EFFECT OF FEDERAL STRUCTURES ON ADJACENT SHORELINES

JULY 11, 1938

BLOCK ISLAND HARBOR OF REFUGE, R. I.

I. GENERAL

1. Location. This harbor is on the east side of Block Island. It is 13 miles south-southwest from Point Judith Harbor, R. I., and about 25 miles southeasterly from Stonington Harbor, Connecticut. (See map R.H.M. 255).

2. Type. Breakwaters.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. General description of locality. The site of the harbor was on the ocean shore, unprotected except for the shore-line of the island, which formed a partial shelter from southerly and westerly storms. There was no natural harbor on the island.

2. Nature of beach and bottom materials. The beach and bottom is composed almost entirely of sandy material interspersed with numerous boulder deposits.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Southwesterly winds prevail. (See wind chart for Block Island, map File No. R.H.M. 255).

5. Direction of prevailing storms. Prevailing storms are from the northeast and southeast.

6. Direction of prevailing littoral drift. Prevailing littoral drift along the east shore of Block Island is indicated as from southeast to northwest.

7. Tidal ranges in the harbor.

Mean 3.0 feet
Extreme 7 feet or more.

8. Direction and intensity of tidal and other currents. Tidal currents flow toward the northwest along the east shore of Block Island on the flood and toward the southeast on the ebb, and are of low velocity.

9. Effect of prevailing winds. The harbor was protected to some extent from prevailing southwesterly winds by the shore-line.

9. Effect of prevailing winds. Prevailing winds cause eastward drift along the north shore of Nantucket Island. Probably little effect.

10. Effect of prevailing storms. The effect of prevailing storms was to increase sand movement on the outer bar. In general, storms caused the closure of one channel and opened another. Previous to the construction of the jetties about $46,000 was spent in dredging a channel through the outer bar. This channel was soon closed by storms and another shoaler channel opened up a short distance eastward.

11. Effect of tidal and other currents. The ebb current issued between Brant and Coatue Points in a northwesterly direction with sufficient force to scour a channel having a least depth of 12 feet at mean low water for 0.6 of a mile. The tidal prism then dispersed fan-wise over the outer bar.

12. Reasons for the construction. The jetties were constructed to provide a stable entrance into Nantucket Harbor by maintaining a suitable depth over the outer bar. They were intended to accomplish this by stopping the littoral drift, and preventing deposition in the dredged channel by concentrating the tidal flow between them. Dredging was contemplated to assist the jetties in attaining and maintaining the channel.

III. CONSTRUCTION.

1. Material. Until 1884 the west jetty was constructed without a core by simply placing large rough stone on the lines of the jetty. The large openings between the stones allowed passage of sand. Later chip stone was used to fill the interstices in this portion of the work.

Since 1884 the construction of both jetties has been carried on with a core of small stone of varying sizes from 5 to 200 pounds in weight, protected by a facing of large stone. The west jetty was completed in 1908, and the east jetty in 1905. Later work classified as repairs increased about 1700 feet of the east jetty to the full section.

2. Method of applying stone in the structure. The structures were built by dumping stone from scows on line, and later placing the facing stone by means of shallow draft lighters. A portion of the east jetty was constructed by government plant with hired labor.

3. Alignment. The west jetty extends approximately normal to the beach west of Brant Point in a straight line except for a short distance on the outer end which curves westward. The east jetty converges from Coatue Point toward the west jetty and then continues in a straight line parallel to it at the outer end.

4, 5, 6, Cross sectional dimensions and side slopes. Lengths, and Distance apart. See map file no. R&HM 256.

7. Depths of water at outer ends. During construction, there was almost no change at the outer end of the west jetty. As construction progressed on the east end jetty, however, scouring was excessive, the depths increasing as much as 10 feet, and making the placement of stone difficult.

8 & 9. Dimensions and Alignment of Channel. See map file No. R&HM 256.

10. Original cost of structures. Including government costs both structures cost $323,779.54.

11.	Unit Costs:	West Jetty:	Cost per lineal foot	$23.00 ±
			Cost per short ton	2.10 ±
		East Jetty:	Cost per lineal foot	23.00 ±
			Cost per short ton	1.95 ±

These figures are for stone in place and do not include the cost for engineering and inspection.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structures. That portion of the west jetty constructed prior to 1884 was composed entirely of large stones and was of a very permeable character. Later the voids were filled to some extent with chip stone making this portion less permeable to sand.

That portion of the west jetty constructed since 1884, and all of the East jetty was constructed with a core of small stones. This has made a compact structure and one practically sand tight.

2. Accretion or shoaling. As the west jetty was constructed shoaling began around the end and on the west side. This process has continued. A large part of the dredging necessary to keep the channel to project depth has been done in the section opposite the outer end of the west jetty and near the inner end of the channel north of the channel along Brant Point. The outer shore line has built out west of the west jetty and east of the east jetty. Coatue Point was building out from 1828 to 1885. The building of the jetties reversed this process and about 400 feet has since been eroded from the Point.

3. Erosion or scouring. Scouring in the gorge between Coatue and Brant points has been great, the tidal flow reaching velocities high enough to scour to depths of 25 feet and more. During construction the channel depth over the outer bar increased by 6 to 8 ft. at mean low water. Some protective riprap revetment was placed at Brant Point by the Lighthouse Service to halt erosion occuring at the tip. For further information refer to accompanying map File No. R&HM 256.

4. Deterioration of structures. The west jetty is in fair condition at the present time, and has suffered very little damage since construction. Maintenance of this jetty has been limited to filling the interstices between the large stones at the inner end with chipstone.

The east jetty is largely a half-tide jetty and has deteriorated badly from the effect of ice. Maintenance operations have merely repaired the damage done by storms and ice.

A total of $7210 has been spent for maintenance to the west jetty, or an average annual cost of about $225, equal to about $0.05 per lineal foot.

On the east jetty maintenance operations have totalled $109,856.04, or an average annual cost of about $3700. The annual maintenance cost per lineal foot has averaged about $0.53. These figures include government costs. It is probable that part of these costs charged to maintenance were expended in enlarging the section of part of the east jetty and should have been charged to new work.

V. CONCLUSIONS

The present structures have reasonably fulfilled their purpose of maintaining a channel into Nantucket Harbor. Before construction the controlling depth over the outer bar was about 6 ft. The channel first obtained by dredging was almost completely filled soon after its completion. Now the inner and outer bars shoal slowly and require dreding at intervals of about 5 years. During these periods the amount of shoaling averages about 3 ft. Complete freedom from dredging could not be expected to result from any change in design or construction of the present structures.

BLOCK ISLAND HARBOR OF REFUGE, R. I.

I. GENERAL

1. Location. This harbor is on the east side of Block Island. It is 13 miles south-southwest from Point Judith Harbor, R. I., and about 25 miles southeasterly from Stonington Harbor, Connecticut. (See map R.H.M. 255).

2. Type. Breakwaters.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. General description of locality. The site of the harbor was on the ocean shore, unprotected except for the shore-line of the island, which formed a partial shelter from southerly and westerly storms. There was no natural harbor on the island.

2. Nature of beach and bottom materials. The beach and bottom is composed almost entirely of sandy material interspersed with numerous boulder deposits.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Southwesterly winds prevail. (See wind chart for Block Island, map File No. R.H.M. 255).

5. Direction of prevailing storms. Prevailing storms are from the northeast and southeast.

6. Direction of prevailing littoral drift. Prevailing littoral drift along the east shore of Block Island is indicated as from southeast to northwest.

7. Tidal ranges in the harbor.

Mean 3.0 feet
Extreme 7 feet or more.

8. Direction and intensity of tidal and other currents. Tidal currents flow toward the northwest along the east shore of Block Island on the flood and toward the southeast on the ebb, and are of low velocity.

9. Effect of prevailing winds. The harbor was protected to some extent from prevailing southwesterly winds by the shore-line.

10. Effect of prevailing storms. Prevailing storms made all forms of navigation in this locality extremely perilous, as there was no harbor where boats could seek shelter.

11. Effect of tidal and other currents. Tidal and other currents had little effect.

12. Miscellaneous effects. None.

13. Reasons for the construction. Block Island is the center of an intensive fishing industry. The harbor of refuge was built to provide a safe anchorage for the fishing boats making it their home port and also for visiting craft. Before construction, boats had to be beached as a protection against storms, as there was no shelter except that provided by the island itself.

III. CONSTRUCTION.

1. Materials. The breakwaters were constructed of riprap granite. When originally built large stone was used exclusively making a very permeable structure. Later small chip stones were placed in the main breakwater as there was considerable seepage of sand through it into the harbor.

2. Method of applying materials in structure. Stone in the main breakwater, except for the detached section, later connected, was placed from cars run on tracks over the breakwater and dumped from the outer end. The basin was originally constructed to shelter government plant engaged in building the main structure.

