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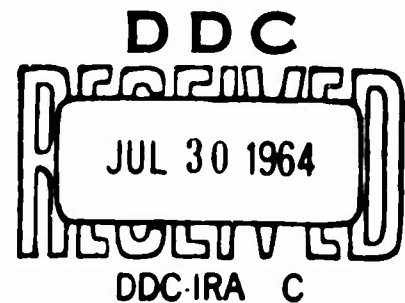
EARTHQUAKE DAMAGE TO ANCHORAGE

AREA UTILITIES - MARCH 1964

BY

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26 June 1964



U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

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ABSTRACT

On 27 March 1964 at 5:36 P.M. an earthquake struck Anchorage with an intensity of IX, as measured by the Modified Mercalli Scale. Between 3 and 13 April a representative from the U. S. Naval Civil Engineering Laboratory visited Anchorage and surveyed the damage to utilities resulting from this giant earthquake.

Electrical power sources for Anchorage and vicinity were spread out and highly diversified, but the earthquake by one means or another immediately disabled or cut off every major source of power available to the city. Although the damage to power plants and transmission lines was serious it was not catastrophic and within five days four out of seven major plants were back to normal output. For emergency power, diesel generators were generally undamaged and aside from some mechanical troubles they performed satisfactorily.

The water system was dealt several heavy blows which led to a critical situation twenty-four hours after the earthquake, but here again the damage was not catastrophic and within a few days about 80 percent of the water system was back to normal.

Damage to the sewer systems was not fully known at the time of this study and probably will not be fully assessed until after the frost is out of the ground. In the meantime, about 90 percent of the system is operating but part of it is in a damaged condition.

Gas lines were steel and therefore tougher than the water and sewer lines, but there were still many lines lost in slide areas. Top priority was given to their repair and with the help of imported labor they were able to restore service to most of the city in two to three days.

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Damage to the telephone system was largely confined to the distribution system. Most of the underground system was disabled and the aerial system in slide areas was lost. Other parts of the aerial system came through with only minor damage.

The cost of repairing the damage to utilities in this city of 48,000 people will probably range from 5 to 8 million dollars.

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INTRODUCTION

Between 1936 and 1954 the U. S. Coast and Geodetic Survey recorded 114 earthquakes in Anchorage, Alaska in which the intensity ranged from a slight tremor to a numerical value of VI on the Modified Mercalli Scale.¹ On 27 March 1964 at 5:36 P.M.,² a very strong earthquake struck Anchorage with an intensity of IX. Its magnitude was 8.5 on the Richter scale and its epicenter was located about 68 miles east of Anchorage and slightly to the south, (Figure 1). Unfortunately no one had installed any large motion seismic instrumentation in the area prior to the quake and consequently accurate information on the shock waves is unavailable. By talking to people who experienced the quake it was clear that the motion was rolling with a period of perhaps one second and its duration was estimated at 2-1/2 to 5 minutes. By examining the buildings it could be determined that the major damage was caused by motion in the north south direction.

The purpose of this report is to describe the nature of damage suffered by utilities such as power, gas and water and, where possible, to review the sequence of events which led to their recovery on a temporary basis.

The damage suffered by the utilities is related to the type of shock waves travelling through the soil and the nature of the soil itself. Much of the soil under Anchorage is Bootlegger Cove clay and silt which has very poor shear strength, and the intense shock of this

¹The Modified Mercalli Scale, 1956 version, is expressed in Roman numerals running from I to XII where I is a tremor not felt and XII is where damage is nearly total. The full scale is given in Richter's "Elementary Seismology," first edition. W. H. Freeman and Company, San Francisco, 1958. pp 137-138.

²Observers differed in their evaluation of the intensity. The value of IX is the author's opinion for most of the areas he inspected.

quake was sufficient in some areas to cause large landslides.³ Utilities in such areas were almost completely destroyed. Where the soil held firm the rolling motion mentioned previously did not have serious effects on mechanical equipment at or near the surface of the earth, however tall structures swayed considerably in all directions resulting in serious damage to fans, motors and piping in the upper floors of some buildings.

The information presented here, which was obtained in Anchorage between 3 and 13 April 1964, is concerned with the city of Anchorage which has a population of approximately 48,000 people (Figure 2), and two adjacent military activities, Fort Richardson and Elmendorf Air Force Base (Figure 3), which together comprise another 40,000 to 50,000 people.

A comparison between earthquakes and atomic bombs with respect to energy released is treated briefly in the Appendix.

POWER

Anchorage has several sources of electrical power. In addition to two gas turbine generators of the Anchorage Municipal Light and Power it can tie in with the Eklutna Power (Bureau of Reclamation), the Chugach Electric Company (REA), Fort Richardson or Elmendorf Air Force Base (Figure 1). Just before the earthquake struck, Anchorage was receiving part of its power from Eklutna, which has a hydro plant about 60 miles to the north east, and the remainder from the Municipal Plant which was operating only one gas turbine at the time.

Anchorage Municipal Light and Power

After the first few tremors the gas turbine cut out in response to an automatic vibration control and the Eklutna power also cut out as a result of circuit breaker damage, leaving Anchorage with no power. This blackout of power proved to be a blessing since fire, the dreaded aftermath of earthquakes, could not be started by live wires. Although fires might have started by other means the Anchorage fire department attributed the lack of fires primarily to the power failure. Before

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An excellent description of the geological formations and conditions which cause slides in this area is given in Geological Survey Bulletin 1093, "Surficial Geology of Anchorage and Vicinity Alaska," by Miller and Dobrovolsky, Washington, 1959. pp 103-4

attempting to restore power, transmission lines were surveyed, severely damaged parts of the system were isolated and minor damage was repaired as quickly as possible. Attention was then given to restoring service but the gas turbines, which were in good condition, remained idle because the 12-inch gas line feeding them had been shattered. Also, six stand-by diesel generators which had continuous-flow water cooling could not be operated for lack of water since the water mains to the building had been broken. Ordinarily, Anchorage would have tied in with one of the other major power sources but all of them were either disabled or cut off from the city. Fortunately the gas turbines were capable of operating on fuel oil; consequently, by starting the turbines with bottled gas and converting to oil, both turbines were operating 2-1/2 hours after the quake. The fuel storage tanks, however, unknowingly had been ruptured by the quake and by midnight they were empty. This emergency caused another time delay but was met in a few hours by bringing in oil by truck from Elmendorf Air Force Base. By Sunday midnight gas service had been restored to the turbines, and power lines repaired to the extent that 95 percent of Anchorage had power available.

Both the aerial transmission lines and underground conduit were able to ride out the rolling motion with minor damage but in the slide areas there was almost complete destruction. Here approximately 50 poles and several hundred feet of underground conduit were lost. Figure 4 shows an undamaged pole near the Cordova Building which was badly shaken; Figures 5 and 6 show poles that stood and poles that fell on 4th Avenue. In the remaining conduit (about 37 miles) the wires were put in tension but remained serviceable. The Municipal Light and Power, as of 9 April 1964, estimated that \$790,000 would be required to restore their system to its original condition. This included \$215,000 for relocating two substations which were in slide areas. Such slides produced a large percentage of all damage which emphasizes the importance of obtaining adequate knowledge of subsurface conditions and using it wisely in the design of quake-resistant structures.

Eklutna Plant

Water for the Eklutna hydro plant is transmitted from Eklutna Lake to the turbines via a tunnel, lined with precast concrete pipe, passing through a mountain for 4-1/2 miles. Shortly after the earthquake pieces of a rubber O ring and some rocks were washed into the turbine inlet. Indications were that the damage to the tunnel had occurred at approximately its mid-section. Complete details on this system were not available at the time of the survey.

Elmendorf Air Force Base Power Plant

The Elmendorf Plant is equipped with stoker fired boilers and steam turbines. The earthquake caused a number of serious breaks which crippled the plant and, although it limped into service six hours later, it was not back to normal for several days. The breaks included a 24-inch cement asbestos line supplying condenser cooling water (Figure 7), some baffling in the boiler and one grate. The 24-inch C.A. line was located on the north bank of Ship Creek and probably would not have broken had it been made of steel. Another unfortunate situation arose when the piping broke on the air controls. The release of air pressure opened automatic valves on four tanks resulting in the loss of 60,000 gallons of treated boiler feedwater.

Fort Richardson Power Plant

The Fort Richardson Plant and Elmendorf Plant are almost identical except for details such as the design of automatic controls. The damage here was less extensive than at Elmendorf and much of it could have been avoided by proper design. For example, a number of tanks, such as water softeners were sitting on cast iron legs about 14 inches high. The rolling motion fractured the legs and the tanks toppled over rupturing the attached piping. Figure 8 shows two tanks tipped over; Figure 9 shows a tank after repair with the broken leg in foreground. Another case of design involves the type of pipe hanger employed. Several different types had been installed here and fortunately a large number of them allowed motion in all directions, but hangers which allowed no motion, or only along the axial line of the pipe, were almost invariably broken. When hangers failed, the pipes usually managed to either support themselves or to support each other in a stack arrangement; the only pipe which actually fell was a 50-foot, 8-inch ash conveyor which had rigid hangers. Further damage as a result of stress at elbows may of course show up later. An indication of how violently the pipes were swinging could be seen by examining the scratches and marks made by the hangers on pipes over a longitudinal distance of 12 to 14 inches. The lack of damage to the steam turbines was attributed to large flexible steel couplings between the turbines and the steam supply lines. Although good photographs of piping in the power plant were not available for this report, Figure 10 shows how well the piping system survived in the First Federal Savings, and Figure 11 shows damage as a result of hanger trouble, in the boiler room of the same building.

Chugach Electric Company

The Chugach Electric Company has a diversified system consisting of a steam generator at Anchorage, gas turbines at the Bernice Lake Power plant near Kenai, and a hydro plant at Cooper Lake. Damage was extensive and at the time of this survey the company was in a state of emergency and could not spare the time to discuss details of their

problems, however, the following information was obtained. The steam plant at Anchorage was disabled but the extent of damage was not available. The gas turbines at Bernice Lake were put out of line and it was reported that they would not be restored for sometime. The hydro plant was not damaged but 19 miles of transmission line between Portage and Anchorage were down, (Figure 1). The high lines in this area were carried on wooden H frames about 40 feet high which were attached to wooden piles set 30 feet in the tidal flats. To the repair men it appeared that the ground must have liquified and the piles assumed almost a horizontal position without breaking. Temporary structures were erected without the necessity of drilling by using a triangular base of three poles and erecting one pole from each corner to form a pyramid.

Emergency Power

Stand-by power systems were extremely valuable during the first few hours after the quake but they were not without their problems. The incapacity of six diesel generators at the Municipal plant has already been mentioned. Also, two of three diesel generators at the Elmendorf Air Force Base hospital were out of commission after a few minutes of operation when their rubber cooling water hose fell apart. Fortunately, the third unit was able to supply sufficient power to meet the most urgent needs. The rubber hoses had been replaced before this survey was made so it is not known if they were rotten from age or torn as a result of the quake, but the former is suspected. In a telephone building on Government Hill, two 15-ton battery plants collapsed and caught on fire. Luckily the fire was quickly brought under control and emergency generators were put into service so that 11 long distance circuits to Seattle were operational within 2-1/2 hours after the quake.

Water Supply

Ship Creek is the main source of water for Anchorage, Elmendorf Air Force Base and Fort Richardson. Water flow is controlled by a dam with a reservoir for 2.5 million gallons. For stand-by purposes Anchorage has six wells (200 to 400 feet deep), Elmendorf has one well, and Fort Richardson has three wells (120-feet deep). One filtration plant serves the city and a second filtration plant serves the two military activities.

When the earthquake struck, a number of things happened simultaneously which in a few hours left the whole area with only a meager supply of water. Landslides (Figure 12), tension breaks in the ground (Figures 13 and 14), and building movements (Figures 15, 16, 17 and 18) broke water mains in many places putting a heavy drain on the reservoir. In the meantime, a slide upstream from the dam stopped the flow of

water into the reservoir. At Fort Richardson one well was put out of commission and at Anchorage one well was lost and three were partially damaged. The city's filtration plant, which was of Lin Tee construction (precast concrete design) had one shear panel damaged and one line of columns shifted about two inches out of line at the base.

Mains were shut off and repairs started immediately and by Saturday noon many areas were ready to receive water but the reservoir was dry and power was not available at the wells. Although the situation was critical it was soon relieved when water flowed over the Ship Creek slide into the reservoir and at approximately the same time power was restored to the wells.

