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UNDERWATER LINING OF OPERATING CANALS

October 1994

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To determine the feasibility of lining a canal without de-watering the canal, the Bureau of Reclamation constructed a 1.5-mile-long test section on the Coachella Canal in the Imperial Valley of southeastern California. The canal was lined with an impervious 30-mil PVC (polyvinyl chloride) geomembrane. The geomembrane lining was protected by a 3-inch-thick concrete cover.

This report discusses the results of the various research programs and construction techniques developed prior to and during the construction of the test section on the Coachella Canal.

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by

William F. Kepler and Alice I. Comer

Materials Engineering Branch
Research and Laboratory Services Division
Technical Service Center
Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

U.S. Department of the Interior
Mission Statement

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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INTRODUCTION

To determine the feasibility of lining a canal without de-watering the canal, the Bureau of Reclamation constructed a 1.5-mile-long test section on the Coachella Canal in the Imperial Valley of southeastern California (see fig. 1). The canal was lined with an impervious 30-mil PVC (polyvinyl chloride) geomembrane. The geomembrane lining was protected by a 3-inch-thick concrete cover. The concrete contained an AWA (anti-washout admixture), which prevented the washout of fines in the flowing water and facilitated placement. A water depth of nine feet was maintained in the canal during construction. The Coachella Canal relining project successfully demonstrated a procedure that can be used on many other unlined canals to reduce water seepage, improve flow characteristics, and facilitate maintenance operations. The project was funded by the Metropolitan Water District of Southern California, the Coachella Valley Water District, and the Bureau of Reclamation.

Figure 1. - The unlined section of the Coachella Canal in southeastern California.

Our research program—Underwater Lining of Operating Canals—developed a number of new construction materials and methods that were used during construction of the Coachella Canal In-Place Lining Project. The new construction materials included a concrete AWA, which increases the cohesiveness of the concrete to allow placement in flowing water without losing cementitious fines. We examined bonded geotextile-geomembrane, which prevents seepage of valuable water and provides a surface to which concrete can bond (Morrison, 1990). We also tested non-toxic concrete curing compounds, which could be placed on the fresh concrete without adding harmful chemicals to the water in the canal (Drottar, appendix).

We developed a number of new construction methods in this research program. We developed a method of placing a 3-inch-thick concrete lining underwater on a 2.5:1 side slope in flowing water (Kepler, 1990). Animal escape curbs developed under this program were used for the first time at Coachella Canal (White, 1990). We examined new methods of seaming geosynthetics both above and below water (Morrison and Swihart, 1990). We also tested the bond between various geosynthetic materials and shotcrete (Comer, 1993), and the shear strength between soil and geomembranes (Young, 1994).

A number of papers on various subjects have been written under the auspices of Underwater Lining of Operating Canals. We developed a number of new construction materials and methods that made it possible to pave the Coachella Canal. Many of these new materials and methods have subsequently been used on other construction projects, such as the Potomac Dams Project, Black Mountain Operating Reservoir, Hoover Elevator Shaft, Central Arizona Project Siphon Repair Project, Tucson Aqueduct - Reach 3, Deschutes Canal Lining Demonstration Project, and the Towaoc Canal - Reach 1.

CONCLUSIONS

1. Reclamation has developed a practical method of placing a concrete lining underwater. This research has lead to improved concrete placing techniques on other projects.

2. Reclamation has determined that a PVC geomembrane can be placed and seamed underwater.

3. Reclamation testing found a concrete curing compound that can be used in environmentally sensitive areas.

4. Reclamation has determined the single operator accuracy for direct shear testing of several geomembrane/soil combinations.

5. Reclamation has determined that moisture affects the adhesion between shotcrete and various geocomposite materials. However, neither wet/dry nor freeze/thaw cycling appear to affect this adhesion.

SEEPAGE PROBLEM

A number of unlined canals in the Western United States have high seepage rates, which can cause water losses as high as 28 percent of the total flow on some reaches. Water delivery commitments preclude taking many of those canals out of service to be lined. The All American and Coachella Canals in southeastern California are prime examples. If 30 miles of the All American and 38 miles of the Coachella Canal were lined, seepage losses of over 100,000 acre-feet per year could be prevented. Desert farms served by the All American and the Coachella Canals require irrigation water 365 days a year. The Bureau of Reclamation developed the in-place lining technique to line canals without de-watering them and interrupting water delivery.

Before development of the in-place lining technique, the only alternative was to build a lined canal parallel to the existing canal, then abandon the leaking unlined canal. The cost of land acquisition and the environmental concerns associated with building parallel canals make the in-place lining technique more cost effective and desirable.

Lining Solution

The in-place lining technique limits construction to one-half of the canal prism at a time, allowing water to bypass construction through the other half prism. The canal is lined with an impervious 30-mil PVC geosynthetic lining system with a protective cover of concrete. The concrete also provides a hard surface that is easy to maintain. The combination of the PVC and concrete cover reduces the water seepage from about 0.45 ft^3/ft^2/day to less than 0.01 ft^3/ft^2/day.

The Bureau of Reclamation originally envisioned trimming the canal to grade, followed by a soil-cement backfill to fill in any low spots. This backfill would then be followed by the placement of the geosynthetic lining and concrete cover (see fig. 2). The contractor, however, developed a single trimming and backfilling operation, using pea gravel instead of soil-cement as backfill.

Test Section

The test section of the Coachella Canal was selected after completion of extensive laboratory work. The canal carries water from the Colorado River, just north of Yuma, Arizona, 123 miles north and west to the Coachella Valley. Eighty-five miles of the canal are lined and 38 miles are unlined. The canal has a maximum capacity of 1300 ft^3/s and supports 78,530 acres of desert farm land.

The test section was 1.5 miles long between siphons 14 and 15 near Niland, California. This particular section was chosen because water flow could be controlled at both ends. The canal has a 48-foot bottom width, 2.5 to 1 side slopes, and an 11-foot depth. The total width of the canal is 103 feet. The water velocity reached a maximum of 2.0 ft^3/s during construction.

LABORATORY WORK

Concrete

A concrete mixture that would work in the field had to be developed in the laboratory prior to construction. The fresh concrete had to meet two primary criteria: (1) it could not wash out in flowing water at the anticipated velocities in the canal and (2) it had to be easily placed underwater. The testing was divided into two parts: erosion testing and small-scale placement testing. In both parts, concrete containing AWA was compared to concrete without AWA.

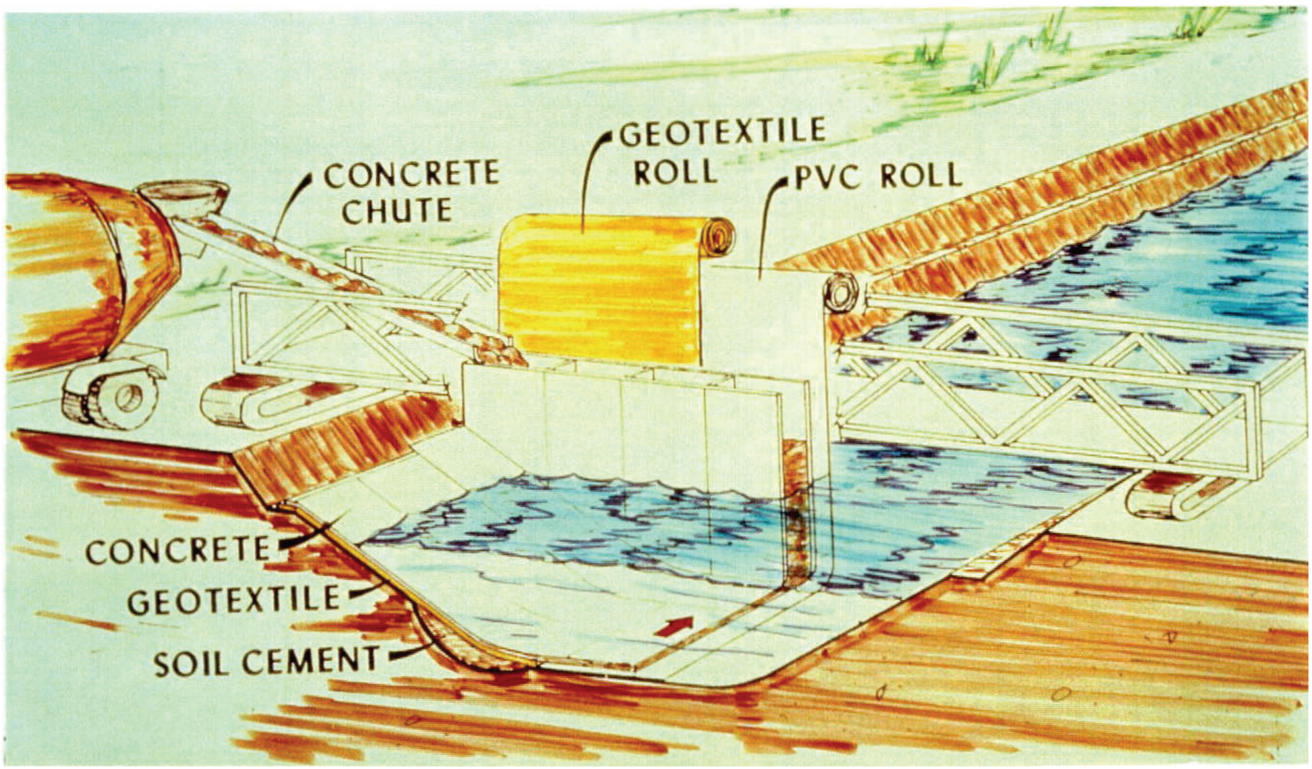

Figure 2. - Proposed placement sequence.

Erosion Testing

The purpose of the erosion testing was to determine the loss of fresh concrete under flowing water and the variables affecting the loss. Water velocities for the tests were 0.5, 1.0, 2.0, and 3.1 ft/s (Fitzwater, 1993).

Fresh concrete samples were tested in a hydraulic flume in which water flowed at the test velocity. The samples measured 2 feet square and 3 inches thick. The sample was placed in the flume, which contained about 6 inches of standing water, so the top of the concrete was flush with the bottom of the flume. The concrete samples were tested from 20 minutes after mixing until 4 hours had elapsed. By this time, the concrete's initial set had begun. The water velocity was measured 6 inches above the concrete surface.

Only negligible (0.02 in) erosion of the fresh concrete occurred while the water velocity remained below 3.1 ft/s. When the water velocity reached 3.1 ft/s, the concrete began to wash out dramatically. At this higher velocity, the top 1/4 inch of the fresh concrete was lost. The AWA did not prevent erosion at this velocity.

During the testing, the water downstream from the fresh concrete was sampled and tested for turbidity, temperature, and pH change. No appreciable change occurred in any of these parameters.

Small-Scale Placement Testing

The purpose of the small-scale placement tests was to examine the possible placing methods and determine the necessary concrete property requirements. The concrete properties investigated included the cohesiveness of the concrete underwater, the slump required to place concrete underwater on a 2.5:1 slope, workability, and the concrete's ability to maintain its shape after placement. Longitudinal contraction joints and animal escape curbs that would be formed into the concrete during construction were added later.

Different placing techniques were considered. The slip-form paver was chosen because of its simplicity. A 1/10-scale model was used first, and then a 1/3-scale model. The slip-form placed concrete 3 inches thick. It placed half of the canal prism at a time and moved longitudinally down the simulated canal.

The paver had three major parts: hopper, throat, and tail. The hopper had to be large enough to supply an uninterrupted flow of concrete to the throat. The throat was kept narrow to minimize the need for excess concrete. The tail was the most important part of the paver because it protected the concrete from flowing water and gave the concrete its final shape and finish. A longer tail improved the concrete finish.

Concrete with AWA performed much better than the concrete without AWA. The AWA increased the cohesiveness of the concrete and made placement much easier. Less washout of portland cement occurred when the AWA was used. The end product had a better finish, and the fresh concrete experienced less tearing during placement. This characteristic was very important because the underwater concrete could not be finished after it had been placed. The AWA also allowed an increased placing speed.

Placing concrete underwater did not change the slump requirement. A 4-inch slump was the maximum that could be used on the 2.5:1 slope without the concrete sliding to the bottom of the slope. Concrete with the proper slump, between 2 and 4 inches, could be placed on a 2.5:1 slope with a smooth finish, and the animal escape steps and longitudinal joints could be formed into the concrete.

The speed of the placement was very important. The placement had to be slow enough to supply an uninterrupted flow of concrete to the bottom of the slip-form, yet fast enough to keep the concrete from bulging out the bottom. A speed between 0.5 and 1.0 ft/min proved satisfactory. The speed of placement depended on the delivery of concrete, the amount of vibration, and the slump.

The vibrators on the slip-form served two functions: (1) to supply a constant flow of concrete to the bottom of the slip-form and (2) to consolidate the concrete. Two different types of vibrators were used: immersion and form. For our placing method and slip-form design, the form vibrators provided a more consistent flow of concrete through the slip-form.