During construction of the main breakwater it was found necessary to construct a jetty west of the main breakwater to stop the heavy waves coming in from the east which caused considerable erosion on the west side of the breakwater and deposition of sand on the east side.

The detached breakwater and the jetty were constructed by dumping stone from shallow draft lighters. The gap in the main breakwater was filled in the same manner.

3-9 Inc. Alignment, Cross sectional dimensions and side slopes, Lengths, Distance apart, Depth of water at outer ends, Dimensions and alignment of channel. See Map file NO. R&HM 258.

10. Cost of structure, original. The cost of the main or east breakwater and basin completed in 1879 was about $350,000 including Government costs.

The contract cost of filling the gap between the detached piece and the main arm was about $21,000.

The cost of the west breakwater, completed in 1893, was about $75,600.

Subsequent work of raising the breakwater and preventing sand leakage cost of dredging the original channel completed in 1906 brought the cost of original work to about $500,000.

11. Unit Cost.

East breakwater cost per long ton = $2.20±

West breakwater cost per long ton = 2.20±

Filling gap cost per long ton = 1.65±

IV. CONDITIONS AFTER CONSTRUCTION

1. Permeability of structures to sand. As originally constructed the main breakwater was built entirely of large stone. Consequently it was of a very permeable nature. The seepage of sand through and over the structure caused so much shoaling in the channel that a project was adopted in 1895 for raising the crest of the breakwater and for making it sand tight. This work was completed in 1908. Repairs were made in 1933 and 1935 to reduce the permeability of the east breakwater.

2. Accretion or shoaling. The shore-line between the east and west breakwaters has built out appreciably and some shoaling is taking place along the sides of both breakwaters and around the end of the west breakwater.

Shoaling in the channel has been great enough to make dredging necessary about every third year in order to maintain a depth of 15 feet at mean low water.

3. Erosion or scouring. There has been some erosion of the shoreline on the east side of the east breakwater. After the permeability of the east breakwater was reduced in 1935 the shore line built out immediately to the east of it. Local interests have constructed short jetties on the stretch of beach southeast of the harbor to check extensive erosion.

4. Deterioration of structures.

a. Block Island is subject to severe northeasterly storms. These storms have caused considerable deterioration of the structures. During construction winter storms caused settlement of as much as three feet along the outer portion of the structure.

b. Maintenance costs have been heavy. Considerable work has been done toward making the main breakwater impermeable and in raising the crest. At the present time the structures are in good condition.

c. The average annual cost of maintenance for all the structures has been about $1670, exclusive of the cost of maintaining the channel by dredging.

d. The average unit cost of maintenance has been about $0.55 per lineal foot of structure.

e. There was no harbor at Block Island previous to the construction of the present harbor of refuge.

V. CONCLUSIONS.

1. Have structures completely fulfilled their purpose? The building of the breakwaters has afforded an excellent shelter for the fishing boats on the east side of the island.

2&3. There has been no failure of the structures to fulfill the purpose for which they were constructed.

4. What changes might have made the structures more successful or more economical? As originally proposed and constructed the project contemplated the construction of the east breakwater as a protection against easterly storms. Later is was found necessary to extend this breakwater and to build a breakwater to the west to form a large interior harbor as the basin was inadequate to meet the needs of existing and anticipated commerce. Thus the harbor as finally completed was the combination of 4 separate projects. There is no reason to believe that these contingencies should have been considered prior to construction.

The costs of maintenance dredging would have been materially reduced if the east breakwater had been made sand tight originally. There has been a great deal of seepage of sand through this structure even though attempts have been made to make it impermeable.

BLOCK ISLAND, R.I. GREAT SALT POND.

I. GENERAL.

1. Location. Great Salt Pond is located near the central part of Block Island and is 12-1/2 miles southwest by south from the harbor of refuge at Point Judith and 20 miles southeasterly from Stonington Harbor, Connecticut. (See map RAHM 255).

2. Type. Jetty.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. Description of locality. The Great Salt Pond was a large pond of brackish water covering an area of 700 acres and separated from the ocean on the west side by a narrow strip of sandy beach. Its greatest depth is about 60 feet and it has an area of about 150 acres exceeding 18 feet in depth. Before the construction of the jetties, local interests had attempted to connect the pond and the sea by dredging openings through the beach at various points. None of these openings was permanent due to the steady movement of sand along the beach from the south.

2. Nature of beach and bottom materials. The beach is almost entirely sandy, and the bottom outside the pond and in the entrance is sand, gravel and clay with a few boulders.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Southwesterly wind prevail. (See wind chart for Block Island. Map file NO. RAHM 255).

5. Direction of prevailing storms. Northeast and southeast storms prevail.

6. Direction of prevailing littoral drift. The littoral current moves along the beach from south to north.

7. Tidal ranges at the entrance.

Mean 3.0 feet.
Extreme 7 feet or more.

8. Direction and intensity of tidal and other currents. Tidal currents of low velocity flow toward the west and northwest around the island on the flood. In the immediate vicinity of Great Salt Pond flood currents flow toward the entrance.

9. Effect of prevailing winds. Prevailing southwest winds cause strong littoral current along the west shore from south to north.

10. Effect of prevailing storms. Storms caused erosion along the beach.

11. Effect of tidal and other currents. Tidal currents probably had little effect on the shore line. Littoral currents moving parallel to the shore line and wave action caused some erosion along the beach.

12. Miscellaneous effects. None.

13. Reasons for the construction. The jetty was constructed to maintain an entrance into the Great Salt Pond. This structure was intended to maintain the entrance by arresting the movement of sand northerly along the beach. Without the action of the jetty, the economical maintenance of a channel connecting the Great Salt Pond with the ocean would have been impossible. It was constructed to make the Pond a harbor of refuge.

III. CONSTRUCTION.

1. Materials. Previous to the adoption of the project by the United States, the state of Rhode Island and the town of New Shoreham, R.I. had constructed 837 feet of the south jetty (completed about 1896). This section was built with a central section of sheet piling surrounded by riprap granite to secure stability. The sheet piling stopped all flow of water and sand through the jetty. Upon adoption of the work by the United States, the jetty was extended using riprap granite only. There is no central core in this extension

2. Method of applying materials in structure. That portion of the jetty constructed by the United States was done under contract with private contractors. The method of placement involved the use of scows and derrick lighters.

3. Alignment. The original project by the United States contemplated the construction of 2 parallel jetties. State and local interests had previously constructed the south jetty 837 feet long, and the north jetty 250 feet in length. Extension of the north jetty has not been commenced by the United States.

4-9 inclusive. Cross-sectional dimensions and side slopes, Lengths, distances apart, Depth of water at outer ends, Dimensions and Alignment of channel. See map file no. R&HM 259.

10. Cost of structure. The contract cost of that portion (854 feet) of the jetty built by the United States was $80,060.79.

11. Unit cost. The unit cost of construction was $93.75 per lineal foot and $1.27 per ton of stone in place.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structure to sand. As originally built, the structure contained a central strip of sheet piling extending 837 feet from shore. This piling prevented any seepage of sand through that part of the structure. The outer 854 feet, built by the United States was not sand tight, as it contained no core. Since the shore line has built out on the south side of the jetty, there has been some seepage of sand through the outer portion.

2. Accretion or shoaling. Shoaling in the channel has been due to two main causes, (1) the drifting of sand over the top of the inner portion

of the jetty, and (2) the deposition of material carried around the end of the jetty by longshore currents. Accretion along the south side of the jetty had built the high water line to 650 feet from the end of the jetty in 1935. This accretion to the shore, along the outside of the breakwater and around the end must continue so long as the sand movement continues.

3. Erosion or scouring. Erosion has occurred along the north side of the entrance cut due to the velocities attained by the tidal prism both on the flood and on the ebb. Although no detailed surveys of the shore line have been made, a study of the accompanying map shows a decided tendency for the shore line to recede along this side of the entrance channel.

The shore line north of the short jetty had eroded in the three years previous to its construction (1895) approximately 100 feet. By 1909, it had been built out to its 1892 position and has remained fairly stable for a distance of 600 feet north of the jetty since 1909.

4. Deterioration of structure. a. There has been some deterioration of the structure along the outer end. This damage has occurred in general along the south slope. The inner portion of the jetty is covered over with sand.

b. Maintenance operations have been solely to keep the structure in such condition as to reduce dredging operations.

c. The annual cost of repairs from 1900-1902 was $2,375. These funds were expended in repairing damage due to storms and settlement before proceeding with the extension of the jetty. Since the completion of the jetty in 1906 there was no maintenance until 1935 when $5,655 was spent. The annual cost of maintenance has been about $183.

d. The average annual unit cost since 1906 has been about $0.11 per lineal foot.

V. CONCLUSION

1. The present structure has fulfilled its purpose of maintaining a channel into Great Salt Pond. It has maintained an entrance which would have become closed within a short time without it. Project depth is 25 ft. in the central 150 feet.

