1,200-gallon tanks deliver the solvent to the channels. A 20-gallon-per-minute pump powered by a 9-1/2-horsepower air-cooled engine is used to apply the solvent through the orifices under water, Figure 19. The trucks, tanks and pumps used in the solvent operation are the same as used in the ditch bank weed control operation. Solvent aquatic weed control is a one-man operation, controlled by a truck driver.

Figure 19. Solvent being introduced into a pump and drainage channel. Photo PX-D-60894.

The table on the next page lists the cost of the solvent control method for the period of this report.

The reduction in cost per mile for 1966 and 1965 over 1964 primarily reflects the efficiency of xylene over the intermediate distillation range solvent used in 1964.

Solvent Control Costs

	1964	1965	1966	Total
Physical operation in laterals	$16,953.07	$13,050.37	$12,863.10	$42,866.54
Removal and disposal of aquatic weeds	.00	.00	.00	.00
Supervisory costs	317.25	104.85	45.45	467.55
Office cost	149.85	140.40	62.10	352.35
Total cost	$17,420.17	$13,295.62	$12,970.65	$43,686.44
Total miles of operation	467.5	400.3	485.9	1,353.7
Average cost per mile of operation	$ 37.26	$ 33.21	$ 26.69	$ 32.27

TEST CHANNEL STUDIES
SILT AND AQUATIC WEED CONTROL

Description of Channels

Four test channels, 1-1/2 miles in length, were selected and used in 1965 and 1966 for the purpose of collecting silt removal costs in addition to the aquatic weed control costs. Each lateral and canal reach consisted of partially lined and partially unlined sections, except for the completely lined channel in which the turbine was used. The laterals were selected for their comparable operating conditions and capacity, and the canal was selected on the basis of being typical of most Project canals.

Originally one aquatic weed control method was assigned to each test channel, and the tables below present the results. It will be noted that supplemental methods were used when the assigned method was not adequate.

Control Costs

Turbine Compressor

(Lined Channel. Normal channel flow rate--20 cfs.
Wetted perimeter--12 feet.)

Control method	*No. of treatments	Cost	Flow rate, cfs
1965 turbine	5.87	$ 826.20	20
1966 turbine	2.33	373.43	20
1966 solvent	1.66	74.38	5
		$1,274.01	

---

*Includes full-length treatments and partial treatments.

The turbine adequately controlled all silt in the test channel, however, in 1966 accumulations of algae created a need for solvent treatments.

Anchor Chain and Disc

(Grand Canal, Unlined and Lined.
Normal channel flow rate--100 cfs.
Wetted perimeter--52 feet.)

Control method	*No. of treatments	Cost	Flow rate, cfs
1965 anchor chain and disc	2.00	$ 502.26	100
1966 anchor chain and disc	1.33	498.72	100
1966 acrolein	3.00	230.56	100
1966 solvent	.67	42.00	25
		$1,273.54	

The anchor chain and disc method controlled silt in the test channel. During the spring of 1966, acrolein was used to control algae growth in the entire canal on several occasions. Solvent was introduced once in the downstream 1-mile section of the test channel to control both algae and rooted aquatic growth.

Excavator

(Canal 3, Lateral 3.2, Lined and Unlined.
Normal channel flow rate--25 cfs.
Wetted perimeter--7 feet.)

Control method	*No. of treatments	Cost	Flow rate, cfs
1965 excavator	.66	$156.47	25
1965 backhoe	1.00	165.80	25
1965 solvent	1.00	30.83	6
1966 excavator	1.13	276.33	25
1966 solvent	1.66	102.38	6
		$731.81	

For 1965 sufficient silt control was obtained with the all-hydraulic excavator. The backhoe was substituted for the excavator on two occasions when all the excavators were employed on construction projects. An algae infestation without a silt accumulation necessitated the use of a solvent treatment. The same situation developed in 1966 when solvent again was employed.

---

*Includes full-length treatments and partial treatments.

Solvent

(Canal 5, Lateral 10, Lined and Unlined.
Normal channel flow rate--25 cfs.
Wetted perimeter--18 feet.)