Water pipe throughout the city was either cement asbestos, cast iron or wood stave. The cement asbestos lines were badly fractured in the area west of Fish Creek and north of Northern Lights Boulevard. To supply water to this area it was necessary to bring in, by air freight, 60,000 feet of 4-inch aluminum pipe and lay it on top of the ground. Connections to residences were made with garden hoses. Although the temperature dropped below freezing during the night, the water in above grade pipe and hoses did not freeze.

In other parts of the town, breaks were numerous--some by tension, some by shear, but public works personnel did not feel that one type of pipe could be considered superior to another. They were relieved to find that perhaps 80 percent of the system remained intact. All city water was declared drinkable on 6 April 1964, which was 10 days after the earthquake.

Sewer System

Sewer piping throughout the city was primarily concrete with tongue and groove connections although transite and wood stave were used in a few areas. At the time of this survey, damage to the sewer system had not been fully assessed. Piping was of course lost in the areas where large ground movement occurred, but breaks in the rest of the system had not been located and evaluated. Generally speaking, the sewage was flowing, which was encouraging, but the accumulation of gravel in manholes indicated the existence of breaks. Plans are that these breaks will eventually be located by inspecting the interior of the system with TV cameras. Damage to manholes was not extensive but in a number of cases the precast concrete cones, which form the upper section, were shifted out of place. The city had no sewage disposal plant. Public Works personnel estimated that \$83,000 would be required for the TV inspection, \$168,000 for new pipe, \$94,000 to flush the system and \$157,000 for center lining or waterproofing. Additional repairs ran the total estimate to \$800,000. Although these figures will no doubt be revised they give some perspective to the scope of the damage.

Natural Gas System

Natural gas for Anchorage and vicinity is supplied by the Anchorage Natural Gas Corporation. The gas is obtained from four wells about 10,000 feet deep located near Kenai, which is approximately 65 miles southwest of Anchorage. Gas is transported from the wells through two 12-inch steel pipes, which for several miles are submerged in part of Cook Inlet called Turnagain Arm. Both lines terminate at the city gate station and from there the gas is distributed in the city through a welded steel pipe system (grade 5LX API). The 10-inch and 12-inch lines have a wall thickness of 0.25 inches and the 3-inch to 8-inch lines have a wall thickness of 0.188 inches.

No damage was suffered by the wells or any part of the two 12-inch transmission lines from Kenai to Anchorage. Gas piping in the city distribution system was lost or broken (Figure 2) in the same areas as water piping but the steel, being much tougher than CI or transite, experienced fewer breaks. Ground movement left part of the system in compression and part of it in tension, which is easy to visualize after noting some of the changes in street length shown in Figure 19. Gas line breaks in the "L" Street slide area (Figure 20) should be compared with Figure 13, and Figure 19 which shows ground displacements in this area. As a matter of comparison the water lines here were virtually wiped out. In some cases the pipe broke and the two ends hammered against each other (Figure 21). The full effect of subjecting the system to these forces will not be known for sometime. To restore service quickly it was necessary to import experienced maintenance men, and to this end the gas companies in Seattle made a valuable contribution by supplying personnel both at the supervisory level and in the field. Gas was so essential at that time of year that top priority was given to the repair of gas lines which meant that all available thawing vehicles were placed at the disposal of the gas corporation. In addition to this a mobile infrared leak detector, about the size of a small station wagon, was flown into Anchorage to search out leaks over the entire system. Within 48 hours gas had been restored to most of the city.

Telephone

The telephone system in Anchorage is operated by the City of Anchorage Telephone Utility. Their equipment is located in the main office at 13th and "E" Streets, and in three other exchanges. Most of the city is served by an aerial system but the business district has 25 miles of underground cable which runs in cement asbestos conduit set in reinforced concrete. Adjacent to the main building is a concrete tunnel 6' x 6' extending approximately two blocks under "E" Street.

The aerial system survived with only minor damage, except where there were landslides, but the underground system was almost completely disabled. This was in sharp contrast to the behavior of the underground power lines which were located in the same area but experienced little damage. The nature of damage suffered by the underground telephone system was unknown at the time of this survey, aside from the knowledge that the system was largely in tension with the result that cables were pulled away from manholes. The failure of telephone cables due to tension was also reported on "Study and Analysis of Damage by Typhoon Karen on Guam."⁴ In that instance the stretching of the lines broke many small lines within the cables and it is quite possible that the same type of failure occurred in Anchorage. The concrete tunnel under "E" Street did not show a trace of damage.

During the first few hours after the earthquake, telephone communication with the outside world was restored by laying 4400 feet of 200 pair cable on top of the ground to bypass the damaged lines.

In the main building, metal covers on the equipment bays were shaken off and they bounced against relays and other small components which they were meant to protect. By the time this survey was made the equipment had been repaired and was operating, although not to the complete satisfaction of the management. From a visitor's point of view the telephone service one week after the earthquake was remarkably efficient.

Mechanical Services within Buildings

Four large buildings; the Fort Richardson Power Plant, Elmendorf Air Force Base Hospital, Hill Building and International Airport, which are located in different areas, were visited for the purpose of examining damage done to mechanical services within buildings. Damage to the Fort Richardson Power Plant was described under the section on Power.

⁴U. S. Naval Civil Engineering Laboratory Technical Note N-497: Study and Analysis of Damage by Typhoon Karen on Guam, by R. M. Webb, et al. Port Hueneme, California, 29 March 1963, p 132. Unclassified.

The Elmendorf Air Force Base Hospital is a large and rather complicated building with a central high-rise section of nine floors plus a penthouse, Figure 22. Steam, which is piped a distance of 11,000 feet from Fort Richardson, is used to heat the first floor and for converters to provide hot water heating for the remaining floors. The building has a 100 percent fresh air ventilation system with supply fans at the lower levels and exhaust fans in the penthouse.

Centrifugal compressors located on the ground floor provide 300 tons of refrigeration. Oxygen, air, vacuum, and propane lines run throughout the building. Copper is used for oxygen; black iron for the others. Power is normally supplied by the Elmendorf Power Plant and emergency power by three diesel generator units (375 KVA) which are located on the ground floor. Diesel exhaust gases are piped away from the building through a concrete tunnel approximately 6' x 6' and 50' long. The building is served by five elevators with their motor-generator sets and other operating equipment located on the ninth floor.

The earthquake gave the building a severe shaking and while damage to equipment on the upper floors was extensive the effect on equipment on the ground floor was negligible. Within 20 minutes after the shaking ceased, all patients had been moved to nearby buildings in accordance with a prearranged plan.

Throughout the building, breaks occurred at numerous places in both the steam and domestic hot water pipes but the oxygen, air, vacuum and propane remained intact.

In the penthouse, anchor bolts on four large centrifugal fans and their motors were sheared off and the equipment in moving around had ripped and crushed the ductwork. It appeared as though the ductwork had acted somewhat as a cushion preventing damage to the fans themselves.

On the ninth floor, five motor-generator sets which provide DC current for the elevators were not bolted down and as a result they were thrown around the floor crashing into the walls and other elevator equipment. Wires were of course torn off and two of the sets were severely damaged. Fortunately, the elevator cable gear and automatic controls were well fastened down. To further complicate the elevator problem, the counterweights which hang freely were set in motion like pendulums and pounded against their rails and roller guides causing considerable damage.

On the ground floor, damage to the refrigeration compressors and diesel generator sets was very minor. Although two of the diesel engines broke down, it seems unlikely that the cause could be attributed to the earthquake. The exhaust gas tunnel was undamaged.

THE HILL BUILDING

The Hill Building located at 6th and "G" Streets, is a large seven-story structure. The mechanical equipment, which was originally installed at a cost of \$600,000, includes a steam heating system with two boilers located on the ground floor and air conditioning units, using city water for cooling, located on the upper floors. Since the building was occupied almost entirely by the Federal Aviation Agency it contained a considerable amount of telephone equipment, including a bank of batteries located on the ground floor. The building is served by three elevators.

From the outside, the building appears to have sustained little damage but in reality the brutal shaking caused by the quake resulted in the downward displacement of three corners of a large reinforced concrete core.

In spite of the serious structural damage the mechanical equipment survived remarkably well. The boilers, fans, coils, ductwork, and telephone equipment, including batteries, were virtually undamaged. In more typical fashion a number of hangers were broken and pipes were sheared where the pipes and buildings could not move together or independent of each other (Figure 23).

The pipes shown in Figure 24 are located in the same room as the one in Figure 23, but no breaks occurred in these pipes because they had adequate freedom of movement. As shown previously in Figure 10 a piping system designed with swing joints which allow it to move relative to the building can sustain a lot of motion without damage. Probably the most serious damage was sustained by the elevators where the counterweights pounded against their guides as they did at the Elmendorf Air Force Base Hospital.

INTERNATIONAL AIRPORT TERMINAL

The terminal is a long low building of reinforced concrete which had a handsome control tower rising from one end, and a large basement designated as a fallout shelter. The mechanical services were quite conventional, including a steam heating system with the boilers located in the basement. Another item worthy of mention was a baggage chute located about 50 feet from the tower and extending from the loading area into the basement. It was made from corrugated steel pipe about 6 feet in diameter and contained a conveyor belt and heating coils.

The control tower was unable to withstand the forces induced on it by the earthquake and as a result it collapsed (Figure 25). The piping in the basement under and near the tower was badly broken (Figure 26).

Shattered sewer pipes spilled their contents on the floor and foul odors from the system permeated much of the basement air. A maintenance man reported that a steam main had broken directly over his head but fortunately discharged toward the ceiling. The boilers in the central part of the basement were intact and the baggage chute and its contents were completely unharmed (Figures 27 and 28). Although the basement was designed to offer protection against fallout, the tower was a vulnerable point in the event of a nuclear attack, consequently the selection of this area as a shelter is questionable.

MISCELLANEOUS OBSERVATIONS

Light Fixtures

One type of damage which was prevalent throughout the city concerned fluorescent lights. In literally hundreds of cases the fixtures had not been well secured to the ceiling and they were shaken until they either fell to the floor or hung precariously by their wires.

Power Tools

The Corps of Engineers reported that electric power tools were in many cases fastened to free standing tables, and the motion set up by the earthquake moved the tables with the result that flexible connections to the junction boxes were broken and wires exposed.

Electrical Conduit

Another case of exposed wires occurred where conduit in interior partitions pulled apart when the partition was damaged. This was particularly true where the conduit was thin wall with no threaded joints and the partition was of 4-inch block. The possibility of unknown breaks in partitions which were badly shaken was of great concern to the Corps of Engineers.

Oil Storage Tanks

The Shell Oil tank farm near the International Airport and the Standard Oil tank farm near the Anchorage docks contained many tanks 32 feet in height and of various diameters. They were filled to different depths and the forces set up by the quake resulted in ruptures to every tank that was considered full. Partially filled tanks were undamaged. Failures were usually characterized by a bulge running around the tank at the ground surface with ruptures in the bottom circumferential seam, and at the point where the pipe entered the tank near the bottom. The bulge may have been caused by a tendency of the tank to rotate on its lower rim as vases have been known to rotate during an earthquake until they "walked" right off a shelf. This type of failure

(Figure 29), plus damage to the top (Figure 30) occurred to numerous tanks including an API Std 650 tank 45 feet in diameter with a capacity of 9000 barrels. It was 32 feet high, filled to a height of 31 feet 4 inches and stood on a pad of sand.

The main piping on the tank farm was undamaged (Figure 31) although it must have been subjected to a great deal of motion as indicated by the scratches on the adjacent tanks which hammered against their catwalks (Figure 32).

Underground Steam Mains

Fort Richardson has 240,000 feet of underground steam mains. All of the lines are either in metal casings (Ric-Wil type) or in insulated concrete (Z-Crete type). One of the longest single lines is a 20-inch pipe in Z-Crete running from the Fort Richardson Power Plant to the Elmendorf Air Force Base Hospital, a distance of 11,000 feet. All lines are at least 3 feet below ground surface. At the time of this survey there appeared to be no serious damage to the underground system. Make-up water to the boilers increased sharply after the earthquake but as buildings were repaired the makeup gradually dropped off.

Railroads

Although damage to railroads throughout Alaska mounted to several millions of dollars, the damage in Anchorage was not extensive. Tracks were disrupted in some areas or put out of line in a snakelike fashion as witnessed near the Anchorage dock, Figures 33 and 34. Many spikes along the tracks and around switching gear were displaced one or two inches, Figure 35.