2. Slight shoaling occurs opposite the inner and outer ends of the jetty. Practically no maintenance dredging has been done in the 25 foot channel. The 18 foot strips on each side of the 25 foot channel were redredged in 1936.

POINT JUDITH, R.I.

I. GENERAL.

1. Location. Point Judith is at the southwestern entrance to Narragansett Bay. It is about 14 miles southwest of Newport Harbor, R.I., and 33 miles east of New London Harbor, Conn. (See accompanying map File No. R&HM 255).

2. Type.

a. Detached Breakwater in V form

b. Breakwaters to the east and west connecting with the shore.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. Description. The harbor at Point Judith was exposed to storms from practically all directions. There was some shelter from northwesterly storms but not enough to warrant the use of this harbor as a refuge. The site of part of the present breakwaters is a shoal ledge, known as Squid Ledge, which extends for nearly a mile in a southeasterly direction about 1-1/2 miles west of Point Judith.

2. Nature of Beach and Bottom Materials. The whole formation at Point Judith under water and along the shore is glacial drift. At the Point the beach is composed of cobbles and boulders. Sand Hill Cove, west of the Point has a sandy beach. The bottom of the harbor is generally hard compact sand with some rocky areas. The holding bottom is poor.

3. Average Slopes of Beaches. No information as to the slope of the beach is available.

4. Direction of prevailing Winds. Prevailing winds are from the southwest, and to a slightly lesser degree, from the Northwest and Northeast. (See wind chart for Block Island, map File No. R&HM 255).

5. Direction of prevailing storms. Northeast and Southeast storms predominate, the former being more severe in this locality

6. Direction of Prevailing Littoral Drift. The littoral drift along the shore west of Point Judith moves in an easterly direction.

7. Tidal Ranges. The mean range is 3.1 feet, and the extreme range, due to the combined effect of wind and other causes is 7 feet or more.

8. Tidal Currents. Flood current moved westward along the shore and ebb current eastward.

9. Effect of Prevailing Winds. Little effect.

10. Effect of Prevailing Storms. Prevailing northeast storms probably had little effect. Southeast storms caused erosion of the beach east of the entrance to Point Judith Pond between 1882 and 1891.

11. Effect of Tidal Currents. Tidal currents had little effect on the shoreline. Littoral currents removed the material eroded from the beach by storms and wave action.

12. Miscellaneous Effects. None.

13. Reasons for the Construction. The main breakwater was constructed to provide a harbor of refuge. The easterly breakwater was constructed "with a view of providing a shelter for a landing place for the passengers, crew, and cargoes of vessels in distress, and other vessels, and for the lifeboats of the Point Judith life saving service." (Extract from Act of June 13, 1902).

The westerly breakwater was constructed in 1914 to prevent sand movements along the coast and provide more protection to the harbor.

III CONSTRUCTION

A. Main Breakwater.

1. Materials. The main breakwater is composed of riprap granite. It has a core of stones exceeding 200 pounds each. The facing of the breakwater is approximately 10 feet thick and is composed of stones exceeding 3 tons each.

2. Methods of Placement. This breakwater was built in part on Squid Ledge. All stone was placed under a continuing contract by private contractors, using scows and derrick lighters. The breakwater was built up gradually by dumping the stone. The slope and cap stones were placed singly with derricks.

3-9, inc. Alignment, etc. See Map File No. R&HM 257.

10. Cost of Structure, original. The main breakwater cost, exclusive of engineering and inspection, $1,194,407.37. Engineering expenses totalled $52,410.62 including $14,500 expended on government plant and expenses incidental to the maintenance of beacons. The total cost of the breakwater completed in 1902 was $1,246,817.99.

11. Unit Cost. The total length of the breakwater is 6,970 feet. The average unit cost per lineal foot was about $179. The breakwater was built under a continuing contract at a unit price of $1.27875 per short ton of stone in place. Including all expenses, the cost per ton of stone in place was $1.40.

B. East Shore Arm.

1. Materials. This breakwater is composed of the same materials as the main breakwater with one exception. The core is composed of stones weighing over 50 pounds each.

2. Method of Placement. The method of placement was the same as for the main breakwater. This breakwater was not built under a continuous contract. It was completed in 1906.

3-9, inc. Alignment, etc. See Map File No. R&HM 257.

10. Cost of Structure, original. The total cost of this structure was $532, 145.12 including engineering and inspection costs of $42,126.52.

11 Unit Cost. The east shore arm is 2,240 feet long. The cost per lineal foot was about $238. The cost of stone per short ton averaged $2.30 in place including all expenses.

C. West Shore Arm.

1. Materials. This breakwater is composed of riprap granite with a core of run of the quarry stone.

2. Method of Placement. The method of placing the stone was similar to the method used for the other structures. The west shore arm was completed in 1914.

3 to 9, inc. Aligment, etc. (See Map File No. R&HM 257).

10. Cost of structure, original. The west shore arm, including engineering and inspection, cost $558,518.01. The cost exclusive of engineering and inspection was $509,877.40.

11. Unit Cost. The west shore arm is 4,200 feet long. Unit costs were about $133 per lineal foot and $1.89 per ton of stone in place.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structure. All of these structures are impermeable to sand. The west shorearm is particularly impermeable as it has a core composed of run of the quarry stone. This type of stone contains enough small stone to fill the voids between the larger stone.

2. Accretion or shoaling. Previous to the construction of the west shorearm there was considerable accretion on the shore immediately east of the entrance to Point Judith Pond. This accretion was diminished considerably by the construction of the impermeable west shorearm.

There has been considerable accretion along the west side of the west shorearm, and some accretion along the east side of the east shorearm.

Shoaling has occurred inside the main breakwater near the apex of the V.

3. Erosion or Scouring. There appears to have been slight scouring between the ends of the breakwaters. Erosion has also occurred on the shore for a short distance immediately to the east of the entrance to Point Judith Pond.

4. Deterioration of structures.

a. The main breakwater is exposed to the force of the wind and waves. The eastern arm has been damaged by the waves breaking over the top during heavy storms. The western arm, not built to full cross section has remained in good condition. The east shorearm breakwater is damaged by wave attack, while the west shorearm suffers only slight deterioration.

b. The greater proportion of the maintenance operations to these structures have been to keep the east arm of the main breakwater and the east shore arm breakwater in good repair. The replacing of cap stones, filling of gaps caused by wave action, and the repair of slopes has been necessary.

c. The average annual cost of maintenance i.e. actual repairs to the structures, has been (1) for the main breakwater about $10,800. (2) for the east shore arm about $760. No repairs have been necessary on the west shore arm.

d. The average annual unit cost of maintenance has been about $1.50 per lineal foot for the main breakwater and about $0.35 per lineal foot for the east shore arm.

V. CONCLUSIONS.

1. The structures have provided a sheltered harbor of refuge at Point Judith. The harbor has poor holding ground for large vessels. A total of 850 vessels of all types sought refuge here in 1936.

2. The west shore arm has greatly decreased the accretion to the shoreline. This accretion is continuing but at a lesser rate.

3. Maintenance expenditures for the main breakwater have totalled nearly one-third of the original cost, due to its exposed position.

4. There are no evident changes in design or construction which would have accomplished better results.

CONNECTICUT RIVER, CONNECTICUT

Saybrook Outer Bar

I. GENERAL

1. Location. The Connecticut River has its source in Connecticut Lake in northern New Hampshire, flows southerly about 380 miles, and empties into Long Island Sound at Saybrook, Conn., 14 miles west of New London, Conn. (See accompanying map File No. R&HM 255).

2. Type. Riprap jetties.

II. CONDITIONS PRIOR TO CONSTRUCTION

1. Description of locality. Before improvement by the United States, the limiting depth over Saybrook Bar was 7 feet at mean low water. There were three channels, the west channel adjacent to Lynde Point being used almost exclusively for navigation.

The bar channel was constantly changing, and a large amount of sediment was deposited on the bar both by the river currents and by the littoral drift in the Sound. Numerous attempts were made to form a channel over Saybrook Bar by dredging. Dredging was necessary annually to maintain any depth over 7 feet at mean low water.

2. Nature of beach and bottom materials. Lynde Point was almost entirely marsh land overlying glacial drift and surrounded by a strip of sandy beach. The bed of the river was composed of mud, hard compacted sand, and some gravel.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Northwest. See wind chart for New Haven, Conn., on map File No. R&HM 255.

5. Direction of prevailing storms. Northeast and southeast storms prevail.

6. Direction of prevailing littoral drift. The littoral drift is said to have been from east to west at the mouth of the river.

7. Tidal ranges at Lynde Point.

Mean 3.6 feet
Extreme 8 feet or more.

8. Direction of tidal and other currents. There is a large tidal flow in Connecticut River. Current in the river is northerly on the flood and southerly on the ebb during summer stages. During large freshet flows the current at the mouth is always in the ebb direction and has considerable strength. The flood current at the mouth comes from a southeasterly direction.