Geosynthetic Lining

The geosynthetic lining material consisted of a PVC plastic geomembrane. On the side slope of the canal, a non-woven geotextile was bonded to the top surface of the geomembrane. The purpose of the geotextile was to provide a surface to which the concrete could bond while sitting on the side slope. This technique prevents the concrete from slipping down the slope before it obtains sufficient strength to hold its shape.

We selected a 30-mil PVC geomembrane to provide seepage control for this project. PVC is highly flexible and retains this property over a wide range of temperatures, which permits it to conform to the subgrade better than other geomembrane materials. PVC is easily field spliced and repaired with a solvent-type cement. PVC also has good puncture, abrasion, and tear resistance, which is important to minimize damage during installation. PVC has been used for over 20 years as a canal lining material.

PVC linings used in canal applications require a cover material to protect them from degradation caused by temperature extremes and exposure to UV (ultra-violet) radiation, as well as mechanical damage from animal traffic or vandalism. Reclamation has used PVC linings from 10 to 20 mils thick. A heavier 30-mil-thick material was used for the Coachella Canal to provide greater tear resistance and tensile strength for the unique installation requirements.

The PVC liner for this project was fabricated into panels 60 feet wide and 200 feet long. Each panel weighed 2,500 pounds and was accordion-folded in both directions to facilitate shipping and handling.

Because the canal lining was done in two passes, a longitudinal overlap seam of the PVC lining was required down the center of the canal. An unbonded, overlapped, longitudinal seam will not provide the necessary seepage control, so we selected a tetrahydrofuran adhesive to bond the two halves together. The specifications called for a 3-foot PVC overlap with a minimum 3-inch bonded width.

Because the PVC and the geotextile were manufactured separately, the contractor spot-glued the geotextile to the PVC using a contact adhesive. Since this contract was awarded, several companies have developed a factory-laminated PVC geotextile material.

The geotextile was originally intended to serve two purposes. First, it was required to prevent slippage of the concrete during placement. Consequently, we selected a non-woven geotextile, which has a good frictional surface. When the geotextile and the geomembrane are bonded together, the geomembrane assists in carrying the slippage forces.

Second, the geotextile was intended to act as a drainage medium to relieve hydrostatic pressure during canal drawdown. However, the geotextile showed very little water flow because of the intrusion of concrete mortar into the geotextile.

Shotcrete/Geosynthetic Interface Testing

As part of the research program, we investigated the bond strength between shotcrete—pneumatically-applied concrete—to various types of geosynthetic composites. We measured the adhesion between the shotcrete and four different geosynthetics to find their relative bond strength. Samples of each material were subjected to wet/dry and freeze/thaw cycling. Results indicate that moisture affects the shotcrete/geosynthetic adhesion, but wet/dry or freeze/thaw cycling does not.

Concrete Curing Compounds

Finding an environmentally safe concrete curing compound proved to be a major dilemma prior to construction. During the first year (1989) of construction, the contractor used water and plastic to cure the concrete above waterline. This technique was very expensive.

That winter, Reclamation began to study concrete curing compounds and their affect on the aquatic environment (appendix). The results of the study indicate that use of a wax-based curing compound should not adversely affect aquatic life, provided that concentrations in the canal water do not exceed 50 p/m. The 50-p/m concentration would occur if 6.7 gal/min of curing compound were introduced into the water at a minimum canal flow of 300 ft^3/s.

Direct Shear Tests Used in Soil-Geomembrane Interface Friction Studies

We also investigated the interface friction, or interface shear strength, between geosynthetics and soil. The direct shear test is the currently accepted method of measuring interface friction. Very little information is available on the accuracy of this test procedure.

Our laboratory tests indicated that the precision of the direct shear test is a combination of the precision in measurement of shear stress and the effect of that precision on the shear strength envelope.

In our tests, the measured maximum shear stress had the following statistics:

(1) The standard deviation varied between 0.02 and 0.28 lbf/in^2.
(2) The range varied from 0.06 to 0.74 lbf/in^2.
(3) The range as a percent of the average varied from 3.5 to 18.3%.
(4) The coefficient of variation varied from 1.4 to 7.0%.

CONSTRUCTION

The $5.2 million contract was awarded to Kiewit Pacific Company, Santa Fe Springs, California, in August 1988. The contract called for construction of a 1.5-mile-long test section of the in-place lining prototype in the Coachella Canal. In February 1989, the contractor began assembling the two specially built pieces of construction equipment at the job site. Gomaco Corporation, Ida Grove, Iowa, built a 175-ton trimmer and a 200-ton paver. Each machine works on half the canal prism at a time. The canal was rough graded, followed by final trimming and backfilling, and then the geosynthetic lining and concrete were placed.

The concrete lining was performed in two separate construction seasons. During the first construction season, which began in May 1989, the contractor was only able to pave about 1,000 feet of the right side. The contractor was unable to continue because of soft spots on the canal bottom which did not allow the geosynthetic lining to pass under the paving machine (Reclamation, 1993).

The contractor was able to modify the paving machine and paving was resumed February 6, 1991. The contractor was able to finish paving the test section by March 12, 1991. Each half of the canal paving operation only lasted one week.

Trimming

The test section was rough graded with telescoping backhoes. A 5-foot-wide berm, 11 feet above the bottom of the canal, was excavated into the canal side slope to provide a working platform for the trimming and paving machines.

The trimmer completed the final trimming to grade using a small dredge with a rotating cutter head that cut material loose from the bottom. A suction pump then drew water and cut material up through a hose and transported it beyond the canal bank. The trimmer removed excess material to grade within 1/4 inch. Trimming was also done between the berm and the waterline by two smaller trimmer heads mounted to the framework of the machine. One head trimmed the berms that the tracks ran on, while the other trimmed the slope above the water.

A spreader box full of aggregate to fill in low spots followed the rotary trimmer. The spreader box extended halfway across the canal prism and was filled with minus 1-inch gravel fed to it by chutes and belts. The trimming and backfilling process advanced at a speed of 0.5 ft/min. Grade was established by string lines, one on each bank.

Some problems occurred during the initial trimming operations. First, the trimmer could not handle large rocks. Second, the trimmer's large weight caused it to sink into soft soils. Finally, the trimming was much slower than the paving.

Paving

The paver has two primary functions: (1) to lay out the geosynthetic lining and (2) to cover the lining with a 3-inch-thick layer of concrete. In the 1989 test, a panel of the geosynthetic lining was laid out on the top deck, then glued to the preceding panel. When tests resumed in 1991, adjacent panels of PVC were joined by a thermal wedge weld. The lining was then fed into guides which brought it down to grade and held it in place until the geosynthetic lining was covered with concrete (see figs. 3 and 4).

The concrete paving machine had two major parts: the hopper and the tail. Concrete was fed into the hopper by a belt from the side of the machine. An auger inside the throat maintained a constant head of concrete within the throat. Vibrators spaced every 18 inches kept the concrete flowing uniformly through the hopper to the tail. The concrete was placed on top of the geosynthetic lining at the bottom of the hopper. The concrete was then shaped by the 4-foot tail, which also formed the longitudinal contraction joints and the animal escape curbs. The paver was capable of placing geosynthetic lining and concrete at a rate of 8 ft/min. However, a rate of 4 ft/min provided the best results.

The paver had three hydraulically operated gates or dams that could be lowered to within 1 foot of the canal bottom. These dams reduced the velocity of the water in the area to be paved and diverted the canal flow to the opposite half of the channel. The paver could be raised to allow a barge to be placed under it to receive wasted concrete. This feature prevented dumping excess concrete into the canal.

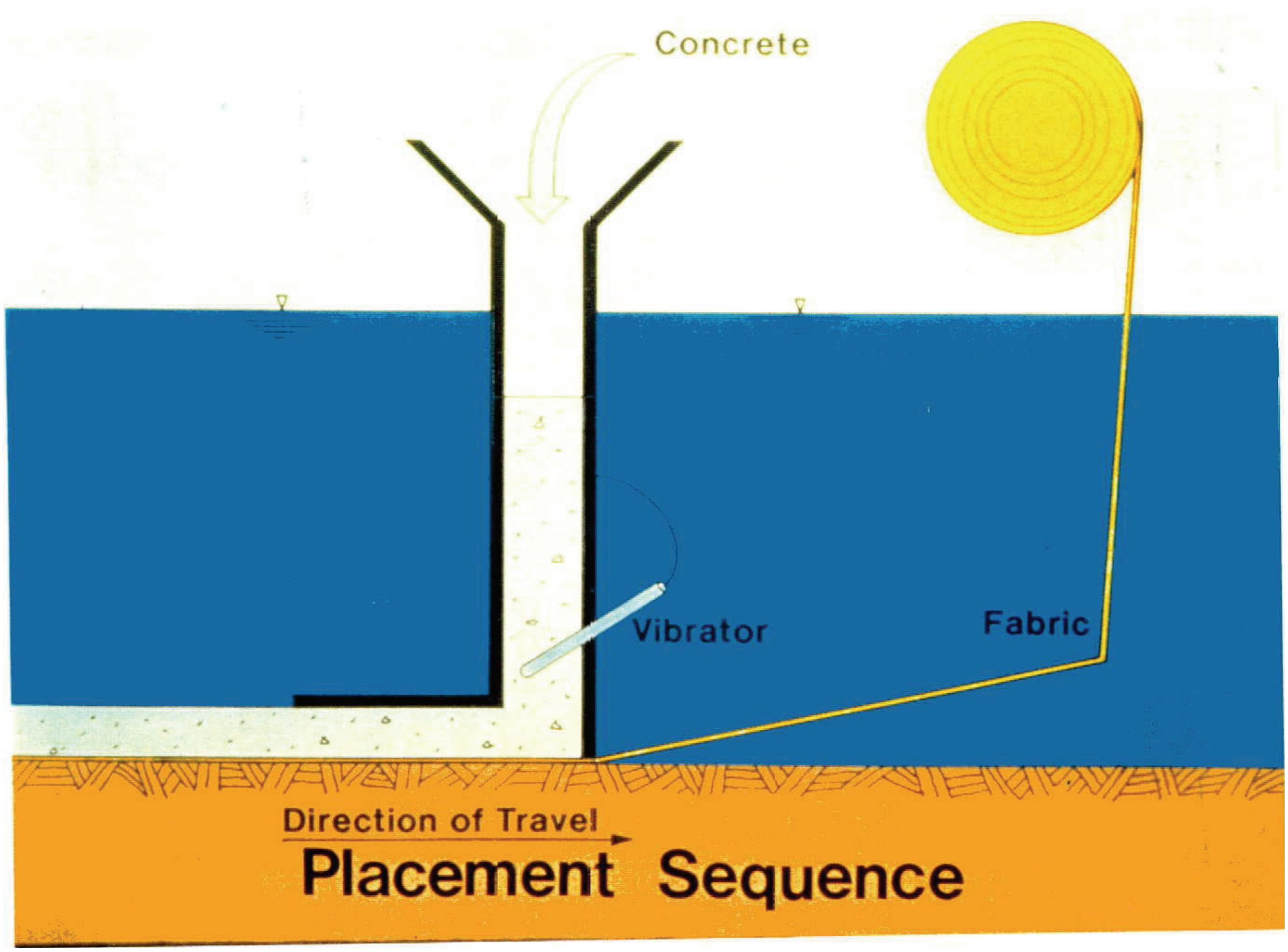

Figure 3. - Placement sequence.

During the first construction season, the paver received concrete from the batch plant, which had two 8-yd^3-capacity tilting drum mixers capable of delivering 700 yd^3/h. This project required a maximum of only 250 yd^3/h. The concrete was dumped from the stationary mixers into 10-yd^3 end-dump trucks and then transported to the canal. The trucks dumped the concrete into a Gomaco 8500 B placer, which transferred the concrete by conveyer belt into the paver hopper.

During the second construction season, ready-mix trucks supplied the concrete, batched nearby. The trucks fed the belt on the right side and a pump on the left side of the machine.

Small pockets of soft soil in the canal bottom failed structurally under the concrete head and moved out ahead of the paving machine. With the loose soil moving ahead of the paver, the geosynthetic lining could not be fed under the paver. This problem stopped the whole paving operation. The Gomaco Corporation investigated this problem by conducting model studies in Iowa and developed modifications for the paving machine. They modified the paver to correct the difficulties with soft soil. Soft soils caused no problems during the second construction season.

Figure 4. - A rear view of the paving machine as it places the geosynthetic lining and the concrete cover.

Finished Concrete

Because the geotextile will not function as a drainage medium, the 3-inch-thick concrete paving has longitudinal contraction joints, 2-1/2 inches deep, spaced every 3 feet. The joints allow water between the concrete cover and the geosynthetic lining to escape during drawdown and prevent failure of the concrete because of hydrostatic pressure behind the lining (see fig. 5).

Unplanned transverse cracks formed in the concrete at regularly spaced intervals between 10 and 20 feet. These cracks followed lines left by the paver's tail when the paver stopped.