An interesting example of damage from compression is shown in Figure 36, which is a photograph of a buckled railroad bridge between Anchorage and Seward.

Wells

Wells for emergency purposes in Anchorage and at the military bases were mentioned under the section on Water, but there were also numerous home-owned wells. These were affected by the earthquake in different ways in that some went dry, some were crushed and some had sewage drain into them. The authorities warned the owners that it would be necessary to chlorinate or boil all water taken from these wells until the frost was out of the ground, and the sewers were repaired.

Docks and Cranes

At the Port of Anchorage were five gantry cranes (Figure 37) whose counterweights were set in motion by the earthquake. As a result of this motion the counterweight arms were twisted and broken and two of the 50-ton weights fell into the water and sank in the mud. The city port dock, built with steel piles, suffered very little damage (Figure 38), however the army dock nearby built with wooden piles was put out of service (Figure 39).

Turnagain Area

The most devastated part of Anchorage was the residential Turnagain area where many homes and their services were demolished. Figure 15 shows the direction and magnitude of the home displacements and Figure 40 is an illustration of the results of this catastrophe. Figure 41 shows a pressure ridge which contributed to the failure of underground utilities close to the slide area.

Evacuation Plans

The value of preplanning for emergencies was clearly demonstrated when both the Elmendorf Air Force Base Hospital and the Presbyterian Hospital had to be evacuated. Patients from the former were moved within 20 minutes to nurses residences close by, while the patients from the latter were moved within 30 minutes to Providence Hospital.

DATA COLLECTION

On the evening of 11 April 1964, a meeting was held in the district office of the Corps of Engineers for the purpose of giving some direction to the enormous amount of data which was being collected by the many professional people studying the earthquake damage. Approximately 60 people attended the meeting including geologists, engineers, educators, seismologists, and people representing professional societies. A steering committee was appointed and it was agreed that the University of Alaska would serve as the central agency or clearing house for all data. More information on what data is being collected and compiled, and how it is to be disseminated, can be obtained by writing to:

Earthquake Information
College of Engineering
University of Alaska
College, Alaska

SUMMARY

Power

Within the geographical area of intense shock, regular electric power was generated by hydro plants, steam plants and gas turbine plants, while emergency power was generated by diesel generators and batteries. Of the seven major power plants, only the Hydro plant at Cooper Lake was unaffected by the quake. Damage to the other major plants came in the way of generator misalignment, fuel loss, water loss and many lesser problems. Of the emergency power systems the diesel-generator sets with closed cooling systems apparently suffered no damage, but batteries in at least one plant were completely destroyed.

In designing power plants against this type of shock the following items should be considered:

- a. Pipe hangers should allow motion in all directions and perhaps be fitted with dashpots to dampen the motion.
- b. All important parts of the system should be well anchored (preferably top and bottom), including water treatment tanks and transformers.
- c. All vital lines should be made of steel, if possible, instead of a brittle material.
- d. Controls should be designed so that loss of power or air will leave the system in safety position.
- e. A new look must be taken at the structural design of fuel storage tanks.
- f. Automatic shut-off mechanisms like the one used on the Anchorage gas turbine should be used extensively not only to protect the equipment but to help prevent fires through power cut-off. Similar devices could be used for gas lines.

In addition to those items concerned with Power, the following general items should be considered:

- a. Fluorescent light fixtures should be well secured to the ceilings.
- b. Electrical conduit should be carefully specified when it runs through flimsy partitions, or in any area in which it might be subject to movement resulting from an earthquake.

c. Elevator designs should be investigated to determine if a simple method can be employed to prevent the counterweights from swinging like pendulums and destroying their surroundings.

d. Electronic and mechanical equipment should not be housed in cabinets with snap-on metal covers which can easily be jarred loose and thrown against the components they are meant to protect.

e. Telephone cable does not have the tension strength of power cable and is therefore more susceptible to damage from earthquakes. For underground cable the problem could be solved quite easily by allowing more slack in the lines.

f. When wells for drinking water are going to be relied on during emergencies they should be completely independent, that is they should have their own stand-by power and purification system.

g. Utility systems and their stand-by equipment require as much flexibility and redundancy as the budget will permit. For example, Anchorage had six emergency wells of which only two were completely undamaged; Elmendorf Air Force Base Hospital had three stand-by diesels and only one of them would operate; when the telephone building on Government Hill lost its batteries the emergency generators were used; and when the Municipal Light and Power gas turbine lost its natural gas it was switched to fuel oil.

h. Advice given by geologists on the stability of soil against earthquakes should be well heeded.

i. Prearranged plans for such disasters are important and not the least of these should concern any river in the area which might become blocked by slides. Fortunately, the Ship Creek slide near Anchorage did not have serious consequences but slides such as the one in Yellowstone Park a few years ago, or more recently on the Zerabashan River in the Soviet Union, required a monumental effort on the part of engineers to release the water which built up behind the slide.

j. All pipes entering buildings or passing through floors or partitions should be provided with swing joints, large pipe sleeves, and other piping arrangements which will allow adequate freedom of movement. Also, pipes connected to other pipes should be free to move relative to each other.

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Much of the information in this report was supplied by the citizens of Anchorage, who were most generous and hospitable in spite of the difficulties under which they were working. The names are too numerous to mention here, but a special word of thanks is given to Walter G. Bagley of Fort Richardson; Francis Anderson, Corps of Engineers; Willard J. Stump, Anchorage Natural Gas; A. L. Renshaw and Bill Duynslager, Anchorage Public Works; C. A. Oliver, Municipal Light and Power; V. Deane, Standard Oil; and Jack Harris, Anchorage Telephone.

Appendix

ATOMIC BOMBS COMPARED TO EARTHQUAKES

In comparing an atomic bomb with an earthquake on a basis of energy released, Richter⁵ makes the following statement: "As in other surface detonations, only a small fraction of the energy of an atomic bomb enters the earth as seismic waves. P waves (longitudinal) recorded for fission bombs at distant stations are of about the same size as those of an earthquake of magnitude 5.5. However, even the total energy released is small compared to that of large earthquakes." Earthquakes causing damage to weak structures are usually of magnitude 5 or over; destructive quakes generally exceed magnitude 6. He mentions⁶ as a point of "journalistic interest" that the energy of the largest earthquakes (10^{25} ergs) is 12,000 times that of a Hiroshima-type bomb.

Any attempt to compare the ground effects of an atomic explosion with those of an earthquake requires consideration of coupling which is the extent of mechanical energy transfer between the explosion and the surrounding soil or rock. Some information on this subject is given in Reference 7.

⁵ Charles F. Richter. Elementary Seismology, First Edition. W. H. Freeman and Company, San Francisco, 1958. p 153.

⁶ Ibid., p 366.

⁷ United States Atomic Energy Commission. The Effects of Nuclear Weapons, Revised Edition, edited by Samuel Glasstone, Washington, April 1962. pp 688-691

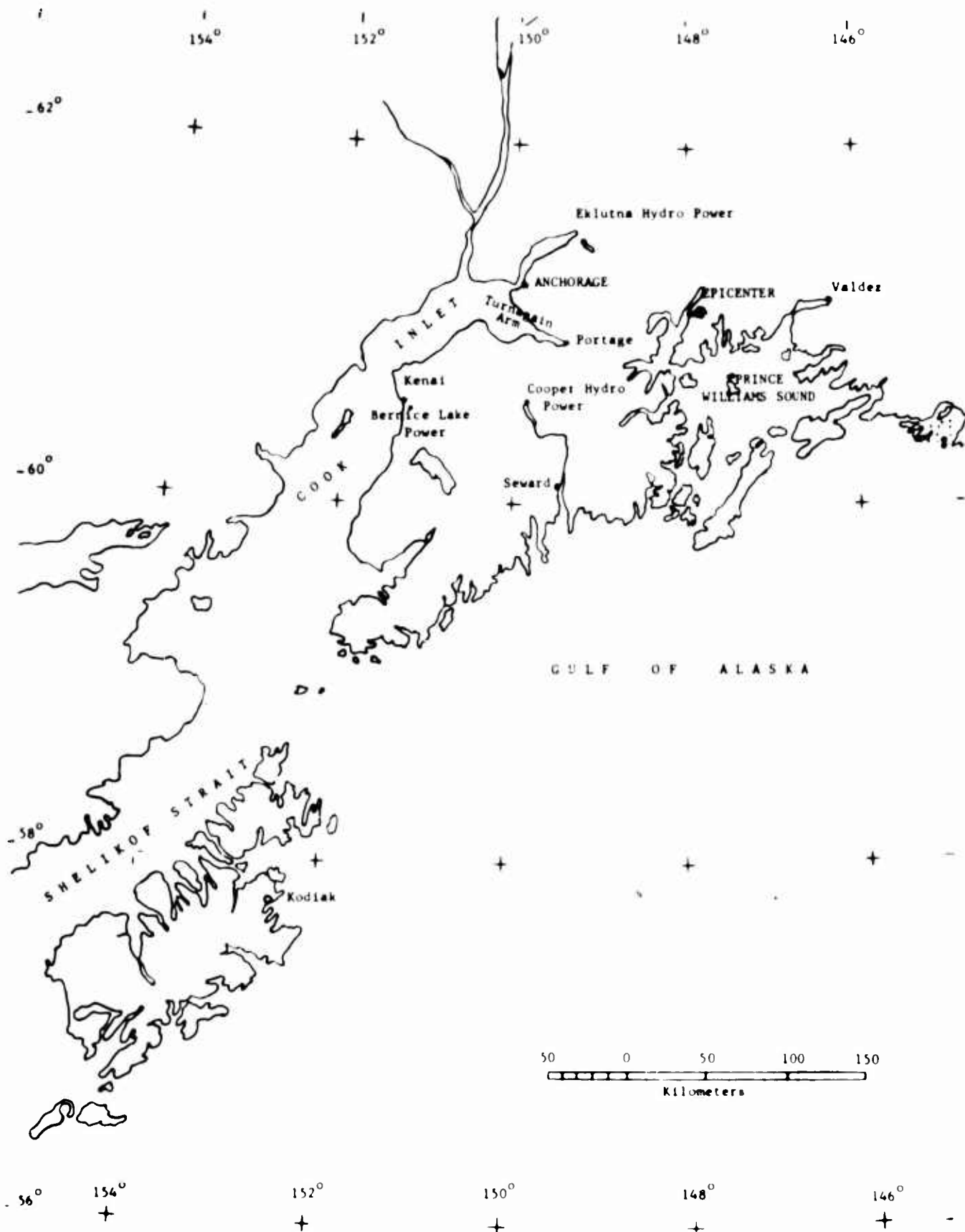
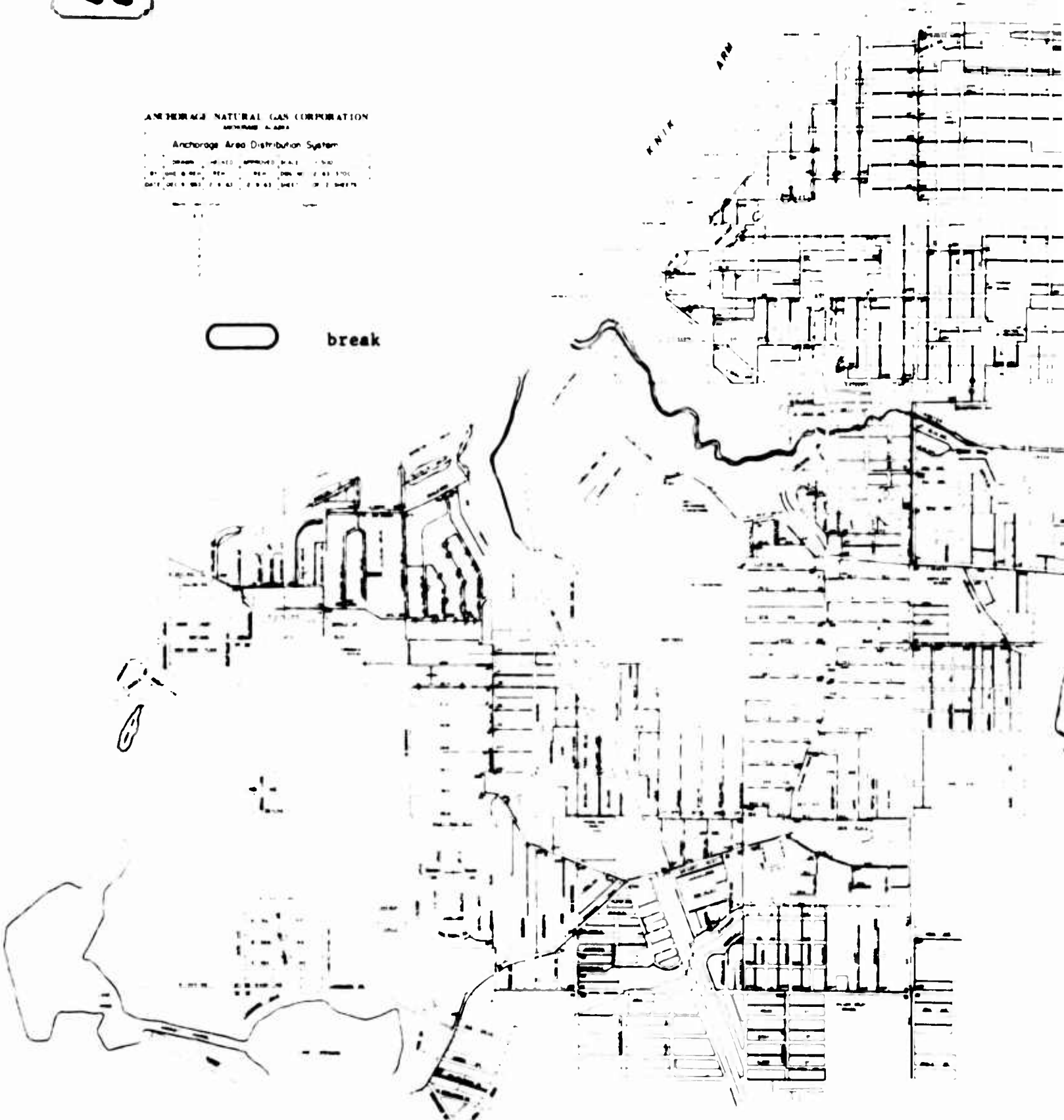


Figure 1. Epicenter and major areas affected by earthquake.