9-10. Effect of prevailing winds and storms. Probably increased shoaling.

11. Miscellaneous effects. Freshets on Connecticut River decreased flood currents, increased ebb currents and brought considerable sediment which shoaled the entrance.

12. Reason for the construction. The jetties were constructed to stabilize the entrance channel and to assist dredging work in maintaining a depth over the outer bar sufficient for the needs of navigation.

III. CONSTRUCTION

A. West jetty.

1. Materials. Riprap granite of large size.

2. Method of applying materials in structure. As originally constructed the west jetty had a triangular cross section. This was built by the deposit of stone from sloops and lighters. The cross section was completed in the same manner by contract in 1914.

3-9. Alignment, cross sectional dimensions and side slopes, length, distance apart, depth of water at outer ends, dimensions and alignment of channel. (See map File No. R&HM 260).

10. Cost of west jetty, original. About $95,000.

11. Unit cost. Average unit cost was about $40.00 per lineal foot. The unit cost of stone varied from $1.23 to $2.23 per ton in place.

B. East jetty.

1. Materials. Granite riprap of large size, with a partial core composed of run of the quarry stone.

2. Method of applying material in structure. This jetty was built as a whole by depositing stone along the entire length and gradually building it up to a triangular cross section. Later the east jetty was extended in the same manner and the cross section increased from the original triangular shape.

3-9. Alignment, cross section dimensions and side slopes, length, distance apart, depth of water at outer ends, dimensions and alignment of channel (see map File No. R&HM 260).

10. Cost of structure original. About $76,000.

11. Unit cost. The average unit cost was about $30.00 per lineal foot.

The unit cost of stone varied from $1.05 to $1.59 per ton in place.

The east jetty was constructed in shoaler water than the west jetty.

IV. CONDITIONS AFTER CONSTRUCTION

1. Permeability of structures to sand. The east jetty as originally constructed was a riprap granite mound. A partial core composed of quarry grout was added when the cross section was increased. There is no excessive sand movement through either jetty.

2. Accretion or shoaling. There is appreciable shoaling between the jetties near the inner and outer ends of the channel. This requires dredging every five or six years to maintain a depth of 15 feet at mean low water. The shore-line has been built out along both sides of the west jetty at its inner end.

3. Erosion or scouring. There has been no noticeable erosion or scouring on the shore-line due to these structures.

4. Deterioration of structures.

<u>a</u>. As originally constructed, due to lack of available funds, the jetties had a triangular cross section side slopes of about 1 on 1. They were completed to this cross section in 1887 and no work was done on the jetties until 1904. By this time, deterioration, due to settlement and wave action, had so reduced the jetties that they not only lacked structural strength, but also were of very little aid in maintaining the channel between them. Repairs were made without enlarging

the cross section t project dimensions. In 1914 th est jetty was completed to project dimensions. It has remained in good repair. The outer reach of the east jetty was brought to full section in 1935. It is in good repair.

b. The average annual cost of maintenance of the structures since 1915 has been about $780.00 for the east jetty and about $160.00 for the west jetty.

c. The average annual unit cost of maintenance has been about $0.35 per lineal foot for the east jetty and $0.10 per lineal foot for the west jetty.

d. Average cost of maintenance before construction is not readily obtainable from old data. If obtained the comparison would be of doubtful value because of the difference in project depths of the channel.

V. CONCLUSIONS

1. Have structures completely fulfilled their purpose? The structures have aided in maintaining a channel over the outer bar. They have provided a sheltered entrance into the Connecticut River, and made it possible to maintain a navigable channel across the outer bar at a much lower annual cost for dredging than otherwise would have been possible.

2. In what way, and to what degree have they failed? The structures have failed to provide sufficient scouring action to permanently maintain the channel between them to a depth of 15 feet at mean low water. The channel must be maintained by dredging every five or six years.

3. What causes may be assigned for the failure? The present project of 15 feet was not authorized until 1911, or 39 years after the design for the jetties had been approved. The design of the jetties contemplated the maintenance of a channel of only 12 ft. They have reasonably fulfilled this purpose.

4. What changes might have made the structures more economical? The structures might have been more economical to construct if they had been built to full projected cross section originally. Lack of funds at the time of construction made this practically impossible. It is doubtful that any structures built at a comparable cost could have completely removed the need for periodical dredging on the outer bar.

DUCK ISLAND HARBOR OF REFUGE

I. GENERAL

1. Location. Duck Island Harbor is a small bay on the north shore of Long Island Sound about 23 miles east of New Haven, Conn., and 7 miles west of the mouth of the Connecticut River. (See map File No. R&HM 255).

2. Type. Breakwaters

II. CONDITIONS PRIOR TO CONSTRUCTION

1. Description of locality. In its original condition, practically no shelter was afforded by this harbor in winds from the east around through the south to the west. Good protection was afforded from all northerly winds. The depths in the bay were adequate for anchorage.

2. Nature of beach and bottom materials. The beach in this locality is a sandy one from 300 to 500 ft. wide above mean high water. The bottom is generally of soft material with scattered rocky outcrops off Menunketesuck and Kelsey Points. These rocky spots on the most part are at a depth such as to be of no hindrance to navigation.

3. Average slopes of beaches. This information is not available.

4. Direction of prevailing winds. Northwest. See wind chart for New Haven on map File No. R&HM 255.

5. Direction of prevailing storms. Prevailing storms come from the east.

6. Direction of prevailing littoral drift. The direction of the prevailing littoral drift in the Harbor appears to have been eastward.

7. Tidal ranges.

Mean 4.2'
Extreme 9 feet or more.

8. Direction and intensity of tidal currents. The tidal current sets approximately parallel to the shore. Flood current moves westward, and the ebb current moves eastward.

9-10. Effect of prevailing winds and storms. Effect on adjacent shorelines not known.

11. Effect of tidal and other currents. Tidal currents had little effect on adjacent shore-lines.

12. Miscellaneous effects. None.

13. Reasons for construction. These structures were built solely

for the purpose of forming a harbor of refuge. There is no commercial activity in this harbor.

III. CONSTRUCTION

A. Duck Island West breakwater, built 1891-1898.

1. Material. Granite riprap.

2. Method of placing. The stone was placed by depositing from sloops, schooners and lighters.

3-9. Alignment, cross sectional dimensions and side slopes, lengths, depth of water at outer ends. See map File No. R&HM 261.

10. Cost of structure original. About $115,000.

11. Unit cost. About $0.95 per long ton or $43.00 per lineal foot.

B. Duck Island North breakwater, built 1911-1912.

1. Materials. Granite riprap.

2. Method of applying materials in structure. This breakwater was built by purchasing stone delivered at the site, and rehandling it with a steam lighter, using a light draft derrick scow for the shoaler portion of the work. This breakwater was constructed with government plant using hired labor.

3-9. Alignment, cross sectional dimensions and side slopes, lengths, distance apart, depth of water at outer ends, dimensions and alignment of channel. See map File No. R&HM 261.

10. Cost of structure original. About $26,600.

11. Unit cost. About $1.40 per long ton or $24.00 per lineal foot.

C. Kelsey Point Breakwater, built 1912-1914.

1. Materials. This breakwater is composed of 40% Connecticut River brownstone, and 60% granite.

The brownstone was used principally as a foundation and deposited under water. The granite was used on the slopes and for facing purposes, although the use of brownstone for capping purposes was allowed.

2. Method of applying materials in structure. The breakwater was built by depositing and placing stones from schooners and lighters.

3-9. Alignment, cross sectional dimensions, and side slopes, length, depth of water at outer ends. See map File No. R&HM 261.

10. Cost of structure original. About $250,000.

11. Unit cost About $1.05 per long ton or $61.00 per lineal foot.

IV. CONDITIONS AFTER CONSTRUCTION

1. Permeability to sand. These structures are fairly permeable. No effort was made to construct them sand tight.

2. Accretion or shoaling. There has been considerable shoaling in the angle formed by the two structures at Duck Island. Periodical dredging is required to keep the harbor to project depth. (16 ft.)

3. Erosion or scouring. The whole beach has been subject to erosion for a number of years. Local interests have constructed a number of small jetties and walls along the beach in an attempt to arrest further erosion and to force the shore line to build out to its original condition.

On the west side of Kelsey Point local interests have constructed short jetties as serious erosion has been taking place in this section. There has been no recent survey of this section to determine what change has taken place in the shore line since 1915.

4. Deterioration of structures.

a. The Duck Island West breakwater settled considerably during construction and had to be partially rebuilt. Settlement was due to soft bottom material. This breakwater is subject to considerably more deterioration than the other two, due to its exposure to southerly storms.

b. Various maintenance operations have been undertaken since construction, mainly to the west breakwater at Duck Island.

c. A total of $46,940 has been spent for maintenance of the breakwaters at an average annual cost of $2040.

d. Unit cost of maintenance has averaged about $6.50 per lineal foot repaired, or about $4.15 per long ton of stone. The annual unit cost of maintenance for the entire project has average about $0.25 per lineal foot.