Geosynthetic Lining

The PVC plastic lining was furnished in panels measuring 200 feet long by 58.6 feet wide for the first pass, and the same length by 54.6 feet wide for the second pass. Three plastic ropes were bonded to each panel at the fabricator's plant to facilitate handling during installation. The ropes, each 200 feet long, were located at each end and in the center of the panel. These ropes fed into a guide system (see fig. 6).

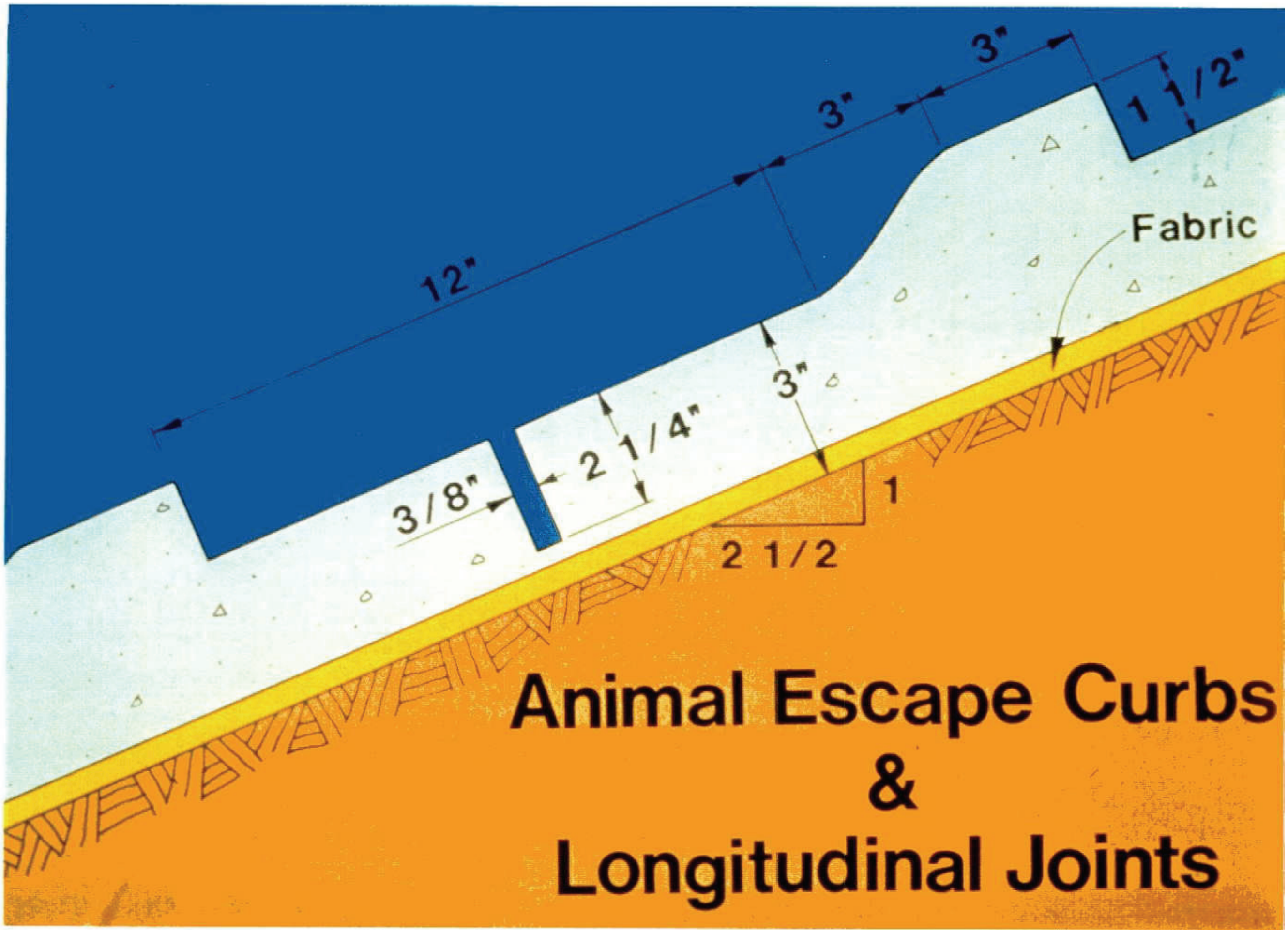

Figure 5. - Schematic of the animal escape curbs and longitudinal joints.

The PVC guide system worked well; however, the 1/4-inch-diameter guide rope occasionally bunched up in the guides. This guidance system had the most problems when the ambient air temperature dropped below 60 °F and the PVC stiffened. PVC, a thermoplastic material, loses flexibility with decreasing temperature. To address this problem, the contractor preheated the plastic lining with portable heaters just before it entered the guidance system.

For future projects, the use of a larger diameter guide rope may improve the PVC feed operation, and devising a method to heat the PVC lining material for night operations may improve the efficiency of the PVC feed system.

Animal Escape Curbs

Concrete canals are extremely dangerous to wildlife, especially deer (White, 1990). When animals enter the canal to drink, the steep, slippery sides can trap them in the canal. Many different types of escape routes have been devised, but none have been very effective. On this project animal escape curbs were cast continuously into the pavement. The curbs are spaced every 1.5 feet and are raised 1.5 inches to provide a means of escape from the canal along its entire length (see figs. 7 and 8).

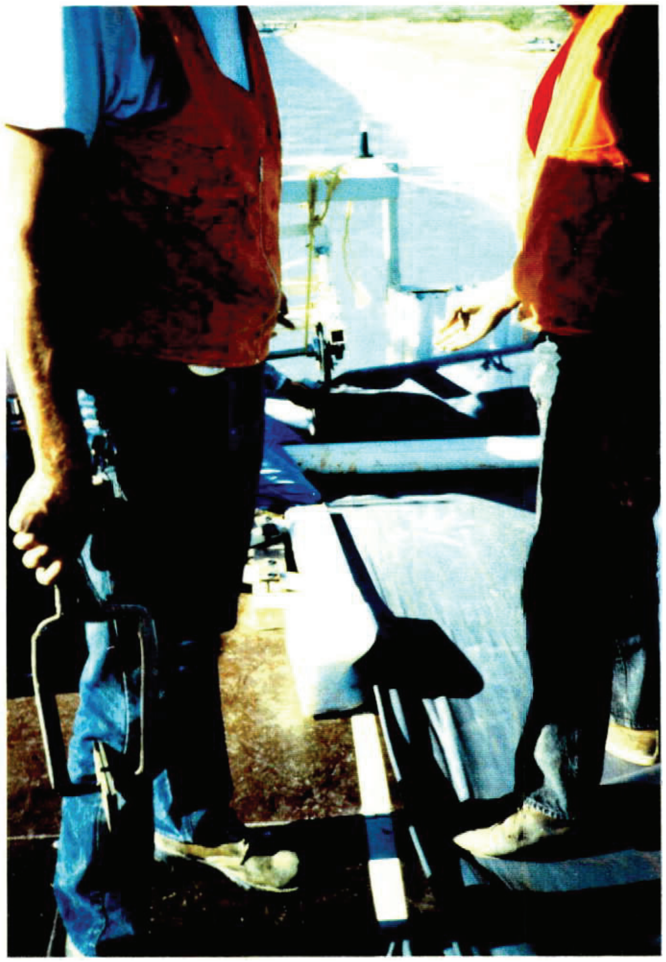

Figure 6. - PVC guide system.

Concrete

The concrete mixture design contained 472 pounds of cement and 118 pounds of Class F fly ash per cubic yard. The water to cement plus fly ash ratio was 0.45. The mixture used ASTM (American Society of Testing and Materials) C-33 #57 coarse aggregate; 45 percent of the total aggregate was sand. The concrete is over-sanded to improve placeability. The concrete contains a WRA (water-reducing admixture) and an AWA.

The AWA is a dry fine powder that is added 1 percent by weight of the cement plus fly ash. The AWA is a cellulose-based water-soluble polymer that increases the viscosity of the fresh concrete. The AWA prevents the cement from washing out in flowing water and increases the viscosity to make concrete placement easier.

The concrete slump averaged 2.0 inches. The fresh concrete's unit weight averaged 140 lb/ft^3. No air entraining admixture was used in the concrete; the AWA and the WRA entrained an average air content of 4.2 percent. The concrete had an initial set time set of 4.5 hours and a final set time of 7 hours. The concrete had an average compressive strength at 28 days of 5,200 lb/in^2.

Petrographic analysis determined that the concrete had barely acceptable freeze-thaw durability. However, freeze-thaw durability was not a problem in this test section. The average values for the air void parameters were:

(1) Air content - 4.47 percent.
(2) Bubble frequency - 7.54 voids per inch.
(3) Specific surface - 678 $inch^{-1}$.
(4) Spacing factor - 0.0075 inch.

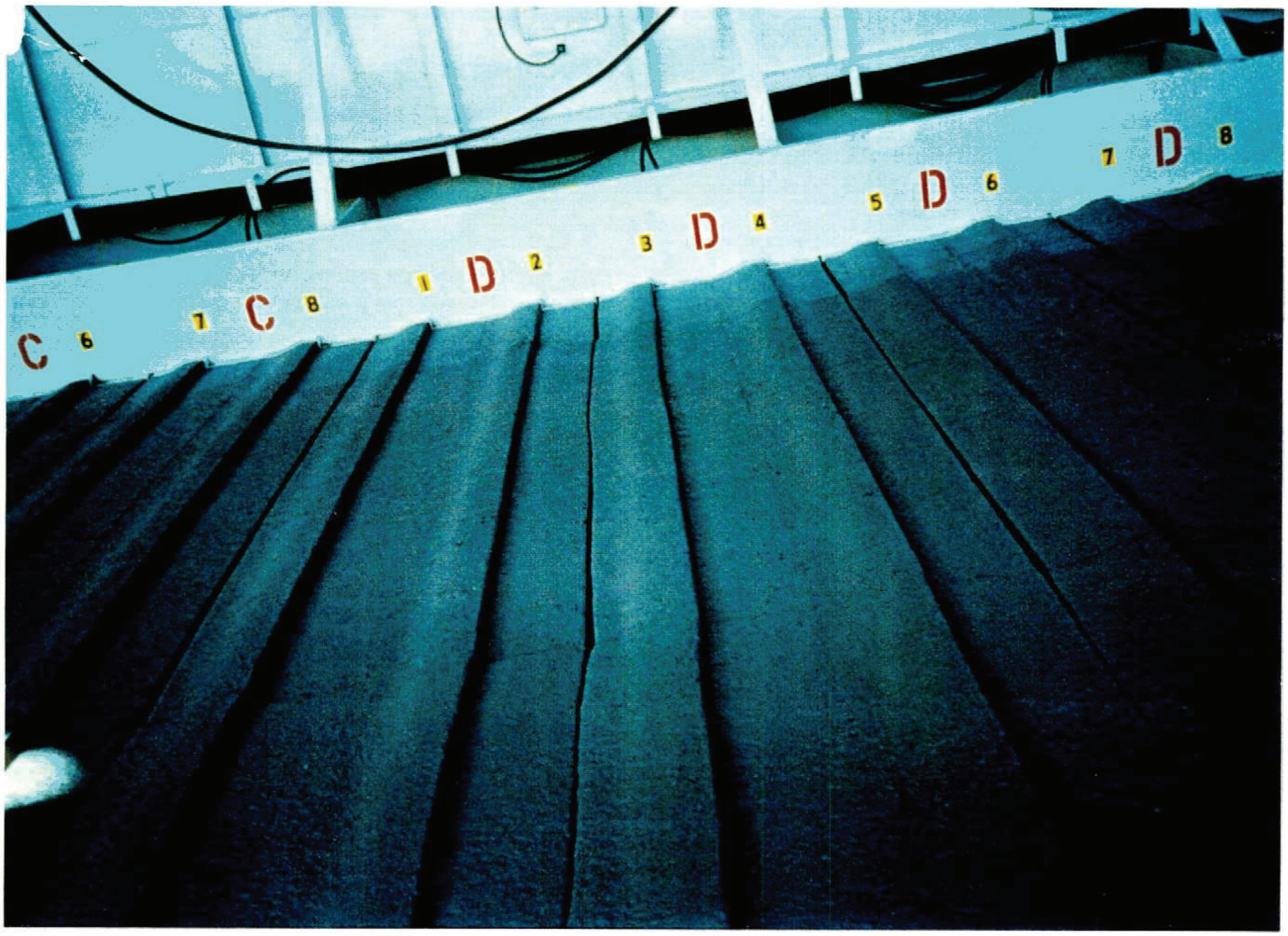

Figure 7. - Animal escape curbs and longitudinal joints.

FUTURE RESEARCH AREAS

The Bureau of Reclamation should investigate the optimum dosage of AWA needed to prevent washout. Cement and fly ash contents should also be adjusted to provide an economical concrete mixture that can be placed underwater.

Underwater repair methods need to be developed for cost-effective maintenance of canals which cannot be taken out of service.