ANCHORAGE AREA NATURAL GAS CORPORATION
ANCHORAGE, ALASKA
Anchorage Area Distribution System

break



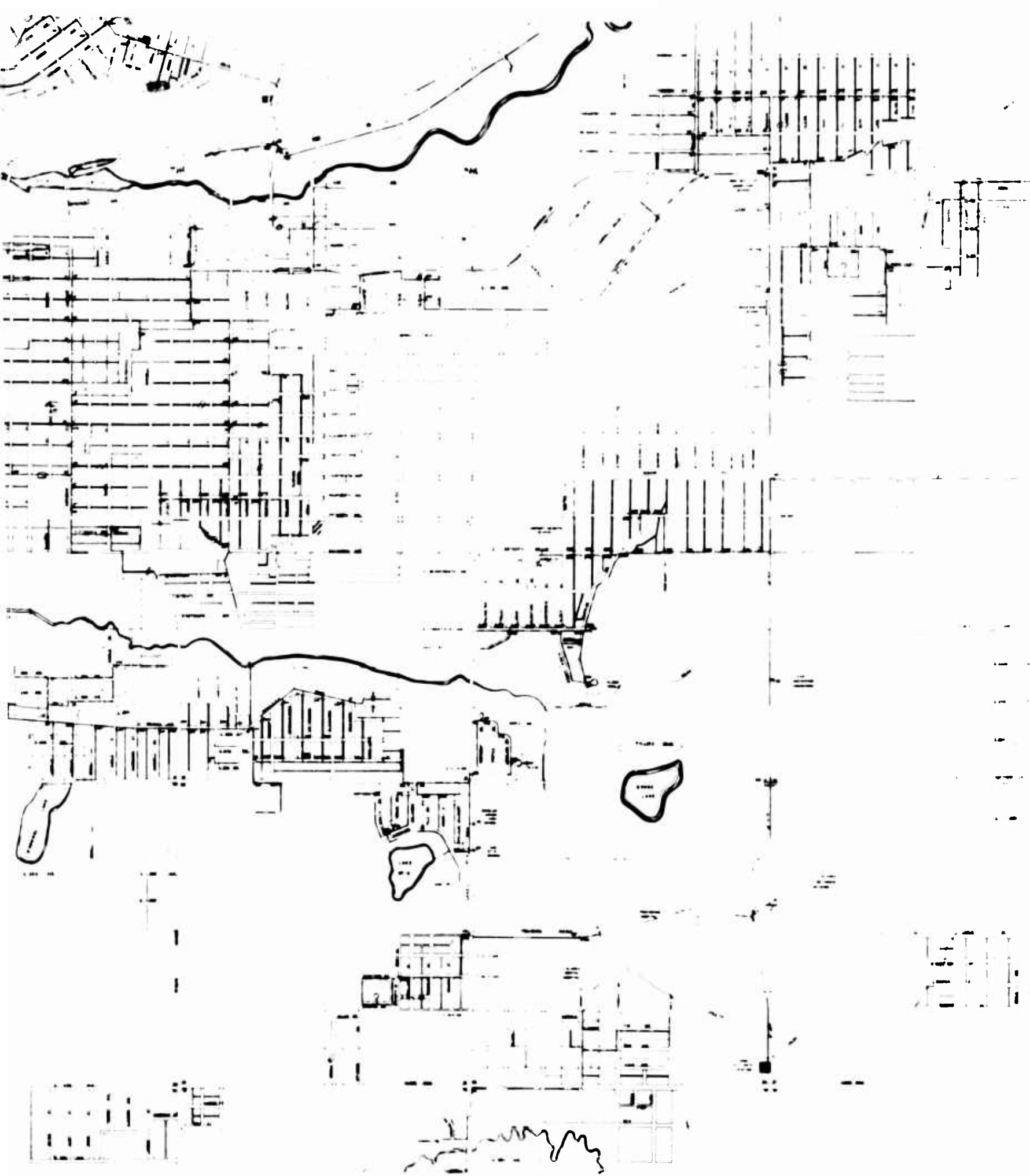


Figure 2. Map of Anchorage.

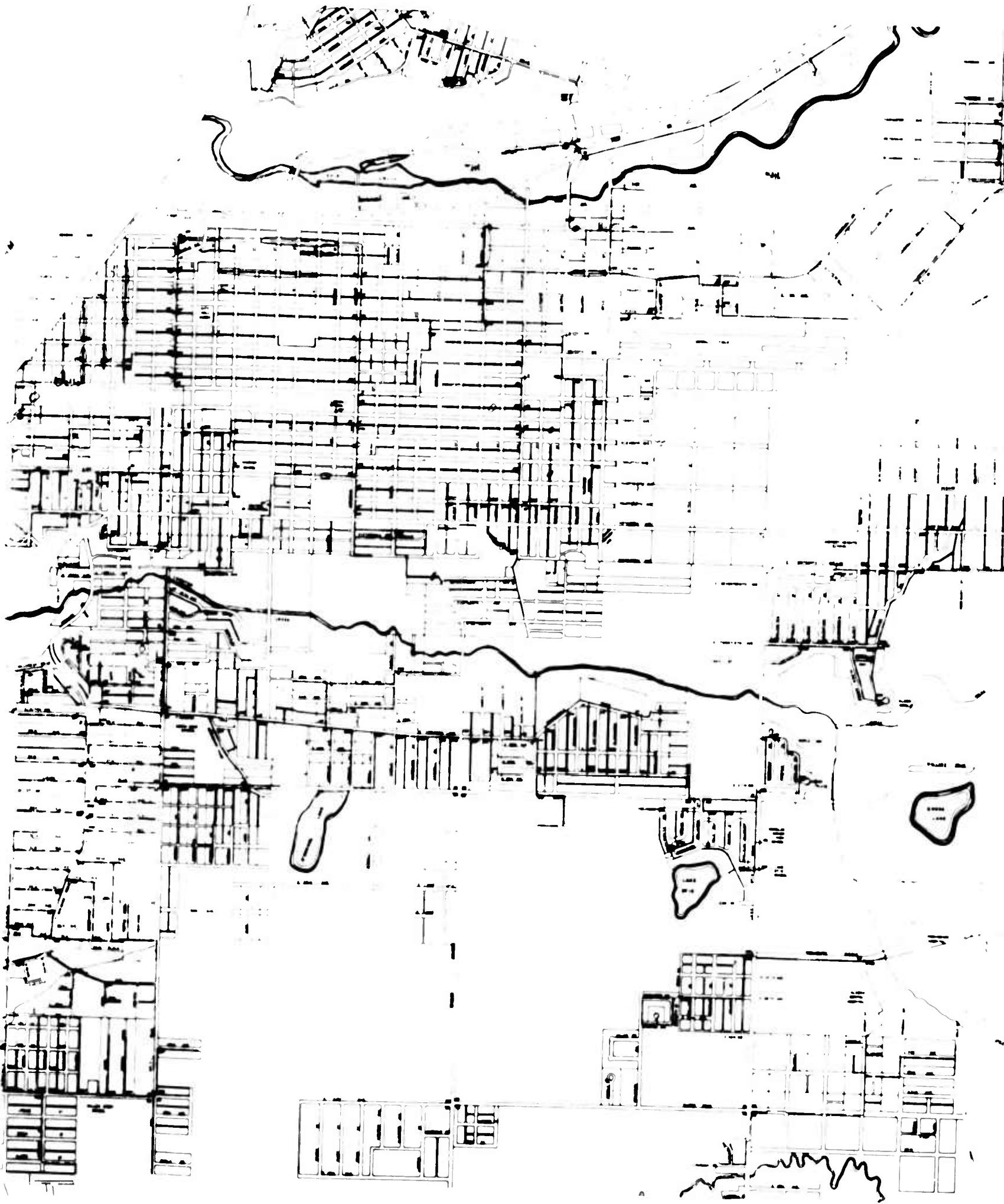


Figure 2. Map of Anchorage.



B



Figure 4. Utility pole beside Cordova Building.



Figure 5. Light pole down on 4th Avenue.



Figure 6. Light pole still standing on 4th Avenue.



Figure 7. 24-inch cement asbestos pipe.



Figure 8 Fallen tanks in Fort Richardson power plant.

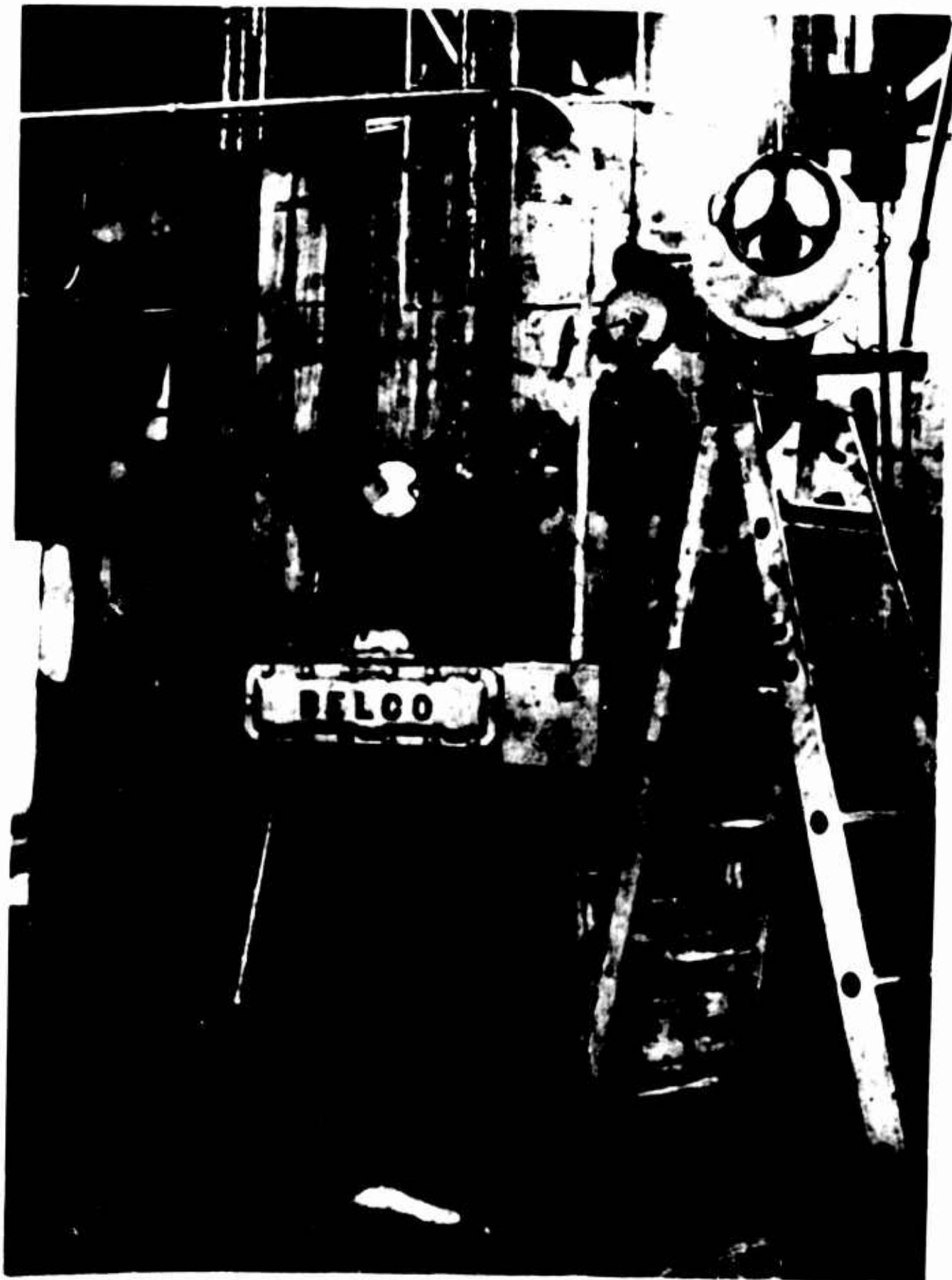


Figure 9. Fallen tank restored to upright position. (Note broken leg in foreground.)

