

GEOTEXTILE CONTAINED DREDGED MATERIAL, RED EYE CROSSING, BATON ROUGE, LA

Jack Fowler¹, Dana Toups², Frank Duarte³, and Paul Gilbert⁴

ABSTRACT

Approximately 7000 ft of underwater dikes were constructed for sedimentation control to reduce dredging at Red Eye Crossing, on the Mississippi River 2 miles south of Baton Rouge, LA. Three dikes were constructed using geotextile containers and three dikes with sandbags filled with river dredged sand. Six sub-aqueous dikes varying in length from 500 to 1800 ft and a maximum height of 30 ft were constructed by placement of 556 containers from split hull bottom dump barges and over 38,000 bags were dropped from flat top barges using front end loaders. The dike crests varied from -2 to -7 ft NGVD and the river depth varied to a maximum depth of 65 ft (-25 ft NGVD) and maximum river velocities were about 4 to 5 ft/sec. The purpose of these dikes was to contract the channel to a width where the river flow at Red Eye Crossing would prevent sediment from dropping out of suspension and reduce or eliminate dredging in this reach. Strain gage and pressure cell data from the geotextile containers and bags was collected and presented in this paper.

INTRODUCTION

Red Eye Crossing is located about 2 miles south of Baton Rouge, LA, on the Mississippi River where the navigation channel crosses from the left side to right of the river as it flows to the Gulf of Mexico. The river widens just at the bend and the velocity drop causes sediment to shoal at various river stages requiring a tremendous amount of dredging throughout the year. Red Eye Crossing was chosen as a demonstration project because it required the largest amount of dredging among the four major crossings south of Baton Rouge, LA. See figure 1.

The Corps of Engineers has constructed contraction dikes at several locations along the Mississippi river from the New Orleans District to the St. Louis District. Contraction dikes constructed using rock fill have historically been used to control erosion on river systems,

¹Jack Fowler, PhD., PE, Geotec Associates, 5000 Lowery Road, Vicksburg, MS, 39180.

²Dana Toups, Nicolon Corporation, Erosion Control Products, 3500 Parkway Lane, Suite 500, Norcross, GA, 30092.

³Frank Duarte, New Orleans District, New Orleans, LA.

⁴Paul Gilbert, Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS, 39180-6199.

but this project is one the first geotextile container and bag dikes of this magnitude constructed in the USA. Prior to construction, the New Orleans District had proposed rock fill dikes; but local barge and shipping interests expressed concern about navigation accidents that could disrupt the water supply to the city of New Orleans. Therefore, the Corps proposed to demonstrate the use of geotextile contained dredged sand for construction of soft-core dikes. Since the Corps successfully completed these dikes in April of 1994, there has been no requirement for dredging at Red Eye Crossing. The Corps had been spending over \$3 million per year on maintenance of this crossing. The total cost of construction of the soft-core contraction dikes was about \$6 million. The benefit to cost ratio for a 40 ft channel will be achieved in about than two years.

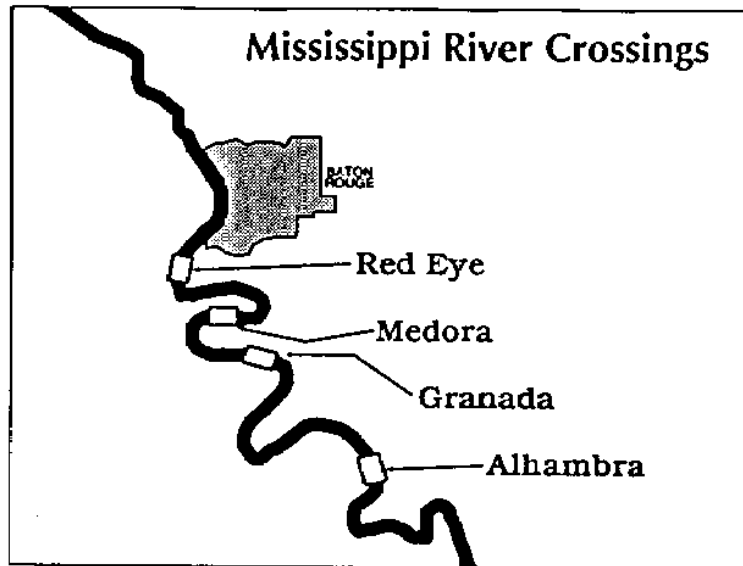


Figure 1. Mississippi River Crossings Between Baton Rouge and Donaldsonville.

BACKGROUND

Strain gage and pressure cells were installed on geotextile containers and bags at Red Eye Crossing under the Construction Production Advancement Research (CPAR) program. The Waterways Experiment Station (WES) and Nicolon Corporation entered into a research agreement. WES under CPAR contributed \$400,000 and Nicolon contributed \$400,000 to conduct research in containment of dredged material in geotextile containers for structural uses. The New Orleans District did not fund this research effort but did provide permission for WES to use this project in their research efforts under CPAR. The CPAR program is

similar to what is commonly done in other countries such as Japan and Holland where the government enters into an agreement with private industry to advance certain types of research techniques and construction methodologies. The agreement that WES and Nicolon entered into was entitled "The Development and Demonstration of Dredged Material Containment Systems Using Geotextiles." The objective of this study was to demonstrate the feasibility of geotextile containers and bags filled with river dredged sand for dike construction.

The objective of the CPAR program was to develop and demonstrate dredged material containment systems that are environmentally sensitive and cost effective for the handling and disposal of dredged materials. The containment systems were originally designed to provide fabricated geotextile tubes and containers that would be used to construct engineered earth mounds above and below water. The use of these geotextile tubes and containers for containment of contaminated dredged material has been a spin off from the original intent of the program. There is presently much more interest in the use of geotextile tubes and containers in Los Angeles, New York-New Jersey and Miami River for disposal of contaminated dredged material than for structural use. The use of geotextile containers and tubes filled with sand has been used for a number of years.

Design and construction methods, techniques, and guidelines for hydraulically and mechanically filling and placing geotextile bags, tubes, and containers with dredged material for engineering structures and disposal of contaminated dredged material are being developed and documented through videos, computer programs, technical notes, papers and reports. Guidelines are being developed that include geotextile bags, tubes and containers designed for filling with different types of dredged materials. Techniques for dynamic placement of geotextile bags and containers are being monitored during placement with bottom dump hopper barges and other placement methods in various water currents and depths in fresh and salt water. Strain gages attached to the geotextile fabric and pressure cells installed inside the containers have provided valuable information for design and fabrication purposes.

An extensive literature review of projects throughout the world was produced through CPAR. Laboratory model tests have been successfully completed using a 1:25 scale model of a bottom dump barge. Prototype tests of filling geotextile tubes for erosion control, groins, wetlands, and dikes have been successfully completed and reports are being prepared that document this work.

Dr. Dov Leshchinsky, University of Delaware, has developed a computer program to aid in design of geotextile tubes and containers under the CPAR program. His work initiated interest in development of a finite difference program at WES and the University of Delaware for mathematically modeling and animating the placement of geotextile containers

in the water column. A video report is being prepared that documents the scale model tests, mathematical models, graphic animation, and a number of prototype tests by WES and others.

A proposed ASTM Standard entitled, "Standard Method for Determining the Flow Rate of Suspended Solids from a Geotextile Containment System for Dredged Material," was prepared during a project for the Port Authority of New York-New Jersey. This method is currently being used by the Port Authority to determine the flow rate of water and sediment and suspended solids passing through a geotextile container used to contain fine-grained contaminated dredged material.

CASE HISTORIES PRIOR TO AND AFTER RED EYE CROSSING

Geotextile containers filled with dredged material offer the advantage of ease of placement and constructability, cost effectiveness, minimal impact on the environment, and confidence in containment. In addition to filling with sandy materials, geotextile containers filled with fine-grained maintenance soils provide the opportunity for beneficial use, storage, and subsequent consolidation of this material in dike construction and wetland construction. It has been demonstrated that these geotextile containers can retain 100 percent of the fine-grained dredged material.

During the past 15 to 20 years various types of containers have been used, for example, GeotubesTM and GeocontainersTM as copyrighted by Nicolon Corporation. Geotextile tubes hydraulically filled with fine-grained sand have been extensively used on the northern shores of the Netherlands for barrier dikes for subsequent hydraulic fill behind the dike.

On a project, Leybucht, on the North Sea in Germany in 1988, geotextile tubes were successfully filled by a hydraulic suction dredge for dike construction. The continuous tubes provided temporary protection from waves and currents until fill was placed behind the structure and more permanent wave armor protection was constructed.

The WES demonstrated in 1992 that geotextile tubes, 15 ft flat width, 500 ft long, and 5 ft high could be filled with fine grained dredged material for potential use by the Corps of Engineers for dike construction and wetland creation at Gaillard Island Dredged Material Disposal Island, Mobile, AL. Vegetation growth through containers is very promising; with natural propagation taking place after the tubes are filled and the fine-grained dredged material consolidates.