Control method	*No. of treatments	Cost	Flow rate, cfs
1965 solvent	5.33	$312.38	6
1965 turbine	.17	27.03	25
1965 excavator	.40	75.36	25
1966 solvent	2.11	207.63	6
1966 turbine	.33	36.04	25
		$658.44	

In 1965 the turbine was used to control silt in a lined portion of the channel and the all-hydraulic excavator was used to control silt in an unlined portion. In 1966 no silt removal was required in the unlined section but the turbine was used for silt control in the lined section.

CONCLUSION

The turbine compressor has been found by experimental use to be an effective tool for aquatic weed control when scheduled in lined laterals with a bottom width of 2 feet or less. No decrease in water delivery is necessary.

The majority of canal aquatic weed control is most efficiently accomplished with the anchor chain and disc method. This method reduces the silt problem by leveling of canal bottoms and dispersion of silt.

In the open lateral system, the use of aromatic solvent is the most commonly used method of aquatic weed control and is the most economical. However, solvent has no effect on silt control. On the other hand, the use of the turbine compressor, excavator and backhoe in aquatic weed control removes or disperses some of the silt accumulation.

It is clear that no one method can be considered best in all circumstances. The most adequate method to suit the condition and the number of treatments per year must be left to the judgment of supervisory personnel.

Since each method is unique in its own ability to control aquatic weed growth and the advantages and disadvantages of each must be considered economically as well as physically, it is difficult to compare costs directly.

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*Includes full-length treatment and partial treatments.

ACKNOWLEDGEMENTS

Acknowledgement is given to the following personnel of the Association for their assistance in making this report possible:

Mr. Reid W. Teeples, Chief Engineer, Salt River Valley Water Users' Association and coauthor.

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Mr. Fred G. Corbus, Weed Control Foreman, and Ray Pristo, Construction Designer who coauthored the report.

The guidance and valued assistance of Mr. Henry Shipley, Assistant General Manager.

All photographs taken by personnel of the Salt River Valley Water Users' Association.

APPENDIX

AQUATIC WEED CONTROL OPERATION SHEET
TURBINE COMPRESSOR

Date________________Based at________________

No. of Men________Classifications________________________________
1. Preparation and Loading Time, Begin______________Finish______________
2. Travel Time to Location, Lv.______________Arrive______________
Location____
Ditch:
Bottom Width______Depth of Water______Gunite______Slipform______Unlined______
Culvert:
Size______________________________Depth of Water______________
Type of Operation:
Moss Removal______________Silt Removal__________Moss & Silt Removal______
Average Measured Depth of Silt________________________________
Moss Growth:
Light______________Medium__________________Heavy______________
Type of Moss:
Algae______________________________Rooted______________________
Condition of Water:
Clear______________Cloudy______________Muddy______________
Set-up time at location, From__________________To__________________
3. Running time

Start Engine	Start Blower	Stop Blower	Stop Engine	Reason for Stop

When moving to a new location the same day, use another sheet starting at (2).

4. Amount Completed

Sec.____T____R____ Sec.____T____R____ Sec.____T____R____ Sec.____T____R____
Length________Mi. Length________Mi. Length________Mi. Length________Mi.

No. of Passes_____ No. of Passes_____ No. of Passes_____ No. of Passes_____

TURBINE COMPRESSOR (CONTINUED)

5. Button-up time at location, From____________________To____________________

Leave location______________Arrive at Base______________Base Location______________
Fuel for Gas Turbine - type______________Quantity______________(Fill Tanks)
Fuel for Truck - type______________Quantity______________(Fill Tanks)

6. Time used to fill form____________________minutes.

Remarks____

Person in charge of operation____________________

Truck No.:______________

Charge No.:______________

7. Reason for selecting Goose:____

Remarks____

Truck & Turbine______________
Cost Rate Per Hour

Signed____________________
Fred Corbus

Field Foreman Time______________

Weed Control Foreman Time______________

AQUATIC WEED CONTROL OPERATION SHEET
ANCHOR CHAIN AND DISC

DATE____________________

1. One sheet to be filled out by each of the following:

   A. Dragline, Demossing Foreman
   B. Cats and chain hookers
   C. Dump trucks and miscellaneous equipment

2. Equipment used and number of men

   Dragline__________ No. of Cats______________ No. of Trucks__________
   Miscellaneous____
   Number of Men__________________ Equipment based at____________
   Classifications______________________________________