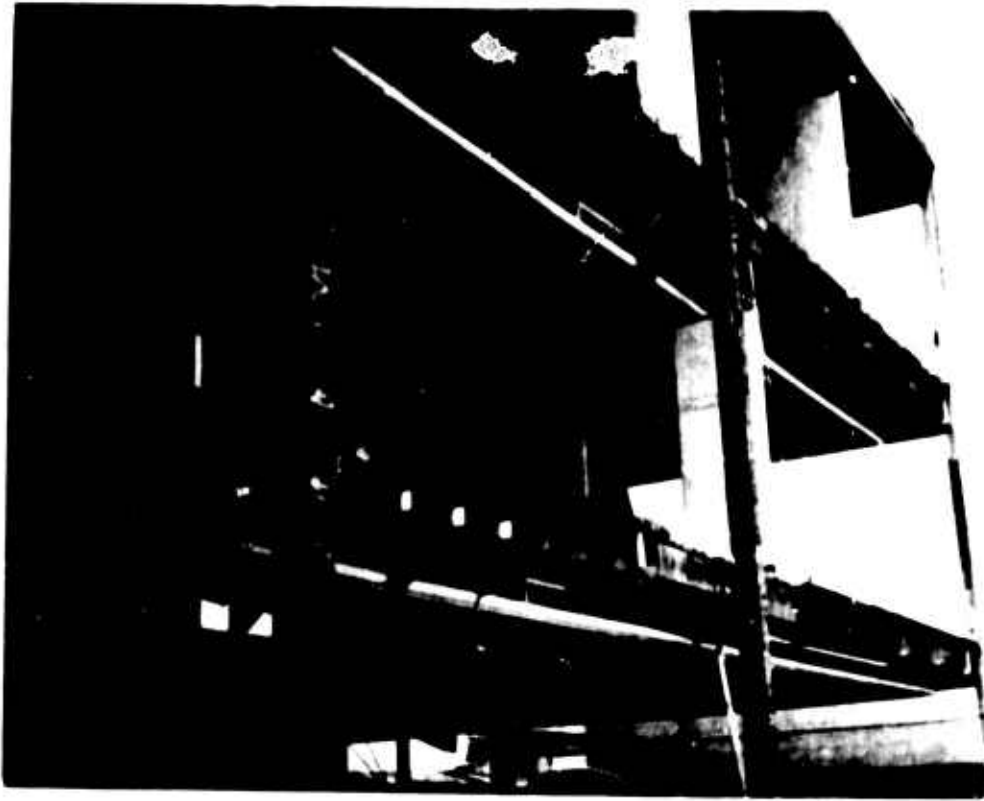


Figure 10. Undamaged piping in First Federal Savings.

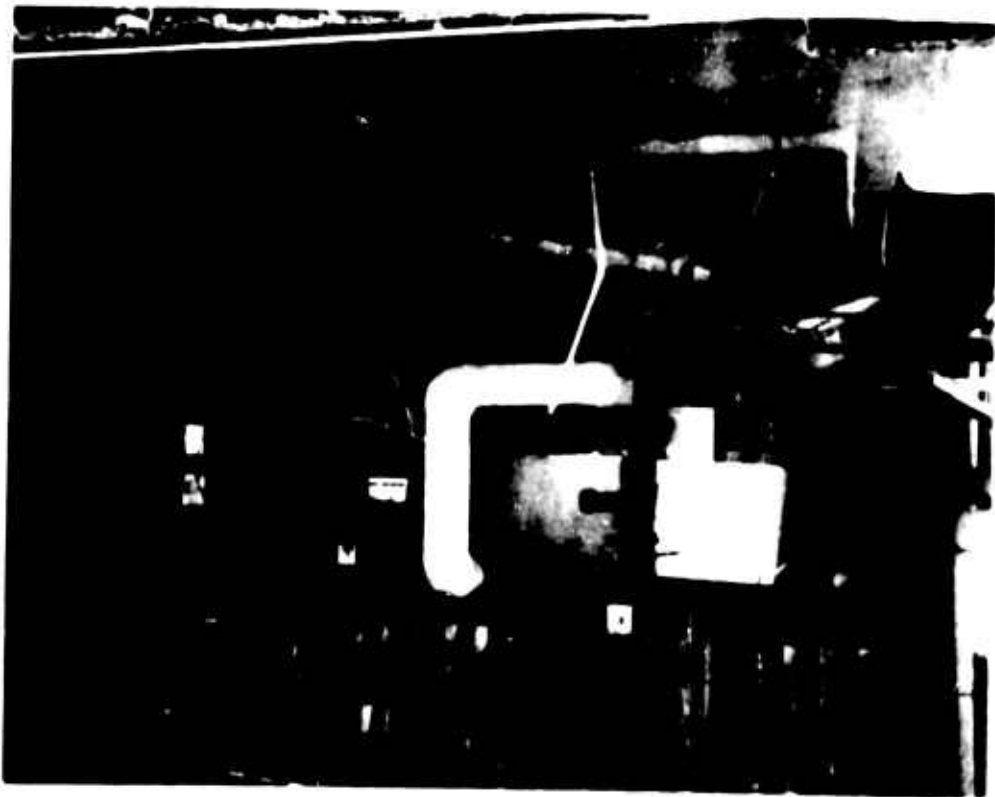


Figure 11. Boiler room in First Federal Savings.

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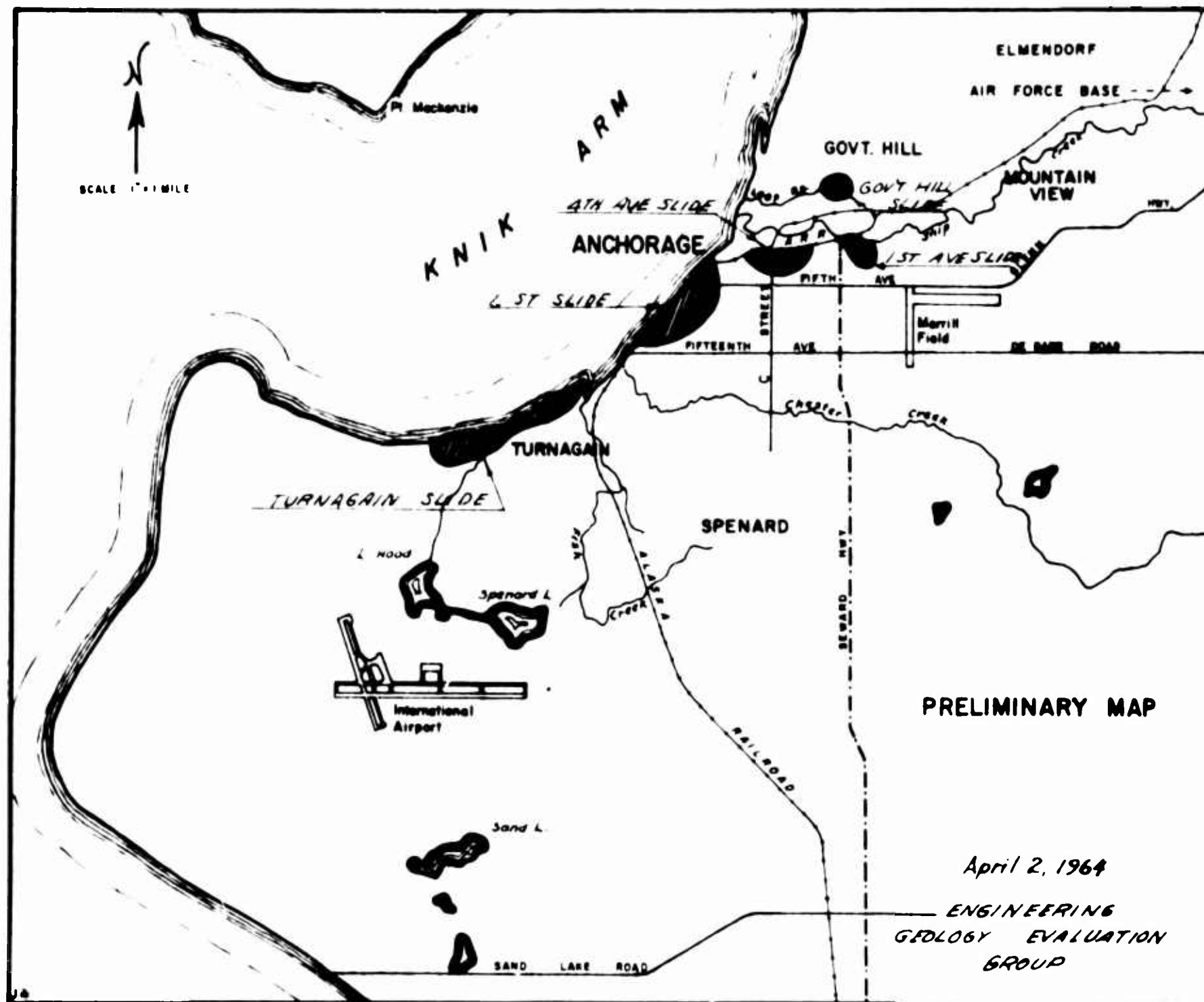


Figure 12. Anchorage slide areas.

TENSION CRACKS

Along old utilities in the
Turnagain Area (Shovel marks
still visible in cracks.)



Engineering Geology Evaluation Group

Figure 14. Tension cracks



Figure 16. Warehouse three blocks east of railroad depot.



Figure 17. Four Seasons apartment building.

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Figure 18. Front view of Penney Building.