Geotextile containers, which are dumped either from dump trucks or split hull bottom

dump hopper barges, have been successfully used to construct underwater stability berms, closures for repair of breached dikes, groins, and thalweg scour protection. These containers have been hydraulically and mechanically filled inside split hull bottom dump hopper barges, moored in place, and dumped. Design concepts for material tensile strength, seaming requirements, and properties with regard to creep, abrasion, ultraviolet protection, tear, and puncture are presently being documented under the CPAR program.

Dredged material filled tubes have been used as containment dikes in Brazil and France (Bogossian and others 1982, Perrier 1986), and more recently in the Netherlands and Germany for river "training" structures on the Waal and Old Meuse Rivers, and as shoreline protection at Leybucht on the North Sea.

Experimentation with dredged material filled fabric tubes was first tried in Brazil in the early 1980's with a variety of fill material types such as clay balls, shells, and fine grained sand for land reclamation for housing. This technique was also used in France to isolate and contain runoff from a contaminated area.

In the Netherlands, ACZ Marine Contractors BV developed dredged material containers for constructing underwater groins for sedimentation control. A prefabricated steel cradle was used to position pre-filled containers without dropping them from a barge. This specially constructed cradle bucket was used to place over 500 containers during construction of 11 groins.

The Public Works Department of the Netherlands, in another Dutch application, placed 233 mechanically filled geotextile containers dropped from a split hull bottom dump barge to fill an eroded river bottom. Another Dutch contractor, Vanden Herik Kust-en Oeverwerken BV, with the help of Nicolon BV, developed this system.

At Marina Del Rey, Los Angeles, CA, approximately 55,000 cy of contaminated maintenance dredged material was successfully dredged and contained in 44 geotextile containers and placed with split hull bottom dump barges in a shallow water habitat and capped with a layer of clean sandy dredged material. The sandy dredged material contained about 7 to 8 percent fine-grained material and was contaminated with lead, zinc and copper. The materials were mechanically dredged with a clamshell bucket and placed in geotextile containers. The containers were sewn closed and placed within the Port of Los Angeles' (POLA) Shallow Water Habitat (SWH) Confined Aquatic Disposal (CAD) site. Forty-four containers were filled with an average of about 1300 cy of contaminated dredged material per container from Marina Del Rey, CA, channel entrance and the Ballona Flood Control Channel, Los Angeles, CA. Dredging began in November and completed in December 1994 with filling about 1.5 containers or about 2000 cy each day. This was the first project of its

kind in the world where contaminated dredged material was successfully contained in geotextile containers, placed, and capped with a sand layer.

The Port of Oakland, CA was involved in filling geotextile tubes with contaminated dredged material during the Marina Del Rey project. Dredged material was mechanically dredged into a holding barge and then hydraulically pumped into geotextile tubes for dewatering and subsequent landfill disposal. Geotextile tubes were successfully filled with contaminated dredged material and allowed to drain to about 40 to 65 percent of their original volume prior to landfill placement.

The New York-New Jersey Port Authority dropped a 4000 cy container filled with fine-grained, maintenance dredged material at the Sandy Hook Mud Dump site, April 1995. The container was instrumented with strain gages and pressure cells.

GEOTEXTILE CONTAINERS, RED EYE CROSSING, BATON ROUGE, LA

The ship channel from the Gulf of Mexico to Donaldsonville, LA, a town 20 miles south of Red Eye Crossing, was deepened in 1988 to a depth of 45 ft to accommodate Deep Draft vessels. During design of the 45 ft deep channel from Donaldsonville to Baton Rouge, which included Red Eye Crossing, it was concluded that it would be more economical to construct contraction to reduce dredging than to continue dredging. The soft core dikes were started about October 1993 and completed in April 1994. The channel was maintained at 40 ft during dike construction but was deepened to project depth of 45 ft after construction.

Dredging Requirements Before Construction.

The Corps of Engineers has dredged the high traffic channel at Red Eye Crossing during the past 5 years, an average of 5,000,000 cy per year. This work is accomplished with the Corps of Engineers dustpan dredge, Jadwin, which dredges and discharges the sandy material in the river current to be carried down stream several times a year. The dredge spends an average of 80 days per year providing 500-ft wide, 40-ft deep channel. If contraction dikes were not constructed the Deep Draft channel of 45 ft would double the dredging requirements at Red Eye Crossing to 10,000,000 cy per year at a cost of about \$0.65 per cy or about \$6.5 million per year. Based on this assumption the pay back for the contraction dike would be one year rather than two years as mentioned earlier.

Model Studies at WES.

Model studies conducted at WES indicated that contraction dikes would eliminate or significantly reduce the dredging requirements at Red Eye Crossing. Contraction dikes are

normally constructed underwater with riprap rock and placed perpendicular to the flow on the slack water side of the river. Figure 2 shows a plan view and location of the proposed soft dikes and channel at Red Eye Crossing. Figure 3 shows a profile view of three of the proposed dikes and their crest elevations and spacing.

A total of six dikes were planned to restrict the flow of the river. During high stages, the river would flow over the dikes. During low water and low flow, sand has a tendency to

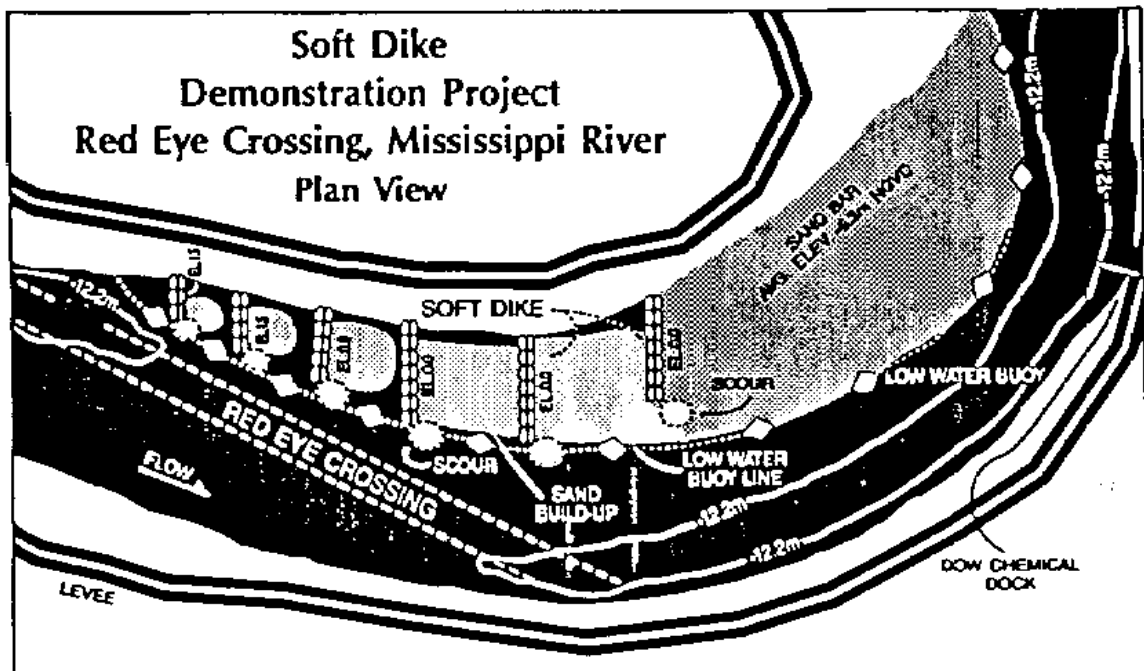


Figure 2. Soft Dike Demonstration Project, Red Eye Crossing, Plan View.

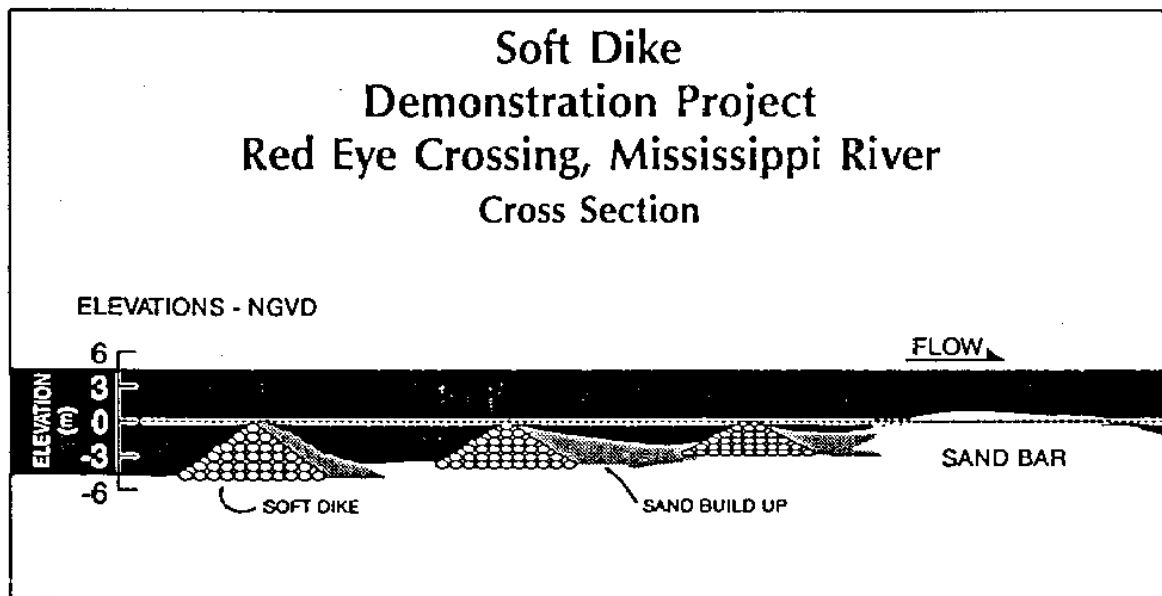


Figure 3. Profile view of Three Proposed Dikes With Crest Elevations and Spacing.