Other types of guidance systems should be developed to facilitate easier handling of the PVC geomembrane over a broad range of ambient temperatures.

Other concrete placement techniques should be investigated which may be more suitable for new types of geomembranes which are being developed.

Figure 8. - A rear view of the paving machine.

As new geosynthetics are developed, they should be tested for suitability for use in this type of construction.

We need to examine additional geosynthetic materials that would prevent canals from failing because of rapid drawdown.

We need more information on the long-term performance of various types of geomembranes.

A number of papers on various subjects have been written under the auspices of Underwater Lining of Operating Canals. We developed a number of new construction materials and methods that made it possible to pave the Coachella Canal. Many of these new materials and methods have subsequently been used on other construction projects. This research program has developed many valuable products for Reclamation.

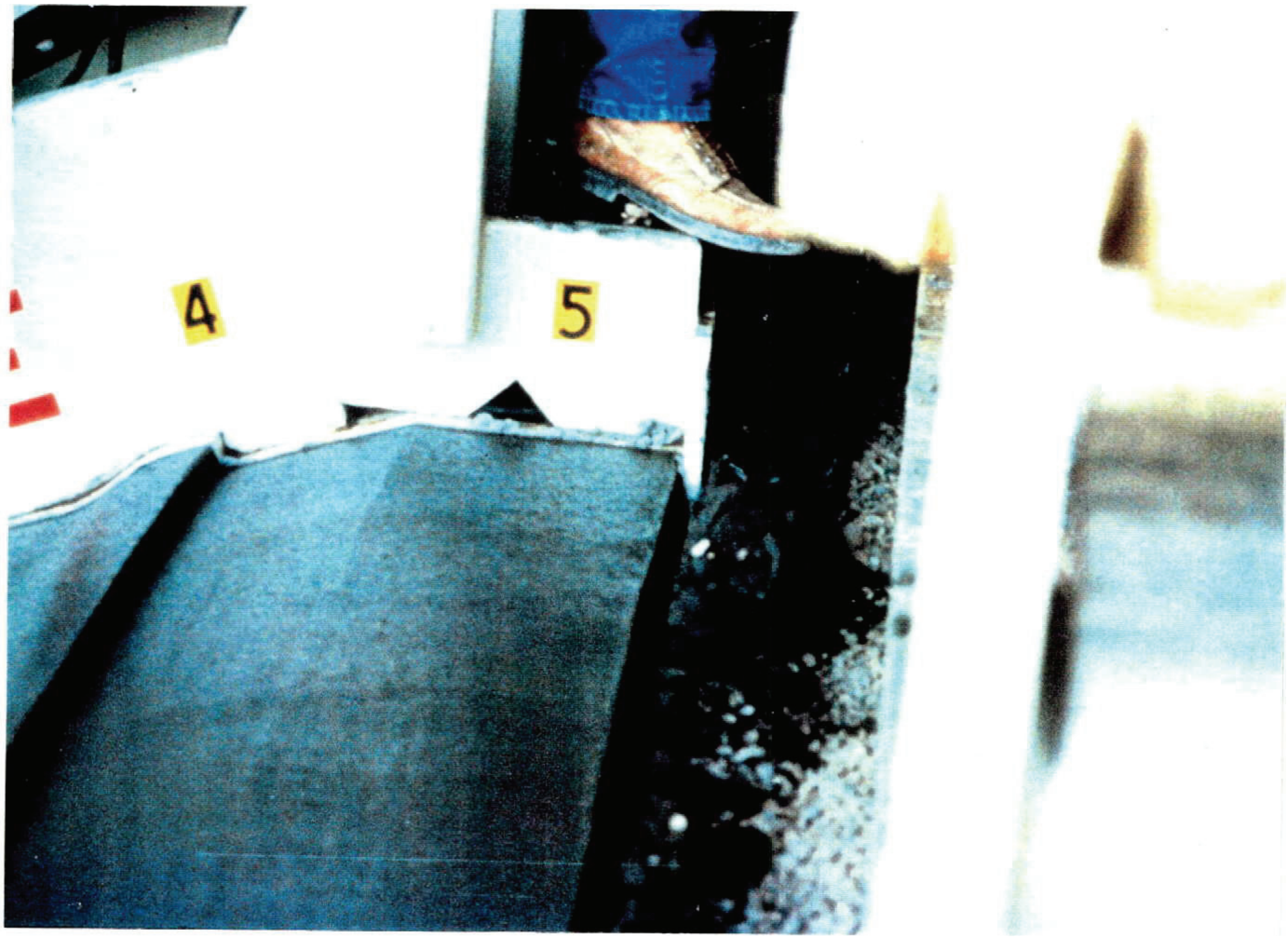

Figure 9. - View of the edge of the canal lining.

BIBLIOGRAPHY

Bureau of Reclamation. *Technical Report of Construction of In-Place Lining Prototype Project Coachella Canal, Imperial County California*. Yuma, Arizona. January 1993.

Comer, Alice I. 1993. "Concrete Placement over Geomembranes." Proceedings of the 7th GRI Seminar, Dec. 14-15, 1993, pp 46-56.

Fitzwater, Jerry. 1993. *Underwater Lining of Operating Canals*. Report No. PAP-559, Bureau of Reclamation. Denver, Colorado, 1993.

Kepler, William F. 1990. "Underwater Placement of a Concrete Canal Lining." *Concrete International*, (June): 54-59.

Morrison, William R. 1990. "Use of Geosynthetics for Underwater Lining of Operating Canals." *4th International Conference on Geotextiles, Geomembranes, and Related Products*. G. Den Hoedt (ed.). A.A. Balkema Publishers, Brookfield, Vermont.

Morrison, William R. and J. Jay Swihart. 1990. "Bureau of Reclamation Experiences with PVC Seams." *The Seaming of Geosynthetics*. R.M. Koerner (ed.). Elsevier Applied Science, New York.

White, Lawrence H. July 1990. "An Evaluation of the Large Mammal Entry/Escape Steps, Coachella Canal In-Place Lining Project." *Proceedings of the 1990 Irrigation and Drainage National Conference*. American Society of Civil Engineers.

Young, Richard. August 1994. *Direct Shear Tests Used in Soil-Geomembrane Interface Friction Studies*, U.S. Department of Interior report R-94-09.

Additional Information:

Bureau of Reclamation. May 1988. *Final Environmental Assessment, Coachella Canal In-Place Lining Prototype, California*. Boulder City, Nevada.

Bureau of Reclamation. November 1990. *Design Summary, Coachella Canal In-Place Lining Prototype, California*. Denver, Colorado.

Einert, Martin P. July 1990. *Development of an Underwater Canal Lining Method*. Proceedings of the 1990 Irrigation and Drainage National Conference. American Society of Civil Engineers.

Fitzwater, J. R. January 1990. *Coachella Canal Underwater Concrete Lining Study*. Report No. PAP-564, Bureau of Reclamation. Denver, Colorado.

APPENDIX

Short-Term Chronic Toxicity of Two Cement Curing Compounds to the Fathead Minnow (Pimephales promelas) Under Static Renewal Test Conditions

Kurt R. Drottar

ENSR Consulting and Engineering Forth Collins
Environmental Toxicology Laboratory

April 1990

Study Title
Short-Term Chronic Toxicity of Two Cement Curing Compounds to the Fathead Minnow (Pimephales promelas) Under Static Renewal Test Conditions.

Author
Kurt R. Drottar

Study Completed On
April 10, 1990

Performing Laboratory
ENSR Consulting and Engineering
Fort Collins Environmental Toxicology Laboratory
1716 Heath Parkway
Fort Collins, CO 80524

Laboratory Project ID
8505-090-053-001, 002

STATEMENT OF GLP COMPLIANCE

This study was conducted and complies with the USEPA (1989) general guidance on Good Laboratory Practices related to effluent toxicity testing.

Kurt R. Drottar
Project Manager/Study Director

4/12/90
Date

STATEMENT OF QUALITY ASSURANCE

The test data were reviewed by the Quality Assurance Unit to assure that the study was performed in accordance with the protocol and standard operating procedures. This report is an accurate reflection of the raw data.

Dan F. Keefe
Quality Assurance Unit

4/13/90
Date

SUMMARY

Sponsor: U.S. Bureau of Reclamation

Project Officer: Rick Roline

Study Director: Kurt R. Drottar

Senior Biomonitoring Technician: Scott J. Patti

Study Task Manager: Scott J. Patti

Test Facility: ENSR Consulting and Engineering, 1716 Heath Parkway, Fort Collins, CO

Location of Data: ENSR Consulting and Engineering, 1716 Heath Parkway, Fort Collins, CO

Test Substances: 1) Wax emulsion and 2) Burke aqua resin

Subject: Fathead minnow larval survival and growth test

Test Dates: April 3 (14:00) to April 10 (14:00), 1990

Length of Study: 7 days

Test Species: Pimephales promelas

Source of Organisms: Florida Bioassay Supply, Gainesville, FL

Age of Test Organisms: <24 hours

Test Concentrations: 0 (dilution water control), 6.25, 12.5, 25 50 and 100 mg/L

Dilution Water: Reconstituted water

Results: 1) Wax emulsion - NOEC = 50 mg/L, LOEC = 100 mg/L and ChV = 70.7 mg/L; and 2) Burke aqua resin - NOEC = 6.25 mg/L, LOEC = 12.5 mg/L and ChV = 8.8 mg/L

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1.0 INTRODUCTION

Two static renewal toxicity tests were conducted at ENSR Consulting and Engineering's Fort Collins Environmental Toxicology Laboratory (FCETL) to determine the short-term chronic toxicity of cement curing compounds to the fathead minnow (Pimephales promelas). The criterion for effect was a significant reduction in survival or growth as compared to experimental controls. Test results are expressed as a no observable effect concentration (NOEC), lowest observable effect concentration (LOEC), and chronic value (ChV), the geometric mean between the NOEC and the LOEC.

All study data are maintained in the FCETL archives, 1716 Heath Parkway, Fort Collins, Colorado.

2.0 MATERIALS AND METHODS

2.1 Test Substances

Two cement curing compounds were delivered to the FCETL by Mr. Rick Roline, U.S. Bureau of Reclamation, on March 20, 1990. The cement curing compounds were labeled as follows: 1) Wax Emulsion, Pigmented, Lot #010125, 1362P (designated FCETL sample #1309); and 2) Burke Aqua Resin, Clear, BUREC, Lot #109283, 1363P (designated FCETL sample #1310).

2.2 Dilution Water

Dilution water used in testing was the reconstituted water prepared to match the hardness and alkalinity of the receiving stream (320 and 140 mg/L as $CaCO_3$, respectively). Initial chemical characterization of the dilution water (FCETL RW #313) was as follows: hardness, 302 mg/L as $CaCO_3$; alkalinity, 137 mg/L as $CaCO_3$; and conductivity, 794 umhos/cm.

2.3 Test Organisms

Fathead minnows were obtained from a commercial supplier (Florida Bioassay Supply, Gainesville, Florida) and were <24 hours old at test initiation. Test organisms (FCETL lot #90-18) appeared to be in good physical condition at test initiation.

2.4 Test Methods

The test was conducted according to FCETL Protocol No. 41 (Appendix A) based on USEPA method 1000.0 (USEPA 1989). Testing was conducted in 1-L beakers containing a final volume of 250 ml of test solution. Ten fathead minnows were randomly distributed to each test container and four replicates were tested per treatment. After a preliminary range finding test, fathead minnows were exposed to 6.25, 12.5, 25, 50 and 100 mg/L for both compounds. Controls consisting of dilution water only were also conducted concurrently. Test solutions were renewed daily with freshly prepared dilutions of an initial stock solution. Fathead minnows were fed 0.1 ml of a concentrated suspension of newly hatched brine shrimp nauplii three times daily during the test. The test was conducted at 25 C under fluorescent lighting with a photoperiod of 16 hours light and 8 hours dark.

In addition to the effluent test, a reference toxicant (NaCl) test was also conducted with the same lot of fathead minnows to determine the sensitivity range of the test organisms.

2.5 Data Analysis

All statistical analysis was conducted with an IBM compatible personal computer utilizing Toxstat version 3.0 software (Gulley et al. 1989). The arcsine squareroot transformation was applied to all survival data. Normality and homogeneity of variance assumptions for survival and mean dry weight data were verified with the Shapiro-Wilk's test and Bartlett's test, respectively ($p \leq 0.01$). If the data met these assumptions, Dunnett's multiple comparison test was used to compare treatment group responses to control responses. If the data did not meet assumptions of normality and homogeneity, Steel's many-one rank test was used to make the comparisons. The NOEC, LOEC, and ChV were determined using the most sensitive (i.e. showing significance at the lowest effluent concentration, $p \leq 0.05$) of survival and/or mean dry weight.