3. Preparation and Loading time, Begin______________ Finish____________

4. Travel Time to Location, Lv.__________________ Arrive____________
   Location____
   Ditch:
   Bottom Width____ Depth of Water____ Gunite____ Slipform____ Unlined____
   Moss Growth:
   Light__________________ Medium____________ Heavy__________
   Type of Moss:
   Algae__________________________ Rooted__________________

   Set-up time at location, From______________ To__________________

5. Running time: (For cats and dragline only)

Start in Canal	Stop in Canal	Reason for Stop

ANCHOR CHAIN AND DISC
(CONTINUED)

6. Amount Completed

Sec._____T_____R_____ Length__________Mi.
No. of Passes_______

Sec._____T_____R_____ Length__________Mi.
No. of Passes_______

Sec._____T_____R_____ Length__________Mi.
No. of Passes_______

Sec._____T_____R_____ Length__________Mi.
No. of Passes_______

7. Button-up time at location, From________________To________________

Leave location__________Arrive at Base__________Base Location__________

8. Time used to fill form____________________minutes.

Remarks____

Person in charge (Demossing foreman or lead cat driver)________________

Charge No.________________

9. Equipment cost per hour

Dragline $________________ Hours charged________________
Cat $________________ Hours charged________________
Truck $________________ Hours charged________________
_____ $________________ Hours charged________________
_____ $________________ Hours charged________________

Remarks:____

Fred Corbus

Field Foreman Time________________

Weed Control Foreman Time____________

AQUATIC WEED CONTROL OPERATION SHEET
GRADALL

Date 10-19-64 Based at N.S.C.

No. of Men 2 Classifications OPERATOR HEAVY TRUCK DRIVER

1. Preparation and Loading time, Begin 7:30 Finish 7:35
2. Travel Time to Location, Lv. 7:35 Arrive 8:20

Location 5E 6¼ N

Ditch:

Bottom Width 6′ Depth of Water 18″ Gunite ___ Slipform ___ Unlined ✓

Type of Operation:

Moss Removal ___ Silt Removal ___ Moss & Silt Removal ✓

Average Measure depth of Silt 6″ TO 12″

Moss Growth:

Light ___ Medium ___ Heavy ___

Type of Moss:

Algae ___ Rooted M TO H

Condition of Water:

Clear ✓ Cloudy ___ Muddy ___

Set-up time at location, From 8:20 To 8:30

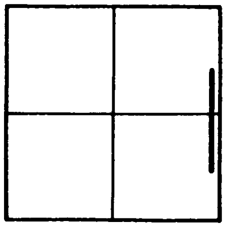
3. Running time

Start	Stop	Reason to Stop
8:30	12:00	LUNCH
12:30	15:00	RETURN TO CAMP

When moving to a new location the same day, use another sheet starting at (2).

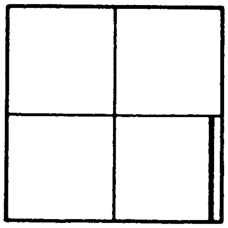
4. Amount completed

Sec. 35 T 2 R 1 Length ½ Mi.



No. of Passes 1

Sec. 23 T 2 R 1 Length ½ Mi.



No. of Passes 1

Sec. ___ T ___ R ___ Length ___ Mi.

No. of Passes ___

Sec. ___ T ___ R ___ Length ___ Mi.

No. of Passes ___

GRADALL (CONTINUED)

5. Button-up time at location, From 15:00 to 15:10

Leave location 15:10 Arrive at Base 15:50 Base Location N. S. C.

6. Time used to fill form 10 minutes.

Remarks

Person in charge of operation EDWIN FERGUSON

Gradall No. 7-43

Charge No. 773-42-534

7. Reason for selecting Gradall

Remarks:

Gradall
Cost Rate Per Hours
Hours Charged
Field Foreman Time

Signed
Fred Corbus

Weed Control Foreman Time

AQUATIC WEED CONTROL OPERATION SHEET
SOLVENT

Date 10-19-64 Based at S.S

No. of Men 1 Classifications LT. TRUCK
1. Preparation and Loading time, Begin 07:30 Finish 08:15
2. Travel Time to Location, Lv. 08:15 Arrive 09:10
Location 5E 9N TO 6E 4N
Ditch:
Bottom Width 50' Depth of Water 6" Gunite ___ Slipform ___ Unlined ✓