drop out and fill the channel crossing. High river velocities caused by the contraction dikes will keep the sediment in suspension during the crossing. In the past the most economical method for dike construction was with riprap stone, but navigation interest were concerned that their ships might strike the rock dikes and cause major oil spills. New Orleans continues to take their drinking water from the Mississippi River and river boat pilot were concerned that barge towboat traffic would be hazardous because of congestion of traffic in the restricted channel. These proposed dikes will not only save about \$6.5 million per year but will also keep the dredge Jadwin from blocking the channel and causing hazardous navigation problems over 80 days per year.

Geotextile containers filled with sand were felt to be an excellent alternative to construction of rock filled dikes where there were concerns expressed by representatives of the Navigation Industry to possible collisions. It was felt that the sand filled geotextile containers would provide a soft cushion effect if a ship struck the soft-core dike. The dikes might lose some of the sand filled containers, but maintenance cost would be minimal compared to ship repairs and possible oil spills. At high water the shallow draft boats and barges continued to navigate over the dike crest during construction in spite of complaints by the contractor. The dikes were designed to accommodate shallow watercraft most of the time.

Soft Core Demonstration Dike

The Corps of Engineers, New Orleans District obtained authority to construct

contraction dikes at Red Eye Crossing to evaluate the construction and performance of this new and innovative technology. The WES conducted mathematical and physical model studies for the District to determine the effects of contraction dikes and to determine proper location and configuration. WES determined that six dikes with crest elevations of -2 to -7 ft NGVD would be required. Dike crest widths of 10 ft and slopes of 1 vertical and 2 Horizontal were specified. Dike lengths varied from 500 to 1800 ft with a maximum height of about 30-ft. To evaluate the type of geotextile containers used, it was decided that dikes 1, 3 and 5 would be constructed with 3 cy sand fill bags and dikes 2, 4 and 6 would be constructed with large containers as large as 550 cy and topped off with 3 cy sand bags. Figure 4 shows a typical configuration of the geotextile containers and bags.

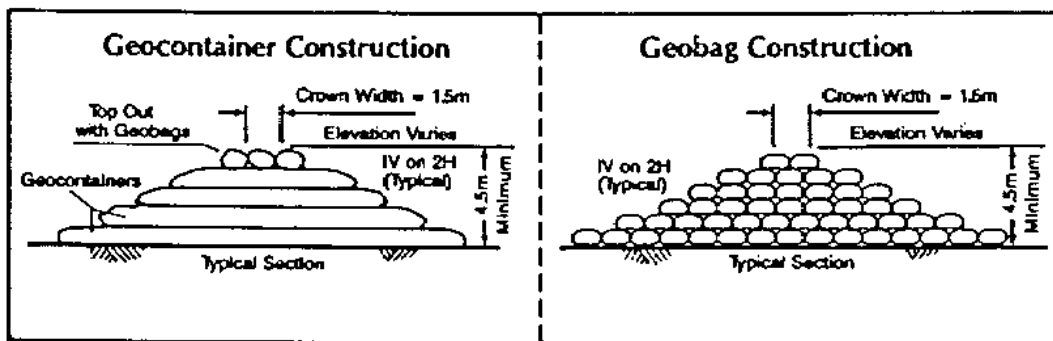


Figure 4. Typical configuration of Geocontainer™ and Geobag™ Construction

The objectives of this demonstration project were to determine:

1. If there were technically qualified contractors to perform this work.
2. If geotextiles could be acquired domestically.
3. If there would be placements problems in swift river currents of 4 to 5 ft per second.
4. If geotextile containers would be stable in river currents.
5. If the model dike performance would compare with the prototype performance.
6. If the measured, strain gage data was comparable to the design computations.
7. If the pressure cell data could be used to determine internal container pressure and terminal velocity.

Geotextile Container Design

The New Orleans district did not have much information from case histories of geotextile containers design to draw from therefore they used information gathered from two

documented projects conducted in Europe. The first project reviewed was in Weekeborg, Germany, where geotextile containers were used to construct a breakwater in maximum water depths of 20 ft. Dutch engineers used information from the construction of this project to predict the construction performance of filling a scour hole with geotextile containers at the Old Meuse (JAGT, H.J. 1988). This project involved placement depths of about 65 ft and current velocities of about 5 ft per second that were quite comparable to those encountered at the Red Eye Crossing project.

Using the data and observations from the Old Meuse project the New Orleans District predicted that the impact momentum between the river bottom and the container would cause the most damage to the container. They used a terminal velocity of 16.4 ft per second, a container length of 85 ft and geocontainer submerged weight of about 346,185 pounds. This yielded a momentum of 176,318 lbs according the principle of conservation of momentum. For the case of constant mass and velocity this is equivalent to Newton's first law of motion. Dividing the momentum by the length of the container provides a fabric strength of about 170 pounds per inch. More recent designs used at Marina Del Rey and New York-New Jersey Port Authority assume a membrane stretched across the barge opening supporting the dredged material.

One of the primary design objectives was to provide a fabric with a large area opening size (AOS) to allow quick release of air and water and to minimize the excess pressure during impact with the river bottom and other containers. The Dutch claimed to have experienced fabric failures caused by large pressures during container impact. The geotextile ultimate strength, seam strength, and AOS mean values are as follows:

Ultimate Tensile Strength in the Warp and Weft	ASTM D 4595	400 lbs/inch
Seam Strength	ASTM D 4595	250 lbs/inch
AOS	ASTM D 4751	No. 30 sieve

Dredged Sand.

The dredged sand was taken directly from a point bar deposit directly beneath the construction site at Red Eye Crossing. The material is light brown, relatively clean, medium to fine quartz sand with sub-rounded to sub-angular bulky particles with about 0.25 percent iron fillings and other magnetic material and minute amounts of mica. Approximately half the sand particles are clear and the other half frosted. The average specific gravity of the material is 2.67; the grain size distribution is shown in Figure 5. The grain-size curve shows the material to be a medium to fine uniform clean sand with less than 1 percent fines. The water content of the sand prior to filling was about 6.5 percent. The moist bulk density was about 1.28 grams per cubic centimeter and the saturated density was about 1.67 grams per

cubic centimeter.

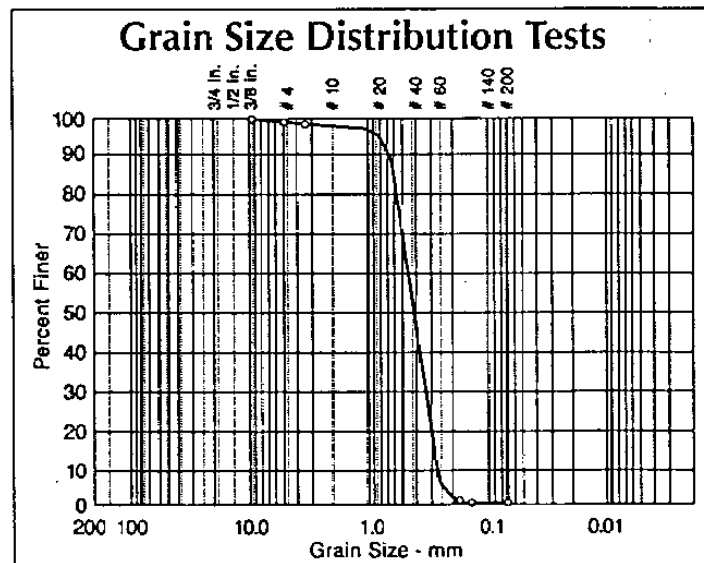
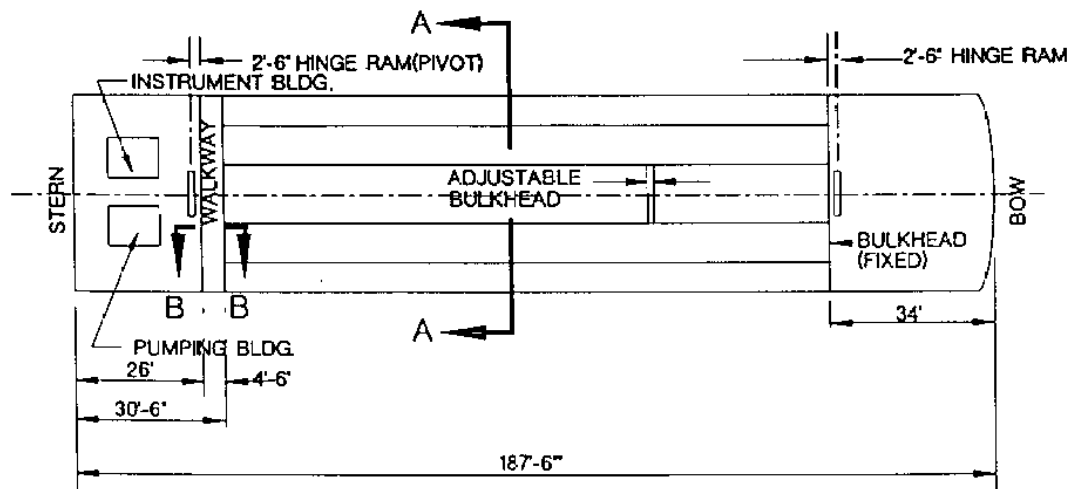


Figure 5. Grain Size Distribution Tests

Barge Dimensions.