3.0 RESULTS AND DISCUSSION

Fathead minnow mortality in the wax emulsion test was ≤15 percent in all treatment groups after 7 days of exposure (Table 3-1). Control mortality was 12.5 percent during the test. The Shapiro-Wilk's test showed that the survival data was not normally distributed among treatment groups. Accordingly, Steel's many-one rank test was used to make the survival comparison. Steel's many-one rank test showed that survival was not significantly reduced in any wax emulsion treatment group in comparison to the control. Dunnett's multiple comparison test showed that mean dry weight was significantly reduced in the 100 mg/L wax emulsion treatment group in comparison to the control. Consequently the LOEC, based on mean dry weight, was 100 mg/L. The NOEC was 50 mg/L and the ChV was calculated to be 70.7 mg/L.

Fathead minnow mortality in the Burke aqua resin test ranged from 17.5 percent the 6.25 mg/L treatment group to 100 percent in the ≥25 percent effluent treatment groups after 7 days of exposure (Table 3-2). Control mortality was 2.5 percent during the test. The Shapiro-Wilk's test showed that the survival data was not normally distributed among treatment groups. Steel's many-one rank test showed that survival was significantly reduced in the ≥12.5 mg/L Burke aqua resin treatment groups in comparison to the control. Dunnett's multiple comparison test showed that mean dry weight was not significantly reduced in the 6.25 or 12.5 mg/L treatment groups in comparison to the control. Consequently the LOEC, based on survival, was 12.5 mg/L. The NOEC was 6.25 mg/L and the ChV was calculated to be 8.8 mg/L.

Throughout both tests, all water quality parameters remained within acceptable levels. On day five of the wax emulsion test, dissolved oxygen concentrations dropped to 3.4 mg/L (40 percent of saturation at sea level, 49 percent of saturation at 4,800 feet elevation above sea level). Consequently, the Study Director authorized mild aeration to all test chambers of the wax emulsion test. After aeration, dissolved oxygen concentrations remained ≥5.8 mg/L (83 percent of saturation at 4,800 feet elevation above sea level). In the Burke aqua resin test, dissolved oxygen concentrations remained ≥3.7 mg/L (53 percent saturation at 4,800 feet elevation above sea level) throughout the test and aeration was not required. Test temperature in both studies was maintained at 25 ±1 C and pH ranged from 8.1 - 8.6.

The 24-hour LC50 for the reference toxicant test was 6,647 mg/L Cl^- as calculated by the binomial method. The FCETL's acceptable range for <24 hour old fathead minnows is 3,756 to 7,659 mg/L Cl^-. The test organisms were, therefore, within the FCETL's historic sensitivity range.

Table 3.1. Survival and growth of fathead minnows exposed to wax emulsion cement curing compound.

Endpoint	Treatment (mg/L)					
	Control	6.25	12.5	25	50	100
% survival	87.5	95	97.5	85	97.5	95
mean dry wt. (mg)	0.50	0.48	0.48	0.54	0.45	0.38[1]

[1]Indicates a significant difference from the control using Dunnett's multiple comparison test ($p \leq 0.05$).

Table 3.2. Survival and growth of fathead minnows exposed to Burke aqua resin cement curing compound.

Endpoint	Treatment (mg/L)					
	Control	6.25	12.5	25	50	100
% survival	97.5	82.5	35[1]	0[1]	0[1]	0[1]
mean dry wt. (mg)	0.48	0.44	0.28	-	-	-

[1]Indicates a significant difference from the control using Steel's many-one rank test ($p \leq 0.05$).

LITERATURE CITED

Gulley, D.D., Boelter, A.M., and H.L. Bergman. 1989. Toxstat Version 3.0. Fish Physiology and Toxicology Laboratory. Department of Zoology and Physiology. University of Wyoming. Laramie, Wyoming.

USEPA. 1989. Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Second Edition. EPA/600/4-89/001.

APPENDIX A

TEST PROTOCOL

Title: Short-Term Chronic Toxicity of Cement Curing Compounds to the Fathead Minnow (*Pimephales promelas*) Under Static Renewal Test Conditions.

Study Sponsor: U.S. Bureau of Reclamation
P.O. Box 25007, D-3742
Denver, Colorado 80225
(303) 236-6005

Project Officer: Rick Roline

Testing Facility: ENSR Consulting and Engineering
Fort Collins Environmental Toxicology Laboratory
1716 Heath Parkway
Fort Collins, Colorado 80524
(303) 493-8878, Ext. 372

Project Manager/Study Director: Kurt R. Drottar

1.0 INTRODUCTION

1.1 Objective

To determine the chronic value (ChV) of the test materials to the fathead minnow (Pimephales promelas) under static renewal test conditions.

1.2 Test Materials

The two test materials will be provided by the sponsor. They will be tested as formulations.

2.0 MATERIALS AND METHODS

2.1 Basis

This protocol is designed to comply with USEPA method 1000.0, Fathead Minnow (Pimephales promelas) Larval Survival and Growth Test (USEPA 1989).

2.2 Test Organism

1. Species - Fathead minnow (Pimephales promelas)
2. Age - Fathead minnows will be <24 hours old.
3. Source - Fathead minnows will be obtained from ENSR's in-house cultures or from a commercial supplier.
4. Feeding - Each fathead minnow test chamber will be fed 0.1 ml of a concentrated suspension of newly hatched brine shrimp nauplii three times daily.

3.0 TEST SYSTEM

3.1 Dilution Water

Dilution water used in toxicity testing will be laboratory reconstituted water, with a hardness and alkalinity similar (±15 percent) to the receiving stream (320 and 140 mg/L as $CaCO_3$, respectively).

3.2 Temperature

Test temperature will be 25 ± 1°C. Testing will be conducted in an environmental chamber or a temperature controlled water bath.

3.3 Test Containers

Test containers will be 1-L beakers containing 250 ml of test solution.

3.4 Photoperiod

The photoperiod will be 16 hours light and 8 hours dark.

3.5 Dissolved Oxygen Concentrations

Dissolved oxygen concentrations will be maintained $\geq$40 percent of saturation. If the dissolved oxygen concentration in any test chamber approaches 40 percent saturation, all test chambers will be aerated moderately.

4.0 TEST DESIGN

4.1 Test Concentrations

Test concentrations will be determined in acute range finding studies. The definitive test will consist of five test concentrations using a dilution factor of 0.5. A dilution water control will also be conducted concurrently.

4.2 Number of Test Organisms

Forty fathead minnows will be exposed to each test concentration and control. Ten fathead minnows will be randomly assigned to each test chamber and four replicates will be tested per treatment.

4.3 Test Initiation/Renewal Frequency

Testing will be initiated within 30 minutes of mixing test solutions. Test samples will be renewed on a daily basis with freshly prepared dilutions of the initial stock solution.

4.4 Chemical and Physical Monitoring

At a minimum, the following measurements will be made:

1. Dissolved oxygen, temperature and pH will be measured in each treatment and control at the beginning and end of each 24 hour exposure period.
2. Conductivity will be measured in each treatment and control at the beginning of each 24 hour exposure period.
3. Hardness and alkalinity will be measured in the high, mid and low test concentrations and the control on the day of test initiation.

4.5 Biological Monitoring

Observations of mortality in each test chamber will be made daily.

4.6 Test Duration

The test duration is seven days. At test termination the larvae in each test chamber will be counted and preserved in 4 percent formalin as a group for later dry weight analysis (if they cannot be weighed immediately). The preserved larvae will be rinsed with distilled water prior to dry weight analysis. The group of rinsed larvae from each test chamber will be transferred to a tared weighing boat and dried at 100°C for a minimum of 2 hours. Immediately after removal from the drying oven, the weigh boats will be placed in a desiccator to prevent absorption of moisture from the air, until weighed. The weights will be measured to the nearest 0.1 mg.

4.7 Calculations

Survival data will be transformed by arcsine squareroot. Growth in each replicate will be determined by the mean dry weight per surviving fish. Normality and homogeneity assumptions of survival and growth data will be evaluated by the Shapiro-Wilk's test and Bartlett's test, respectively ($p \leq 0.01$). If the data meet the assumptions, Dunnett's procedure will be used to make the comparison. If the data do not meet the assumptions, Steel's many-one rank test will be used to make the comparison. The no observable effect concentration (NOEC), lowest observable effect concentration (LOEC), and ChV (the geometric mean of the NOEC and LOEC) will be calculated on the basis of survival and/or growth.

4.8 Quality Criterion

The test will not be considered valid if control mortality exceeds 20 percent or if mean dry weight per surviving control fish is <0.25 mg.

5.0 TEST REPORT

The report will be a typed document describing the results of the test and will be signed by the Study Director and Quality Assurance Unit. The report will include, but not be limited to the following:

- A copy of all raw data.
- Name of test, Study Director, and laboratory.
- Test organism scientific name, age, and diet.
- A description of the experimental design and the test chambers, the number of test organisms, replicates per treatment, and the lighting.
- A detailed description of the test material including its source, composition, known physical and chemical properties, and any information that appears on the sample container or has been provided by the sponsor.

- The source and characterization of the dilution water, and a description of any pretreatment.
- A description of any aeration performed on test solutions before or during the test.
- Percentage of test organisms that died in all treatments.
- The calculated NOEC, LOEC, and ChV values and a reference to calculation methods.
- The minimum dissolved oxygen concentration, range in test temperature and pH, and all visual observations of test solutions.
- Any deviations from protocol.

6.0 LITERATURE CITED

USEPA. 1989. Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Second Edition. EPA/600/4-89/001.

7.0 GOOD LABORATORY PRACTICES

All test procedures, documentation, records, and reports will comply with USEPA (1989) general guidance on Good Laboratory Practices related to effluent toxicity testing. To this end, random audits of the test may be scheduled while the test is in progress. The raw data will be checked and compared to protocol requirements and Standard Operating Procedures, and the final report will be audited for accuracy and signed, if satisfactory, by the individual responsible from the Quality Assurance Unit.

8.0 PROTOCOL AMENDMENTS AND DEVIATIONS

All changes (i.e., amendments, deviations, and final report revisions) of the approved protocol plus the reasons for the changes must be documented in writing. The changes will be signed and dated by the Study Director and maintained with the protocol. All amendments must be authorized in advance by the Sponsor.

9.0 SPONSOR AND STUDY DIRECTOR APPROVAL

Sponsor Approval: Richard Roline Date: 3-21-90

Study Director: [signature] Date: 3/22/90

APPENDIX B

TEST DATA

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SUBJECT: PHYSICAL & CHEMICAL DATA FOR FATHEAD MINNOW SUBCHRONIC TEST

KRD 4/12/90

SUBSTANCE: Wax Emulsion
BEGINNING: DATE 4/3/90 TIME 1400
CLIENT: B.O.R.
ENDING: DATE 4-10-90 TIME 1400
PROJECT NO. 8505-090
053-001

ENSR # 1309
LOT # 90-18/<24 hrs
RW # 313
CI - LC50 = 6647
RANGE = 3756-7659 (BIN.)

NO. OF SURVIVING ORGANISMS

CONC. mg/l	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7
Control	A	10	10	10	10	10	10	10	10
|	B	|	~~10~~ 9	9	8	8	8	8	8
|	C	|	10	9/8*	10	10	8	8	8
	D	|	10	10	9	9	9	9	9
6.25	A	|	10	10	10	10	10	10	10
|	B	|	10	10	10	10	10	10	9
|	C	|	10	10	10	10	10	10	10
	D	|	10	10	10	10	9	9	9
12.5	A	|	10	10	10	10	10	10	10
|	B	|	10	10	10	9	9	9	9
|	C	|	10	10	10	10	10	10	10
	D	|	10	10	10	10	10	10	10
25	A	|	10	8	8	8	8	8	8
|	B	|	9	10	10	10	10	9	8
|	C	|	8/9	10	10	10	10	10	10
|	D	|	8/9	8	8	8	8	8	8
METER NO.		–	–	–	–	–	–	–	–
DATE		4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
TIME		1400	1500	0930	1345	1500	1410	1545	1400
INITIALS		[illegible]	MED	DH	MED	SB	RDS	SB	SWC

DISSOLVED OXYGEN (mg/l)