**"L" STREET SLIDE
DOWNTOWN ANCHORAGE AREA**

**SURVEY PLAT
SHOWING CHANGES IN STREET LENGTH**

DATA COMPILED APRIL 6, 1964
SCALE 1"=100' DATE 4-12-64

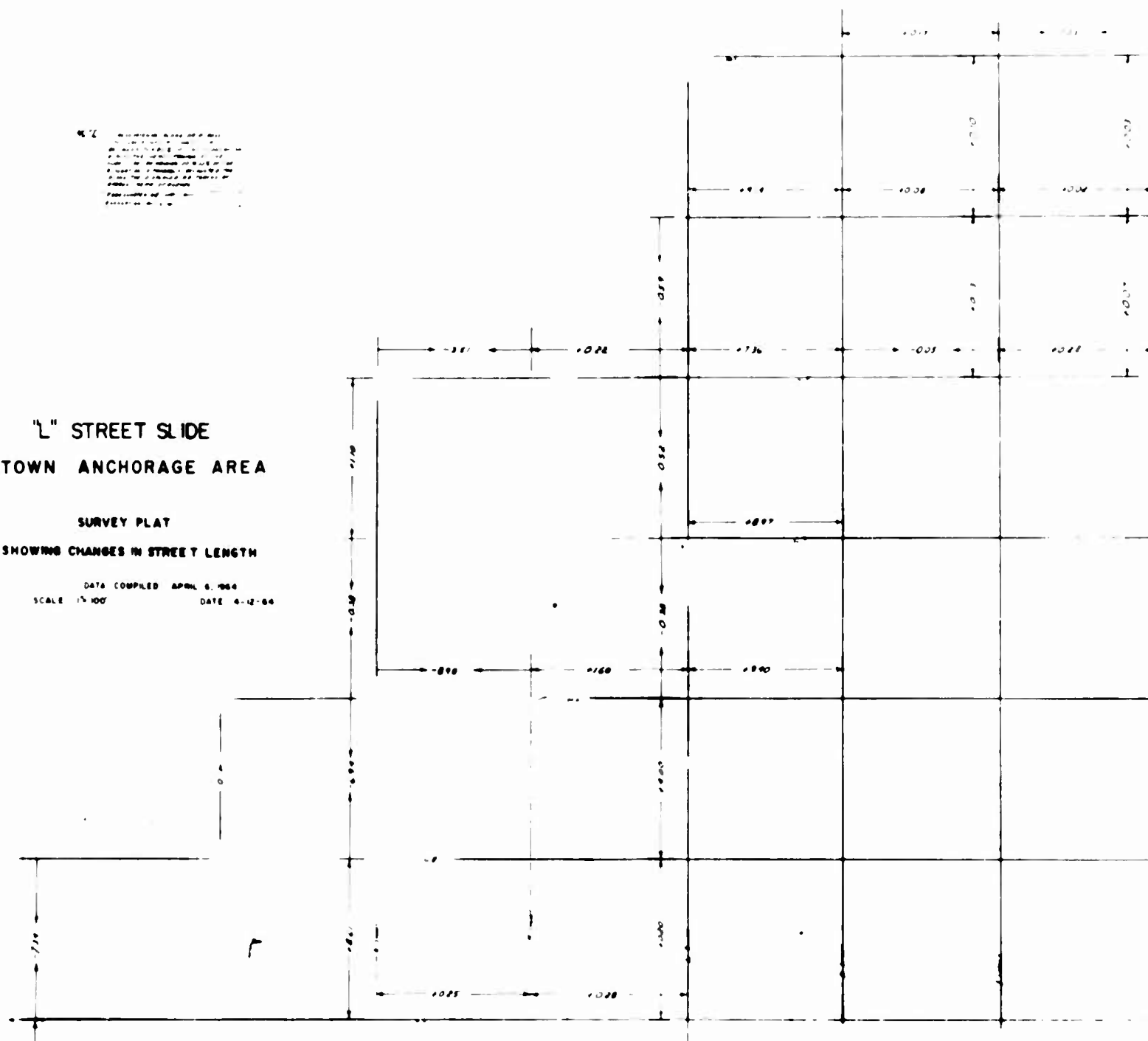


Figure 19. Changes in street length.

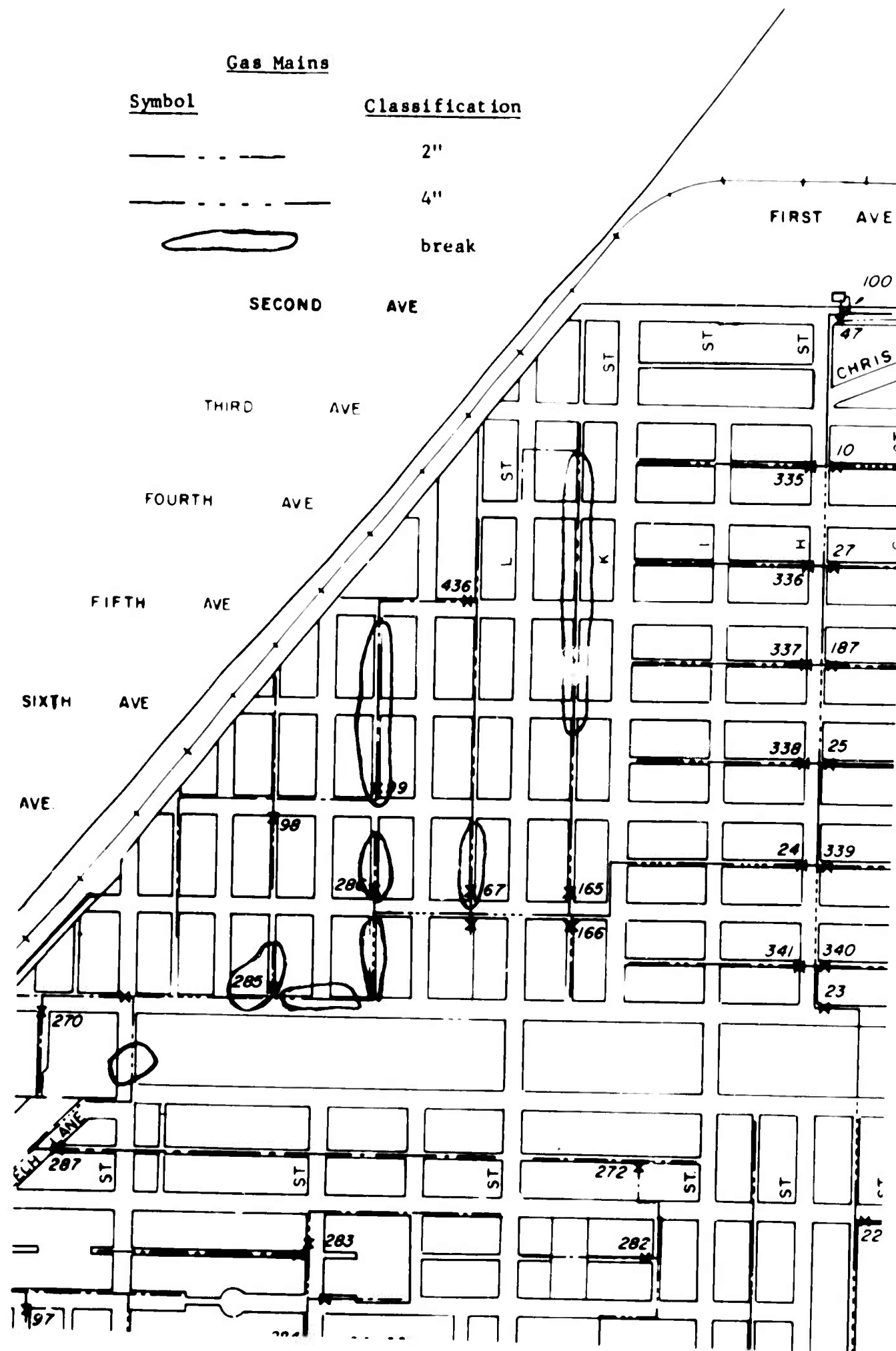


Figure 20. Gas line breaks in "L" street slide area.

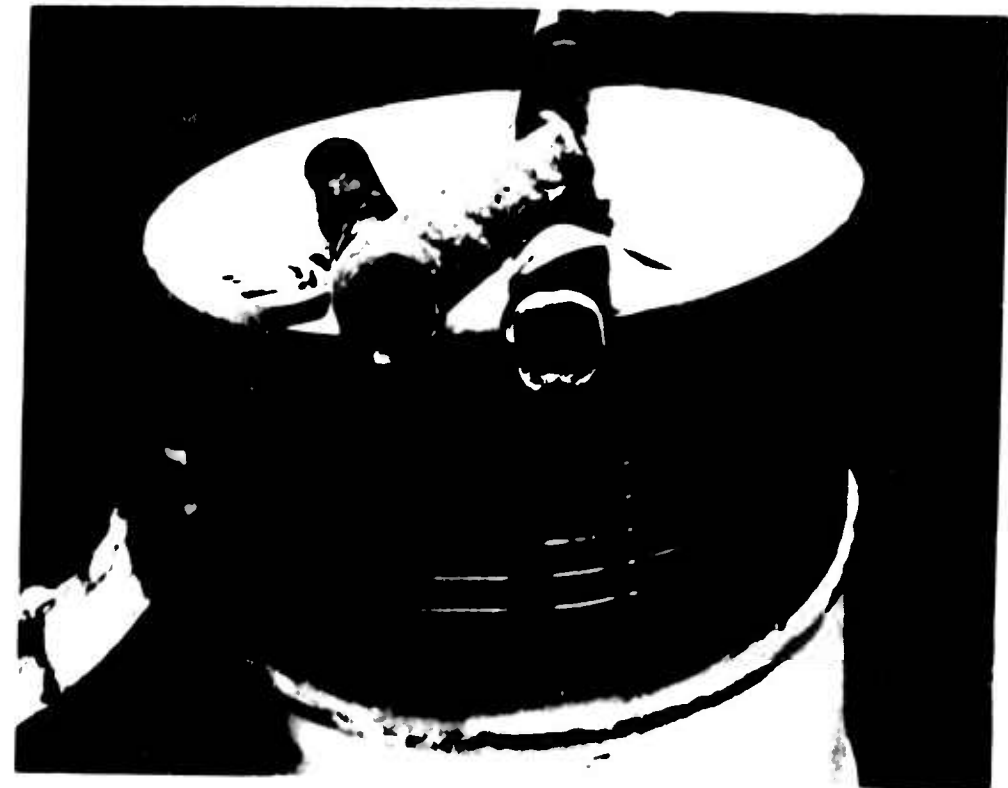


Figure 21. Gas line break.



Figure 22. Elmhurst Air Force Base hospital after earthquake.



Figure 23. Pipe rupture in Hill Building (Small displacement)

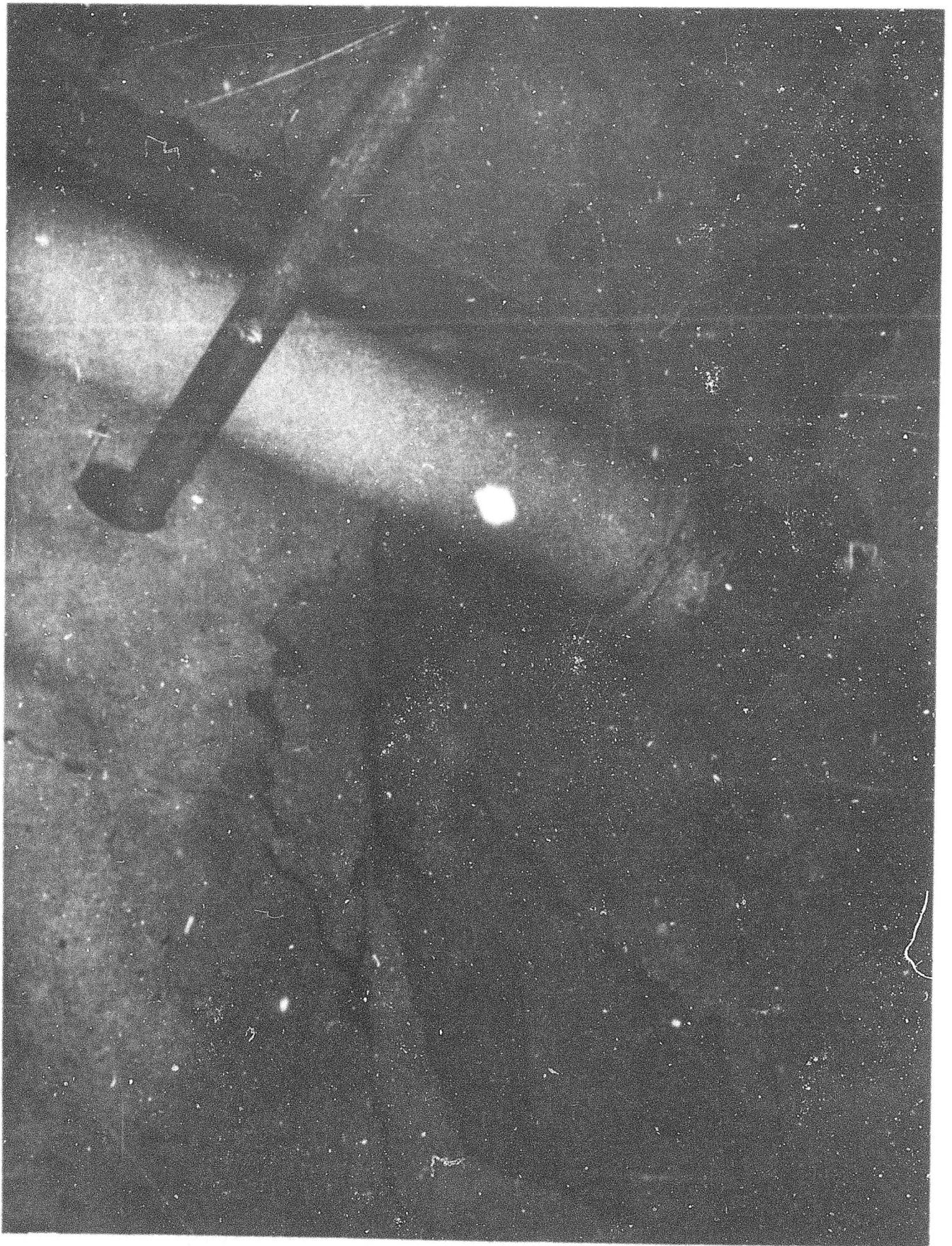


Figure 24. Undamaged pipes in Hill Building (large displacement).