Two split hull bottom dump barges were modified to accommodate the geotextile containers specified in the contract. The modified barge dimensions are shown in Figures 6. The original bin volume was reduced from about 1380 cy down to about 560 cy. Because of the problem of only one fabric vendor meeting the fabric strength requirements, for larger containers, the geotextile container dimensions were modified to fit the reduced barge bin and lower the strength requirements. To accommodate the smaller containers false bulkheads were constructed as shown in Figure 7. About 120 cy of sand was placed in the bottom of the barge underneath the fabric, because the bins were fabricated larger than the maximum allowed container circumference and sewing shut the containers after filling was difficult without this added height.



KING BARGE #120

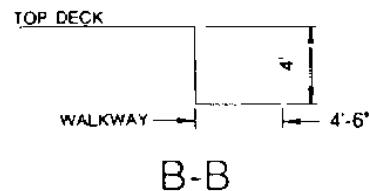
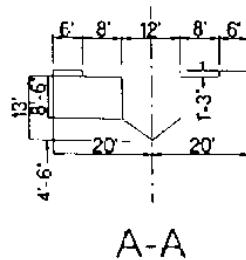
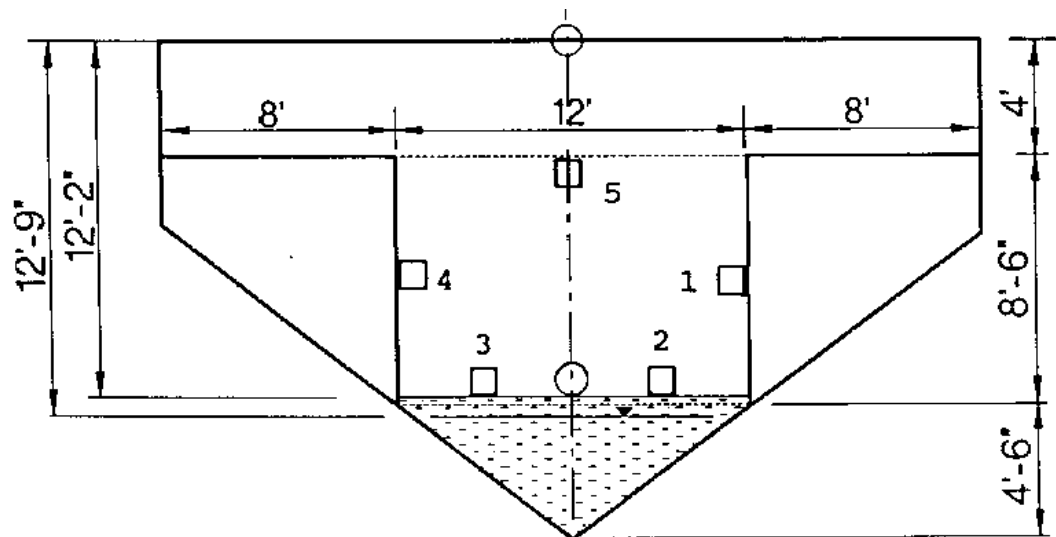


Figure 6. Modified Barge Dimensions.

Geotextile Container Dimensions.

Figure 7 shows an end view of the split hull bottom dump barge and the 12 ft wide, 13 ft deep bin. The bin was filled to a depth of about 4-ft with about 120 cy of dredged material prior to placement of the geotextile container. This quantity varied deepening on the length of container. The geotextile container was constructed to fit the dimensions of the barge depending on its position in the dike prism. Container lengths varied from about 40 to 115 ft and the circumference was maintained at 45 ft. Circular vents were constructed in the ends and top of the container with a No. 20 AOS fabric to allow the release of trapped air and water to reduce possible internal pressure. Container volumes varied from 80 to 550 cy. After the container is filled with dredged material the top is folded into place and sewn closed as shown in Figure 8.



Strain Gage Location
Pressure Cells

Figure 7. Cross Section of Split Hull Bottom Dump Barge and Strain Gage Locations.

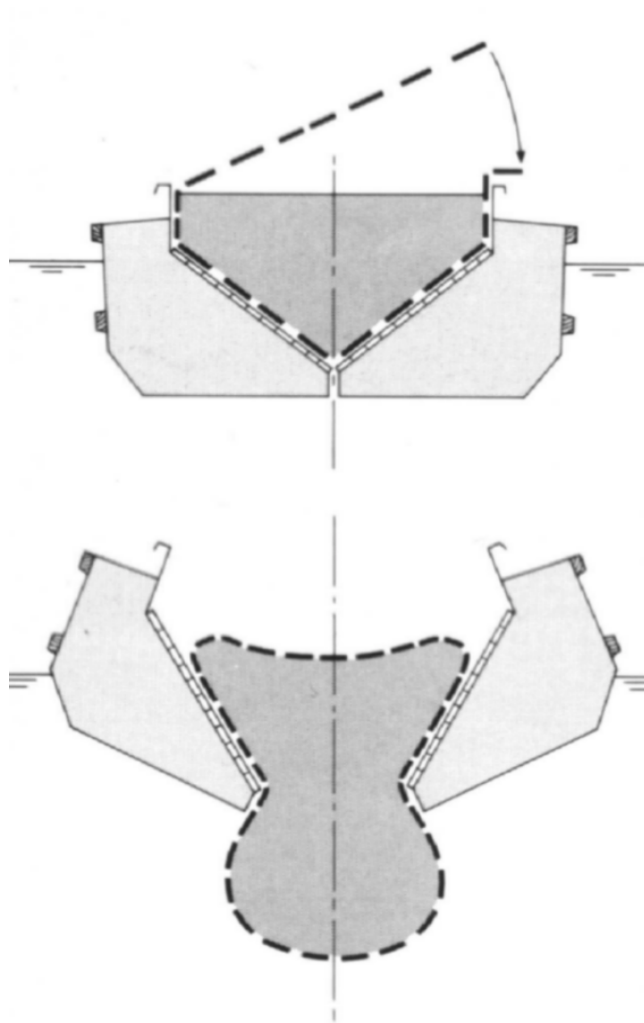


Figure 8. Barge After Filling and During Dumping.

Dike Construction.

Approximately 38,000 three cubic yard bags were dropped an average height of about 7.5 ft above the water surface from flat top barges. An average of 373 bags a day were filled with moist sand and dropped during the project. The bags were filled rather loosely to avoid high fabric stresses during impact with the water surface and river bottom. After the bags were filled they were sewn closed with a hand held sewing machine by sewing two rows of stitches. The bags were generally dropped up stream a distance equal to the water depth. Bags were dropped from a metal basket using front-end loaders. The river velocity, placement depth, and dike surveys were checked frequently. Numbered floats were installed inside the first 3500 bags and monitored for failure. There were no failures caused by impact

with the water or river bottom.

Five hundred and fifty-six geotextile containers were filled with moist sand and placed to construct three dikes. Two barges and two crews, working only daylight hours, filled an average of about eight containers each day. The most filled in a day was 12. The largest container was 552 cy and was dropped in 65 ft of water. The containers were dropped on 20 ft spacings and the space was subsequently filled in. The container dropped from the split hull uniformly with very little release of air. The containers deployed from the barge similar to the diagram shown in Figure 8. The container drift downstream was less than the bags. The drift recorded for the three, instrumented containers dropped at depths of about 60 ft was about 40 ft. The containers were topped out with bags where needed. Numbered floats were installed in 160 containers. In the beginning of the project, when the containers were filled above the 70% specified allowance, six floats were lost due to seam failure near the corners.

The bag and container placement operation was conducted from October 1993 to April 1994 when river velocities ranged from 3.5 to 4.9 ft/sec. River stages ranged during this same period from 12.7 to 29.9 NGVD.