CONC. mg/l	TEST CONTAINER NUMBER	0 NEW	1 OLD	1 NEW	2 OLD	2 NEW	3 OLD	3 NEW	4 OLD	4 NEW	5 OLD	5 NEW	6 OLD	6 NEW	7 OLD
Control	A	6.8	6.0	6.7	5.0	7.0	4.8	6.3	—	6.5	—	6.3	5.1	6.8	6.0
|	B	C	–	C	–	C	–	C	4.5	C	4.3	C	–	C	–
|	C	|	6.0	|	5.0	|	4.8	|	—	|	—	|	5.1	|	6.0
	D	|	–	|	–	|	–	|	4.5	|	4.3	|	–	|	–
6.25	A	6.9	5.4	6.7	5.5	7.3	5.1	6.3	—	6.4	—	6.2	6.1	6.8	6.1
|	B	C	–	C	–	C	–	C	4.1	C	4.0	C	–	C	–
|	C	|	5.4	|	5.5	|	5.1	|	—	|	—	|	6.1	|	6.2
	D	|	–	|	–	|	–	|	4.1	|	4.0	|	–	|	–
12.5	A	6.8	5.1	6.8	4.9	7.7	4.5	6.3	—	6.4	—	6.2	5.9	6.8	6.0
|	B	C	–	C	–	C	–	C	4.8	C	4.6	C	–	C	–
|	C	|	5.1	|	4.9	|	4.5	|	—	|	—	|	5.9	|	6.0
	D	|	–	|	–	|	–	|	4.8	|	4.6	|	–	|	–
25	A	6.8	5.9	6.8	4.5	7.[illegible]	4.8	6.3	—	6.4	—	6.1	5.7	6.8	5.8
|	B	C	–	C	–	C	–	C	4.5	C	4.3	C	–	C	–
|	C	|	5.9	|	4.5	|	4.8	|	—	|	—	|	5.7	|	5.8
|	D	|	–	|	–	|	–	|	4.5	|	4.3	|	–	|	–
METER NO.		5	5	5	5	5	5	5	5	5	5	5	5	5	5
DATE		4/3	4/4	4/4	4/5	4/5	4/6	4/6	4/7	4/7	4/8	4/8	4/9	4/9	4/10
TIME		1400	1100	1115	0915	1015	1000	1345	0950	1455	1100	1430	1200	1600	0930
INITIALS		[illegible]	MED	MED	MED	DH	MED	MED	SB	RDS	SB	RDS	MD	SB	SWC

TEMPERATURE (C)

CONC. mg/l	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7
		NEW SOLUTIONS ONLY							OLD
Control	A	25	25	25	25	25	25	25	25
|	B	|	C	C	C	C	C	C	–
|	C	|	|	|	|	|	|	|	–
	D	|	|	|	|	|	|	|	–
6.25	A	|	25	25	25	25	25	25	25
|	B	|	C	C	C	C	C	C	–
|	C	|	|	|	|	|	|	|	–
	D	|	|	|	|	|	|	|	–
12.5	A	|	25	25	25	25	25	25	25
|	B	|	C	C	C	C	C	C	–
|	C	|	|	|	|	|	|	|	–
	D	|	|	|	|	|	|	|	–
25	A	|	25	25	25	25	25	25	25
|	B	|	C	C	C	C	C	C	–
|	C	|	|	|	|	|	|	|	–
|	D	|	|	|	|	|	|	|	–
METER NO.		8	6	6	6	6	6	6	6
DATE		4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
TIME		1400	1500	1015	1345	1455	1430	1600	0930
INITIALS		[illegible]	MED	DH	MED	RDS	RDS	SB	SWC

*Not found, found in ~~Cont~~ 6B DH 4/5

DH 4/13/90

ERT

ERT QA Form No. 18
Effective: 3/87

SUBJECT: PHYSICAL & CHEMICAL DATA FOR FATHEAD MINNOW SUBCHRONIC TEST [illegible] 4/13/90

SUBSTANCE: Wax Emulsion BEGINNING: DATE 4/3/90 TIME 1400

CLIENT: B.O.R. ENDING: DATE 4-10-90 TIME 1400

PROJECT NO. 8505-040
053-001

NO. OF SURVIVING ORGANISMS (AED 4-4-90)

CONC.	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7
50	A	10	10	10	10	10	10	10	10
|	B	|	10	10	10	10	10	10	10
|	C	|	9	9	9	9	9	9	9
|	D	|	9	10	10	10	10	10	10
100	A	|	9	10	10	10	10	9	9
|	B	|	10	10	10	10	9	9	9
|	C	|	10	10	10	10	10	10	10
|	D	|	10	10	10	10	10	10	10
METER NO.		–	–	–	–	–	–	–	–
DATE		4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
TIME		1400	1500	1009	1045	1500	1410	1545	1400
INITIALS		[illegible]	AED	DH	AED	SB	RDS	SB	SWK

DISSOLVED OXYGEN (mg/l)

CONC.	TEST CONTAINER NUMBER	0 NEW	1 OLD	1 NEW	2 OLD	2 NEW	3 OLD	3 NEW	4 OLD	4 NEW	5 OLD	5 NEW	6 OLD	6 NEW	7 OLD
50	A	6.8	5.9	6.8	5.1	7.7	4.3	6.3	—	6.4	—	6.2	5.8	6.8	6.1
|	B	C	–	C	–	C	–	C	3.8	C	4.4	C	–	C	–
|	C	|	5.9	|	5.1	|	4.3	|	—	|	—	|	5.8	|	6.2
|	D	|	–	|	–	|	–	|	3.8	|	4.4	|	–	|	–
100	A	6.9	5.9	6.8	5.3	7.7	5.0	6.3	—	6.5	—	6.2	6.3	6.8	6.1
|	B	C	–	C	–	C	–	C	4.3	C	3.4	C	–	C	–
|	C	|	5.9	|	5.3	|	5.0	|	—	|	—	|	6.3	|	6.1
|	D	|	–	|	–	|	–	|	4.3	|	3.4	|	–	|	–
METER NO.		5	5	5	5	5	5	5	5	5	5	5	5	5	5
DATE		4/3	4/4	4/4	4/5	4/5	4/6	4/6	4/7	4/7	4/8	4/8	4/9	4/9	4/10
TIME		1400	1100	1515	0915	1015	1600	1345	0959	1455	1100	1430	1200	1600	0930
INITIALS		[illegible]	AED	AED	AED	DH	AED	AED	SB	RDS	SB	RDS	AED	SB	SWK

TEMPERATURE (C) (0–6: NEW SOLUTIONS ONLY; 7: OLD)

CONC.	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7 OLD
50	A	25	25	25	25	25	25	25	25
|	B	|	C	C	C	C	C	C	–
|	C	|	|	|	|	|	|	|	–
|	D	|	|	|	|	|	|	|	–
100	A	|	25	25	25	25	25	25	25
|	B	|	C	C	C	C	C	C	–
|	C	|	|	|	|	|	|	|	–
|	D	|	|	|	|	|	|	|	–
METER NO.		8	6	6	6	6	6	6	6
DATE		4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
TIME		1400	1500	1015	1345	1455	1430	1600	0930
INITIALS		[illegible]	AED	DH	AED	RDS	RDS	SB	SWK

[illegible] 4/13/90

ERT

SUBJECT: CHEMICAL DTA FOR FATHEAD MINNOW SUBCHRONIC TEST

KWD 4/12/90

SUBSTANCE: Wax Emulsion BEGINNING: DATE 4/3/90 TIME 1400

CLIENT: B.O.R. ENDING: DATE 4-10-90 TIME 1400

PROJECT NO. 8505-090
053-001

pH (columns 0–6 NEW SOLUTIONS ONLY; 7 OLD)

CONC.	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7 (OLD)
Control		8.4	8.4	8.6	8.5	8.5	8.5	8.4	8.4
				C	c		C		–
				|					–
6.25		8.4	8.4	8.6	8.5	8.5	8.6	8.5	8.4
				C					–
				|					–
12.5		8.4	3.4	8.6	8.5	8.5	8.6	8.5	8.4
				C					–
				|					–
25		8.4	8.4	8.6	8.5	8.5	8.5	8.5	8.4
				C					–
				|					–
50		8.5	8.4	8.6	8.6	8.5	8.6	8.5	8.4
				C					–
				|					–
100		8.5	8.4	8.6	8.5	8.4	8.6	8.5	8.4
				C					–
				|					–
METER NO.		26	26	26	26	26	26	26	26
DATE		4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
TIME		1400	1515	1015	1345	1455	1420	1600	1930
INITIALS		[illegible]	ASD	DH	ASD	RDS	RDS	SB	[illegible]

CONDUCTIVITY (umhos/cm) (columns 0–6 NEW SOLUTIONS ONLY; 7 OLD)

CONC.	0	1	2	3	4	5	6	7 (OLD)
Control	774	824	863	814	911	888	859	
			C				C	
			|				|	
6.25	815	844	849	851	844	839	844	
			C				+	
			|				
12.5	832	835	851	845	844	839	840	
			C				+	
			|				
25	834	825	842	845	859	832	836	
			C				+	
			|				
50	830	825	836	840	836	842	832	
			C				+	
			|				
100	828	819	844	840	837	837	837	
			C				+	
			|				
METER NO.	9	9	9	9	9	9	9	
DATE	4/3	4/4	4/5	4/6	4/7	4/8	4/9	
TIME	1400	1500	1015	1345	1445	1430	1550	
INITIALS	[illegible]	ASD	DH	ASD	RDS	RDS	SWC	

ALKALINITY (mg/l) and **HARDNESS (mg/l)** (NEW SOLUTIONS ONLY)

CONC.	Alk. 0	Alk. 1	Alk. 2	Alk. 3	Alk. 4	Alk. 5	Alk. 6	Alk. 7	Hard. 0	Hard. 1	Hard. 2	Hard. 3	Hard. 4	Hard. 5	Hard. 6	Hard. 7
Control	137								302							
	C								C							
	|								|							
METER NO.	T								T							
DATE	4/3								4/3							
TIME	1540								1540							
INITIALS	SB								SB							

dk 4/13/90

KAM 4/12/90

SUBJECT: DAILY LOG 8505-090-053-001

ALL ENTRIES MUST BE INITIALLED WITH DATE AND TIME:

~~4/3/90 - WAX EMULSION does not go completely into solution~~ 1400 [illegible]

Date		C	6	12	25	50	100		
4-4-90	Old pH	8.5	8.3	8.4	8.4	8.4	8.4	#26	@1050 NED
	Old Temp	25	25	25	25	25	25	#6	
4-5-90	Old pH	8.3	8.4	8.3	8.2	8.3	8.3	#26	@0900 NED
	Old Temp	25	25	25	25	25	25	#6	
4-6-90	Old pH	8.3	8.3	8.2	8.2	8.2	8.3	#26	@1000 NED
	Old Temp	25	25	25	25	25	25	#6	
4-7-90	Old pH	8.2	8.1	8.2	8.1	8.1	8.1	#26	@0935 RDS
	Old Temp	25	25	25	25	25	25	#6	
4-8-90	Old pHs:	8.2	8.1	8.2	8.2	8.2	8.3	#26	1045
	Old Temps:	25	25	25	25	25	25	#8	SB

4-8-90 Initiated aeration in all test chambers @ 1100 due to low D.O.'s (34) (SB)

Date		C	6	12	25	50	100		
4-9-90	Old pH	8.4	8.4	8.3	8.4	8.4	8.3	#26	@114- NED
	Old Temp:	25	25	25	25	25	25	#6	

dh 4/13/90

ERT

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Effective: 2/87

PREPARATION OF STOCK SOLUTIONS

KAS 4/12/90

Substance: WAX EMULSION | Project No.: 8505-090-053-001

Sponsor: B.O.R. | Substance on Page 1309 of Test Substance log

Lot #: 010125 | Purity: N/A

Test Type: Short-Term Chronic | Species: Pimephales promelas

Amt. Weighed 10,000 mg | Diluted To: 1 L

Solvent: HOH | Solvent Lot #: N/A

Solvent on Page N/A of Reagent log | Solvent Manufacturer: N/A

Final Stock Concentration: 10g/L

SERIAL DILUTIONS

Initial Concentration	Diluted To	Final Conc.	(1,2,3)
10,000 mg/l	———	10,000 mg/l	1°

Data By: [signature] 4/3/90 [initials] 4/13/90

ERT

SUBJECT: TEST ORGANISM LENGTHS, WEIGHTS, AND LOADINGS

[initials] 4/12/90

SPONSOR: [illegible] PROJECT NO: [illegible]-053-001
TEST SUBSTANCE: WAX EMULSION SPECIES: FHM
DATA BY: DN DATE [illegible] TIME 0900 LOT/BATCH NO: 90-18

WEIGHT: TYPE DRY

NO.	LENGTH TYPE N/A	TARE	GROSS	NET	$\bar{X}$/fish
1	Control-A	1.3305	1.3354	0.0049	0.49
2	B	1.3595	1.3633	0.0038	0.48
3	C	1.3448	1.3490	0.0042	0.52
4	D	1.3569	1.3615	0.0046	0.51
5	6.25 mg/L A	1.3518	1.3562	0.0044	0.44
6	B	1.3372	1.3420	0.0048	0.53
7	C	1.3454	1.3504	0.0050	0.50
8	D	1.3269	1.3309	0.0040	0.44
9	12.5 mg/L-A	1.3325	1.3372	0.0047	0.47
10	B	1.3366	1.3406	0.0040	0.44
11	C	1.3410	1.3461	0.0051	0.51
12	D	1.3489	1.3538	0.0049	0.4[illegible]
13	25 mg/L A	1.3326	1.3366	0.0040	
14	B	1.3574	1.3610	0.0036	0.[illegible]
15	C	1.3667	1.3718	0.0051	0.5[illegible]
16	D	1.3682	1.3737	0.0055	0.69
17	50 mg/L-A	1.3659	1.3704	0.0045	0.45
18	B	1.3630	1.3679	~~0.0039~~ 0.0049 DH 4/11	0.45
19	C	1.3239	1.3281	0.0042	0.47
20	D	1.3237	1.3275	0.0038	0.38
RANGE					
MEAN					
S					

DH 4/13/90

TEST SOLUTION VOLUME ______ LOADING RATE ______

SUBJECT: TEST ORGANISM LENGTHS, WEIGHTS, AND LOADING [initials] 4/12/90

SPONSOR: [illegible] TEST SUBSTANCE: WAX EMULSION DATA BY: DH DATE 4-10-90 TIME 0900
PROJECT NO: 8505-090-053-001 SPECIES: FHM LOT/BATCH NO: 90-18

WEIGHT: TYPE DRY

NO.	LENGTH TYPE	TARE	GROSS	NET	$\overline{X}$/fish
21	100mg/L A	1.3219	1.3254	0.0035	0.39
22	B	1.3327	1.3356	0.0029	0.32
23	C	1.3485	1.3522	0.0037	0.37
24	D	1.3722	1.3767	0.0045	0.45
25	Blank	1.3602	1.3599	-0.003	—
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
RANGE					
MEAN					
S					

dh 4/13/90

TEST SOLUTION VOLUME ________ LOADING RATE ________

505-090-053-001 Fathead Minnow Survival
ile: A:053.1S   Transform: ARC SINE(SQUARE ROOT(Y))

ihapiro Wilks test for normality

) =   0.226

ih 4/13/90

I =   0.884

critical W (P = 0.05) (n = 24) = 0.916
critical W (P = 0.01) (n = 24) = 0.884

Data FAIL normality test. Try another transformation.