V. CONCLUSIONS

1. The improvement affords shelter for the passing commerce of Long

Island Sound, adding materially to the safety thereof.

2. There are no evident changes in design or construction which would have produced more satisfactory conditions.

NEW HAVEN HARBOR, CONNECTICUT

Sandy Point Dike

I. GENERAL

1. Location. On the north shore of Long Island Sound about 71 miles east of New York City. The harbor consists of a bay about 4 miles long and from 1 to 4 miles wide. Mill and Quinnipiac Rivers enter at the northeast corner of the harbor. West River enters the west side of the harbor north of Sandy Point. (See accompanying map File No. R&HM. 255).

2. Type. Dike and training wall.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. General description of locality. Sandy Point is a long sand spit extending easterly from the west side of the harbor opposite Fort Hale. There was very little change in its shape prior to the construction of the dike, although its position had changed considerably between 1872 and 1886.

2. Nature of beach and bottom materials. The beach is composed mainly of sandy material. The bottom in this vicinity, as determined prior to the construction of the dike, was mud to a depth of about 25 feet below mean low water overlying a stratum of sand.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Northwesterly winds prevail. (See wind chart for New Haven, Connecticut, on map File No. R&HM. 255).

5. Direction of prevailing storms. Prevailing storms are easterly.

6. Direction of prevailing littoral drift. The littoral drift is said to have been westward at the entrance of the harbor.

7. Tidal ranges.

Mean	6.3	feet
Extreme	10	feet or more.

8. Direction and intensity of tidal and other currents. The direction of the tidal currents in the inner harbor is northerly on the flood and southerly on the ebb. Flood currents flow northwesterly from the Sound into

the outer harbor turning northeasterly toward Sandy Point when they reach the west shore.

There is some fresh water inflow, but its effect is of minor importance.

9. Effect of prevailing winds. Prevailing winds had little effect in the inner harbor.

10. Effect of prevailing storms. Prevailing storms decreased the action of the ebb tide in removing material from the inner harbor, and thus, with the aid of high waves induced by these storms, increased the deposition in the inner harbor.

11. Effect of tidal and other currents. Both flood and ebb currents carry material in suspension.

12. Miscellaneous effects. The dumping of sewage in the harbor may have caused some deposition on the bar below Fort Hale.

13. Reasons for the construction. Sandy Point Dike was constructed to contract and direct the tidal flow over Fort Hale Bar in order to maintain the dredged channel over the bar.

III. CONSTRUCTION

1. Materials. 1294 feet of the inner end of the shore arm are of riprap. The outer part of the shore arm and 254 feet of the north end of the channel arm are built of 2 rows of creosoted piling, 8 feet apart, filled with riprap; 1815 feet of the channel arm south of the pile work are of riprap construction, of which the north 273 feet are on a log foundation. At the north end of the channel arm is an ice breaker, 20 feet long, of heavy riprap on a log foundation.

4. Cross sectional dimensions and side slopes. That portion of the dike built of riprap is of triangular cross section with side slopes of about 1 on 1. The remainder of the dike is of pile and riprap construction 8 feet wide with vertical sides. Both were built to a height of 5.25 feet above mean low water.

5-9 inc. Length, depth of water at outer ends, dimensions and alignment of channel. See map file No. B&HM. 262.

10. Cost of structure, original. Cost exclusive of engineering and inspection was $57,174.

11. Unit cost. Log foundation cost $6.10 per lineal foot. Pile and riprap construction cost $21.83 per lineal foot. The average cost of riprap construction was $9.88 per lineal foot. The average cost of riprap was $1.16 per ton in place.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structures to sand. This structure is permeable to sand, but there is no evidence of sand movement through it.

2. Accretion or shoaling. The high water line at Sandy Point has built out northward from the dike in a long spit. Its eastward extension has totalled almost 140' since 1886 immediately below the dike.

The low water line has been more permanent except west of the dike where some shoaling has occurred. (See accompanying map File No. R&HM. 262).

3. Erosion or scouring. There has been no erosion immediately adjacent to the structures. Sandy Point itself has been in the past and still is of unstable character.

In the channel, there has been no scouring. All depths were attained by dredging. The structure caused a reduction in the amount of material deposited on the bar.

4. Deterioration of structure. There have been no maintenance operations on Sandy Point dike since its completion. There has been some settlement of the riprap section and some degradation of top stones due to ice pressure.

Piles show worm attack and scarification by ice. The cross section is still ample and efficient.

V. CONCLUSIONS.

Sandy Point dike and training wall has decreased the width of the waterway between Sandy Point and Fort Hale sufficiently to lessen the deposition of material on the bar. The structure has been reasonably successful in accomplishing its purpose. There are no evident changes in design or construction which would have produced better results.

MILFORD HARBOR, CONNECTICUT.

I. GENERAL

1. Location. Milford Harbor is on the north shore of Long Island Sound about 8 miles west of New Haven Harbor. (See accompanying map File No. R&HM. No. 255).

2. Type.

2 stone jetties

12 stone jetties for shore protection on east shore of Harbor northwest of Welch's Point (not shown on map - location indefinite).

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. General description of locality. Milford Harbor consists of a broad open bay, the Wepawaug River, a small tidal stream, extending about three-quarters of a mile north to Milford; and the Indian River, another small tidal stream, extending northeasterly. The mouth of the Indian River is partly closed by a dam formerly used to create power for a tide mill.

The original depth on the bar immediately outside the mouth of the river was 2 feet at mean low water, and in some places between this bar and the Town Wharf, the channel was nearly bare at low tide.

Erosion of the east shore of the outer harbor, caused by southerly storms, was the predominant cause of the bar in the upper harbor.

2. Nature of beach and bottom materials. The beds of the rivers are composed of clayey mud, while just outside their mouths is a broad flat sand bar. Both sides of Wepawaug River are composed of tidal marshland. The east shore of the outer harbor is a gravelly beach with some rocky material.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Northwesterly and southwesterly winds prevail. (See wind chart for New Haven, Connecticut, on map File No. R&HM. 255).

5. Direction of prevailing storms. Southeasterly storms prevail.

6. Direction of prevailing littoral drift. The littoral drift moves northwesterly up from Welch's Point and then across the mouth of the river taking a westerly direction.

7. Tidal range at Burns Point.

Mean 6.2 feet
Extreme 10 feet or more.

8. Direction and intensity of tidal and other currents. The flood current passes westward in Long Island Sound and flows along the east shore of the Milford Harbor in a northwesterly direction. The ebb tide reverses this direction.

There is very little fresh water flow into Milford Harbor. The Wepawaug River is a tidal stream, and the fresh water flow in Indian River is so slight as to be practically negligible.

9-10. Effect of prevailing winds and prevailing storms. Prevailing winds and prevailing storms from a southerly direction caused erosion along the east side of the outer harbor in the vicinity of Welch's Point. This material moved northerly on the flood tide and was deposited on the outer bar. The force of the ebb tide was insufficient to remove it.

11. Effects of tidal and other currents. The effect of the tidal currents was to increase the deposition of material in the outer harbor and to aid in the erosion of the east shore.

12. Miscellaneous effects. None.

13. Reasons for the construction. The shore protection on the east shore at Welch's Point was intended to prevent the continuous erosion of the bank and the movement of material up the harbor.

The long jetty below the mouth of Indian River was constructed to prevent the filling in of the channel by sand brought along the shore and to direct the tidal current into the dredged channel.

The Burns Point jetty was intended to modify the direction of the tidal currents so as to conduct them along the excavated channel and to prevent the erosion of the west bank immediately below Burns Point.

III. CONSTRUCTION.

1. Material. The material used for nearly all the original jetty work was stone picked up along the beach and placed by day labor.

2. Method of applying material in structures. All of the jetty work was done by day labor. The placement of stone was done by hand except for the larger pieces which were placed with a derrick from shore. A small portion of the stone in the outer ends was placed from derrick scows.

3. Alignment. All jetties are straight.

4. Cross sectional dimensions and side slopes.

a. Short jetties along Welch's Point.

These jetties were of triangular cross section, about 9 feet in height above mean low water with side slopes of about 1 on 1.

b. Long jetty below Indian River.

This jetty is 10-1/2 feet high, above mean low water, 6 feet wide on top with side slopes of 2 on 3 on the outer side, and 1 on 1 on the inner side.

c. Burns Point jetty.

This jetty is of triangular cross section, with height of 7 to 8 feet above mean low water, and side slopes of 1 on 1.

5. Lengths.

a. Short jetties along Welch's Point.

These jetties varied from 100 to 130 feet in length.

b. Long jetty. Built in reduced section in 1875, completed in 1892.