Instrumentation Measurements

Strain gages and pressures cells were installed on three bags and three containers. The instrumented containers were about 115 ft long and 45 ft in circumference. This work was performed by WES personnel and funded through the CPAR program.

Bag Data. Three bags were instrumented with two strain gages located on the center front and two on the center back of the bag. One of the gages at each location was oriented in the transverse direction and one in the longitudinal direction of the bag. Pressure cells were located near the top end of the bag with one measuring pressure outside the bag and one measuring pressure inside the bag.

The instrumentation records for the pressure cells and longitudinal and transverse strain gages for the bags are shown in figures 9, 11 and 12 for Drop numbers 3, 2 and 1 respectively. The maximum pressure measured inside and outside the bag occurred during impact with the water surface and river bottom. The maximum impact pressure outside bag was about 17 ft of water or about 7.5 psi during surface water impact. The maximum impact pressure inside the bags was minimal during water surface and river bottom impact. The pressure measured inside and outside the bag was about the same, indicating about the same rate of descent and depth of water. The initial change in pressure could be attributed to temperature changes. These pressure were well within the specified fabric strengths. The terminal velocity or maximum drop velocity after the bag enters the water was determined to be about 7.7 ft/sec for drop number 1 and 2 and 10 ft/sec for drop number 3.

Maximum strain measured in the longitudinal directions of the bag during impact with the water surface varied from about +2 to -3.5 percent. The maximum strain measured

in the transverse directions during impact with the river surface varied from about +1 to -1 percent. Maximum strains measured in the transverse and longitudinal directions during impact with the river bottom varied from -1 to +2 percent. The strain measured in the fabric was well within the maximum fabric strain of 20 percent measured at failure during laboratory tests. Some of the variations in strain measured in the bags could be attributed to changes in temperature from air, 18 degrees centigrade, to river water temperature of 5 degrees centigrade.

Container Data. Three containers were instrumented with 10 strain gages and two pressure cells each. The strain gages were located on the circumference of the container near the center of the 115 ft long containers as shown in Figure 7. Longitudinal and transverse strain gages were location at each of the five locations. Two of the strain gages were located where they would correspond with the barge slopes and two on the vertical sides and one on the on top of the container. The pressure cells were located on the centerline of the barge on the same alignment with the strain gages. Both of the pressure cells were located just inside the container in the sand fill, but one of the pressure cells was connected to a one inch diameter tube that exited to the outside of the container into the sand fill in the bottom vee of the barge.

The pressure cell and strain gage data are shown in Figures 12 through 17 for container drop numbers 1, 2, and 3 respectively. The pressure cell data inside and outside the containers is shown at the top of each figure. Figures 12, 14, and 16 show the transverse strain gage data and Figures 13, 15, and 17 show the longitudinal strain gage data. The pressure cell cables did not fail during placement of the three containers but all of the strain gage cables failed prior to impact with the river bottom during drops 1 and 3. The river stage was higher than expected and the contractor dropped the containers in deep water near the end of the dikes. All pressure cells and strain gages survived deployment from the barge and impact with the river bottom during drop number 2.

The barge opened to full width, 9.5 ft, in about 68 seconds or about 75 percent of the 12-ft bin width. The original bin width prior to modification was 28 ft. During this time period as the barge opened, the pressure cell data indicated that the container dropped about 5 to 6 ft before the container free fell abruptly through the opening. The pressure cell data indicated that the terminal velocity was achieved almost immediately as the container left the barge. The containers free fell a distance of about 55-ft in 4 seconds or an average terminal velocity of about 13.8 ft per second. Because the fabric weave was very open and the container was filled with a clean sand, the pressure measured inside and outside the container was about the same. Excess pressure measured inside the container during impact was also almost nonexistent. There was excess pressure measured underneath the container number 1, during drop number 2, but this excess pressure does not effect the design capacity of the container fabric. Some of the sharp spikes in the measured data may not be significant and may have been caused by abrupt temperature changes, cables or strain gages trying fail or by electrical noise and vibration.

As the barge opened and the container began to drop during drop number 1, the fabric was being dragged down the vertical steel face of the barge. The transverse strain gage locations at 1 and 4 indicated a gradual decrease of about two percent strain on the right side and a two percent increase on the left side of the barge. This could have been caused by the container trying to rotate or by the difference in friction between the steel barge and the container. This phenomenon did not occur during other drops. Transverse strain gage locations 2 and 3 located on the sand plug in the barge Vee indicated a gradual increase in strain as the barge opened and the sand fell from beneath the fabric. The transverse and longitudinal strain gage locations on top of the container did not respond until the barge was approaching a full open position.

During drop number 2, only two longitudinal strain gage locations indicated any significant change in strain at gage locations 2 and 3 as the barge began to open. The largest response in strain in all cases started to occur in both the transverse and longitudinal locations about 5 to 6 seconds prior to the barge opening and container free falling.

The maximum strains monitored occurred as the barge opened and the sand blanket in the Vee was being lost as the container started making its way out the barge opening. Maximum strains measured in the longitudinal direction ranged from about 8 to 12 percent. Strains measured in longitudinal and transverse directions during free fall and after impact with the river bottom were less than 1 to 2 percent. The maximum strains measured in the transverse direction prior to free fall and during opening of the barge ranged from about 6 to 7 percent. The cost of the large containers was about \$10/cy, and the cost of the 3 cy bags was about \$30/cy.

CONCLUSIONS

The successful construction of this project has shown that subaqueous soft dikes can be designed and constructed in a riverine environment using geotextile containers. The contractor was able to work even though river stages were high during most of the construction period. The contractor was able to accurately place bags and containers and accurately construct dikes in currents as high as 5 ft per second at river depths greater than 65 ft. There has been no evidence that the bags or containers have moved. The largest amount of strain occurred during the opening of the barge and not during the impact with the bottom. The largest strains in the bags occurred during impact with the river as postulated in the initial design assumptions. The pressure cells were very successful in determining the terminal velocity and pressure in the bags and containers. Terminal velocities were achieved almost immediately after free fall. The strain gage data indicated that the containers' fabric did not fail. Model dike tests conducted by WES have shown that the prototype dike is working better than predicted. The fabric manufacturers and supplier in this country have shown that they can respond to projects of this magnitude and the required fabric specifications.

This project has also shown that this innovative technique is not only technically feasible but is also economically feasible and competitive with rock. As the contractors learn to fill and close the containers more efficiently, either mechanically or hydraulically, the cost of this construction methodology will become more competitive with rock dikes. The use of large containers is three times more economical than the 3 cy bags. The use of contraction dikes at Red Eye Crossing has shown that this project can pay for itself in a period of about one year.

RECOMMENDATION

It is recommended that future demonstration projects such as those conducted at Red Eye Crossing, Marina Del Rey, and New York-New Jersey Port Authority be conducted to further the knowledge and experience in this area. It is also recommended that prior to construction, a parametric study be conducted using a finite difference program and the data collected from these projects be used to develop and calibrate a mathematical model to aid in container fabric design.

ACKNOWLEDGEMENTS

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REFERENCES

Bogossian, T., Smith, R.T., Vertematti, J.C., and Yazbek, O. (1982). Continuous Retaining Dikes by Means of Geotextiles, Second International Conference on Geotextiles, Las Vegas, NV, pp. 211-216.

Fowler, J., Sprague, C.J. and Toups, D. (1994). Dredged Material-Filled Geotextile Containers, Environmental Effects of Dredging Technical Notes, U.S. Army Engineer, Waterways Experiment Station, Vicksburg, MS.

Jagt, H.J. (1988). Bed Protection, Old Meuse, By Means of Geocontainers, Rijkswaterstaat, Public Works Department of the Netherlands, April 1988

Pilarczyk, Krystian W. (1994). Novel Systems in Coastal Engineering, Geotextile System and Other Methods, an Overview, Rijkswaterstaat, Road and Hydraulic Engineering Division, Delft, The Netherlands.

Perrier, H. (1986). Use of Soil-Filled Synthetic Pillows for Erosion Protection. Third International Conference on Geotextiles, Vienna, Austria, pp 1115-1119.

Risko, A.J. (1995). Memorandum for the Record, FY 95 Marina Del Rey Detailed Project Summary, U.S. Army Engineer District, Los Angeles, Los Angeles, CA.