Warning - The two homogeneity tests are sensitive to non-normal data and should not be performed.

:505-090-053-001 Fathead Minnow Survival
'ile: A:053.1S   Transform: ARC SINE(SQUARE ROOT(Y))

Bartletts test for homogeneity of variance

Calculated B statistic =   2.22
Table Chi-square value =   15.09 (alpha = 0.01)
Table Chi-square value =   11.07 (alpha = 0.05)

Average df used in calculation ==>   df (avg n - 1) =   3.00
Used for Chi-square table value ==>   df (#groups-1) =   5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

page 9 of 12
KGS 4/12/90

505-090-053-001 Fathead Minnow Survival
ile: A:053.1S Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

RP	IDENTIFICATION	N	MIN	MAX	MEAN
1	Control	4	1.107	1.412	1.219
2	6.25	4	1.249	1.412	1.331
3	12.5	4	1.249	1.412	1.371
4	25	4	1.107	1.412	1.183
5	50	4	1.249	1.412	1.371
6	100	4	1.249	1.412	1.331

ckh 4/13/90

505-090-053-001 Fathead Minnow Survival
ile: A:053.1S Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

RP	IDENTIFICATION	VARIANCE	SD	SEM
1	Control	0.021	0.145	0.073
2	6.25	0.009	0.094	0.047
3	12.5	0.007	0.081	0.041
4	25	0.023	0.152	0.076
5	50	0.007	0.081	0.041
6	100	0.009	0.094	0.047

505-090-053-001 Fathead Minnow Survival
ile: A:053.1S Transform: ARC SINE(SQUARE ROOT(Y))

STEELS MANY-ONE RANK TEST - Ho:Control<Treatment

ROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	Control	1.219				
2	6.25	1.331	22.00	10.00	4.00	
3	12.5	1.371	23.00	10.00	4.00	
4	25	1.183	16.50	10.00	4.00	
5	50	1.371	23.00	10.00	4.00	
6	100	1.331	22.00	10.00	4.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

05-090-053-001 Fathead Minnow Mean Dry Weight
le: A:053.1W   Transform: NO TRANSFORMATION

apiro Wilks test for normality

= 0.058

= 0.942

dh 4/13/90

itical W (P = 0.05) (n = 24) = 0.916
itical W (P = 0.01) (n = 24) = 0.884

---

ta PASS normality test at P=0.01 level. Continue analysis.

05-090-053-001 Fathead Minnow Mean Dry Weight
le: A:053.1W   Transform: NO TRANSFORMATION

rtletts test for homogeneity of variance

---

lculated B statistic = 8.70
ble Chi-square value = 15.09 (alpha = 0.01)
ble Chi-square value = 11.07 (alpha = 0.05)

erage df used in calculation ==> df (avg n - 1) = 3.00
ed for Chi-square table value ==> df (#groups-1) = 5

---

ta PASS homogeneity test at 0.01 level. Continue analysis.

TE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

05-090-053-001 Fathead Minnow Mean Dry Weight
le: A:053.1W Transform: NO TRANSFORMATION

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

P	IDENTIFICATION	N	MIN	MAX	MEAN
	Control	4	0.480	0.520	0.500
	6.25	4	0.440	0.530	0.478
	12.5	4	0.440	0.510	0.477
	25	4	0.450	0.690	0.538
	50	4	0.380	0.490	0.448
	100	4	0.320	0.450	0.383

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05-090-053-001 Fathead Minnow Mean Dry Weight
le: A:053.1W Transform: NO TRANSFORMATION

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

P	IDENTIFICATION	VARIANCE	SD	SEM
	Control	0.000	0.018	0.009
	6.25	0.002	0.045	0.022
	12.5	0.001	0.030	0.015
	25	0.011	0.105	0.052
	50	0.002	0.048	0.024
	100	0.003	0.054	0.027

505-090-053-001 Fathead Minnow Mean Dry Weight
ile: A:053.1W Transform: NO TRANSFORMATION

ANOVA TABLE

OURCE	DF	SS	MS	F
etween	5	0.055	0.011	3.667
ithin (Error)	18	0.058	0.003	
otal	23	0.113		

Critical F value = 2.77 (0.05,5,18)
Since F > Critical F REJECT Ho:All groups equal

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505-090-053-001 Fathead Minnow Mean Dry Weight
ile: A:053.1W Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

ROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	Control	0.500	0.500		
2	6.25	0.478	0.478	0.581	
3	12.5	0.477	0.477	0.581	
4	25	0.538	0.538	-0.968	
5	50	0.448	0.448	1.356	
6	100	0.383	0.383	3.034	*

unnett table value = 2.41 (1 Tailed Value, P=0.05, df=18,5)

505-090-053-001 Fathead Minnow Mean Dry Weight
ile: A:053.1W Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

ROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	Control	4			
2	6.25	4	0.093	18.7	0.023
3	12.5	4	0.093	18.7	0.023
4	25	4	0.093	18.7	-0.037
5	50	4	0.093	18.7	0.053
6	100	4	0.093	18.7	0.118

ERT QA Form No. 18
Effective: 3/87

SUBJECT: PHYSICAL & CHEMICAL DATA FOR FATHEAD MINNOW SUBCHRONIC TEST

KBS 4/12/90

SUBSTANCE: AQUA RESIN BEGINNING: DATE 4/3/90 TIME 1400

CLIENT: B.O.R. ENDING: DATE 4-10-90 TIME 1400

PROJECT NO. 8505-090
053-002

CNSR#1310
LOT#90-18/<24hrs
RW#313
CI- LC50 = 6647
RANGE = 3756-7659

NO. OF SURVIVING ORGANISMS

CONC.	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7
Control	A	10	10	10	10	10	10	10	10
	B	|	|	10	10	10	10	10	10
	C	|	|	10	10	10	10	10	10
	D	|	|	10	10	10	9	9	9
6.25	A	|	|	10	9	9	9	9	9
	B	|	|	10	10	10	9	8	8
	C	|	|	10	8	8	8	7	7
	D	|	|	10	10	9	9	9	9
12.5	A	|	|	9	8	8	7	6	4
	B	|	|	10	7	5	5	2	2
	C	|	|	10	8	8	7	7	7
	D	|	|	9	2	1	1	1	1
25	A	|	|	6	0	—	—	—	—
	B	|	7	6	1	0	—	—	—
	C	|	9	4	0	—	—	—	—
	D	|	9	4	0	—	—	—	—
	METER NO.	—	—	—	—	—	—	—	—
	DATE	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
	TIME	1400	1430	1020	1400	1500	1450	1619	1400
	INITIALS	[illegible]	ASD	ASD	ASD	SB	RDS	[illegible]	RWC

DISSOLVED OXYGEN (mg/l)

CONC.	TEST CONTAINER NUMBER	0 NEW	1 OLD	1 NEW	2 OLD	2 NEW	3 OLD	3 NEW	4 OLD	4 NEW	5 OLD	5 NEW	6 OLD	6 NEW	7 OLD
Control	A	6.7	5.6	6.5	5.0	6.4	5.0	6.4	—	6.5	4.6	6.2	4.6	6.9	5.3
	B	c	—	c	—	c	—	c	3.7	c	—	c	—	c	—
	C	|	5.6	|	5.0	|	5.0	|	—	|	4.6	|	4.6	|	5.3
	D	|	—	|	—	|	—	|	3.7	|	—	|	—	|	—
6.25	A	6.7	5.1	6.6	5.3	6.5	5.3	6.4	—	6.5	4.4	6.2	4.5	6.9	5.2
	B	c	—	c	—	c	—	c	4.0	c	—	c	—	c	—
	C	|	5.1	|	5.3	|	5.3	|	—	|	4.4	|	4.5	|	5.2
	D	|	—	|	—	|	—	|	4.0	|	—	|	—	|	—
12.5	A	6.7	5.1	6.6	5.1	6.5	5.4	6.4	—	6.5	4.4	6.2	4.8	6.9	5.3
	B	c	—	c	—	c	—	c	3.7	c	—	c	—	c	—
	C	|	5.1	|	5.1	|	5.4	|	—	|	4.4	|	4.8	|	5.3
	D	|	—	|	—	|	—	|	3.7	|	—	|	—	|	
25	A	6.7	5.1	6.5	4.8	6.5	4.9	—	—	—	—	—	—	—	—
	B	c	—	c	—	c	—	6.3	4.2	—	—	—	—	—	—
	C	|	5.1	|	4.8	|	4.9	—	—	—	—	—	—	—	—
	D	|	—	|	—	|	—	—	—	—	—	—	—	—	—
	METER NO.	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	DATE	4/3	4/4	4/4	4/5	4/5	4/6	4/6	4/7	4/7	4/8	4/8	4/9	4/9	4/10
	TIME	1400	1100	1430	0920	1020	1000	1400	0950	1510	1110	1500	1200	1610	0930
	INITIALS	[illegible]	ASD	ASD	ASD	ASD	ASD	ASD	SB	RDS	SB	RDS	ASD	[illegible]	SWC

TEMPERATURE (C)

CONC.	TEST CONTAINER NUMBER	0 (NEW)	1 (NEW)	2 (NEW)	3 (NEW)	4 (NEW)	5 (NEW)	6 (NEW)	7 (OLD)
Control	A	25	25	25	25	25	25	25	25
	B	c	c	c	c	c	c	c	—
	C	|	|	|	|	|	|	|	—
	D	|	|	|	|	|	|	|	—
6.25	A	|	25	25	25	25	25	25	25
	B	|	c	c	c	c	c	c	—
	C	|	|	|	|	|	|	|	—
	D	|	|	|	|	|	|	|	—
12.5	A	|	25	25	25	25	25	25	25
	B	|	c	c	c	c	c	c	—
	C	|	|	|	|	|	|	|	—
	D	|	|	|	|	|	|	|	—
25	A	|	25	25	25	—	—	—	—
	B	|	c	c	c	~~25~~	—	—	—
	C	|	|	|	|	—	—	—	—
	D	|	|	|	|	—	—	—	—
	METER NO.	8	6	6	6	6	6	8	6
	DATE	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
	TIME	1400	1430	1020	1400	1510	1500	1610	0930
	INITIALS	[illegible]	ASD	ASD	ASD	RDS	RDS	[illegible]	SWC

dh 4/13/90

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ERT QA Form No. 18
Effective: 3/87

SUBJECT: PHYSICAL & CHEMICAL DATA FOR FATHEAD MINNOW SUBCHRONIC TEST KRA 4/12/90

SUBSTANCE: AQUA RESIN   BEGINNING: DATE 4/3/90 TIME 1400

CLIENT: B.O.R.   ENDING: DATE 4-10-90 TIME 1400

PROJECT NO. 8505-090
053-022

NO. OF SURVIVING ORGANISMS

CONC.	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7
50	A	10	1	0	—	—	—	—	—
	B	|	0	0	—	—	—	—	—
	C	|	0	0	—	—	—	—	—
	D	|	2	1	0	—	—	—	—
100	A	|	2	0	—	—	—	—	—
	B	|	0	0	—	—	—	—	—
	C	|	0	0	—	—	—	—	—
	D	|	0	0	—	—	—	—	—
METER NO.		-	-	-	-				
DATE		4/3	4/4	4/5	4/6				
TIME		1400	1430	1020	1400				
INITIALS		[illegible]	ASD	ASD	ASD				

DISSOLVED OXYGEN (mg/l)