Moss Growth:
Light ___ Medium ___ Heavy ___
Type of Moss:
Algae M Rooted H
Condition of Water:
Clear ✓ Cloudy ✓ Muddy ___
Set-up time at location, From 09:10 To 09:15
(Reason for delay, if any) ___ From ___ To ___

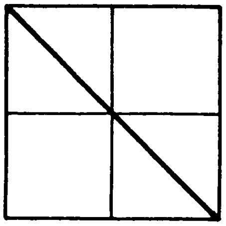
3. Running Time of Pump: 6 HRS.

Start	Stop	Reason for Stop
5E 9N 09:15	15:15	FINISH CHG.

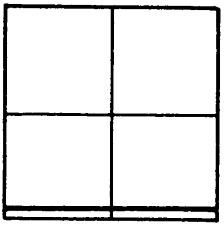
When moving to a new location the same day, use another sheet starting at (2).

4. Amount Completed

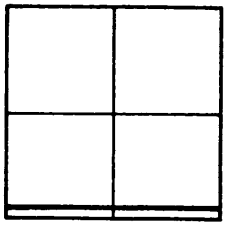
Sec. 14 T 2N R 1E
Length 1 1/4 Mi.



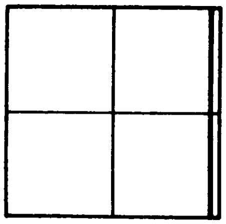
Sec. 10 T 2N R 1E
Length 1 Mi.



Sec. 9 T 2N R 1E
Length 1 Mi.



Sec. 17 T 2N R 1E
Length 1 Mi.



(For additional section squares see opposite side)

Zanjero ___ Lateral ___ Rate of Water Flow 300" +

L O C A T I O N S

Sec 36 T 3N R 1E Sec __ T __ R __ Sec __ T __ R __

Sec __ T __ R __ Sec __ T __ R __ Sec __ T __ R __

Sec __ T __ R __ Sec __ T __ R __ Sec __ T __ R __

Sec __ T __ R __ Sec __ T __ R __ Sec __ T __ R __

GPO 844-260

Demossing No. of Men	Remove & Dispose No. of Men	CLASSIFICATION
1		5450
1		9721

RATE PER HOUR	
Demossing	Dispose & Remove
372	
295	
TOTAL 667	

OFFICE USE ONLY

Demossing No.	Remove & Dispose No.	EQUIPMENT USED	No. of Miles Used
		Dragline	X
		Tractor	X
1		Turbine	X
		Gradall	X
		Solvent Truck	X
		Chemical Truck	X
		Truck, Group 1	
		Truck, Group 3	
		Truck, Group 4	X
		Truck, Group 5	
		Backhoe	X

RATE PER HOUR	
Demossing	Dispose & Remove
1250	
TOTAL 1250	

++ DEMOSSING AND DESILTING OPERATION REPORT

Location: **Canal** 1 (1) Lateral 1 9 . 0 (2 3 4) Date: Mo: 1 1 (5 6) Day 1 2 (7 8) Yr. 5 (9)

TYPE OF OPERATION (Removal of)	TYPE OF DITCH	WATER FLOW M. I.	DEPTH OF SILT Inches	WATER CONDITION	AVRG. GROWTH OF ALGAE	AVRG. GROWTH OF ROOTED MOSS
14	15	16 - 20	21 22	23	24	25
1 - Moss 2 - Silt [✓ 3 - Moss & Silt]	[✓ 1 - Gunite] 2 - Slipform 3 - Unlined 4 - Mixed	0 0 0 5 0	1 4	[✓ 1 - Clear] 2 - Cloudy 3 - Muddy	0 - None [✓ 1 - Light] 2 - Medium 3 - Heavy	0 - None 1 - Light 2 - Medium [✓ 3 - Heavy]