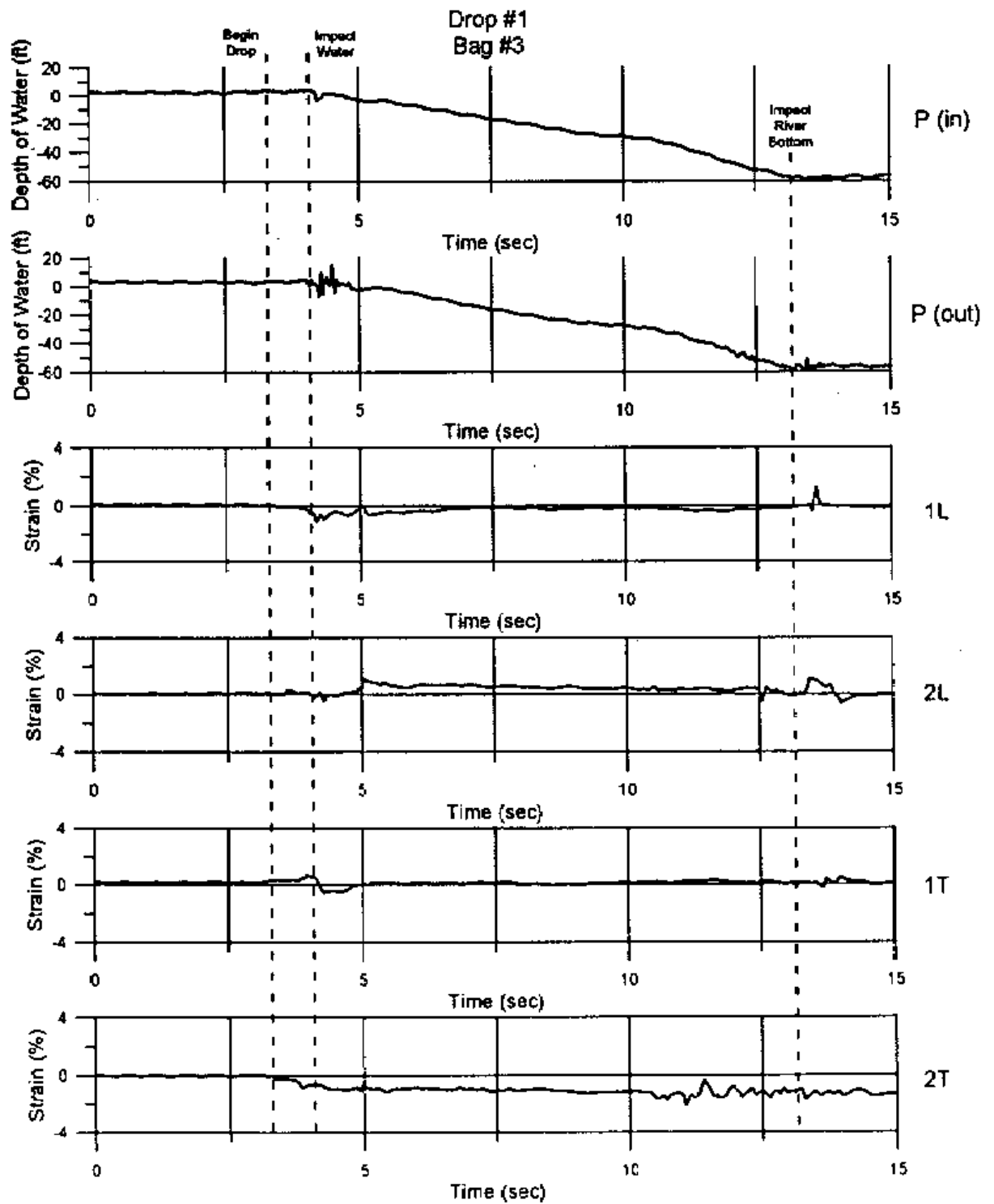


Figure 9. Drop #1, Bag #3, Pressure Strain Verses Time

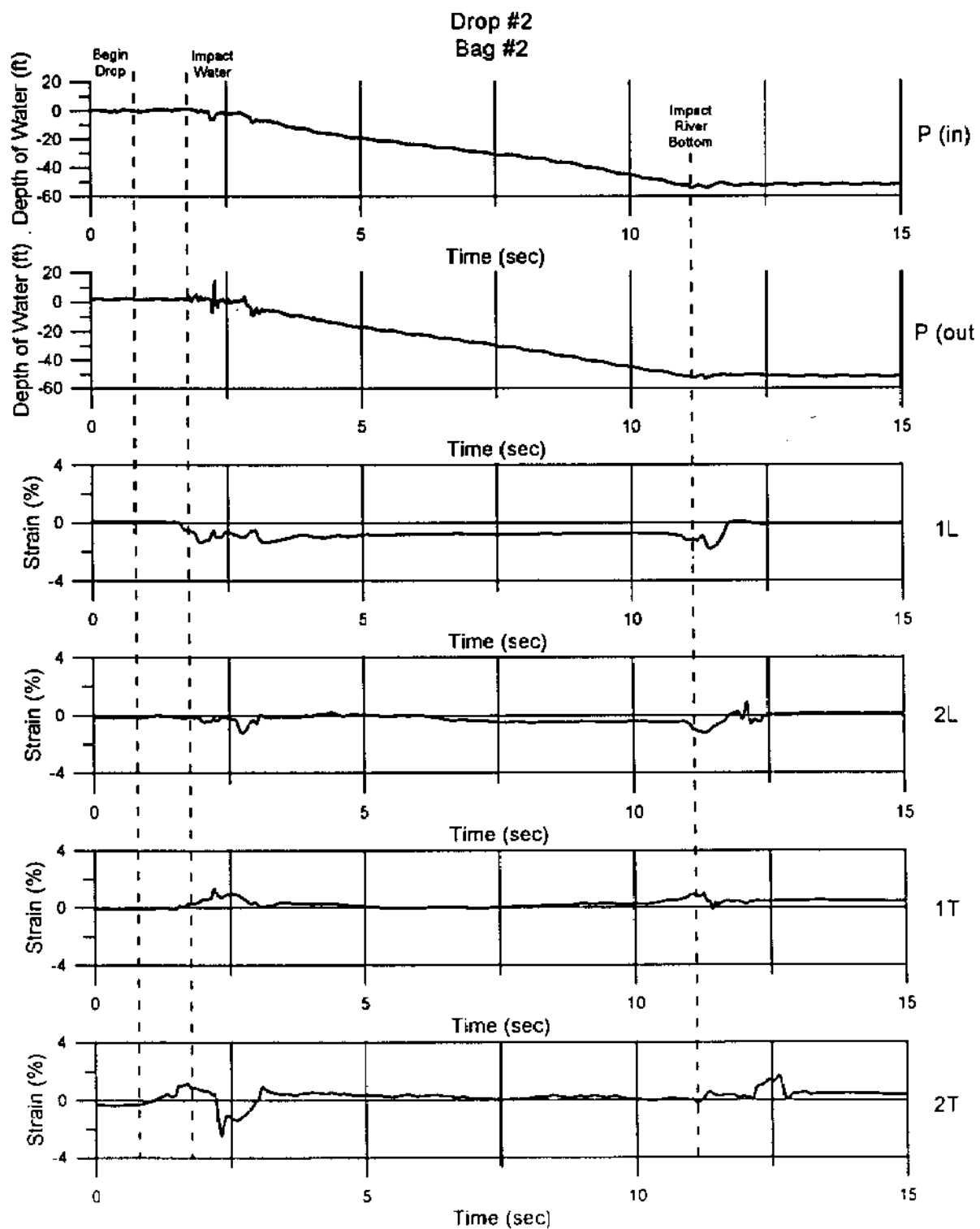


Figure 10. Drop #2, Bag #2, Pressure and Strain Verses Time

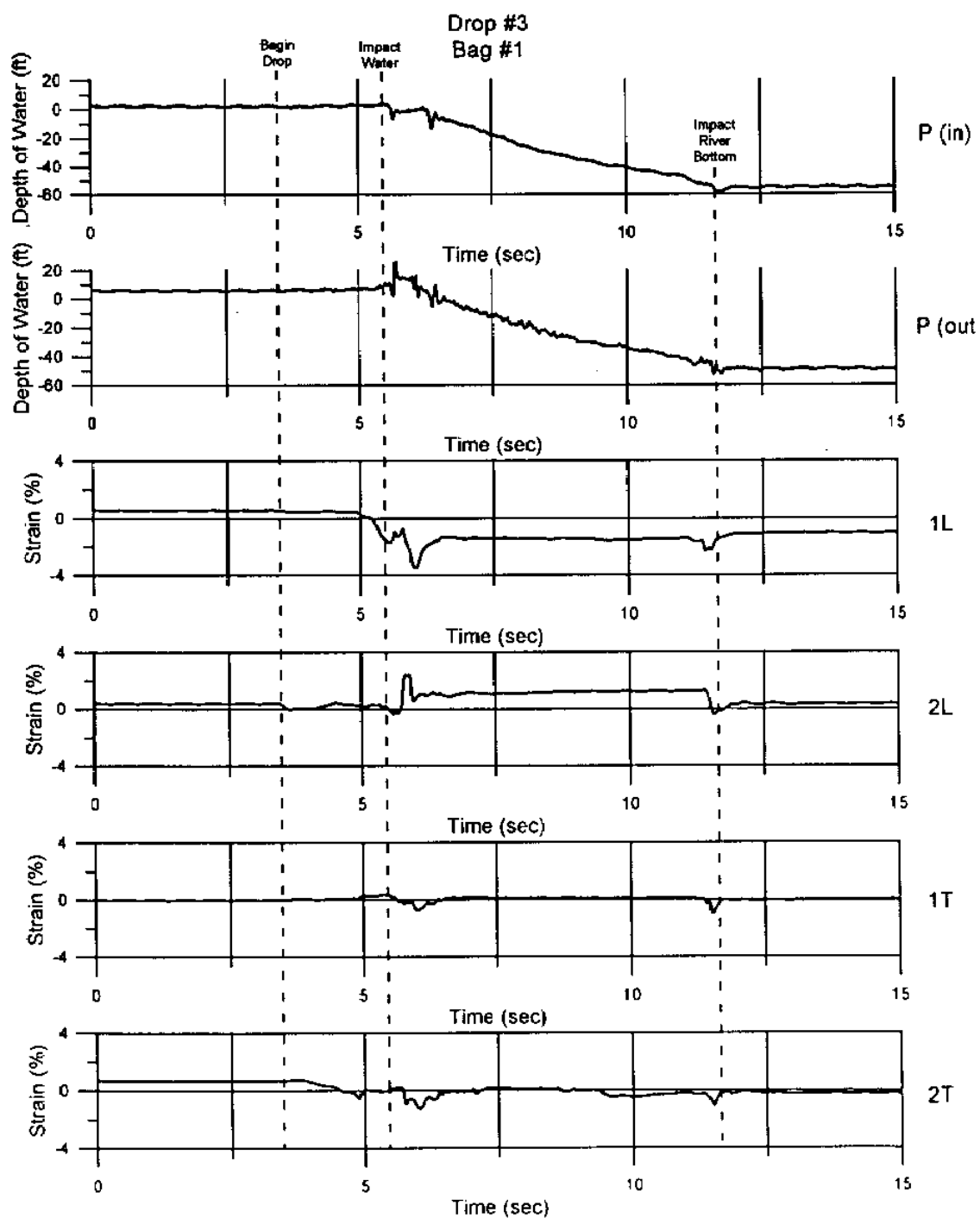