This jetty is 510 feet in length.

c. Burns Point jetty, completed in 1879.

The jetty at Burns Point is 350 feet long.

6. Distance apart.

The jetties for the protection of the east shore of the harbor were placed about 100 feet apart.

The long jetty and the jetty at Burns Point are approximately normal to each other and 280 feet apart.

7-9. Depth of water at outer ends, dimensions and alignment of channel. See map File No. R.H.M. 263.

10. Cost of structures original.

a. Jetties for shore protection, completed 1874.

Total cost: $5,000 for 12 short jetties, or about $400 each.

b. Long jetty.

Cost: about $6,000.

c. Burns Point Jetty.

Coast: about $1500.

11. Unit cost.

a. Jetties for shore protection.

About $3.60 per lineal foot, or about $1.30 per ton in place.

b. Long jetty.

About $11.00 per lineal foot, or about $1.40 per ton in place.

c. Burns Point jetty.

About $4.30 per lineal foot or about $1.65 per ton in place.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structures to sand. All of the structures were fairly permeable to sand although there has been but little seepage through them.

2. Accretion or shoaling. The shoaling of the outer harbor, due to the littoral drift along the east shore, was arrested to some extent by the short protective jetties which prevented erosion in this locality.

Shoaling occurs around the end of the long jetty, but this process is not great enought to be serious.

Shoaling in the channel, noticeable before the construction of the Burns Point jetty, has been decreased appreciably.

3. Erosion or scouring. Erosion along Welch's Point has been checked due to the construction of 12 short jetties.

Currents between the end of the long jetty and Burns Point jetty are sufficient to prevent excessive deposition in the channel.

4. Deterioration of structures.

<u>a</u>. Storms have caused considerable damage to the protective jetties along Welch's Point. The other two jetties have not deteriorated greatly, and are in fair condition at the present time.

<u>b</u>. Slight repairs were made to the jetties along the east shore shortly after their construction. Their locations are now not clearly defined.

The long jetty at the mouth of Indian River was built out to projected cross section in 1892. The repairs done at this time were directed in increasing the side slopes on the outer side from 1 on 1 to 2 on 3.

<u>c</u>. Average annual cost of maintenance.

The average annual cost of maintenance for the long jetty has been about $60.00.

The costs of maintenance on the short jetties is not available. This sum would be very low. So far as is known, no repairs have been made to the Burns Point jetty.

<u>d</u>. Average annual unit cost of maintenance.

The average annual cost of maintenance for the long jetty has been about $0.10 per lineal foot.

The cost per ton of stone in 1892 for repairs to the long jetty was $2.50.

<u>e</u>. Average annual unit cost of maintenance, before and after construction.

There were no operations in Milford Harbor previous to the construction of the jetties.

V. CONCLUSIONS.

1. Have structures completely fulfilled their purpose? The structures checked erosion along the east shore of the harbor and lessened the deposition of material on the bar.

2. & 3. Not applicable.

4. What changes might have made the structures more successful or more economical? No suggestions.

HOUSATONIC RIVER, CONNECTICUT

I. GENERAL

1. Location. The Housatonic River rises in northwestern Massachusetts, flows southerly 130 miles through Massachusetts and Connecticut, and empties into Long Island Sound at Stratford, 5 miles east of Bridgeport Harbor (See accompanying map File No. R&HM 255).

2. Type.

a. Breakwater

b. Dike

II. CONDITIONS PRIOR TO CONSTRUCTION

1. General description of locality. The original depth on the bar across the mouth was 4 feet at mean low water.

Above the mouth, the river flows through alluvial flats and marshes.

The mouth of the river had a main channel and a lesser channel, thus lessening the scouring effect of the tidal flow.

2. Nature of beach and bottom materials. The bottom at the mouth is composed of a non-erodible compact gravel. Above the mouth, the bottom is generally sandly. Milford Point is a sand spit. The shore, in general, is glacial material.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. Northwesterly and to a slightly lesser degree southwesterly winds prevail. (See wind diagram for New Haven, Conn., map File No. R&HM 255).

5. Direction of prevailing storms. Southerly and easterly storms prevail.

6. Direction of prevailing littoral drift. The prevailing littoral drift is from east to west except that from Stratford Point to Crimbo Point the drift is northerly.

7. Tidal ranges.

Mean 6.4 feet at the mouth
5.4 feet at Stratford

Extreme 11 feet or more at the mouth diminishing towards the head.

8. Direction and intensity of tidal and other currents. Flood current flow northwesterly into mouth of river and ebb current reverses this direction.

Spring freshets reduce flood and increase ebb currents.

9-10. Effect of prevailing winds and prevailing storms. Prevailing winds and storms tended to change the shape of Milford Point and to shoal the outer bar.

11. Effect of tidal and other currents. Tidal currents were insufficient to prevent shoaling on the inner and outer bars.

12. Miscellaneous effects. None.

13. Reasons for the construction. The breakwater was constructed to aid in the maintenance of the bar at the mouth and to protect the channel from littoral drift moving in a westerly direction.

Stratford dike was constructed to concentrate the flow of the river into one fixed channel.

III. CONSTRUCTION

a. Breakwater

1. Materials. The breakwater was built of riprap granite and New York gneiss, no attempt being made to obtain any uniform proportion.

2. Method of applying materials in structure. The stone was placed from light draft lighters.

3-9. Alignment, cross sectional dimension and side slopes, length, depth of water at outer end, dimensions, and alignment of channel.

(See map File No. R&HM 264).

10. Cost of structure, original. The breakwater was completed in reduced section in 1895 at a total cost of about $73,000.

11. Unit cost.

Cost per lineal foot was about $13.00.

Cost per ton in place was about $1.30.

b. Stratford Dike

1. Materials. Riprap construction. Outer 700 feet built on a layer of quarry grout and main structure contains quarry grout also.

2. Method of applying materials in structure. All stone was placed from shallow draft lighters.

This dike was built in sections at various times. The first section to be completed in 1893 was 555 feet in length. It was extended 365 ft. in 1908 and completed to its present length of 1255 feet in 1916.

3-9. Alignment, length, depth of water at outer ends, dimensions and alignment of channel. (See map File No. R&HM 264).

10. Cost of structure, original. About $25,000 for 1255 feet.

11. Unit cost. The cost per lineal foot was about $20.00.

The cost per ton of stone in place was about $1.60.

IV. CONDITIONS AFTER CONSTRUCTION

a. Breakwater

1. Permeability of structure to sand. This structure is built entirely of large size stone. It is permeable to sand.

The inner portion of the breakwater is below high tide level, and some sand is washed over the top of the structure.

2. Accretion or shoaling. Littoral drift causes some sand to be carried around the end of the breakwater and deposited on the outer bar.

Milford Point has elongated and is now approximately parallel to the channel at the outer end.

3. Erosion or scouring. There has been enough scouring power induced by the breakwater to maintain a fairly constant depth over the outer bar.

Some scouring has occurred around the outer end of the breakwater. This has not been excessive.

Immediately following construction, a break was formed in the inner arm where it crossed an old natural channel. After repairs were made, no more trouble was experienced at this point.

4. Deterioration of structure.

a. The breakwater as originally completed in 1895 was in greatly reduced section. Consequently, it was structurally weak. Much damage was caused by ice and southerly storms.

b. Maintenance operations have been extensive. The breakwater has been strengthened, raised, and widened between 1897 and 1915 bringing it to its present cross section as shown. Repairs were made again in 1935. Although it never was built to the proposed dimensions, it is strong enough to withstand the effects of ice and storms.

c. The average annual cost of maintenance since 1895 has been about $1280.

d. The average annual unit cost of maintenance has been about $0.25 per lineal foot.

e. The average annual unit cost of maintenance before and after construction cannot be readily determined.

b. Stratford dike

1. Permeability of structure to sand. The dike is permeable to sand, but there is very little sand movement through it.

2. Accretion or shoaling. The dike's function is primarily that of a training wall. There has been little shoaling in the channel near this structure.

3. Erosion or scouring. The dike has concentrated the flow of the river in one channel and decreased the deposition so that dredging operations in this vicinity have been materially reduced.

4. Deterioration of structure. There has been only slight deterioration of the structure. It is in fair condition at the present time.

There have been no maintenance operations on the dike.

V. CONCLUSIONS

1. a. Since the completion of the breakwater, the shoaling of the channel west of the breakwater has been reduced. Slight shoaling occurs in the channel near the outer end of the breakwater.

b. The Stratford dike has been very successful in its operation.

2. The original completion of the breakwater to greater structural strength would have reduced maintenance operations but would have had only a minor influence upon its effectiveness.

BRIDGEPORT HARBOR, CONN., OUTER HARBOR.

I GENERAL.

1. Location. Bridgeport Harbor is on the north shore of Long Island Sound about 57 miles east of New York City. (See accompanying map File No. R&HM 255).