METHOD	No. of Charges	No. of Recharges	Gals. Turbine Fuel, Solvent or Chemical Used	Cost per Gallon Solvent or Chemical	Miles Completed (Miles & Tenths)	Preparation & Loading Time (Minutes)	Total Travel Time (*See Footnote) (Minutes)	Total Set-up & button-up time (Minutes)	Operation Time (Minutes)	Down or Idle Time (Minutes)	Time to fill Form per Crew (Minutes)	Total Crew Work Time (Minutes)
31	32	33	34-36	37-40	41-43	44-46	47-49	50-52	53-55	56-58	59-60	61-64
1 - Tractor	X	X	X	X	- - -	- - -	- - -	- - -	- - -	- - -	03	- - - -
2 - Gradall	X	X	X	X	- - -	- - -	- - -	- - -	- - -	- - -	10	- - - -
3 - Solvent			- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	20	- - - -
[✓ 4 - Turbine]	X	X	X	X	003	—	050	024	100	—	06	0180
5 - Turbine Canal	X	X	X	X	- - -	- - -	- - -	- - -	- - -	- - -	06	- - - -
6 - Chemical			- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	20	- - - -
7 - Backhoe	X	X	X	X	- - -	- - -	- - -	- - -	- - -	- - -	10	- - - -
8					- - -	- - -	- - -	- - -	- - -	- - -		- - - -

TOTAL

Report No. 1 3 7 0 (10 11 12 13)

SUPERVISORY TIME				
FIELD Minutes			OFFICE Minutes	
26	27	28	29	30
0	—	—	1	0

OFFICE USE ONLY

Demossing Crew		Disposal Crew	
Hrly. Total Man-Power Rate	Hrly. Total Equipment Rate	Hrly. Total Man-Power Rate	Hrly. Total Equipment Rate
65-68	69-72	73-76	77-80
0667	1250	0	—

++ 88.8 Pump Ditch
99.9 Waste Ditch

* Base to site, site to site, site to Base.

Name:

Checked:

SOLVENT (CONTINUED)

5. Buttom-up time at location, From 15 : 15 To 15 : 20

Leave location 15 : 20 Arrive at Base 16 : 00 Base Location C&M [illegible].S.
Number of charges / Number of recharges ____ Quantity of solvent used ____
Time Required to Prepare for next job, From ____ To ____

6. Time used to fill form 20 minutes

Remarks MUDDY WASTE WATER APPROX. 75"

Person in charge of operation BILL COOK

Truck No. 9-942

Charge No. 773-42-531 & 773-41-531

7. Reason for selecting Solvent: ____

Remarks ____

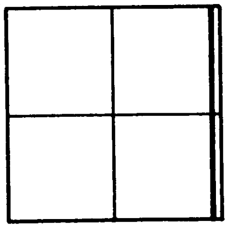
Equipment ____
Cost Rate Per Hour ____
Hours charged ____
Field Foreman Time ____

Signed F. Corbus
Fred Corbus

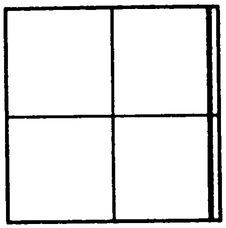
Weed Control Foreman Time ____

Cost per gal. of solvent ____

Sec. 20 T 2N R 1E
Length / Mi.



Sec. 29 T 2N R 1E
Length / Mi.



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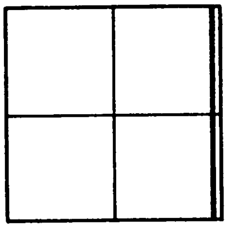
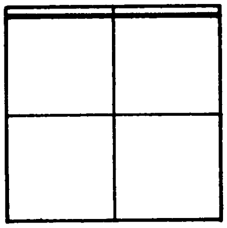
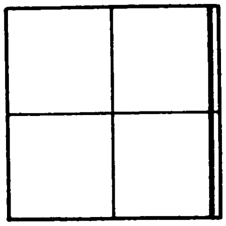
Length / Mi.



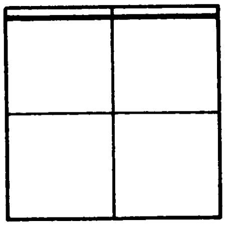
Sec. 5 T 1N R 1E
Length / Mi.



Sec. 6 T 1N R 1E
Length / Mi.



Sec. 7 T 1N R 1E
Length / Mi.



Sec. ____ T ____ R ____
Length ____ Mi.

Sec. ____ T ____ R ____
Length ____ Mi.