Figure 11. Drop #3, Bag #1, Pressure and Strain Verses Time

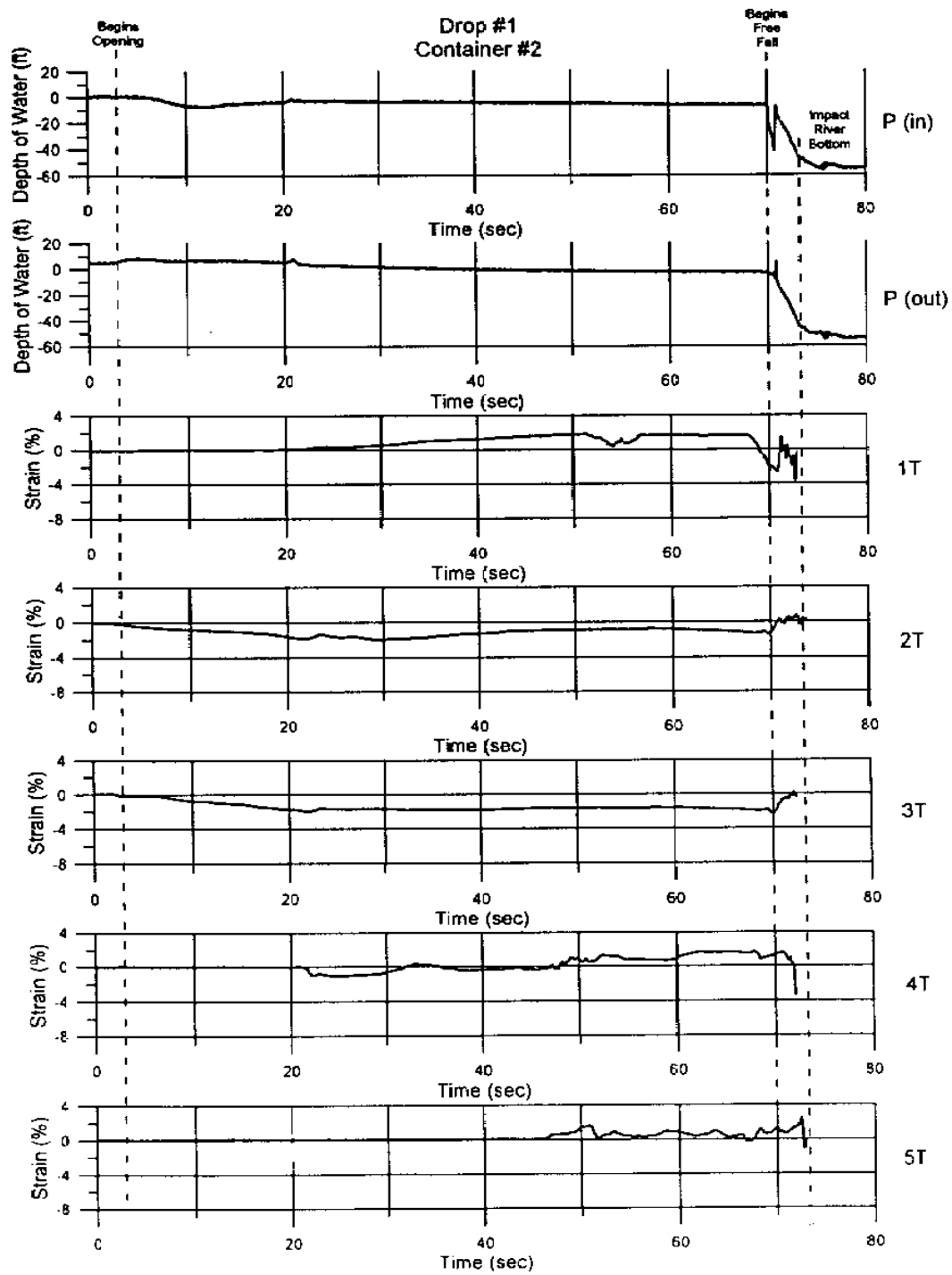


Figure 12. Drop #1, Container #2, Pressure and Transverse Strain Verses Time

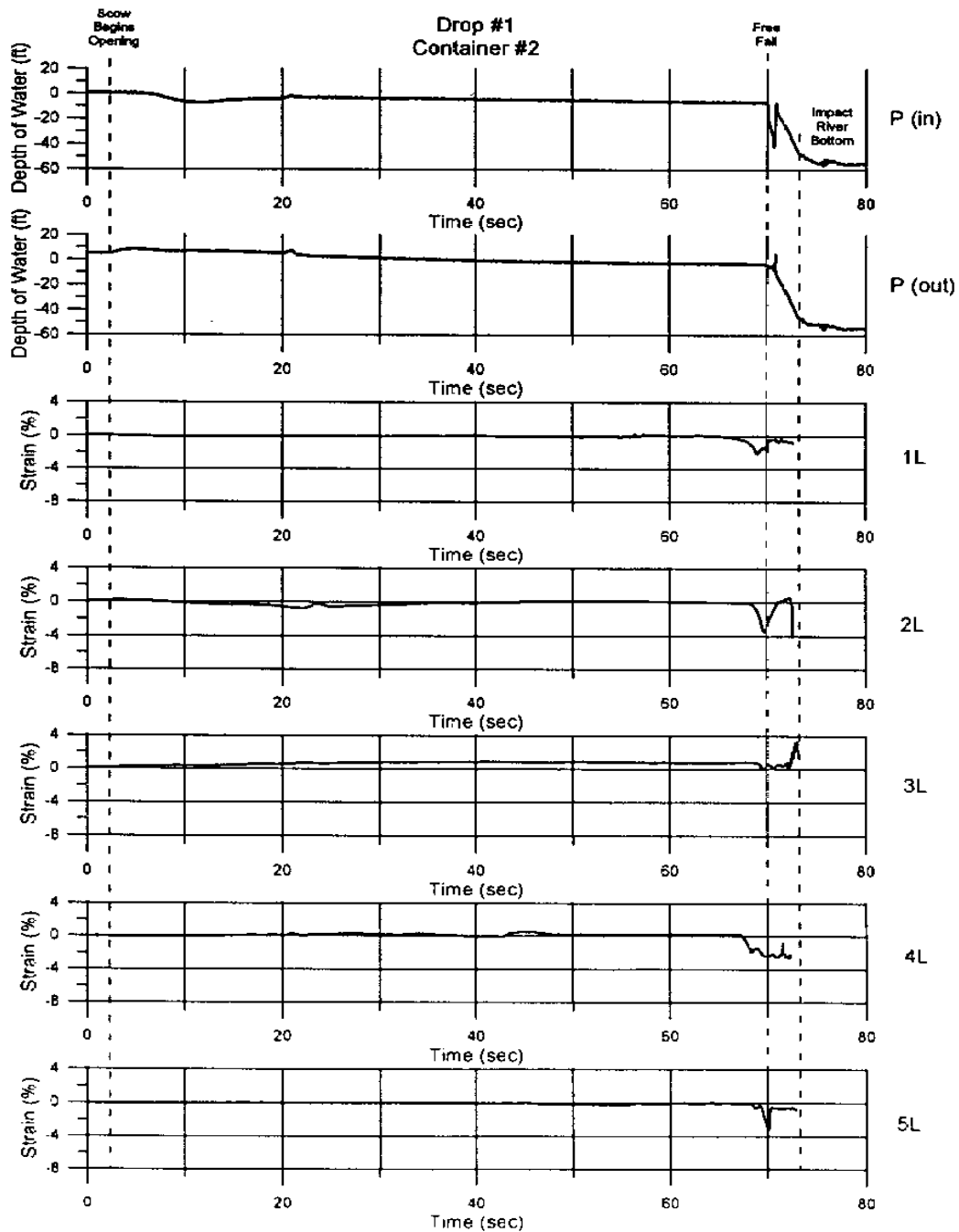


Figure 13. Drop #1, Container #2, Pressure and Longitudinal Strain Verses Time