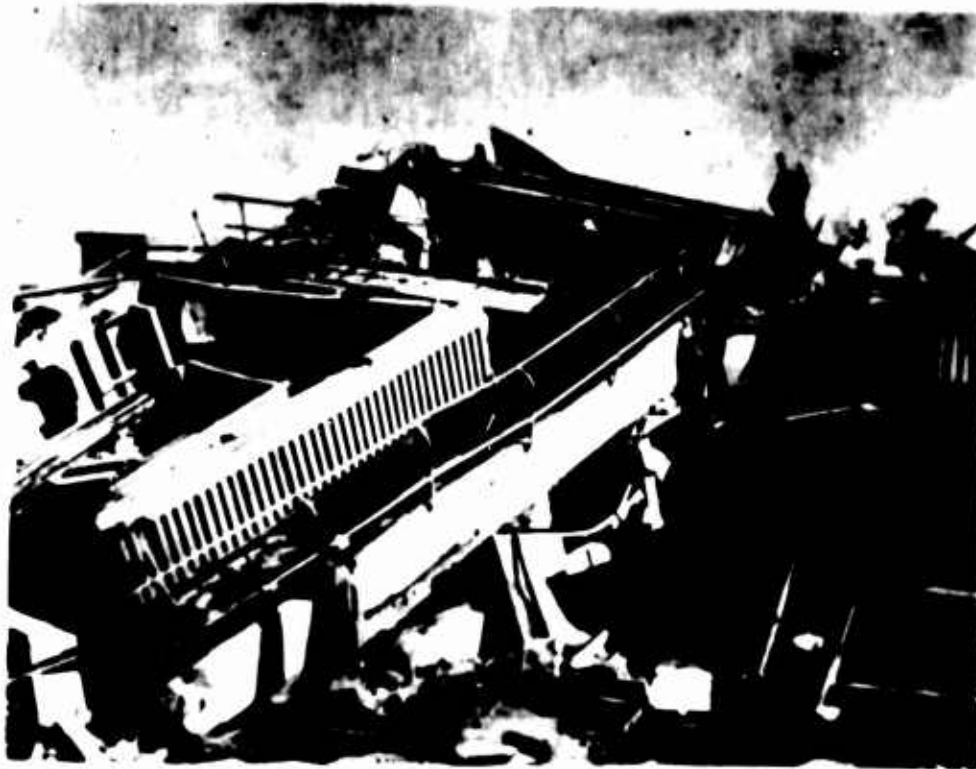


Figure 25. Control tower at International Airport.



Figure 26. Broken pipes under control tower.



Figure 27. Baggage chute located close to the control tower.



Figure 28. Inside of baggage chute undamaged.

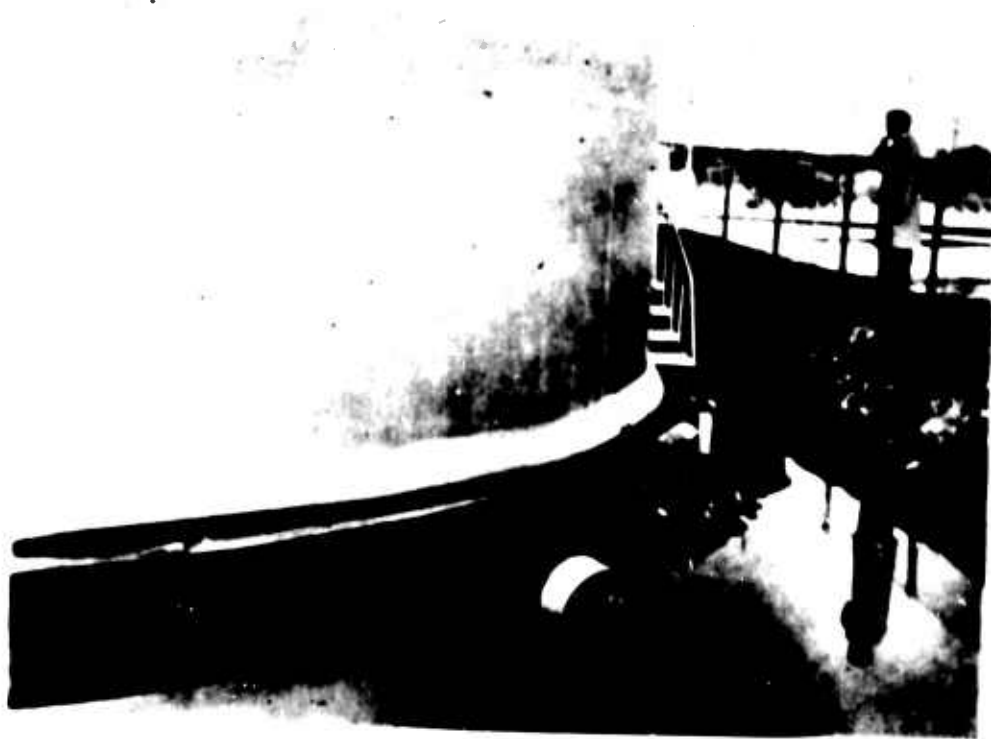


Figure 29. Bulge type failure near bottom of oil tank.



Figure 30. Damage to top of oil tank.

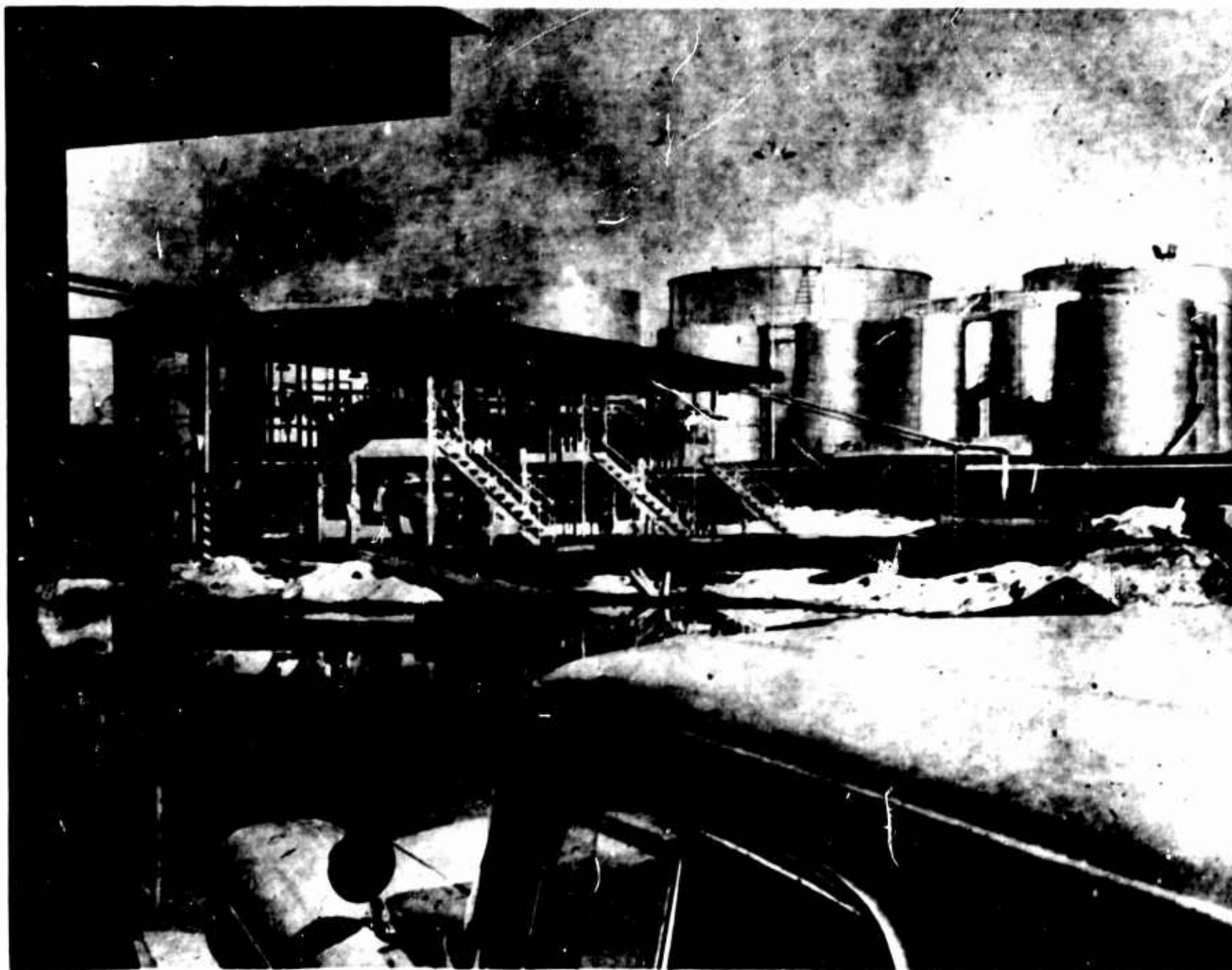


Figure 31. Piping at standard oil tank farm.

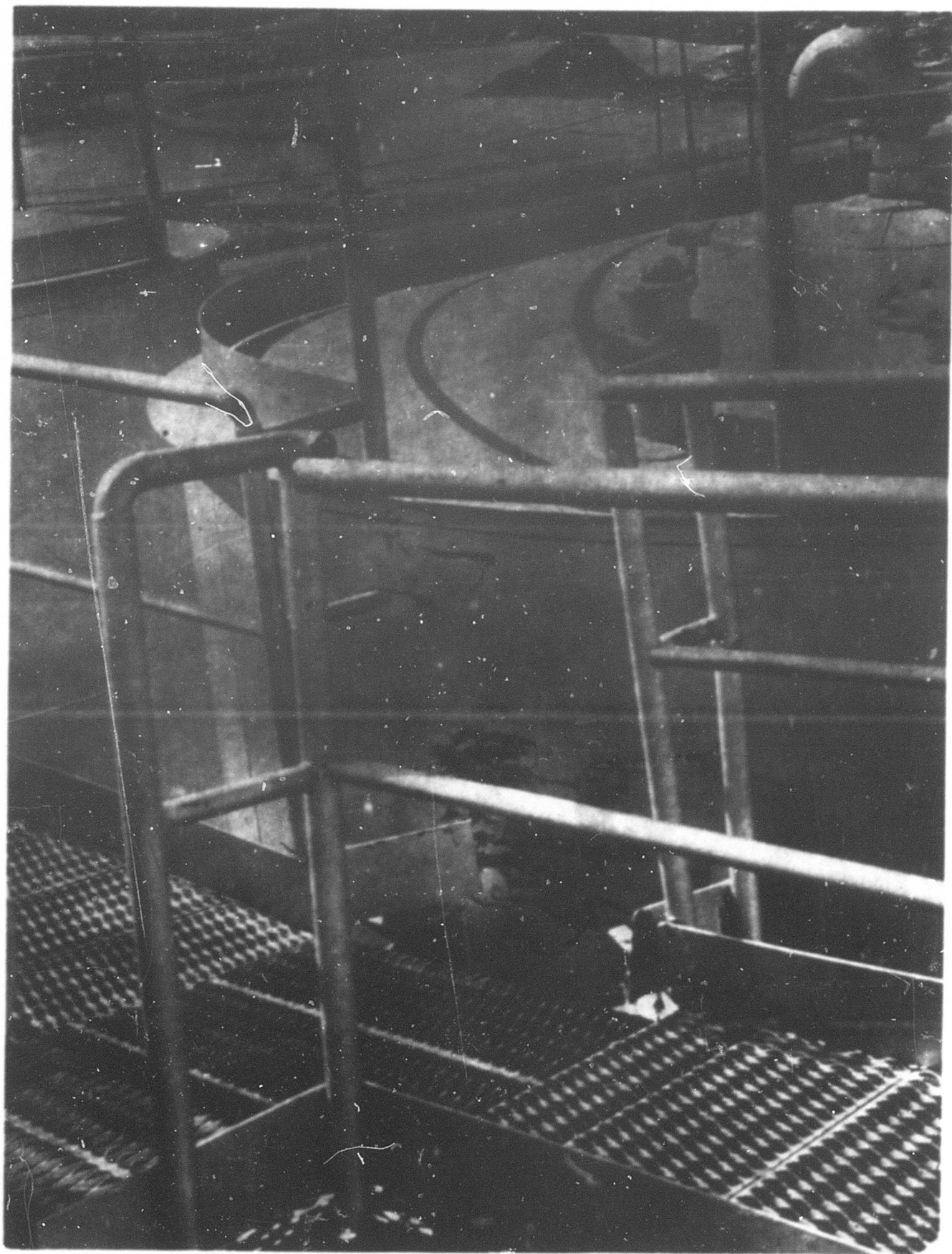


Figure 32. Scratches indicate hammering between tank and catwalk.