CONC.	TEST CONTAINER NUMBER	0 NEW	1 OLD	1 NEW	2 OLD	2 NEW	3 OLD	3 NEW	4 OLD	4 NEW	5 OLD	5 NEW	6 OLD	6 NEW	7 OLD
50	A	6.7	4.5	6.5	4.8	6.4	—								
	B	C	-	C	-	C									
	C	|	4.8	|	4.8	|									
	D	|	-	|	-	|	5.2	—	—						
100	A		4.7	6.5	4.8	—									
	B	6.8	-	C	-	—									
	C	C	4.7	|	4.8										
	D	|	-	|	-										
METER NO.		5	5	5	5	5	5	5	5						
DATE		4/3	4/4	4/4	4/5	4/5	4/6	4/9	4/9						
TIME		1400	1100	1430	0920	1020	1000	1200							
INITIALS		[illegible]	ASD	ASD	ASD	ASD	ASD	ASD							

TEMPERATURE (C) — NEW SOLUTIONS ONLY (7: OLD)

CONC.	TEST CONTAINER NUMBER	0	1	2	3	4	5	6	7 OLD
50	A	25	25	25	—	—	—	—	—
	B	C	C	C	—	—	—	—	—
	C	|	|	|	—	—	—	—	—
	D	|	|	|	—	—	—		
100	A	|	25	—	—	—	—	—	
	B	|	C	—	—	—			
	C	|	|	—	—	—			
	D	|	|						
METER NO.		8	6	6					
DATE		4/3	4/4	4/5					
TIME		1400	1430	1020					
INITIALS		[illegible]	ASD	ASD					

dh 4/13/90

ERT QA Form No. 19
Effective: 3/87

SUBJECT: CHEMICAL DTA FOR FATHEAD MINNOW SUBCHRONIC TEST

KRD 4/12/90

SUBSTANCE: AQUA RESIN BEGINNING: DATE 4/3/90 TIME 1400

CLIENT: B.O.R. ENDING: DATE 4-10-90 TIME 1400

PROJECT NO. 8505-090
053-002

CONC. mg/l	TEST CONTAINER NUMBER	pH 0	pH 1	pH 2	pH 3	pH 4	pH 5	pH 6	pH 7 (OLD)	Cond. 0	Cond. 1	Cond. 2	Cond. 3	Cond. 4	Cond. 5	Cond. 6	Cond. 7 (OLD)
Control		8.4	8.5	8.6	8.5	8.5	8.5	8.5	8.2	770	811	819	812	811	824	807	
											C						
6.25		8.4	8.5	8.6	8.5	8.5	8.6	8.5	8.2	796	833	823	840	808	838	840	
12.5		8.4	8.5	8.6	8.5	8.6	8.6	8.5	8.3	824	840	832	838	832	838	840	
25		8.4	8.5	8.6	8.5	—	—	—	—	824	838	832	845	—	—	—	—
50		8.5	8.5	8.6	—	—	—	—	—	830	843	834	—	—	—	—	—
100		8.5	8.5	—	—	—	—	—	—	838	830	—	—	—	—	—	—
METER NO.		26	26	26	26	24	26	26	26	9	9	9	9	9	9	9	
DATE		4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/3	4/4	4/5	4/6	4/7	4/8	4/9	
TIME		1400	1430	1020	1400	1510	1500	1610	0930	1400	1430	1020	1400	1510	1500	1610	
INITIALS		KF	AED	AED	AED	RDS	SB	KF	EWC	KF	AED	AED	AED	RDS	SB	KF	

pH and CONDUCTIVITY (umhos/cm): NEW SOLUTIONS ONLY (columns 0–6); 7 = OLD

CONC. mg/l	Alk. 0	Alk. 1	Alk. 2	Alk. 3	Alk. 4	Alk. 5	Alk. 6	Alk. 7	Hard. 0	Hard. 1	Hard. 2	Hard. 3	Hard. 4	Hard. 5	Hard. 6	Hard. 7
Control	137								302							
	C								C							
	+								+							
METER NO.	T								T							
DATE	4/3								4/3							
TIME	1540								1540							
INITIALS	SB								SB							

ALKALINITY (mg/l) and HARDNESS (mg/l): NEW SOLUTIONS ONLY

4/13/90

ERT TOXICOLOGY GROUP
FT. COLLINS, COLORADO

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Effective: 3/87
KBS 4/12/90

SUBJECT: DAILY LOG 8505-090-053-002

ALL ENTRIES MUST BE INITIALLED WITH DATE AND TIME:

		C	6	12	25	50	100		
4-4-90									
	Old pH	8.4	8.4	8.4	8.4	8.3	8.2	#26	@1050
	Old Temp	25	25	25	25	25	25	#6	NED
4-5-90		C	6	12	25	50	100		
	Old pH	8.4	8.4	8.4	8.3	8.3	8.2		@0900
	Old Temp	25	25	25	25	25	25		NED
4-6-90		C	6	12	25	50			
	Old pH	8.3	8.3	8.4	8.2	8.4		#26	@1000
	Old Temp	25	25	25	25	25		#6	NED
4-7-90		C	6	12	25				
	OLD pH	8.1	8.1	8.1	8.2			#26	@0935
	OLD Temp	25	25	25	25			#6	ROS
4-8-90		C	6	12	25				
	OLD pHS:	8.2	8.2	8.2	NA			#26	1050
	OLD TEMPS:	25	25	25	~~25~~ NA (SB 4-8)			#8	SB
4-9-90		C	6	12					
	Old pH:	8.1	8.2	8.1				#26	@1145
	Old Temp:	25	25	25				#6	NED

dh 4/13/90

ERT

ERT QA Form No. 5
Effective: 2/87

PREPARATION OF STOCK SOLUTIONS

KRD 4/12/90

Substance: AQUA RESIN
Project No.: 8505-090-053-002
Sponsor: B.O.R.
Substance on Page 13/10 of Test Substance log
Lot #: 109283
Purity: N/A
Test Type: Short-term Chronic
Species: Pimephales promelas
Amt. Weighed 10,000 mg
Diluted To: 1 L
Solvent: HOH
Solvent Lot #: N/A
Solvent on Page N/A of Reagent log
Solvent Manufacturer: N/A
Final Stock Concentration: 10g/L

SERIAL DILUTIONS

Initial Concentration	Diluted To	Final Conc.	(1,2,3)
10,000 mg/l	———	10,000 mg/l	1°

DK 4/13/90

Data By: [signature] 4/3/90

ERT

ESE QA Form No. __
Effective: 5/87
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SUBJECT: TEST ORGANISM LENGTHS, WEIGHTS, AND LOADING 4/14/90

SPONSOR: ECP - Black
TEST SUBSTANCE: Aqua [illegible]
DATA BY: DN DATE 4-1[illegible] TIME 0900

PROJECT NO: [illegible]-053
SPECIES: FHM
LOT/BATCH NO: 90-18

WEIGHT: TYPE DRY

LENGTH TYPE N/A

NO.	LENGTH TYPE N/A	TARE	GROSS	NET	X/fish
1	Control A	1.3591	1.3645	0.0054	0.54
2	B	1.3508	1.3559	0.0051	0.51
3	C	1.3690	1.3732	0.0042	0.42
4	D	1.3705	1.3745	0.0040	0.44
5	6.25mg/L A	1.3686	1.3722	0.0036	0.40
6	B	1.3465	1.3494	0.0029	0.36
7	C	1.3432	1.3467	0.0035	0.50
8	D	1.3452	1.3497	0.0045	0.50
9	12.5mg/L A	1.3656	1.3674	0.0018	0.45
10	B	1.3537	1.3542	0.0005	0.25
11	C	1.3444	1.3475	0.0031	0.44
12	D	1.3611	1.3609	-0.0002	0.0
13	Blank	1.3602	1.3599	-0.0003	
14					dh 4/13/90
15					
16					
17					
18					
19					
20					
RANGE					
MEAN					
S					

TEST SOLUTION VOLUME ______ LOADING RATE ______

505-090-053-002 Fathead Minnow Survival
ile: A:053.2S   Transform: ARC SINE(SQUARE ROOT(Y))

hapiro Wilks test for normality

= 0.322

= 0.815

ritical W (P = 0.05) (n = 24) = 0.916
ritical W (P = 0.01) (n = 24) = 0.884

[handwritten initials] 4/13/90

---

ata FAIL normality test. Try another transformation.

arning - The two homogeneity tests are sensitive to non-normal data and should not be performed.

505-090-053-002 Fathead Minnow Survival
ile: A:053.2S   Transform: ARC SINE(SQUARE ROOT(Y))

artley test for homogeneity of variance
artletts test for homogeneity of variance

---

hese two tests can not be performed because at least one group has
ero variance.

ata FAIL to meet homogeneity of variance assumption.
dditional transformations are useless.

KAS 4/12/90

05-090-053-002 Fathead Minnow Survival
le: A:053.2S   Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

P	IDENTIFICATION	N	MIN	MAX	MEAN
	Control	4	1.249	1.412	1.371
	6.25	4	0.991	1.249	1.149
	12.5	4	0.322	0.991	0.615
	25	4	0.159	0.159	0.159
	50	4	0.159	0.159	0.159
	100	4	0.159	0.159	0.159

Dh 4/13/90

05-090-053-002 Fathead Minnow Survival
le: A:053.2S   Transform: ARC SINE(SQUARE ROOT(Y))

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

P	IDENTIFICATION	VARIANCE	SD	SEM
	Control	0.007	0.081	0.041
	6.25	0.016	0.125	0.062
	12.5	0.085	0.292	0.146
	25	0.000	0.000	0.000
	50	0.000	0.000	0.000
	100	0.000	0.000	0.000

05-090-053-002 Fathead Minnow Survival
le: A:053.2S   Transform: ARC SINE(SQUARE ROOT(Y))

STEELS MANY-ONE RANK TEST   -   Ho:Control<Treatment

OUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	Control	1.371				
2	6.25	1.149	11.00	10.00	4.00	
3	12.5	0.615	10.00	10.00	4.00	*
4	25	0.159	10.00	10.00	4.00	*
5	50	0.159	10.00	10.00	4.00	*
6	100	0.159	10.00	10.00	4.00	*

Critical values use k = 5, are 1 tailed, and alpha = 0.05

```
;05-090-053-002 Fathead Minnow Mean Dry Weight
.le: A:053.2W        Transform: NO TRANSFORMATION

.apiro Wilks test for normality
-----------------------------------------------------------------------------

=     0.159

=     0.909

:itical W (P = 0.05) (n = 12) = 0.859
:itical W (P = 0.01) (n = 12) = 0.805
-----------------------------------------------------------------------------

.ta PASS normality test at P=0.01 level. Continue analysis.
```

4/13/90

```
·05-090-053-002 Fathead Minnow Mean Dry Weight
.le: A:053.2W        Transform: NO TRANSFORMATION

rtletts test for homogeneity of variance
-----------------------------------------------------------------------------

.lculated B statistic =     5.27
ıble Chi-square value =     9.21  (alpha = 0.01)
.ble Chi-square value =     5.99  (alpha = 0.05)

'erage df used in calculation  ==>   df (avg n - 1) =    3.00
;ed for Chi-square table value ==>   df (#groups-1) =    2
-----------------------------------------------------------------------------

.ta PASS homogeneity test at 0.01 level. Continue analysis.

'TE: If groups have unequal replicate sizes the average replicate size is
     used to calculate the B statistic (see above).
```

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05-090-053-002 Fathead Minnow Mean Dry Weight
le: A:053.2W Transform: NO TRANSFORMATION

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 1 of 2

P	IDENTIFICATION	N	MIN	MAX	MEAN
	Control	4	0.420	0.540	0.478
	6.25	4	0.360	0.500	0.440
	12.5	4	0.000	0.450	0.285

4/13/90

05-090-053-002 Fathead Minnow Mean Dry Weight
le: A:053.2W Transform: NO TRANSFORMATION

SUMMARY STATISTICS ON TRANSFORMED DATA TABLE 2 of 2

P	IDENTIFICATION	VARIANCE	SD	SEM
	Control	0.003	0.057	0.028
	6.25	0.005	0.071	0.036
	12.5	0.045	0.211	0.106

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8505-090-053-002 Fathead Minnow Mean Dry Weight
File: A:053.2W   Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	2	0.083	0.042	2.333
Within (Error)	9	0.159	0.018	
Total	11	0.242		

Critical F value = 4.26 (0.05,2,9)
Since F < Critical F FAIL TO REJECT Ho:All groups equal

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8505-090-053-002 Fathead Minnow Mean Dry Weight
File: A:053.2W   Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	Control	0.478	0.478		
2	6.25	0.440	0.440	0.395	
3	12.5	0.285	0.285	2.029	

Dunnett table value = 2.18 (1 Tailed Value, P=0.05, df=9,2)

8505-090-053-002 Fathead Minnow Mean Dry Weight
File: A:053.2W   Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	Control	4			
2	6.25	4	0.207	43.3	0.038
3	12.5	4	0.207	43.3	0.193

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American Public.