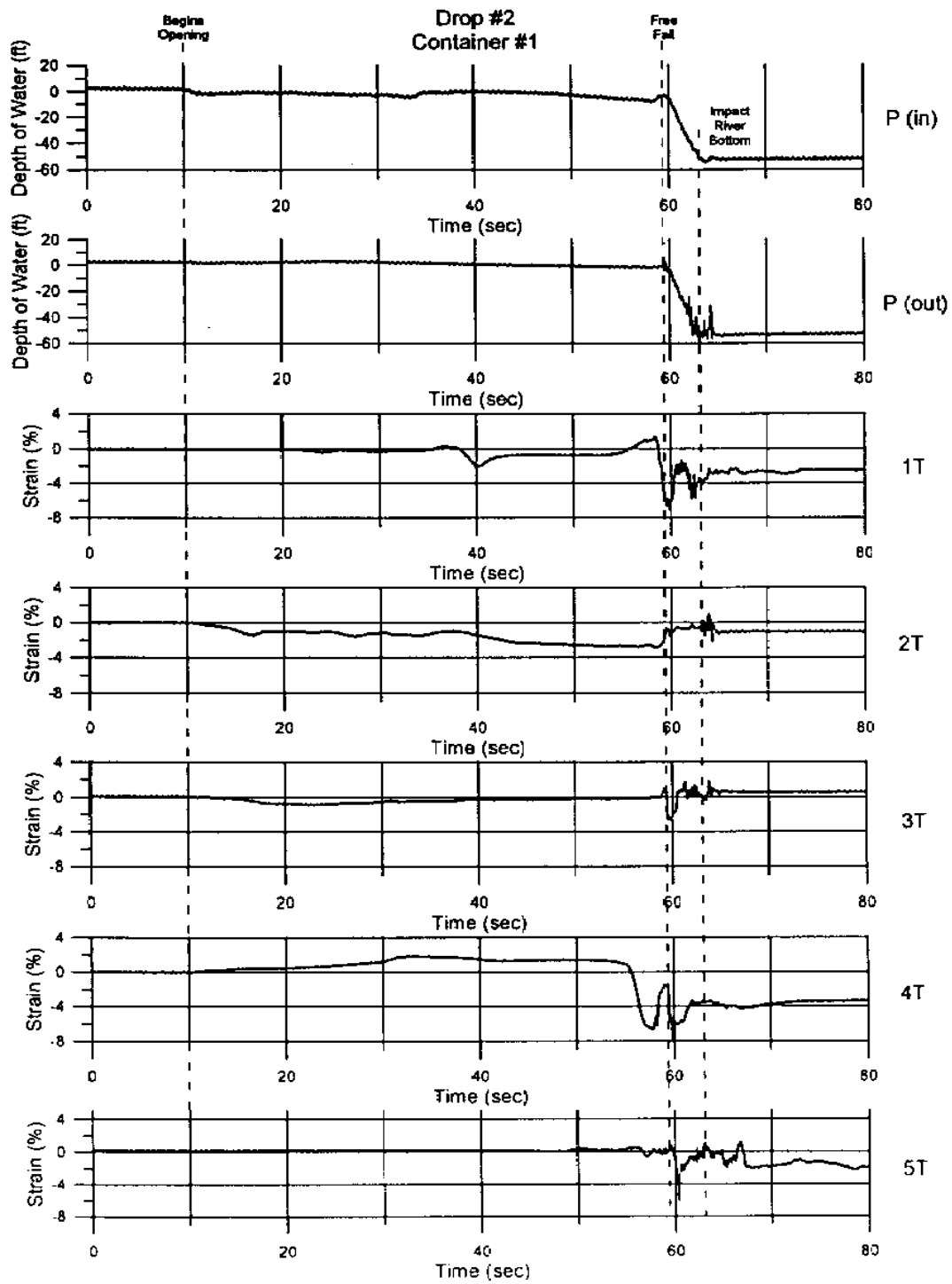


Figure 14. Drop #2, Container #1, Pressure and Transverse Strain Verses Time

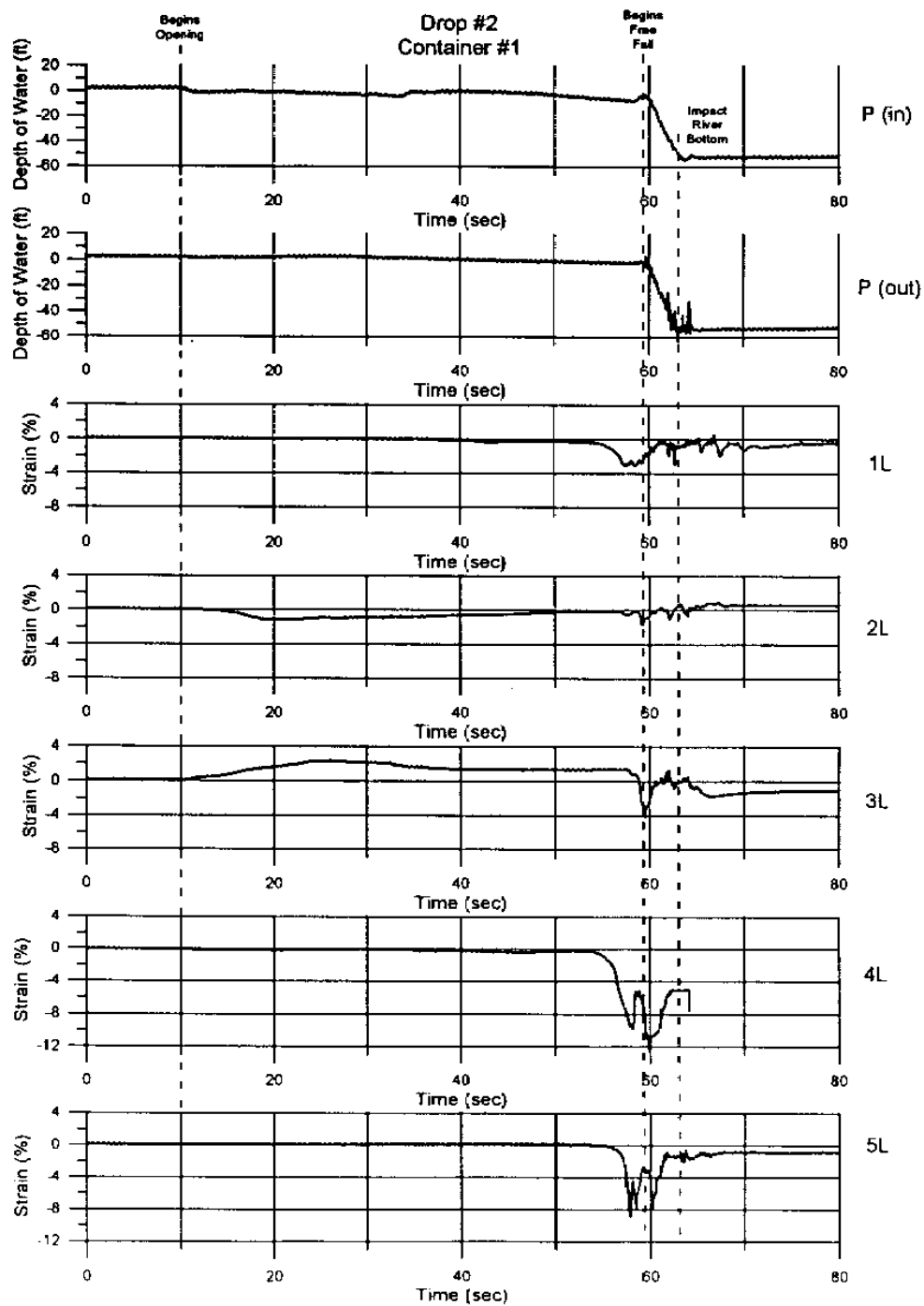


Figure 15, Drop #2, Container #1, Pressure and Longitudinal Strain Verses Time