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Figure 33. Railroad tracks approaching the Anchorage docks.



Figure 24. Railroad tracks near the Anchorage docks

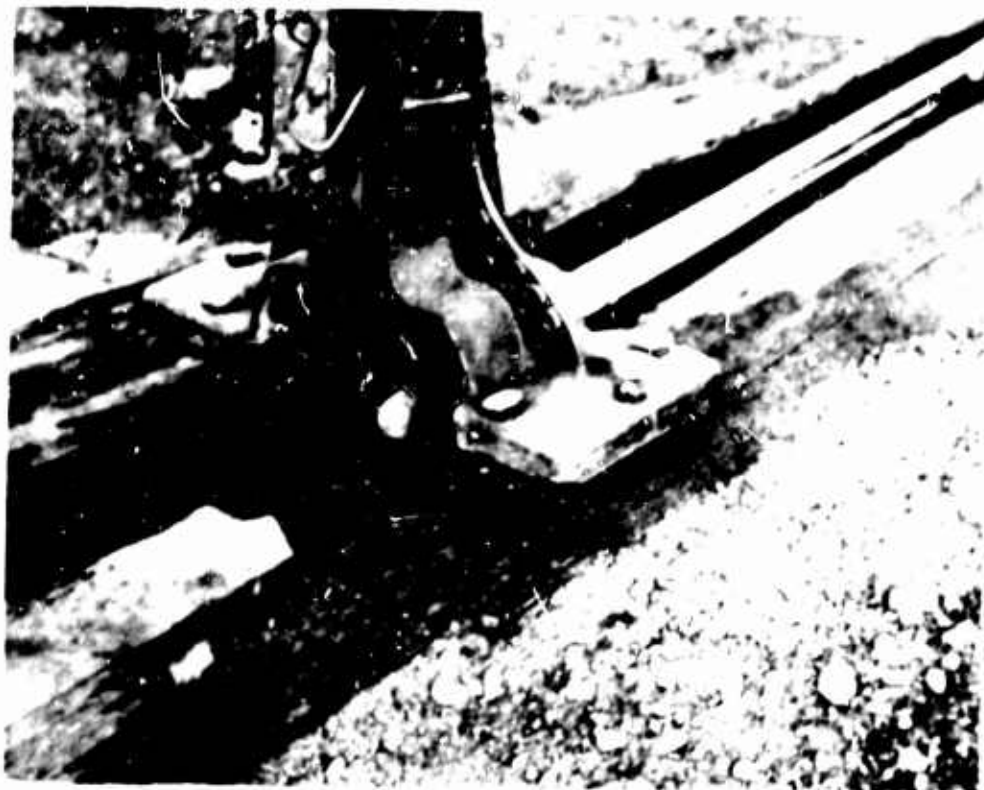


Figure 35. Railroad spike displacement.



Figure 36. Railroad bridge between Anchorage and Seward.

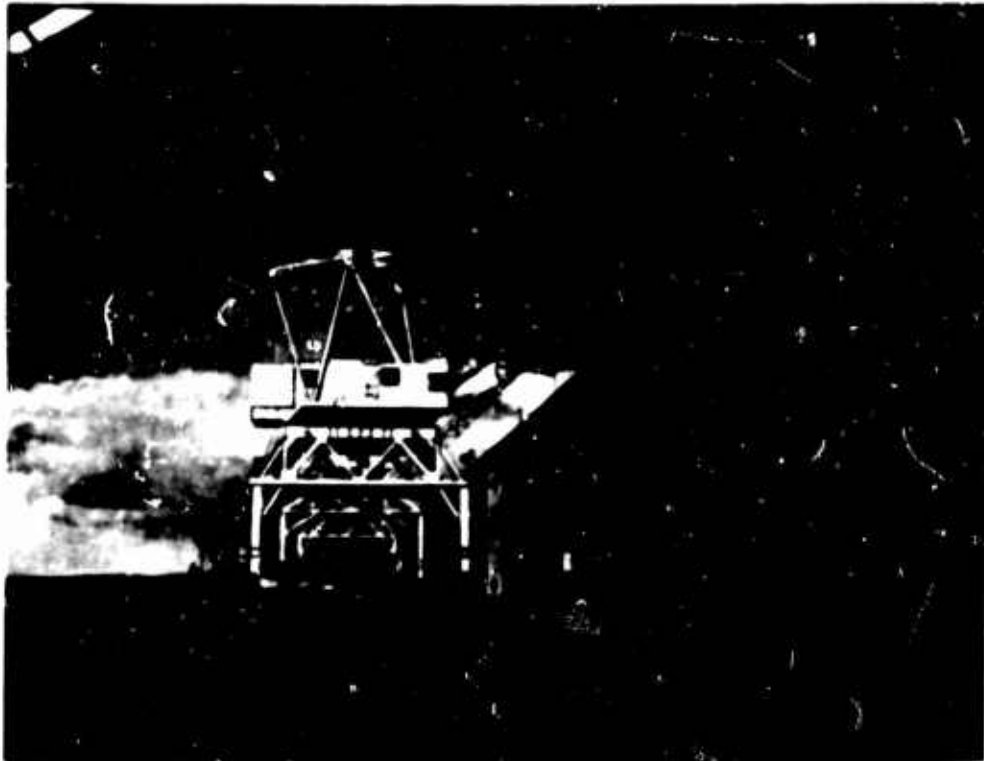


Figure 37 Dock cranes at the Port of Anchorage with counterweights in place.

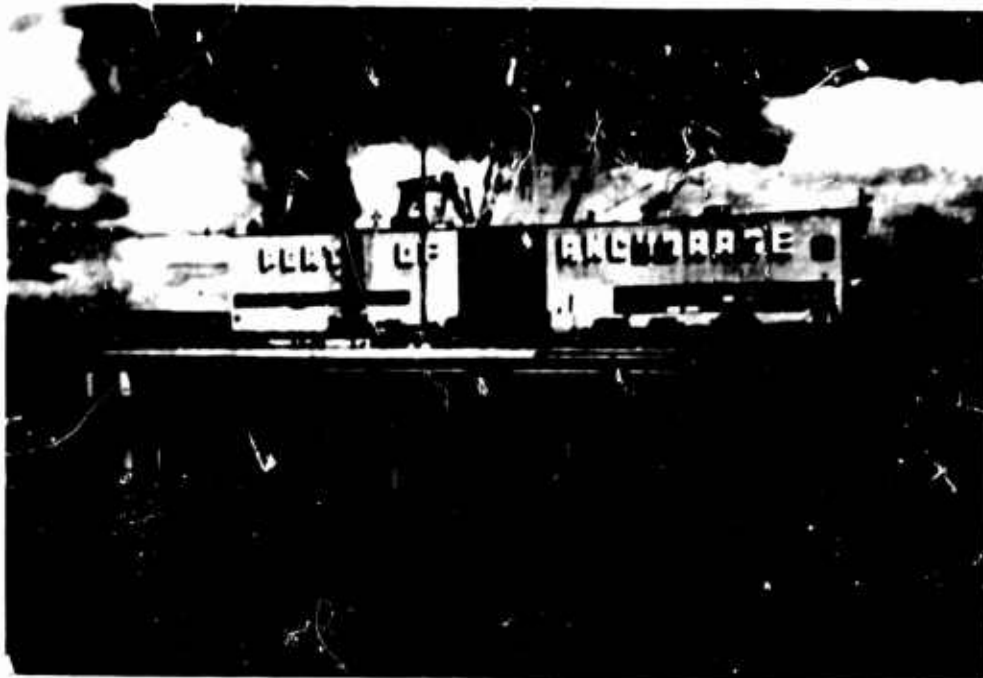


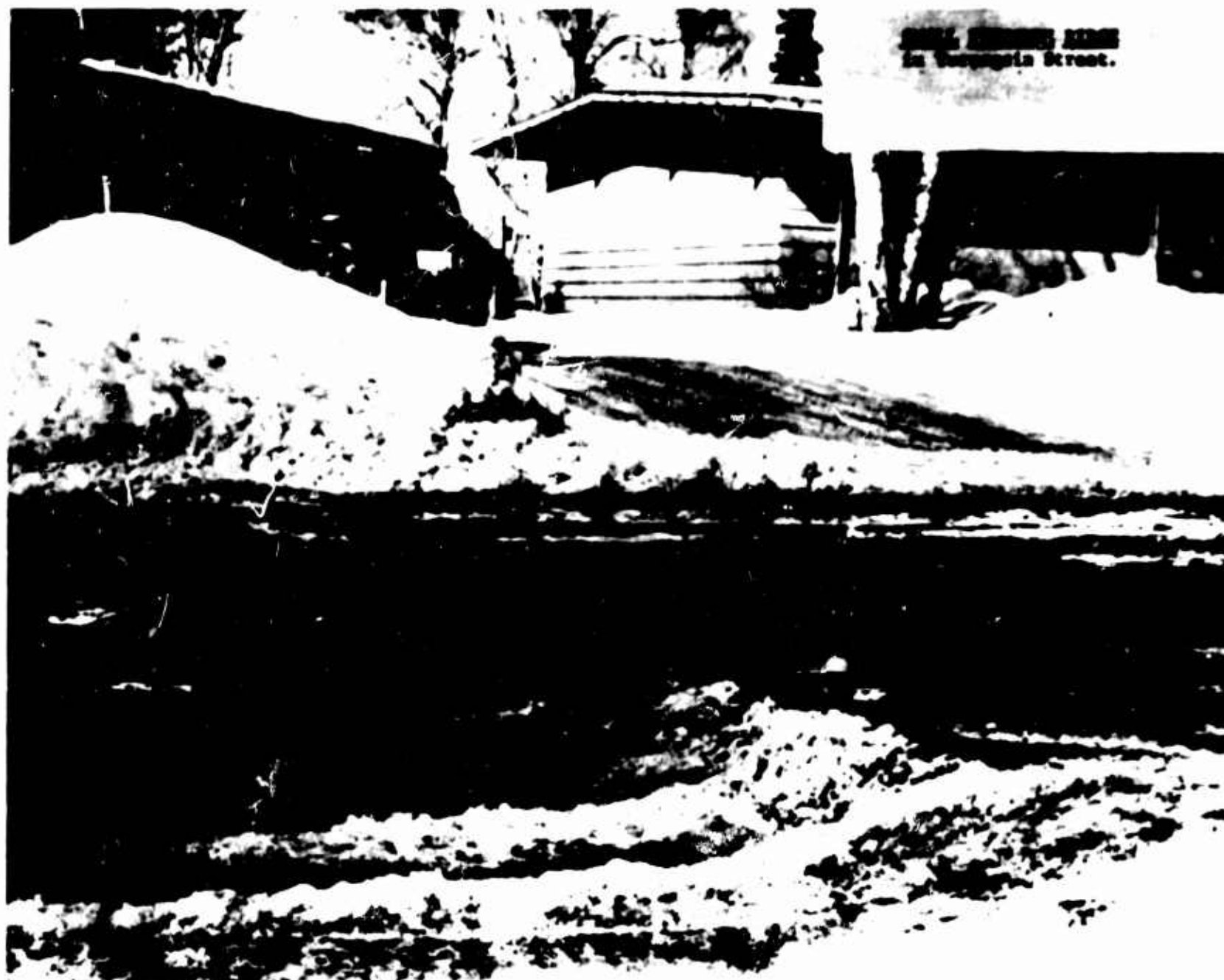
Figure 38. City dock (steel piles).



Figure 39. Army dock adjacent to Port of Anchorage
(wooden piles)



Figure 40. Devastated part of Turnagain Area



PRESSURE RIDGE
in Turnagain Street.

Figure 41. Pressure ridge in Turnagain Street.