2. Type.

a. 2 converging breakwaters at entrance.

b. Inner breakwater.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. Description of locality. Bridgeport Harbor consists of an outer main harbor about 2,500 feet long and 4,000 feet wide. The minimum low water depths on the bar at the entrance was 5 feet.

Long Beach, on the eastern side of the harbor, had been extended northward in the face of the current coming out of Lewis Gut channel on the ebb tide, until the channel had been curved to the northward. Meanwhile, the mainland on the north side of this channel had been considerably eroded.

2. Nature of beach and bottom materials. Long Beach is a sand spit. The bottom was composed of sand and coarse gravel and mud in the inner bar and mostly sand in the outer bar.

3. Average slopes of beaches at various points. This information is not available.

4. Direction of prevailing winds. From available information, northwest winds prevail. (See wind diagram for New Haven, Conn., on Map File NO. R&HM 255).

5. Direction of prevailing storms. Easterly storms prevail.

6. Direction of prevailing littoral drift. The prevailing littoral drift is from east to west.

7. Tidal ranges at entrance.

Mean 6.4 feet.
Extreme 11 feet or more.

8. Direction and intensity of tidal and other currents. The ebb current emitting from Lewis Gut forced the ebb tide coming down from the inner harbor to the west side of the main entrance in a southwest direction until it met the ebb tide in the Sound, when the resultant of these currents assumed a southward direction.

9. Effect of prevailing winds. Unknown.

10. Effect of prevailing storms. Prevailing easterly storms in Long Island generally cause an increase in the height of the flood tides and increase the erosive power due to wave action. At Bridgeport southerly and easterly storms increased the carrying power of the longshore currents along Long Beach.

11. Effect of tidal and other currents. The ebb tide running out of Bridgeport Harbor in a southwesterly direction kept the depth fairly permanent on the westerly side, probably due to its failure to deposit on this side. The current was spread over such a large area that there was little or no scouring effect.

The current of the flood tide ran northwesterly along Long Beach. This longshore current carried sand and other material along the beach and probably deposited some sand along the north tip at the entrance to Johnsons River.

12. Miscellaneous effects. None.

13. Reasons for the construction. The outer breakwaters were constructed to provide a permanent channel into Bridgeport Harbor, and to decrease the necessity for annual dredging after the required depth over the outer bar had been attained. They were also built to provide protection from storms.

The inner breakwater at Tongue Point was built to protect the inner harbor and to make the channel more permanent by concentrating the tidal action of the ebb current from the inner harbor and its tributaries.

III CONSTRUCTION

A. East Breakwater completed 1906.

1. Materials. Of riprap granite construction, stones averaging 1-1/4 tons each with none less than 1/4 ton. The portion completed in 1873 has a foundation of very large flat sone.

2. Method of applying materials in structure. Stone was deposited from lighters.

3-9, inc. Alignment, cross sectional dimensions and side slopes, lengths, distance apart, depth of water at outer end, dimensions and alignment of Channel. See Map File No. R&HM 265.

10. Cost of structure, original. The east breakwater cost about $90,000.

11. Unit Cost. The average cost per lineal foot was about $28.
The average unit cost per ton in place was $1.50.

B. West Breakwater, completed 1909.

1-2. Same as east breakwater.

3-9, inc. Alignment, cross sectional dimensions and side slopes, lengths, distance apart, depth of water at outer end, dimensions and alignment of Channel. See Map File No. R&HM 265.

10. Cost of structure, original. The west breakwater originally cost about $46,000.

11. Unit cost. The average cost per lineal foot was about $22.00. The average cost per ton of stone in place was $1.17.

C. Inner breakwater completed 1892, outer 350 feet removed in 1920.

1. Materials. Riprap granite.

2. Placement. Same as other structures.

3-9, inc. Alignment, cross sectional dimensions and side slopes, lengths, distances apart, depth of Water at outer end, dimensions and alignment of channel. See Map File No. R&HM 265.

10. Cost of structure original. About $12,000.

11. Unit cost. The average cost per lineal foot was about $10.

The average cost per ton of stone in place was about $1.29.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structure to sand. Some attempt was made to make these structures sand tight, but they are not essentially impermeable structures as no core was used in them.

2. Accretion or shoaling. Shoaling on the south side of the east breakwater has been steady. At the present time the high water line has been extended as much as 600 feet. This building out of the high water line along Long Beach has been apparent for some distance south of the breakwater.

On the north side of the east breakwater, the high water line has built out about the same distance namely 600 feet, but the width of this sand strip is only about 100 feet.

The longshore currents coming up Long Beach have been deflected westward along the breakwater and deposited material along its entire length.

Shoaling adjacent to the other two breakwaters is not as extensive. Some shoaling has occurred along the west breakwater on the inner side at the western end. The shore on the west side of the harbor is entirely enclosed by walls and bulkheads.

3. Erosion or scouring. The only discernible erosion or scouring due to these structures has been directed in the channels, and this may well be due to a lack of deposition rather than to any scouring effect. Whether there would have been erosion on the west shore is unknown as this entire section is protected by walls and bulkheads. House Document No. 89, 62d Cong. 1st Session contains report on condition of Long Beach.

4. Deterioration of structures.

a. The structures have shown little deterioration. No maintenance has been necessary on the inner breakwater. The outer breakwaters have been damaged somewhat by storms.

b. Maintenance operations on the outer breakwaters have repaired the slopes and replaced stones on the top damaged by storms.

c. The average annual cost of maintenance has been about $675.00 for the east breakwater and about $370.00 for the west breakwater.

d. The average annual maintenace cost per lineal foot has been about $0.20 for both breakwaters.

e. The average annual unit cost of maintenance before and after construction is not applicable.

V. CONCLUSIONS.

These structures have been quite successful. There is practically no shoaling in the harbor due to littoral drift and the outer channel has been fairly permanent since their construction. Little dredging has been required to maintain a project channel.

The east breakwater might have been constructed at a less cost if it had been built as a whole. However, as it was built originally it was adequate for the then existing needs of the harbor.

There are no evident changes in design or construction which would have produced better results.

BRIDGEPORT HARBOR, CONNECTICUT.

Black Rock Harbor

I. GENERAL

1. Location. Black Rock Harbor is on the north shore of Long Island Sound abour 2 miles west of Bridgeport Main Harbor. (See map File No. R&HM. 255).

2. Type.

a. Breakwater connecting north and south portions of Fayerweather Island.

b. Breakwater connecting Fayerweather Island with the mainland.

c. Jetties for the protection of Fayerweather Island.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. General description of locality. Black Rock Harbor is a small bay now almost entirely protected on the east by Fayerweather Island. Before any improvements were made, this island was in 2 parts, separated by a narrow strip of sand, bare at low water. Separating the island from the mainland to the northeast was a broad flat sand bar bare at low water. The island was connected to the mainland in 1885 by a breakwater over the flat in an attempt to increase the tidal flow past the west side of the island into Cedar Creek.

Before improvement, Cedar Creek extending to the northeast had a depth of from 2 to 4 feet at mean low water, and Burr Creek extending to the north was almost bare at low water.

The depth of water in the outer harbor was from 6 to 12 feet at mean low water.

2. Nature of beach and bottom materials. The upper part of Fayerweather Island was entirely sand and marsh. The lower portion was, and is gravel and boulders.

The harbor bottom is composed generally of sand and mud with some gravel, and numerous rocky outcrops opposite the south end of the island.

3. Average slopes of beaches at various points. This information is not available.

4 to 7 inc. Direction of prevailing winds and storms, direction of prevailing littoral drift, tidal ranges. See report on Bridgeport Main Harbor.

8. Direction and intensity of tidal and other currents. The flood tide swept from the southeast between and around the 2 detached portions of Fayerweather Island.

The ebb tide from high water to half tide ran between Fayerweather Island and the mainland in a southeasterly direction. The remainder of the ebb ran southerly past Fayerweather Island.

9 & 10. Effect of prevailing winds and storms. Prevailing winds and prevailing storms caused the wave action on Fayerweather Island and aided in its erosion.

11. Effect of tidal and other currents. Wave action on Fayerweather Island was gradually eroding it and tidal currents carried the sandy material westerly and northerly into the harbor and Cedar Creek. As the harbor was used considerably as a harbor of refuge the loss of protection afforded by the island was serious. Sand travel into Cedar Creek damaged the dredged channel.

12. Miscellaneous effects. None.

13. Reasons for the construction. The breakwater connecting the two detached section of Fayerweather Island was built to prevent the total destruction of the island by wave action and tidal currents.

The breakwater connecting the island to the mainland was constructed to protect the channels in Cedar Creek from littoral drift and to increase the tidal flow on the west side of Fayerweather Island.

The jetties along the west side of the island were intended to protect the island from erosion and the Cedar Creek channel from deterioration.

III. CONSTRUCTION.

A. Breakwater connecting two portions of Fayerweather Island.

1. Materials. Cobbles and small boulders, faced with larger flat stone.

2. Method of applying materials in structure. No data.

3 to 9 inc. Alignment, cross-sectional dimensions and side slopes, length, dimensions and alignment of channel. See map File No. R&HM. 266. Available data shown on map.

10. Cost of structure, original. $21,550 appropriated and spent on this structure.

11. Unit cost. Average cost per lineal foot was about $10.00.

B. Breakwater connecting Island and Mainland.

1. Materials. Riprap construction.

2. Methods of placing materials in structure. This breakwater was built from lighters.

3 to 9 inc. Alignment, cross-sectional dimensions and side slopes, lengths, dimensions and alignment of channel. See map File No. R&HM. 266. Available data shown on map. Length 2744 feet.

10. Cost of structure, original. About $13,000 as constructed. This breakwater was never completed as originally proposed. The area north and south of it has been filled for use as a city park.

11. Unit cost. The average cost per lineal foot was about $5.00. The cost per ton of stone in place was $1.22.

C. Shore protection on Fayerweather Island.

1. Material. Riprap construction.

2. Method of applying materials in structures. Placed from lighters, under contract.

3 to 9 inc. Alignment, cross-sectional dimensions and side slopes, lengths, distances apart, depth of water at outer ends. See map File No. R&HM. 267.

10. Cost of structures, original. About $7,500.

11. Unit cost. The average cost per lineal foot was about $6.50.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of structures to sand. These structures were practically sand tight.

2. Accretion or shoaling. Up to the time the short protective jetties

were built, there was practically no accretion to the shore line. Shoaling occurred in the Cedar Creek Channel.

After the construction of the jetties on Fayerweather Island some accretion began to occur along the west shore immediately adjacent to each jetty. The shoaling of Cedar Creek was materially reduced.

3. Erosion or scouring. Erosion of practically the entire shore line on the west side of Fayerweather Island occurred previous to the construction of the protective jetties in 1901.

The construction of jetties protected the shore line. At the present time the west shore is fairly stable.

Considerable erosion has taken place on the southern tip of the island. Wave action has eroded material on the east side of the island and the littoral currents have carried this material around the end of the island into the harbor. See map File No. R&HM. 266.

Insufficient data makes it impossible to determine the shore line changes since 1929.

4. Deterioration of structures.

a. The breakwater connecting the two parts of Fayerweather Island is exposed to the force of the waves from the east. Considering the age of this structure, it has withstood the effects of storms and wave action remarkably well. Some of the top stones of the structure had been displaced and some danger of its undermining was imminent up to the time of its repair in 1903. This structure is in need of repairs at the present time.

Likewise the jetties have suffered some deterioration due to wave action. Damage has consisted in displacing the top stones and undermining at the outer ends. These structures were repaired in 1907 and are in good condition.

The breakwater connecting the mainland was never completed to projected cross section as it was believed to be sufficiently strong as built. The structure is now buried under a hydraulic fill. The area is used for park purposes.

b. Maintenance operations undertaken on the breakwater connecting the two portions of the island consisted in resetting displaced face stones on the sound side, filling the interstices between them with concrete, placing a concrete toe at the foot of the slope and protecting this toe with an apron of cobbles, and protecting the rear (harbor) slope with riprap where necessary. This breakwater was extended by filling and paving a breach at its north end.

c. The average annual unit cost of maintenance has been: For the breakwater connecting the two portions of the island a total of $11,000 has been spent since 1838 at an average annual cost of about $110.00.

For the protective works: a total of $1680 for repairs at an average annual cost of about $47.00.

d. The average annual unit cost of maintenance per lineal foot of jetty has been about $0.05

3. Average annual unit cost of maintenance before and after construction is not applicable.

V. CONCLUSIONS.

1. The breakwater connecting the parts of the island has been very successful.

2. The protective works failed to immediately halt the erosion of Fayerweather Island. Between 1913 and 1929 a fairly stable condition had been reached.

3. It is believed that with a closer spacing the jetties would have been more effective.

SOUTHPORT HARBOR, CONN.

I. GENERAL.

1. Location. Southport Harbor is on the north shore of Long Island Sound about 50 miles east of New York City, and 6 miles west of Bridgeport Harbor (see accompanying map File No. RAHM 255).

2. Type.

1. Breakwater.

2. Dike.

II. CONDITIONS PRIOR TO CONSTRUCTION.

1. Description. Southport Harbor includes the tidal portion of Mill River, about 1 mile long, entering an outer bay extending one-half mile south and about 1 mile wide. Before any work was done in this harbor by the United States the navigable low water depth was less than 2 feet, and the channel was in danger of becoming filled in by sand carried in by the littoral currents from the east.

2. Nature of Beach and Bottom Materials. The beach is sandy while the bottom is composed of mud and sand overlying numerous ledge outcrops. The area immediately east of the present breakwater was tidal marsh land.

3. Average Slopes of Beaches at Various Points. This information is not available.

4. Direction of Prevailing Winds. Prevailing winds are northwest and to a slightly lesser degree southwest. (See wind chart for New Haven, Conn. on map File No. RAHM 255.)

5. Direction of prevailing Storms. Easterly storms prevail.

6. Direction of Prevailing Littoral Drift. The prevailing littoral currents move parallel to the shore from east to west in this locality.

7. Tidal Ranges. The mean range of tide is 6.9 feet, and the extreme range, due to the combined effect of wind and other causes, is 11 feet or more.

8. Direction and Intensity of Tidal and other Currents. There is no information available relating to tidal currents in the locality.

9. Effect of Prevailing Winds. Unknown.

10. Effect of Prevailing Storms. Prevailing storms increased the action of the littoral currents.

11. Effect of Tidal and other Currents. Mill River is a tidal stream. The small tidal flow in and out of this stream maintained a depth of about 2 feet at mean low water.

12. Miscellaneous Effects. None.

13. Reasons for the Construction. The structures were built to confine the tidal prism to the main channel and to prevent sand drifting in from the eastward.

III. CONSTRUCTION.

1. The original breakwater was built of long and large stone quarried in the vicinity of Southport. These stones were laid as headers with a core of small stone. The structure was capped and raised 2 feet with large stones in 1875. The total length of this breakwater was 1,320 feet.

The dike was built 1,350 feet long of marsh sods laid with a batter of approximately 1 on 1. The interior was formed of alternate layers of brush and mud. Where the bottom was soft a foundation of fascines was used. Revetment was then placed on the channel side of the dike.

2. Method of Applying Materials. Both structures were built from land during the times of low water. No floating equipment was used except for the transportation of stone and for the placement of large caps.

3. to 9., inclusive. Alignment, etc. See map File No. RAHM 268.

10. Cost of Structures (original). The breakwater and dike cost $10,587.23 including the cost of engineering and inspection.

11. Unit Cost. It is impossible to break down the total cost into unit costs as the individual costs of the breakwater and dike are not known.

IV. CONDITIONS AFTER CONSTRUCTION.

1. Permeability of Structures to Sand. The breakwater was of impermeable construction. There has been little or no seepage of sand or other material through the structure.

2. Accretion or shoaling. Accretion has occurred by the action of sand drifting over the top of the breakwater and passing through holes breached by wave action. The high water line on the east side had built out about 150 feet between 1896 and 1933. There has been some shoaling on the west side of the entrance as evidenced by the change of the low water lines between 1910 and 1933. As there is no map available prior to construction in 1838 the changes occuring in the shore-lines immediately after construction are not known.

3. Erosion or scouring. There has been practically no erosion at Southport.

4. Deterioration of structures.

a. The breakwater has deteriorated from wave attack. This damage has largely consisted in breaches near the beach line and the consequent displacement of the cap stones. Some settlement has occurred along the structure.

b. Between 1836 and 1875 the residents of Southport repaired the breakwater annually, replacing cap stones and filling any gaps caused by wave action.

Since 1875 the United States has repaired the structures at various times. In 1875 the breakwater was raised 2 feet with a stone coping 5 feet wide. Since 1875 various maintenance operations have been completed to the breakwater. The expense has been slight.

c. The average annual cost of maintenance prior to 1875 was $60. for the breakwater.

Since 1875 the average annual cost of maintenance for the breakwater has been about $110.

For the dike about $130. was spent in repairs in 1876. Since that time there have been no maintenance operations. The sunken ground in back of the dike has been filled with dredged material by the Fairfield Country Club.

d. The average annual unit cost of the breakwater since 1875 has been about $0.10 per lineal foot.

V. CONCLUSIONS

The breakwater and dike have assisted in the maintenance of the channel. A channel sufficient for the needs of the locality has been supplied by dredging. The harbor is used almost exclusively by pleasure craft. The breakwater has prevented excessive drifting of sand.

These structures were built at a reasonable first cost and the cost of maintenance has been low.